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Summary

- Optimization study of a medical phantom allowing the mapping of absorbed dose induced by Ionizing radiations.
  
  *Sofia ELJ, Ahmed BEN ISMAIL.*

- Factors affecting Small Signal Stability in Two Area System.
  

- Performance Analysis of Quadratic Phase Shift Keying Bandpass Modulation Using Simulink.

  *Nsreen Hawisal, Amer M. Daeri and Amer R. Zerek.*

- Open Loop V/F Control of Induction Motor based on PWM Technique.

  *Prof. Rajab Isbaim, Eng. Ashraf Shariha, Dr. Ali A Mehna.*

- Principle of Modified Incremental Conductance Sliding Mode MPPT Control Applied of Photovoltaic system.

  *Rabhaa Gammoudi, Houda Brahmi, Othman Hasnaoui.*

- Smart Cooling System For High Transformer.

  *Salem Aboalkasem, Mohamed Alafrah, Hamza Abdussallam, Ali.salem.*

- Modeling and Performance Analysis of RF Satellite Link System Using 16 QAM.

  *Kheriya. F. Alhaddar , Amer M. Daeri and Amer R. Zerek.*

- Prediction of Cloud attenuation for 6B Arabsat Satellite Link at Ku, Ka, and V Bands over Libya Based on ITU-R P.840-5 Model.

  *Nafiaa M. Shebani, Abdalnaser F. kaeb, Amer R. Razek.*

- Usability Evaluation Model for Electronic Assessments.

  *Eman I.B. Elmasmare, Kenz A. Bozed, Youssif H. Mousa.*


  *Rachid Dehini, Berbaoui Brahim.*

- Non-invasive glucose monitoring: Application and technologies.

  *Ghoszi Dorsaf, Manai Yacine, Nouri Khaled.*

- Numerical and experimental evaluation of a photovoltaic thermal air collector’s performance(PVT) under Tunisian climatic conditions.

  *M.Fterich , H. Choukhi, H. Bentaher, S. Sandoval-Torres and A. Maalej.*

- Sliding Mode Control of An Autonomous Sailboat.

  *Helmi Abrougui, Samir Nejim.*
  K. Bedoud, A. Rhif, T. Bahi, H. Merabet, A. Bouazdia.

- Application of Neural Networks in Perception System Management for an Indoor Mobile Robot.  
  Djalal Djarah, Abdeslam Benmakhlef, Ghania Zidani.

- Study of the variation of refractive index for different organic liquids of an optical channel drop filter on a 2D photonic crystal ring resonator.  
  Ghomazi Mehdi, Abdessalam Hocini.

- Sliding Mode Control For PV-Wind Hybrid System Connected to Grid.  
  Houda LAABIDI, Houda JOUNI, Abdelkader MAMI.

- Tracking Control of Wheeled Mobile Robot through Neural Networks.  
  Zidani ghania, Djalal Djarah, Abdeslam Benmakhlef.

- Control of the DC Voltage Output Photovoltaic System.  
  A. Henchiri, T. Bahi, L. Khochemane, S. Lekhchine.

- Contribution to the degradation modelling of a photovoltaic cell under the effect of stochastic thermal cycles of a desert environment.  
  M. Boussaid, A. Belghachi, K. Agroui.

- Control of Active and Reactive Powers Of The DFIG By Neural Network Technology.  
  Mansouri smail, benatallah ali.

- Multi-wind generators to supply water pump system based on cascaded H-bridge inverters.  
  Imen Jaafar, Oussama Bouaziz, Faouzi Ben Ammar.

- Optimization of Two Stage-High Rate Algal Pond for the purification of wastewater has a large organic charge.  
  Siham BOUMAAZA, Najoua HADDAOUI et Jamal Eddine JELLAL.

- Control and Filter Design of Single Phase Grid-Connected Inverter for PV applications.  
  Meriem Dardouri, Sejir Khojet el Khil, Khaled Jelassi.

- Multi-objective powertrain cost and autonomy optimization dedicated to electric vehicles.  
  Mariem BEN AMOR, Souhir TOUNSI.

- Strategies of Speed Control of Induction Motor Drive.  
  S. Lekhchine, T. Bahi, Z. Layate, A. Henchiri.

- Technico-economic aspect analysis in the design of solar chimney power plants.  
  IKHLEF Khaoula, LARBI Salah.
SMART BUILDING Using EEG Signal Controller (First Controlling Method).

A Study of Wind Turbine Blade Structure Based on Cellulose Fibers Composite Material.
Abderraouf GHERISSI.

Particle swarm optimization (pso) for photovoltaic generator
operating under partially shaded conditions.
Banawaz Marwa, Zeddini Mohamed Ali, Mansouri Mohamed Nejib.

Enumeration of the Zeros of the Generalized Mittag-Leffler E_{
u}(z) as Bargmann Functions.
Hend Abdelgader Eissa1, Nuria Hassan Elfakih and Hend Belaid Masaoud.

Zineb Barhoum, Ouahiba Belaid, Bacha Oussama.

Three dimensional simulation of magnetic field effect on natural convection of nanofluid.
Boubaker dhibi, Brahim Ben-Beya.

IMPLEMENTATION OF SMART BUILDING (a Complete End to End Solution for Smart Building System).

Comparative Study of the Performance of Two Heating Ways in the Greenhouse Production.
Douja Sellami, Salwa Bouadila, Hassen Boughanmi, Asma Ben Salem-Fnayou.

Determining Hansen Solubility Parameters by StefanisPanayiotou Method for Fatty Acids
Extraction by Petrochemical and Green Solvents.
Sadja Bertouche, Naima Sahraoui, Chahrazed Boutekeddjiret, Amina Hellal.

A New Criteria for Evaluating Quality Educational Websites.
Siham Husin BinKhalifa, Rehab. R.Alsoudani.

Feasibility Study of Grid Connected Photovoltaic Power Plant In the Southern of Tunisia.
Drissi Hanen, Jalel KHediri, Massimo Gori, Luca Gregori, Begnis Francesco.

SMART BUILDING Using Web Application (Second Controlling Method).

L’impact énergies renouvelables dans la planification urbaine, l’exemple de Bechar ville.
Dr Sara ZATIR.

Moroccan wearable artificial kidney (morwak): requirement and use
case diagrams
Yasstine Zahidi, Abdellah Aitaleb, Abdellah Boualam, Mohammed Zamd, Benyounes Ramdani.
Optimization study of a medical phantom allowing the mapping of absorbed dose induced by ionizing radiations

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Abstract—Monte Carlo codes are among the most used tools for calculations and simulations relating to medical physics and particularly for studies of low dose medical applications. The results, presented in this paper, were focused on the optimization of a medical phantom for mapping the absorbed doses produced by ionizing radiation. The cobalt 60 irradiator of the CNSTN (the National Centre for Nuclear Science and Technology) served as the experimental validation platform for the present study. Monte-Carlo modeling of the irradiator was carried out with Geant4 tool. Part of dose deposition results, obtained with this model, has been validated using as reference previous experimental data, performed on the same irradiator. The same Geant4 model was then adapted to our study case, with the development of a more specific configuration, suitable for the diagnosis of the effects induced by gamma radiation beams at different energies. The distribution study of doses produced by these photons, inside a water filled phantom, was thus realized. The numerical results obtained, with the Geant4 model, show variable behaviours according to the studied energies. An analytical model is then proposed, for the prediction of these dose distributions.

Keywords — Applications in medicine, Geant4 Monte Carlo calculations, Nuclear techniques, Radiation protection.

I. INTRODUCTION

Monte Carlo computational methods are increasingly demonstrating their reliability in modelling physics governing energy deposition in particular environments. In line with this statement, we have used one of the most widely used Monte Carlo tools: the Geant4 tool [1], for the deposit dose calculation in the case of medical physics applications. Optimization study of a medical phantom, in the case of gamma beams, was performed, in this paper, with the Geant4 tool. This study investigates the behaviour of the absorbed dose profile in a water filled phantom, taking into account the energy variation of the incident beams. Photon attenuation in matter complies with the conventional Beer-Lambert law:

\[ D = D_0 \exp^{-\mu x} \]  

Conditions allowing the application of this law, for the case of intensity attenuation through a material, are: beam mono-chromaticity and absorbing material homogeneity and stability. In our study, the absorbing material undergoes some generated different secondary radiations: Compton effect, fluorescence and annihilation. Part of these scattered radiations contributes to increasing the dose rate of in the objects studied.

For radioprotection studies, the most widely used method [2] for determining gamma beam attenuation applies an accumulation factor, universally designated by the symbol B. Equation (1) becomes then:

\[ D = BD_0 \exp^{-\mu x} \]  

Equations describing the accumulation factor B are a function of the attenuation coefficient, the photon energy, the material nature, the screen dimensions and the distance from the source.

Several methods are possible for calculating the dose accumulation factor. Among these methods, figure (1) the linear formula \( B(\mu r) = 1 + k(\mu r) \); one of the simplest and least accurate approximations [3]; (2) Berger’s formula: \( B(\mu) = 1 + a \mu r \times e^{b \mu r} \); establishing a good compromise between accuracy and computational complexity [4]; (3) the formula of Capo: \( B = \sum \beta(\mu r) \) [5] and (4) the formula of Taylor: \( B = A \exp^{-\mu x \alpha_1} + (1 - A) \exp^{-\mu x \alpha_2} \), which appears as the formula, relatively, the most used and the most accurate [6]. The coefficients A, \( \alpha_1 \) and \( \alpha_2 \) of this formula are commonly explained. [7]

To overcome the different limits of these models, we propose a new analytical model based on the results of the Geant4 modeling of the phantom, described above, for the case of gamma beams, at energies ranging from 0.32 to 12 MeV; the conventional maximum energy delivered by a linear medical accelerator. Preliminary validations of this model have been made using as reference previous numerical and experimental data, also performed on the CNSTN’s gamma irradiator.
II. USED MATERIAL AND METHOD

A. Background and experimental equipment

An experimental validation setup has been installed close to the CNSTN’s gamma irradiator source. This irradiator has, today, an activity of 10 kCi [8], employs cobalt-60, as radioactive source, and has a vertical structure, with two built-in cylinders, each containing 4 cobalt pencils of 0.37 cm diameter and 40.6 cm length. The experimental setup included a phantom and a lead brick mask with 1 cm slit. Among the radiation produced by the irradiator, only a beam, of a 1 cm width, irradiated thus the phantom (cf. Fig 1). Absorbed dose distribution, induced by the incident beam, was measured using Fricke dosimeters [9].

![Experimental setup](image1)

**Fig. 1:** Experimental setup

B. Geant4 Tool

Geant4 is a computational tool, succeeding the series of GEANT software developed by CERN, and allowing simulation of radiation transport for many types of particles and many radiation geometries. Its fields of application include high energy, nuclear and accelerator physics, as well as studies of medical and spatial sciences. [8]

Version 10.0 of Geant4 was initially used to model our CNSTN’s gamma irradiator and to calculate the dose distribution around this installation. A more specific model of the source, using gamma beams, was then developed for the calculation of the dose in the water filled phantom. The entire installation geometry, as well as the experimental setup, was modeled with regard to the real dimensions and disposition of each component. Primary particles were generated with random directions and positions; according to the actual characteristics of the source. These primary particles are distributed between beta radiation at 0.318 MeV energy and two gammas at 1.17 MeV and 1.33 MeV. [10]

We used this experimental configuration for the validation of the model Geant4 at a mean energy, gammas, of 1.25 MeV. Then we modeled gamma beams at varying energies from 0.32 MeV to 12 MeV.

III. DEVELOPED WORK

A. Preliminary validation of the model

The first part of the validation has consisted of reproducing the dose mapping (dose absorbed in the air) around the gamma irradiator. This part uses, for the validation, already elaborated experimental and numerical results (cf. Fig 2).

![Dose mapping around the gamma irradiator](image2)

**Fig. 2:** Dose mapping around the gamma irradiator

Results obtained with the present Geant4 model are quite comparable with the previous results of experimental measurements and also numerical calculations (cf. Table I). Some rather significant deviations are however recorded and can be justified by parameters uncertainties when elaborating these previous data.

<table>
<thead>
<tr>
<th>Dosimeters</th>
<th>Difference between previous experimental results and results developed with the current model [%]</th>
<th>Difference between previous numerical results and the results developed by the current model [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>D_1</td>
<td>9.79</td>
<td>37.34</td>
</tr>
<tr>
<td>D_2</td>
<td>2.3</td>
<td>38.95</td>
</tr>
<tr>
<td>D_3</td>
<td>24.78</td>
<td>9.98</td>
</tr>
<tr>
<td>D_4</td>
<td>52.85</td>
<td>97.4</td>
</tr>
<tr>
<td>D_5</td>
<td>33.3</td>
<td>20.06</td>
</tr>
</tbody>
</table>

The second part of the validation used results of calculations (numerical and experimental), also already elaborated. These calculations were performed for the case of a water-filled phantom, Fricke’s dosimeters and beam extraction using a mask. Comparison of the results, obtained
by the current model and these previous numerical and experimental results has been established.

The objective here was to develop new analytical model, reproducing our results of Monte Carlo calculations and also overcoming the limits of the models described in paragraph I. In order to fit resulting numerical results, produced by Geant4, we have used the calculation tool Matlab [11] for each case of studied energy. Matlab tool provided a mathematical model for each dose profile and we have noticed that obtained models are always following this equation:

$$ D = a \times \exp(bx) + c \times \exp(dx) \quad (3) $$

Numerical values of the coefficients $a$, $b$, $c$ and $d$, obtained at each beam energy, are indicated in the following table (cf. Table III). $x$ being the depth through the phantom, in cm.

<table>
<thead>
<tr>
<th>Energy [MeV]</th>
<th>$a$</th>
<th>$b$</th>
<th>$c$</th>
<th>$d$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.32</td>
<td>101.2</td>
<td>-0.1152</td>
<td>-1.098</td>
<td>-1.112</td>
</tr>
<tr>
<td>0.6125</td>
<td>100.9</td>
<td>-0.0833</td>
<td>-0.9497</td>
<td>-1.638</td>
</tr>
<tr>
<td>1</td>
<td>95.67</td>
<td>-0.07493</td>
<td>4.786</td>
<td>-0.04603</td>
</tr>
<tr>
<td>1.25</td>
<td>103.5</td>
<td>-0.06264</td>
<td>-31.72</td>
<td>-12.51</td>
</tr>
<tr>
<td>2</td>
<td>104.7</td>
<td>-0.04917</td>
<td>-52.7</td>
<td>-5.297</td>
</tr>
<tr>
<td>3</td>
<td>106</td>
<td>-0.03977</td>
<td>66.35</td>
<td>-3.39</td>
</tr>
<tr>
<td>4</td>
<td>107.2</td>
<td>-0.03402</td>
<td>-73.61</td>
<td>-2.589</td>
</tr>
<tr>
<td>6</td>
<td>107.6</td>
<td>-0.0278</td>
<td>-80.99</td>
<td>-1.866</td>
</tr>
<tr>
<td>8</td>
<td>109</td>
<td>-0.02442</td>
<td>-86.34</td>
<td>-1.558</td>
</tr>
<tr>
<td>10</td>
<td>108.9</td>
<td>-0.02212</td>
<td>-88.71</td>
<td>-1.361</td>
</tr>
<tr>
<td>12</td>
<td>109</td>
<td>-0.02059</td>
<td>-90.51</td>
<td>-1.232</td>
</tr>
</tbody>
</table>

The compilation of these obtained data, using the Geant4 and Matlab calculations, has enable to elaborate the following proposal of an analytical model, that describes the behavior of the absorbed dose as a function of the incident radiation energy and the depth $x$ through the phantom:

$$ D = D_{\text{max}} \times e^{-\mu x} + (D_{\text{max}} - D_0) \times e^{d x} \quad (4) $$

TABLE III:

**COEFFICIENT NUMERICAL VALUES OF DEVELOPED MODEL**

**Energy [MeV]**

**Coefficient**

---

**Results of the upgraded configuration of the model**

Following the preliminary validations, presented above, we modeled the gamma beam cases, with the calculation of the dose profiles and the depth yields, in homogeneous water phantom and as a function of the primary photons energy (cf. Fig 4).

**Fig. 4: Comparison of dose deposition for photons**

**Fig. 5: Coefficient $d$, as a function of the incident beam energy**
Coefficients $D_{\text{max}}$ and $D_{\text{b}}$ correspond respectively to the maximum dose and the surface dose that can be obtained for each case of energy. The coefficient $\mu$ is the same as the conventional attenuation factor [12]. The coefficient $d$ varies according to the incident radiation energy and was determined from a fitting with Matlab (cf. Fig 5). The mathematical equation related to this coefficient $d$ is then given by:

$$d(E) = f \times e^{iE} + j \times e^{kE} \quad (5)$$

where, $f = -97.02$, $i = -1.899$, $j = -3.972$ and $k = -0.1095$.

The illustrations below show some examples of dose profiles obtained (1) with our proposed mathematical model, (2) Matlab and (3) the latest Geant4 simulation results.

The three curves representing the dose profile in the water-filled phantom for the case of 0.32 MeV are almost the same. Fig. 9 illustrates comparison between these same three dose profiles, using relative differences, starting from the depth of 3 cm inside the phantom.

![Relative differences between the dose values obtained with Geant4, Matlab and the mathematical model. For the case of $E = 0.32$ MeV.](image)

The model results developed demonstrate perfect agreement for relatively low energies. An accentuated disparity is however noted for cases of higher energies. This discordance, at high energies, will be corrected by revising the coefficients calculations of the model.

**IV. Conclusions**

The objective of this work was to study phantom dimension optimization by proposing analytical model that results from carrying out experimental manipulations and validations of numerical modeling, elaborated with the Monte-Carlo Geant4.

The numerical model performed with Geant4 allowed the study of the dose distributions produced by CNSTN’s gamma irradiator. This same numerical work has enables preliminary validations by comparisons with experimental and numerical results previously carried out.

Specific numeric model configuration for cases of gamma beams, at different energies, has been then developed. The results obtained by this configuration were fitted using Matlab tool.

An analytical model, that describes the behavior of the absorbed dose, as a function of the incident radiation energy and the depth $x$ through the phantom, was afterward proposed.

The obtained results are promising. An improvement of the present model, as well as the transition to a 2D modeling are planned.
REFERENCES

Factors affecting Small Signal Stability in Two Area System

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Abstract—Small signal stability both inter and local area oscillation are affected by many factors, these factors should be concerned when performing a dynamic study of an interconnected system, therefore.

This paper concentrated on factors affecting the small signal stability that could change the system stability such factors are: The amount of power transferred on the Tie Line, the weakness and strong of interconnected line between two areas, the type of exciter used, also the type of PSS insulted on the exciter system. In addition, value of parameters used in the exciter and PSS systems were investigated.

The analysis is to determine the nature of inter-area and local area modes in power systems. By using Kundur (two area system), the system eigenvalues, eigenvectors, and participation factor were computed for a number of different system conditions and configurations, related to the previous mentioned factors. The study was carried out on Kundur Network system which consists of two area connected by tie line of 220km long. The results show that the small signal stability can be improved selecting the best parameters of that factors.

Keywords—Low frequency oscillation, global and Local area Oscillations. Small Signal Stability; Power System Stabilizer.

I. INTRODUCTION

Electro mechanical oscillations between interconnected synchronous generators are occurrences essential to power system. An unexpected change of load, and generator shaft speed change may increase the oscillations of low frequency. These oscillations are undesirable as they have an effect on the power transfer capability of transmission lines and induce stress in generator shaft [1].

The stability of these oscillations is of great importance, and is a requirement for secure system operation. For many years, the oscillations detected to be troublesome in power system, were associated with a single generator, or a very closely connected group of units at a generating plant. Some low frequency unstable oscillations were also detected when large systems were connected by somewhat weak tie lines, and special control methods were used to stabilize the interconnected system. These low frequency modes were discovered to include groups of generator, or generating plants, on one side of the tie oscillating against group of generators on the other side of the tie. Many researchers have studied small signal stability for power systems. Among them are:

In 1990, M. Klein, G. J. Rogers and P. Kundur [2], focused on Inter-area oscillations in power systems. The objective of the research have determined the fundamental nature of low frequency inter area modes of damping to develop analysis techniques for large power system. Where in 2016 S. Bagchi. S. Goswami, R. Bhaduri, M. Ganguly and A. Roy [3] have studied small signal stability analysis incorporating Doubly Fed Induction Generator (DFIG) by analyzing and comparing two shunt connected FACTS devices such as STATCOM and SVC.

This paper presents factors affecting the small signal stability such as power transferred, tie line impedance, adding exciter and PSS systems. In addition, PSS and Exciter will be tuned to find the optimum parameters that achieve the best system stability performance.

Small signal stability is defined as the ability of the system to maintain synchronism when small disturbances appeared [4]. Such disturbance happens on the system because of small variation in loads and generation.

A disturbance is considered to be small if the linearized system still represents the dynamics of the original system under this disturbance [5].

Small signal stability is largely a problem of deficient damping of oscillations. Where the types of oscillations is of concern:

- Local mode problems may also be associated with oscillations between the rotors of a few generators close to each other. Local modes normally have frequencies in the range 0.7 to 2.0 Hz. [6].
- Global or inter area small-signal stability problems which are caused by interactions among large groups of generators have widespread effects. Inter area oscillations have frequencies in the range 0.1 to 0.8 Hz [6].

Eigen values, Eigen vectors and participation factor analysis are the most effective method to analyze the small signal stability of any state space system which in form of equation 1.

\[ \dot{X} = AX + BU \] (1)

Where A is the state system matrix of size n x n, and B is the input matrix.

Stability of the linearized system is explained by the eigenvalues of the state matrix A. Eigenvalues can be found from the state
equation given by is extra analyzed by taking the Laplace transform. Then the new equation (2) will be derived as:

$$\det (S[I] - [A]) = 0$$  \hspace{1cm} (2)

Where $$\lambda$$ is the eigenvalue of the system. For an $$n \times n$$ matrix they have $$n$$ eigenvalues. A real eigenvalue, or a pair of complex eigenvalues, is usually referred to as a mode.

For a complex mode:

$$\lambda = \sigma \pm j\omega$$  \hspace{1cm} (3)

From this mode two quantities are of main interest:

- Frequency (in Hz) \( f = \frac{\omega}{2\pi} \)  \hspace{1cm} (4)
- Damping Ratio (in %) \( \zeta = \frac{\sigma}{\sqrt{\sigma^2 + \omega^2}} \)  \hspace{1cm} (5)

Eigenvectors can be satisfied from eigenvalue because each eigenvalue has eigenvector. For any eigenvalue \( \lambda_i \), the column vector \( x_i \) that satisfies is called the right eigenvector for \( \lambda_i \), and the next equation shows how to find the eigenvectors:

$$Ax_i = \lambda_ix_i$$  \hspace{1cm} (6)

$$x_i = \begin{bmatrix} x_{i1} \\ x_{i2} \\ \vdots \\ x_{in} \end{bmatrix}$$  \hspace{1cm} (7)

The right eigenvector show the distribution of the modes of response (eigenvalues) through the power system state variables. So from right eigenvector mode shape can be known the observability of the mode, and from left eigenvector knows the controllability of the mode or illustrates participation factors [7].

**II. MODEL USED FOR THE STUDY**

Two area Kundur system is tested in this paper where it is consisted of two similar areas connected by a weak tie. Each area consists of two coupled units, each unit having 900 MVA and 20 KV. The system parameters have found in appendix [2].

**III. SIMULATION AND RESULTS**

In this section, simulation of three different scenarios are analyzed to determine the nature of inter area and local area modes in power system. The system eigenvalues, eigenvectors, and participation factor were computed for a number of different system conditions and configuration as following:

**Scenario 1: Effect of Amount Power Flow on Tie Line**

Three cases were evaluated to investigate the effect of power flow in tie line on damping of system oscillations.

**Case 1 (No Power Flow on Tie Line)**

In this case, both area are producing power about 1400 MW and feeding a load of 1367 MW so no power will flows in the tie line. So effect of Frequency and Damping Ratio are of the inter and local area mode represented in table 1.

<table>
<thead>
<tr>
<th>Eigenvalue Real Part</th>
<th>Eigenvalue Imaginary Part</th>
<th>Damping Ratio</th>
<th>Frequency</th>
<th>Maximum Participated State Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.033</td>
<td></td>
<td></td>
<td></td>
<td>GEN 1 (E=1271)</td>
</tr>
<tr>
<td>-0.144</td>
<td>-0.015</td>
<td>0.041</td>
<td>0.076</td>
<td>GEN 2 (E=1272)</td>
</tr>
<tr>
<td>-0.144</td>
<td>0.012</td>
<td>0.041</td>
<td>0.076</td>
<td>GEN 2 (E=1272)</td>
</tr>
<tr>
<td>-0.144</td>
<td>0.02</td>
<td>0.041</td>
<td>0.076</td>
<td>GEN 1 (E=1271)</td>
</tr>
<tr>
<td>-0.068</td>
<td>-0.072</td>
<td>0.069</td>
<td>1.126</td>
<td>GEN 2 (E=1272)</td>
</tr>
<tr>
<td>-0.068</td>
<td>0.072</td>
<td>0.069</td>
<td>1.126</td>
<td>GEN 1 (E=1271)</td>
</tr>
<tr>
<td>-0.068</td>
<td>0.084</td>
<td>0.059</td>
<td>1.089</td>
<td>GEN 2 (E=1272)</td>
</tr>
<tr>
<td>-0.068</td>
<td>-0.084</td>
<td>0.059</td>
<td>1.089</td>
<td>GEN 1 (E=1271)</td>
</tr>
<tr>
<td>-0.057</td>
<td>-0.085</td>
<td>0.059</td>
<td>1.089</td>
<td>GEN 2 (E=1272)</td>
</tr>
<tr>
<td>-0.057</td>
<td>0.085</td>
<td>0.059</td>
<td>1.089</td>
<td>GEN 1 (E=1271)</td>
</tr>
</tbody>
</table>

From the above table, it concludes that 0.575Hz frequency is the inter area oscillation, with damping ratio of 0.041, and the 1.089Hz mode is the inter machine oscillation local to area(1), with damping ratio of 0.085, while the 1.126Hz mode is the inter machine oscillation local for area(2), with damping ratio of 0.089. Where the location of the roots on s-plane are shown in figure (2).

![Figure (2): locations of the roots on s-plane of case 1](image)

Figure (2) shows three pair of roots cause the oscillation, one of the pair of roots cause inter area oscillation, while the two other roots cause local area oscillation.

Figures (3) and (4) show The mode shapes (normalized eigenvector components corresponding to rotor speeds of four machine), for both inter and local area oscillation are shown respectively.
From figure(5a), it is clear that the G3 and G1 are more sensitive than G2 and G4 in inter area oscillation, while in figure(5b) generator 2 is more sensitive than generator 1 in local area 1 oscillation, where figure(5c) shows that G4 is more participate than G3 in local area 2 oscillation.

Case 2 (200MW Transferred From Area1 To Area2):
In this case, both area are producing power about 1400MW where the first area is feeding a load of 1167MW and the other area load is 1567MW so 200MW of power flows in the tie line. Damping Ratio are of the inter and local area mode represented in table 2.

<table>
<thead>
<tr>
<th></th>
<th>Eigenvalue Real Part</th>
<th>Eigenvalue Imaginary Part</th>
<th>Damping Ratio</th>
<th>Frequency</th>
<th>Maximum Participated State Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/s</td>
<td>1/s</td>
<td>-</td>
<td>Hz</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>-0.532</td>
<td>-0.579</td>
<td>0.039</td>
<td>0.570</td>
<td>GEN 1 (ID 32721; der)</td>
</tr>
<tr>
<td>2</td>
<td>-0.130</td>
<td>-0.579</td>
<td>0.030</td>
<td>0.570</td>
<td>GEN 1 (ID 32722; dthela)</td>
</tr>
<tr>
<td>3</td>
<td>-0.146</td>
<td>-0.579</td>
<td>0.030</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; ps_rtd)</td>
</tr>
<tr>
<td>4</td>
<td>-0.162</td>
<td>-0.579</td>
<td>0.030</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; dthela)</td>
</tr>
<tr>
<td>5</td>
<td>-0.362</td>
<td>-0.480</td>
<td>0.062</td>
<td>1.124</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
<tr>
<td>6</td>
<td>-0.586</td>
<td>-0.480</td>
<td>0.066</td>
<td>1.124</td>
<td>GEN 1 (ID 32741; dthela)</td>
</tr>
<tr>
<td>7</td>
<td>-0.590</td>
<td>0.562</td>
<td>0.062</td>
<td>1.124</td>
<td>GEN 1 (ID 32741; dthela)</td>
</tr>
<tr>
<td>8</td>
<td>-0.567</td>
<td>0.836</td>
<td>0.088</td>
<td>1.088</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
<tr>
<td>9</td>
<td>-0.587</td>
<td>0.836</td>
<td>0.088</td>
<td>1.088</td>
<td>GEN 1 (ID 32741; dthela)</td>
</tr>
<tr>
<td>10</td>
<td>2.372</td>
<td>4.606</td>
<td>0.088</td>
<td>1.088</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
<tr>
<td>11</td>
<td>3.269</td>
<td>4.606</td>
<td>0.088</td>
<td>1.088</td>
<td>GEN 1 (ID 32741; dthela)</td>
</tr>
<tr>
<td>12</td>
<td>-4.764</td>
<td>0.579</td>
<td>0.039</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
<tr>
<td>13</td>
<td>-23.228</td>
<td>0.579</td>
<td>0.039</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; dthela)</td>
</tr>
<tr>
<td>14</td>
<td>-29.367</td>
<td>0.579</td>
<td>0.039</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
<tr>
<td>15</td>
<td>-54.171</td>
<td>0.579</td>
<td>0.039</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
<tr>
<td>16</td>
<td>-56.160</td>
<td>0.579</td>
<td>0.039</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
<tr>
<td>17</td>
<td>-35.946</td>
<td>0.579</td>
<td>0.039</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
<tr>
<td>18</td>
<td>-36.110</td>
<td>0.579</td>
<td>0.039</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
<tr>
<td>19</td>
<td>-57.183</td>
<td>0.579</td>
<td>0.039</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
<tr>
<td>20</td>
<td>-57.259</td>
<td>0.579</td>
<td>0.039</td>
<td>0.570</td>
<td>GEN 1 (ID 32741; der)</td>
</tr>
</tbody>
</table>

From the above table, the 0.570Hz frequency is the inter area oscillation, with damping ratio of 0.039, and the 1.088Hz mode is the inter machine oscillation local to area(1), with damping ratio of 0.086 while the 1.124Hz mode is the inter machine oscillation local for area(2), with damping ratio of 0.082, and the location of the roots on s-plane are shown in figure(6) where there are three pair of roots cause the oscillation, one pair cause inter area oscillation and two cause local area oscillation.
Figures (7) and (8) illustrate the mode shapes (normalized eigenvector components corresponding to rotor speeds of four machine), for both inter and local area oscillation are shown respectively.

The results which are given in table 3 show that 0.544Hz frequency is the inter area oscillation, with damping ratio of 0.038, and the 1.084Hz mode is the inter machine oscillation local to area(1), with damping ratio of 0.088 while the 1.119Hz mode is the inter machine oscillation local for area(2), with damping ratio of 0.086, and the location of the roots on s-plane are shown in figure(9).

Figures (10) and (11) illustrate the mode shapes (normalized eigenvector components corresponding to rotor speeds of four machine), for both inter and local area oscillation are shown respectively.

**Case 3 (400MW Transferred From Area 1 To Area 2):**

In this case, the first area is feeding a load of 967MW and the other area load is 1767MW so 400MW of power flows in the tie line. The damping ratio of the inter and local area mode are represented in table 3.

**Table 3: The Eigenvalue of the System, Frequency and Damping Ratio.**

<table>
<thead>
<tr>
<th>Eigenvalue Real Part</th>
<th>Eigenvalue Imaginary Part</th>
<th>Damping Ratio</th>
<th>Frequency</th>
<th>Maximum Participated State Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>-0.035</td>
<td>-6.417</td>
<td>0.036</td>
<td>0.544</td>
<td>GEN 3 (ID=3272): dcrf</td>
</tr>
<tr>
<td>-0.131</td>
<td>3.417</td>
<td>0.036</td>
<td>0.544</td>
<td>GEN 1 (ID=3271): dcrf</td>
</tr>
<tr>
<td>-0.131</td>
<td>3.417</td>
<td>0.036</td>
<td>0.544</td>
<td>GEN 1 (ID=3271): dcrf</td>
</tr>
<tr>
<td>-0.188</td>
<td>-0.009</td>
<td>0.036</td>
<td>1.084</td>
<td>GEN 2 (ID=3273): dcrf</td>
</tr>
<tr>
<td>-0.172</td>
<td>-0.009</td>
<td>0.036</td>
<td>1.084</td>
<td>GEN 2 (ID=3273): dcrf</td>
</tr>
<tr>
<td>-0.354</td>
<td>-6.309</td>
<td>0.036</td>
<td>1.119</td>
<td>GEN 4 (ID=3274): dcrf</td>
</tr>
<tr>
<td>-0.685</td>
<td>-0.009</td>
<td>0.036</td>
<td>1.119</td>
<td>GEN 4 (ID=3274): dcrf</td>
</tr>
<tr>
<td>-0.605</td>
<td>-0.322</td>
<td>0.036</td>
<td>1.119</td>
<td>GEN 1 (ID=3271): dcrf</td>
</tr>
<tr>
<td>-0.499</td>
<td>-0.277</td>
<td>0.036</td>
<td>1.119</td>
<td>GEN 1 (ID=3271): dcrf</td>
</tr>
</tbody>
</table>
Figure (11) mode shape of local area oscillation

Figure (10), shows that the generator (G1) oscillated in anti-phase with generator (G3), and generator (G2) oscillated in anti-phase with generator (G4) for the root value of (-0.131+j3.417). Figure (11) shows the oscillation of local area (1) (the higher figure) by the root(-0.601+j6.809), and the oscillation of local area (2) (the lower one), by the root (-0.605+j7.033).

It is noted that generator(1) swinging against generator(2), and generator(3) swinging against generator(4).

Table 4 shows results of the three case for scenario 1.

### Table 4: Results of Tie Line Power Transferred

<table>
<thead>
<tr>
<th>Power flow (MW)</th>
<th>Inter area mode</th>
<th>Local area 1 mode</th>
<th>Local area 2 mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Damping ratio</td>
<td>Freq (Hz)</td>
<td>Damping ratio</td>
</tr>
<tr>
<td>0</td>
<td>0.041</td>
<td>0.575</td>
<td>0.085</td>
</tr>
<tr>
<td>200</td>
<td>0.039</td>
<td>0.570</td>
<td>0.086</td>
</tr>
<tr>
<td>400</td>
<td>0.038</td>
<td>0.544</td>
<td>0.088</td>
</tr>
</tbody>
</table>

From table 4 it concludes that when tie line power flow increase, the damping ratio of inter area mode decrease.

**Scenario 2: Effect of Tie Line Impedances**

In this scenario, three different cases will be investigated by increasing the number of tie line. Firstly two parallel tie lines. Secondly three parallel tie lines. Finally four parallel tie lines. The power flow in tie line for all three cases is 400MW.

Table 5 shows results of the three cases for this scenario.

### Table 5: Results of Tie Line Impedance Effect

<table>
<thead>
<tr>
<th>Number of tie line</th>
<th>Inter area mode</th>
<th>Local area 1 mode</th>
<th>Local area 2 mode</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Damping ratio</td>
<td>Freq (Hz)</td>
<td>Damping ratio</td>
</tr>
<tr>
<td>2</td>
<td>0.036</td>
<td>0.700</td>
<td>0.084</td>
</tr>
<tr>
<td>3</td>
<td>0.036</td>
<td>0.641</td>
<td>0.086</td>
</tr>
<tr>
<td>4</td>
<td>0.038</td>
<td>0.544</td>
<td>0.088</td>
</tr>
</tbody>
</table>

From table 5 it can conclude that when a number of tie line increase the damping ratio of inter area mode increase.

For all cases in this scenario were investigated as scenario one, in which the effect of Frequency and Damping Ratio of the inter and local area mode and Mode shape of the system were studied.

### Scenario 3: Effect of exciter and PSS

In this scenario, four different cases will be performed. Firstly adding Exciter without tuning where the power provided by each area is about 1400MW, the load of area (1) is 967MW and the load of area (2) is 1767MW so 400MW of power flows in the tie line. the type of exciter will be used is (TYPE 15). Secondly adding Tuning Exciter with the same data of case 1. Then the third case adding PSS without tuning, where the type of PSS is SYSTEM STABILIZER PSS2. Finally adding tuning PSS with similar data of case 3.

For all cases in this scenario were investigated as scenario one where effect of Frequency and Damping Ratio of the inter and local area mode and Mode shape of the system were studied. Table 7 shows results of the all cases of this scenario.

### Table 6: Results of Tie Line Impedance Effect

From table 6, It concludes that when adding a control devices to the system. The devices is needed to tuning, in order to increasing damping ratio. Also, using PSS help to increasing damping ratio, and this case is the best case.

### IV. Conclusion

From the results obtained some conclusion can be outlined.

- The damping ratio of inter area mode decreases As the amount of power increase.
- The generators in one area swing in anti-phase with the generators in the other area, in case of zero power flows on the tie line, as shown in inter area mode shape, while with 200MW & 400MW tie line flow condition, the inter area mode shape shows no longer oscillate purely in anti-phase.
- The damping ratio of the system increase when the tie line impedance increases.
- Selecting the suitable excitation system adopting to the machine will improve the damping ratio, and adding Power System Stabilizer to the excitation system is best than using excitation alone in damping ratio.
- Good tuning of Power System Stabilizer will improve the system stability.
REFERENCES


APPENDIX

A. Generators Data.

The generator parameters in per unit on the rated of MVA and KV base are the follows:

\[ X_d = 1.8 \quad X_p = 1.7 \quad X_0 = 0.2 \quad X'_d = 0.3 \quad X'_q = 0.55 \]
\[ X''_d = 0.25 \quad X''_q = 0.25 \quad R_a = 0.0025 \quad T_d = 8 \quad T_q = 0.4 \]
\[ T'_d = 0.03 \quad T'_q = 0.05 \quad A_{sat} = 0.015 \quad B_{sat} = 9.6 \quad vT = 0.9 \]
\[ H = 6.5 \quad (for \ G1 \ and \ G2) \quad H = 6.1725 \quad (for \ G3 \ and \ G4) \]
\[ K_d = 0 \]

B. Transformer Data.

There are two step up transformer and each one has an impedance of 0+0.15 per unit on 900MVA and 20/230kV base, and has off- nominal ratio of 1.

C. Transmission Line Data.

The transmission system nominal voltage is 230kV. The line lengths are showed in figure 1. The parameters of line in per unit on 100MVA, 230kV base are

\[ R = 0.0001 \quad x_s = 0.001 \quad b_c = 0.00175 \]
Performance Analysis of Quadratic Phase Shift Keying Bandpass Modulation Using Simulink

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Abstract—According to the range of frequencies communication systems can be classified into two schemes used to transmit information or data such as baseband and bandpass communication systems. Baseband transmission sends the information signal as it is without frequency shifting while bandpass transmission shifts the signal to be transmitted from low frequency to a higher frequency and then sends it, where at the receiver side the signal is moved back to its original frequency. Once a digital communication systems becomes complex and sophisticated, a detailed study and investigation is needed in order to understand the different digital modulation techniques to be implemented in the communication system.

In this paper one of the digital modulation techniques known as Quadratic Phase Shift Keying BandPass modulation(QPSKBP) is being investigated to evaluate its performance in terms of Bit Error Rate over the AWGN channel using Matlab with Simulink package. The obtained simulation results are very encouraging. This modulation technique is suitable for transmission and in the same time can save the power and bandwidth.

Keywords—Bandpass Modulation, Bit Error Rate (BER), QPSKBP.

I. INTRODUCTION

Bandpass Modulation (BPM) or sometimes called Passband Modulation (PBM) which refers to modulation of signal over a carrier frequency. In these modulation techniques the signal to be transmitted is sent by modulating either one or more of the three properties of carrier signal i.e amplitude together with phase, that is Quadrature Amplitude Modulation (QAM) or Frequency Shift Keying (FSK) or Phase Shift Keying (PSK) of the carrier signal. The Phase Shift keying Band Pass modulation (PSKBP) is one of the main schemes of the M-ary carrier digital modulation. In this type of modulation technique the data bits select one of M-aryphase shifted versions of the carrier to transmit data. Thus, the M possible waveforms all have the same amplitude and frequency but different phases. The use of multiple levels can be extended beyond taking two bits at a time. It is possible to transmit three, four, five bits... etc. at a time using eight, sixteen, thirty two .... etc of different phase angles respectively [1,2,6].

II. BANDPASS MODULATION

The process of converting a data signal to a sinusoidal waveform where its amplitude, phase or frequency, or a combination of them, are varied in accordance with the transmitted data while the result of this processing are representing the amplitude shift keying (ASK), frequency shift keying (FSK), phase shift keying (PSK), quadrature amplitude modulation (QAM) respectively.

The main different between baseband and bandpass modulation is that the baseband does not require modulation while the bandpass needs modulation. The bandpass modulation technique is needed for several reasons such as transmitting the Information for long distance without interference, noise immunity, modulation for bandwidth alteration, modulation to reduce noise and interference .modulation to increase efficiency of radiation, modulation to overcome equipment limitation, etc. [3,4]

III. QUADRATIC PHASE SHIFT KEYING BANDPASS MODULATION

The QPSKBP is one of the M-ary carrier digital modulation schemes and widely used in several communication area application. The mathematical representation and some of the main parameters of the QPSKBP modulation are described briefly in the following points.[1,5]
A. Mathematical Representation

An QPSKBP mathematical formula is given by:

\[ v_n(t) = A \cos(\omega_c t + \alpha_n) \quad \text{(1)} \]

Where:

\[ \alpha_n = \frac{2(n-1)\pi}{M} \]

\( n \) = an integer number i.e. \( n = 2 \)

\( A \) = Carrier amplitude

\( \omega_c \) = Carrier frequency in (rad)

\( M \) = number of the levels-4

B. Parameters of an QPSK Passband Modulation

The most important parameter of QPSKBP modulation is the bit rate \( (f_b) \) which is defined as an amount allowed by a system to transmit data over a communication channel and it is measured by unit bit per second (bps) and baud rate \( (D) \) refers to the rate of change of a signal on the transmission medium after encoding and modulation have occurred. Hence, baud is a unit of transmission rate, modulation rate, or symbol rate i.e.

Bit rate \( (f_b) = \frac{1}{2} \) baud \( (D) \).

Also the probability error of QPSKBP calculation involves analyzing the received phase at the receiver in the presence of noise, and comparing it to the actual phases. In an QPSKBP modulation technique the probability of the error rate can be written mathematically as follows:

\[ P(e) = \left( \frac{1}{2} \right) \operatorname{erf} \left( \frac{E_b}{\sqrt{N_o}} \right) \quad \text{(2)} \]

Where \( \operatorname{erf} \) is an error function, \( (E_b) \) energy per bit and \( (N_o) \) Noise power

IV. QPSKBP SIMULATION MODEL

The QPSKBP transmitter /receiver model is constructed using Simulink as shown in figure 1. This simulation model contains the following parts;

- random integer generator
- M-PSK modulator baseband
- raised cosine transmit filter, up-converter
- AWGN channel, down-converter, raised cosine receive filter
- M-PSK demodulator baseband, error rate calculation

![Figure 1 QPSKBP Simulation Model](image)

After implementing and setting the simulation parameters of the transceiver of an M-ary PSK model shown in figure 1 for \( M=4 \) i.e QPSK model. Two tests with and without nonlinearity interface are carried out as illuminated in the following points:-

(a) Test 1: In this test nonlinearity interface is not considered. The obtained results of simulation, where the power spectra of the transmitted and received random integer signals, the desired signal and interference signal and the power spectra of the signals after the filter at transmitter side and before the filter at the receiver side as illustrated in figures 2 to 4 respectively.
From the obtained results, the power spectra of transmitted and received signals are very close and the interference signal has a minimal effect on the desired signal. I.e. when there is no nonlinearity in the channel the QPSKBP performs very well.

(b) Test II: This test similar to the first test, but in this case a nonlinearity exist in the channel. The obtained simulation results are shown in figures 5 and 6. The obtained results indicated that there is an effect of nonlinearity on the desired signal and that quite clear from figure 5.

V. Performance Evaluation of QPSKBP

The simulation was run several times by varying the $E_b/N_0$ value for both cases with and without nonlinearity using the model in fig 1. The range for $E_b/N_0$ at which the BER values are calculated is 0 to 8 dB as shown in figure 7. From the obtained results a comparison chart was generated for the BER for QPSKBP for both test cases with and without nonlinearity interface. From the figure it can be seen that QPSKBP without nonlinearity interface performs better over the QPSKBP with nonlinearity interface. At BER value of $10^{-3}$, the $E_b/N_0$ value was nearly 8 for the case without nonlinearity interference and was close to 10 for the case when nonlinearity interference existed.
VI CONCLUSION

From the obtained results it can be concluded that QPSKBP without nonlinearity interference performs better than QPSKBP modulation with nonlinearity interference in terms of BER, which indicates that QPSKBP without interference has a better bandwidth efficiency and hence it can be used for systems with less power since it has a better channel frequency error.

REFERENCES

1. Ian Glover, Digital Communications, 2000
2. AmerDaeri and AmerZerek, "Effects of AWGN channel and Eb/No on the system performance in LTE Downlink Transport Channel using QPSK Modulation", 3rd International Conference on Automation, Control, Engineering and Computer Science (ACECS-2016) 20 - 22 March 2016 - Hammamet, Tunisia
Open Loop V/F Control of Induction Motor based on PWM Technique

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ABSTRACT— The rapidly developments in power semiconductors technology, converter topologies and control techniques with increased reliability and reduced cost led to the production of AC induction drives. The need for variable speed of an AC motor with maintain torque constant is necessary in many industrial applications. So, the line voltage should also be varied directly with frequency to remains torque very nearly constant. In this paper a three-phase voltage source inverter is used here to provide variable voltage and frequency supply required by AC drives. The Pulse width modulation technique (PWM) techniques are used here to control frequency voltage-sourced inverters. The relationship between supply frequency and speed of induction motors is directly proportional, i.e., the increase in supply frequency of induction motor, corresponds to increasing in speed induction motor and vice versa. The total harmonics distortion (THD) are measured at varying modulation indexes. The simulation test-bed is described and simulated using MATLAB/SIMULINK. Lastly, results are discussed, and conclusions are provided.

Keywords— Induction Motor (IM), Speed Control, Frequency, PWM, Inverter, Rectifier, Filter, Total harmonic distortion (THD).

I. INTRODUCTION

Induction motors are widely used in industrial applications “Workhorse of the Industry” [1-5]. They have a lot of advantages like, low manufacturing cost, wide speed range, high efficiency, robustness……etc [6]. Also, this kind of motors are used in different applications such as industries, transportation, household appliances, laboratories …etc. They cheaper then DC and Synchronous motors. Also, they have very high starting torque which makes useful in applications especially where the load is applied before starting the motor. In addition, induction motors are very reliable, and they have high efficiency of energy conversion [7]. And other advantages which make them widely used in all the world. The voltage source inverters (VSI’s) are widely used to control the speed of three-phase Induction Motors (IM’s) over a wide range by varying the stator frequency. Generally, the most modern variable frequency drives operate by converting an AC voltage source to DC voltage using rectifier. After the power flows out of the rectifiers it is stored on a dc bus. The dc bus has capacitors for accepting power from the rectifier, stores it, after that it delivers that power through the inverter. The inverter contains power electronics switches that deliver power to the motor [2]. There are various methods to control speed of an IM, such as pole changing variable, supply frequency control, variable supply voltage control, variable rotor resistance control, voltage / frequency (V/f) control vs. slip recovery and vector control. But the V/f control is the most popular method used to control the speed of an IM for many reasons, such as it provides good range of speed. Also, the transient performance and running of this type of IM is good. In addition to, the starting current is had low. Also, It has a wider stable operating region [8]. At base speed Voltage and frequencies reach rated values. So, Induction motors run at constant speed which its speed depends on frequency. By changing the frequency can be controlling and changing the range of speed. The ratio of the applied voltage / frequency of supply is directly proportional with torque that developed by the IM. By varying the frequency and voltage, but keeping their ratio constant, throughout the speed range the torque developed can be kept constant as shown in figure 1 [9]. Output voltage of an inverter can be controlled with in the inverter itself which it is called (internal control), or from outside either from the input of inverter (External control of dc input voltage) or from the output side of the inverter which it is called (External control of ac output voltage). Pulse width modulation is one of methods that controlling output of inverter from inside the inverter, which comes under internal control [10]. An ideal inverter should give a sinusoidal output voltage waveform. But practical inverters produce non-sinusoidal waveforms which they contain harmonics [11]. The one of the objectives of PWM techniques in this paper is to reduce these harmonics that content in Three Phase VSIs.

II. THREE PHASE INVERTERS

Static inverters may be classified into two types based on their operation: Voltage source inverter (VSI) and Current sources inverter (CSI) [9]. In this report just will concentrate about the first type voltage sources inverter (VSI). In figure. 1 below shows a circuit diagram of a three-phase inverter. This
inverter consists three arms and six semiconductor devices which arranged in each arm has two semiconductor devices. It is fed from a rectifier circuit or any other dc supply sources. It works to convert the input dc supply into three phase ac output supply, where the amplitude, phase, and frequency of the voltages should always be controllable [11].

![Three Phase Induction Motor](image)

**Fig. 1 Three—phase Voltage Source Inverter**

III. **SINUSOIDAL PULSE WITH MODULATION IN THREE-PHASE INVERTER**

In sinusoidal pulse width modulation (SPWM) there are multiple pulses per half-cycle and the width of them pulses is varied with respect to the sine wave magnitude. To output 120o out-of-phase load voltages, are used three modulating signals that are 120o out of Figure 2. shows the ideal waveforms of three—phase sinusoidal pulse width modulation. To maintain the features of the PWM technique and use a single carrier signal, the normalized carrier frequency should be an odd multiple of 3. Therefore, all phase voltages \( V_{AN}, V_{BN}, V_{CN} \) are identical but 120o out of phase without even harmonics [12].

The amplitude of a sinusoidal signal is \( A_s \), and the amplitude of triangular carrier wave is \( A_c \), so the ratio \( m = \frac{A_s}{A_c} \) is known as the Modulation index. Figure 2. shows the general scheme to SPWM, a high frequency triangular carrier wave is compared with the sinusoidal reference wave determines the switching instant [5,13]. Generating controllable magnitude and frequency balanced for three phase sinusoidal wave forms is a little difficult task for an analog circuit, so a mixed analog and digital circuits is often preferred.

![Triangular Carrier Wave](image)

**Fig. 2 Sinusoidal Pulse width modulation**

![Sinusoidal Reference Wave](image)

The the three phase PWM signal is showed in Figure 3. Which \( V_{tri} \) is waveforms of carrier wave signal and \( V_{control} \) is control signal, inverter output line to neutral voltage \( (V_{AN}, V_{BN}, V_{CN}) \), inverter output line to line voltages \( (V_{AB}, V_{BC}, V_{CA}) \), respectively [11].

\[
\begin{align*}
V_{AB} &= V_{AN} - V_{BN} \\
V_{BC} &= V_{BN} - V_{CN} \\
V_{CA} &= V_{CN} - V_{AN}
\end{align*}
\]

Amplitude Modulation, \( M_a = \frac{A_s}{A_c} \)

Frequency Modulation, \( M_f = \frac{f_s}{f_c} \)

![Waveforms of three—phase SPWM inverter](image)

**Fig. 3 Waveforms of three—phase SPWM inverter**

Percentage of individual harmonics is calculated by the eqn. where, \( n = \text{nth harmonics} \).
Percentage of total RMS of the output, when \( M_f \) is even

\[
\frac{\text{rms}(n)}{V_{DC}} = 100 \left( \frac{4}{n\pi\sqrt{2}} \sum_{p=1}^{M_f} (-1)^{p+1}\cos\alpha_i \right)
\]

where, \( n = \text{nth} \) harmonics

Percentage of total RMS of the output, when \( M_f \) is odd

\[
\frac{\text{rms}(n)}{V_{DC}} = 100 \left( \frac{2}{\pi} \sum_{p=1}^{M_f-1} (\alpha_{2p} - \alpha_{2p-1}) \right)
\]

When \( M_f \) is odd

\[
\%V_n = 100 \times \sqrt{\frac{M_f}{\pi} \sum_{p=1}^{M_f-1} (\alpha_{2p} - \alpha_{2p-1})}
\]

Total harmonics distortion (THD) is given by,

\[
THD = \frac{V_h}{V_1}
\]

Where:

\[
V_h = \sqrt{\sum_{n=2,3,...}^\infty V_n^2} \quad \text{or} \quad V_h = \sqrt{V_{out}^2 - V_1^2}
\]

IV. THREE PHASE INDUCTION MOTORS

A. Constriction

An induction motor is a machine that contains a rotor part and a stator part. The windings are three-phase which put in the slots of stationary part of the machine "stator". The stationary part of motor is composed of laminations of high-grade sheet steel. The rotating part of induction motor "rotor" also contains either a distributed three-phase winding or cage of interconnected copper bars that serve as rotor winding conductors. Not like dc machine, induction motors have a uniform air gap [14].

B. Working

The stator winding is energized by a three-phase supply, a rotating magnetic field in this machine is established which rotates around the stator at synchronous speed \( N_s \). The stationary rotor is cut by this flux and in the rotor, windings induces an electromotive force. So, the current flows in the rotor windings because of short-circuited in them. Mechanical force will be exerted in the conductors that placed is stator by Lenz's law. Lenz's law said that the direction of rotor currents will be such that they will try to oppose the cause producing them. Hence, a torque is produced which tries to reduce the relative speed between the rotor and the magnetic field. Thus, the rotor and flux will rotate in the same direction. Thus, the relative speed between the magnetic field and the rotor will be drives the rotor. Hence the rotor speed \( N_r \) of this kind of motor remains less than the synchronous speed \( N_s \). So, the Induction Motors are also called Asynchronous Motors [7].

C. Torque-Speed Analysis

The equivalent circuit of an Induction Motor can be depicted as shown in figure 4.

![Fig. 4 Equivalent Circuit of an Induction Motor](image)

Where:

\( X_m = \text{Magnetizing Reactance} \)
\( X_s = \text{Stator Reactance} \)
\( X_r = \text{Rotor Reactance} \)
\( R_s = \text{Stator Resistance} \)
\( R_r = \text{Rotor Resistance} \)
\( S = \text{slip} \)
\( p = \text{pole per phase} \)
\( F = \text{output frequency} \)

In an Induction Motor the slip is given as

\[
S = \frac{N_r - N_s}{N_s}, \quad N_s = \frac{120F}{p}
\]

Where:

\( N_s = \text{Synchronous speed} \)
\( N_r = \text{Rotor speed} \)

The following expressions can be derived from the above circuit

Rotor Current

\[
I_2 = \frac{V_o}{(R_s + R_r) + j(X_s + X_r)}
\]

Torque

\[
T = \mp \frac{R_s E_o}{\omega d\left[\left(R_s E_o\right)^2 + \left(X_s + X_r\right)^2\right]}
\]

The mechanical power developed \( P_m \)

\[
P_m = T \frac{2\pi N}{60} \quad \text{where} \quad \omega = \frac{2\pi N}{60} \quad \text{so} \quad P_m = T \omega
\]

\( \omega = \text{output speed} \quad \text{rad/sec} \)

The following are the torque and speed characteristics for an Induction Motor for various frequencies as shown in figure .5.
V. MODELING OF INDUCTION MOTOR DRIVE FED BY PWM INVERTER.

The Block diagram of a voltage source inverter fed IM drive is shown in Figure 6. It consists mainly four blocks as it can be seen below, three-phase rectifier, filter circuit (DC link), three phase inverters and PWM generator. All those blocks are used to feed a three-phase IM. Firstly, the three-phase AC voltage are converted into DC using diode rectifier circuit. Then the output DC voltage of rectifier is filtered using capacitor C for reducing ripple voltage. After that the obtained DC voltage supplied to the three phase IGBT inverter in which converted back again to AC output power, but with variable voltage and frequency to feed IM. The switching frequency is set to 3 KHz using PWM technique.

VI. SIMULATION RESULTS AND ANALYSIS

Figure 7 shows the Simulink model for three Phase inverter fed IM drive which has been designed and implemented by using MATLAB Simulink. The parameters of IM that used for simulation are as follows: 5.4 Hp, 2 pole, 1430 rpm, 3-phase with parameters: $V_{rms} = 400$ volt, $f = 50$ hz, $R_s = 1.405$ ohm, $R_r = 1.395$ ohm, $L_s = L_r = 0.005839$ H, $L_m = 0.1722$ H, $J = 0.0131$ kg.m2, $F = 0.002985$ N.m/s.

The dc link filter parameter is $C = 0.1$ µF. The load torque applied to the machine’s shaft is constant = 20 N.m. The inverter which used in this model has been built using six IGBT semiconductor devices.

From the figures below, it has been observed that the IM attains steady state at $t = 0.15$ s approximately. Figure 8 shows the waveform of input phase voltage before rectified and output of rectifier waveform after filtered. In figure 9. the output phase current and output phase voltage of inverter are showed. While figure 10. is illustrated the three phases stator current of IM. Lastly the waveform in figure 11. shows the torque response, the torque is started at high value then it settles and remains a constant as the IM attains the speed. The output voltage harmonics are presented out as sidebands of the switching frequency and its multiples in a PWM inverter. The table I. below represents the changes in total harmonic distortion according to different modulation indexes. The speed of IM is controlled by varying in frequency as shown in table II. But should keep the ratio of voltage/frequency constant to maintain torque load constant.
VII. CONCLUSION

In this paper, a speed control of IM is presented. It can be concluded that as the modulation index increases total harmonic distortion (THD) decreases. Therefore, THD can be reduced by increasing modulation index. Also, the variations in modulation index affects the speed of IM drive. The speed of IM drive has been controlled by varying supply voltage and frequency with constant (Voltage/frequency) ratio. Hence, the motor runs at variable speed below rated speed by maintaining constant V/F ratio to maintain torque load constant. The speed change ratio of IM is not fixed, in which increases more at low frequencies. Also, the THD of voltage is high at low frequencies. Therefore, this method of controlling speed induction motor is useful more at high frequencies. Graph for
the torque response rises to a maximum value and then settle down to steady state value, whereas the rotor speed reached the rated speed and remain constant. The motor was fully utilized, and successful speed control was accomplished.

REFERENCES


[5] Phase AC Motor Control with V/Hz Speed Closed Loop Using the 56F800/E Freescale Semiconductor, 2005


Principle of Modified Incremental Conductance Sliding Mode MPPT Control Applied of Photovoltaic system

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Abstract— In order to operate the photovoltaic generator in its optimal regime, it is necessary to introduce an adaptation stage between the source and the load. This stage is generally in the form of a static converter (DC/DC). To extract the maximum power at each moment from the generator photovoltaic, the control (Maximum Power Point Tracking) acts on the duty cycle of the DC-DC converter to extract the Maximum Power Point. These methods are classified into three categories: indirect, direct and intelligent methods. In this work we will make a combination between a direct method which is characterized by its simplicity of implementation and another method among the intelligent methods which is characterized by a very good response time of the system and offers a minimization of oscillation around the maximum power point. These methods are: the incremental conductance method and the sliding mode method. With this mixture between these two methods, an improvement has been applied which is a starting system which facilitates the attack of the maximum power point during the starting phase through the open circuit voltage. This combination gives a very good extraction of the point of maximum power, this is demonstrated by the simulation results.

Keywords— Incremental Conductance (IC), Modified incremental conductance sliding mode method (MICSMM), Maximum power point tracking (MPPT), Sliding mode control (SMC).

I. INTRODUCTION

The renewable energy penetrates becoming more and more important in national electricity production. The Tunisian strategy plans to bring back the share of renewable energies in electricity production from around 2% in 2010 to 30% in 2030.

In the last decades, following the improvement of the yield of photovoltaic panels as well as the increase of the advantages notably the subsidies, the profitability of a photovoltaic installation became justified. A problem we may encounter is the high dependence of the output characteristics of a photovoltaic generator with the climate conditions (Temperature and irradiation). So we have to find ways to still extract the maximum power of PVG and send it to the load.

To ensure an optimal operation of the photovoltaic generator (For a given illumination and temperature), there is an optimal voltage $V_{opt}$ and an optimal current $I_{opt}$ which generates an optimal power $P_{opt}$ delivered by the photovoltaic generator. As a result, there are different search techniques of the MPP that lead to reducing the error between the voltage of the photovoltaic generator and the optimal reference voltage which varies according to the climatic conditions. Several methods are used to avoid this operating problem by generating a suitable $V_{opt}$ reference voltage. These methods are summarized in three categories: Indirect, Direct and Intelligent methods.

Among these different methods, we have chosen to make a combination between two methods belonging to two different categories; Incremental conductance and sliding mode methods. The purpose of this combination is to take advantage of the advantages of each of these methods to have a very good extraction of maximum power in terms of response time, oscillation minimization and simplicity of implementation.

1
The rest of this paper is organized as follows: The modeling of the PV System is introduced in section 2. Section 3 is interested in the description of proposed MPPT algorithm. In section 4, the simulation results are provided.

II. CONFIGURATION OF PV POWER SYSTEM

The system thus synthesized presents a photovoltaic system without storage energy. It consists of a resistive load powered from a renewable energy source (photovoltaic energy). The stage of adaptation between the load and the source is ensured through the addition of a booster chopper. Chopper control is done with a Maximum Power Point Tracking (MPPT) command to extract a maximum power from the load. Fig.1. shows the block diagram of the study system.

A. Electrical model of a real solar cell

The equivalent diagram of a photovoltaic cell is given by the Fig 2.

![Fig 1: General structure of the PV system](image)

![Fig 2: Equivalent circuit of real solar cell](image)

The mathematical model of a photovoltaic cell is given by the following equation (1):

\[
f(v_{pv}, i_{pv}) = i_{pv} - i_{ph} + i_{s} (\exp(\frac{v_{pv} + r_{ph} i_{pv}}{v_{t}}) - 1)
\]

With \( V_{pv} \) and \( I_{pv} \) are respectively the output voltage and the output current of PV Generator, \( i_{ph} \) is the photocurrent, \( i_{s} \) is the reverse saturation current of the diode, \( v_{t} \) is the solar cell thermal voltage, \( R_{s} \) and \( R_{sh} \) are respectively the series and shunt resistors of the cell. The PV Generator is constituted by an assembly of photovoltaic panels; the panels in turn are constituted by photovoltaic cells.

B. Modeling of the PVG-BOOST chain

Fig. 3. shows the block diagram of a parallel chopper:

![Fig 3: Block diagram of a parallel chopper](image)

To extract maximum power from PVG, we must act on the chopper by the action of the duty cycle that is given by the following equation:

\[
V_{dc} = \frac{V_{pv}}{1 - \alpha}
\]

Fig.4. and Fig.5. show the structure of the chopper boost in both cases of the controlled switch:

- **Closed switch structure**

![Fig 4: Block diagram of closed switch structure](image)

\[
\frac{d i_{c}(t)}{dt} = \frac{V_{pv}(t)}{L}
\]

\[
\frac{d V_{dc}(t)}{dt} = \frac{V_{dc}(t)}{R c_{2}}
\]

- **Structure with open switch**
\[ \frac{d(t)}{dt} = \frac{V_{p(t)}}{L} - \frac{V_{d(t)}}{L} \]
\[ \frac{dV_{d(t)}}{dt} = \frac{I_{d(t)}}{C} - \frac{V_{d(t)}}{C_R} \]

From (3) and (4), the mathematical model of the PVG-BOOST system is as follows:

\[ \frac{d(t)}{dt} = \frac{V_{p(t)}}{L} - \frac{I_{d(t)}}{L} \]
\[ \frac{dV_{d(t)}}{dt} = \frac{V_{d(t)}}{C} + \frac{(1-u)I_{d(t)}}{C_R} \]

With \( u \) is the switching state.

If we ask that: \( x = [x_1 \ x_2]^T = [i(t) \ V_{d(t)}] \)

so, we get the following model:

\[ \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & \frac{x_2}{L} \\ \frac{x_1}{C} & \frac{x_2}{R} \end{bmatrix} x + \begin{bmatrix} \frac{V_{p(t)}}{L} \\ 0 \end{bmatrix} \]

### III. PRINCIPLE OF THE PROPOSED MPPT TECHNIQUE

The output characteristics of a photovoltaic generator are influenced by climatic conditions. Therefore, MPPT techniques are required to follow the maximum power point to maximize the extracted power. This MPPT as its name suggests can track the PVG maximum power point.

#### A. Incremental conductance method

Incremental conductance algorithm is based on the following equation

\[ \frac{\partial I_{pv}}{\partial V_{pv}} + \frac{I_{pv}}{V_{pv}} = 0 \]

When the operating point is in the right of the maximum power point, so we have:

\[ \frac{\partial I_{pv}}{\partial V_{pv}} + \frac{I_{pv}}{V_{pv}} < 0 \]  \hspace{1cm} (8)

If this point is to left of maximum power point, we obtained:

\[ \frac{\partial I_{pv}}{\partial V_{pv}} + \frac{I_{pv}}{V_{pv}} > 0 \]  \hspace{1cm} (9)

The optimum can be followed by comparing the instantaneous conductance \( I_{pv} \) and the incremental conductance \( \frac{\partial I_{pv}}{\partial V_{pv}} \). If the optimum is reached, the operation of the PVG is maintained at this point and the disturbance stops until a new change in current level is noted, [1], [2]. In this case, the decrease in the algorithm or the increment is performed to follow the new maximum power point. This method provides a good performance in rapidly changing weather conditions.

#### B. Modified Incremental Conductance Sliding Mode Control (MICS)

The variable structure control with sliding mode is a control technique that is essentially characterized by: the robustness of a system in front of parametric variations and external disturbances.

The feasibility of this control technique is validated theoretically as well as the practical plan. The control of variable structure systems occupies a nonlinear control class of systems. It is essentially characterized by a structure that varies with the evolution of the order, [3]-[5].

Sliding mode control is a technique that occupies a large part in different applications (robotics, aeronautics, automobile, electric actuators, etc ...).

The synthesis of the sliding mode control consists essentially of three parts,
- The choice of the sliding surface;
- The establishment of the conditions of existence;
- The determination of the control law.

In this part, we studied the continuous-time Sliding Mode Control (SMC) theory while providing an improvement to it, [6], [7].

MICS method consists firstly in a combination of the incremental conductance method and the sliding mode. We will choose as sliding surface \( S \) the equation that characterizes the IC method:

\[ s(x) = \frac{I_{pv}}{V_{pv}} + \frac{\partial I_{pv}}{\partial V_{pv}} \]

At the point of maximum power, We have:
\[
\frac{I_{pv}}{V_{pv}} + \frac{\partial I_{pv}}{\partial V_{pv}} = 0 \implies I_{pv} = -\frac{\partial I_{pv}}{\partial V_{pv}} \quad (11)
\]

We will consider \( y = -\frac{\partial I_{pv}}{\partial V_{pv}} \) as incremental inductance and \( y = \frac{I_{pv}}{V_{pv}} \) as instantaneous conductance. So we can write the sliding surface in another form according to the current \( I_{pv} \):

\[
s(x) = y(I_{pv}) - Y(I_{pv}) \quad (12)
\]

We distinguish three cases of operation:

- To the left of the PPM:
  \( y(I_{pv}) - Y(I_{pv}) > 0 \implies y(I_{pv}) > Y(I_{pv}) \)

- To the right of the PPM:
  \( y(I_{pv}) - Y(I_{pv}) < 0 \implies y(I_{pv}) < Y(I_{pv}) \)

- At the PPM:
  \( y(I_{pv}) - Y(I_{pv}) = 0 \implies y(I_{pv}) = Y(I_{pv}) \)

This principle can be explained by the following figure:

![Fig. 6 Cases of operation](image)

Once the sliding surface is chosen. We will determine the control law which is generally constituted by two terms. It is written in the following form:

\[
u = u_{eq} + u_{nl} \quad (13)
\]

\( u_{eq} \): It is the equivalent command whose operating point remains on the sliding surface. It is determined from the derivative of the switching function which is equal to zero.

\( u_{nl} \): It is the discontinuous term. The operating point must remain in the vicinity of the surface \( S \).

During the sliding mode, we have: \( s = \dot{s} = 0 \) et \( u = u_{eq} \).

Gold, the sliding surface depends solely on \( x_i = i_L \), which gives us,

\[
\dot{s} = \frac{\partial s}{\partial x_i} \dot{x_i} - \frac{\partial x_i}{\partial i_L} i_L = \frac{\partial Y}{\partial i_L} \times \frac{V_{pv}}{L} \times (-1 - u) \frac{V_{dc}}{L} = 0 \quad (14)
\]

The equivalent order is calculated as follows:

\[
u_{eq} = 1 - \frac{V_{pv}}{V_{dc}} \quad (15)
\]

The nonlinear component is given by:

\[
u_{nl} = -k|s|^\beta \text{sgn}(s) \quad (16)
\]

With \( 0 < \beta < 1 \) and \( K \) is a constant.

So, finally we get:

\[
u = \nu_{nl} + u_{eq} = 1 - \frac{V_{pv}}{V_{dc}} - k|s|^\beta \text{sgn}(s) \quad (17)
\]

The conditions of existence are verified, if there is a function of Lyapunov such that:

\[
\nu = \frac{1}{2}s^2, \quad d\nu = \dot{s}.s < 0 \quad (18)
\]

This condition is called condition of attractiveness.

After the calculations and simplifications, we obtained

\[
d\nu = \frac{A\times V_{dc}}{L} u_n \times s(x) < 0
\]

\[
= -\frac{A\times V_{dc}}{L} |s|^\beta \times s(x) \times \text{sgn}(s) \quad (19)
\]

Thus, the sign of \( A \times \frac{\partial s}{\partial i_L} \frac{\partial Y}{\partial i_L} \) is always negative.

So, to ensure the stability of the system: \( k < 0 \)

The data cycle of the chopper is given by:

\[
\alpha = \begin{cases} 
0 & u \leq 0 \\
0 < u < 1 & \text{else} \\
1 & u \geq 1
\end{cases} \quad (20)
\]
Temperature is the second most important parameter in the behavior of a photovoltaic cell. By setting the illumination to a fixed value, the changing of the temperature leads to the change of the MPP. The open circuit voltage decreases by increasing of the temperature which causes a decrease in the maximum power.

We note that the optimum voltage is directly related to the open circuit voltage as shown in equation (3):

\[ V_{pv\_opt} = K \cdot V_{oc} \]  

(21)

With \( K = 0.77 \)

We will use these results to improve the proposed method because it is known that at the beginning the photovoltaic system takes a long time to reach the MPP. So we will add a starter system that can find the optimal voltage that corresponds to the MPP which is equal to 77% of \( V_{oc} \).

IV. SIMULATION RESULTS

To compare the performances of the MICSM algorithm and the conventional IC method, a MATLAB-SIMULINK model of a PV system is developed. At the beginning, we will test these two approaches with standard test conditions (INS=1000w/m², T=25°C). The results obtained of IC method are presented in Fig. 7, and Fig.8. The results obtained of MICSM method are presented in Fig.9, Fig.10 and Fig.11.

The simulation results show the effectiveness of the MICSM method compared to the conventional IC method. the system reaches its maximum power with minimum oscillation and even for the optimal voltage which is on the order of 150V.

In order to validate the proposed method, a test were carried out taking into account an irradiation scenario (800=>900=>1000W/m²). The evolution of powers for IC and MICSM methods are given by Fig.12. and Fig.14. The evolution of the MPP for the two methods are given by Fig.13. and Fig.15.
Table (1) summarizes the results obtained from the previous figures with respect to response time and the speed of tracking of the MPP.

TABLE I

<table>
<thead>
<tr>
<th>Methods</th>
<th>800 =&gt; 900</th>
<th>900 =&gt; 1000</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC</td>
<td>0.035s(3500 cycles)</td>
<td>0.035s(3000 cycles)</td>
</tr>
<tr>
<td>MICSIM</td>
<td>0.005s(500 cycles)</td>
<td>0.005s(500 cycles)</td>
</tr>
</tbody>
</table>

The two MPPT techniques are compared in terms of dynamic response and oscillation around MPP, the results show that the MICSIM method is much better than the classical method IC. The response time is much better in the case of the modified method and even for the oscillation which is decreased compared to the classical method.

V. CONCLUSION

The control strategy proposed in this work is applied to a photovoltaic system (resistive load). This requires, in the first place, the analysis of the source-side system, that is to say the elaboration of a command that uses the search of the optimal point of the power (MPPT) applied to the association "photovoltaic generator - chopper. The interesting part of this work is devoted to the control of the proposed PV system with a technique that comes from a combination of two different methods (incremental conductance and sliding mode) and with an improvement based on the addition of a starting system which makes it possible to attack the point of maximum power more quickly at the start of control. In this context, we present results based on a comparative study of performances in terms of response time and oscillations. The results of the simulations obtained confirm the validity of the proposed approach (MICSIM).

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REFERENCES


Smart Cooling System For High Transformer

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Abstract— Some countries, including Libya have adopted high capacity oil-cooled transformers that require constant monitoring by engineers to ensure they operate in a way that enable to reach their full capacity, especially in the summer because of the high temperature of the weather, which adversely affects the capacity of transformers. The transformer heat increases and the separation mechanical system could not disconnect the transformer Because of its famous failures, or if the controller engineer which observe the manual separation is not at the station during the fault on the transformer. This will cause damage to the transformer. In this paper, smart cooling circuit is designed to protect the transformers from increase in temperature, which in turn protect the transformers from the damage and combustion.

Keywords— transformer; buchholz relay; GSM SIM800; Microcontroller;

I. INTRODUCTION

Transformers are considered to be the devices that helped people meet their energy needs, where transformer is a static device consisting of a winding, or two or more coupled windings, with or without a magnetic core, for inducing mutual coupling between circuits Transformers are exclusively used in electric power systems to transfer power between circuits through the use of electromagnetic induction [1], Power transformers must be used at each of these points where there is a transition between voltage levels and for step-down operation, mainly used to feed distribution circuits. The construction of a transformer depends upon the application. For instance, transformers intended for indoor use are primarily of the dry type but can also be liquid immersed for outdoor usage [2], Most countries especially North African countries including Libya Depends on the oil-cooled transformers especially the 30 kV transformers For their high efficiency to reach the highest conversion rate designed for it, where Increasing the cooling rate of a transformer from increases its capacity, Cooling methods must not only maintain a sufficiently low average temperature but must prevent an excessive temperature rise in any portion of the transformer (i.e., it must prevent hot spots). For this reason, working parts of large transformers are usually submerged in high-grade insulating oil [3], But transformers oil-cooled need constant monitoring, Is divided into self-monitoring which is a protective device designed to deal with the events of emergency on the transformers and be installed inside the operating room of the transformer. It can be divided into special protection devices transformers into two types, first Prevention mounted on body transformer, second The protection on the transformer circuit that deals with the problems of the transformer with the electrical network Gas Relay - Oil Level Gauges - Lightning Arrestors - Protective Relay - Differential Protection - Over Current Protection – Buchholz Relay, a Buchholz relay Commonly known as the gas accumulation relay is constructed so that it accumulates all or a fixed portion of the gas released by the protected equipment. It operates when the volume of gas reaches a certain level [4], And human monitoring of manual handling of emergency events on transformers, Which determines the type of control is the key next to the converter either be automatic or manual, where Libyan state has adopted a control management to manual monitoring oil-cooled transformers called operating management and monitoring Its mission is to employ engineers who supervise the operation of transformers In alternating groups throughout the 24-hour to Follow-up the distribution of the required load efforts as well as the control of transformers from an emergency occurs to it as coolant Low oil level in the transformer tank, increase load signals, and converter oil pressure signal Using Buchholz which consists of 2 Relays the first to determine the level of transformer oil and the second to sense the pressure of gases inside the transformer body pressed as the oil temperature rises send the sensor A signal that the heat of the transformer has risen to A protective or monitoring device for self-separating transformer This increase in temperature is usually caused by increased load, Precisely at peak times during hotter or cooler weather, And human monitoring of manual handling of emergency events on transformers, Which determines the type of control is the key next to the converter either be automatic or manual, especially During summer season, many power transformers are exposed to intensive, direct insolation. On the other hand, in recent years, the use of increasing number of air conditioning systems during summer, caused growing trend of electrical load. As the consequence, black-outs of power transformers occurred during summer [5] Often it consumes a gas pressure sensor a mechanical because it has a mechanical movement Its consumption by causes oil loss its properties So that makes it calculations hinder his movement and becomes compressed gas inside the
transformer and the sensor mechanical unable to move to feel the protective device that the heat has risen And then the monitoring device will not disconnect the adapter and then will cause serious damage if the engineer cannot turns off the transformer because of his increased voice which indicates that the load has increased , If the engineer is outside the power station, severe damage to the transformer will cause damage and fire This is the most common problem experienced by the General Electric Company in Libya and can be Embodied solve this problem installing smart cooling system on the body of the transformer Where reading the temperature in an instantaneous way by a sensor installed inside the poles of the converter It sends readings to the system and compares readings with a stored reference and displays them on a LCD display within the operating station and on the comparison result the system determines its function . Either run a large-sized fan installed on the oil cooling plates or run the alarm horn to alert engineer The supervisor or the separation of the adapter, and then send a text message to a phone engineer That the emergency happens to the elbow their last temperature reading in the text message

II. SYSTEM COMPONENTS

These problems are common in adapters especially in 30 kv transformer in Libya. The engineers and researchers focus on finding solutions to these problems that causing fires in transformers and increase periodic maintenance of the transformers periods for the purpose of continuous detection and by preventing the development of calcifications. Also, to detect a predictive oil and fined some other solutions that are special protection for heat Without tying them with oil protection so that they do not get affected by oil damage or even discharge from the body, Transformers and for this we deliberately in this report separation between control of transformer oil and temperature control Heat the transformer electrodes using a smart cooling system that it consist from 10 components.

1. Microcontroller (arduino)

It is an electronic circuit and is a small computer that can interact and control the surrounding environment better than other microcontrollers. It contains a small atmega 328 chip, which is used in controlled programming by atmel. This circuit provides ports for connecting electronic components, The Arduino circuit also contains a 16-megahertz (Crystal Oscillator) with a USB port for connection to the computer, and a separate power input. This circuit shown in Fig. 1.

2. liquid crystal screen

The LCD screen is a thin flat screen consumes a very small amount of energy as shown in fig. 2. The screen is used to display letters and numbers, some of which can display graphs.
In this report you used to display letters and numbers which is a 2×16 screen, which means that it is a two-line screen on which each line can write 16 characters or numbers

3. Sensors DS18B20

The temperature can measure in the center surrounding. it can be immersed in water or oil, And the nature of his work is that when we give it in its 5 volts The output exceeds 1 mV, Per Celsius degree i.e. that at 1 ° C the output will be 1 mV, Ranging from reading this sensitive from -50 to 150 ° C. This type is shown in fig. 3.

4. Resistors

A resistor placed on the entrances and exits of controlling the minute is considered the protection of micro-controlling which (560 ohms 10 Kilwaam). Fig.4 is the resistors shape.
5. Relays
The relay is one of the most important elements used in electronic control of various types as shown in fig. 5. It works to relay a voltage and a small current to carry a large load and the advantages of the relay lies in its ability to completely isolation between the source and load circuit.

![Fig. 5 Relay](image)

6. Light diode
Fig. 6 shows some photovoltaic diodes. These are small and resemble small lamps, Turns the power supply into light, Optical diodes are available in different colours (red, green, orange, yellow, white and blue).

![Fig. 6 Light diodes (lamp)](image)

7. Bipolar Digital Integrated Circuit ULN2803
The way ULN2803 works when receiving a signal from the Arduino connects the ground line to the relay so that the complete nutrition. Next figure shows this type of the circuit.

![Fig. 7 ULN2803 piece full of transistors](image)

8. Buzzer
Buzzer is an electronic component that emits a sound when a suitable voltage placed at both ends as shown in fig. 8.

![Fig. 8 Siren](image)

9. Fan
Fan an electric matter that has blades to move the air during the movement of the motor as shown in fig. 9.

![Fig. 9 Fan](image)

10. GSM SIM800
GSM SIM800 is a small device with an SMS card to send a message sent by the controller. This kind of GSM is shown in Fig. 10.

![Fig. 10 GSM SIM800](image)

III. Theory and Design
All system components are connected to the control panel and the heat sensor is also installed Inside the transformer and be the income of the system ,and the fan is installed on the transformer oil cooling boards , Outside the operating station, the LCD display is installed , and the red and green lamps and the alarm Buzzer And all are installed inside the operating station , This system is programmed to include a reference numbers temperatures , If the heat of the transformer is increased and sent to the system by temperature sensor, It was compared with the any from the references numbers which has been divided into four stages from 0 to 100 degrees centigrade , where these stages are less than 40 degrees centigrade from the hot spots that cause the collapsed the transformer , which will be at 140 degrees centigrade. Fig. 11 shows the final assembly of a circle.
The task of this system is early warning and cooling, when high temperature the sensor sends the temperature to the microcontroller, which in turn compares them with the reference stages (Normal heat mode, High temperature, Very high temperature, Full closure for transformer for service) and the temperature is displayed on the screen LCD for all stages and on the comparison results the microcontroller selects function of the system, either by sending the signal to activated the fan on level the first or second or sends the signal to turn the lamp red or green or sends the signal to activated the siren to inform the supervising engineer that the transformer is at a critical stage, or sends the signal to disconnect the transformer from service. It then sends a message to Phone the admin Engineer on operating station in the form of text (The heat of the transformer has risen and the transformer has been separated from the service) Via piece GSM, to teach him what happened to the transformer if the engineer outside the operating station. Fig. 12 shows the connection of the system to the transformer body. Also, Fig. 13 is illustration scheme for the entrances and exits of the system.

Next, we bring the program stored as (Simple.cpp.hex) of the Arduino as shown in fig. 15.
First, we run the program. Then, we change heat sensor readings, and on the basis of comparisons, a microcontroller defining the type of outputs (Display, green light, red light, alarm clock, signal wire connected to the separation circuit of a transformer and fan) as shown in fig. 16.

The input is displayed from heat sensor on the display screen over a four comparison stages:

1. Normal heat mode: In this part of the comparison, a temperature will be between (0, 70) centigrade degree. In this period, the microcontroller function is to run green lighting with momentary display on-screen of heat degrees that coming from the sensor. This situation is shown in fig. 17.
2. High temperature: In this part of the comparison, a temperature will be between (70, 80) degrees Celsius. In this period, the microcontroller function is to separate the green lighting and replace it with red light. As well as running the fan on the first level with an instantaneous display of temperature on the screen. Fig. 18 represents this situation.

3. Very high temperature: In this part of the comparison as shown in fig. 19, a temperature will be between (80, 90) degrees Celsius. In this period, the microcontroller function is to continue the red lighting as well as running the alarm clock. Also, the fan will be run on the second level.
4. Full closure for transformer for service: In this part of the comparison, a temperature will be between (90, 100) degrees Celsius. In this period, the microcontroller function is continue to turn on the red light as well as the alarm clock and the fan on the second level until the temperature reaches 95 degrees Celsius. Thereupon microcontroller will send a signal pulse to the line which will be linked to the separation circuit of a transformer (Off-duty). Also, the microcontroller works on extinguish the fan and the alarm will work continuously. Finally, a message will be sent by GSM. This stage is shown in fig. 20.

V. CONCLUSIONS

Smart cooling circuit has been designed in the paper. Depending on this design, and after using this system on transformers. The transformers was kept from the unwanted rise in temperature and the risk of damage due to the large error rate in the mechanic sensor Balbakhlu. These errors caused a combustion of several transformers which commissioned the General Electricity Company in Libya huge sums of money.

REFERENCES

Modeling and Performance Analysis of RF Satellite Link System Using 16 QAM

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Abstract- In this paper, the performance of the satellite system for the C and Ku bands using 16 QAM digital modulation techniques is analyzed and investigated. The Quadrature Amplitude Modulation (QAM) is an important modulation scheme with many practical applications, including current and future wireless technologies. More spectrally efficient digital modulation scheme, such as M-ary quadrature amplitude modulation (QAM), is an attractive technique to achieve high rate transmission without increasing the bandwidth and exact evaluation of bit error probability for M-ary QAM can be obtainable for arbitrary M. For the case of M = 16 QAM, this paper will show some practical results using tests on Matlab Simulink satellite system model for the C band at 4GHz and Ku at 8 and 12 GHz bands to investigate the effect of gain, attenuation and SNR on BER. The results showed that the BER for the C band is better than the Ku band for this model.

Keywords—Bit Error Rate (BER), M-ARY Quadrature Amplitude Modulation (QAM), SNR, C band, Ku band

I. INTRODUCTION

Satellite communications are used to provide communication links between different points on the Earth by receiving a signal from a transmitting earth station. Satellite communications play a vital role in the global communications system. Nearly 2,000 satellites are orbiting the Earth relaying analog and digital signals carrying audio, video and data to and from one or many locations around the world.

Especially in the recent years, personal wireless communication is getting more and more popular and is continuing to grow at an exponential rate. This growth has triggered a tremendous demand for not only higher transmission capacity, but also greater coverage area and better quality of service. This demand is being served by employing digital modulation, which provider noise immunity and robustness to channel deterioration and a better error detection and correction control. [1]

A communications satellite is an orbiting artificial earth satellite that receives a signal from a transmitting earth station, amplifies and potentially processes it, then transmits it back to a ground station. Communications information does not start and/or end in the satellite itself. The satellite is an active relay, similar to the propagation function of towers used in terrestrial microwave communications. [2]

Recent theoretical studies of communication systems show much interest in high-level modulation, such as M-ary Quadrature amplitude modulation (M-QAM), and most related works are based on the simulations. In this paper, a simulation model to study various QAM modulation
techniques is proposed. The simulation model is implemented in Matlab/Simulink.

The rest of paper is organized as follows: section II outlines the M-ARY Quadrature amplitude modulation, section III explains the QAM performance measures, section IV details simulation being performed and the results are shown in section V. Section VI gives the conclusion being drawn from this work.

II. M-ARY QUADRATURE AMPLITUDE MODULATION

Quadrature amplitude modulation is the combination of amplitude shift keying and phase shift keying. Quadrature amplitude modulation is a system in which data is transferred by changing some aspect of a carrier signal, or the carrier wave, usually a sinusoid in response to a data signal.

In the case of QAM, the amplitude of two waves of the same frequency, 90° out-of-phase with each other in quadrature are changed modulated or keyed to represent the data signal.

In quadrature amplitude modulation, a signal obtained by summing the amplitude and phase modulation of a carrier signal a modulated sine and cosine waves or quadrature waves are used for the data transfer [3].

The mathematical representation of the M-ARY QAM is:

\[ S(t) = \{a_i \cos(2\pi f t) + b_i \sin(2\pi f t)\} \]  (1)

Where: \(0 \leq t \leq T; i=1,2,\ldots,M\)

Phase modulation (analog PM) and phase-shift keying (digital PSK) can be regarded as a special case of QAM, where the magnitude of the modulating signal is a constant, with only the phase varying. This can also be extended to Frequency modulation (FM) and frequency-shift keying (FSK), for these can be regarded as a special case of phase modulation.

In a constellation diagram, constellation points are arranged in a square grid with equal horizontal and vertical spacing other configurations are possible as well.

In digital communication, as data is binary, it follows that the number of points in the grid usually will be a function of the power of 2 (2, 4, 8, 16, etc.) [1, 4, 5]

III. M-QAM PERFORMANCE MEASURES

There are several parameters of QAM, which are explained some of them briefly in the following points

A. Constellation Diagram

Planetary diagrams can simulate different shapes of situations within different combinations of QAM, quadratic width formation. As the configuration order increases, the number of points in the QAM constellation increases. Figure (1) shows the constellation diagram of 16 QAM, M=16-QAM, Symbol=4bits, 2^n bits=16

![Figure 1: Constellation Diagram of 16 QAM](image)

B. Bit Error Rate Probability

The probability of error of QAM system is given by following equation.

\[ P_e = \frac{2(M-1)}{M} \cdot Q\left[ \frac{6 \log_2(M)}{M^2 - 1} \cdot \frac{E_b}{N} \right] \]  (2)

Where:

\(E_b\): Bit energy.

\(N\): Noise power.

\(M\): Number of output levels
Bit error rate is a general performance test for digital communication systems. For RF satellite systems, BER is defined at several points on the transceiver link. The bit errors counted are then related to the number of bits transmitted within the corresponding period, providing the bit error rate (BER).

\[
\text{BER} = \frac{\text{bit errors}}{\text{transmitted bits}}
\]  

\(3\)

VI. 16 QAM SIMULATION MODEL

Simulation is a technique of constructing and running a model of the real system in order to study its behavior. Also, a simulation can be defined as the process of modeling any system.

In this paper the a Matlab with Simulink V. 2016a is used to implement and simulate the RF satellite link system using the 16 QAM model to obtain the power spectra for Tx and Rx, constellation.

Figure (2) illustrates the overall outline of the basic satellite communications system. The communication system consists of several ground stations on the ground and these are connected with the satellite in space by means of free space link. The user connects to the earth station over a terrestrial network and the terrestrial network may be a telephone adapter or land station connection.

The user creates the primary band signal processed through a terrestrial network and is transferred to a satellite on the ground station. The satellite transponder consists of a large number of space transmitters, receives the radio waveform in the uplink frequency spectrum from all earth stations, amplifies these carriers and sends them back to earth stations in the downlink frequency spectrum.

To avoid interference, the downlink spectrum should differ from the uplink frequency spectrum. The signal is processed at the receiving ground station to retrieve the primary band signal, which is sent to the user via the ground station.[7]

VII. SIMULATION RESULTS

Three tests were performed after setting all the simulation parameters of the system.

The extended C band is used for uplink transmission with a frequency of 8000 MHz and 4000 MHz for downlink.

The modification used here is QAM to save the bandwidth. The extended C band is more common, due to a lower spread problem. Rain attenuation and low sky noise at the 4 GHz downlink of the C band, so it is possible to build a receiver system.

Figure (2) Simulation Model of RF Satellite

The extended Ku band was also used for uplink transmission at 8000 MHz band the downlink and its 12000 MHz band for the uplink. In the same modification, Flaten made it more problematic in terms of noise and attenuation from the C band.

Test 1: in this test when the carrier frequency is 4000 MHz, the power spectrum of the transmitter and receiver as well to constellation diagram are achieved after setting
all the simulation parameters of the overall RF satellite link system in 16 M-ary QAM. The achieved simulation results are shown in figure (3)

Figure (3) Transmit and Receive Spectra at the carrier frequency of 4000 MHz

In Figure (3) Spectral transmission and reception show that the transmitted spectrum signal is shown in yellow and the signal received is shown in blue. Both spectra are almost identical but some of the effects of noise, heat and attenuation caused by the signal in the space can be seen in the spectral of the received signal.

From Figure (3) it is clearly indicated that Transmitted power spectrum is (-55.6221dBm/Hz) and received power spectrum is(-54.391dBm/Hz) ,the difference between them (1.230dB/Hz).

Figure (4) shows the constellation diagram of the transmitted and received signals at the 4 GHz frequency. It is quite clear from the figure the effect of noise on the received signal.

Figure (5) indicates the constellation diagrams for the transmitted signal before and after the high power amplifier. From the figure it can be seen that the effect of amplification and the improvement of the constellation at the amplifier output.

Figure (5) constellation diagram of transmitted signal before and after HPA

Test 2: in this test when the carrier frequency is 8000 MHz, the power spectrum of the transmitter and receiver are shown in figure (7)

Figure (6) Transmit and Receive Spectra at the carrier frequency of 8000 MHz

In Figure (6) Spectral transmission and reception show that the transmitted spectrum signal is shown in yellow and the signal received is shown in blue. In this case it can be noted that the difference in transmission and receptions spectrum is higher
than test1, where it is 12.318 dB/Hz since the transmitted power spectrum is (-61.1116dBm/Hz) and received power spectrum is (-48.7935dBm/Hz).

![Figure (7) Transmit and Receive Constellation Diagrams](image)

Figure (7) Transmit and Receive Constellation Diagrams

Figure (7) shows the constellation diagram of the transmitted and received signals at the 8 GHz frequency. As in the previous case the effect of noise on the received signal is very visible.

![Figure (8) constellation diagram of transmitted signal before and after HPA](image)

Figure (8) constellation diagram of transmitted signal before and after HPA

Figure (8) indicates the constellation diagrams for the transmitted signal before and after the high power amplifier. From the figure it can be seen that the effect of amplification and the improvement of the constellation at the amplifier output for 8 GHz KU band.

Test 3: in this test the carrier frequency is set at 12000 MHz, the power spectrum of the transmitter and receiver were measured as indicated in figure (9).

![Figure (9) Transmit and Receive Spectra at the carrier frequency of 12000 MHz](image)

Figure (9) Transmit and Receive Spectra at the carrier frequency of 12000 MHz

Figure (9) shows the transmitted power spectrum signal and the signal of the received power spectrum. Both spectra are very close but due to some of the effects of noise, heat and attenuation the received signal power spectrum is distorted. As indicated in figure (10) the transmitted power spectrum is (-55.6221dBm/Hz), the received power spectrum is (-53.6074dBm/Hz) and the difference between them is (2.015dB/Hz).

![Figure (10) Transmit and Receive Constellation Diagrams at frequency of 12 GHz](image)

Figure (10) Transmit and Receive Constellation Diagrams at frequency of 12 GHz

Figure (10) shows the constellation diagram of the transmitted and received signals at the 4 GHz frequency. It is quite clear from the figure the effect of noise on the received signal Figure (11) indicates the constellation...
diagrams for the transmitted signal before and after the high power amplifier when frequency was 12 GHz.

From the figure it can be seen that the effect of amplification and the improvement of the constellation at the amplifier output.

Figure (11) constellation diagram of transmitted signal before and after HPA at 12 GHz

The curves of Bit Error Rate variations versus Gain using 16QAM are shown in Figure (12), with varying the frequency values 4000, 8000 and 12000 MHz. From the results shown, it is observed that Bit Error Rate decreases as the Gain increases, but increases with carrier frequency increase.

Figure (12) The Relationship Between Bit Error rate and the Gain

The curves of Bit Error Rate variations versus attenuation using 16QAM are shown in Figure (13), with varying the frequency values 4000, 8000 and 12000 MHz. From the results shown in plots, it is observed that Bit Error Rate decreases as the attenuation increases, although for the 4GHz frequency case the variation in BER is not significant.

Figure (13) The Relationship Between Bit Error rate and the Attenuation (dB)

The variation of BER when SNR was varied is shown in figure (14).

It is clearly shown in the figure that as the SNR increases the BER decreases. The amount of BER reduction is closely related to the carrier frequency being used, the higher the frequency the higher the BER. Therefore BER reduction is inversely proportional to carrier frequency.

Figure (14) The Relationship Between Bit Error rate and the SNR (dB)

VIII. CONCLUSION

The performance of the satellite system using 16 QAM digital modulation technologies in the proposed satellite system model was investigated and analyzed. The tested model performed better for the extended C band (4GHz) than the extended KU band (8 -12GHz) in terms of BER
against the system gain, the attenuation and the SNR parameters.

This means that 16 QAM modulations is better used for the C band satellite system since BER values are at a level that does not have a sever effect on the overall performance of this type of system.

REFERENCES

7. IJDPS. C-Band VSAT Data Communication System and RF Impairments. 2015.
Prediction of Cloud attenuation for 6B Arabsat Satellite Link at Ku, Ka, and V Bands over Libya
Based on ITU-R P.840-5 Model

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Abstract— In this paper, the cloud attenuation is computed in three sites in Libya for 6B Arabsat satellite link. ITU-R P.840-5 model is used to estimate the cloud attenuation at Ku (12 to 18 GHz) and Ka (24 to 40 GHz) bands based on the variation of the operating frequency with changing the columnar liquid water content of the cloud that are 0.2 kg/m² and 0.4 kg/m², also based on the visible range of geostationary satellites for each site, the cloud attenuation and elevation angle are computed. And to evaluate the earth-space link performance at V band (40-75 GHz), the cloud attenuation is estimated at V band uplink and downlink frequencies with variation of the longitude of geostationary satellites, and the surface temperature.

Keywords— ITU-R P.840-5, cloud attenuation, satellite link, liquid water content, Ku, Ka, and V bands

I. INTRODUCTION

Propagation impairments produced by the troposphere are a limiting factor for the effective use of the frequency bands above about 10 GHz for satellite communication applications. In general, propagation impairments of the troposphere increase in severity with the increase of frequency. The rapid growth of satellite services using frequency bands above10 GHz has highlighted a need for estimating propagation factors that are normally considered benign or negligible at the lower frequency bands [1].

Satellite communication is normally thought of as a robust means of communication, not sensitive to environmental impacts. This perception is not totally accurate. Satellite communication can be and is affected by the environment in which it operates. Space environmental effects on satellite communication can be separated into (1) effects on the space element (i.e. the satellite), (2) effects on the ground element (i.e. the Earth station), and (3) effects on the signals propagating through the Earth’s lower and upper atmosphere. The propagating signal may be affected by its passage through the ionosphere (upper atmosphere) or the troposphere (lower atmosphere). These effects depend significantly on frequency, but include signal absorption, scintillation, Faraday rotation and bandwidth decoherence. Geographic location and signal propagation path can also determine the extent to which the signal is affected [2].

Accurate prediction of impairment statistics is very important for the design and deployment of satellite systems. Although raindrops have been found to be the most significant hydrometeors affecting radio wave propagation for frequency above 10 GHz, the influence of clouds and fog are very important on earth-space paths links at Ku, Ka, and V bands. But cloud attenuation, that may cause deep fades in these bands, is one of the components that need to be considered for low availability satellite links owing to its higher probability of occurrence [3].

To measure the impact of cloud attenuation there are various models to incorporate. Several models were recommended into literature [2]. DAH model segregates different cloud types based on their properties, these include water content, horizontal and vertical extent and probability of occurrence. This is valid for transmission carrier frequencies up to 35 GHz. A better and more accurate modelling technique can be performed through Salonen and Uppala work. This model is also known as Teknillinen Korkeakoulu (TKK) model. The model requires input data to predict the accurate cloud attenuation results. This model is a global model that can predict the attenuation regardless of the geographical location of use and uses liquid water content (LWC) to predict the same. Additional parameters required are input vertical profiles of pressure, relative humidity and temperature. Another, approximate model is also presented by ITU-R §40.4 [4] to compute the cloud attenuation for communication links operating over 10 GHZ band. The specific attenuation is calculated in accordance with the SU model, additionally, LWC is also required as an input to compute cloud attenuation for a communication link [5].

This paper aims to estimate the cloud attenuation based on ITU model for 6B Arabsat satellite link at Ka and Ku bands for several locations in Libya, the cloud attenuation is computed based on the variation of the operating frequency. Additionally, by changing the longitude of the satellite location, the cloud
attenuation and the elevation angle are determined for earth station. Additionally, it determined at uplink and downlink frequencies in V band in visible range to geostationary satellite of each stations.

II. ITU-R P.840 Module

The ITU-R provides a model to calculate the attenuation along an earth-space path for both clouds and fog in Recommendation ITU-R P.840. The model was originally adopted into Recommendation P.840 in 1992 and has been updated in 1994, 1997, and 2012. It is valid for liquid water only and is applicable for systems operating at up to 200 GHz. The input parameters required for the calculations are: $f$ is frequency (GHz), $\theta$ is the elevation angle (degrees), $T$ is a surface temperature in (K), and $L$ is the columnar liquid water content (kg/m²).

An intermediate parameter required for the calculation is the inverse temperature constant, $\phi$ determined from

$$\phi = \frac{300}{T}$$

Where $T$ is the temperature in K.

For fog attenuation, $T$ is equal to the ground temperature.

The step-by-step procedure now follows [4]

Step 1: Calculate the relaxation frequencies:

Calculate the principal and secondary relaxation frequencies, $f_p$ and $f_s$, in GHz, as the following

$$f_p = 20.09 - 142(\phi - 1) + 294(\phi - 1)^2$$

$$f_s = 590 - 1500(\phi - 1)$$

Step 2: Complex dielectric permittivity:

Calculate the real and imaginary components of the complex dielectric permittivity of water from

$$\varepsilon''(f) = \frac{\varepsilon_0 - \varepsilon_1}{f_p \left[ 1 + \left( \frac{f}{f_p} \right)^4 \right]} + \frac{\varepsilon_1 - \varepsilon_2}{f_s \left[ 1 + \left( \frac{f}{f_s} \right)^4 \right]}$$

$$\varepsilon'(f) = \frac{\varepsilon_0 - \varepsilon_1}{\left[ 1 + \left( \frac{f}{f_p} \right)^4 \right]} + \frac{\varepsilon_1 - \varepsilon_2}{\left[ 1 + \left( \frac{f}{f_s} \right)^4 \right]}$$

Where $\varepsilon_0 = 77.6 + 103.3(\phi - 1)$, $\varepsilon_1 = 5.48$, and $\varepsilon_2 = 3.51$.

Step 3: Specific attenuation coefficient:

Calculate the specific attenuation coefficient, $K_l$ (dB/km)/(g/m3), from

$$K_l = \frac{0.819f}{\varepsilon''(1 + \eta^2)}$$

Where $\eta = \frac{2 + \varepsilon'}{\varepsilon''}$

$K_l$ represents the ‘point’ attenuation at the specified frequency and water vapour concentration.

Step 4: Columnar liquid water content:

Determine the columnar liquid water content of the cloud, $L$, in (kg/m²). In cases where the statistics of cloud liquid water content are not available for the location(s) of interest, the ITU-R contain global maps that provide contours of cloud liquid water content. Present contours of cloud liquid water content in kg/m² exceeded for 20%, 10%, 5%, and 1% of an average year, respectively. For a location different from the grid points, obtain the total columnar content at the desired location by performing a bi-linear interpolation on the values at the four closest grid points, as described in Recommendation ITU-R P.1144 [6].

Step 5: Earth Station Parameters:

The elevation angle for the earth station, as shown in Fig. 1, is calculated by [7]

$$\theta = \cos^{-1}(R + h)/D \sqrt{1 - \left[ \cos^2(\alpha_{ES}) \cos^2(\theta_{SAT} - \theta_{ES}) \right]}$$

Where $\theta$ is the angle of elevation, $R$ and $h$ are 35786 km and 6378.1 km and are the distances of the geosynchronous orbit and the radius of the Earth respectively. $\alpha_{ES}$ is the latitude of the earth station, $\theta_{SAT}$ is the longitude of the satellite, $\theta_{ES}$ is the longitude of the earth station, and $D$ is calculated by:

$$D = \sqrt{h^2 - 2R(h + R)[1 - \cos(\alpha_{ES}) \cos(\theta_{SAT} - \theta_{ES})]}$$

Fig. 1. Schematic presentation of an Earth-Space path

Step 6: Total attenuation:

The total cloud attenuation $A_c$ (dB), is then found as:

$$A_c = \frac{L \cdot K_l}{\sin \theta}$$

Where $10^\circ \leq \theta \leq 90^\circ$; For elevation angles less than $10^\circ$ the $(1/\sin \theta)$ relationship cannot be employed, because this would assume a cloud of nearly infinite extent. Therefore, a physical limit to the path length should be imposed when performing calculations where the elevation angle approaches $0^\circ$.

III. Simulation Results

The cloud attenuation is estimated based on the ITU-R P.840-5 model at Ka, and Ku bands for 6B Arabsat satellite with several locations in Libya that named Tripoli, Shahat, and Zuwarah. The earth stations parameters are listed in Table I. The cloud attenuation for these locations are computed based on the variation of the frequency at the surface temperature of 293 K, and for two values of the total columnar content of cloud liquid water, of 0.2 kg/m² (for 5% unavailability of an average year), and 0.4 kg/m² (for 1% unavailability of an average year).
Furthermore, the cloud attenuation and the elevation angle are calculated based on the visible range of each station, which listed in Table I, to geostationary satellites.

<table>
<thead>
<tr>
<th>Station</th>
<th>Coordinates of location</th>
<th>Visible Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Longitude (E)</td>
<td>Latitude (N)</td>
</tr>
<tr>
<td>Tripoli</td>
<td>13.19°</td>
<td>32.88°</td>
</tr>
<tr>
<td>Shahat</td>
<td>21.58°</td>
<td>32.80°</td>
</tr>
<tr>
<td>Zuwarah</td>
<td>12.08</td>
<td>32.93</td>
</tr>
</tbody>
</table>

### A. Cloud Attenuation for Tripoli Earth Station

Figures 1, and 2 show the variation of the cloud attenuation versus the operating frequency at Ku, and Ka bands respectively for Tripoli Earth station.

From Fig. 1, it can be noted that the cloud attenuation is increased by 0.0407 dB, when the frequency change from 12 GHz to 18 GHz and the liquid water content is 0.4 kg/m².

Moreover, when the liquid water content change from 0.2 kg/m² to 0.4 kg/m² at 18 GHz, the cloud attenuation increased by 0.04553 dB. And From Fig. 2, it can be seen that at the liquid water content is 0.4 kg/m², the cloud attenuation is 0.188 dB at 26 GHz and it is 0.4.4331 dB at 40 GHz. Also, when the liquid water content change from 0.2 kg/m² to 0.4 kg/m², the cloud attenuation increase by 0.2165 dB.

Fig. 3 shows the cloud attenuation and elevation angle for Tripoli earth station based on the variation of longitude of the satellite location. From the figure, it can be shown that the cloud attenuation is 0.540 dB, and the elevation angle is 23.29° for the satellite located at 65° longitude, and for the satellite that located at 80° longitude, the cloud attenuation is 1.144 dB, and the elevation angle is 10.77°.

### B. Cloud Attenuation for Shahat Earth Station

The variation of the cloud attenuation versus the operating frequency at Ku band for Shahat Earth station is shown in Fig. 4. From the figure, when the frequency change from 12 GHz to 18 GHz, it can be noted that the cloud attenuation is increased by 0.04878 dB and 0.02439 dB when the liquid water content is 0.4 kg/m² and 0.2 kg/m² respectively. Additionally, when the liquid water content is changed from 0.2 kg/m² to 0.4 kg/m² the cloud attenuation increased by 0.01971 dB and 0.0441 dB at the frequency of 12 GHz and 18 GHz, respectively.
For Shahat Earth station, Fig. 5 shows the variation of the cloud attenuation versus the frequency at Ka band. From the figure, it can be seen that, at the liquid water content of 0.4 kg/m², the cloud attenuation is 0.1821 dB at 26 GHz and it is 0.4195 dB at 40 GHz; and the cloud attenuation is changed from 0.09103 dB to 0.2097 dB when the frequency changed from 26 GHz to 40 GHz, at the liquid water content of 0.2 kg/m².

![Fig. 5 Cloud attenuation vs. Frequency for Shahat station at Ka band and T = 293 K](image)

Fig. 6 shows the cloud attenuation and elevation angle for Shahat earth station based on the variation of the longitude of satellite location. From the figure, it can be observed that for the satellite that located at 65°, the elevation angle 30.11°, and the cloud attenuation of 0.426 dB. And for the satellite that located at 80°, the cloud attenuation of 0.69773 dB, and the elevation angle of 17.84°.

![Fig. 6 Cloud attenuation, and Elevation Angle vs. longitude Satellite location for Shahat station at f = 32 GHz, and T = 293 K](image)

C. Cloud Attenuation for Zuwara Earth Station

Figures 7, and 8 show the variation of the cloud attenuation versus the frequency at Ku, and Ka bands respectively for Zuwara Earth station.

![Fig. 7 Cloud attenuation vs. Frequency for Zuwara earth station at Ku band and T = 293 K](image)

From Fig. 7, at Ku band (12/18 GHz), it is clear that the cloud attenuation is increased by 0.05002 dB and 0.02501 dB when the liquid water content is 0.4 kg/m² and 0.2 kg/m² respectively. Furthermore, when the liquid water content is changed from 0.2 kg/m² to 0.4 kg/m² the cloud attenuation increased by 0.02022 dB and 0.044523 dB at the frequency of 12 GHz and 18 GHz, respectively.

![Fig. 8 Cloud attenuation vs. Frequency for Zuwara station at Ka band and T = 293 K](image)

From Fig. 8, it can be shown that when the frequency changes from 26 GHz to 40 GHz, the cloud attenuation increased by 0.2469 dB and 0.12343 dB at the liquid water content of 0.4 kg/m² and 0.2 kg/m². Also, it can be observed that when the liquid water content is changed from 0.2 kg/m² to 0.4 kg/m², the cloud attenuation is increased by 0.09463 dB and 0.2181 dB at the operating frequencies is 26 GHz and 40 GHz respectively.

![Fig. 9 shows the cloud attenuation and elevation angle for Zuwara earth station based on the variation of the longitude of satellite location. From the figure, it can be noted that for the satellite that located at 65°, the elevation angle 22.36°, and the cloud attenuation is 0.562 dB. Additionally, for the satellite that located at 80°, the cloud attenuation of 1.253 dB, and the elevation angle is 9.82°.](image)
D. Cloud Attenuation over Libya at V-Band (40 – 75 GHz)

At the surface Temperature $T = 293$ K, and total columnar content of cloud liquid water is 0.4 kg/m$^2$, the cloud attenuation is simulated at uplink frequency (50 GHz), and V band downlink frequency (40 GHz) for the three sites versus according the visible range to the longitude of geostationary satellites.

Figures 10, 11, and 12 show Cloud attenuation versus longitude of Satellite location for Tripoli, Zuwara, and Shahat earth stations respectively.

From Figure 10, in the visible range of the Tripoli earth station, it can be observed that at the V-band uplink frequency (50 GHz), the lowest value of cloud attenuation is 0.6371 dB with higher elevation angle of 51.70° for the GEO satellite located at the longitude of 12 E; and the highest values of cloud attenuation are 2.736 dB, and 2.702 dB at the GEO satellites located at the longitude of 55W and 79E respectively.

Based on the cloud attenuation for Tripoli earth station that illustrated in Figure 11 at the uplink frequency (50 GHz), it can be noted that within the visible range, the lowest value of cloud attenuation is 0.6367 dB with higher elevation angle of 51.75° for the GEO satellite located at 13 E; and the highest values of cloud attenuation are 2.758 dB, and 2.677 dB at the GEO satellites located at 54W and 80E respectively.

At the V-band uplink frequency (50 GHz), and according to the visible range of the Shahat earth station which shown in Figure 12, it can be seen that the lowest value of cloud attenuation is 0.6363 dB with higher elevation angle of 51.802° for the GEO satellite located at 22 E; and the highest values of cloud attenuation are 2.684 dB, and 2.744 dB at the GEO satellites located at the longitude of 45W and 89E respectively.
For 79E satellite link with the total columnar content of cloud liquid water is 0.4 kg/m²; Tables II, and III show the variation of cloud attenuation with changing the surface temperature at V-band uplink frequency (50 GHz) and V-band downlink frequency (40 GHz) respectively. From these Tables, it can be noted that, the cloud attenuation is increased by decreasing of the surface temperature.

With the reference surface temperature is 20 °C. From Table III, it can be founded that the cloud attenuation is increased by 22.9%, 53.3%, and 80.1%, when the temperature is decreased by 10 °C, 20 °C, and 28 °C respectively. And from Table III, it can be shown that the cloud attenuation is increased by 24.7%, 59.7%, and 94.8%, when the temperature is decreased by 10 °C, 20 °C, and 28 °C respectively.

**TABLE III**

<table>
<thead>
<tr>
<th>Surface Temperature</th>
<th>Cloud Attenuation (dB)</th>
<th>Zuwara</th>
<th>Tripoli</th>
<th>Shahat</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 °C</td>
<td></td>
<td>2.703</td>
<td>2.485</td>
<td>1.562</td>
</tr>
<tr>
<td>10 °C</td>
<td></td>
<td>3.323</td>
<td>3.056</td>
<td>1.92</td>
</tr>
<tr>
<td>0 °C</td>
<td></td>
<td>4.144</td>
<td>3.810</td>
<td>2.394</td>
</tr>
<tr>
<td>-8 °C</td>
<td></td>
<td>4.868</td>
<td>4.476</td>
<td>2.813</td>
</tr>
</tbody>
</table>

**TABLE III**

<table>
<thead>
<tr>
<th>Surface Temperature</th>
<th>Cloud Attenuation (dB)</th>
<th>Zuwara</th>
<th>Tripoli</th>
<th>Shahat</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 °C</td>
<td></td>
<td>1.775</td>
<td>1.632</td>
<td>1.026</td>
</tr>
<tr>
<td>10 °C</td>
<td></td>
<td>2.214</td>
<td>2.036</td>
<td>1.279</td>
</tr>
<tr>
<td>0 °C</td>
<td></td>
<td>2.835</td>
<td>2.607</td>
<td>1.638</td>
</tr>
<tr>
<td>-8 °C</td>
<td></td>
<td>3.457</td>
<td>3.179</td>
<td>1.998</td>
</tr>
</tbody>
</table>

**IV. CONCLUSIONS**

For fixed satellite link between 6B Arabsat satellite and three earth stations in Libya, the cloud attenuation is estimated by using ITU-R P.840-5 Model based on the variation of liquid water content at Ku, Ka, and V bands.

Depending on the simulation results, it can be concluded that, the cloud attenuation is increased as both of the operating frequency and the liquid water content increase. Based on the increasing of the longitude of satellite location in both directions west, and east, the cloud attenuation is increased, and the elevation angle is decreased. According to the variation of temperature, the cloud attenuation is increased by decreasing of the surface temperature.

The simulated cloud attenuation results were obtained will be useful to design a reliable satellite link for Libyan earth stations.

**REFERENCES**


Usability Evaluation Model for Electronic Assessments

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Abstract—In the last decade of the twentieth century and the beginning of the twenty-first century, an information technology has witnessed tremendous progress, that was led to a modern scientific revolution penetrated all disciplines and fields until it reached to the education, especially at critical part of education process i.e (The assessment), whereby the traditional assessment consists of some complicated issues related to time, effort, and consumption cost of the papers. The Electronic Assessments (E-Assessments) is considered one application of Human-Computer Interaction (HCI). Therefore, it can measure Usability and UX for E-assessments. This paper will present a proposed model to evaluate usability for E-Assessments, and to ensure reliability of the model. It was validated by applying the proposed model on two E-Assessments (Computer-Based Assessments, and online assessments). Results were calculated and proved by A Measurement Model Based on Usability Metrics (MMB-UM) for E-Assessments.

Keywords— Usability Models; Electronic Assessments (E-Assessments); Computer Based Assessments (CBAs); Usability evaluation; Measurement Model Based on Usability Metrics (MMB-UM)

I. INTRODUCTION

In the middle of acceleration of life and changes, which brought by the information technology. The people look for something to make their lives easy and enjoyable, that led to the question, asked when describes the contradiction of technology “But what good is technology if it is very complicated to use”[1].

Usability cited as a concept appeared as a result of HCI and it is considered one of the most important quality factors for the web application [2]. Also, Usability is defined as: "The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use"[3]. Usability refers to the “quality of the interaction in terms of parameters such as time taken to perform tasks, a number of errors made, and the time to become a competent user” [7]. “Usability is a quality attribute that assesses how easy user interfaces are to use” [8]. The word “Usability” also refers to methods for improving ease-of-use during the design process.” There are varying sets of definitions specific attributes of Usability (facets, aspects, factors) defined by standards and authors. Table 1 summarizes some of these definitional sets. Concerning attributes of Usability apparent in the table row, for example, all sources in Table 1 describe "efficiency" as Usability attribute, although not all sources use this particular term.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>SETS OF DEFINITIONS SPECIFIC ATTRIBUTES OF USABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nielsen(1993)</td>
<td>Efficiency of use</td>
</tr>
<tr>
<td>Constantine &amp; Lockwood (1999)</td>
<td>Efficiency in use</td>
</tr>
<tr>
<td>Constantinos &amp; Du (2007)</td>
<td>Learn ability (Ease of learning)</td>
</tr>
<tr>
<td></td>
<td>Memorability</td>
</tr>
<tr>
<td></td>
<td>Errors/ Safety</td>
</tr>
</tbody>
</table>

B. Overview Usability Models

Usability concept has been defined in multiple ways, also evolved over a period [9]. There are three major to identify
efficiency, effectiveness, and satisfaction as key attributes [3]. Usability as software quality attribute decomposed into five factors understandability, learn-ability, and operability, attractiveness, and Usability compliance [5]. There are many Usability models, but no one of these models covers all aspects of Usability. Such as Usability, models include [10].

C. Computer - Based Assessment (CBAs)

The developments in computer technology and informatics, insert many new methods for education, to change is the life of students and the tutors. One of these methods is to use computers in teaching and testing students since of the 80s [7]. The Computer-Based Assessment can contain elements of the multi-media such as video, images, and sounds, different from the limited evaluation over Paper Based Assessments [11]. (PBAs) lists five methods of collecting students answer in CBAs:

1. Choose the answer.
2. Write short answer questions.
3. The arrangement and choice.
4. The connection between the answer and questions symmetry.
5. Locate the image and write the correct answer on the image.

(JISC, 2007:6) The CBAs are distinguished from Computer Assisted Assessment (CAA) in doing all assessment process parts are delivered and corrected by computers; whilst CAA is only used as part of the assessment process [6]. Features of the CBAs that can be used for diagnostic, formative, or summative assessment also can be supervised or not- supervised.

Many researchers and international miens try to define “assessment” word; definitions of assessment in appendices B, the purpose of assessment is making decisions or judgments about the students, by the system of collecting the information [8]. Form all above inference that Assessment is the process, which tries to evaluate the knowledge, understand and skills, leaner owns it.

The performance of the educational system is affecting the global economy, which posed the technological innovation, attempted to adapt the changing in requirements of new technology. In the traditional learning environments; digital tools and technology are becoming standard, in many different environments, CBAs is already used widely. In essence, CBAs are a practice of giving quizzes and tests on the computer instead of using pencil and paper [12].

III. THE MEASUREMENT MODEL BASED ON USEABILITY MATRICES (MMB-UM)

There are many famous measurements, models to measure both factors [13]. Evaluation to design the user interface applications for children's education, and applied study on two different systems of children's applications are running Android provided, attempted to re-examine the guidelines, menu interface, thus the development of the measurement model, the study pointed to the possibility of applying the standard on any system and other devices; also, offers a comprehensive structural model to evaluate the Usability [14]. By based they in this paper the MMB-UM chosen to measure (Usability, UX) and the reason for this selection was the ability to measure the two factors together, reverse all famous measurements that measure each factor separately.

In addition, the MMB-UM selected for the following reasons:

- It considers the first time to use in the Electronic-Assessments (E-Assessments).
- User satisfaction in the measurement is equal to the UX.
- It presented the Usability as objective, and the UX as subjective.

Figure.1 shows the MMB-UM model for measuring the Usability of Electronic Assessments (E-Assessments). The proposed model consists mainly of three phases: The first phase Usability factors for E-Assessments. The details are listed in Table 2 and each factor corresponds to a description, clarified and presents the Usability characteristics and guidelines for E-Assessments. In the second phase Goals, Questions, and Metrics of Usability. In the last phase, the metrics are separate into the objective (Usability) and subjective (UX) metrics, which used to develop two measurements instrument task list and questionnaire respectively.

![Fig. 1 General Structure of proposed Model (MMB-UM) for E-Assessments](image-url)
Table 4 and Table 5. The questionnaire has 26 questions appropriate for E-Assessments, based on the Usability factors, which defined in Table 2.

**TABLE 2**
**PROPOSED USABILITY FACTORS FOR E-ASSESSMENT SOFTWARE**

<table>
<thead>
<tr>
<th>USABILITY CHARACTERISTICS</th>
<th>GOALS</th>
<th>QUESTIONS</th>
<th>METRICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td>Interactivity</td>
<td>Is it easy to interact with the proposed prototype?</td>
<td>Number of mistakes during interaction</td>
</tr>
<tr>
<td>Understandability</td>
<td>Input/output</td>
<td>Does the proposed prototype provide easy ways of input for students?</td>
<td>The number of mistakes to enter</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Time required</td>
<td>How much time taken by the application to load?</td>
<td>Time is taken to load application rating scale for time response</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Attractive</td>
<td>Is the proposed prototype attractive for students?</td>
<td>Rating scale for Attractive screen design</td>
</tr>
<tr>
<td>Security</td>
<td>Secure</td>
<td>Is the proposed prototype safety the confidence of tutors?</td>
<td>Number of mistakes in secure</td>
</tr>
</tbody>
</table>

**TABLE 3**
**PHASE II IS ILLUSTRATING USABILITY CHARACTERISTICS, GOALS, QUESTIONS AND METRICS**

<table>
<thead>
<tr>
<th>#UF</th>
<th>Proposed Factors</th>
<th>Sub Factors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Efficiency</td>
<td>-----------</td>
<td>Efficiency indicates once users have learned the proposed prototype, how quickly they can perform tasks.</td>
</tr>
<tr>
<td></td>
<td>Effectiveness</td>
<td>-----------</td>
<td>Efficiency indicates once users have learned the proposed prototype, how quickly they can perform tasks.</td>
</tr>
<tr>
<td></td>
<td>Functionality</td>
<td>Security</td>
<td>Security is the quality factor in dealing with those attributes of software that “bear on its ability to prevent unauthorized access, whether accidental or deliberate to program or data”. Also, the most important quality factor to be taken into account when evaluating a CBAS proposed prototype.</td>
</tr>
<tr>
<td></td>
<td>Satisfaction</td>
<td>-----------</td>
<td>Satisfaction refers to the subjective responses from users about their feelings when using the software.</td>
</tr>
</tbody>
</table>

**TABLE 4**
**PHASE III QUESTIONNAIRE OF MMB_UM FOR E-ASSESSMENTS**

<table>
<thead>
<tr>
<th>Question Index</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I found it easy to understand this application.</td>
</tr>
<tr>
<td>2</td>
<td>The application is too slow I had to wait for a response to continue</td>
</tr>
<tr>
<td>3</td>
<td>The application took a lot of time for loading</td>
</tr>
<tr>
<td>4</td>
<td>The application provides a visual display to show the loading process.</td>
</tr>
<tr>
<td>5</td>
<td>The application gives feedback on whether my answer is correct or wrong</td>
</tr>
<tr>
<td>6</td>
<td>The application does not provide appropriate feedback to my answers.</td>
</tr>
<tr>
<td>7</td>
<td>I was comfortable with the screen orientation of the application.</td>
</tr>
<tr>
<td>8</td>
<td>The main menu of the application is confusing.</td>
</tr>
<tr>
<td>9</td>
<td>The app provides clear and understandable navigation keys such as back/next buttons to move to the previous / next screen</td>
</tr>
<tr>
<td>10</td>
<td>The application provides useful help information</td>
</tr>
<tr>
<td>11</td>
<td>It was difficult to find help</td>
</tr>
<tr>
<td>12</td>
<td>It was difficult to understand the language used in the application</td>
</tr>
<tr>
<td>13</td>
<td>The topics/concept and information was understandable</td>
</tr>
<tr>
<td>14</td>
<td>I need to remember a lot of information throughout several actions to perform a task.</td>
</tr>
<tr>
<td>15</td>
<td>It is easy to complete the tasks without much effort</td>
</tr>
<tr>
<td>16</td>
<td>It is difficult to learn to use the application</td>
</tr>
<tr>
<td>17</td>
<td>The application provides a progress report/result of my performance in every activity</td>
</tr>
<tr>
<td>18</td>
<td>The application gives error messages that clearly tell me how to fix problems</td>
</tr>
<tr>
<td>19</td>
<td>It was easy to read the text in this application</td>
</tr>
<tr>
<td>20</td>
<td>The text size used in this application is too small</td>
</tr>
<tr>
<td>21</td>
<td>It is easy to find the information I needed</td>
</tr>
<tr>
<td>22</td>
<td>I find the design of application attractive</td>
</tr>
<tr>
<td>23</td>
<td>The colours used in this application are not attractive</td>
</tr>
</tbody>
</table>
The icons and buttons used are attractive and recognizable.

The application gives interesting rewards on my performance.

Overall, I enjoyed using the application.

**TABLE 5**

**PHASE III TASK LIST OF MMB-UM FOR E-ASSESSMENTS**

<table>
<thead>
<tr>
<th>Task Index</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>The icons and buttons used are attractive and recognizable</td>
</tr>
<tr>
<td>25</td>
<td>The application gives interesting rewards on my performance</td>
</tr>
<tr>
<td>26</td>
<td>Overall, I enjoyed using the application.</td>
</tr>
</tbody>
</table>

**TABLE 6**

**OBJECTIVE USABILITY RESULTS OF EXPERIMENTS**

<table>
<thead>
<tr>
<th>Objective Code</th>
<th>Objective Metrics</th>
<th>CBAs Mean</th>
<th>Online Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>O1</td>
<td>Number of mistakes during interaction</td>
<td>1.1</td>
<td>2.4</td>
</tr>
<tr>
<td>O2</td>
<td>The number of mistakes to enter</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>O3</td>
<td>Time is taken to load the application</td>
<td>0.031</td>
<td>1.037</td>
</tr>
<tr>
<td>O4</td>
<td>Rating scale for time response</td>
<td>0.20</td>
<td>0.57</td>
</tr>
<tr>
<td>O5</td>
<td>Rating scale for the attractive screen design</td>
<td>0.8</td>
<td>0.9</td>
</tr>
<tr>
<td>O6</td>
<td>Number of mistakes insecure</td>
<td>0.01</td>
<td>0.7</td>
</tr>
</tbody>
</table>

**IV. EXPERIMENTAL RESULTS**

Data compiled and analyzed according to answers to the questionnaire; it is given to twenty students of Information Technology-Faculty (ITF).

The experiments were conducted in a quiet and comfortable lab at Benghazi University. Before the experiments began the lab was prepared (equipment, tools…etc.), and installed the CBAs on computers. The exam took between 15 and 20 minutes with a mean time of 17.5 minutes, i.e. the exam time was distributed as follows:

Student participants listened to the Instructions around 2 minutes, then they started to answer the exam in 10 minutes. Upon completion, students filled the questionnaire which took about 6 minutes. The CBAs experiments were included 20 students, to take the exams.

These experiments were carried out to ensure that the MMB-UM model is reliable and effective for evaluating the Usability and UX of E-Assessments by (User satisfaction questionnaire and task list) which are sections of the model.

To validate the model this experiment used two types of assessments CBAs offline and online assessments that designed for higher education. Usability evaluation the subjective data were collected using the five points from the Likert scale (that illustrate in Table 6) user satisfaction questionnaire developed in the MMB-UM model and objective data were collected through the task list to prepare tasks for each assessment. Obtained the results for both subjective and objective metrics are presented separately and comparison of results presented for both assessments to check significant differences in Usability and UX of the two E-Assessments.

**A. Objective Usability Results of Experiments**

In Tables below, labels O1-O6 were used to represent the objective metrics. For a comparative analysis of the two E-Assessments, the results are presented in Table 7, which calculated by Usability metric equations, in [15] had indicated to (ISO/IEC 9126-4) that recommends that Usability metrics should include obtaining outcomes effectiveness, efficiency, and user satisfactions. The data for objective measures were collected during the Usability measure and summarized the data for each of the six objective metrics. The mean score for each measure is presented in Table 7 for both E-Assessments for –
The comparative analysis is carried out to determine which is the best type of E-Assessments in the experiments of whence Usability. The results indicate that online assessments have higher failure and a number of mistakes of all objective measures shown in Fig. 2, except for navigation.

Fig. 2 General Objective Usability of E-Assessments for A-course

**B. Subjective Usability Results of Experiments**

The data for subjective measures were collected through five points Likert scale user satisfaction questionnaire presented in the model. The questionnaire was filled by the students after performing tasks, at the end of the test session for each assessment. The analysis of data based on a Likert scale satisfaction questionnaire was done according to the statistical procedure described [16]. For each subjective metric, the questions from satisfaction questionnaire were matched with the metric. In Table 7 presents the results of subjective measures for course-A. The labels “S1 to S23” are used to represent each subjective metrics.

**TABLE 7**

<table>
<thead>
<tr>
<th>Subjective Code</th>
<th>Subjective Metrics</th>
<th>Quest ion No</th>
<th>CBA Mean</th>
<th>On-line Mean</th>
</tr>
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<tbody>
<tr>
<td>S6</td>
<td>Rating scale for easy to understand output</td>
<td>1</td>
<td>30%</td>
<td>43%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>1.5</td>
<td>2.15</td>
</tr>
<tr>
<td>S7</td>
<td>Rating scale for loading application</td>
<td>4</td>
<td>77%</td>
<td>62%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.85</td>
<td>3.1</td>
</tr>
<tr>
<td>S8</td>
<td>Rating scale for time to respond</td>
<td>3</td>
<td>66%</td>
<td>21%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3.3</td>
<td>1.05</td>
</tr>
<tr>
<td>S9</td>
<td>Rating scale for task effort</td>
<td>17,18</td>
<td>50%</td>
<td>55%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.5</td>
<td>2.75</td>
</tr>
<tr>
<td>S10</td>
<td>Rating scale for finding help</td>
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<td>14.3%</td>
<td>18%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>0.715</td>
<td>0.9</td>
</tr>
<tr>
<td>S11</td>
<td>Rating scale for appropriate language</td>
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<td>77%</td>
<td>88%</td>
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<td></td>
<td>3.85</td>
<td>4.4</td>
</tr>
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<td>Rating scale for appropriate content</td>
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<td></td>
<td></td>
<td>1.95</td>
<td>2.3</td>
</tr>
<tr>
<td>S13</td>
<td>Rating scale for ease of learning</td>
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<td>66%</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td>1.65</td>
<td>1.1</td>
</tr>
<tr>
<td>S15</td>
<td>Rating scale for performance assessment</td>
<td>23</td>
<td>49%</td>
<td>50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<td>S16</td>
<td>Rating scale for error messages</td>
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<td></td>
<td></td>
<td></td>
<td>0.8</td>
<td>0.95</td>
</tr>
<tr>
<td>S17</td>
<td>Ease of readability</td>
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<td>22%</td>
<td>35%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.1</td>
<td>1.75</td>
</tr>
<tr>
<td>S18</td>
<td>Satisfaction with text</td>
<td>26</td>
<td>80%</td>
<td>74%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>3.7</td>
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<td>S19</td>
<td>Rating scale for engagement</td>
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<td>63%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>2.5</td>
<td>3.15</td>
</tr>
<tr>
<td>S20</td>
<td>Rating scale for screen layout</td>
<td>29,30</td>
<td>49%</td>
<td>57%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2.45</td>
<td>2.85</td>
</tr>
<tr>
<td>S21</td>
<td>Rating scale for attractive screen design</td>
<td>31</td>
<td>33%</td>
<td>19%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.65</td>
<td>0.95</td>
</tr>
</tbody>
</table>
than CBA offline, from the students’ standpoint.

The MMB-UM model proposed in this research is effective and reliable.

To conclude, it is evident from the results that different E-Assessments but also helpful to uncover Usability issues and UX. To conclude, it is evident from the results that Usability and the UX are important factors to evaluate the HCI applications. Concepts of evaluation, Usability, and Usability testing are different and nested.

The overall analysis shows that both subjective and objective data for evaluating the Usability of E-Assessments. Concepts of evaluation, Usability, and Usability testing are different and nested

names, but provided the same results to measure Usability. Ease of use represents the functionality, and user satisfaction represents the requirements of the user of the functionality.

### V. CONCLUSIONS

Comparative analysis introduces the results for subjective measures are presented diagrammatically from Figure 3 for mean and percent respectively. The results of the subjective Usability for CBAs metrics express better subjective Usability than online assessments, although, the results too convergent, except for text size, the manner of questions view, performance assessment from the tutors’ standpoint where online assessments showed better results, which means that students were more satisfied with online assessments and had good experience using it. However, both E-Assessments showed poor Usability help, and error messages. Furthermore, the students were unsatisfied with text size, readability of the CBAs. These user interface design attributes need to be improved.

The results indicate that the user satisfaction questionnaire developed in the model is reliable and effective for collecting subjective data for evaluating the Usability of E-Assessments. The overall analysis shows that both subjective and objective results correlate, and closely linked harmonization between them. In addition to, the results showed that the model is not only useful for evaluating Usability and comparison of different E-Assessments but also helpful to uncover Usability issues and UX. To conclude, it is evident from the results that the MMB-UM model proposed in this research is effective and reliable.

The CBAs one of the HCI applications, which attracts users its. The Usability and the UX are important factors to evaluate the HCI applications. Concepts of evaluation, Usability, and Usability testing are different and nested
A Power System Connected Fuel Cell Based On Dynamic Voltage Restorer (DVR)

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Abstract—This paper is about the active and reactive power flow analysis inside the Dynamic Voltage Restorer (DVR) during several cases, when this DVR is powered by Fuel Cell. The system is the unification between DVR and shunt inverter, and they still provide one of the best solutions by mitigating the voltage sags and swells problems on distribution network. This analysis can provide the helpful information to well understand the interaction between the DVR, the inverter, the Fuel Cell and electrical network. The mathematical analysis is based on active and reactive power flow through the system. Wherein DVR can absorb or deliver the active power from the Fuel Cell to mitigate a swell or sag voltage, in the both cases it absorbs a small reactive power quantity, whereas the inverter supply linear loads with energy from fuel cells and to compensate reactive current. The voltage sag and voltage swell are usually interpreted through the DC bus voltage curve. These two phenomena are introduced in this paper with a new interpretation based on the active and reactive power flow analysis inside the DVR. The simulation results are carried out to confirm the analysis done.

Keywords — Fuel Cell, DVR, Power flux analysis, Power factor, Sag and Swell voltage.

I. INTRODUCTION

Actually, the low costs of power electronic devices has led to the wide spread increase of power electronic loads in industry. As a result the significant non-linear loads, mass inductive loads and sensitive loads appear in a considerable amount of harmonics injection, low power factor and voltage disturbances in power systems [1-5]. They tend to introduce voltage sag/swell, flicker, harmonics and asymmetries at the point of common coupling (PCC). These instabilities cause devices malfunctioning, overheating of power factor correction condensers, motors, transformers and cables. In addition, sensitive loads may not tolerate sags and/or swells and the electrical energy distributor may penalize low power factor at the PCC. Customers describe equipment tripping resulting from perturbation in the supply voltage as “poor power quality”.

Specific devices are used as solutions for immediate treatment of each individual problem, such as using the Shunt APF to absorb the current harmonics, and Series APF to mitigate the voltage harmonics, and using the DVR to adjust the sensitive load voltage at the time when the sag and swell voltage occur, and using the SVG to generate the reactive power for the load.

This paper presents a custom power device, which combines the series and shunt active inverter functioning together, integrating these two inverters. On the DC side, the two inverters are connected back-to-back sharing a common Fuel Cell [6]. The DVR component inserts a voltage in order to maintain the load terminals voltage at a certain level. This voltage is proceeded from a voltage source inverter (VSI) operated under pulse width modulation (PWM). At the same time, the system shunt component injects current in the AC system to compensate for reactive current in order to correct the power factor of the supply side near to unity, as well as to inject the Fuel Cell power into the utility grid under fixed fuel cells power conditions Fig. 1 shows a basic system configuration. This paper interests with the active and reactive power flow analysis between DVR and the system components during voltage sag and swell at steady state. Aim is to maintain the load bus voltage at desired constant level in all operating conditions. This power flow analysis plays an important role to well understanding the relationship between the DVR during the compensation of some problems.

![DVR circuit configuration](image-url)
II. THE POWER FLOW STUDY IN THE DVR.

The DVR is controlled in such a way that the voltages across the load are always equal to a desired value. Therefore, the voltage injected by the DVR equals the difference between the supply voltage and the ideal desired voltage across the load. The function of a shunt active inverter is to maintain the DC bus voltage at a constant value and to compensate the reactive powers required by the load; hence, the network provides only the active power.

In what follows, the load voltage is considered in phase with the supply voltage. This is done by injecting a voltage in phase or in opposition phase with the source voltage respectively in cases of voltage sag or voltage swell. This leads to a bidirectional power flow (System-Network) through the DVR. The voltage injected by the DVR must be positive or negative, according to the source voltage amplitude, voltage swell or sag. On account of this, the active power is absorbed or supplied by the DVR. In this case the reactive power is fully compensated by the parallel active inverter.

The load used has been assumed linear with a power factor equals 0.87. The equivalent system model single phase circuit is presented in the figure below.

![Fig. 2 Equivalent circuit of the System](image)

With:

- $I_{S}$: The supply current.
- $V_{S}$: The voltage at the point of common coupling (PCC).
- $I_{L}$, $V_{L}$: The load current and load voltage respectively.
- $I_{f}$: Shunt inverter injected current.

$V_{L}$ is taken as reference phasor and $\cos \phi_{L}$ is the power factor corresponding to the load, it can be written that:

\begin{align*}
V_{L} &= V_{L} \angle 0^0 \\
I_{L} &= I_{L} \angle - \phi_{L} \\
V_{S} &= V_{L}(1+k) \angle 0^0
\end{align*}

Where $k$ is the voltage fluctuation factor at the point of common coupling (PCC), defined as:

\begin{equation}
k = \frac{V_{L} - V_{S}}{V_{L}}
\end{equation}

The series injected voltage equals:

\begin{equation}
V_{L} + P_{FC} = V_{L} \cdot I_{L} \cos \phi_{L}
\end{equation}

Supposing that DVR is without losses, the active power required by the load equals to that at PCC and the power injected by the Fuel Cell. This power can be expressed as follows:

\begin{equation}
P_{S} + P_{FC} = P_{L}
\end{equation}

\begin{equation}
V_{S} \cdot I_{L} + P_{FC} = V_{L} \cdot I_{L} \cos \phi_{L}
\end{equation}

\begin{equation}
V_{L}(1+k)I_{L} + P_{FC} = V_{L} \cdot I_{L} \cos \phi_{L}
\end{equation}

\begin{equation}
I_{S} = \frac{I_{L}}{1+k} \cos \phi_{L} - \frac{P_{FC}}{V_{L}(1+k)}
\end{equation}

Equation (9) shows that the source current depends on the $k, \cos \phi_{L}$ factor, load current $I_{L}$ and the Fuel Cell power $P_{FC}$.

The apparent power absorbed by the DVR can be written as:

\begin{equation}
\vec{S}_{S} = \vec{v}_{S} \vec{i}_{S}
\end{equation}

\begin{equation}
P_{S} = V_{S} \cdot I_{S} \cos \phi_{S} = -kV_{L} \cdot I_{S} \cos \phi_{S}
\end{equation}

\begin{equation}
Q_{S} = V_{S} \cdot I_{S} \sin \phi_{S}
\end{equation}

$\phi_{S} \approx 0$, the Shunt inverter of the Fuel Cell maintains the unit power factor on the supply side:

\begin{equation}
P_{S} = V_{S} \cdot I_{S} = -kV_{L} \cdot I_{S}
\end{equation}

\begin{equation}
Q_{S} \approx 0
\end{equation}

The apparent power absorbed by the inverter of the Fuel Cell is:

\begin{equation}
\vec{S}_{f} = \vec{v}_{f} \vec{i}_{f}
\end{equation}

The current provided by the shunt inverter equals the difference between the source current and load current including both active and reactive currents, thereby having:

\begin{equation}
i_{f} = i_{S} - i_{L}
\end{equation}

\begin{equation}
i_{f} = I_{S} \angle 0^0 - I_{L} \angle - \phi_{L}
\end{equation}
\[ i_f = I_s - (I_L \cdot \cos \phi_L - j I_L \cdot \sin \phi_L) \]  \hspace{1cm} (18)

\[ i_f = (I_s - I_L \cdot \cos \phi_L) + j I_L \cdot \sin \phi_L \]  \hspace{1cm} (19)

\[ P_f = V_L I_f \cdot \cos \phi_f \]  \hspace{1cm} (20)

\[ P_f = V_L (I_s - I_L \cdot \cos \phi_L) \]  \hspace{1cm} (21)

\[ Q_f = V_L I_f \cdot \sin \phi_f = V_L I_L \cdot \sin \phi_L \]  \hspace{1cm} (22)

III. PEM FUEL CELL GENERATOR MODELING

Electrical energy needs are still increasing over these last years but production constraints like pollution and global warming lead to development of renewable energy sources, particularly chemical energy. Fuel cells (FCs) are static energy conversion devices that convert the chemical energy of fuel directly into DC electrical energy [10]. The fuel cell consists of two porous electrodes (anode and cathode) and an electrolyte layer in the middle. Figure (3) illustrate Fuel cell (PEMFC) [6].

Hydrogen oxidation and oxygen reduction are separated by a membrane, which is conducting protons from the anode to the cathode side [9].

\[ \text{H}_2 \rightarrow 2 \text{H}^+ + 2 e^- \text{ anode} \]  \hspace{1cm} (24)

\[ \text{O}_2 + 4 e^- \rightarrow 2 \text{O}_2 \text{ cathode} \]  \hspace{1cm} (25)

The protons are diffused through the membrane, and the electrons are carried across an electric circuit, the electrical energy is produced. The cell voltage was defined as:

\[ V_{FC} = E_{net} - V_{act} - V_{ohm} - V_{conc} \]  \hspace{1cm} (26)

\[ E_{net} = 1.229 + 0.85 \cdot 10^{-7} (T - 298.15) + 4.31 \cdot 10^{-6} T \cdot \ln \left( \frac{P_{H_2}}{P_{O_2}} \right) \]  \hspace{1cm} (27)

\[ P_{H_2} \text{ and } P_{O_2} \text{ are the partial pressures of hydrogen and oxygen (atm) respectively.} \ T \text{ the cell operation temperature (K).} \]

\[ V_{act} = \frac{1}{\xi_1} + \frac{1}{\xi_2} T + \frac{1}{\xi_3} T \cdot \ln(CO_2) + \frac{1}{\xi_4} \cdot \ln(I_{stack}) \]  \hspace{1cm} (28)

Where \( I_{stack} \) is the cell operating current (A), and the \( \xi \)'s represent parametric coefficients for each cell model, whose values are defined based on theoretical equations with kinetic, thermodynamic, and electrochemical foundations [6]. \( CO_2 \) is the concentration of oxygen in the catalytic interface of the cathode mol/cm, determined by:

\[ CO_2 = \frac{P_{O_2}}{5.08 \times 10^{8} \cdot e^{\omega_{sys}/T}} \]  \hspace{1cm} (29)

\[ V_{ohmic} = I_{stack} \cdot (R_m + R_e) \]  \hspace{1cm} (30)

Where \( R_c \) represents the resistance to the transfer of protons through the membrane, usually considered constant and: \( R_m = \frac{\rho L}{A} \) with:

\( \rho \) : is the specific resistivity of the membrane for the electron flow (cm)

\( A \) is the cell active area (cm)

\( l \) is the thickness of the membrane (cm), which serves as the electrolytic of the cell.
\[ V_{\text{con}} = B \ln(1 - \frac{J_n}{J_{\text{max}}}) \]  

(31)

Where \( B \) (V) is a parametric coefficient, which depends on the cell and its operation state, \( J_n \) represents the actual current density of the cell (A/cm²).

Due to very limited conversion efficiency, it is necessary to optimize all the conversion chain and specifically DC-DC converters [7]. There are many types of DC/DC converters, in this paper; only typical boost converter is discussed. Figure (4) shows the circuit diagram of a boost DC/DC converter (inside the rectangle). The average value of the output voltage is given as:

\[ V_{\text{out}} = \frac{V_{\text{in}}}{(1-d)} \]  

(32)

Where \( d \) is the duty ratio of the switching pulse.

![Boost DC/DC converter](image)

Fig. 4 Boost DC/DC converter

Since \( 0 \leq d < 1 \), the output voltage is always higher than the input voltage. That is why the circuit in Figure (4) is called a boost DC/DC converter. PWM used to generate a pulse with the right duty ratio so that the output voltage follows the reference value.

Our PEMFC generators consist of two modules interconnected in parallel for a given operating voltage an output power. The VSI is controlled in such a way that it can be used to inject sinusoidal current into the grid for energy extraction from the PEMFC cells during linear or non-linear load conditions.

IV. SIMULATIONS AND DISCUSS

Figure 1 shows the test system implemented using MATLAB SIMULINK software. The test system comprises a utility with sinusoidal and symmetrical voltage at frequency of 50Hz, a constant RMS value 220 V (feeding a fixed inductive load (94.2 Kw, 16.5Kvar). A DVR is connected to a power system to keep load voltage at nominal value. This DVR is supplied by Fuel Cell. To show the effectiveness of this controller in providing continuous voltage regulation; simulations are carried out with and without disturbance voltage.

Firstly the terminal voltage decreases with 50 %at 0.5s to 0.6 s (Voltage Sag), than the supply voltage is increased to 50 % at 0.8s to 0.9 s (Voltage Swell). The three-phase load voltage waveforms are presented in Fig. 3.

The system uses two Fuel Cell Stack. Each Stack is modelled at 625Vdc, 50kW PEM Fuel Cell Stack, connected to a 1515Vdc DC/DC converter. The converters are connected to shunt inverter. The utilization of the hydrogen is constant to the nominal value (\( \text{H}_2 = 99.25\% \)) and oxygen (\( \text{O}_2 = 56.67\% \)), each Stack has 900 cells; next voltage of one cell is about 1.138v.

![Supply voltages (V)](image)

(c) The load voltages (V).

![Supply currents (A)](image)

(c) The load currents (A).
A. Normal case

In normal operation, the shunt inverter (SI) injects the Fuel Cell power to the load and compensates the load reactive power through the semiconductor devices, while the DVR does not exchange any active or reactive power with the electrical network, the shunt inverter power depends mainly on the injected current to the network, which depends on the load power factor and the source currents. So, the power flow is summarized by the following schemes:

B. Voltage sag case

In voltage sag case, \( V_S < V_L \), and according to equation (4), where \( k < 0 \), it signifies that the DVR injects an active power to the electrical network (PDVR). (See figure 7). The decrease in current injected by the Fuel Cell to the load is caused by the fact that a part of Fuel Cell power feeds the DVR, in order to compensate the sag voltage, so the source current will be increased to meet the requirement of load power (see figure 6). At all the time the shunt inverter compensates the load reactive power by injecting a reactive power \( (Q_{sh}) \) in order to keep the power factor at the unite value figures 8 and 9. Then, the power flow is summarized by the following scheme:

C. Voltage swell case

In voltage swell case, \( V_S > V_L \), where \( k > 0 \), it signifies that the DVR absorbs an active power (PDVR) from the electrical network (See figure 7), while the supply current increasing \( (I_{S}) \) means that the Fuel Cell active power injected by the shunt inverter \( (P_{sh}) \) is increased by the addition of that is absorbed by DVR this excess power is released to stabilize the DC bus condenser at a constant value (see figure 6). Concerning the reactive power, during the voltage swell time, the shunt inverter compensates, during all the time, the load reactive power by injecting reactive power \( (Q_{sh}) \) figures 8 and 9. Thus, the power flow is summarized by the following scheme:
V. CONCLUSION

For well understanding the functioning of the DVR supplied by Fuel Cell, an analysis of active and reactive power has been presented in this paper. The paper system is designed to compensate, sometimes, several disturbances at the same time. So it can compensate simultaneously such voltage sag and swell by the DVR and a reactive current through the shunt inverter, as well as the system release the excess power in order to stabilize the DC bus voltage. As a result a new interpretation of the compensation phenomena for a voltage sag or swell with improving the power factor, based primarily on an analysis of the power flow has been presented in this paper.

REFERENCES


Non-invasive glucose monitoring: Application and technologies

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Abstract— The chronic metabolic disorder, diabetes mellitus is a fast-growing global problem with huge social, health, and economic consequences. The prevailing method for determination of blood glucose concentration is using a self-monitoring glucose meter. Most of the commercially available devices for glucose measurement are invasive or minimally invasive. Invasive devices used for blood glucose monitoring are painful whereas minimal invasive devices have limited time span and stability. Thus, there is a need of an economic, compact, painless and convenient non-invasive device which can promote frequent blood testing which help in control of blood glucose level. There have been numerous developments in the field of non-invasive glucose monitoring NGM during the last decade, which stress the need for a critical review. This manuscript aims to review the various NGM techniques and application. The limits and future trends in NGM are also discussed.

Keywords— Non-invasive glucose monitoring, Diabetes, Technology, Application.

I. INTRODUCTION

The prevalence of diabetes is constantly increasing worldwide at an alarming rate. According to the International Diabetes Federation in 2015, an estimated 415 million people globally were suffering from this condition [1]. Currently no treatment exists or is under development which could possibly cure this illness in the near future. The therapy of diabetes mellitus so far consists in monitoring the blood glucose (BG) level of a patient to avoid the danger of hypo- and hyperglycemias and to assist in adjusting the diet and medical treatment.

Self-monitoring of BG concentrations has advanced over the past few years. Glucose values determined by home meters correlate well with laboratory results. Because of the importance of precision and accuracy of self-monitoring BG devices, guidelines for the performance of these devices were recommended in 1987 by the American Diabetes Association [2].

Almost all commercial blood glucose monitoring devices (BGMD) employ a cost-effective electrochemical biosensor, which is capable of being mass produced and responding rapidly to glucose detection. They use automatic lanced devices to prick the fingertip of diabetics to measure blood glucose very frequently. There have been tremendous developments in the last few decades to develop improved BGMD [6] with reduced blood sample requirement of less than 1 μL. The painful aspect are minimized by employing alternate sampling sites (hand, arm). However, the cost of strip and the boredom of making repeated measurement are becoming most important. The minimally invasive approaches have been developed by using subcutaneous sensors to determine glucose concentration in interstitial fluid. But they suffer from limitations in terms of discomfort to patients, requirement of continuous calibration, and high susceptibility to biofouling. Therefore, the development of NGM techniques [7,8] is the only way to develop pain-free glucose monitoring technology for diabetics. This is the major stimulant for continuous ongoing developments in the field of NGM. There have been continuously increasing number of publications in NGM (Fig.1).

The developments undertake to improve the way of measuring the BG depend on several parameters such as the reading accuracy, techniques and approach, size of the device, and technology of the embedded systems. Each of this generation will be discussed.

Fig. 1 Number of articles pertaining to non-invasive glucose monitoring published during the mentioned period.
The recent development of the BGMD is more toward non-invasive method. This method is used to measure BG levels in the human body by only placing the sensors directly to the human targeted area without drawing blood and insertion of needles or any types of biosensors. The study on the development of this technology has begun since 1957 and the works are still continuing up to the present. Since 2014, only a few numbers of devices that have been produced using this technology and they are only available in certain countries. Most of the noninvasive BGMD is registered under consumer product and not under a medical product because this device reads the value of the blood glucose without directly in contact with the blood. This manuscript provides an update of various potential NGM technologies and devices along with their advantages, limitations.

The goal of this study is to provide an update of various potential NGM technologies and devices along with their advantages and limits. In section II non-invasive glucose monitoring technologies have been discussed, while section III discusses the proposed NGM application, and section IV discusses technology versus application. Conclusions and future developments have been illustrated in section V.

II. NON-INVASIVE GLUCOSE MONITORING TECHNOLOGIES

Non-invasive methods for glucose monitoring are more desirable and excellent alternatives to the above-mentioned technologies [21]. This could make millions of people more relaxed and comfortable about regular blood glucose testing. Although a large number of research works have already been carried out in this area, the search of a successful non-invasive technique still continues [22].

The order of presentation is partially arbitrary: we tried to report first those technologies more known, used and described.

A. Near infrared spectroscopic

It is a spectroscopic method which uses radiation in the near infrared (NIR) region of the electromagnetic spectrum (750-2500 nm) [6-7]. There are mainly three bands in NIR range: combination overtone band (2000-2500nm), first overtone band (1400-2000 nm) and second or higher overtone band (750-1400 nm). It allows the glucose measurement under the skin to a depth of few mm in range. The penetration of light into the skin decreases with the increase in wavelength [8]. As the light interacts with tissue, it is partially absorbed and scattered due to interaction with chromophores within the tissue [9]. The combination and the first overtone regions are dominated by glucose absorption information while shorter wavelength region mainly carries scattering information [10].

NIR light transmission or reflectance has been studied through an ear lobe, finger web and finger cuticle, skin of the forearm, lip mucosa, oral mucosa, tongue, nasal septum, cheek, and arm.

NIR diffuse reflectance measurements performed on the finger showed a correlation with BG but predictions were often not sufficiently accurate to be clinically acceptable [11]. The technique has serious limitations as it is affected by physicochemical parameters such as changes in body temperature, blood pressure, skin hydration, and concentrations of triglyceride and albumin. Moreover, it is sensitive to environmental variation in temperature, humidity, atmospheric pressure and carbon dioxide content. The measurement are also affected by the thickness and thermal properties of the skin [12-13], and the disease states such as hyperglycaemia and hyperinsulinemia [14-15].

B. Mid-infrared spectroscopy

Mid-infrared (Mid-IR) spectroscopy is based on light in the 2500-10.000 nm spectrums [16]. The physical principle is similar to that of NIR. When compared to NIR, however, due to the higher wavelengths, Mid-IR exhibits decreased scattering phenomena and increased absorption. For this reason, the tissue penetration of light can reach a few micrometers [17]: in the case of human skin, that corresponds to the stratum corneum. As a consequence, only reflected, scattered light can be considered: there is no light transmitted through a body segment. On the other hand, a possible advantage of Mid-IR compared to NIR is that the Mid-NIR bands produced by glucose, as well as other compounds, are sharper than those of NIR, which are often broad and weak. Mid-NIR is less studied technique compared to NIR for glucose measurement, probably due to the strong limitation in penetration. Studies are reported related to finger skin and oral mucosa [18].

One strong limitation is the poor penetration. Furthermore, Mid-IR is a affected by similar problems and confounding factors than NIR, despite glucose bands potentially improved for instance, some studies have shown significant dependence of skin Mid-IR spectrum on its water content [17].

C. Raman spectroscopy

Raman spectroscopy used laser radiation source from visible to Mid-IR, when some portion of scattered light shows a different wavelength from that of excitation beam, the effect is known as Raman effect [61-62]. When scattered light has a higher wavelength and lower intensity (10^3 times) than the original signal shown in Fig2.
only on glucose, but on several parameters, such as skin pigmentation, redness, epidermal thickness [21].

III. NON-INVASIVE GLUCOSE MONITORING: APPLICATION

A. GlucoWatch®

The first commercial U.S. Food and Drug Administration (FDA) approved non-invasive glucose monitor was the GlucoWatch® biographer (Cygnus Inc.). This wrist worn system electrochemically measured glucose concentrations in skin interstitial fluid (ISF) extracted by reverse iontophoresis (RI) [23-24]. The GlucoWatch® electrochemically detected levels of extracted ISF glucose through enzymatic glucose oxidation at skin-worn sensing electrodes modified with glucose oxidase (GOx). The GlucoWatch® had a user-friendly interface that included an alarm for greater than 35% changes in glucose, an activity marker (for meals, exercise, and insulin injection), accompanying software for data analysis and internal memory to store up to 8500 readings [24-25]. Clinical trials of the GlucoWatch® showed adequate precision for home blood-glucose monitoring. The Cygnus GlucoWatch was marketed in the early 2000s but was retracted from the market due to various reasons, which included reported skin irritation caused by the RI process, the long necessary warm up time (2-3 h), and the need for calibration using standard blood glucose strips. To address these drawbacks, recent research efforts have focused on producing reliable, efficient non-invasive glucose monitoring platforms.

B. Tattoo-based glucose sensor

Wang et al. recently developed a wearable, tattoo-based non-invasive glucose monitoring platform based on integrating RI with amperometric glucose detection on a flexible substrate [26]. The iontophoretic and glucose sensing electrodes were fabricated on a single temporary tattoo platform using screen-printing, leading to a body-compliant and easy to wear flexible, conformal device for single use glucose measurements. This sensing platform obviated the discomfort of Glucowatch® by reducing the applied iontophoretic current for ISF extraction and by utilizing a low voltage cathodic detection of the GOx-generated hydrogen peroxide at the Prussian Blue electrode transducer. The performance of the tattoo-based electrodes was evaluated with healthy human subjects by comparing the recorded glucose signals before and after meal, and the results were validated by simultaneous blood glucose measurement using a commercial glucometer. Control experiments were carried out without enzyme modification of the glucose sensor to confirm the sensing mechanism. Although the tattoo-based device was intended for disposable use, such a sensor holds considerable promise for continuous non-invasive ISF glucose monitoring by offering a body-compliant, flexible and cost-effective platform. Future work toward the development of such systems should focus on the testing of performance over long-time periods.
term use, sensor integration with wireless electronics, and examination with large populations of both healthy and diabetes suffering individuals.

C. Non-invasive sweat glucose monitoring

Sweat is a very attractive bio-fluid toward non-invasive, continuous monitoring applications due to its distinct advantages, such as having the most sampling sites outside the body, continuous access, an ease of collection device placement and comfort, as well as its composition of physiologically important electrolytes and metabolites [27]. Gao et al. demonstrated a flexible and fully integrated sensor array platform for multiplexed in situ perspiration analysis, measuring multiple sweat metabolites (glucose and lactate) and electrolytes (sodium and potassium) as well as skin temperature in a wearable patch type platform [28]. The reported device integrated signal transduction, processing and wireless transmission for the realization of a practical wearable sensor device.

D. Pendra

Pendra from pendragon medical ltd, Switzerland was another NGM device in the form of a wrist-watch, which based on impedance spectroscopy. It was approved by FDA in may, 2003 as an adjunctive device to standard blood glucose meters to detect trends and patterns in glucose levels. It consists of an open resonant circuit (1-200 MHz) that lies in contact with skin with the help of a tape on the backside of the device and performs the impedance measurements. It can perform up to four measurements per minute with sensitivity in the range of 20-60 mg dL\(^{-1}\) glucose per ohm. It has USB connectivity for downloading data to a PC. Pendra user software for data analysis. The correlation studies showed a poor correlation of only 35.1%.

The production of Pendra was stopped as the company went bankrupt in 2005.

IV. APPLICATION VERSUS TECHNOLOGIES

In this review, we presented a description of NGM. According to the indications of the health technology assessment (HTA) methodology, we carried out the analysis on the basis of clear and objective criteria. Some of the technologies have not been exploited in a device yet, while some others have led to a device at least in advanced prototype condition. It must be noted however, that currently only three devices have reached a regulatory approval for commercialization in United States and/or Europe.

Among these three, for different reasons two of them are not on the market anymore. The only available one is the GlucoWatch, and in any case it cannot completely substitute a traditional meter. Furthermore, GlucoWatch is reported to possibly have some drawbacks: in fact, it sometimes causes skin irritation, and it may be uncomfortable to use in the daily life of the patients.

The development of non-invasive glucose biosensors for diabetes management is just beginning. Despite promising recent advances, there yet remain numerous challenges to overcome for the successful implementation of non-invasive glucose monitoring technologies, combining accurate real-time glucose readings with long-term stability. In particular, large-scale studies are required to critically assess the accuracy.

A reliable means of efficient, selective fresh glucose uptake is crucial to the development of sweat-based monitoring systems [56]. Further efforts should focus on accurate epidermal glucose measurements by combination with sensing of other physiological parameters (pH, temperature, humidity) toward continuous calibration and improved accuracy and correlation with blood glucose level. Future efforts should also aim at simultaneous monitoring of additional diabetes related markers toward a more comprehensive array of information regarding real-time glucose metabolism. Further improvement in iontophoretic sweat stimulation is desired for controllable (consistent and reproducible) sweat generation without the need for exercise. Additional work should also focus on improved sweat collection, flow and replenishment in connection to epidermal flexible microfluidics devices. Overcoming these and other challenges will be crucial for the advancement of continuous epidermal glucose monitoring to realize its potential impact.

To achieve the targeted goals, a thorough understanding of all components of the non-invasive monitoring systems are required, including the applied technologies, skin physiology, device surface and material chemistries, and sensing electrochemistry as well as the interface of these systems. The successful realization of non-invasive glucose monitoring platforms require not only consideration of scientific problems, but also economic, legal and commercial concerns with the patient and physician education of key importance. We envision that through a combination of these technological advances with large scale studies, glucose concentrations can be reliably and noninvasively monitored with minimal discomfort to patients for widespread applications toward improved glycemic control and autonomous therapeutic interventions through integration with autonomous, closed-loop insulin delivery systems. Given the rapid recent progress, it seems that non-invasive glucose monitoring has only scratched the surface of its full diagnostic potential and is poised to significantly increase its impact on medicine.
V. CONCLUSION

The non-invasive devices have tremendous appeal and a market in excess of at least one billion dollar per year worldwide. However, the development of non-invasive devices has been hampered by unsubstantiated claims, which proved to be misleading if not false.

In conclusion, the problem of non-invasive glucose monitoring is currently not solved, and further efforts are still necessary to reach the goal of having a reliable and inexpensive device for the benefit of the diabetic patient.

REFERENCES


Numerical and experimental evaluation of a photovoltaic thermal air collector’s performance (PVT) under Tunisian climatic conditions

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Abstract—

In this work we present a numerical simulation and mathematical model of a hybrid photovoltaic/thermal (PVT) collector. The hybrid collector has two purposes: 1) The cooling of the PV module, 2) the recovery of heat dissipated therein consequently the provision of hot-air used to dry the agriculture products. The proposed model is used to evaluate the thermal energy performance and to determine the optimum air speed, A 2D transient heat conduction model was developed in COMSOL Multiphysics (3.4.b). The model considers the outside temperature, solar irradiation, and air velocity. The simulation shows a good agreement with experimental data for the photovoltaic cell temperature, air temperature inside the channels and the outlet temperature.

Keywords—component;  Photovoltaic thermal air collector (PVT), Performance evaluation, Experiments, Simulation,

I. Introduction

Among the renewable energy resources, solar energy is considered the most promising and highly reliable clean energy technology. Solar energy may be harnessed and utilized in two forms, such as heat and electricity. Solar thermal energy is collected by solar thermal collectors and electrical energy is produced by photovoltaic (PV) modules. Among the sources used to provide the needs is the solar energy [1]. Solar energy is universally accepted as the most potential alternative power source due to its inexhaustible availability, diverse conversion technology and environmental friendly. A solar thermal (PT) collector may be connected in series, parallel, or a series-parallel combination. A configuration in series results in a larger system but higher temperature whereas a parallel connection would result in a smaller configuration but with lower temperature. A decreases in the thermal transfer coefficient diminish the cooling effect on the absorber plate which allows a higher plate temperature and lower air stream temperature, then the efficiency is reduced [2]. The heating curves of a new flat-plate, sandwich-like solar collector with serpentine ducts were experimentally measured and compared to those of a commercial collector with parallel ducts. The serpentine geometry is seen to show a better performance than the parallel one in what the heating curve of the storage tank water is concerned [3]. Secondly The photovoltaic collector (PV) provides only electricity but only around 10–20% of the solar radiation can be converted into electricity by the PV cells, and most of the rest is rejected as heat in the module, meanwhile, the heat will increase the PV temperature and reduce the PV conversion efficiency [4].
Thirdly the solar hybrid photovoltaic-thermal collector (PV/T). It is used to ameliorate the energetic efficiency of photovoltaic by the removal of the waste heat from the PV cells at the same time cooling the PV module and increases their electrical efficiency. An optimized solar energy system that produces electricity and thermal energy simultaneously from the same physical configuration, which provides the utmost usage of solar energy [5]. Compared with the solar thermal collector (PT) or the photovoltaic-collector (PV), the market for the PV/T collectors is still very small today, but the interest in this technology has been increased in last year’s [6]. Ooshaksaarei et al (2017) affirm the total output energy and total output exergy of the PVT collector proposed are two key parameters for evaluating the performance of a PVT collector [7]. A temperature gradient on the PVT collector allows a variation in the efficiency due to a non-uniform temperature distribution on the PV cells [8]. Ibrahim et al. Studies the performances of a water-based PV/T system with a spiral flow absorber, the results showed the PV/T energy and exergy efficiencies of this system were 55–62% and 12–14%, respectively [9]. Several geometries have been suggested for PVT solar collectors, ranging from the most frequently used fin-and tube collector to sandwich-like collectors with ducts where the fluid directly contacts the absorbing surface [10]. Othman et al studied the performance analysis of PVT combination flat plate collector of water and air heating system. They concluded the advantage of the having two types of cooling medium in one system PV/T, the temperature of PV panel will be reduced and cell efficiency will be greatly improved at instant [11]. Hasila Jarimi et al [number?] studied, a novel design of a hybrid solar collector which integrates the use of both water and air as the working fluids, they are concluded, that simultaneous use of both fluids led to the decrease in the temperature of the PV panel. This fact leads to the increase in electrical performance more significantly. The increment of solar intensity contributes to enhancement of outlet temperature of both fluid and electrical power of the whole system. Mass flow rate plays an important element for cooling effect on PV solar cells by reducing the outlet temperature in the channel and tubes [12]. In this sense, in the past year’s numerical simulation has been revealed as an important tool in order to provide an insight into physical industrial processes allowing to improve systems performance and process optimization [13].

In the present study, a steady state thermal model of a PV/T air solar collector under forced flow mode was developed, validated with experimental data and then used to study the effects of various parameters on the performance of the system. This simulation program considers the local climate conditions, Tunisia-Sfax, to review and understand the procedure of hybrid solar collector (PVT) and develop a mathematical model for thermal analysis of PVT. To analyse the effect of the airflow in the Outlet temperature and the efficiency of the PV panel for the photovoltaic-thermal collector (PVT).

II. Design of the system

The experimental measurements were carried out using the hybrid solar collector prototype (Figure 1), located at the National Engineering School of Sfax-Tunisia, and tested in several sunny days. This solar collector was designed and constructed in the framework of the European project “ESSORENTERPRISE” according to climatic conditions of Sfax city in Tunisia. The design specifications of PVT solar collector are given in Table 1. This prototype was fixed facing south direction with an angle of inclination of 45°. The inclination of the PVT collector is taken as 45° from horizontal to receive maximum radiation. The PVT collector absorbs the solar radiation and produce both thermal and electrical energy. The air flux enters in aluminum tubular canals 0.04 m * 0.04 m to provide a heat exchange below the PV panel. A 0.04 m layer of glass fiber was used to isolate the back of the panel. A Gap of 0.02 m was used between the PV panel and the external ultra-transparent glass layer each of 0.008 m thickness.

To simplify calculation, some assumptions have been made below:
Fig 1. Solar PV/T solar collector

### Table 1. Design specifications of PVT solar collector

<table>
<thead>
<tr>
<th>Details of particulars</th>
<th>Specification</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PV panel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>1.3</td>
<td>m</td>
</tr>
<tr>
<td>width</td>
<td>0.88</td>
<td>m</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.005</td>
<td>m</td>
</tr>
<tr>
<td><strong>Glass Cover</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>1.3</td>
<td>m</td>
</tr>
<tr>
<td>width</td>
<td>0.88</td>
<td>m</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.008</td>
<td>m</td>
</tr>
<tr>
<td>Spacing between glass cover and PV panel (Gap)</td>
<td>0.02</td>
<td>m</td>
</tr>
<tr>
<td><strong>Aluminium Tubes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Dimension</td>
<td>0.04*0.04</td>
<td>m</td>
</tr>
<tr>
<td>Spacing between two tubes</td>
<td>0.04</td>
<td>m</td>
</tr>
<tr>
<td><strong>Aluminum Plate</strong></td>
<td>1.3<em>0.88</em>0.00</td>
<td>2 m</td>
</tr>
</tbody>
</table>

### Conversation Equations

**Fig 2. Cross sectional view of PV/T solar collector**

**III. Assumptions**

1. There are two separate phases, fluid and solid, which are not in thermal equilibrium. This was the case for low thermal conductivity fluid and low volumetric heat transfer coefficient between the fluid and solid domains.
2. The temperatures at the front side and back side of the bifacial PV panels are assumed to be equal.
3. There are no air leaks from the collector.
4. Air can be considered as an incompressible fluid.
5. A laminar regime is developed.

**IV. Conservation equations**

Heat transfer through solid surface to the flow channel is solved by the heat convection.

\[
\nabla \cdot (k \nabla T) = 0 \quad (1)
\]

In fluid domain inside the flow channel the heat transfer mechanism has been considered as a conjugate heat transfer of conduction and convection. The conjugate heat transfer equation solved for heat transfer in the fluid domain is given in equation (2) taking air as the fluid.

\[
\rho C_p \frac{\partial T}{\partial t} + \rho C_p u \cdot \nabla T = \nabla \cdot (k \nabla T) + Q + Q_{vb} + W_p \quad (2)
\]

The mass and momentum conservations for the fluid flow are given below equation (3):

\[
\rho \left( \frac{\partial u_z}{\partial t} + \rho (u_z \cdot \nabla) u_z \right) = \nabla (-p I + \mu \nabla u_z + (\nabla u_z)^T) - \frac{2}{3} \mu (\nabla \cdot u_z) I + F
\]

\[
\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho u_z) = 0
\]

The PV/T panel shown in Figure 1 receives energy from the solar irradiance, converts some of it into electricity through the PV effect and the rest is transformed into heat. The objective of attaching the thermal panel underneath the PV cell is to remove as much as this heat as possible in order to increase the efficiency.

The heat absorbed of a PV/T collector can be calculated from Equation (4).

\[
Q_a = Q_{ab} + Q_{cv} + Q_{rd} \quad (4)
\]
The heat loss due to forced convection on the top and bottom surfaces of a PV/T collector is given by Equation (5).

\[ Q_{cv} = h_{cv} \cdot A_g \cdot (T_a - T_g) \] (5)

The long wave radiation heat loss can be calculated from Equation (6).

\[ Q_{rd} = \varepsilon \cdot \sigma \cdot A_g \cdot (T_a^4 - T_g^4) \] (6)

The heat source is given by equation (7).

\[ Q_{sb} = \alpha_g \cdot G \] (7)

**Boundary conditions:**

For the fluid domain the inlet boundary conditions were specified as velocity inlet along the z-axis and is expressed by the following condition.

\[ u_z = u_0, v = w = 0 \]

\[ T_g = T_{int} \] (8)

Wall boundary conditions were used to bound fluid and solid regions. Wall is at no slip condition and the outlet condition is kept at zero-gauge pressure and no viscous stress.

\[ u_z = 0 \] (9)

Thermal insulations are taken:

\[ -n_z (-k \nabla T_z) = 0 \] (10)

**V. Numerical simulation**

The model consists of five solid domains for PV/T collector: front cover (glass), PV cells, Aluminum tube, back sheet aluminum, and the Insulation.

The cross section of the considered PV/T model is shown in Fig. 2. The system consists of eight layers (including solid and liquid layers) for the PV/T module. A non-isothermal laminar flow and conjugate heat transfer physics module was used. The three modes of heat transfer are involved when considering a PV / T model. Heat is transferred to the solid domain by conduction, heat is transferred between the solid and fluid by convection and a forced convection and radiation between ambient medium and the upper surface of the collector. The finite element method was used in comsol multiphysics.

**VI. Results-Simulation**

To run the program, various properties of the materials must be adjusted according to a real case scenario. The actual values used, are shown in Table 2.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Density [kg/m³]</th>
<th>Thermal Conductivity [(W/mK)]</th>
<th>Heat capacity at constant pressure [(J/KgK)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass</td>
<td>3000</td>
<td>1.8</td>
<td>500</td>
</tr>
<tr>
<td>PV-Panel</td>
<td>1500</td>
<td>134</td>
<td>677</td>
</tr>
<tr>
<td>Alum inum</td>
<td>2700</td>
<td>160</td>
<td>900</td>
</tr>
<tr>
<td>Air</td>
<td>( \rho A (1/k Pa, T[1/K]) ) 0.0262 [W/(m^2 - 1)*(K^2 - 1)]</td>
<td>( C_p(T[1/K]) )</td>
<td></td>
</tr>
</tbody>
</table>

Table2. Properties of the various construction components

(a) **Axis X**

(b) **Axis Y**

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page 74
© Axis Z

Fig 3. 3D air distribution in PV/T following the three axes with \( V_{int} = 1.5 \text{ m/s} \)

In figure 3, we show airflow distribution in non-homogeneous, a higher air velocity is observed at the center of the collector, then our physical configuration must be modified.

Fig 4. Speed profiles in tubes along the X-axis With \( V_{e} = 3.4 \text{ m/s} \) for several \( \beta \) angle

Figure 4 depicts the air velocity inside the tubes. An important difference of the velocity at different locations show variations near from 1.5 m/s. This fact enhances the heat transfer in some locations, but diminish the transfer in another tubes.

Fig 5. 2D Geometry of PV/T

Fig 6. 2D air distribution in the PV/T \( (Q_{m} = 0.0188 \text{ Kg/s}) \)

(a) \( t=0 \text{ h} \)

(b) \( t=12 \text{ h} \)

(c) \( t=14 \text{ h} \)
given temperature difference, more heat is transferred at higher velocities, thereby increasing the thermal efficiency. As both the electrical and thermal efficiencies increase with increasing inlet velocity, so the overall efficiency also increases.

Results from the developed model such as efficiency of the collector for specific flow rate, inlet and outlet temperature of air or temperature lift of the collector are compared with experimental data. It is found that, the Experimental results are in good agreement with the numerical simulation.

VII. Conclusion

This study was carried out with the main objective being to evaluate the performance of photovoltaic-thermal (PVT) air system. A model of PV/T has been presented both numerically and experimentally, was created in COMSOL Multiphysics 3.4.b, we used the heat conjugate (heat transfer and laminaire flow), the experiments are carried out at outdoor conditions. Note that these estimates are approximate only and accuracy depends on the parameters of the materials and other measurements. The results indicate that the collector was no more significant difference between the experimental data and numerical results. We conclude that the on homogeneous air flow distribution, higher velocity in the center, the air temperature increases as solar radiation increases, furthermore heterogeneous airflow distribution in the tubes and the simulations describe correctly the evolution of temperature inside the collector.

References.

channel under different operating conditions in Malaysia, *solar energy*, 144, 517–528, (2017)
Sliding Mode Control of An Autonomous Sailboat

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Abstract—This paper presents a study on the development of an autopilot based on sliding mode method for a sailing vessel. This autopilot is synthesized through a model with three degrees of freedom, which represents the dynamics of the boat. The dynamic equations of motion are strongly nonlinear. However, we will design control laws to stabilize the boat heading and sail opening angle in order to make it follow a given path. We first describe the nonlinear three-degree-of-freedom dynamic model for the sailing vessel. Then, we design an autopilot using sliding mode techniques. Finally, some simulations are carried out to illustrate the behaviour of the overall system.

Keywords—autonomous sailboat; autopilot; sliding mode control.

I. INTRODUCTION

Due to their low energy consumption, robotic sailing boats offer a promising solution for observation or monitoring missions at sea. Actually, many autonomous sailboat projects have been launched throughout the world over the last decade [3]. Generally, the sailboat propulsion depends on the wind. Even though this propulsive resource is free and environment friendly, its major disadvantage resides in the uncontrollability and unpredictability of the wind. Hence, we need an effective adjustment of the sail and the rudder angle to overcome this weakness. This adjustment must be effective to control the sailboat heading and the sail opening angle. For this purpose, it will be necessary to determine a dynamic model of the sailboat. In this context, several approaches have been developed. Actually, the classical techniques of Lagrangian and Newtonian mechanics are the most used methods for modelling the behaviour of the sailboat in the presence of the different efforts applied to the boat. In this context, two types of dynamic models are distinguished, those of three degrees of freedom with no drift effect, especially announced in [6], and those with drift effect highlighted in [13]. Also, other examples of developed dynamic models are presented in [13 and 14]. In [8] Legursky determined also a 4-DOF¹ sailboat dynamic model using another approach with a modification in the aerodynamic effort.

To ensure an effective and safety navigation of autonomous sailboats, several control laws have been applied. In [1], Brière developed a linear controller to calculate the sail opening angle as a function of the apparent wind angle. Another controller based on fuzzy logic techniques has been developed in [15] and [10] to ensure an optimal roll angle of the sailboat. In 2010, a controller based on extremum-seeking was proposed by Jouffroy in order to calculate the optimal control of the sail and to maximize the boat linear velocity [11].

To guide the sailboat to its destination, an appropriate control of the rudder angle must be achieved. The most used regulators are the PID correctors (see [2] and [9]). This command is synthesized according to the modelling of the sailboat rotation with the first order Nomoto model. Another fuzzy-based controller has been established by Gomes [16] where the rudder angle was calculated using the heading and the desired angular velocity. Moreover, a back-stepping approach was introduced by Jouffroy [13] to design a nonlinear rudder controller.

In this paper, an autopilot was designed using sliding mode techniques for controlling the rudder and the sail opening angle in the same time letting the sailboat follow a given path.

In the following section, before the design of control laws are presented, a mathematical model of a sailboat with three degrees of freedom was described. In section III, the sail and heading controller were applied and tested on the presented model. Finally, some simulations were carried out to illustrate the approach.

II. SAILBOAT DYNAMIC MODEL

In this paper our objective is to design an autopilot for controlling the heading and sail opening angle of the sailing

¹ Degree of freedom
boat. Firstly, the nonlinear 3-DOF dynamic model for the sailing vessel is described. This model is inspired from [5] under the following assumptions:

- The wind speed and direction are constant.
- Rolling motion and drift effect are neglected.
- The boat is assumed to be rigid with 3 DOFs: surge, sway and yaw. (see Appendix B)
- The sailboat is assumed to evolve in calm waters.
- The environmental disturbances are ignored.

The figure (Fig. 1) shows the sailing boat to be modeled. Let the North-East-Down NED coordinate system \((x, y, z)\) be the inertial reference frame \((n-frame)\) and let the \((x_b, y_b, z_b)\) be the body fixed frame \((b-frame)\)(Fig.1). The latter is the rotating reference frame attached to the boat with yaw velocity \(\dot{\psi} = r\) relative to the \((n-frame)\).

![Fig. 1. Graphic representation of the modelled sailboat and Description of the (b-frame) coordinate system](image)

The kinematic equations are:

\[
\begin{align*}
\dot{x} &= u \cos \psi + V_C \cos \phi \\
\dot{y} &= u \sin \psi + V_C \sin \phi \\
\dot{\psi} &= r
\end{align*}
\]

(1) (2) (3)

According to [5] and [17], the wind generates an aerodynamic force on the sail which is equal to:

\[
f_s = p_w V_w \sin(\psi - y + \delta) - u \sin \delta_s
\]

(4)

On the other hand, the water generates a hydrodynamic force on the rudder which is equal to:

\[
f_r = p_u u \sin \delta_r
\]

(5)

For simplicity reasons, we will assume here that the force friction applied to the boat depends on \(u^2\) and it is equal to \(-p_u u^2\) [4].

According to Newton’s second law of motion in the \((b-frame)\), we have:

\[
p_u \dot{u} = f_s \sin \delta_s - f_r \sin \delta_r - p_u u^2
\]

(6)

The forces acting on the sailboat rotation are \(f_s, f_r\) and an angular friction force \(-p_u r\). Therefore, the Newton’s second law of motion is given by:

\[
p_{10} \dot{r} = d_s f_s - d_r f_r - p_u r
\]

(7)

By introducing

\[
d_s = p_u - p_r \cos \delta_s \\
d_r = p_u \cos \delta_r
\]

(8)

Thus, equation (7) becomes:

\[
p_{10} \dot{r} = (p_u - p_r \cos \delta_s) f_s - p_u \cos \delta_r f_r - p_u r
\]

(9)

Therefore, the state equations which describe the kinematics of the boat with three degrees of freedom are:

\[
\begin{align*}
\dot{x} &= u \cos \psi + V_C \cos \phi \\
\dot{y} &= u \sin \psi + V_C \sin \phi \\
\dot{\psi} &= r \\
\dot{\delta}_s &= u_1 \\
\dot{\delta}_r &= u_2 \\
\dot{u} &= (f_s \sin \delta_s - f_r \sin \delta_r - p_u u^2)/p_u \\
\dot{r} &= ((p_u - p_r \cos \delta_s)f_s - p_u f_r \cos \delta_r - p_u r)/p_{10}
\end{align*}
\]

(10)

This differential equation system is highly nonlinear, it has the following form; \(\dot{X} = f(X, U)\)

With:

\[
X = (x, y, \psi, \delta_s, \delta_r, u, r)^T
\]

the state vector, and

\[
U = (\delta_s, \delta_r)^T
\]

the input vector.

III. AUTOPilot DESIGN FOR THE SAILBOAT

Our goal is to design an autopilot capable of autonomously bringing the sailboat to a desired ocean position \((x_d, y_d)\). Generally, such an autopilot is composed of two regulators: a low-level regulator and a high-level regulator. The first one controls the heading and the sail opening angle. The second one acts as a setpoint generator of two variables: the desired opening angle of the sail \(w_1 = \delta_s^{ref}\) and the desired boat heading \(w_2 = \psi^{ref}\) that will guide the sailboat to its destination. These two regulators have various inputs, such as the wind direction and speed, the sea current, the system state space and the desired position. Fig 3 shows a block diagram of the proposed autopilot. In this study, we will focus on the low-level regulator only. According to the setpoint generator, we will use the trajectory planning proposed in [5] with minor improvements.

![Fig. 2. The sailboat autopilot](image)

The mathematical model obtained (10) is strongly nonlinear. In fact, the state vector is of dimension seven. According to the flatness theory [8], the vector \(Y = (\delta_s, \psi)^T\) is a flat output and consequently the system is flat.
The sliding mode control design involves two steps: the selection of a sliding surface in the state/error space on which motion should be restricted, called the switching function, and the synthesis of a control law which makes the selected sliding surface attractive.

A. Selection of the sliding surface

In order to apply a feedback linearization method, the output vector was differentiated three times for $\psi$ and once for $\delta_s$. So, we have:

$$
\dot{\delta}_s = A_{11}(X)u_1 + A_{12}(X)u_2 + B_{11}(X) \tag{11}
$$

With:

$$
A_{11}(X) = 1 \quad A_{12}(X) = 0 \quad B_{11}(X) = 0
$$

The relative degree of the differential equation (11) is equal to one so the chosen sliding surface is given by

$$
S_1 = e_1 \tag{12}
$$

Where $e_1 = w_1 - \delta_s$ represents the error on the sail opening angle. From (10), we extract the following yaw/heading sub dynamics:

$$
\ddot{\psi} = \frac{p_4 - p_2 \cos(\delta_s) f_y - p_8 \cos(\delta_r) f_r - p_3 \psi}{p_{10}} \tag{13}
$$

With $\psi \in [-\pi, \pi]$. We derive another time $\psi$ so, we obtain:

$$
\ddot{\psi} = A_{21}(X)u_1 + A_{22}(X)u_2 + B_{21}(X) \tag{14}
$$

With:

$$
A_{21}(X) = \frac{p_2 f_y \sin \delta_s + p_8 p_2 \cos(\delta_s) - p_6 p_2 \cos(\delta_s) u \cos(\delta_s)}{p_{10}}
\quad A_{22}(X) = \frac{-p_1 f_y \sin \delta_s - p_8 p_2 \sin(\delta_s) \cos \delta_s}{p_{10}}
\quad B_{21}(X) = -\frac{p_2 f_y \sin \delta_s}{p_{10}}
$$

The relative degree of the differential equation (14) is equal to 3. So, the chosen sliding surface is given by:

$$
S_2 = \lambda_1 e_2 + \lambda_2 e_2 + \lambda_3 e_2 \tag{15}
$$

with $e_2 = w_2 - \psi$ the heading error of the vessel. The coefficients $\lambda_1, \lambda_2, \lambda_3$ are chosen by pole placement method: $\lambda_1 = 1; \lambda_2 = 2; \lambda_3 = 1$

Thereafter, the sliding surface $S$, which allows the system to converge to the desired state, is written in the form:

$$
S = \left( \begin{array}{c} S_1 \\ S_2 \end{array} \right) = \left( \begin{array}{c} e_1 \\ e_2 + 2 \dot{\delta}_s + \ddot{\delta}_s \end{array} \right) \tag{16}
$$

B. Synthesis of the control law

According to the sliding-mode control theory, we have

$$
U = \begin{bmatrix} u_1 \\ u_2 \end{bmatrix} = U_{eq} + U_{cor} \tag{17}
$$

$U_{eq} = \begin{bmatrix} u_{1eq} \\ u_{2eq} \end{bmatrix}$ represents the equivalent control. It makes the derivative of the sliding surface equal to zero in order to stay on the sliding surface.

$U_{cor} = \begin{bmatrix} u_{1cor} \\ u_{2cor} \end{bmatrix}$ is the corrective control letting the system to compensate the deviations from the sliding surface.

$U_{eq}$ is the solution of the equation system (18):

$$
\begin{cases}
\dot{S} = \left( \begin{array}{c} S_1 \\ S_2 \end{array} \right) = \left( \begin{array}{c} 0 \\ 0 \end{array} \right) \\
U = U_{eq}
\end{cases} \tag{18}
$$

In other words,

$$
-A(X)U_{eq} - B(X) - C(X) = 0
$$

$U_{eq} = -A^{-1}(X)(B(X) + C(X)) \tag{19}$

This relation is verified if the matrix $A(X)$ is invertible. With

$$
A(X) = \begin{bmatrix} A_{11}(X) & A_{12}(X) \\ A_{21}(X) & A_{22}(X) \end{bmatrix}
\quad B(X) = \begin{bmatrix} B_{11}(X) \\ B_{21}(X) \end{bmatrix}
\quad C(X) = \begin{bmatrix} C_{11}(X) \\ C_{21}(X) \end{bmatrix} = \begin{bmatrix} 0 \\ C_{21}(X) \end{bmatrix}
$$

Let us now determine the singularities of the matrix $A(X)$. By calculating the expression of $\det(A(X))$, we can show that we have a singularity when this quantity is equal to zero, in other words:

$$
\det(A(X)) = 0
$$

Then $u = 0$ or $\delta_r = \frac{\pi}{4} + k \frac{\pi}{2}$

This configuration corresponds to a singularity that should be avoided. Hence, the maximum rudder angle will be set to $\delta_r = \frac{\pi}{3}$.

For a scalar function $f$ we denote $\tilde{f}$ the following vectorial function:

$$
\tilde{f}: \mathbb{R}^2 \rightarrow \mathbb{R}^2 \tag{20}
$$

Thus, the expression of the corrective control function $U_{cor}$ is calculated by the resolution of the following equation:

$$
\dot{S} = -K_s \tilde{g}(S) \tag{21}
$$

where $K$ is a positive design constant. Or, we have:

$$
\begin{cases}
\dot{S} = -A(X)U - B(X) - C(X) \\
U = U_{eq} + U_{cor} \\
U_{eq} = -A^{-1}(X)(B(X) + C(X))
\end{cases} \tag{22}
$$

Therefore, using (21) and (22) we get:

$$
U_{cor} = A^{-1}(X)(K_s \tilde{g}(S)) - B(X) - C(X) \tag{23}
$$

As a consequence, the control expression is given by:

$$
U = U_{eq} + U_{cor} = -A^{-1}(X)(B(X) + C(X)) + A^{-1}(X)K_s \tilde{g}(S) - B(X) - C(X) \tag{24}
$$
proof
Let the candidate Lyapunov function be defined by:

\[ V = \frac{1}{2} S^T S \]  
(25)

To ensure the stability and attractiveness of the sliding surface of the control law developed, it is sufficient that \( \dot{V} < 0 \).

We have

\[ \dot{V} = \frac{1}{2} (S^T S + S^T S) \]
\[ = \frac{1}{2} ( - S^T \text{sign}(S) - K \text{sign}(S) S^T ) \]
\[ = - K [|S_1| + |S_2|] < 0 \]  
(26)

So, the asymptotic convergence of the trajectory to the sliding surface is proven.

To reduce the chattering effect, the "signum" function was replaced with an "arc-tangent" function, in order to avoid actuators (rudder and sail) strain and obtain a smooth control behaviour, therefore, we obtain:

\[ U = A^{-1}(X)(\frac{2}{\pi} \tan^{-1}(\frac{\pi}{2} S) - B(X) - C(X)) \]  
(27)

This low-level regulator generates the control laws

\[ U = \begin{pmatrix} u_1 \\ u_2 \end{pmatrix} \]

regulate the boat heading and the sail opening angle using the sliding mode method. According to the desired position \((x_d, y_d)\), measured heading \(\psi\) and wind data the high-level regulator which is inspired from [5] will generate the desired heading \(\psi_2 = \psi_{ref}\) and the desired sail opening angle \(\psi_1 = \delta_{ref}^s\).

As we know, if the boat heading is too close to the wind direction, the sail will be luffing ("flapping") in the breeze and cannot generate an aerodynamic force, only making noise like a flag. Different sailboats, have different performance characteristics. These characteristics depend on such variables as sail area, boat mass, hull and keel design.

The polar diagram of a sailboat is the set of all pairs \((\psi, u)\) that can be reached by the sailboat when it navigates. The area of direction that cannot be reached is called a no-go zone. The size of the no-go zone (no-go-angle) will differ based on the performance characteristics of the particular sailboat.

In case that the boat is up the wind \((\gamma = \pi + \psi)\), to avoid the no-go-zone, the high-level regulator generates desired heading

\[ \psi_{ref} = \frac{-2\pi}{3} + \gamma \quad \text{and} \quad \psi_{ref} = \frac{2\pi}{3} + \gamma \]  
(28)

letting the boat tack and reach its destination with maximum speed according to the used boat polar diagram (see Appendix C). When the desired position is located on the south of the boat position, the desired heading given by

the high-level regulator which is defined by \(atan2^3\) function equal to

\[ \psi_{ref} = atan2(y - y_d, x - x_d) \]  
(29)

Using the sailboat heading \(\psi\) the desired sail opening angle is given by (Fig.3):

\[ \delta_{ref}^s = \pi \left( \frac{\psi}{2\pi} + \frac{1}{2} \right) \]  
(30)

IV. SIMULATION

In order to validate the control law developed in this work, the overall system was simulated.

During this simulation, the wind is blowing from the north \((\gamma = \pi)\) and its speed equal to 10 m/s. It is indicated by a red arrow (see Fig.6 and Fig.7).

The controller (27) is tuned with \(K = 3.5\).

In order to visualize the behaviour of the sailboat facing the wind and down the wind also the robustness of the proposed control law, we have chosen two desired way-point, the first one is located in the south east of the initial position \((0,0)\) and the second one is situated on the north east of the initial position \((0,0)\). Both simulations were started with initial values.

\[ X(t = 0) = (0 0 -45^\circ 67.5^\circ 3.9^\circ 80^\circ)^T \]

- The first simulation result represented in Fig.4, shows that the boat goes directly to the desired position which is located in the south east of the initial boat's position.
- Fig.5 shows the path followed by the sailboat during the second simulation. The boat performs the tacking manoeuvre when it is facing the wind. The simulation results show that there is a good synchronization between the rudder and the sail control (Fig.6 and

\[ atan2(y, x) \in [-\pi, \pi] \]  
3 \(atan2(y, x) \in [-\pi, \pi]\) is the four-quadrant inverse tangent.
Fig. 7) in order to contribute to the direction of the wind that isn’t convenient for sailboats.

- Fig. 8 show that $\psi(t)$ eventually converges to the desired heading $\psi^{\text{ref}}(t)$ with an error $\psi^{\text{ref}}(t) - \psi(t) \approx 0$

![Fig. 7. Time evolution of the sail opening angle control](image)

![Fig. 8. Time evolution of the desired heading $\psi^{\text{ref}}$ and the sailboat heading $\psi$](image)

V. CONCLUSION

In this paper, a 3-DOF mathematical model describing the dynamic motion of a sailboat was presented. This model is simple and contains several approximations such as the neglect of drifting effect and rolling motion but it is an adequate model in order to apprehend the sailboat dynamic motion in the horizontal plane. The sliding mode control approach is employed to perform heading and sail opening angle control for the sailing boat.

The simulation results show that the used control technique gives good results in terms of regulation but with relatively small errors, this technique has also some disadvantages, such as the chattering phenomenon caused by the ‘signum’ function. However, this problem is solved by applying the ‘arc-tangent’ function which gives better results in terms of regulation through a smooth control. Future work in this area is the design of a sailboat autopilot based on sliding mode control applied to the non-linear system without feedback linearization method and the next step a
comparison between these two control laws will be discussed.

After the validation of the proposed control law through simulation, the proposed control law will be tested on a real sailboat.

REFERENCES


Application of Direct Power Control in Wind Energy Conversion System

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Abstract—This paper describes the performance evaluation of the direct power control for a three-phase pulse with modulation inverter fed by a variable speed wind energy conversion system. This, to ensure a maximum power point tracking of a wind. Proposed direct power control strategy is implemented in the d-q reference frame. The system modeling and control scheme are implemented on Matlab/Simulink. The simulation results show that the use of the direct Power Control provide nearly sinusoidal input wave form current, constant switching frequency operation, regulation of unity power factor in the connection of the grid side converter with the grid and the maintain of the DC-link voltage constant. Finely, the results verify the validity and effectiveness of the proposed control.

Keywords—Renewable energies, wind energy conversion system, direct power control, simulation.

I. INTRODUCTION

Nowadays, energy is one of the central and foremost grand challenges facing our society today. Particularly, wind energy is becoming one of the most important renewable energy sources; it will likely provide the main renewable contributions to the growing need for clean energy [1], [2]. Variable speed Wind Energy Conversion System (WECS) have become the industry standard because of their advantages over fixed speed ones such as improved energy capture, better power quality. With the growing of power electronic devices, three-phase rectifiers have been widely applied to wind energy system. A three-phase voltage source converter offers many advantages, namely bidirectional power flow, low harmonic distortion of input currents and regulation of input power factor to unity, low switch voltage stress and low switching frequency [3],[4]. In recent years, different strategies have been proposed for controlling Pulse With Modulation (PWM) converter. The main goal of these control strategies is to obtain the high power control and sinusoidal current estimated flux signal used in the control system [5]. In this paper, the Direct Power Control (DPC) is considered, so, the converter switching states are selected by a switching table based on the instantaneous errors between the commanded and estimated values of the active and reactive power, and voltage position vector [6]. For such several advantages, the DPC has attracted attention and a lot of curiosity of many researchers.

The present paper is organized as follow: In section II, wind energy conversion system model is presented. After, the principle of direct power control is explained in Section III. The rectifier control using direct power control is programmed under Matlab/Simulink environment and the analyzes of the performances are given in Section IV. Finally, simulation results and conclusion are presented.

II. WIND ENERGY CONVERSION SYSTEM MODEL

Wind energy conversion system considered in this work is shown in figure 1. It includes the wind turbine, gearbox, Double Fed Induction Generator (DFIG), and back-to-back converters whereas the rotor is fed by back-to-back bidirectional converter and the stator is directly connected to the grid. This system allows conversion of the wind energy through the turbine to the three-phase DFIG. This energy is transmitted directly through a bridge rectifier and inverter to the electrical network.

![Schematic diagram of wind energy conversion system](image)

Fig.1. Schematic diagram of wind energy conversion system

II.1 Turbine modelling

Wind power $P_w$ and the aerodynamic power $P_a$ captured by the wind turbine are given by:

$$P_w = C_p(\lambda, \beta) \frac{\rho Sv^2}{2}$$  \hspace{1cm} (1)

Where,
\[ C_p(\lambda, \beta) = 0.22 \left( \frac{116}{\lambda_1} - 0.4\beta - 5 \right) e^{-\frac{12.6}{\lambda_1}} \]  

(3)

\[ \frac{1}{\lambda_1} = \frac{1}{\lambda + 0.08\beta} \cdot \frac{0.035}{1 + \beta^2} \]  

(4)

So, the aerodynamic torque is expressed by:

\[ T_{\text{tur}} = \frac{P_{\text{tur}}}{\omega_{\text{tur}}} = C_p(\lambda, \beta) \cdot \frac{\rho S V^3}{2} \cdot \frac{1}{\omega_{\text{tur}}} \]  

(5)

The mechanical equation of the system is characterized as follow:

\[ \frac{df_{\text{mec}}}{dt} = T_{\text{mec}} - T_{\text{em}} - f_{\Omega_{\text{mec}}} \]  

(6)

Figure 2 shows the relation between the turbine power and rotor speed for different wind speed. We can deduce that there is one value which ensures maximum power captured from the wind for each wind speed value.

Fig. 2: Turbine power versus rotor speeds and wind speed

II.2 Modeling of the DFIG

The DFIG model is obtained in synchronous d-q reference frame where the d-axis is aligned with the stator flux vector position (Fig. 3). The influence of the stator resistance can be neglected and the grid is supposed stable with voltage \( v_s \) and synchronous angular frequency \( \omega_s \). Consequently [7]:

\[
\begin{align*}
V_{sd} &= \frac{d\varphi_{sd}}{dt} = 0 \\
V_{sq} &= \omega_s \varphi_{sd} = V_s
\end{align*}
\]  

(7)

Hence, the DFIG mathematical model can be written as follow:

\[
\begin{align*}
V_{sd} &= -\frac{R_s}{L_s} \varphi_{sd} - \frac{R_s}{L_s} i_{rd} \frac{d}{dt} \\
V_{sq} &= -\frac{R_s}{L_s} \varphi_{sq} + \omega_s \varphi_{sd} \\
V_{rd} &= R_r i_{rd} + \sigma \frac{L_s}{L_s} \frac{d}{dt} i_{rd} + e_{rd} \\
V_{rq} &= R_r i_{rq} + \sigma \frac{L_s}{L_s} \frac{d}{dt} i_{rq} + e_{rq} + e_{\varphi} \\
\varphi_{rd} &= \left( L_r - \frac{M^2}{L_s} \right) i_{rd} + \frac{v_s}{\omega_s L_s} \\
\varphi_{rq} &= \left( L_r - \frac{M^2}{L_s} \right) i_{rq}
\end{align*}
\]  

(8)

FIG. 3 Stator field oriented control technique

\[
\begin{align*}
P_s &= -\frac{V_s^2}{L_s} i_{rq} \\
Q_s &= -\frac{v_s^2}{\omega_s L_s} i_{rd} \\
P_r &= \frac{v_s^2}{L_s} i_{rd} \\
Q_r &= \frac{v_s^2}{L_s} i_{rq}
\end{align*}
\]  

(9)

With:

\[
\begin{align*}
e_{rd} &= -\sigma \frac{L_s}{L_s} \varphi_{rd} i_{rd} \\
e_{rq} &= \sigma \frac{L_s}{L_s} \varphi_{rd} i_{rd} \\
e_{\varphi} &= \omega_s \varphi_{sd} i_{rd} \\
\sigma &= 1 - \frac{M}{\sqrt{L_s L_r}}
\end{align*}
\]  

(10)

From equation (13), we can deduce that the active and reactive powers can reach decoupling control. The electromagnetic torque is as follows:

\[
T_{\text{em}} = -P_r \frac{M}{L_s} \varphi_{sd} i_{rq}
\]  

(13)

II.3 Modeling of three-phase PWM converter

The mathematic model of the converter can be expressed in matrix form with following equations [8]:

\[
\begin{bmatrix}
V_{sa} \\
V_{sb} \\
V_{sc}
\end{bmatrix} = R \begin{bmatrix}
\frac{d}{dt} i_a \\
\frac{d}{dt} i_b \\
\frac{d}{dt} i_c
\end{bmatrix} + \begin{bmatrix}
i_a \\
i_b \\
i_c
\end{bmatrix}
\]  

(14)

The voltages \( v_a \), \( v_b \) and \( v_c \) are defined as:
\[
\begin{align*}
\nu_a &= \frac{v_d}{3} (2S_a - S_b - S_c) \\
\nu_b &= \frac{v_d}{3} (-S_a + 2S_b - S_c) \\
\nu_c &= \frac{v_d}{3} (-S_a - S_b + 2S_c)
\end{align*}
\]

Where the switching states can be represented as:

\[
S_k = \begin{cases} 
+1 & \text{for } k = a, b, c. \\
-1 & \text{for } k = a, b, c.
\end{cases}
\]

The DC-link current can be written by the following relation:

\[
c \frac{dn_{dc}}{dt} = S_{d} i_d + S_{b} i_b + S_{c} i_c - S_{e} i_l
\]

III. DPC CONTROL STRATEGY

The aim is to directly control active and reactive power in a PWM rectifier. Indeed, the errors between the reference values of the instantaneous active and reactive powers and their measurements are introduced in two hysteresis comparators which determine, with the help of a switching table and the value of the sector where the mains voltage is located, the semiconductors switching state. The active and reactive powers are directly controlled by selecting the optimal switching state and with hysteresis controllers. Furthermore, the switching table principle is based on the position of the instantaneous active and reactive powers errors variations “\(\Delta p\)” and “\(\Delta q\)” and the position of mains voltage vector, where the reference of the instantaneous active power is achieved with the PI controller by regulating the DC-link voltage. In this section, direct power control scheme that uses multistage band hysteresis comparator and a switching table is proposed. The reference frame is divided into six sectors (6) as shown in Fig. 4, which the sectors can be numerically expressed as:

\[
\frac{\pi}{6} + (k - 1) \frac{\pi}{3} \leq \theta(k) \leq \frac{\pi}{6} + (k - 1) \frac{\pi}{3} \quad \text{Or, } k=1, 2, \ldots 6
\]

![Sector Diagram](image)

The errors between the reference and the actual power \(\Delta p\) and \(\Delta q\) were quantified into two levels “0” and “1” by a multistage band hysteresis comparator. The following algorithm describes two-stage hysteresis regulators for instantaneous active and reactive power. The DPC (see Fig.5) consists of selecting a control vector from a switch table. This last is based on the numerical errors \(S_p, S_q\) which are limited by a hysteresis band, as well as on the angular position of the voltage at the connection point of the load with the network. The plane (\(a, b\)) is divided into six sectors to determine the sector. The choice of the switching mode of the rectifier is realized so that the error between the reference value of the instantaneous active power, \(P_{ref}\), and the measured value of power, falls within the hysteresis band 2\(\Delta q\). In the same way, the reactive power error must remain in the hysteresis band 2\(\Delta q\). To achieve this objective, the instantaneous active and reactive power errors are processed by two two-level hysteresis comparators, whose outputs \((d_p, d_q)\) are set to 0 and 1 when the control variable \((p, q)\) has to be increased and to 0 when the control variable must remain unchanged or must decrease [9].

\[
\begin{align*}
-H_q &\leq \Delta q \leq H_q \quad \text{and} \quad \frac{\Delta q}{\Delta t} > 0, \quad S_q = 0 \\
-H_q &\leq \Delta q \leq H_q \quad \text{and} \quad \frac{\Delta q}{\Delta t} < 0, \quad S_q = 1 \\
\Delta q &< -H_q, \quad S_q = 0 \\
\Delta p &> H_q, \quad S_q = 1
\end{align*}
\]

\[
\begin{align*}
-H_p &\leq \Delta p \leq H_p \quad \text{and} \quad \frac{\Delta p}{\Delta t} > 0, \quad S_p = 0 \\
-H_p &\leq \Delta p \leq H_p \quad \text{and} \quad \frac{\Delta p}{\Delta t} < 0, \quad S_p = 1 \\
\Delta p &< -H_p, \quad S_p = 0 \\
\Delta p &> H_p, \quad S_p = 1
\end{align*}
\]

Where \(H_p\) and \(H_q\) are the hysteresis band of active and reactive powers comparators, respectively. Table I presents the signs variation of the instantaneous active and reactive power for each input voltage vector according to the sector \((j = 1, 6)\). By choosing the appropriate output vector, it is possible to select the active and reactive power variation signs independently. An analysis of the table shows that in some cases there are several possibilities of obtaining the same increment (the same signs of \(\Delta p\) and \(\Delta q\) are obtained by applying different vectors). In these cases, the choice of the voltage vector is that which causes the lowest power variation. Only four voltage vectors: \(v(k-1), v(k), v(k+1)\) and \(v(k+2)\) meet this criterion.

![Table](image)

<table>
<thead>
<tr>
<th>(\Delta p)</th>
<th>(\Delta q)</th>
<th>(c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>V(k)</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>V(k+1)</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>V(k-1)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>V(k+2)</td>
</tr>
</tbody>
</table>

The voltage vector used are: \(V_0(000), V_1(100), V_2(110), V_3(010), V_4(011), V_5(001), V_6(101), V_7(111)\), where only six vectors are activated. Binary number in the brackets shows switching states in the phase sequence a, b and c.
The obtained results are interpreted and criticized in the following section to highlight the performance of the proposed control.

IV. SIMULATION AND RESULTS

The global system simulation (source, load, rectifier) is performed under the Matlab / Simulink environment. The controlled reactive power is set to zero for unity power factor operation and active power delivered from the outer PI-DC voltage controller are compared with the estimated reactive and active values, respectively. The errors are DC quantities that are delivered to PI controllers that eliminate steady state error. The output signals from PI controllers are used for switching signals generation. In order to evaluate the performances and to validate the command, the results are shown in figure 6, 7, 8 and 9. First, Figures 6 and 7 show, respectively, the evolutions of the active and reactive powers and their references. We notice that they follow well their magnitudes of references. First, Figures 6 and 7 shows the voltages and currents of electrical network lines.
Figure 8 shows the reference voltage (Vref) and the continuous DC voltage (Vdc) at the output of the converter. This, for four voltages levels (600V, 800V, 900V and finally 1000V).

Figures 9 and 10 show, respectively, the evolutions of the active and reactive powers and their references. We notice that they follow well their magnitudes of references. Note that the tensions are clearly superposed. Finally, these representations confirm that the performances are good.

V. CONCLUSION

In this article, the direct power control structure has been proposed for the side converter (GSO). This will make it possible to take advantage of the two techniques. The results of global system simulation such as speed control, indirect active and reactive powers control, DC Link voltage control give very high performances.

REFERENCES


Application of Neural Networks in Perception System Management for an Indoor Mobile Robot

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Abstract— In the mobile robotics field, localization and map building are very important tasks that a mobile robot must perform for a safe navigation. The present paper presents a multi-layer perceptron (MLP) neural classifier of obstacles with coded outputs. This means that the number of the network outputs is lower than the number of the recognizable patterns. In this way, the neural network is less cumbersome; this will make easier the network parameterizing and resizing to be applied to other type of environment. The developed classifier ensures the discrimination of all possible patterns using a little number of elements in the training set. Subsequently the problem of training slowness is avoided.

Keywords— Mobile robot, perception, neural network, pattern recognition, laser range sensor

I. INTRODUCTION

The autonomy of a mobile robot reflects its ability to behave cleverly in an unexpected situation [1]. This can only be accomplished when the robot is fitted with means to gather the maximum of information about its current surrounding and a suitable tool to interpret them [2][3][4]. Even though a lot of work in this field has been done till now, the appearance of artificial intelligence has provided new tools which has persuaded the researchers to take back their work. The development of neural networks, which is one of the modern control methods, is essentially based on two objectives. The first objective is to develop computational methods that can perform reasoning and problem solving that require human skills. The second one is to explore an effective trade-off between precision and the cost in developing an approximate model of a complex system or function. One of several reasons of choosing modern method is their ability that allow a mobile robot to sense the environment in real-time and to act on the basis of the acquired data [3][6].

A mobile robot must be able to know its position in the environment in geometric coordinates [2]. This paper presents a simple method to design a pattern classifier with high performance. The interest of the developed system is that the robot can recognize the different situations encountered in an indoor environment such wall, passage, corner....

Neural networks are powerful tools to be used in pattern classification [7] and recognition [8] due to their:

- noise tolerance,
- training and generalization ability,
- real time processing.

The patterns recognition and classification system is illustrated in Fig. 1, it is built around a neural network.

A laser range telemeter is used as input device; its role is to provide measurements of the actual situation of the environment in order to create a relationship between perception and navigation [9]. In [8], a classical pattern classification approach is presented based on a MLP network where the number of the output neurons is equal to the number of recognizable patterns. It is to notice that the system is very complicated and the training data set is very important so the training time will be very large.

Our system (classifier) is based on the idea of coded outputs what allows him to avoid the problems reproaching much standard classifier neural network (MLP) such as the slowness of training [6][7]. Thus, our system is well adapted, has such problems what him a makes it possible to have good results compared to other approaches [2][4].

This paper is organized as follows: First we begin by explain the problem often met in robot mobile navigation, follows by simulation results and a general conclusion is given in the end.

Flow of information from the robot environment

Data acquisition

Neural network (MLP)

Obstacles classification

Mobile robot control

Environment

Fig. 1 Synoptic diagram of the designed system
II. OBSTACLE CLASSIFICATION IN MOBILE ROBOTICS

A mobile robot can meet several situations in an environment, Table 1. In this environment the robot must answer “I am in front of such a quite precise situation” thus it must solve the problem of confusion and overlapping between the various situations in its mission.

![Table 1](image)

III. CODED PATTERNS APPROACH

One the disadvantages of the use of the conventional MLP neural networks in classification; their training slowness especially when an important number of patterns has to be discriminated [2], [10]-[12]. Another inconvenience is the cumbersome of the network architecture. In order to circumvent this problem, coded patterns approach is used. In this approach, patterns are coded in the way to get less outputs and a smaller training set. With n coded outputs, the MLP can discriminate $2^n$ patterns [2][11][13].

![Diagram](image)

In this paper, a multi-layer perceptron with a several layers of hidden nodes are used, apart from the output layer. We will look at feed forward architectures where no feedback connection is available, Fig. 2 shows a generic 3-layer network with $N$ inputs, $N_h$ hidden nodes and $M$ output nodes.

Let’s consider $x = (x_0, x_1, x_2, \ldots, x_N)$, the input pattern with threshold, the values on the hidden nodes is:

$$h_j = \varphi_h(h_j) = \varphi_h(\sum_{k=0}^{N} w_{jk} x_k), \quad j = 1 \ldots N$$

(1)

Where, $\varphi_h$ is the activation function used in the hidden layer, and $h_0 = 1$ to introduce a threshold when calculating the output. The outputs $y_1, y_2, \ldots, y_M$ are given by:

$$y_i = \varphi_0(y_i)$$

(2)

$$y_i = \varphi_0\left[\sum_{j=1}^{N_h} w_{ij} \varphi_h(\sum_{k=0}^{N} w_{jk} x_k) + w_{i0}\right]$$

(3)

Where $\varphi_0$ is the activation function for the output layer?

Learning Algorithm

The training algorithm chosen for this type of problem is the RPROP because of that it is characterized by its speed and its best convergence towards a minimum of the quadratic error and it requires especially a very little place in memory.

RPROP is a technique of training based on the value of the differential $\frac{\partial E}{\partial w_{ij}}$, and to take only of its sign changes, the weights update is given by the following formula:

$$\Delta w_{ij} = -\text{sign}\left(\frac{\partial E}{\partial w_{ij}}\right) \Delta_{ij}$$

(4)

$\Delta_{ij}$: update-value: value of modification of the weight, evolves acting changes of differentials sign of this same weight. The weights are changed only after each time (batch learning). During one step (iteration), differentials obtained after each presentation are added the element of the training set.

$$\Delta_{ij}^{(t)} = n^{+} \Delta_{ij}^{(t-1)}, \quad \text{if} \quad \frac{\partial E}{\partial w_{ij}} \frac{\partial E}{\partial w_{ij}} > 0$$

$$\Delta_{ij}^{(t)} = n^{-} \Delta_{ij}^{(t-1)}, \quad \text{if} \quad \frac{\partial E}{\partial w_{ij}} \frac{\partial E}{\partial w_{ij}} < 0$$

$$\Delta_{ij}^{(t)} = \Delta_{ij}^{(t-1)}, \quad \text{else}$$

Where $0 < n^- < 1 < n^+$

$$\Delta w_{ij}^{(t)} = -\text{sign}\left(\frac{\partial E}{\partial w_{ij}}\right) \Delta_{ij}$$

(5)

If the differential changed sign compared to (t-1): at this time, we passed above a local minimum, and we returned to the preceding weight (backtracking):

$$\Delta w_{ij}^{(t)} = -\Delta w_{ij}^{(t-1)}, \quad \text{if} \quad \frac{\partial E}{\partial w_{ij}} \frac{\partial E}{\partial w_{ij}} < 0$$
IV. SIMULATION RESULTS

The data-gathering is performed by a simple perception system, which ensures this collection, built around a laser sensor. It is a turret placed in front of the mobile robot. Having a rotation of 180° to a prefixed step makes it possible to collect a well-defined whole of measurements, as shown in Fig. 3. These measurements give a satisfactory idea on a zone of manoeuvrability whose swept surface depends on the mobile robot and its nature of movement. For more clarity an example was selected in order to show the values resulting from the laser rangefinder and their correspondent in mode reduced for various useful zones from detection.

![Image](image_url)

Fig. 3 Sweeping of a sensor has rangefinder laser

A. Rate of Recognition

Once the neural networks involved (after training), it is necessary to test it on a different data base from those used for training. This test at the same time makes it possible to appreciate the performances of the neural system and to detect the type of data which pose problem. In the case, we tried to test the degree of identification of elements within the same class, which led to the results of Table 1. limited at the number of 5 patterns for the training and 5 others for generalization.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Rate of the situations recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Passage</td>
</tr>
<tr>
<td>Training</td>
<td>5</td>
</tr>
<tr>
<td>Generalization</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Piece</td>
</tr>
<tr>
<td>Training</td>
<td>5</td>
</tr>
<tr>
<td>Generalization</td>
<td>3</td>
</tr>
</tbody>
</table>

B. Resolution of Indecisions

What will the network answer in indecisions situations? A solution insists to include these situations of indecision in one of the classes between which the network hesitates [1]. If one wants to solve the majority of the conflicts the aspect passage is most common in the indicated in the conflict event.

C. Tests of Invariance by Deformation, Translation and Homothety

The network allows recognizing forms independently of transformations such as translation, homothety and deformation. For geometrical forms this invariance is checked rather well.

1) Deformation

In this test, the performance of the network is obtained by a deformation of the forms which constitute the base of training (disturbed forms) and thus the network can recognize the object of Fig. 5 to belong to the same class as the object of Fig. 4.

![Image](image_url)

Fig. 4 U shaped Impasse (during the training)

![Image](image_url)

Fig. 5 Form recognized like impasse (during the validation)
2) Translation

In this case, the performance of the network is checked by testing the recognition during displacement of the sensor (mobile robot) with respect to the obstacle. Thus, the network can recognize the object of Fig. 7 to belong to the same class as the object of Fig. 6 for various distances separating the robot from the obstacle. It is to be noticed here that the obstacle always remains inside the critical zone of pattern recognition.

![Fig. 6 T-crossing Form (during the training)](image)

![Fig. 7 T-crossing Recognition after sensor translation](image)

3) Homothety

The performance of the network is tested by the multiplication of obstacles dimensions by factors called homothety factors. The factors retained for the tests are: 0.8, 0.9, 1.1 and 1.2 corresponding respectively to a contracting and an enlargement of the obstacles. Table 3 shows the rate of recognition of various forms for 5 values of homothety factor. Five values for the factor of homothety were selected to show the different cases of enlargement and contracting of the obstacles.

The results in Table 3 show very interesting rates of recognition. It is noticed that the developed neural network, reacts well during the multiplication by homothety factors which simulates changes in obstacle dimensions.

<table>
<thead>
<tr>
<th>factor of homothety</th>
<th>passage</th>
<th>wall</th>
<th>Impasse</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>0.9</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>1</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>1.1</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>1.2</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

D. Confusion Matrix

In the confusion matrix, different situation of conflict and overlapping are shown.

<table>
<thead>
<tr>
<th>Confusion Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>passage</td>
</tr>
<tr>
<td>----------</td>
</tr>
<tr>
<td>Passage</td>
</tr>
<tr>
<td>Impasse</td>
</tr>
<tr>
<td>Input</td>
</tr>
<tr>
<td>Piece</td>
</tr>
<tr>
<td>Crossing</td>
</tr>
<tr>
<td>T- Crossing</td>
</tr>
<tr>
<td>Wall</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>crossing</th>
<th>T- Crossing</th>
<th>Wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing</td>
<td>86.67%</td>
<td>13.33%</td>
</tr>
<tr>
<td>T- Crossing</td>
<td>6.66%</td>
<td>93.34%</td>
</tr>
<tr>
<td>Wall</td>
<td>0%</td>
<td>6.66%</td>
</tr>
</tbody>
</table>
V. CONCLUSION

This study enters within the general framework of classification. We chose to implement a neural network classifier with coded outputs because that it is well adapted with this type of problem, of which gives good results, for the classification operation, we tried to maintain the suggested structure the simplest as possible. Indeed, instead of reserving by each class an exit of the network what increases considerably the number of neurons in the output layer we limited to this level the number of neurons with 4 which can decode 16 possible forms. Thus, the conceived network could discriminate a significant number of forms all while maintaining a structure simple. The results obtained show, that with a restricted number of the shapes of obstacles at the time of the training, a good classification during tests of generalization. However, the principal function of a mobile robot is to achieve its goal, it is thus necessary to integrate this module in a control to make it possible to generate the adequate order for the skirting of the obstacle following its form. We estimate that this work is used to look further into the general information of the neuronal approach in the applications of classification.

REFERENCES


Study of the variation of refractive index for different organic liquids of an optical channel drop filter on a 2D photonic crystal ring resonator

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Abstract — in this work, a study of the variation of refractive index for different organic liquids of an optical channel drop filter (CDFs) based on 2D photonic crystal ring resonators (PCRRs) is presented. The structure is composed of dielectric rods immersed in air. We set square-fold quasi crystal at the middle of 3X3 square cavity for creating a ring resonator structure and designed an optical channel drop filter by using a finite element method (FEM). At $\lambda=1550$nm, an important wavelength for optical communication systems, the numerical results show the propagation and transmission for different refractive index of water, silicone oil and carbon disulfide: 1.333, 1.52045 and 1.628 respectively. As follows, the dielectric rods ($r$), the radius ($r$) of the rods and the lattice constant ($a$) are three important parameters. At this work we focus our study on the refractive index variation and we fix the radius ‘$r$’ of the rods at 118.37 nm and the lattice constant ‘$a$’ to 623 nm.

Keywords — Photonic crystals, Channel drop filter, ring resonators, FEM.

I. INTRODUCTION

Photonic crystals (Phcs) are defined as periodicity structures having a refractive index that are modulated with a wavelength —scale periodicity in one to three dimensions [1]. Phcs have a special frequency (wavelength) range in which the propagation of optical waves inside these artificial structures is forbidden. This special range is called the photonic band gap [2]. The PBG effect has been adapted to develop many optical devices such as: power splitters [3], optical reflectors [4]. A lot of structures channel drop filters based on 2D Phcs have been designed like Pc ring resonators (PCRRs) [5]. We remove some rods or holes inside the Pc structure in order to have a ring shape.

Not long ago, several researches were based on CDF ring resonator of square and triangular lattices as: David and Abrihshamian who work on a multichannel —drop filter with PhcRR by using two different refractive indexes in the 2D—PC with square lattice [6]. Other authors like Mehdizadeh et al studied the effect of several parameters such as refractive index of dielectric rods and so on…which are important parameters for tuning the filter [7].

This article will investigate a variation of refractive index for different organic liquids of an optical channel CDF based on new configuration of 2D photonic crystal ring resonator by using finite element method (FEM).

II. DESIGN PROCEDURE

A lot of methods have been proposed for studying, analyzing, and extracting the proprieties of PC devices. We used COMSOL software that is based on finite element method to investigate the band gap characteristics of 2D crystal photonic composed of square lattice of rods embedded in air which is verified by plane wave expansion method (PWE). The results are very reliable, proving that COMSOL® can be used for the full characterization of the structures.

In this work, we took a two dimensional photonic crystal composed of square lattice of rods in an air background with lattice constant $a=0.623\mu m$. The effective refractive index of the rods is taken to be 2.838 and for the air background $n=1$. The radius of rods of perfect PC (with no defects) is $r=0.19a$.

Firstly and before designing the filter, we should define the PBG region. By using Eigen-value, the band diagram of the PC is calculated and depicted in Fig 2.

In this paper, we investigated the photonic band structure, propagation and transmission calculations of 2D photonic by using finite element method (FEM). F.E.M method is a very reliable and effective numerical approach for modelling and simulating a large range of problems in physics, in particular for complex structures. Moreover, it is possible to resolve and express wave propagation in the same way of the dispersion diagram of photonic crystal structures [8-10]. We put into operation for our calculations commercial software COMSOL based on finite element method [11].

First, we considered photonic crystals composing of dielectric rods in air arranged by lattice arrays. By solving Maxwell’s Equations, we studied electromagnetic wave propagation in a photonic crystal structure [12].
Fig. 1 Direct lattice, reciprocal lattice and Brillouin zone including symmetry points of the most common lattices in dimension: square lattice. The high symmetry points of the first Brillouin zone are shown (Γ, X, M).

Fig.1 show the direct lattice, reciprocal lattice and Brillouin zone of in gray areas, indicating the high symmetry points

Filter design

Firstly and before designing the filter, we should solve eigenvalue calculations for band structures of the 2D dielectric photonic crystals in order to design our proposed structure which is 33X20 square lattice of dielectric rods immersed in air. The FEM calculation is applied for the dispersion relation of square lattice pattern for TE and TM polarizations. The studied geometry is two-dimensional PC cylindrical dielectric (silicon) rods in square lattice in air background. The effective refractive index 2.38 and the radius of dielectric rods is r=0.19a embedded in air (ε=1) as shown schematically in Fig.1, where “a” is the lattice constant of the Phc structure. The rods from a square lattice array with lattice spacing (a=623nm). Light propagation is considered in the xy plane of the square lattice structure. The band structure diagram of the Phc with aforementioned values is depicted in Fig.2. In the next section our simulations are adapted to the proposed structure of a channel drop filter based on 2D photonic crystal ring resonator.

From the figure above, we notice that our structure displays three PBGs. The First two PBGs in TM mode and one PBG in TE mode. The TM PBGs are in 0.32 < a/λ < 0.44 and 0.77 < a/λ < 0.78 range and the TE PBGs is in 0.85 < a/λ < 0.86 range. Only the first PBG in TM mode is large enough for covering the sufficient wavelengths for optical communication applications. We choose the lattice constant a= 623nm in order to have maximum compatibility with optical communication ranges. Then, the suitable PBG of our initial Phc structure will be in 1415nm < λ < 1946nm range in TM mode.

The next step consists in realizing the proposed filter in a fundamental platform, by removing a complete row of dielectric rods in the Γ-M direction to create the bus waveguide and then, by removing some rods in the M-X direction we created the output waveguide. After that is creating resonant ring between bus waveguide and the output waveguide, first we removed from a 7X7 array of dielectric rods at the appropriate place some rods for creating a square form. This square shape is created by 9-fold quasi crystal which is quasi-periodic structure and composed of one central air pore as core rod. The radius of the square form is the same as the radius of all other rods in the initial Phc structure. The final schematic diagram of the proposed filter is depicted in Fig.3.
Similar to any other PCRR-based CDF, our proposed filter has 3 ports: The input port in the left side of the top (bus) waveguide is marked as port (1) whereas the output waveguide is marked as port (2) and called as the forward transmission terminal. The port (3) of waveguide is denoted as forward dropping. Optical waves enter the structure through port (1) and exit it from port (2), however at the desired wavelength the optical wavelengths drop to drop waveguide through the resonant ring and travel toward port (3). Square shape have similar radius and effective refractive index ($n_r=2.838$) as the initial structure. Moreover, as depicted in Fig. 3. The refractive index of the frame surrounding the square resonator has been changed for different organic liquids such as water, silicone oil and carbon disulfide. The refractive index rods changed are labelled with blue circle as shown in fig4.
Fig. 6. The propagation of the field distribution of the proposed CDF for different refractive index of (a) Water, Silicone oil (b) and Carbon disulfide (c) respectively at $\lambda = 1550$nm.

Fig. 7. The output spectrum of the proposed CDF for water (d), Silicone oil (e) and carbon disulfide (f).
III. SIMULATION AND RESULTS

Numerical simulations were performed using Finite Element Method (FEM) COMSOL Multiphysics software [13]. We use the RF module to solve 2D model Maxwell’s equations for optical field distribution and other optical properties of PhCs. In this paper, the method is used to investigate the influence of refractive index of different organic liquids of water, silicone oil and carbon disulfide respectively. The Finite element method (FEM) by COMSOL Multiphysics [14] was employed to simulate the transmission and the propagation (distribution of electromagnetic field) in photonic crystals structures and versus wavelength.

Finite Element Method (FEM), simulations:

This section is devoted to calculate the transmission spectra and distribution of magnetic field of 2D-photonic crystals square lattice of dielectric rods of Si ($n_s = 2.838$)/air. COMSOL Multiphysics considers the plane (xz) as the plane of propagation of the electromagnetic wave. The TE mode (where H located in the planes (xz)) or TM mode is in the plane (xy). The transmission spectrum of magnetic field is shown in Fg.7 for wavelength range from 1.53μm to 1.57μm. This frequency range is associated with the PBGs (calculated by the FWE method in the first section). The transmission spectrum of the filter is shown in Fg.7. In this figure the normalized transmission of the structure at port (2) and (3) are depicted with green and red curves.

From Figure 7, the transmission efficiency for the three indices of refraction, water, silicone oil and carbon disulfide will pass through maximum, for the case of water we see that the transfer of energy from port 1 to port 3 reaches a transmission efficiency maximum of 0.5552 for a wavelength at 1.539 μm, as well as for the case of silicone oil which reaches a transmission efficiency maximum of 0.9613 for a wavelength of 1.539 μm and for the disulfide of carbon which completes a transmission efficiency maximum of 0.951 for the telecommunication wavelength $\lambda = 1.55 \mu m$.

Therefore, carbon disulphide is the best refractive index for the transfer of the signal from port 1 to port 3 (see fig.7 (d)) where the resonance is maximum for the telecommunication wavelength $\lambda = 1.55 \mu m$. ratio to the water whose maximum signal will be transferred to the port 2 (fig.7 (c)) for a wavelength $\lambda = 1.539 \mu m$ and for the silicone oil the maximum of the signal towards the port 3 but a length of wave $\lambda = 1.539 \mu m$ (fig.7 (f)) which suffers losses for a max of 88 as well as for silicone oil which reaches a max for a wavelength of 1.54 μm.

IV. CONCLUSION

In summary, a new structure for designing CDF based on PhCRR. 2D-FEM (Finite element method) was used to analyze the proposed structure. The results of our simulations by using COMSOL Multiphysics provide the different behavior of the signal compared to the organic liquids used. The results obtained from simulation show that the resonant wavelength of filter depends on refractive index. Such structures have the abilities to be used as nano-materials for bio-sensing.

ACKNOWLEDGMENT

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REFERENCES

Sliding Mode Control For PV-Wind Hybrid System Connected to Grid

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Abstract—This work focuses on the development of a nonlinear Sliding Mode Controller (SMC) for photovoltaic-wind hybrid energy system connected to electrical grid. Several benefits are offered by this method such as robustness against a parameter variation, minimum output current distortion and excellent reference tracking. The maximum power extracted from wind turbine and PV array is fed to utility grid via a three phase inverter interface by maintaining constant DC-link voltage. Simulation results under Psm environment show a fast dynamic behavior of hybrid system with minimal errors, accuracy and usefulness of the considered control strategy.

Keywords—SMC; hybrid system; MPPT; grid; Wind/PV

I. INTRODUCTION

Applications with ecological and renewable resources such as wind and photovoltaic energies have become the major promising technologies. They have been improved significantly in the last decades due to the high petroleum prices, the harmful effects caused by conventional sources on the planet and increasing energy demand [1]. Particularly, photovoltaic and wind generation systems have enhanced their employment in hybrid configurations. The considered combination is one of the most efficient key used as a grid-connected energy systems or an isolated load to supply power. At present, many investigations have been carried out on the PV-Wind hybrid system techniques. The most traditionally strategies based on linear controllers were presented by (Bariša et al, 2015),[2] showing that the Field Oriented Control (FOC) is separately controls the electromagnetic torque and the magnetic flux. Another study given by [3], have focused on power Voltage Oriented Control (VOC) due to its simple structures. One of the most remarkable drawbacks is their highly dependence on machine parameter variations. Another control techniques mentioned by some authors are based on non-linear hysteresis control such as Direct Power Control (DPC) [4] and Direct Torque Control (DTC)[5]. The switching frequency variation is the main drawbacks of these methods which cause the grid current distortions.

In this context, this paper aims to analyse a connected grid hybrid system behavior under different climatic conditions. This study is organized as follows; the PV-Wind system structure and its components modeling are introduced in the first section. Then MPPT method and Sliding Mode Controller (SMC) design for back to back converter are detailed. Simulation results and discussions are presented in the last section in order to evaluate the proposed photovoltaic-wind system configuration performances.

II. PV-WIND SYSTEM CONFIGURATION

The proposed PV-Wind hybrid power system is described by Fig 1. it is composed of two parallel conversion chains. The first one consists of the photovoltaic power system which includes a PV module as energy source and DC/DC converter using a boost chopper. The wind energy conversion system presents the second chain that is equipped with its variable speed wind turbine coupled to Permanent Magnet Synchronous Generator (PMSG) and a three phase rectifier. The hybrid system is connected to grid via DC/AC inverter linked to RL filter to eliminate the current harmonics. The mathematical models of each block are introduced in the following subsections.

![Fig. 1: Photovoltaic-wind hybrid system](image-url)
A. Photovoltaic chain modeling

The photovoltaic cells are characterized by the non-linear curves. These curves are determined as the most important.

These curves are determined by the important parameters given by the cell manufacturer. The maximum power point is the nominal operating point for which the PV module can deliver the maximum power. P&O and Incremental Conductance (INC) algorithm are the most commonly used MPPT methods [6]; P&O algorithm is widely used due to its easy implementation. However Incremental Conductance (INC) strategy can precisely track the maximum power point, with a faster dynamic response under rapidly weather conditions changing. Fig. 2 shows MPPT controller based on Incremental Conductance (Inc.Cond) algorithm which is used in the PV system to force the DC/DC converter circuit to track the maximum power for different solar irradiances.

![Fig. 2: Photovoltaic module characteristics](image)

B. Wind energy chain modeling

1) Wind turbine model

The mechanical power produced by the wind turbine can be calculated by the following equation:

\[
P_m = \frac{1}{2} \rho \cdot \pi \cdot R_t^2 \cdot C_p(\lambda, \beta) \cdot V_w^3
\]

Where \( \rho \) is the air specific density (kg/m3), \( R_t \) is the wind turbine rotor radius (m), \( V_w \) is the wind speed (m/s), \( C_p(\lambda, \beta) \) is the turbine power coefficient, \( \beta \) is the blade pitch angle and \( \lambda \) is the tip-speed ratio which is expressed as [7]:

\[
\lambda = \frac{\Omega_v \cdot R_t}{V_w}
\]

where \( \Omega_v \) is the rotor angular speed (rad/s). Many power coefficient approximations are mentioned in literature; among these forms we choose this expression.

\[
C_p(\lambda, \beta) = c_1 \left( \frac{c_2}{\lambda} - c_3 \cdot \beta - c_4 \right) \cdot e^{\frac{-c_5}{\lambda}} + c_6 \cdot \lambda
\]

with

\[
\frac{1}{\lambda} = \frac{1}{\lambda_0} + \frac{0.035}{\beta^3 + 1}
\]

The coefficients are: \( c_1 = 0.5176 \), \( c_2 = 116 \), \( c_3 = 0.3 \), \( c_4 = 5 \), \( c_5 = 21 \) and \( c_6 = 0.0068 \).

The mechanical torque \( (T_m) \) expression can be developed as given in the Equation (5).

\[
T_m = \frac{\rho_s \cdot V_s^3}{2} \cdot \frac{1}{\Omega_v}
\]

Permanent Magnet Synchronous Generator (PMSG)

The electrical model of the PMSG in a (d, q) reference frame, is written by the following equations [8]

\[
\begin{align*}
\frac{di_{ds}}{dt} &= -\frac{R_s}{L_d} \cdot i_{ds} + \frac{u_{ds}}{L_d} \cdot i_{qs} + \frac{V_{ds}}{L_d} \\
\frac{di_{qs}}{dt} &= -\frac{R_s}{L_q} \cdot i_{qs} - \frac{u_{qs}}{L_q} \cdot i_{ds} - \frac{\omega_{eq} \cdot \Phi_e}{L_i} + \frac{V_{qs}}{L_q} \\
\frac{d\Omega_r}{dt} &= \frac{C_m}{J} - \frac{T_{em}}{J} - \frac{f}{J} \Omega_r
\end{align*}
\]

where \( V_{ds} \) and \( V_{qs} \) are, respectively, the d-axis and q-axis stator voltage (V), \( i_{ds} \), \( i_{qs} \) are the d-axis and q-axis stator current(A), \( R_s \) is the resistance of stator windings (Ω), \( L_d, L_q \) are the inductance of stator windings (mH), \( \omega_{eq} \) is the permanent magnetic flux (wb), \( \phi_e \) electrical pulsation (rad/s) and \( p \) is the number of pole pairs of the PMSG.

The active and reactive powers are given by:

\[
\begin{align*}
P &= \frac{3}{2} (V_{ds} \cdot i_{ds} + V_{qs} \cdot i_{qs}) \\
Q &= \frac{3}{2} (V_{qs} \cdot i_{ds} - V_{ds} \cdot i_{qs})
\end{align*}
\]

The mechanical equation is expressed as follows:

\[
T_m - T_{em} = J \cdot \frac{d\Omega_r}{dt} + f \cdot \Omega_r
\]

The PMSG electromagnetic torque can be expressed using the following equation:

\[
T_{em} = \frac{3}{2} \cdot p \cdot \Phi_e \cdot i_{qs}
\]

In order to deliver the entire electrical power to the grid, a back-to-back converter are controlled using the sliding mode strategy. For that, two sliding mode are required and detailed in the next section: one to the AC/DC Rectifier and one to the DC/AC inverter.

III. SLIDING MODE CONTROLLER METHOD

The sliding mode controller design is mainly involved three steps. The appropriate sliding mode surfaces choice is done in the first step. The general equation used to choose these sliding surfaces is proposed by [9] [10]:

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\[ S(X) = \frac{dX}{dt} + \lambda^{-1} (X^d - X) \quad (10) \]

Where: \( X \): state variable of the control signal; \( \lambda \): positive constant; \( r \): the system degree; \( X^d \): the desired signal.

In order to ensure the convergence towards the sliding surface trajectory, the convergence condition based on Lyapunov equation is defined in the second step.

\[ S(X)S(\dot{X}) < 0 \quad (11) \]

Finally, the control signal calculation is expressed by the following relation:

\[ U = U_{eq} + U_s \quad (12) \]

where \( U_{eq} \) is the equivalent control and \( U_s \) is the switching control term.

A. SMC For AC/DC Rectifier

The three phase rectifier used in the wind energy conversion chain is controlled by a sliding mode method in order to obtain the maximum wind power according to variable weather conditions. To achieve these objectives; two control loops are presented in Fig 3: external speed control loop and inner current control loop. Among the different used modern strategies, SMC is intended for non-linear systems since it has robust characteristics against uncertain system parameter and external disturbances.

![Fig 3. Generator Side Converter Control](image)

1) External speed control loop

The surface \( S(\Omega_e) \) is chosen as:

\[ S(\Omega_e) = \Omega_{r,ref} - \Omega_e \quad (13) \]

\( \Omega_{r,ref} \) is the reference value of generator speed.

During the steady state, the surface \( S(\Omega_e) \) is equal to zero as is its derivative:

\[ S(\dot{\Omega}_e) = \dot{\Omega}_{r,ref} - \dot{\Omega}_e \quad (14) \]

\[ S(\dot{\Omega}_e) = \frac{C_m}{J} + \frac{C_m}{J} + \frac{p}{J} \Omega_e \quad (15) \]

So, the quadrature stator current reference is defined by:

\[ i_{qs,ref} = i_{qs,eq} + i_{qs,n} \quad (16) \]

the equivalent control \( i_{qs,eq} \) is expressed as follows

\[ i_{qs,eq} = \frac{2}{3} \frac{1}{p} \frac{\Omega_{r,ref} - \Omega_{n} - \Omega_{r}}{\tau_{qs} \left( i_{qs} - i_{qs,ref} \right)} \quad (17) \]

the switching control is written as:

\[ i_{qs,n} = -K_i \text{sign}(S(\Omega_e)) \quad (18) \]

2) Inner current control loop

Two sliding surfaces are required to control d- and q- axis stator current components:

\[
\begin{align*}
\begin{cases}
S(i_{ds}) = i_{ds,ref} - i_{ds} \\
S(i_{qs}) = i_{qs,ref} - i_{qs}
\end{cases}
\end{align*}
\]

(19)

where \( i_{ds,ref} \) and \( i_{qs,ref} \) are the stator current references.

The sliding surfaces and their derivatives should validate the following conditions:

\[ S(i_{ds})S(i_{ds}) < 0 \quad (20) \]

\[ S(i_{qs})S(i_{qs}) < 0 \]

The derivative of these surfaces are given by:

\[
\begin{align*}
\begin{cases}
S(i_{ds})' &= \frac{R_s}{L_{ds}} i_{ds} - \frac{1}{L_{ds}} i_{qs} - \frac{1}{L_{ds}} \frac{V_{ds}}{L_{ds}} \\
S(i_{qs})' &= \frac{R_s}{L_{qs}} i_{qs} + \frac{1}{L_{qs}} i_{ds} + \frac{1}{L_{qs}} \frac{V_{qs}}{L_{qs}}
\end{cases}
\end{align*}
\]

(21)

Therefore, the d-axis controlled voltage is defined by the continuous and the discontinuous components voltage:

\[ V_{ds,ref} = V_{ds,eq} + V_{ds,n} \quad (22) \]
During the steady state, the surface $S(i_{dq})$ is equal to zero, as well as its derivative, which leads to the expression of the equivalent command $V_{ds\_eq}$ is given by:

$$V_{ds\_eq} = R_s \cdot i_{ds} - p \cdot \Omega_s \cdot i_{q} + i_{ds} \tag{23}$$

and

$$V_{ds\_n} = K_{ds} \cdot \text{sign}(S(i_{ds})) \; ; \; K_{ds} > 0 \tag{24}$$

the d-axis controlled voltage is defined by:

$$V_{qs\_ref} = V_{qs\_eq} + V_{qs\_n} \tag{25}$$

Where

$$V_{qs\_eq} = R_s \cdot i_{qs} - p \cdot \Omega_s \cdot i_{q} + p \cdot \Omega_s \cdot i_{d} + \phi_f \tag{26}$$

and

$$V_{qs\_n} = K_{qs} \cdot \text{sign}(S(i_{qs})) \; ; \; K_{qs} > 0 \tag{27}$$

B. SMC For DC/AC Inverter

The proposed control scheme of the grid connected inverter consists of three parts. Fig. 4. Adjusting the DC-link voltage is the first part which is usually focused on the DC-link voltage control ($V_{dc}$) by using PI regulator in order to generate the reference value of d-axis current. The second one is intended to regulate the grid currents by using sliding mode controller (SMC). The grid synchronisation method is the last part adopted to synchronize between the grid-interfacing inverter and the electrical grid. It is based on PLL (Phase Locked Loop) technique.

![Grid Side Converter Control](image)

**Fig.4: Grid Side Converter Control**

1) DC link voltage loop

The external DC-link voltage loop is based on PI controller;

the DC bus voltage $V_{dc}$ is written as:

$$V_{dc} = \frac{1}{C_{p}} \cdot i_{c} = \frac{1}{C_{p}} (i_{rc} - i_{mv}) \tag{28}$$

The transfer current of DC-link voltage control loop is expressed as:

$$\frac{V_{dc}}{V_{dc\_ref}} = \frac{k_p}{C} p + \frac{k_i}{C} \; \frac{p}{p^2 + \frac{k_p}{C} p + \frac{k_i}{C}} \tag{29}$$

The PI controller parameters $k_p$ and $k_i$ are tuned as follows by imposing the natural oscillations frequency $\omega_n$ and damping ratio $\xi$ values.

$$\begin{cases}
    k_p = 2 \zeta \omega_n \\
    k_i = \zeta \omega_n^2
\end{cases} \tag{30}$$

2) DC link voltage loop

Two switching surfaces are chosen $S(i_{dq})$ and $S(i_{qs})$ in order to regulate d-axis and q-axis grid current components.

$$\begin{cases}
    S(i_{dq}) = i_{dq\_ref} - i_{dq} \\
    S(i_{qs}) = i_{qs\_ref} - i_{qs}
\end{cases} \tag{31}$$

Where $i_{dq}, \ i_{qs}$ are the desired current values of d and q axis;

The current references $i_{dq\_ref}$ and $i_{qs\_ref}$ are maintained constants. Therefore, the sliding surfaces derivatives can be written as follows:

$$\begin{cases}
    S(i_{dq}) = i_{dq\_ref} - i_{dq} = -i_{dq} \cdot \frac{1}{L_s} (v_{dq} + R_i i_{dq} - \Omega_l e_{dq} - e_{dq}) \\
    S(i_{qs}) = i_{qs\_ref} - i_{qs} = -i_{qs} \cdot \frac{1}{L_s} (v_{dq} + \Omega_l e_{dq} - e_{dq})
\end{cases} \tag{32}$$

The sliding surfaces and their derivatives should validate the following conditions:

$$S(i_{dq}) S(i_{dq}) = 0 \tag{33}$$

Therefore, the d-axis controlled voltage is defined by:

$$v_{dq\_ref} = v_{dq\_eq} + v_{dq\_n} \tag{34}$$

with

$$\begin{cases}
    v_{dq\_eq} = v_{dq} + R_i i_{dq} - \Omega_l e_{dq} \\
    v_{dq\_n} = k_{dq} \text{sgn}(S(i_{dq})) \; ; \; k_{dq} > 0
\end{cases} \tag{35}$$

the q-axis controlled voltage is defined by

$$v_{qs\_ref} = v_{qs\_eq} + v_{qs\_n} \tag{36}$$

with
\[
\begin{align*}
V_{\text{eq}} &= R_i I_{\text{eq}} + \omega_0 I_{\text{eq}} \\
V_{\text{eq}, n} &= k_{\text{eq}} \text{sgn}(i_{\text{eq}}); q > 0
\end{align*}
\]

(37)

IV. SIMULATION RESULTS

As a perspective to test the effectiveness of the proposed sliding mode controller to the PV-wind hybrid system, many simulations were carried out using PSIM Software using the system parameters listed in Table I.

<table>
<thead>
<tr>
<th>TABLE I: Parameters of PV module and wind turbine</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum Power Point [Pmpp]</td>
<td>200W</td>
</tr>
<tr>
<td>Maximum Power Point Voltage [Vmpp]</td>
<td>26.3V</td>
</tr>
<tr>
<td>Maximum Power Point Current [Impp]</td>
<td>7.61A</td>
</tr>
<tr>
<td>Open Circuit Voltage [Voc]</td>
<td>32.9V</td>
</tr>
<tr>
<td>Short Circuit Current [Isc]</td>
<td>8.21A</td>
</tr>
<tr>
<td>Rated turbine Power</td>
<td>19 KW</td>
</tr>
<tr>
<td>Rated Wind Speed</td>
<td>10m/s</td>
</tr>
<tr>
<td>Air Density</td>
<td>1.22 kg/m³</td>
</tr>
</tbody>
</table>

Case 1: The Photovoltaic system response

The proposed photovoltaic system configuration consists of 36 PV modules distributed as ten modules in series and three arrangements in parallel. The simulation of this photovoltaic chain performances is based on solar condition level variations when the temperature T is kept constant at 25°C as shown in Fig.5. At t=1 sec irradiation level is increased from 700 to 1000 W/m² and decreased from 1000 W/m² to 400 W/m² at t=2sec. Fig.5 (b-c-d) illustrates, respectively, the output PV power, current and voltage behaviors when facing the solar radiation changes. It can be seen that the PV array is able to deliver a maximum power of 18.8 kW at 1000 W/m². The power generated using Inc.Cond MPPT Controller is followed the optimal power with a good accuracy. It can be shown also that the \( V_{\text{pv}} \) array voltage is about 460 V. However the maximum output current \( I_{\text{pv}} \) is highly dependent on solar irradiance variation.

Case 2: The Wind system response

The wind speed is dropped from 10 m/s to 6m/s at t=1.5sec and is increased from 6 m/s to 8 m/s at t=2.5s as shown in Fig.6 (a). An excellent PMSG rotor speed tracking to the reference speed is depicted in Fig.6 (b). The rotational speed \( \Omega_{\text{rpm}} \) is well monitored and controlled according to the captured wind velocity with a rapid dynamic performance. It is illustrated also that the generator torque \( T_m \) can follow proportionally the abrupt wind speed variations as shown in Fig.6 (c). The MPPT block is able to calculate the actual optimal rotation speed and generate the maximum power \( P_{\text{turbine}} \) equal to 18.5kW shown in Fig. 6.

Case 3: The grid side inverter response

The PV array and the wind turbine sources provide together the active power \( P_{\text{active}} \approx 37.3 \text{ kW} \) injected by three phase inverter into the grid as shown in Fig.7. It is clear that the active power is highly related to the different solar irradiance and wind speed profile variations. However the delivered reactive power \( Q_{\text{reactive}} \) is fixed at zero to keep the unity power factor. The DC-link voltage is maintained constant at 700 V over the time period of 3.5 sec; it follows correctly its reference value (Fig.8). The injected current \( i_{\text{eq}} \) should be in phase with the grid voltage \( V_{\text{eq}} \) proving unity power factor transmission as shown in Fig.9 and finally the grid currents have a sinusoidal waveforms with a constant grid frequency value equal to 50 Hz thereby confirming the usefulness of the established SMC controller (Fig.10).

The simulation results reveal that the developed SMC method under divers operating weather conditions present an excellent dynamic response and very good steady state performances.
IV. CONCLUSION

The proposed hybrid system has been tested using sliding mode controller for different weather cases by evaluating the following performances: the maximum power is extracted from renewable energy sources, the DC-link voltage is maintained at constant level, the reactive power injected to the grid is set at zero in order to achieve the unity power factor condition. All results shown, verify the usefulness of the proposed PV-Wind hybrid system techniques.

References


[5] Z. Zhang; R. Kennel; C. Hackl, two direct torque and power control methods for back-to-back power converter PMSG wind turbine systems, 8th International Power Electronics and Motion Control Conference (IPEMC-ECCE Asia), 2016.


Tracking Control of Wheeled Mobile Robot through Neural Networks

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Abstract—The problem addressed in this article, constituted the intersection of the domains of the mobile robotics and the artificial neural networks (ANNs). The navigation of a mobile robot is one of the key problems in the robotics community. A control architecture based on ANN is developed in the context of the control of a mobile robot (car type). In this work, we are interested in two approaches to ensure a tracking reference trajectory, issued by a planner. The first is an inverse model approach, concerning the second approach is a neural PD controller with adaptive coefficients, learning is done online. Numerical simulation show that the proposed controllers ensure good path tracking.

Keywords—Kinematic artificial neural network, tracking trajectory, neural PD controller, adaptive coefficients, wheeled mobile robot

I. INTRODUCTION

The techniques based on the use of artificial neural networks arouse today is growing interest in the areas of control and robotics. Processing speed, learning and adaptive capacities, but also the robustness of these approaches largely motivate many studies in the area command mobile robots [1], [2], [3]. The networks of artificial neurons are mainly procedures allowing to approach any linear function or not [4], [5]. It is this property which motivates their use for the realization of nonlinear systems of command by learning. The conception of the organ of command is preceded by a phase of modeling of the process [1], [6], [7]. The central problem in this paper is control of nonholonomic wheeled mobile robot. In this context may be mentioned the works of Barraquand and Latombe, Divelbiss and Wen, Li and Gurvits, Jacob and al., Laumond, Laumond and al. Mirtich and Canny and Sahai. In (Tanner and Kyriakopoulos, 2003) a combined kinematic/torque controller law is developed using backstepping algorithm. (Tanner and Kyriakopoulos, 2003) solve the problem of mobile robot stability using nonlinear backstepping algorithm, (Oriollo and al., 2002) with the known functions and (Fierro and Lewis, 1997) with constant parameters [8], [9].

This paper is organized as follows: Section 2 provides the kinematic model of the mobile robot of unicycle-type. The first approach, inverse model, is investigated in Section 3. In Section 4, the neural PD controller with adaptive coefficients is presented. Finally, Section 5 concludes the paper.

II. ROBOT MODEL

We restrict ourselves with the unicycle type wheeled mobile robot. We appoint by the latter, a robot actuated by two motorized independent wheels, its structure is illustrated in Fig. 1. [9], [10], [11]. Immediate Center of Rotation (ICR): wheels having the same axis of rotation, the ICR is a point on this axis, as showing in Fig. 2. Where $v$ is the velocity of the center of surface of robot, $v_l$ and $v_r$ are the velocities of the left and right wheels respectively, $r$ is the radius of each wheel, $L$ is the distance between both wheels, $x$ and $y$ are the position of the mobile robot and $\theta$ is its orientation [12].

The kinematic model is given by [6].

$$\begin{align*}
\dot{x} &= v \cos\theta \\
\dot{y} &= v \sin\theta \\
\dot{\theta} &= w
\end{align*}$$  \tag{1}

![Fig. 1 Mobile robot structure](image)

Technical tracking: The path to follow is stored in the memory as a vector of three elements $(x_d, y_d, \theta_d)$. The Fig. 2 illustrates the principle of displacement of the robot from the current point to the target point.
After the training phase, the system is theoretically capable of providing the control of supplying the command $u(t)$ necessary to obtain an output $\theta(t)$ supplied as input. The neural controller is thus placed directly in series with the commanded system, as shown in Fig. 3. During the learning phase, it is necessary to go through the process all of its possible states, or at least all the states that will be used during the control phase [1], [4], [6].

The general structure is illustrated in the previous figure.

### A. Network selection

The multilayer network has a single input, two hidden layers of neurons with sigmoid activation functions and one output with linear activation function. Its learning is carried out using the algorithm of backpropagation of the gradient based on the error $e$=desired output-real output, the results are:

- **Quadratic Average Learning Error**, $QALE = 9.9550e-004$.
- **Quadratic Average Learning Error Test**, $QALT = 9.2389e-004$.

![Fig. 5 Sequence learning](image)

### B. Simulation results

To show the effectiveness of the proposed controller, simulations were performed in Matlab Simulink. The examples are for the tracking of an echelon path, a square path and sinusoidal path, the results are illustrated in Figs. 6–9.
The first approach, inverse model, gave good performances. It is noted that it ensures the flexibility of movements, with the observation of a small tracking error value.

IV. NEURAL PD WITH ADAPTIVE COEFFICIENTS

The PD controller Proportional Diverter is the combination of two modules, the proportional P module that provides the function of basic setting and module diverter D which improves stability and accelerates the setting. This regulator supplies a control signal proportional to the deviation and its derivative [1], [4], [7].

By exploiting the learning ability of neural networks, we develop a system to estimate these two parameters.

A. Auto adjusting the parameters of a PD

In this approach, the neural network will be used to adjust $k_p$ and $k_d$, parameters of the conventional controller in PD the same way as when they are adjusted by a human operator [1], [4], [7].

![Fig. 10 Structure of neural PD control](image-url)
The basic structure for estimating these parameters is detailed in the followings figure.

Gains $k_p$ and $k_d$, proportional and derivative gains are determined in real time by the neural network. The network input vector has two components. The error and its derivative. Weights, $w_1(t)$ and $w_2(t)$ weighted the error input and the input of the error derivative are associated to the factors P and D, respectively.

The error of learning is $e = \theta - \hat{\theta}$ and the algorithm of update of the weights is that of modified Widrow-Hoff. A learning is stopped when the system arrives to follow the trajectory planned and the according to the criteria originally set. The network behaves as an adaptive PD. If significant changes occur in the system to control, learning can take back.

B. Simulation results

To test this controller on the tracking performance, we applied this approach to different trajectories and for different values of $l_r$ and $m$, learning coefficient and coefficient of term time, respectively, representing parameters in the neural network.

For $l_r = 0.00009$ and $m = 0.9$

For $l_r = 0.00002$ and $m = 0.9$
We note that with this neural controller “PD to adaptive learning coefficient is done online, we first applied for a echelon, sudden change of trajectory to determine the stability and accuracy then for tracking of a sinusoidal trajectory, we observe that the change $I$, and $m$, learning coefficient and coefficient of the term time respectively, has a large influence on the results. It is noted that the use of the latter approach gives satisfactory results.

The purpose of this approach is to design an adaptive PI controller and exploit the simplicity of setting Adaline networks.

V. CONCLUSIONS

In this paper a control approach using multilayer artificial neural networks is realized. A second approach uses the principle of a PD controller and use a network to adapt the proportional and derivator parameters. Learning is done online. Several tests validations of these approaches are tested, the results are acceptable in particular the response of the system following the application of a echelon.

Neural networks are a credible means for the control of mobile robots and determination of PD parameters.

ACKNOWLEDGMENT

The motor and robot parameters are as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance $R$</td>
<td>$1\Omega$</td>
</tr>
<tr>
<td>Inductance $L$</td>
<td>$1.5,H$</td>
</tr>
<tr>
<td>friction $f$</td>
<td>$0.1$</td>
</tr>
<tr>
<td>Inertia $J$</td>
<td>$0.01,Kgm^2$</td>
</tr>
<tr>
<td>Counter electromotive force constant $K$</td>
<td>$0.01$</td>
</tr>
<tr>
<td>torque constant $K$</td>
<td>$0.01$</td>
</tr>
<tr>
<td>Radius of wheel $r$</td>
<td>$0.1,m$</td>
</tr>
<tr>
<td>Width of the robot $L$</td>
<td>$1,m$</td>
</tr>
</tbody>
</table>

REFERENCES


[6] Z. Ryad, Contribution à la surveillance des systèmes de production à l'aide des réseaux de neurones dynamiques: Application à l'e-


[9] V. Jasmin, B. Lavecic and N. Osmic, Nonlinear motion control of mobile robot dynamic model, University of Sarajevo Bosnia and Herzegovina, pp 529-550, Croatia


Control of the DC Voltage Output Photovoltaic System

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Abstract— In this paper explains the simulation and control of DC/DC converter based solar energy conversion system. Controls strategies are investigates for the operation in the maximum power and constant output voltage under various temperature and irradiation levels. Photovoltaic array is charged at the Maximum Power Point (MPPT) near operating point and had done with MPP Tracking Algorithm. In order to extract the maximum amount of power from the PV generator, ‘Perturb and Observe’ control method for the MPPT of a PV system under variable temperature and insulation conditions, is considered.

The study system is simulated with MatLab/Simulink under different temperature and irradiance levels. Different cases are simulated, and the results have verified the validity of models and control schemes. The simulation results shows the controllers ensures to operate photovoltaic panel at its maximum power point and provide the DC output voltage at its reference whatever are the atmospheric conditions.

Keywords- Renewable energy, PV system, voltage control, MPPT, climatic conditions.

1. Introduction

Several forms of renewable energies have emerged in recent years and photovoltaic systems have being undergoing a dramatic development and have become more popular now[1, 2]. It is used today in many applications. Indeed solar energy can be used with photovoltaic solar conversion systems to convert solar radiation into electrical energy. These sources of energy take a very important place in energy conversion systems but the performances are influenced by the climatic conditions. Indeed, the voltage current and power values change according to temperature, solar radiation and the variation of the load. The PV generators exhibit non-linear current-voltage characteristics. On the other hand, the optimum operating point changes with the solar irradiation, and cell temperature. Therefore, online tracking of the maximum power point of a PV array is an essential part of any successful PV system. A variety of maximum power point tracking (MPPT) methods is developed in literature.

In this paper explains the simulation and control of DC/DC converter based solar energy conversion system. Controls strategies are investigates for the operation in the maximum power and constant output voltage under various temperature and irradiation levels. The photovoltaic system studied is constitute by PV panel, MPPT buck converter where the Perturb and Observerve (P&O) algorithm and a three-level inverter feeding a three-phase load is investigate. To convert DC to AC, inverters are used. The boost converters are used to transfers maximum power from the solar array to the DC bus, in a coordinated way and at a voltage always greater than the input magnitude.
Photovoltaic array is charged at the Maximum Power Point (MPPT) near operating point and had done with MPP Tracking Algorithm [3-5]. In order to extract the maximum amount of power from the PV generator, ‘Perturb and Observe’ control method for the MPPT of a PV system under variable temperature and insulation conditions, is considered. The significant advantage of controlled design propose is capable the ensure DC voltage desired. The loop control uses a proportional–integral (PI) controller to obtain a suitable duty cycle the keep the output voltage according to the reference level of DC bus [6-7].

The study system is simulated with MatLab/Simulink under different temperature and irradiance levels. Different cases are simulated, and the results have verified the validity of models and control schemes. The simulation results shows the controllers ensure to operate photovoltaic panel at its maximum power point and provide the DC output voltage at its reference whatever are the atmospheric conditions.

2. Model of solar systems

The photovoltaic energy production can be directly converts the under exposed solar radiation into DC electric power [8-9].

![Electrical equivalent circuit of a photovoltaic cell](image)

The output current and the voltage of the photovoltaic cell are given by the following equations:

\[ I_{pv} = I_{ph} - I_D - I_{sh} \]  \hspace{1cm} (1)

Where; \( I_{ph} \) presents the generated photo-current which is strongly related to the solar operating and standard radiation \( (G_o \text{ and } G_s) \) and solar cell operating and standard temperature \( (T_o \text{ and } T_s) \) according to the following relation [10]:

\[ I_{ph} = \frac{G_o}{G_s} \left[ I_{sc} + K(T_o - T_s) \right] \]  \hspace{1cm} (2)

With \( I_{sc} \) is the cell’s short-circuit current at standard temperature \( T_s=25^\circ C \).

\( I_D \) is the current across the diode \( (D) \) and affected by the diode saturation current \( I_{ds} \) [11]:

\[ I_D = I_{ds} \left( \exp \frac{V_{pv} - R_s}{V_T} - 1 \right) \]  \hspace{1cm} (3)

Where; \( V_T \) presents the thermal voltage expressed by:
\[ V_p = \frac{n R T_a}{q} \]  

(4)

With \( n \) is the diode ideality factor, \( K \) is the Boltzmann constant \((K = 1.38 \times 10^{-23} \text{ J/K})\) and \( q \) is the electron charge \((q = 1.6 \times 10^{-19} \text{ C})\).

And the shunt resistor current \( I_{sh} \) is denoted by the given expression:

\[ I_{sh} = \frac{V_{pv} + R_s I_{pv}}{R_{sh}} \]  

(5)

To form a photovoltaic panel, the cells must be assembled in series and parallel where, connecting cells in series increases the output voltage, however the parallel connection increases the output current. The mathematical model presenting the produced power of the photovoltaic panel becomes a simple algebraic model defined by the current-voltage relation [12]:

\[ I_{pv} = N_p I_{ph} - N_p I_{D0} \left\{ \exp \left( \frac{V_{pv} - R_s N_p}{N_s N_p} \right) - 1 \right\} - \frac{N_p}{R_{sh}} \left( V_{pv} - R_s \right) \left( \frac{I_{pv} R_p}{N_p} \right) \]  

(6)

Where; \( N_s \) and \( N_p \) present the connected series and parallel cells number, respectively.

3. Voltage control
The voltage and current supplied by the photovoltaic network are affected by unstable climatic conditions [6]. In order to ensure the proper functioning of the PV module at its maximum power point, we use the algorithm "disturb and observe (P & O)" [7]. P & O is simple and uses a few measured parameters. This method consists of two input signals: the PV voltage and the current, and an output signal which is the optimal voltage to be applied to the controller. Its connection is indicated by the below (Fig. 2).

![Figure 2: Photovoltaic conversion chain](image-url)
The steps of the P & O algorithm are described as shown in the following figure (Fig. 3) [8].

![Diagram of P&O algorithm](image)

Figure 3: Algorithme P&O

The booster chopper is characterized by its duty ratio $d$ ($0 < 1$) with which the average values of the output quantities can be expressed with those of the input. The electric diagram of the booster chopper is given in the figure (Fig. 4).

![Diagram of booster chopper](image)

Figure 4: Convertisseur (DC/DC) survolteur de tension (type Boost)

The Boost converter is known by the name of voltage booster. At the first cycle ($\alpha_T$), the transistor (TR) is closed, the current through the inductance increases gradually, it stores energy during the first cycle. Then, the transistor (TR) opens and the inductance (L) opposing the current decrease ($I$), generates a voltage which is added to the source voltage, which is applied to the load (R) through the diode (D) [9]. Kirchhoff's laws are applied to the two equivalent electric circuit cases of the chopper.

For the first period $\alpha_T$s: TR closed:

$$I_{C_1} = C_1 \frac{dV_s}{dt} = I_g - I_L$$

$$I_{C_2} = C_2 \frac{dV_s}{dt} = -I_o$$

$$V_L = L \frac{dI_L}{dt} = V_s - R_L I_L$$

Kirchhoff's laws are applied to the two electric circuits of the chopper.

For the first period $\alpha_T$s: TR closed:

$$I_{C_1} = C_1 \frac{dV_s}{dt} = I_g - I_L$$

$$I_{C_2} = C_2 \frac{dV_s}{dt} = I_L - I_o$$

$$V_L = L \frac{dI_L}{dt} = V_s - V_o - R_L I_L$$
4. Result simulations

According the simulation parameters from the KC200GT solar array at nominal operating conditions 25°C, 1000W/m², we have analysed to obtain the simulation results.

The characteristics I=f(V) and P=f(V) for different temperatures such as 25°C (standard temperature), 40°C, 60°C, 80°C and 100°C with standard irradiation E=1000W/m² are, respectively, presented in figures 2 and 3. It is observed that as the temperature increases the open circuit voltage decreases without any considerable change in the short circuit current.

Moreover, it is very important to note that the maximum power (Pmax) is decreasing.

The figure 5 and 6 shows the I=f(V) and figure 7 and 8 shows P=f(V) characteristics for different solar irradiance 400W/m², 550W/m², 700W/m², 800W/m² and 1000W/m² (standard solar irradiance), with the standard temperature T=25°C. In these conditions, it is observed that for low values of solar irradiations the short circuit current is reducing but the change in open circuit voltage is very less.

Under the conditions of a radiation G = 1000 and a temperature of 25 °C, the figure (Fig. 7) shows the evolution of the duty cycle applied to the chopper and the figure (Fig. exit).

---

**Graphs:**

- Fig.5 I=f(V) of PV with T=25°C and G variation
- Fig.6 P=f(V) of PV with T=25°C and G variation
- Fig.7 I= f(V) of PV with G=1000W/m² and T variation
- Fig.8 P= f(V) of PV with G=1000W/m² and T variation
- Fig.9 Output voltage
5. Conclusion

At the end of this work, we conclude that the models of the constituent parts of the training chain are validated by simulation. The maximum power generated from a solar module strongly depends on the intensity of solar radiation as well as the temperature. It can be seen that the open circuit voltage is dominated by temperature, and irradiation has strong influence on short circuit current. This structure is clearly recommended for photovoltaic installations installed in isolated areas.

Annexe :

Electrical characteristics of the photovoltaic module MSX60

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eclairement standard, G</td>
<td>1000W/m²</td>
</tr>
<tr>
<td>Température standard, T</td>
<td>25°C</td>
</tr>
<tr>
<td>Puissance maximale $P_{max}$</td>
<td>60W</td>
</tr>
<tr>
<td>Tension à $P_{max}$ ou tension optimale $V_{opt}$</td>
<td>17.1 V</td>
</tr>
<tr>
<td>Courant à $P_{max}$ ou courant optimal $I_{opt}$</td>
<td>3.5 A</td>
</tr>
<tr>
<td>Courant de court-circuit $I_{sc}$</td>
<td>3.8 A</td>
</tr>
<tr>
<td>Tension à circuit ouvert $V_{oc}$</td>
<td>21.1V</td>
</tr>
<tr>
<td>Nombre des cellules en série</td>
<td>36</td>
</tr>
<tr>
<td>Energie de la bande interdite</td>
<td>1.12 eV</td>
</tr>
<tr>
<td>Coefficient de température de $I_{sc}$</td>
<td>65 mA/°C</td>
</tr>
<tr>
<td>Coefficient de température de $V_{oc}$</td>
<td>-800 mV/°C</td>
</tr>
<tr>
<td>Coefficient de température de puissance</td>
<td>(0.5±0.05)%/°C</td>
</tr>
<tr>
<td>Courant de saturation $I_{sat}$</td>
<td>20 nA</td>
</tr>
</tbody>
</table>

RÉFÉRENCES


[9] H. Hanfhi, B. Badi, I. Khouchmane. Performances of solar photovoltaic under different climatic conditions, CIMS, November 2017, Mecanical Deparment, Skikda University, Algeria


 Contribution to the degradation modelling of a photovoltaic cell under the effect of stochastic thermal cycles of a desert environment

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Abstract— a photovoltaic module is characterized by the electric power it delivers when conventionally subjected to standard conditions (1000W/m², 25°C). Unfortunately, this power suffers degradation over time. The climatic factors degrading these electric generators vary from one natural environment to another. In this study, and independently of any other environmental factor, we have arrived to simulate by the accelerated tests (which was the only possible methodology) the effect of stochastic thermal cycles (exhibiting the narrow variation in daily temperature in the Sahara of Algeria) on the continuous degradation of electrical characteristics, in particular the nominal power, of a polycrystalline PV module. Modeling by Weibull model allowed us to estimate an average life of 27 years for degradation 52% about. This result comparable by what is already published in this area confirms the responsibility of the varied temperature in the form of stochastic thermal cycles in desert environments on the degradation phenomenon of PV modules.

Keywords—— degradation, cell photovoltaic, thermal cycles, desert environments, lifetimes.

I. INTRODUCTION

Several studies of the literature have presented the degradation of polycrystalline silicon PV modules, when exposed in natural environments. Among these studies, a study confirmed that after 20 years of continuous exposure, a matrix of 70 polycrystalline silicon photovoltaic modules has undergone an average performance decay of 0.24% per year, in a moderate subtropical climate environment. (Ispra, Italy) [1,2]. Another study stated that after only one year of exposure in a tropical climate environment, the electrical powers of two modules of type (a-Si) and (poly-Si) were degraded to 60% and 56% respectively their initial values [3]. In addition to these results, another study has shown that some PV modules (m-Si and Poly-Si) have been degraded by ranging from 0.22% / year to 2.96% / year [4]. The polycrystalline modules were the best in terms of reliability, long term, with a degradation of 0.41% per year, in a natural environment, lower than the value presented by Jordan and Kurtz (0.61% / year) [5]. In a tropical environment (Ghana), the exposure of 14 polycrystalline silicon modules during a 19-year period recorded a degradation rate of the nominal power of 21% to 35% [6]. Examination of failure showed degradation at a rate of 1.2% per year for polycrystalline modules, 0.8% per year for mono-crystalline modules [7]. An important study has found that the power of 204 modules (123 m-Si and 81 poly-Si) have recorded degradations that vary between 0 and 6% per year, after exposure periods of 18 to 24 years, in a moderate subtropical environment. The average degradation is of the order of 2.4% ± 1.7% per year for both types of modules [8]. In a Saharan environment (southern Algeria), the degradation rate of the polycrystalline modules was very high, ranging from 3.33% / year to 4.64% / year, unlike the mono-crystalline modules which recorded a rate of the order of 1.22% / year after 28 years of exposure [9, 10]. These measurement uncertainties, which gave different results, for the estimation of the degradation of the polycrystalline modules, were the objective of a study which had presented some methods of evaluation of degradation after duration of exposure of 12 years in a Saharan environment. It has managed to estimate an average rate by all methods of 2% per year [11]. We believe that accelerated tests are the only possible methodology to independently see the effect of daily temperature variation in a desert environment on the degradation of a module, as we can never move away from other factors in the air of a natural. Wolgemut (2011) presented a table showing failure modes according to the type of accelerated test. The breakdown or disconnection of the cells is appropriate for a thermal cycling test of IEC61215 type [12, 13]. Remi Laronde. using the accelerated tests, estimated an average lifetime of 438.54 years ± 8.01years, and 25-year duration for degradation close to 0.0132% for mono crystalline PV modules in a hot, humid climate environment [14].

II. RESEARCH METHOD

The strategy of accelerated tests theory is based on the effect of exposing the studied system to amplified conditions compared with normal conditions ones in order to deduce the degradation of the constitutional characteristics of the system (reliability law, lifetime ...). Then, by means of a law of acceleration (law of accelerated life), we will be able to determine the characteristics under normal conditions. The theory is to follow the steps below:

1. Know the mechanisms of failure under the normal conditions of use.

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page 116
2. Choose the amplified constraints while respecting the technological limits.
3. Establish the reliability laws under the applied constraints.
4. Identify the law of acceleration of passage between the amplified conditions and the normal conditions.

We have exposed two cells homologous of polycrystalline silicon; they have the same characteristics, named (C1 and C2) at 200 regular thermal cycles, such as:
- The first cell (C1) is exposed to cycles varying from (+ 5°C to + 75°C).
- The second cell (C2) is exposed to cycles ranging from (+ 5°C to + 85°C).

Each cycle lasted an hour and a quarter. Figure 1 presents these cells:

![Fig 1 The PV cell before exposure to the test](image)

The average stochastic variation in daily temperature over a year in the Saharan environment (the region of south-west Algeria) is usually between (+ 5°C and 45°C). Figure 2:

![Fig 2 Annual limits of temperature in the region of Adrar [15]](image)

Hence the accelerated test is defined by the following stress cases:
- The 1st stress constitutes 200 regular thermal cycles of (5°C to + 75°C), named S1.
- The 2nd stress constitutes 200 regular thermal cycles, from (5°C to + 85°C), named S2.
- The normal stress (under normal conditions), from (5°C to + 45°C), named S0.

The graphs of the electrical characteristics (I-V, P-V) of the PV cells are plotted by means of a solar analyzer linked to a PC, Figure 3:

![Fig 3 the original characteristics of cell before exposure to the thermal cycling test](image)

The data we received is redrawn under the standard conditions and presented in the figures below. The characteristics before exposure to thermal stresses are presented in the following figure 4:

![Fig 4 Characteristics of cell before exposure to the thermal cycling test in STC conversion](image)

Since, we do not have a climatic chamber to carry out the thermal cycles in a continuous way, according to the norms IEC61215; we used a laboratory thermal oven where the cycles are realized, manually and discontinuously.
The following figure 5 presents the diagram of the simulated cycles:

![Fig 5 Simulated thermal cycles](image)

### III. RESULTS AND DISCUSSION

After each 40 thermal cycles (50 hours), the results obtained are shown in Figure 6, 7, 8, 9, 10 and 11, respectively (they are given in the standard conditions-1000W/m² and 25°C- using the solar analyser).

![Fig 6 Characteristics of the two cells after exposure to 40 thermal cycles](image)

![Fig 7 Characteristics of two cells after exposure to 80 thermal cycles](image)

![Fig 8 Characteristics of two cells after exposure to 120 thermal cycles](image)

![Fig 9 Cell (C2) after exposure to 160 thermal cycles](image)

![Fig 10 Characteristics of the cell (C1) after exposure to 160 thermal cycles](image)
Quantities extracted from curves of the preceding figures indicate the degradation of the electrical performance of the two cells. They are shown in Table 1 below.

**TABLE 1**

<table>
<thead>
<tr>
<th></th>
<th>( I_{sc} ) (A)</th>
<th>( V_{oc} ) (V)</th>
<th>( P_{m} ) (W)</th>
<th>( FF ) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before exposure</td>
<td>2.262</td>
<td>2.218</td>
<td>1.310</td>
<td>0.261</td>
</tr>
<tr>
<td>After exposure to 40 thermal cycles Cell 1</td>
<td>3.161</td>
<td>1.194</td>
<td>1.289</td>
<td>0.342</td>
</tr>
<tr>
<td></td>
<td>3.107</td>
<td>1.218</td>
<td>1.127</td>
<td>0.298</td>
</tr>
<tr>
<td>After exposure to 80 thermal cycles Cell 1</td>
<td>2.128</td>
<td>1.581</td>
<td>0.846</td>
<td>0.251</td>
</tr>
<tr>
<td></td>
<td>1.563</td>
<td>1.523</td>
<td>0.699</td>
<td>0.294</td>
</tr>
<tr>
<td>After exposure to 120 thermal cycles Cell 1</td>
<td>3.108</td>
<td>0.822</td>
<td>0.697</td>
<td>0.273</td>
</tr>
<tr>
<td></td>
<td>1.623</td>
<td>0.919</td>
<td>0.209</td>
<td>0.140</td>
</tr>
<tr>
<td>After exposure to 160 thermal cycles Cell 1</td>
<td>3.124</td>
<td>0.622</td>
<td>0.638</td>
<td>0.328</td>
</tr>
<tr>
<td></td>
<td>4.15</td>
<td>0.643</td>
<td>0.380</td>
<td>0.245</td>
</tr>
<tr>
<td>After exposure to 200 thermal cycles Cell 1</td>
<td>2.415</td>
<td>0.643</td>
<td>0.380</td>
<td>0.245</td>
</tr>
<tr>
<td></td>
<td>4.15</td>
<td>0.643</td>
<td>0.380</td>
<td>0.245</td>
</tr>
</tbody>
</table>

It noted that a 20% higher degradation of the maximum power delivered by a cell makes the system in a pseudo-fault state [12]. We notice that:

- The starting power of the two cells is degraded successively. The degradation in cell C2 is higher than that in cell C1.
- The same remark for the voltages of the open circuit (after simple increases).

- A slight increase in short circuit current is recorded in both cells. This result is in agreement with those already published by the references [16, 17].
- The FF (form factor) is slightly increased at the beginning, so that it eventually becomes degraded.

**IV. MODELING OF THE RELIABILITY**

The Weibull distribution is already tested, by previous studies [12, 14, and 18], that it was adequate to estimate the reliability of the photovoltaic modules. It is normal to choose it to model the reliabilities of the cells under the constraints defined previously. The Weibull model is characterized by [19, 20, and 21]:

- Reliability function is:

\[
R(t) = e^{-\left(\frac{t}{\eta}\right)^{\beta}}
\]  

(2)

With:
- \( \beta \): parameter of the form of model \((\beta > 0)\)
- \( \eta \): scale parameter \((\eta > 0)\), which indicates the magnitude of the average lifetime, denoted by MTBF (Mean Time Between Failure)
- The instantaneous failure rate is given by:

\[
h(t) = \frac{\beta}{\eta} \left(\frac{t}{\eta}\right)^{\beta-1}
\]  

(3)

- The average life (MTBF) is given by:

\[
MTBF = \frac{\eta \Gamma\left(1 + \frac{1}{\beta}\right)}{\Gamma\left(1 + \frac{1}{\beta}\right)}
\]  

(4)

- Where \( \Gamma \) is the function defined by:

\[
\Gamma\left(1 + \frac{1}{\beta}\right) = \int_{0}^{\infty} x^{\frac{1}{\beta}} e^{-x} dx
\]  

(5)

The Weibull model can model the reliability of an electronic system according to the \( \beta \) value in the three life phases [14]:

1) If \( \beta < 1 \) the failure rate decreases, this is the run-in period. This decrease is explained by the gradual elimination of defects. When this period is shorter, the system is reliable.

2) If \( \beta = 1 \) (Practically about 1) the failure rate is constant. The system is in useful period (should be the longest). The Weibull model in this case is an exponential model.

3) If \( \beta > 1 \) the failure rate is increasing, it is the period of the aging system.

The parameters of the model, under both stresses are determined by the average of a genetic algorithm. It’s an iterative stochastic algorithm that uses an initial population to reach an optimal solution of any problem. The chosen population initially has evolved from generation to generation, or the individuals, the most adapted, have the great chance to reproduce. The following figure 12 shows the steps followed:
Through the application of these 7 steps, a program was built by Matlab. We obtained the following results table 2:

<table>
<thead>
<tr>
<th>Stress</th>
<th>Shape parameter(β)</th>
<th>Scale parameter(η)</th>
<th>Average lifetimes (τ in thermal cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>2.3333</td>
<td>203</td>
<td>179.8735</td>
</tr>
<tr>
<td>S2</td>
<td>2.3333</td>
<td>94</td>
<td>83.2912</td>
</tr>
</tbody>
</table>

The graphs of the following Figure 13, 14 show the reliability of cells (C1, C2) under stress S1, S2.

By choosing the model of Coffin-Manson, the most suitable for thermal cycles [22], defined by:

\[
\tau = \frac{A}{\Delta T^2} = N(T) \quad (6)
\]

- \(\tau\): The average lifetime of the components subjected to fatigue due to the variation in temperature
- \(N(T)\): Number of cycles up to break
- \(A\) and \(B\): characteristic constants estimated from the results of the test.
- \(\Delta T\): Width of temperature variation (thermal cycle)

By the calculation, the constants of the model and the lifetime of the cells under the stress S0 are presented by:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>(\beta )</th>
<th>(\eta )</th>
<th>(\tau ) (cycle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7823*10^4</td>
<td>5.7658</td>
<td>2.3333</td>
<td>210010</td>
<td>186090</td>
</tr>
</tbody>
</table>

TABLE 2
Weibull parameters estimated under amplified stress conditions

TABLE 3
Constants of models (Coffin Manson and Weibull) under stress S0
The graph of Reliability in this case is simulated by:

![Graph of Reliability](image)

Fig 15 Reliability of polycrystalline cell under normal conditions

The mean lifetime under the stress S0, transformed into unit of time, has presented in:

<table>
<thead>
<tr>
<th>Stress</th>
<th>T (thermal cycle)</th>
<th>( \tau ) (hour)</th>
<th>( \tau ) (year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>179.8735</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>83.2912</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S0</td>
<td>186090</td>
<td>232612.5</td>
<td>26.5357 = 27</td>
</tr>
</tbody>
</table>

The estimated duration for a degradation of 20% of the starting power of cell is about 17 years, giving a degradation rate of 1.17% per year. This result is acceptable by comparing at the rate of degradation of 1% per year for the mean of a polycrystalline module in a similar natural medium [8]. (This is acceptable because the cell must be degrading more than the module).

V. CONCLUSION

Our main objective of this study was the approximate estimation of the effect of stochastic cycles of temperature in a desert environment (independently of other climatic factors) on the degradation phenomenon of polycrystalline PV cells. Accelerated testing was the only average that can be used to achieve this objective. Modeling by Weibull model allowed us to estimate an average life of 27 around years, for a degradation of 52% about, of the power initial value. The duration to see a degradation of 20% (pseudo-failure state) is order of 17 years. The average annual rate of degradation is order of 1.17% per year. By comparing this result with others presenting the degradations of the polycrystalline PV modules, we conclude the important role of the stochastic thermal cycles of a desert environment on the degradation phenomenon of PV cells (modules). For increase the service life of solar panels operated in Saharan natural environments, it’s necessary to look for the reliable techniques to block the effect of narrow variation of temperature.

VI. ACKNOWLEDGMENT

I thank M. OTMANI permanent researcher from the Research Unit in Renewable Energy in Saharan Environments (URERMS-Adrar) for their help in experimentation.

VII. REFERENCES


Control of Active and Reactive Powers Of The DFIG By Neural Network Technology

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I- Introduction:

Abstract: Artificial intelligence (AI) techniques, particularly the neural networks, are recently having significant impact on power electronics and motor drives. Neural networks have created a new and advancing frontier in power electronics, which is already a complex and multidisciplinary technology that is going through dynamic evolution in the recent years. In this paper I use this techniques for control of power active and power reactive of the DFIG and perspective of neural network applications in the intelligent control [5]. in this paper include direct control of active power and reactive power. Additional selected applications in the literature are included in the references. From the current trend of the technology, it appears that neural networks will find widespread applications in power electronics

Keywords: DFIG, PI, neural controller, power system

Neural networks have known for some years growing success in various fields of Engineering Sciences; the electrical engineering is no exception to this rule. Unfortunately, the literature is full of examples where the implementation of neural networks is more a recipe for a reasoned approach. In addition, biological connotations of neural networks, and the use of the term learning, often brought great confusion; they led to connect abusively neural networks in artificial intelligence, while they are fundamentally statistical tools. The aim of this chapter is to show how, from the fundamentals, it is possible to achieve genuine methodology implementation, in particular in the modeling framework of the process. We show in particular that, contrary to widespread belief, neural networks are not necessarily black boxes. On the contrary, it is perfectly possible, and even highly recommended to introduce into the neural network, from its conception, all mathematical knowledge available regarding the process to be modeled or control.[1]
II- The DFIM Modeling:

The classical electrical equations of the DFIG in the Park frame are written as follows

\[
\begin{aligned}
\nu_{ds} &= R_s i_{ds} + \frac{d\varphi_{ds}}{dt} - \omega_s \varphi_{qs} \\
\nu_{qs} &= R_s i_{qs} + \frac{d\varphi_{qs}}{dt} - \omega_s \varphi_{ds} \\
v_{dr} &= R_r i_{dr} + \frac{d\varphi_{dr}}{dt} - (\omega_s - \omega_r) \varphi_{qr} \\
v_{qr} &= R_r i_{qr} + \frac{d\varphi_{qr}}{dt} - (\omega_s - \omega_r) \varphi_{dr}
\end{aligned}
\]

(1)

The stator flux can be expressed as:

\[
\begin{aligned}
\varphi_{ds} &= L_s i_{ds} + L_m i_{dr} \\
\varphi_{qs} &= L_s i_{qs} + L_m i_{qr}
\end{aligned}
\]

(2)

The rotor flux can be expressed as:

\[
\begin{aligned}
\varphi_{dr} &= L_r i_{dr} + L_m i_{ds} \\
\varphi_{qr} &= L_r i_{qr} + L_m i_{qs}
\end{aligned}
\]

(3)

The active and reactive powers at the stator are defined as:

\[
\begin{aligned}
P_s &= \nu_{ds} i_{ds} + \nu_{qs} i_{qs} \\
Q_s &= \nu_{qs} i_{ds} - \nu_{ds} i_{qs}
\end{aligned}
\]

(4)

The active and reactive powers at the rotor are defined as:

\[
\begin{aligned}
P_r &= \nu_{dr} i_{dr} + \nu_{qr} i_{qr} \\
Q_r &= \nu_{qr} i_{dr} - \nu_{dr} i_{qr}
\end{aligned}
\]

(5)

The electromagnetic torque is expressed as:

\[
C_{em} = P (\varphi_{ds} i_{qs} - \varphi_{qs} i_{ds})
\]

(6)

With P is the number of pair poles.

III- the indirect control:

The principle of this method consists in not measuring (or estimating) the amplitude of flux but only its position, the idea is proposed by Hasse[2].

III.1- Active and reactive power strategy of control:

When the DFIM is connected to an existing network, this connection must be done in three steps. The first step is the regulation of the stator voltages with the network voltages as reference. The second step is the stator connection to this network. As the voltages of the two devices are synchronized, this connection can be done without problem. Once this connection is achieved, the third step, is the transit power regulation between the stator and the network[3].
\begin{align*}
I_{ds} &= \frac{\varphi_s}{L_s} - \frac{L_m}{L_s} I_{ds} \\
I_{qs} &= -\frac{L_m}{L_s} I_{qr}
\end{align*}
\tag{7}

Stator power and rotor courant can be rewritten as following:
\begin{align*}
P_s &= -\nu S \frac{L_m}{L_s} I_{qr} \\
I_{qs} &= -\nu S \frac{v_s}{\omega_s L_s} - \nu S \frac{L_m}{L_s} I_{dr}
\end{align*}
\tag{8}

Stator voltages and rotor courant can be rewritten as following:
\begin{align*}
V_{dr} &= R_r i_{dr} + L_r \sigma \frac{di_{dr}}{dt} - \omega_r L_r \sigma i_{qr} \\
V_{qr} &= R_r i_{qr} + L_r \sigma \frac{di_{qr}}{dt} + \omega_r L_r \sigma i_{dr} + \omega_r \frac{L_m}{L_s} \omega_s i_{qs}
\end{align*}
\tag{9}

Knowing the relations precedent, it is possible to design the regulators. The global block-diagram of the controlled system is depicted on Figure 4.4

Figure (5.a) represents the active power and the figure (5.b) represents the reactive power of the stator, the figure (5.c) is quadratic in the live and fixed speed rotor currents.

Interpretation of simulation results:

we note a good continuation of active and reactive power of the stator that is either fixed or variable speed [see figure 5a, 5b]. It is observed the static error is zero. The currents of the rotor have faster dynamics.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{fig2.png}
\caption{Block diagram of DFIG power control}
\end{figure}

VI- NEURON NETWORK CONTROL
The idea is to replace the two PI controllers for direct control by neural controllers (RN) simple. For learning, we use retro algorithm propagation of Levenberg-Marquardt (LM) [1].
Fig. 3: Multilayer Perceptron: structure(2-3-1) [1]

Each neural network performs a well-defined function depending on the chosen architecture (number of hidden layers and the number of neurons in each hidden layer). The problem is to find a structure that gives better results.

For this, we made several tests to determine the optimal network architecture. The most sensible choice was to take a neural network structure with one hidden layer containing three neurons using the sinusoid activation function, (Fig. 8).

V- results and analysis:
Fig.4. simulation of direct control of active and reactive powers

Fig.5. results of neural control
Simulation results of the direct control of active and reactive power with neural controllers are given in Figure 9.

The simulation results show good performance in terms of response time and tracking set point for active power and reactive power.

The comparison between the two regulators show that the neural controller has good performance. By cons, for the PI controller, its performance is completely deteriorated.

**Conclusion:**

The work done a comparative study of the performance and robustness of Reviewers: Neuronal and PI. Direct vector control of the generator double-fed asynchronous allows for a decoupling and a control independent of the active and reactive power.

The first step, the regulation is made with PI controllers. In the second step, the command is based on neural networks. The architecture of restraint neural corrector is 2-3-1. She gave us a hand, to improve the dynamic and static performances of the DFIG and secondly, to ensure robustness of working of the machine.

**REFERENCES**

[1] DJERIRI YOUCEF, « Commande vectorielle d’une MADA intégrée à un système éolien », Thèse de Magister en Electrotechnique, université djillali liaabes de sidi bel-


Multi-wind generators to supply water pump system based on cascaded H-bridge inverters

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Abstract—In this paper authors propose the supply of a water pumping system by small scale wind turbines designed for remote area. The power conversion is based on cascaded H-bridge inverters controlled by asymmetrical Phase Disposition Pulse Width Modulation. Simulation results in both identical and different wind conditions are presented. The proposed structure improves reliability and also allows operation in fault tolerant operating mode.

Keywords— Cascaded H-bridge inverter, small scale wind turbines, PDPWM, water pumping.

I. INTRODUCTION

The exploit of renewable energy is attractive for water pumping applications in remote rural areas. Wind turbines have an increasing importance in the field of standalone generation systems especially in the agriculture system irrigation [1],[2].

To such purpose, the adoption of wind turbines directly coupled to permanent-magnet generators represents a convenient solution, thanks to the insensitivity towards the wind direction, to the capability of exploiting turbulence in short distances and to the high efficiency of the PM generators [3].

Otherwise, in agriculture the reliability and availability of farm system irrigation are critical and crucial factors in the good crop production. Therefore, the design of high-level reliability solutions is very required.

A water storage tank is used instead of electric battery energy storage in order to guarantee, low cost and high-level reliability. In fact, the variable frequency three-phase induction machine is used since the voltage delivered to the pump varies with wind speed and accordingly a variable water flow.

In this paper, the authors propose a solution for water pumping system based on the integration of the cascaded H-bridge inverters in the power supply of three phase induction machine driving a water pump from several small scale wind turbines designated for remote area.

Compared with conventional solution, the one proposed in this paper has two major advantages: the structure modularity existing both on the energy source and on the power converter; the ability of the structure to drive the water pump even in degraded mode.

In the first part of this paper, the general aspect of the configuration of the water pumping system is presented. The main topology based on the cascaded H-bridge inverter and its different elements are shown. Secondly, the authors present the simulation results of the three phase induction machine driving a water pumping system in different cases of wind conditions. Finally, degraded operation mode of the system is presented when one of the converter cell fails.

II. THE CONFIGURATION OF THE WIND POWER CONVERSION SYSTEM

The different elements of the studied water pumping system based on water storage are presented in Fig. 1.

Fig. 1 Schematic diagram of the studied water pumping system

The system is composed from three small scale wind turbines based on axial flux direct-drive permanent magnet synchronous generator PMSG. Each generator delivers three AC output voltages feeding the induction motor via power converters. The three phase IM drives a water pump. This pump sucks water at a variable flow rate because it is influenced by the wind speed. The extracted water is stored in a tank for use in a fixed flow irrigation system. Two topologies of the conversion power system are feasible. The first one is given by Fig. 2. Each generator is connected to a diode rectifier and a DC/AC converter feeding
then a phase of the three phase motor pump. This structure offers the segmentation of power between the three wind turbines and consequently uses modular power converters. Furthermore, the direct-drive PMSG wind turbines are exposed to different wind speed which is changing on time. This unequal variable distribution of wind energy leads to unequal dc bus voltages. Thus, this phenomena can cause phase failure or unbalance that is not suitable for the motor pump.

![Diagram of three phase motor pump fed by three H-bridge inverters](image)

**Fig. 2 Three phase motor pump fed by three H-bridge inverters**

Accordingly, a second structure given by Fig.3 is proposed to overcome the limitations of the previous one, specially the phase unbalance. In fact, the integration of the multilevel cascaded H-bridge inverter in the conversion system seems to be interesting in terms of reliability, flexibility, extensibility and power segmentation [4],[5].

In this structure, each phase is supplied by three H-bridge DC/AC converters associated in series and having different dc input voltages E1,E2 and E3 which are provided respectively by the three wind generators G1,G2 and G3.

According to the wind speed distribution, each turbine is responsible of the value of the dc bus of the corresponding level of the power converter.

For example, the three cells of the first level are connected to equal dc bus voltages (E1) since they are delivered by the same generator G1. Thus, the motor pump is always supplied by a three phase balanced system.

Besides, the three dc voltages of the same generator are electrically separated since they are the outputs of different single phase rectifiers connected to the PMSG via a multiwinding transformer with an unified transformation ratio.

![Diagram of three phase motor pump fed by multilevel cascaded H-bridge inverter](image)

**Fig. 3 Three phase motor pump fed by multilevel cascaded H-bridge inverter**

A more detailed description of the multilevel converter and the PWM control is given in the following section of the paper.

III. THE CASCaded MULTILEVEL CONVERTER

The cascaded multilevel converter can synthesize an important output voltage from several small voltages since the resulting voltage is the sum of the output voltages of the different cells. For a given phase, non identical inputs are attributed to the multilevel inverter through the dc sides. This is the so called asymmetrical cascaded multilevel inverter [6].

The three phase cascaded multilevel converter represented in Fig. 4 contains three H-bridge converters per phase. Each H-bridge inverter is composed from two legs and a dc source; each leg is composed of two IGBT switches called \( T_{k}(i,j) \) and \( T_{k}(i,j) \) having complementary switching signals \( S_{k}(i,j) \) and \( S_{k}(i,j) \).

The indexes k, i and j indicate respectively the half H-bridge index \( k \in [1,2] \), the phase's number \( i \in [1,2,3] \) and the cell's number \( j \in [1..p] \) where \( p \) is the total number of the commutation cells per phase.

The per-cell output voltage is given by the following equation

\[
V_{ij} = S(i,j)V_{c}(i,j)
\]

Where \( S(i,j) = S_{1}(i,j) + S_{2}(i,j) - 1 \)

For \( p \) power cells, the output voltage per phase contains \( p+1 \) levels and it is equal to

\[
V_{m} = \sum_{j} V_{ij} = \sum_{j} S(i,j) \cdot V_{c}(i,j)
\]

The line to line output voltage of a three phase cascaded converter has \( 2p+1 \) levels.
The modulation control used for controlling the gate drive signals for the cascaded inverter is based on the multicarrier PWM strategies. Phase Disposition PWM is among the commonly used control technique and offers satisfying harmonics reduction results [7]. Further, it is adopted to the asymmetrical structure [8].

It is based on applying six triangular signals (Ap1...Ap6) vertically disposed and comparing them separately with three sinusoidal reference signals corresponding to the three phases. The synoptic scheme presenting the PWM principle for phase 1 is given by Fig. 5. For the other phases, the same carriers are kept, only the reference signal has to be shifted by the adequate angle.

Note that there are two triangular carriers for each cell having different offsets and same amplitude equal to the value of the corresponding dc voltage value (Ej=Vc(i,j)). In fact, the Ej values are given by a real time voltage measurements of the different dc voltages delivered by the three generators.

The sinusoidal signal has an amplitude Am equal to Am=2ΣEj.

Consequently, each time the DC input value changes, the amplitude of the triangular carriers and the sinusoidal reference signal will change.

Fig. 5 Principle of asymmetrical PWM per phase (phase 1)

IV. SIMULATION RESULTS

A. Simulation Conditions

The whole system is implemented and simulated in Matlab/Simulink environment. Each wind generator has a nominal power equal to 500W. The three small scale wind turbines are associated to the cascaded multilevel converter for feeding a 1.5kW three-phase water pump.

The induction machine is controlled using constant (V/Hz) law with a resistive torque proportional to the square of the speed:

\[ C_r = k\omega^2 \]

The simulations are assured for different cases given in the following sections.

B. Case of Identical Wind Speeds

For this case, the wind turbines turn at the same wind speed (20m/s) corresponding to the maximum allowed value. Thus, all dc voltages have the same value (E1=E2=E3=110V) it is the case of symmetrical cascaded inverter. The single voltage waveforms of phase 1 and phase 2 as well as the phase to phase voltage applied to the induction machine are given in Fig. 6. A zoom effect shows that the simple phase voltage has seven equal levels counted peak to peak. The phase to phase voltage has eleven levels.

Fig. 7 presents the evolution of the stator currents of the first phase, the speed and the torque of the motor pump. After a transient mode, the machine reaches its nominal speed and provides the resistive torque.
voltages. The stator current, the rotor speed and the torque are represented by Fig. 10.

Although variations, the rotor continues running and variable speed and assures the load torque which guarantees extracting water but with variable flow.

Fig. 8 Variation of the three dc voltages E1, E2 and E3

![Image]

Fig. 7 Waveforms of stator current, electromagnetic torque and the speed of the induction machine

**C. Case of Different Wind Speeds**

Different wind speeds are applied to the three turbines. Consequently, the dc voltages delivered by the permanent magnet generators are not equal as shown in Fig. 8. Besides, at time equal to 2s, the wind turbine 2 has a velocity variation that the dc voltage is changing from 42 V to 108 V. Through real-time simulation, the triangular carriers are adapted to the variations of the dc voltages.

Fig. 9 shows the waveforms of the different voltages and a zoom effect is done around 2s to present the evolution of the

![Image]

Fig. 10 stator current, torque and speed of the induction machine in case of different wind speed.
D. Operation in Degraded Mode

One of the advantages of the CHBI structure is to ensure the supply of the load even if a fault (open or short circuit) occurs at a semiconductor device of a cell [9].

Of course, the Cascaded inverter will not operate at full rated power after the bypass of a level. Surely a reduction of the rated power is more desirable than a complete shutdown specially in the application of water pumping.

The reconfiguration method adopted in this case consists on bypassing the faulty cell. For instance, if cell 12 has an open-circuit fault at $T_1 (1,2)$, hence, $T_2 (1,2)$ and $T_3 (1,2)$ need to be turned on while $T_4 (1,2)$ needs to be turned off to bypass cell 12 as shown in Fig. 11.

The two other cells (cell 22 and cell 32) should also be bypassed to ensure a balanced supply of the motor pump.

The 7 level cascaded inverter is equivalent to a 5 level one in this kind of degraded mode. The number of levels of the simple phase voltages is reduced after the reconfiguration of the structure as shown by Fig. 12. Otherwise, Fig. 13 shows the continuity of service of the motor pump at reduced speed and torque. Consequently, the operation of the pumping system is ensured in reduced flow rate.

Fig. 11 Reconfiguration of the structure in degraded mode

Fig. 12 Evolution of the output voltages when a default in cell12 at t=2s

Fig. 13 Behavior of the induction machine: current, speed and torque after a fault at t=2s

V. CONCLUSIONS

In this paper, three small wind generators are used to supply three phase induction machine water pump system through multilevel cascaded H-bridge inverters. The asymmetrical PDPWM is very adapted to the asymmetrical converter which dc buses are depending on wind distribution.

In the simulation results, the operation of the motor pump for different winds and even low values are presented. Also, it has been proved that such topology ensures the pumping in low rated flow in case of degraded mode.

Note that the case of degraded mode is equivalent to a healthy operating in an absence of wind except that when a faulty occurs, a reconfiguration control must be applied to the structure which is extremely related to the emplacement and the nature of the fault.
REFERENCES


Optimization of Two Stage-High Rate Algal Pond for the purification of wastewater has a large organic charge.

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Abstract

The goal of this study is to develop the optimal model based on the kinetics of organic matter removal in an integrated system anaerobic reactor-high rate algal pond in two stage (AR-TS-HRAP), and this to have a sizing tool adapted to the Moroccan context. Contrary to Oswald's approach, which is based on the algae energy balance, this model has been developed according to an engineering concept that takes into account the design parameters of the reactors (flow, charge and residence time).

The tests of the modeling of the organic matter diffusion for an important organic charge of 750 mg / l for different residence times in the high and low channel, allowed us to find the optimal residence time to have a total yield very interesting also win half a day. So we can consider that the combination of a residence time of 1.5 days in the high channel and 2 days in the low channel using the CFD FLUENT tool, would be a good basis for sizing these systems in Morocco. In order to treat twice of the rate by the same area and to adapt the system to large agglomerations.

Keywords
High rate algal pond (HRAP), The Two Stage High rate algal pond (TS-HRAP), Wastewater, Residence time, Purification, Organic matter. Diffusion, Simulation, optimization, ANSYS, CFD FLUENT.

1. INTRODUCTION

Morocco is a country facing the problem of water scarcity. Indeed, it will soon reach in 2020 the critical threshold of 500 m3 per inhabitant per year, a threshold commonly accepted as the threshold of absolute water scarcity, the country should then face a permanent lack of water. Currently, the resources are under increasing pressure, they are increasingly polluted, the purification sector has a serious delay. Indeed, a significant difference has been unsaturated
between the rhythm of implementation of water supply networks and that of investments reserved for sanitation and wastewater treatment.

The wastewater treatment has become a necessity that should not be neglected, it should not be considered just as a means of pollution control, but also as a means of recycling of wastewater after purification, in order to relieve the water deficit that Morocco will face in the future.

It is therefore imperative to develop the purification processes that offer this possibility, and answer to the recycling requirements dictated by the WHO, such as the integrated system Anaerobic Reactor-High Rate Algal Pond, which is an extensive system requiring low energy costs and small areas.

The High Rate Algal Pond (HRAP) process is known as a real reactor for intensive algae cultivation. It is based on the symbiotic interaction between heterotrophic bacteria and algae produced in this lagoon (OSWALD, 1977) where the goal is to accelerate the purification process by promoting algal production. HRAP seems to be an interesting technique for the treatment of wastewater because of the high efficiency of assimilation of nitrogen and phosphorus by microalgae (EL HALOUANI et al., 1993). However the integrated system AR-HRAP is intended for small and medium-sized agglomerations.

To overcome this problem, the idea of adding a second stage to the high rate algal pond has been chosen to make the extensive system an intensive system to treat twice of the flow by the same area and to adapt it to large agglomerations. The Two Stage-High Rate Algal Pond (TS-HRAP) came into being as a result of research work initiated at “Institut Agronomique et Vétérinaire Hassan 2” in Rabat. For this purpose, the main objective of this study is to optimize the performance of the Two Stage-High Rate Algal Pond (TS-HRAP) in the elimination of organic matter for the wastewater treatment of the large agglomeration.

2. Material and Methods

2.1. Hydrodynamics of the TS-HRAP

The High Rate Algal Pond in stage mode consists of two identical channels, so the hydrodynamic study that will be established later is valid for the high channel and the bottom channel.

The fluid within the channel is a mixture of waste water and microscopic algae, the concentration of algae is too low to influence the liquid’s physical characteristics. Therefore, the fluid will now be considered Newtonian.

For an average flow velocity of 15 cm / s, corresponding to the velocity recommended by OSWALD for optimum and economical functioning, hydraulic flow parameters are shown in the following table:
Table 1: The hydraulic parameters of the TSHRAP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Mach</td>
<td>0.0001</td>
<td>Incompressible mixture</td>
</tr>
<tr>
<td>Number of Reynolds</td>
<td>56250</td>
<td>Turbulent flow</td>
</tr>
<tr>
<td>Number of Froude</td>
<td>0.005</td>
<td>River flow</td>
</tr>
</tbody>
</table>

According to these parameters, the fluid nature is incompressible and the flow regime is turbulent and fluvial.

2.2. Equation setting:

The equations ruling over the TS-HRAP’s hydrodynamics are:

2.2.1. The continuity equation or the mass conservation equation:

\[
\frac{\partial \rho}{\partial t} + \text{div} (\rho \vec{v}) = S
\]

\( \rho \) : fluid’s density (kg.m\(^{-3}\))
\( \vec{v} \) : fluid’s velocity (m.s\(^{-1}\))
\( S \) : term wells / source (kg.m\(^{-3}\).s\(^{-1}\)).

2.2.2. The equation of momentum:

\[
\frac{\partial (\rho \vec{v})}{\partial t} + \text{div}(\rho \vec{v} \vec{v}) = -\text{grad} p + \text{div} \vec{\tau} + \vec{f}
\]

- \( \rho \vec{v} \vec{v} \) : the momentum tensor;
- \( \text{div}(\rho \vec{v} \vec{v}) \) : the flow balance input/output of momentum for the elementary volume;
- \( \vec{\tau} \) : the stress tensor due to the viscosity of the liquid (Pa)

2.2.3. The equation of energy:

\[
\frac{\partial (V (\rho E + p))}{\partial x_i} = \frac{\partial}{\partial x_i} \left[ k_{\text{eff}} \frac{\partial T}{\partial x_i} - \sum_{j} h_j J_j + V_{i} (\tau_{ij})_{\text{eff}} \right] + S_h
\]

- \( k_{\text{eff}} \) : the effective conductivity defined by:
  \( K_{\text{eff}} = K_{\text{moy}} + K_{\text{tur}} \)
  As \( K_{\text{moy}} \): the average conductivity; \( K_{\text{tur}} \): the turbulent conductivity.

- \( J_j \) : the specific diffusion flow of the species \( j \).
- \( E \) : is the result of the formula:
  \[
  E = h - \frac{p}{\rho} + \frac{\vec{v}^2}{2}
  \]

\( h \) : the sensitive enthalpy, for an incompressible fluid.
2.2.4. The transport equation:

\[
\frac{\partial}{\partial t} (\rho Y_i) + \frac{\partial}{\partial x_i} (\rho V_i Y_i) = \frac{\partial}{\partial x_i} J_i + R_i
\]

- \( V_i \): component of the velocity along an axis;
- \( Y_i \): mass fraction of each species;
- \( R_i \): Reaction rate or Production rate of the species \( i \);
- \( J_i \): The diffusion flow of species \( i \) due to the concentration gradient.

After the equation, simplifying assumptions are required for the numerical resolution by the software, namely:
- The flow regime is permanent, so: \( \frac{\partial}{\partial t} = 0 \)
- The mixture is considered to be a homogeneous and incompressible fluid, so the variation of \( \rho \) is negligible regarding time and space:
  - \( \rho = \text{constant} \);
- The mixture is considered to be a Newtonian fluid, so the fluid’s viscosity: \( = \text{constant} \);
- The mixture is subjected to a single volume force which is its weight:
  \( \vec{f} = \rho \vec{g} \)

Where:
- \( \vec{g} \): the acceleration of gravity

2.3. Balance of organic matter:

During TS-HRAP’s operation, the organic matter balance is written as follows:

2.3.1. In series

\[
S_0 - S_3 = \frac{\alpha_a \times b}{D_a + \alpha} + \frac{\alpha_h \times b_h}{D_h + \alpha_h} + \frac{\alpha_b \times b_b \times (D_c + a_h) \times (D_c + a_h)}{(D_c + a_h) \times (D_c + a_h)}
\]

2.3.2. In parallel:

2.3.2.1. High channel

\[
S_0 - S_2 = \frac{\alpha_a \times b}{D_a + \alpha} + \frac{\alpha_h \times b_h}{D_h + \alpha_h}
\]

2.3.2.2. Bottom channel
\[ S_0 - S'_2 = \frac{\alpha_a \times b}{D_a + a} + \frac{\alpha_b}{\gamma_b} \times \frac{b_b}{D_b + a_b} \]

With:
- \(X\): the bacterial biomass concentration (mg / l)
- \(S\): the substrate concentration (mg / l)
- \(\alpha_a\): the biomass-substrate conversion rate
- \(a_b\) and \(b_b\): the kinetic constants of the high channel
- \(a_b\) and \(b_b\): the kinetic constants of the bottom channel
- \(D_a\): the dilution rate of TS-HRAP
- \(a\): coefficient that has the characteristic of a growth rate
- \(b\): coefficient that has the characteristic of a speed
- \(\gamma\): the factor connecting the bacterial and algal biomasses, in which: \(\gamma = \frac{d\Lambda}{dt} / \frac{dX}{dt}\)

2.4. Numerical simulation

The numerical simulation of the diffusion of organic matter in TS-HRAP was done by a Calculation Code FLUENT, which is a CFD (Computational Fluid Dynamics) type software used for complex multiphase calculations. The latter will give 3D images illustrating the profiles of the diffusion of the organic matter according to the geometry of the channel.

2.4.1. Geometry:
To present the geometry of TS-HRAP it is not necessary to represent the two channels, up and down, in GAMBIT, because they have the same geometry.

![Figure 2: The geometry of HRAP](image)

It defines the configuration of the problem to be analyzed. It involves:
- Creating the system’s geometry in ANSYS Design Modeler;
- Editing and improving the created geometry while making the necessary readjustments.
- Explicitly identifying all fluid and solid areas of the model.

The dimensions of our channel are as follows:

<table>
<thead>
<tr>
<th>Straight section</th>
<th>Curved section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>50</td>
</tr>
<tr>
<td>Width (m)</td>
<td>3</td>
</tr>
<tr>
<td>Height (m)</td>
<td>0,5</td>
</tr>
</tbody>
</table>
2.4.2. *The meshing*

The mesh used in this study is of refined type which makes it possible to have results of good precision.

2.4.3. *Boundary conditions*

The simulation program requires the definition of certain boundary conditions, concerning the free surface, the stirring wheel and the contact surfaces between the different materials.

<table>
<thead>
<tr>
<th>Items</th>
<th>Boundary conditions (fluent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>enter</td>
<td>Velocity inlet</td>
</tr>
<tr>
<td>exit</td>
<td>Out flow</td>
</tr>
<tr>
<td>background</td>
<td>Wall</td>
</tr>
<tr>
<td>wall</td>
<td>Wall</td>
</tr>
<tr>
<td>free surface</td>
<td>Symmetry</td>
</tr>
</tbody>
</table>

2.4.4. *Setting and solution (FluentSolver)*

The setting component helps to specify the physical and chemical phenomena to be modeled and the types of used materials (fluid or solid) and their properties. As for the solution component, it allows to choose the iterative process, proposing in particular several numerical schemes for the spatial and temporal discretization, and for the velocity/pressure coupling as well.

2.4.5. *Results (Post Processeur)*

This component allows visualizing the field’s geometry and mesh, displaying the required results with the post-processor tools that are integrated in "Fluent solver" such as: Graphics and Animation, Plots and Reports.

2.4.6. *Convergence*

At every iteration, Fluent helps to judge the convergence’s state by calculating the residues, which corresponds to the imbalance of the equation (the general discretized equation) summed on all the cells of the field.

3. *Results and discussion*

At present, the studies that have been done on the TS-HRAP for low organic charge have shown that the TS-HRAP in serial mode can have significant yield compared to the parallel mode, keeping 1.5day residence time in the Anaerobic Reactor, the time enough to purify the domestic wastewater similar of Rabat.

In order to find the TS-HRAP optimal residence time in series mode for an important organic charge according to the correlations and the results of the modeling of organic matter
diffusion, we choose to purify an organic charge effluent of 750 mg/l for a large agglomeration, a coupling of residence time:

$$T_{high} = 1.5 \, \text{day} \quad \text{et} \quad T_{bottom} = 2 \, \text{day}$$

By ANSYS have obtained the following contours illustrate the distribution of the substrate in both high and low channels.

➢ The Higher Channel:

![Figure 3: Profile of the concentration of OM, in the high channel, 1st day (Ts = 1.5days)](image)

![Figure 4: Profile of the concentration of the MO, in the high channel, 2nd day (Ts = 1.5day)](image)
Bottom channel:

![Profile of the concentration of OM in the low channel (Ts = 2day)](image)

**Figure 5:** Profile of the concentration of OM in the low channel (Ts = 2day)

Summary Table:

**Table 5:** Summary of the case in series T = 1.5day at the high, T = 2day at the bottom

<table>
<thead>
<tr>
<th>(1.5day ; 2day)</th>
<th>Higher channel</th>
<th>Bottom channel</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>input</td>
<td>output</td>
</tr>
<tr>
<td>COD (mg/l)</td>
<td>750</td>
<td>263.12</td>
</tr>
<tr>
<td>yield (%)</td>
<td>64.92</td>
<td></td>
</tr>
<tr>
<td>Total yield (%)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Discussions

- The relationship between yield in the higher channel (R1), yield in the bottom channel (R2) and total yield (R) is as follows:

  \[ R = \frac{(R1 + R2)}{2} \]

- The substrate concentrations decrease along the channels; we think this is due to the bacterial activity within the basins.

- It is noted that the rate of degradation of the upper basin substrate is greater than that of the lower basin, because the sunlight, in the latter, is unfavorable and also because the input charge is lower.

- The numerical results obtained by FLUENT allowed us to know the yield of each channel for 750mg/l organic charge. These results led us to find the optimale residence time.
- For an important charge, we could reach a very important yield (80%), and at the same time we win half a day in the total residence time in both channels (3.5 days, instead of 4 days). Thus, we gained in terms of the population served and in terms of the half-day stay.

- These results show that TS-HRAP is an effective solution that makes this system intensive, and thus to adapt to larger agglomerations.

4. Conclusion

RA-TS-HRAP integrated system technology can be recommended for large agglomerations. It can also be part of collective sanitation schema, in which small wastewater treatment plants can be built in the urban fabric and integrate perfectly with the landscape without occupying a large area.

Therefore, we have contributed to modeling the integrated system TS-HRAP with the kinetics of elimination of organic matter by the calculation code FLUENT in its version ANSYS, Inc. Products 18.0 (academic version). It was based on experimental and theoretical studies already established on the high rate algal pond of “Institut Agronomique et Vétérinaire Hassan 2”. Then we developed a model on Fluent, on which we applied several couplings of residence time, staying in the total of 4 days in the TS-HRAP.

Furthermore, the results obtained have revealed the possibility to improve the performance and the operation of integrated system TS-HRAP in series mode. Indeed, we thought to decrease the residence time in the high channel in order to keep some of the material easily biodegradable to degraded them in the bottom channel also to improve the performance of the bottom channel. So we can apply a larger organic charge and have an important yield (80%) with a 3.5 day residence time and win a half day in residence time. Instead of treating an organic charge at a residence time of 4 days.

REFERENCES:


Control and Filter Design of Single Phase Grid-Connected Inverter for PV applications

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Abstract— Solar power represents an important potential that has been widely exploited over the last years. For PV-Grid connected applications, the grid current has to be controlled in a way that ensures sinusoidal current injection to meet all standards regarding grid-tied systems. This paper presents the control strategy of a single-phase LCL-Filter grid connected inverter for PV applications. Firstly, PV system and P&O MPPT technique are presented followed by a three grid interfacing passive filters topologies comparison in order to validate the performance and effectiveness of each one. It is then shown that the LCL-Filter provides better harmonic attenuation also a filter size reduction. In addition, this paper suggests a design procedure as well as a passive damping method to avoid instability problems caused by LCL-Filter resonance peak. Furthermore, a control strategy based on a PI-PR controllers combination is introduced to provide high power quality. Several simulations tests are presented to validate the effectiveness of the proposed control procedure for a 4kW PV grid-connected inverter.

Keywords— PV panel, MPPT, L-LC-LCL Filters, harmonic distortion, passive damping, PI-PR controllers, grid-connected inverter.

I. INTRODUCTION

For too long fossil fuels have met most of the world’s energy need. However, they are environmentally damaging techniques and of high cost. Therefore, renewable energy such as wind, sun, biomass,… have arisen as attractive solution since they are environmental friendly and inexhaustible sources of energy. Out of these, PV energy is perhaps the right direction considering that in an hour, the sun radiates solar clean energy enough to cover human energy consumption for a year, which makes it one of these resources that has undergone very quick growth lately [1]-[2]. However, some factors like solar radiance temperature as well as the non-linearity of the PV cells affect the PV system performance [3].

To reduce these challenges effects, a maximum power tracking MPPT algorithm is generally used as an effective technique for maximum power extraction [4].

The connection of the PV source to the main grid requires the use of power electronics since they gives good results and performances [5]. Depending on the nature of the source, several conversion chains are used. In all cases, the output stage is similar and consists of a controlled voltage inverter injecting sinusoidal current to the grid. However, the switching of the power conversion devices causes high frequency harmonics, which is why the used converter is usually connected to the grid via passive filters. Even though its simple structure and control strategy, L filter is considered voluminous and inefficient in order to satisfy harmonic standard regulations stated in IEEE-1547 [6]. To overcome this issue, high order filters were introduced as a solution and more precisely LCL filters thanks to its low cost as well as its excellent harmonic suppression ability [7]. However, it provides an unwanted resonance effect that generates stability problems. In order to solve this, many techniques have been proposed to damp this unwanted resonance, including passive [8] and active damping [9]. Furthermore, high performances operating in terms of injected grid current is essential for DC/AC converters.

This paper proposes a simple and effective control strategy for single-phase grid-tied LCL filter VSI. The proposed structure, shown in Fig. 1, is composed of two cascaded regulation loops resulting in a robust and well-damped control system. The paper also deals with the design procedure of the passive damped LCL filter as well as a comparison of ideal-PR
and non-ideal-PR controllers is presented based on both performances.

II. SYSTEM OVERVIEW

The proposed work presents a grid-connected PV system for residential application. Fig.1 shows the typical structure of a two-stage single-phase grid-connected photovoltaic (PV) system.

The LCL filter composed of series connected \( L_{cl} \), \( L_{cg} \) and \( C_f \) + \( R_d \) is used to attenuate the harmonic injected into the grid caused by the switching of the inverter switches. The VSI’s function is to inject a sinusoidal current in the grid with unity power factor.

According to Fig.1, the VSI mathematical model is as follow:

\[
\begin{align*}
\frac{dL_{cl}}{dt} &= V_{inv} - V_c - R_d I_c \\
\frac{dL_{cg}}{dt} &= V_c - V_g - R_d I_c \\
C_f \frac{dv_c}{dt} &= I_c \\
I_1 &= I_g + I_c
\end{align*}
\]  
(1)

The PV system draws the maximum power from the PV panel (MPPT operation) and transfers it to the grid with high quality power using different control techniques. The most used control strategies in single-phase inverters has two cascaded control loops. The inner loop is a current loop, the outer loop is a voltage control loop, in which the voltage of the DC-side can be ensured, and a reference of the inner current loop is calculated simultaneously in the outer loop.

III. PV SYSTEM CONTROL

The PV panel is a set of series (\( N_p \))-parallel (\( N_s \)) connected pv cells. Thus, modelling a PV panel is modeling a simple pv cell. This section analyzes at first the electrical part of a PV panel through the study of the equivalent circuit of the ideal PV cell and the fundamental equations that describe it and presents next the P&O MPPT technique.

A. Photovoltaic cell model

The pv cell, as reported in Fig.2, consists of a current source in parallel with a diode D and series and parallel resistances \( R_s \), \( R_p \), and \( R_{sh} \).

![Fig.2. Equivalent circuit of solar pv cell](image)

The basic equation describing the \( I_{pv} \sim V_{pv} \) characteristic of the ideal PV is expressed by the following expression [10]:

\[
I_{pv} = I_{ph} - I_0 \left[ \exp \left( \frac{V_{pv}}{V_{oc}} \right) - 1 \right] - \frac{V_{pv} + R_s I_{pv}}{R_{sh}}
\]  
(2)

For a PV panel series cells and \( N_p \) parallel cells, the expression (2) turns into [14]:

\[
I_{pv} = N_p I_{ph} - N_p I_0 \left[ \exp \left( \frac{V_{pv} + R_s}{N_p V_{oc}} \right) - 1 \right] - \frac{N_p V_{pv} + R_s I_{pv}}{R_{sh}}
\]  
(3)

B. Maximum Power Point Tracking

The amount of maximum power that can be extracted from the PV panel at a given time is a function of the solar irradiance and the ambient temperature which are continuously changing so a maximum power tracking algorithm is necessary. Perturb and observe (P&O) algorithm is simple and the most widely used MPPT algorithm, illustrated by Fig.3, because of its balance between performance and simplicity [11]. The P&O algorithm is based on the application of a perturbation to the system and detecting the PV panel output power variation. The duty cycle of the DC-DC converter is then varied and the process is repeated until the maximum power point is reached.
IV. GRID INTERFACING

A. Filters topologies

This part discusses different types of grid connection's filter. In the literature, three filters were proposed:

- First order L Filter;
- Second order LC Filter;
- Third order LCL Filter;

In order to choose the optimal filter topology, filters with reduced power losses and high attenuation performance have priority.

- L Filter: a first order filter that has a -20db/decade attenuation. The transfer function of the L filter is:
  \[ H_L(s) = \frac{1}{sL + R} \]  
  (4)

- LC Filter: a second order filter that has a -40db/decade attenuation and presents a peak at the resonance frequency \( f_{res} \). The transfer function of the LC filter is:
  \[ H_{LC}(s) = \frac{1}{s^2L + C} \]
  (5)

- LCL Filter: a third order filter that has a -60db/decade attenuation and also presents a resonance peak. The transfer function of the LCL filter is:
  \[ H_{LCL}(s) = \frac{1}{s^2L + C} \]
  (6)

Fig. 4. Harmonic Attenuation of L, LC, LCL Filters

In Fig. 4 is reported the Bode diagram of the three filters: At low frequencies, LCL and L filters present a similar attenuation behavior. LC and LCL filters present both a large resonance peak in the second zone, which can cause instability to the system while L filter offers better attenuation. For high frequencies, LCL filter has a better attenuation than that L and LC filter and it is in this zone where lies its interest.

When taking into consideration cost, weight and harmonic attenuation, LCL filter seems to be more suited for our application but it presents resonance peak which can be eliminated by a passive damping strategy.

B. LCL filter design procedure

Due its resonance peak, LCL filter must be designed precisely according to the parameters of the inverter. The design procedure of the LCL filter is inspired from [12].

The first step in the process of designing LCL filter parameters is the calculation of the basic impedance \( Z_b \) and filter capacity \( C_b \) values as indicated below [12]:

\[ Z_b = \frac{V_d^2}{p_n} \]
(7)

\[ C_b = \frac{1}{w_a Z_b} = \frac{1}{2\pi f_e Z_b} \]
(8)

The main LCL-Filter design steps are summarized in Fig.5.
of the LCL filter while large values allow to obtain a filter that is not only bulky but also more expensive.

\[ L_{T_{\text{max}}} = (L_{cl} + L_{cg})_{\text{max}} = 10\% \cdot L_{Tb} = 10\% \cdot \frac{Z_{g}}{2\pi f_{g}} \quad (10) \]

The inverter side inductance is given by the following expression: \[ L_{cl} = \frac{V_{DC}}{6 \cdot \Delta I_{L_i, \text{max}}} \quad (11) \]

Where \( \Delta I_{L_i} \) is the 10% current ripple specified by [16]:

\[ \Delta I_{L_i, \text{max}} = 0.1 \cdot \frac{\sqrt{2} P_{e}}{V_{g}} \quad (12) \]

The grid side inductance can be then deduced from the equation (10) Finally, after designing the filter, the resonant frequency must be calculated to ensure that it satisfies the third limitation of the LCL filter sizing procedure.

C. LCL-Filter Passive Damping

Passive damping methods gain a lot of interest because of their simplicity, cost and simple implementation. Simple series passive damping is considered as the simplest and most adopted method for LCL filter resonance damping [17]. It is obtained by introducing a series resistor with the filter capacity \( C_f \) (Fig.6).

The transfer function of the series \( R_d \) damped LCL filter is expressed by the following equation:

\[ H_{Rd} = \frac{1 + R_d C_f}{l_{cl} l_{cg} C_f s^3 + (l_{cl} + l_{cg}) R_d C_f s^2 + (l_{cl} + l_{cg}) s} \quad (13) \]

The stability of the system is analyzed based on the Bode diagram of the transfer function \( H_{Rd} \) reported in Fig.7.
Fig. 5 shows the Bode diagram of the LCL filter transfer function for different values of the damping resistor. As shown in this figure, the higher is the damping resistor, the more the filter resonance is attenuated. The appropriate value of the damping resistor $R_d$ can be calculated by setting the resonance pulsation and the filter capacity as follows: [18]

$$R_d = \frac{1}{3\omega_{res}C_{F}}$$

V. CONTROL STRATEGY

The aim of control of the grid connected inverter is to ensure a sinusoidal current injection in the grid, a constant dc-link voltage as well as a unity power factor.

Fig. 8. The inverter control strategy

Fig. 8 explains the control strategy: it includes an external PI control loop for the output current regulation, stabilized by an inner PR control loop for the inverter current: the output voltage error $\Delta V_{dc}$ is fed to a PI regulator, which generates reference current $I_{r}$. The PWM inverter is then modulated according to the output of the PR controller.

A. Grid Monitoring

Different methods using different techniques for monitoring the grid voltage are presented in the literature. Among these, the second-order generalized integrator-based PLL (SOGI-PLL) is an effective approach thanks to its fast dynamic response, high filtering capacity, …[20].

B. Voltage Control Loop

The main purpose of the dc-link voltage control loop is to maintain this voltage at a constant reference value while ensuring a zero state error. The voltage control loop is based on a simple PI controller since it is simple, easy to implement and present good results when regulating DC-quantities.

C. Current control Loop

Current controller performance determines the performance of the overall system. In the literature, many control methods have been proposed especially PI and PR controllers. PI controllers are used in order to control the DC-quantities while PR controllers are used to control the AC-quantities [19].

In fact, PI current controller has a considerable steady state error when following the reference current while the steady state error is less for the PR current controller, practically negligible. The PR current controller $C_{PR}(s)$ is represented by [19]:

$$C_{PR\_ideal}(s) = K_p + \frac{K_i s}{s^2 + \omega_0^2}$$

The main drawback is the ideal PR controller infinite gain that can cause instability. This shortcoming can be avoided by using a non-ideal PR controller as shown in the following expression [19]:

$$C_{PR\_non\_ideal}(s) = K_p + \frac{K_i w_c s}{s^2 + 2w_c s + w_0^2}$$

In Fig. 9 is reported bode plot of both ideal and non-ideal PR controllers: As shown, the ideal PR controller presents an infinite gain while the gain of the non-ideal PR controller at the AC frequency $\omega_0$ is finite but it is still large enough to provide only a very small steady state error.

The control model of the current corrector can be derived by simplifying the LCL filter into an L filter. [21]

This simplification is justifiable since at low frequencies, the LCL and L filters present a similar behavior (Fig.4-zone1) as well as the impedance of $C_l$ at low frequencies is high so:

- $L_T = L_{cl} + L_{cg} + L_g$ (16)
- $R_T = R_{cl} + R_{cg}$ (17)

To tune the resonant corrector, we used the criterion of the generalized stability margin [22]: to have the best performance of the system several values of the stability margin $\sigma$ have been tested.

VI. SIMULATIONS RESULTS AND DISCUSSION

The overall control strategy of the PV grid-tied inverter with LCL filter passive damping method is studied and analyzed using the software Matlab-Simulink in this paper. The system parameters used in this study are illustrated in Table I and the PV panel are presented in Table II.
TABLE I
SYSTEM PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid Voltage $V_g$ [V]</td>
<td>230</td>
</tr>
<tr>
<td>Rated Power $P_r$ [w]</td>
<td>4000</td>
</tr>
<tr>
<td>Grid Frequency $f_g$ [Hz]</td>
<td>50</td>
</tr>
<tr>
<td>Switching Frequency $f_{sw}$ [Hz]</td>
<td>10000</td>
</tr>
<tr>
<td>DC Link Voltage $V_{dc}$ [V]</td>
<td>400</td>
</tr>
<tr>
<td>Grid side inductance $L_{gs}$ [mH]</td>
<td>1</td>
</tr>
<tr>
<td>Inverter side inductance $L_{ci}$ [mH]</td>
<td>2</td>
</tr>
<tr>
<td>Filter capacitor $\mu F$</td>
<td>6</td>
</tr>
<tr>
<td>Damping resistor $R_d$ [Ω]</td>
<td>3.5</td>
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</table>

Table II
PV Datasheet

<table>
<thead>
<tr>
<th>Parameter</th>
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<td>$P_{max}$ [w]</td>
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</tr>
<tr>
<td>$I_{mp}$ [A]</td>
<td>5.43</td>
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<tr>
<td>$V_{mp}$ [V]</td>
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<tr>
<td>$I_{oc}$ [A]</td>
<td>5.67</td>
</tr>
<tr>
<td>$V_{oc}$ [V]</td>
<td>46.43</td>
</tr>
</tbody>
</table>

Fig. 10. Grid current Harmonic spectrum (a) L-Filter (b) LC-Filter (c) LCL-Filter
Fig. 11. SOGI-PLL simulation results: grid voltage $V_g$ and grid estimated angle $\theta_g$

Fig. 13. DC-link voltage control simulation results

Fig. 12. Grid current control loop simulation results

Fig. 14. Grid voltage and current simulation results
As shown in Fig.10, the grid current THD improves slightly depending on the adopted grid connection filter. In fact, when using an L-Filter, the THD is of 4.08% (Fig10.a) reduced to 3.08% (Fig10.b) with an LC-Filter and reach finally a value of 1.26% (Fig10.c) with an LCL-Filter. The obtained results confirm then the effectiveness of the LCL-Filter compared to other passive filters topologies.

Fig.11 shows the phase angle obtained with the SOGI-PLL technique: it clearly coincides well with the grid voltage $\nu_g$.

From the simulation results shown in Fig.12, using PR controller, the grid current follows its reference presenting a slight steady state error, practically negligible. This insignificant error is a result of the use of the non-ideal PR controller as it provides small steady state error while avoiding the ideal PR controller instability. We therefore see the particular interest of the use of the resonant corrector for the regulation of sinusoidal quantities.

Similarly, from the simulation results shown in Fig.13, the DC-link voltage $\nu_{dc}$ follows perfectly the reference voltage $\nu_{ref}$.

In addition, the single-phase waveforms of grid current and grid voltage are presented in Fig.14: The power factor is 0.9999 and since the THD of the grid current is equal to 1.26%, the quality of the grid current is fairly good.

VII. CONCLUSION

This paper proposes a complete control strategy for a single-phase inverter for PV applications with associated controllers operating in LCL-grid-connected mode to ensure high power quality injection along with a low grid current THD and stable dc-link voltage.

The effectiveness of the designed LCL-Filter when attenuating the grid current harmonic distortion has been proven with simulation results.

The control topology based on three control loops: a phase locked loop, an inner PR current control loop and external PI voltage control loop has been presented.

This simple proposed control system has been tested and validated with simulation, which has shown that the system meets requirements and standards.

REFERENCES


Multi-objective powertrain cost and autonomy optimization dedicated to electric vehicles

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Abstract—weak autonomy and high manufacturing cost are the main restrictions of Electric Vehicles (EVs). To solve these problems, several research studies try to improve the electric vehicle performance.
This paper is about providing a multi-objective optimization algorithm combined with analytical model of electric vehicle. Permanent Magnet Synchronous Machine (PMSM) is chosen as the power train engine. The motor mathematical modelling is first described and the genetic algorithm is then detailed. This study aims to find best design parameters of motor-converter that provide optimal autonomy with an acceptable cost.

Keywords—powertrain; autonomy optimization; cost optimization; genetic algorithm; multi-objective optimization; PMSM; weighted sum method

I. INTRODUCTION

Nowadays, different types of electric vehicles are increasingly designed because they represent an ideal substitute to solve pollution problems and provide a big contribution in reducing carbon and greenhouse gases.

Nevertheless, the major drawbacks of electric vehicles are their weak autonomy, which is directly bound to the low-level storage capacity of batteries, and their high cost. [1][2]
This fact prevents their introduction in the consumer market in important numbers.

The electric vehicle (EV) system includes two subsystems: the electric machine and the vehicle platform (electrical energy source, control system and a power converter) [1][3]
In this context, choosing the best motor configuration and finding its optimum design parameters are an important task for an acceptable autonomy and affordable cost.

The permanent magnet synchronous motor (PMSM) with radial flux is chosen in this study. It does not require an external power source for excitation and demonstrate high efficiency ratios compared with induction motors. [4][5]

This paper is organized as follow: First, the structure of the powertrain is briefly introduced. Then, the PMSM model is detailed. Next, we formulate the multi-optimization problem by fixing the objective function and the technological and geometrical constraints. Simulation results are then presented and discussed.

I. POWERTRAIN MODELLING

The powertrain design is an important step that can highly influence the autonomy and the cost. It’s in fact a multidisciplinary task that needs a deep research on different components, their size and composition.
Electrical, mechanical and material knowledge is required to make compromises between all the deives. [6]

As illustrated in fig.1, the powertrain of an EV is composed of: A battery, DC/AC converter, electric motor and mechanical linkage system (differential, reduction gear and wheels) [7][8].

Fig.1 Electric vehicle powertrain structure

A drive system of an electric vehicle should include the following proprieties:
- High robustness facing various operating conditions
- Rational cost
- High torque in starting phase and climbing
- Regenerative system when braking
- Acceptable efficiency

To drive an electric vehicle system, two configurations could be noted: one electric motor or two electric motors each for each wheel.
In this paper, one front drive electric motor is chosen.

II. MATHEMATICAL MODELLING OF PMSM

The permanent magnet synchronous motor is an AC machine composed of three stator windings Y connected and displaced by 120 electrical degrees.
The motor model can be expressed when transformed in the rotor oriented coordinates d-q as follow: [4][9]

\[ u_d = r_s i_d + \frac{d\Phi_d}{dt} - \omega \Phi_q \]  \hspace{1cm} (1)

\[ u_q = r_s i_q + \frac{d\Phi_q}{dt} - \omega \Phi_d \]  \hspace{1cm} (2)
\[ \Phi_{sd} = L_{sd} i_{sd} + \Phi_f \]  
\[ \Phi_{sq} = L_{sq} i_{sq} \]  
\[ C_r = \frac{3}{2} p \left[ \Phi_f I_q + (L_d - L_q) I_s I_q \right] \]  
\[ C_r - C_s = J \frac{d\Omega}{dt} + f \Omega \]  
\[ \Phi_{sd} = L_{sd} i_{sd} + \Phi_f \]

Where \( \Omega \), \( p \), \( J \), \( f \), \( C_r \), \( C_s \), \( \Phi_f \) denote: the rotation’s speed, the number of pairs of poles, the moment of inertia, the coefficient of viscous friction, the resistive torque, the electromagnetic torque and the flux produced by the permanent magnet.

\( L_{sd} \), \( L_{sq} \), \( V_{sd} \), \( V_{sq} \), \( r_i \) respectively: “d” axis stator inductance, “q” axes stator inductance, “d” axis stator voltage, “q” axis stator voltage and the stator windings resistance.

III. FORMULATION OF COST AND AUTONOMY OPTIMIZATION PROBLEM

The traction motor and the controller are the two main elements of an electric drive system. Therefore, they must be designed to operate with each other as one system.

After defining the powertrain configuration, we explain in this section the optimization problem that focus on the motor-converter mathematical equations to find compromises between higher autonomy and affordable production cost.


A. Autonomy objective function

The electric vehicle autonomy is expressed for any velocity profile as follow:

\[ Au = \frac{W_b \eta \eta V_m}{P_u} \]  

Where \( W_b \) is the stocked energy in battery, \( \eta \) is the traction chain efficiency, \( V_m \) is the average speed and \( P_u \) is the average useful power.

\( V_m \) is calculated according to the following formula:

\[ V_m = \frac{1}{n} \sum_{k=1}^{n} V(k) \]  

The autonomy is directly related to the powertrain efficiency. Minimizing the autonomy is therefore minimizing the powertrain efficiency which is expressed as:

\[ \eta = \frac{P_u}{P_u + P_c + P_i + P_m + P_r + P_{\text{cond}}} \]  

\( P_u, P_c, P_i, P_m, P_r, P_{\text{cond}} \) are respectively: average useful power, copper losses, iron losses, mechanical losses, reducer losses and converter losses.

They are given by the following expressions:

\[ P_u = \frac{C_{\text{wm}} V_m}{R_w} \]  

where \( C_{\text{wm}} \) is the average torque should be developed by motor wheels.

\[ P_i = q f^{1.5} (M_{\phi_s} B_{cs}^2 + M_{\phi} B_{s}^2) \]  

\[ P_o = 3. R \left( \frac{I}{\sqrt{2}} \right)^2 \]  

We define \( R \) as the motor phase resistance and expressed as follow:

\[ R = \rho \frac{\sqrt{L_{sp} n t c}}{3 I} \]  

and \( I \) motor average current on the circulation mission:

\[ I = \frac{2 C_d}{3 r_s K_m} \]  

\[ K_m = \frac{8}{\pi} N_{\text{sp}} D_o D_i B_{\phi_s} \sin \left( \frac{\pi}{2} \beta \right) \sin \left( \frac{\pi}{2} \beta \alpha \right) \]  

\[ P_m = \frac{C_{\text{wm}} V_m}{(1 - K_m)(1 - K)} \]  

\[ P_r = K_r \left( \frac{C_{\text{wm}} V_m}{R_w} \right) \]  

\[ P_c = a I_m^2 + b I_m + c \]  

After defining the losses equations, we have noticed that the autonomy depends directly on the following design parameters: \( R_w, r_g, D_i, D_o, B_{\phi_s}, \delta, B_{cs}, B_{ce} \) and \( N_{\text{sp}} \).

\( R_w \): Wheel radius

\( r_g \): Gear reduction ratio

\( D_i \): Motor inner diameter

\( D_o \): Motor outer diameter

\( B_{\phi_s} \): Air-gap induction
\( \delta \): Acceptable current density in coils

\( B_{cs} \): Magnetic induction in stator yoke

\( B_{cr} \): Magnetic induction in rotor yoke

\( N_{sph} \): Number of spires per phase

As a result, the autonomy is function of:

\[
A_u = f \left( R_u, r_e, D_i, D_o, B_g, \delta, B_{cs}, B_{cr}, N_{sph} \right) \tag{19}
\]

B. Cost objective function

To minimize the EV cost, we have focused in this work on the motor-converter set since they are the main parts of a powertrain.

The cost objective function is expressed as follow: [3][11]

\[
\text{Cost} = C_m M_m + C_m M_m + (M_{\eta} + M_{\eta} + M_{\eta}) \left( C_{\eta} + C_{\eta} \right) + C_{\eta} U_{dc} \cdot I_m \tag{20}
\]

Mass equations are given by: [10]

\[
M_m = \pi \left[ \left( \frac{D_s + e}{2} + H_{ho} \right)^2 - \left( \frac{D_s + e}{2} + H_{ho} \right)^2 \right] D_i M_{st} \tag{21}
\]

\[
M_m = \frac{A_{wi}}{2} N \left[ \left( \frac{D_s + e}{2} + H_{ho} \right)^2 - \left( \frac{D_s + e}{2} + H_{ho} \right)^2 \right] D_i M_{st} \tag{22}
\]

\[
M_m = \pi \left[ \left( \frac{D_s + e}{2} - H_m \right)^2 - \left( \frac{D_s + e}{2} - H_m \right)^2 \right] D_i M_{st} \tag{23}
\]

\[
M_m = M_{m} \cdot p \left[ \left( \frac{D_s + e}{2} - H_{ho} \right)^2 - \left( \frac{D_s + e}{2} - H_{ho} \right)^2 \right] D_i M_{st} \tag{24}
\]

\[
M_{c} = 3 \cdot 2 D_s + 4 A_{wi} \cdot \left( \frac{D_s + e}{2} + H_{ho} \right) \frac{N_{sph} \cdot I_m}{\sqrt{2} \Delta} \tag{25}
\]

\[
I_m = \frac{2}{3} \frac{R_u M_m}{r_e K_e} \left[ \frac{V_h}{I_d} + 9.8 \cdot \sin \left( \frac{\pi}{180} \right) \right] \tag{26}
\]

We define:

\( C_m \): Cost of a kilogram of magnet

\( C_c \): Cost of a kilogram of copper

\( C_i \): Cost of a kilogram of iron

\( C_{fkh} \): Motor cost fabrication/Kg

\( C_{conv} \): Converter cost per KW

\( M_m \): Magnet mass

\( M_c \): Copper mass

\( M_{\eta} \): Stator yoke mass

\( M_s \): Stator teeth mass

\( M_{\eta} \): Rotor yoke mass

\( U_{dc} \): DC bus voltage

After fixing all the mass equations we can conclude that the cost is function of:

\[
\text{cost} = f \left( R_u, r_e, D_i, D_o, B_g, e, U_{dc} \right) \tag{27}
\]

“e” represents the gap thickness.

C. Problem constraints

To establish the different constraints of autonomy-cost problem, we have considered physical, technological and expert properties.

1) Geometrical constraints:

\[
100 \text{mm} \leq D_s \leq 250 \text{mm}
\]

\[
90 \text{mm} \leq D_i \leq 140 \text{mm}
\]

\[
1 \text{mm} \leq e \leq 8 \text{mm}
\]

2) Technological constraints

\[
0.25 \text{m} \leq R_u \leq 0.35 \text{m}
\]

\[
3 \leq r_e \leq 8
\]

\[
2 \leq \delta \leq 7
\]

\[
20 \leq N_{sph} \leq 400
\]

3) Magnetic constraint

\[
0.1 \text{T} \leq B_g \leq 1.04 \text{T}
\]

\[
0.2 \text{T} \leq B_{cr} \leq 1.6 \text{T}
\]

\[
0.2 \text{T} \leq B_{cr} \leq 1.6 \text{T}
\]

IV. MULTIOBJECTIVE OPTIMIZATION

A. Principle

A multi-objective optimization is a mathematical optimization problem that involves minimizing or maximizing more than one objective function. It has been applied in different fields especially engineering and economics. It has in general the following form: [10][12]
Minimise/Maximise: \( F(X) = (F_1(x), F_2(x), \ldots, F_n(x)) \)

With:

\[
\begin{align*}
    g_j(X) &= 0, \quad j = 1, \ldots, m \\
    h_k(X) &= 0, \quad k = 1, \ldots, k
\end{align*}
\]

n: Number of objective functions
m: Number of equality constraints
k: Number of inequality constraints

In this study, increasing the power train autonomy will highly increase its cost.

In this context, the challenge of a multi-objective optimization problem is to find optimal solutions despite the presence of conflicting objective functions.

A. Weighted sum method

To solve the multiple objectives optimization problem, combining all the objectives into a single one is the solution.

The weighted sum is the simplest method to make decision in a multi-criteria problem. [10] [13]

We define:

\[
F(F_1, F_2) = F(w_1, w_2) = w_1 F_1 + w_2 F_2
\]

\( F \) is the function to maximize.

\( w_1 \) and \( w_2 \) are weighting values.

The objective function can be divided by a positive number without changing the solution. [11]

When dividing (30) by \( w_1 \), we can define \( w \) as:

\[
w = \frac{w_2}{w_1}
\]

Then (30) takes the following form:

\[
F(w) = F_1(X) + wF_2(X)
\]

The cost minimization problem is transformed into a maximization problem to have a homogenous function. Therefore, our cost and autonomy optimization problem consists in maximizing \( F \) function taking into account to keep \( \text{Im} \succ \text{Id} \) and \( \eta \geq 0.95 \)

\[
F = Au + a.(Cm - Cost)
\]

\( Cm \) is a pre-defined maximum cost of the motor-converter

To conclude, the optimization problem can be expressed as follow:

\[
\begin{align*}
    &\text{Maximize } F \\
    &I_m \geq I_d \\
    &\eta \geq 0.95 \\
    &0.1 \leq B_{\alpha} \leq 1.04 \\
    &250 \leq R_w \leq 350 \\
    &3 \leq r_e \leq 8 \\
    &90 \leq D_i \leq 140 \\
    &100 \leq D_e \leq 250 \\
    &1 \leq e \leq 8 \\
    &2 \leq \delta \leq 7 \\
    &0.2 \leq B_{\alpha} \leq 1.6 \\
    &0.2 \leq B_{\alpha} \leq 1.6 \\
    &20 \leq N_{\text{wh}} \leq 400 \\
    &200 \leq U_{\text{dc}} \leq 400
\end{align*}
\]

V. SIMULATION AND RESULTS

The genetic algorithm method was used in this study to solve the optimization problem [14].

The figure 2 describes the steps of the optimization process.

Fig 2 Cost and autonomy multi-objective algorithm
The Genetic Algorithm (GA) was coded with Matlab using the parameters summarized in the table below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population size</td>
<td>1022</td>
</tr>
<tr>
<td>Mutation probability</td>
<td>0.01</td>
</tr>
<tr>
<td>Crossover probability</td>
<td>0.85</td>
</tr>
<tr>
<td>Generations number</td>
<td>100</td>
</tr>
</tbody>
</table>

The following table resumes the EV simulation parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle mass</td>
<td>800Kg</td>
</tr>
<tr>
<td>Maximal speed of the EV</td>
<td>100Km/h</td>
</tr>
<tr>
<td>Vehicle front area</td>
<td>1.4m²</td>
</tr>
<tr>
<td>Rolling resistance coefficient</td>
<td>0.013</td>
</tr>
</tbody>
</table>

After 100 iterations, the optimal values of objectives function for a maximal autonomy and minimal motor-converter cost are given in the following table.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Optimal solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bg</td>
<td>0.1175T</td>
</tr>
<tr>
<td>Rw</td>
<td>0.2519m</td>
</tr>
<tr>
<td>rF</td>
<td>3.0929</td>
</tr>
<tr>
<td>Dl</td>
<td>90.9286mm</td>
</tr>
<tr>
<td>Do</td>
<td>102.7859mm</td>
</tr>
<tr>
<td>e</td>
<td>1.0929mm</td>
</tr>
<tr>
<td>δ</td>
<td>2.0929</td>
</tr>
<tr>
<td>Bca</td>
<td>0.226T</td>
</tr>
<tr>
<td>Bcr</td>
<td>0.226T</td>
</tr>
<tr>
<td>Nspb</td>
<td>27.0577</td>
</tr>
<tr>
<td>Ud</td>
<td>201.8573V</td>
</tr>
<tr>
<td>Optimal value of autonomy function</td>
<td>211.111 Km/h</td>
</tr>
<tr>
<td>Optimal value of cost function</td>
<td>1724.333 $</td>
</tr>
</tbody>
</table>

Fig. 3 Evolution of some optimization parameters function of iterations

The figure 3 illustrates the evolution of the wheel radius, the gear reduction ratio, the outer and inner diameter and the air-gab induction in function of iterations.

We can notice that some values are quite far from the optimal result. This fact is due to mutations.

The obtained results of optimal solutions conforms the constraints we have previously fixed.
Optimal autonomy and cost values are acceptable with demonstrates that the proposed approach to solve the multi-objective problem is satisfying.

Conclusions

In this paper, we have developed a multi-objective optimization approach using the weighted sum method.

The developed problem aims to find the optimal configuration that maximizes the overall powertrain efficiency with a minimum possible cost of the motor-converter.

The optimum results obtained respect the fixed constraints which shows the efficiency of the proposed algorithm.

II. REFERENCES


Strategies of Speed Control of Induction Motor Drive

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Abstract—The synthesis of the standard proportional integral regulator types is characterized by its sensitivity during parametric variations of controlled system controlled. So, to remedy this problem the adjustment techniques are developed. In this order, the work presented in this paper proposes the use of a fuzzy regulator for controlled the speed of a three-phase induction machine.

For this purpose, the model of the induction machine is presented as well as the structure of the fuzzy control adopted. Then, thanks to the numerical simulation under MatLab the performances during the variation of the rotor resistance are analyzed compared to the result with a PI controller.

Keywords—Induction motor, FLC controller, PI controller, speed control, Performances, simulation.

I. INTRODUCTION

In industry, variable speed electric drives are often used. He are generally equipped with electric machines such as squirrel induction machines because require the lower maintenance, smaller motor size, and improved reliability. But, there control is complex due highly non-linear and time-varying dynamics. So, the vector control strategy has solved the coupling problem in separation between the flux and electromagnetic torque but this control is sensitive to drive parameter variations and therefore the performance may deteriorate if conventional controllers are used [1]. So, the cage induction motor (IM) is most often used of variable speed.

Generally, the variable speed application requires the high performances. However, field oriented control of induction machines was introduced by Blaschke and Hasse which has better dynamic response. This method is one of the most popular drive machine due to its dynamic performance [2-4].

Most of the research on the drive design of the IM concentrated on the modern control design, such as Sliding Mode Control [5], Fuzzy Logic Control [6], Neural Networks Control [7], IL Control [8], Neural-Fuzzy Control [9], etc. However, the rotor flux indirect vector control technique is most widely used [10]. The main objective of the FOC is to independently control the flux and the torque.

These two control methods are introduced and applied to an indirect field oriented induction motor. These controllers are evaluated under simulations for a variety of operating conditions of the drive system and the results demonstrate the ability of the proposed control structures to improve the performance and robustness of the drive system.

The organization of this paper is as follows. Section II develops the model of IM and introduces the field oriented control method applied for induction machine. Section III presents the synthesis of speed fuzzy logic controller. Section IV shows the simulation results and their discussion. Finally, section V presents the conclusion.
II. SYSTEM DESCRIPTION AND CONTROL

The description of indirect field oriented control (IFOC) considered is show in Fig. 1 and the induction motor parameters are indicates in the Table I.

\[ T_e = K_f \left( \Phi_{ds} i_{qs} - \Phi_{qr} i_{qs} \right) \]  

(4)

Where, \( K_f = \frac{3}{2} \frac{L_m}{L_r} \) is the torque constant with \( p \) is number of pairs poles.

The success of FOC is based on the proper division of stator current into two components: the torque component \( i_{ds,ref} \) and magnetizing flux component \( i_{dq,ref} \). The IFOC method uses a slip equation for partitioning the stator current [15-17]:

\[ \omega_{sl,ref} = -\frac{R_s}{L_s} \frac{i_{ds,ref}}{L_d} \frac{i_{dq,ref}}{L_q} \]  

(5)

With: \( \omega_{sl,ref} = \omega_s - \omega_r \)

Where, \( R_s \) an \( L_r \) rotor resistance and inductance referred to stationary side respectively; \( \omega_{sl,ref} \) : slip frequency; \( \omega_s \): synchronous speed; \( \omega_r \): rotor speed.

A block diagram of IFOC is shown in Fig. 2.

The classic Proportional and Integral (PI) controller is firstly calculated, by the method of location of poles. Considering the transfer function of the mechanical part of the machine:

\[ \frac{\Omega(s)}{T_{em}(s)} = \frac{1}{k_f + J.S} \]  

(6)

The structure speed control is show by Fig. 3.

The transfert function is:

\[ \frac{\Omega(s)}{\Omega^*(s)} = \left( \frac{K_p S + K_i}{J} \right) \left( \frac{1}{P(s)} \right) \]  

(7)

Where

\[ P(s) = s^2 + \frac{k_f + K_p}{J} + \frac{K_i}{J} = 0 \]  

(8)
Imposing two (2) conjugated complex poles: $P_{1,2}=\alpha(\pm j)$, in closed loop, we deduce by identification:

$$S^2 + 2\alpha S + 2P^2$$  \hspace{1cm} (9)

So, $$K_p = 2\alpha J - k$$  \hspace{1cm} (10)

And, $$K_i = 2\alpha^2 J$$  \hspace{1cm} (11)

III. FUZZY LOGIC PRINCIPLE

In this section, we will illustrate the principles of fuzzy controllers, their design and their use in vector control of the IM. The principle of fuzzy logic controllers is based on the techniques of artificial intelligence whose theoretical foundations have been made by Zadeh [18]. The fuzzy logic controller operates in know ledge-based way, and its knowledge relies on a set of linguistic if...then rules, like human operator. The block diagram of fuzzy logic control is mainly depicted in Fig. 4 [19].

![Fig. 4. The structure of a fuzzy logic](image)

The FLC is made up of parameters such as rules base, data base, membership functions, input and output scaling factor (SF) [20-22].

In order to apply the vector control of IM, we define the error ($e$) and the derivative of the error ($de$) of the variable to be controlled:

$$\begin{cases} e_X(k) = X_{ref}(k) - X(k) \\
d e_X(k) = e_X(k) - e_X(k-1) \end{cases}$$  \hspace{1cm} (12)

Where $X$ present, currents components $i_{ds}$, $i_{qs}$, and speed $\omega_c$.

The definition of membership function, the controllers has too inputs ($e(k)$ , $de(k)$) and a single output ($u_a$), see Fig. 5, Fig. 6 and Fig. 7. Otherwise the Fig. 8 and Fig. 9 shows respectively, the surface and rules.

![Fig. 5. Inputs membership function of “e” and of “de”](image)

Fig. 6. Output membership function of “$du_a$”

![Fig. 7. Surface of FLController](image)

![Fig. 8. Rules of FLC](image)

TABLE II: Rules tables

1. If (e is ng) and (de is is ng) then (du is is ng)
2. If (e is ng) and (de is ez) then (du is is ng)
3. If (e is ng) and (de is pg) then (du is is ng)
4. If (e is ez) and (de is ng) then (du is is ng)
5. If (e is ez) and (de is ez) then (du is ez)
6. If (e is ez) and (de is pg) then (du is pg)
7. If (e is pg) and (de is ng) then (du is is ng)
8. If (e is pg) and (de is ez) then (du is pg)
9. If (e is pg) and (de is pg) then (du is pg)
The number of linguistic value are characterized by the symbols likewise: ng: negative big, ez: zero equal; pg: positive big.

The development of the basic rules of the controller is interpreted by the rules of the form (If….Then). The fuzzy rules that defined the output of the controllers according to inputs. Where Table 2 present two linguistics variables of inputs “e” and its variation “de” and the output variable « du ».

Table 1: Rules tables

<table>
<thead>
<tr>
<th>dc / e</th>
<th>ng</th>
<th>ez</th>
<th>pg</th>
</tr>
</thead>
<tbody>
<tr>
<td>ng</td>
<td>ng</td>
<td>ng</td>
<td>ez</td>
</tr>
<tr>
<td>ez</td>
<td></td>
<td>ez</td>
<td></td>
</tr>
<tr>
<td>pg</td>
<td>ez</td>
<td>pg</td>
<td>pg</td>
</tr>
</tbody>
</table>

IV. SIMULATION RESULTS

Validation of this study was done by comparison and performance analysis engine magnitudes.

The parameters motor are: \( R_e = 0.435 \Omega \), \( R_r = 0.316 \Omega \); \( L_s = 2 \text{ mH} \); \( L_r = 2 \text{ mH} \); \( L_m = 9.3 \text{ mH} \); \( J = 0.089 \text{ Kg.m}^2 \); \( K_f = 0.0002 \text{ Kg.m/s} \) and \( p = 2 \).

For this purpose, Two cases of operating are considered: the case where the motor parameters are nominal and the case where the rotor resistance changes. For a reference speed of 1400 rpm, Figure 9 shows the velocity speeds when the rotor resistance is nominal. The essential parts are represented by the zooms A and B. Fig. 10 and Fig. 11 show the superposition of speed responses, respectively, for the case where PI and FLC are used.

It is clear that for PI Controller performance degrades during the application of the load at the moment 3 seconds (loops of speed control); that is, the speed does not follow its reference. On the other hand, when using the controller FLC, the speed correctly follows its reference despite the load (see zoom C). Thus, the performance for FLC is much better.

V. CONCLUSIONS

In this paper, the fuzzy field-oriented control of an induction motor has presented. Different regimes of operation are studied. The case of the variation of rotor resistance was considered to evaluate the performance of the fuzzy approach. The simulation
results have shown that the fuzzy logic controller has very good dynamic performances. Additionally, the robustness tests have shown that FFOC was insensitive to parameters variation. This returns to the fact that the fuzzy logic controller synthesis was realized without taking account of the machine model.

REFERENCES


TECHNICO-ECONOMIC ASPECT ANALYSIS IN THE DESIGN OF SOLAR CHIMNEY POWER PLANTS

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Abstract—The present work is dedicated to the techno-economic analysis of the solar chimney power plant (SCPP) of Manzanares site. This site is located in the south region of Spain. Manzanares. This prototype reached a production of 44MWh/year with a power peak of 50kW [7]. A mathematical model [1] was presented to describe the solar chimney power plant mechanism in detail, establish a technical study, evaluate the annual performances, and study the effect of various parameters on power output. The economic study is based on the calculation of the LCOE "Levelized Cost of Energy" which corresponds to the complete price of energy over the lifetime of the equipment. A profitability study of the prototype of Manzanares is developed for Maghreb countries such as Algeria, Tunisia and Morocco as well as for some European countries: Spain, Germany and Denmark.

Keywords—Renewable energies, Solar chimney power plant, Technico-economic study, Mathematical modeling.

Technical Symbol | Signification | Units
--- | --- | ---
Aₙb | Cross sectional area of the solar chimney | m²
Aₑ | Area of the solar collector | m²
Cₚ | Specific heat of air | J/kg.K
G | Solar heat flux | W/m²
H | Solar chimney height | m
h | Outflow heat transfer coefficient | W/m².K
M | Air mass flow rate | kg/s
Pₑ | Max. output mechanical power | kW
Pₑ | Electric power produced | kW
Q | Heat absorbed by air in the collector | kW
Tₑ | Temperature of air in the collector | °C
Tₑ | Ambient temperature | °C
vₑ | Air velocity of the solar chimney | m/s
α | Absorbance of the solar collector |
ηₑ | Efficiency of solar collector |
ηₑ | Electrical generator efficiency |
ρₑ | Air density in the collector | kg/m³
ρₑ | Ambient air density | kg/m³
ΔP | Pressure difference between the chimney base and the surroundings |

Economical Signification | Units
--- | ---
I | Total investment cost | Mio. €
κ | Discount rate | %
κ | Expected lifetime of power station | year
Mₑ | Annual operation & maintenance cost | Mio. €/a
Eₑ | Electrical energy generated in the year | kWh

I. INTRODUCTION

In order to ensure sustainable development and to diversify its energy needs, the world is engaged in an important program of development of renewable energies. To meet its energy needs, it aims to significantly increase the contribution of renewable energies. One of the options that will help meet these demands is the solar chimney power plant (SCPP). The SCPP is a device of renewable energy power plant that transforms solar energy into electricity.

The first SCPP prototype was proposed by Schlaich and built in 1982 in Manzanares, Spain [3, 4]. Research works were conducted on the power plant and it proved that the SCPP concept is technically viable for power generation [5]. There are normally three methods in studying the performance characteristics of a solar chimney power plant: analytical method, numerical method and methods based on similarity theory [6].

The Manzanares solar updraft tower (Spain, 150 km south of Madrid) is considered in this study. It is a prototype, built between 1982 and 1989 years. The prototype has a tower of 200m high and a collector of 45 000m². It reached a production of 44MWh/year, for a peak power of 50kW [7].

| TABLE I | Technical data of Manzanares prototype [7]. |
--- | --- |
Hₑ | Tower height [m] | 194.6 |
Rₑ | Tower radius [m] | 5.08 |
Rₑ | Mean collector radius [m] | 122 |
Hₑ | Mean roof height [m] | 1.85 |
Uₑ | Upwind velocity [m/s] | 5 |
ηₑ | Turbine efficiency | 0.83 |
α | Friction loss factor | 0.9 |

II. MATHEMATICAL MODEL

The analysis presented in this paper is based on the following simplifying assumptions [1]:

1- Uniform heating of the solar collector surface.
2- No temperature gradient of the air inside the collector.
3- No heat loss from the chimney walls.
4. Friction losses of the flowing air in the chimney are neglected.

A. Technical Model

A.1. The Solar Collector

The heat balance equation of the collector can be simplified as:

\[\alpha G A_{\text{coll}} - \dot{h}_{\text{coll}} A_{\text{col}} (T_{\text{col}} - T_0) = m C_p (T_{\text{col}} - T_0)\]  \hspace{1cm} (1)

Where:

\[n = \frac{\dot{h}_{\text{coll}}}{A_{\text{coll}} C_p}\] \hspace{1cm} (2)

The efficiency of the solar collector can be defined as:

\[\eta_{\text{coll}} = \frac{\dot{h}_{\text{coll}}}{\alpha G A_{\text{coll}}}\] \hspace{1cm} (3)

A.2. The Chimney

Pressure developed due to the air density between entrance at temperature \(T_{\text{col}}\) and exit at \(T_0\) in the chimney is calculated as:

\[\Delta P = g \int_{T_0}^{T_{\text{col}}} \frac{(\rho - \rho_{\text{coll}})}{\rho_{\text{coll}}} \, dx\] \hspace{1cm} (4)

For a vertical adiabatic chimney, the integrating equation (4) gives:

\[\Delta P = g \left(\rho - \rho_{\text{coll}}\right) H\] \hspace{1cm} (5)

The air velocity in the chimney can be evaluated using Bernoulli equation as follows:

\[u = \sqrt{2 \Delta P / \rho_{\text{coll}}}\] \hspace{1cm} (6)

Substitution of equation (5) into equation (6) gives:

\[u = \sqrt{\frac{2 g H (\rho - \rho_{\text{coll}})}{\rho_{\text{coll}}}}\] \hspace{1cm} (7)

Using the following approximation for ideal gas:

\[\frac{P_{\text{coll}}}{P_{\text{exit}}} = \frac{T_{\text{coll}}}{T_{\text{exit}}}\] \hspace{1cm} (8)

The air velocity in the chimney can be written as:

\[u = \sqrt{\frac{2 g H (T_{\text{coll}} - T_0)}{T_0}}\] \hspace{1cm} (9)

Combine equations (1) and (9) yields:

\[\frac{2 g H}{\alpha G A_{\text{coll}}} - \frac{\dot{h}_{\text{coll}}}{\rho_{\text{coll}} A_{\text{col}} C_p} + \frac{\dot{h}_{\text{coll}}}{\rho_{\text{coll}} A_{\text{coll}} C_p} (u^2 + \dot{h}_{\text{coll}} T_0/\rho_{\text{coll}}) - 2 g H \alpha G A_{\text{coll}} = 0\] \hspace{1cm} (10)

The last equation can be solved numerically to evaluate the air velocity through the chimney, taking the value of heat transfer coefficient:

\[b = 5.7 + 0.8 \times V_{\text{wind}}\] \hspace{1cm} (11)

A.3. The Turbine

Turbines are located at the bottom of the chimney. The maximum mechanical power taken up by the turbines as recommended by Schlaich [9] is:

\[P_{\text{max}} = \frac{1}{2} \text{u} A_{\text{ch}} \Delta P\] \hspace{1cm} (12)

Where:

\[\Delta P = \rho_{\text{coll}} g H \frac{T_{\text{coll}} - T_0}{T_0}\] \hspace{1cm} (13)

The heat absorbed by the solar collector can be written as:

\[Q = \eta_{\text{coll}} A_{\text{coll}} G\] \hspace{1cm} (14)

If the generator efficiency defined as \(\eta_g\), the electric power from the solar chimney becomes:

\[P_e = \eta_g P_{\text{max}}\] \hspace{1cm} (15)

B. Economical Model [2]

The levelized cost of electricity (LCOE) is given by:

\[LCOE = \frac{I + \frac{E}{(1 + r)^n} - \text{M}_{\text{p}}}{E_p}\] \hspace{1cm} (16)

According to the formulation above, if the mass flow rate is known or assumed then the power output can be determined. The different steps of the power output computation are:

1. Choose a density,
2. Calculate \(u\) using Eq. (10),
3. Calculate \(T_{\text{col}}\) using Eq. (9),
4. Calculate \(\rho_{\text{coll}}\) using Eq. (8) and perform the iteration,
5. Calculate \(\eta_{\text{coll}}\) using Eq. (3),
6. Calculate \(P_{\text{max}}\) using Eq. (14),
7. Calculate \(P_e\) using Eq. (15),
8. Calculate \(P_{\text{col}}\) using Eq. (15),
9. Calculate \(\text{LCOE}\) using Eq. (16),

A flowchart for these procedures is illustrated in Fig. 1 [1].

![Flow chart of computational procedure](image)

---

III. RESULTS AND DISCUSSION

A. Technical Model

The maximum horizontal solar irradiation and the ambient temperature of the city of Ciudad Real (Manzanares, Spain) are used to analyze the performance of the solar chimney. Meteorological data are taken by METEONORM 7 software.
with period data (1991-2010). These are illustrated in the following table:

<table>
<thead>
<tr>
<th>Month</th>
<th>Solar Heat Gain [W/m²]</th>
<th>Max. Monthly average Temp [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>566</td>
<td>279.25</td>
</tr>
<tr>
<td>2</td>
<td>699</td>
<td>281.55</td>
</tr>
<tr>
<td>3</td>
<td>928</td>
<td>284.85</td>
</tr>
<tr>
<td>4</td>
<td>950</td>
<td>287.15</td>
</tr>
<tr>
<td>5</td>
<td>975</td>
<td>291.85</td>
</tr>
<tr>
<td>6</td>
<td>993</td>
<td>298.45</td>
</tr>
<tr>
<td>7</td>
<td>989</td>
<td>300.85</td>
</tr>
<tr>
<td>8</td>
<td>986</td>
<td>300.25</td>
</tr>
<tr>
<td>9</td>
<td>870</td>
<td>295.45</td>
</tr>
<tr>
<td>10</td>
<td>767</td>
<td>289.55</td>
</tr>
<tr>
<td>11</td>
<td>652</td>
<td>283.15</td>
</tr>
<tr>
<td>12</td>
<td>531</td>
<td>279.85</td>
</tr>
</tbody>
</table>

To validate the analytical model, the theoretical results were compared with experimental data obtained on Manzanares prototype. The power plant results are given in Table 3.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>I [W/m²]: Irradiation</td>
<td>1000</td>
<td>975</td>
</tr>
<tr>
<td>T₀ [°C]: Ambient temperature</td>
<td>302</td>
<td>291.85</td>
</tr>
<tr>
<td>nₑ: Collector efficiency</td>
<td>0.32</td>
<td>0.29648</td>
</tr>
<tr>
<td>Pₑ [kWe]: Power output</td>
<td>50</td>
<td>48.67137</td>
</tr>
<tr>
<td>u [m/s]: Upwind velocity in the collector</td>
<td>15</td>
<td>17.65388</td>
</tr>
<tr>
<td>ΔT [°C]: Temperature difference (collector / ambient)</td>
<td>20</td>
<td>23.8231</td>
</tr>
</tbody>
</table>

The results displayed in figure 2 illustrate the SCCP performances such as the power and efficiency. In general, the output power increase during the summer months as solar heat flux increases which generates the increase of the efficiency.

![Annual collector efficiency](image1)
![Annual power produced](image2)

Figure 3 presents a comparison between measured and calculated average monthly energy outputs, showing that there is good agreement between the theoretical and measured values. The total annual energy measured is around 44,623 MWh and the total annual calculated energy is 46,028 MWh.

3.2. Economical results

Electricity produced by the solar updraft tower is proportional to the intensity of global solar radiation, the collector area and tower height. There is in fact no optimum physical size for such plants. Optimal dimensions can be calculated only by including specific component costs (collector, tower, turbines) for individual sites [8].

To give an overview, typical dimensions for selected solar updraft tower capacities are given in Table 4 [10].

<table>
<thead>
<tr>
<th>50 kWe</th>
<th>750m</th>
<th>90m</th>
<th>3750m</th>
<th>153GWh/yr</th>
<th>120GWh/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hₜ</td>
<td>Dₜ</td>
<td>Dc</td>
<td>Pₑ at 2300 kWh/m²yr</td>
<td>Pₑ at 1800 kWh/m²yr</td>
</tr>
<tr>
<td>Value</td>
<td>90m</td>
<td>3750m</td>
<td>153GWh/yr</td>
<td>120GWh/yr</td>
<td></td>
</tr>
</tbody>
</table>

Based on specific costs (To produce 50 kW of electricity, the total investment cost is 302Mio € and annual operation & maintenance cost are 1.6Mio €/a) and the dimensions from Table 1, investment costs were calculated for Manzanares solar updraft tower and the results are plotted in the following figure.
IV. CONCLUSIONS

Generation of electricity using solar energy is an alternative for power generation over conventional power plants. Many research works based on numerical and experimental studies are carried out by keeping Manzanares power plant as a reference. It is concluded that such system should be constructed in a very large way to generate large amount of electricity.

The work presented in this study is related to the technical-economic study of the solar chimney of Manzanares. The obtained results show:

1. The generated power depends on the solar irradiance and the ambient temperature.
2. The efficiency both of the collector and the turbine has a significant role in the improvement of the system performances.
3. The mathematical model presented here is relatively simple while provides a very accurate result as shown in Table 3.
4. Maghreb countries have really small conventional electricity cost because of natural sources (oil and gas) which makes the solar chimney unprofitable (negative return). On the other hand, the cost of the kWh produced by solar chimneys in Europe is profitable (positive return).

REFERENCES


SMART BUILDING
Using EEG Signal Controller
(First Controlling Method)

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Abstract—At the root of all our thoughts, emotions and
behaviours is the communication between neurons within
our brains. Brainwaves are produced by synchronised
electrical pulses from masses of neurons communicating
with each other and they change according to what we’re
doing and feeling.

Brainwaves are detected using sensors placed on the scalp,
such as the EEG sensor which record the human brain’s
electric field.

This work aims to study the possibility of controlling the
smart building using Mind wave Mobile Headset to provide
easy way to control the whole building, specially for people
who have physical impairment.

This paper describes part of an integrated project for
implementation of smart building controlled by several
ways, which is considered as a First Method to control the
building.

Keywords—EEG signal, Mind wave, Android application,
Smart building.

I. INTRODUCTION

In general a smart building is any structure that uses
automated processes to automatically control the
building’s operations including heating, ventilation, air
conditioning, lighting, security, entertainment audio &
video systems, TVs, computers, camera systems and other
systems that are capable of communicating with one
another and can be controlled remotely from any room in
the building, as well as remotely from any location in the
world by phone or internet.

Smart building incorporated common devices that control
features of the building. A concept on smart building
application and development includes various
implementation techniques and is ever growing. Smart
building systems are created based on analysis on client
needs and budget to cater for the system. With
technologies available today, efficient integration of this
system could have been achieved. Building automation is
a new concept that encompasses the ability to control
electrical and electronic devices at home remotely so
providing ease of access to the users. This concept may be
applied in various manners to fit the requirement of a
smart building.

The Brain-Computer Interface technique is treated as a
communication system that serves the person to operate
the devices by using his or her own thoughts. The data
flows from brain to the outside machinery. Different
research groups have examined and used different
methods to achieve this. All these method uses
 electroencephalography (EEG) signals which are taken
from the scalp. The different brain states are the outcome
of the various arrangements of neural interaction. These
pattern leads to the waves that are characterized by
various amplitude and frequency values.

This work aims to use a new innovation “Mind Wave
Mobile Headset” which is put on the head of a human
and takes the mind signal, interoperated and converted it
to an electrical signal used to control the whole building
utilities through an Android application, as shown in Fig1.

1. Intelligent Building Diagram

This work is organized as follows: Section II covering the
main concepts of the EEG system controller. Section III
representing important information about Mindwave
Mobile Headset. Then the Android Application is defined
in section IV. Section V contains the practical part of
Mindwave Mobile Headset and Android Application.
Finally section VI drawing the major conclusions from
this work.

II. EEG SYSTEM CONTROLLER

Electroencephalography (EEG) is an
electrophysiological monitoring method to record
electrical activity of the brain. EEG measures voltage
fluctuations resulting from ionic current within the
neurons of the brain. In clinical contexts, EEG refers to
the recording of the brain’s spontaneous electrical activity
over a period of time [1].
Dendrites can consist of thousands of branches, with each branch receiving a signal from another neuron. The axon is a single branch which transmits the output signal of the neuron to other neurons. The transmission of information from one neuron to another takes places at the synapse, a junction where the terminal part of the axon is in contact with another neuron. The signal, initiated in the soma, propagates through the axon encoded as a short, pulse-shaped waveform, the action potential. Initially electrical signal is converted in the presynaptic membrane to a chemical signal (neurotransmitter) which diffuses uses across the synaptic gap and is then reconverted to an electric signal in the postsynaptic membrane of another neuron. [3]

The electric potential generated by a single neuron is far too small to be measured by EEG. So EEG measures electrical field as the summation of the synchronous activity of millions of neurons that have similar spatial orientation. The electrical field is mainly generated by currents that flow during synaptic excitation of the dendrites, the excitatory postsynaptic potentials. [4]

B. Brainwaves

Brain is constantly producing electrical signals while it operates, as the cellular components of the brain (neurons) communicate with each other. They produce a range of frequencies that scientists have found relate to particular mental states. For example, a sleeping person’s brain produces an abundance of delta waves, whereas an alert and awake person concentrating hard on something will produce far more beta waves.

The Mindwave headset picks up the brain’s electrical activity and divides the signal by frequency into various types of waves, allowing it to infer human mental state. The table gives a general synopsis of some of the commonly-recognized frequencies that tend to be generated by different type of activity in the brain [5]:

<table>
<thead>
<tr>
<th>Brainwave Type</th>
<th>Frequency range</th>
<th>Frequency range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delta</td>
<td>0.1Hz to 3Hz</td>
<td>Deep, dreamless sleep, non-REM sleep, unconscious</td>
</tr>
<tr>
<td>Theta</td>
<td>4Hz to 7Hz</td>
<td>Intuitive, creative, recall, fantasy, imaginary, dream</td>
</tr>
<tr>
<td>Alpha</td>
<td>8Hz to 12Hz</td>
<td>Relaxed, but not drowsy, tranquil, conscious</td>
</tr>
<tr>
<td>Low Beta</td>
<td>12Hz to 15Hz</td>
<td>Formerly SMR, relaxed yet focused, integrated</td>
</tr>
<tr>
<td>Midrange Beta</td>
<td>16Hz to 20Hz</td>
<td>Thinking, aware of self &amp; surroundings</td>
</tr>
<tr>
<td>High Beta</td>
<td>21Hz to 30Hz</td>
<td>Alertness, agitation</td>
</tr>
</tbody>
</table>

The difference between these waves can be more easily understood in Fig3.
C. MindWave Mobile Technology

In the proposed system as shown in Fig.4, a NeuroSky brainwave sensor is used to analyse the EEG signals. The BCI is a direct communication pathway between the human brain and an external device.

Brainwaves are tiny electrical impulses released when a neuron fires in the brain. NeuroSky’s brain-computer interface (BCI) works by monitoring these electrical impulses with a forehead sensor. The neural signals are input into ThinkGear chip. The measured electrical signals and calculated interpretations are then output as digital messages to the computer, or mobile device, allowing us to see the brainwaves on the screen, or use the brainwaves to affect the device’s behavior [2].

- ThinkGear

ThinkGear should be included inside every EEG product that enable a device to interface with the wearer’s brainwaves. It includes the sensor that touches the forehead, the contact and reference points located in the ear clip, and the on-board chip that processes all of the data. Both the raw brainwaves and the eSense Meters (Attention and Meditation) are calculated on the ThinkGear chip [5].

- eSense

eSenseTM is an algorithm for characterizing mental states. To calculate eSense, the ThinkGear technology amplifies the raw brainwave signal and removes the ambient noise and muscle movement. The eSense algorithm is then applied to the remaining signal, resulting in the interpreted eSense meter values [5].

- eSense Meter

The eSense meters are a way to show how effectively the user is engaging Attention (similar to concentration) or Meditation (similar to relaxation).

In many cases, people tend to be better at one eSense than the other, that means they must try different tactics until they are successful with one. Then they will be able to duplicate the action more easily with additional practice.

For each type of eSense (i.e. Attention, Meditation), the meter value is reported on a relative eSense scale of 1 to 100. The eSense Attention meter indicates the intensity of mental “focus” or “attention”. While the eSense Meditation meter indicates the level of a user’s mental “calmness” or “relaxation”.

4. Brain-Computer Interface System
Mindwave Mobile is an EEG headset that safely measures and transfers the power spectrum (alpha waves, beta waves, etc) data via Bluetooth to wirelessly communicate with the device, and works with most modern operating systems.

The MindWave Mobile headset, can be simply slipped on to be able to see human brainwaves change in real time. For example with the Mindwave Mobile we can monitor the levels of attention, relaxation, meditation and eye blinks.

The Mindwave headset picks up the brain’s electrical activity and divides the signal by frequency into various types of waves, allowing it to infer human mental state.

The Mindwave Mobile as shown in Fig5 is surprisingly simple consisting only of a headset, an ear-clip, and a sensor arm. The headset’s reference and ground electrodes are on the ear clip, while the EEG electrode is on the sensor arm, resting on the forehead above the eye.

Unfortunately human body makes a lot of other electrical noise, in addition to the activity coming from his brain. For this reason there is a ‘reference’ contact, in the form of a clip that attaches to your earlobe, which allows the headset to filter out non-brain related electrical activity.

To get a prepare interface the usually minimum system requirements for PC/Mac are [5]:

<table>
<thead>
<tr>
<th>Operating system</th>
<th>PC</th>
<th>Mac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor</td>
<td>Intel Core Duo or equivalent</td>
<td>Mac OS X 10.5.8 or later</td>
</tr>
<tr>
<td>Memory</td>
<td>1GB or more</td>
<td></td>
</tr>
<tr>
<td>Video</td>
<td>DirectX 9.0 or greater</td>
<td>Intel GMA900 or greater</td>
</tr>
<tr>
<td>Hard disk</td>
<td>1GB free disk space</td>
<td></td>
</tr>
<tr>
<td>USB</td>
<td>An available USB port</td>
<td></td>
</tr>
</tbody>
</table>

To get a prepare interface the usually minimum system requirements for iOS/Android are [5]:

<table>
<thead>
<tr>
<th>Operating system</th>
<th>iOS</th>
<th>Android</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processor</td>
<td>iOS 4.3.3 or later</td>
<td>Android 2.2 or later</td>
</tr>
<tr>
<td>Hard disk</td>
<td>at least iPhone, iPad or iPod Touch 3</td>
<td>Compatible Android phone or table</td>
</tr>
<tr>
<td>Wireless</td>
<td>Bluetooth</td>
<td></td>
</tr>
</tbody>
</table>

IV. ANDROID APPLICATION

The Android application has been used in this work as an intermediary between the smart building controller and the mind wave mobile headset.

An Android app is a software application running on the Android platform. Because the Android platform is built for mobile devices, a typical Android app is designed for a smartphone or a tablet PC running on the Android OS [6].

An Android application is defined using one or more of Android’s four core application components: Activity, Service, Broadcast Receiver and Content Provider [7].

- **Activity** is an application component that provides a screen with which users can interact in order to do something. If an application has more than one activity, then one of them should be marked as the activity that is presented when the application is launched.
- **Service** is an application component that can perform long-running operations in the background without a user interface.
- **Broadcast Receivers** simply respond to broadcast messages from other applications or from the system.
- **Content Providers** component supplies data from one application to others on request.

A. The Basics of Android Applications

These are the basics of Android applications [8]:

- **Android applications** are composed of one or more application components (activities, services, content providers, and broadcast receivers).
C. Advantages of Android Application

Android is free and an open platform built on Linux. It is an open source solution for mobile devices offering a complete software stack including operating system, middleware, and key mobile applications. Apart from its speed, scalability, and performance, there are many other advantages of Android application development which includes [10]:

- Open Source: The Android platform is open source which means the Android Software Development Kit (SDK) can be leveraged without having to worry about the licensing costs or royalty. Developers can interact with the Android developer community for the forthcoming versions which they can incorporate into their Android app development projects. These benefits make Android a lucrative prospect for enterprises, device manufacturers and wireless operators alike, resulting in rapid development of the applications.

- Customizable User Interface: A user interface can either make or break your app. Android-based applications are highly customizable and easier to manage. Google is highly focused on making its user interface customizable to help developers create custom Android apps for business. Being an open source platform, it allows developers to turn their creative ideas into reality and build innovative and interactive apps. It offers a wide array of customization options. Even the data management functions and multimedia tools can be easily updated to the app.

- Low Investment and High ROI: Android has a relatively low barrier to entry. Its Software Development Kit (SDK) is available for free to developers which significantly reduces the development costs. However, the app development costs can be bifurcated into three major parts: development, testing, and deployment. Developers are required to pay a one-time registration fee for application distribution. Thereafter, they can leverage any computer device to build and test the product on their smartphones, ensuring low investment and increased engagement among users. Ultimately, users get an interactive app and the enterprise gains higher return on investment.

- Multiple Sales Channels: Unlike other mobile platforms, Android applications can be deployed in different ways. You do not have to rely on a single market to distribute your applications. Besides using Google Play Store and other third-party app marketplaces, you can create your own distribution and sales channels. You build it, you publish it. With your choice of promotional strategy, you can reach your end users through multiple channels.

- Easy to Adopt: Android apps are scripted in Java programming language that leverages a rich set of libraries. Any developer familiar with Java can build Android applications easily. As per a developer survey, many Java experts find it easier to write apps for Android as compared to programmers with command over other programming languages.
V. PRACTICAL PART “MINDWAVE MOBILE HEADSET AND ANDROID APPLICATION”

Mindwave Mobile headset shown in Fig7 as clarified in Section III, is a wireless device used to record the EEG signals, then it sends a corresponding data of the brain waves to the device connected with it via Bluetooth connection.

7. The MindWave Mobile headset

The headset uses eSense meters for Attention and Meditation. The meter value for each type of eSense is reported on a relative eSense scale of 1 to 100.

Given that the Attention can be controlled through a focus, two actions have been chosen in practical implementation of this work "single and double blinking " which they give different range of values on eSense scale.

The headset records low frequencies of single blinking and gives small values on eSense scale while higher frequency is recording when the human blinks his eyes twice and the values will be higher on eSense scale.

Android application is designed to communicate with the headset and it acts as an intermediary between the Mindwave Mobile Headset and the smart building controller "The Arduino ". It takes advantage of these values in order to send commands to the Arduino.

Android mobile which contains this application, receives signals from the Mindwave Mobile Headset via Bluetooth connection and it also sends orders to the Arduino via Bluetooth connection.

A. The Interface of The Smart Building Android Application

This Application includes a set of buttons as shown in Fig8 that we can select one of them and change their status through the Mindwave Mobile Headset.

8. The Interface of Android Application

B. The Android Application and Mindwave Mobile Headset Flow Chart

The flow chart in Fig9 clarifies how the Mindwave mobile headset and Android mobile contact with each other to send orders to the smart building controller.

If the user blinks his eyes once the mobile will change the focus to another button, and if the user blinks his eyes twice a certain button will be selected and the mobile will connect to the Arduino and sends data corresponding to this button ( the letters ).

9. Android Application Flow Chart
VI. CONCLUSION

Mindwave Mobile headset is a wireless device used to record the EEG signals, then it sends a corresponding data of the brain waves to the device connected with it via bluetooth connection.

This work aims to use the Mind Wave Mobile Headset to control the whole building utilities through an Android application.

The Android application is designed to communicate with the headset and it acts as an intermediary between the Mindwave Mobile Headset and the smart building controller "The Arduino".

Two actions have been chosen in practical implementation of this work "single and double blinking " which they give different range of values on eSense scale of the Headset.

The Android application takes advantage of these values in order to send commands to the Arduino.

REFERENCES

A Study of Wind Turbine Blade Structure Based on Cellulose Fibers Composite Material.

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Abstract—In the present study, the feasibility of using the cellulose fibers in the natural fiber reinforced polymer composites (NFC) for constructing wind turbine blade structure will be reported. To do that, it was necessary to identify first, the principal solicitations exerted wind turbine blades. Second, categorize the principal characteristic of cellulose fibers compared with ordinary synthetics fibers, in the way of evaluating their principal characteristics relative to comprehensive desired measures required in wind stresses resistance. And third, report the natural fibers effects on wind blade behavior through FE simulation of different types of blade composite structure. To ensure the potential and competitiveness of the natural fibers in developing the sustainability of wind blades several comparisons between fiber types commonly used was carried out. The FE results of wind turbine blade based on different types of NFC were evaluated. The resistance of the composite structure to the multi complex loading is numerically approved through several FE simulations and comparison. The numerical study gives encouraging results in the sense of using NFC based on cellulose fibers for constructing turbine blades.

Keywords—Wind energy; Wind turbine blades; Cellulose fibers; Natural Fiber Composites (NFC); FEM

I. INTRODUCTION

For the reduction of the fossil fuel needed, many countries resort to the use of the renewable energy, in particularly, wind energy production. And this energy it will be highly expanded in the next years. Then the installation and use of large numbers of wind turbines it will be a very significant energy requirements. Then the performances of such wind turbine can be fulfilled only by using innovative, lightweight and highly durable composite materials such as natural fiber composite (NFC).

The most important parts of the turbines, produced from composites, wind turbine blades, are subject to complex, combined impact, static and random cyclic loading. In order to resist these loading over many years and hundreds of millions of loading cycles and to reduce the different types of forces, the wind blades are built from fiber reinforced polymer composites. It is apparent that the currently available solutions for fibers reinforcement composite is the use of E-glass/epoxy composite [1]. But recently, there has been a rapid growth in research and innovation in the natural fibre composite (NFC) area. The uses of NFC gives resistant and environmentally friendly and recyclable composites for wind turbines.

The strength and durability of wind blades are controlled by damage processes at the microlevel, in fibers, on the fiber/matrix interfaces, between plies. Also the materials with nanoengineered matrix (or sizing) and microscale (e.g., carbon fiber) reinforcement can demonstrate in some cases the up to 80% higher fracture toughness and lifetime than the neat composites [2]. For that reason in this work and in order to evaluate the blade structure made of NFC it was necessary to identify first, the blade composition and the applicable solicitation. Second the cellulose fibers characteristics and third, test the structure under the complex load in FE simulation.

II. WIND TURBINE BLADES

A. Principal solicitations in wind turbine blade

Blades are the most important composite based part and the highest cost component of the wind turbines. A wind turbine blades consists of two faces joined together and stiffened both by one or several integral webs linking the upper and lower parts of the blade shell or by a box spar with shell fairings) [3] see Fig.1. On wind turbine blades, the flapwise load is caused by the wind pressure, and the edgewise load is caused by gravitational forces and torque load. The parts of blade which are made from different types of composite structures, are primarily designed against several solicitation and are shown in Table 1.

As shown in table 1, the diverse loading that exist at several locations at the blades suggest that it could be gainful to use different composite materials according to the different zones of blades see Fig.2.
<table>
<thead>
<tr>
<th>Blade parts</th>
<th>Structure</th>
<th>Solicitation needed to resist</th>
</tr>
</thead>
<tbody>
<tr>
<td>The two external faces:</td>
<td>Triaxial laminates</td>
<td>Edgewise bending, Cyclic tension-tension loads, Cyclic compression-compression loads</td>
</tr>
<tr>
<td>The upper part of the blade shell</td>
<td>Uniaxial laminates</td>
<td>Flapwise bending</td>
</tr>
<tr>
<td>The lower part of the blade shell</td>
<td>Foam</td>
<td></td>
</tr>
<tr>
<td>The shear webs</td>
<td>Foam</td>
<td>Bending moments associated with the Gravitation loads</td>
</tr>
<tr>
<td>The spar caps</td>
<td>Foam</td>
<td>Bending moments associated with the Gravitation loads</td>
</tr>
<tr>
<td>The aeroshells</td>
<td>Sandwich structure</td>
<td>Elastic buckling</td>
</tr>
<tr>
<td>The leading and trailing edge panels</td>
<td>Foam</td>
<td></td>
</tr>
</tbody>
</table>

In order to modelling the wind turbine blades it is necessary to identify the load cases, for this study it was considered two cases of load at Normal operation and at Extreme wind loading.

The vortex system induces on a wind turbine an induced axial velocity and an induced tangential velocity components. The induced axial velocity is specified through the axial induction factor $a$ as $aVo$, where $Vo$ is the undisturbed wind speed. The induced tangential velocity is in the rotor wake is specified through the tangential induction factor $a'$ as $2a'\omega r$. Since the flow does not rotate upstream of the rotor, the tangential induced velocity in the rotor plane is thus approximately $a'\omega r$. $\omega$ denotes the angular velocity of the rotor and $r$ is the radial distance from the rotational axis. If $a$ and $a'$ are known, a 2-D equivalent angle of attack could be found based to the work of Martin O. L. Hansen [4] as:

$$Va = (1-a)Vo$$

$$Vrot = (1+a')\omega r$$

The relative wind speed $V_{rel}$ has direction $\phi = \alpha + \theta$

Where:
- $\theta$: The local twist angle of blade
- $\alpha$: The local angle of attack

$$V_{rel} \cos \phi = a\omega(1+a')$$

$$\tan \phi = \frac{(1-a)V_0}{(1+a')\omega r}$$

- The lift and drag normal and tangential forces are:

$$F_N = F_L \cos \phi + F_D \sin \phi$$

$$F_T = F_L \sin \phi - F_D \cos \phi$$

- The normal and tangential force coefficients are:
\[ C_N = C_L \cos \phi + C_D \sin \phi \]  
\[ C_T = C_L \sin \phi - C_D \cos \phi \]  

The uses of the momentum theory to equate the momentum changes in the air flowing through the turbine with the forces acting upon the blades, gives for normal forces:

\[ 4 \pi a = \frac{B (1 - a)}{2 \sin^2 \phi} \frac{C_N}{a} \]  

Hence:

\[ \frac{4 \sin^2 \phi}{a} = 1 - a \]  

Where:

- \( \sigma \) is the rotor solidity: \( \sigma = \frac{B(r)B}{2 \pi a} \)
- \( B \): Number of blades
- \( \phi \): the momentum theory for Tangential forces gives:

\[ 4 \pi a' = \frac{B}{2} \frac{(1 + a')}{\sin \phi \cos \phi} \frac{C_T}{a'} \]  

Hence:

\[ \frac{4 \sin \phi \cos \phi}{\sigma C_T} a' = 1 + a' \]  

These equations can be rearranged to give the axial and angular induction factors as a function of the flow angle.

Axial induction factor:

\[ a = \frac{1}{4 \sin^2 \phi + 1} \]  

Angular induction factor:

\[ a' = \frac{1}{4 \sin \phi \cos \phi} - 1 \]  

The normal force \( F_N \) causes a “flapwise” bending moment at the root of the blade.

\[ M_N = \frac{R}{r_{min}} \int F_N (r - r_{min}) \, dr \]  

The tangential force \( F_T \) causes a tangential bending moment at the root of the blade.

\[ M_T = \frac{R}{r_{min}} \int F_T (r - r_{min}) \, dr \]  

If neglected the relatively small twist of the blade cross section and assume that these bending moments are aligned with the principal axes of the blade structural cross section.

The maximum tensile stress due to aerodynamic loading is therefore given by:

\[ \sigma_{\text{max,aero}} = \frac{M_N}{I_{TT}} \frac{d_a}{2} + \frac{M_T}{I_{NN}} \frac{b}{2} \]  

Consider equilibrium of element of blade:

\[ \frac{d F_c}{dr} = -m(r) \omega^2 r \]  

\[ \sigma_c = \frac{F_c(r)}{A(r)} \]  

- Self-Weight loading

The bending moment at the blade root due to self-weight loading can dominate the stresses at the blade root. Because the turbine is rotating the bending moment is a cyclic load with a frequency of \( f = \omega / 2 \pi \). The maximum self-weight bending moment occurs when a blade is horizontal. Bending moment at root of blade due to self-weight

\[ M_{SW} = \frac{R}{r_{min}} \int m(r) g (r - r_{min}) \, dr \]  

Where \( m(r) \) is the mass of the blade per unit length. This is a tangential (edge-wise) bending moment and therefore the maximum bending stress due to self-weight is given by:

\[ \sigma_{\text{max,sw}} = \frac{M_{SW}}{I_{NN}} \frac{b}{2} \]  

- Combined Loading

\[ \sigma_{\text{max}} = \sigma_{\text{max,aero}} + \sigma_c + \sigma_{\text{max,sw}} \]  

III. CHARACTERISATION OF THE CELLULOSE FIBERS

The cellulose long or woven fibers, fig.3 could be extracted from several types of natural materials such as Alpha [5], wood, palm, Flax, Hemp [6] etc.  

Fig. 4 Cellulosic source of natural fibers: long and woven fibers
According to the work of Murali Rao et al. [6] and Mark C. Symington et al [7] the estimate cross-section of cellulose fiber was carried out using a digital micrometer. And according to Mark C. Symington et al [7] due to the potential variability in natural fiber properties, 25 tests per fiber might help to increase the quality of approximation. This was felt necessary due to the errors already associated with measuring the cross-sectional areas. For the tensile testing of cellulose natural fiber, the closest applicable standard used was ASTM D 3822 [8]. The mechanical behavior of some ordinary fibers and cellulose fibers was collected and then compared and verified based to literature. In the table 2 various mechanical properties of the different standard fibers materials used in turbine blade construction are tabulated.

### TABLE II

<table>
<thead>
<tr>
<th>Type of fibers</th>
<th>Designation</th>
<th>Young Modulus (GPa)</th>
<th>Tensile strength (MPa)</th>
<th>Density (g/cm³)</th>
<th>Tensile strain to failure (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synthetic Fibers [9]</td>
<td>Glass – E</td>
<td>73</td>
<td>3500</td>
<td>2.54</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Carbon</td>
<td>350</td>
<td>4000</td>
<td>1.75</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>Aramid</td>
<td>120</td>
<td>3600</td>
<td>1.45</td>
<td>11</td>
</tr>
<tr>
<td>Natural Fibers [10-14]</td>
<td>Abaca</td>
<td>12</td>
<td>764</td>
<td>6.2</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>Bagasse</td>
<td>17</td>
<td>290</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Bamboo</td>
<td>11</td>
<td>140</td>
<td>0.6-1.1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Flax</td>
<td>54</td>
<td>1339</td>
<td>1.5</td>
<td>3.27</td>
</tr>
<tr>
<td></td>
<td>Hemp</td>
<td>70</td>
<td>900</td>
<td>1.47</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Jute</td>
<td>20</td>
<td>533</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td></td>
<td>Kenaf</td>
<td>53</td>
<td>930</td>
<td>1.45</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>Sisal</td>
<td>9</td>
<td>568</td>
<td>1.5</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Ramie</td>
<td>24.5</td>
<td>560</td>
<td>1.5</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>Oil palm</td>
<td>3.2</td>
<td>248</td>
<td>0.7-1.55</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Pineapple</td>
<td>1.44</td>
<td>400</td>
<td>0.8-1.6</td>
<td>14.5</td>
</tr>
<tr>
<td></td>
<td>Coir</td>
<td>6</td>
<td>175</td>
<td>1.2</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Curaua</td>
<td>11.8</td>
<td>500</td>
<td>1.4</td>
<td>3.7-4.3</td>
</tr>
<tr>
<td></td>
<td>Alpha</td>
<td>18-25</td>
<td>588-308</td>
<td>1.4</td>
<td>1.5-2.4</td>
</tr>
</tbody>
</table>

Based on the results gathering in the table 2, it is reassuring to see that most of the behaviors of natural fibers are so much feeble comparing with the synthetics fibers. From the literature of the tensile tests it is see that the mechanical behavior could be affected by the humidity and it may be necessary to investigate that cause more deeply in next steps of this research work. The Hemp and flax fiber there are the most resistant fibers compared with other types and they could bring a good resistance to the wind blade.

#### IV. THE AEROFOIL SELECTION AND THE FEM OF THE BLADE SUCTION

In this part the finite element model of the blade was established based to a simple Procedure for calculation and choosing of blade shape, composite structure for a matrix of Resin Epoxy and selected fibers from table n2. The FE simulation of the NFC structure of the wind turbine Blade is detailed in the diagram in fig. 8. The structure was first selected as a part of the hole blade and based to the loading and boundary conditions a CFD simulation was conducted to observe the wind velocity effect on the top surface of the blade see fig.7. One of the first observations made in this FEM is the Von Mises results on different types of composites made from cellullosic natural fibers and Resin Epoxy. By analysis of the wind turbine blade and by solving the combined stress (equation 22), it can be seen that the biggest stress occurs in the center of the blade, but the maximum stress is less than the tensile strength of the natural fiber reinforced Resin epoxy plastic.

![Fig. 5 Model and boundary condition](image)

![Fig. 6 CFD results on Arefoil wind turbine blade](image)

![Fig. 7 Wind blade FE results on NFC](image)
The fig. 9 illustrate the FE results of the resistance of the wind turbine blade structure to the combined loading through several fibers sources. By fixing the same boundary conditions and applied forces. It was observed that the change of fibers types brings a remarkable change in resistance of wind turbine blade. It is concluded that uses of Hemp or Alpha fibers in the structure of wind turbine blades brings a suitable resistance to the complex loading.

Fig. 8 Procedure for choosing and FE simulate of the NFC structure of the wind turbine blade.

Fig. 9 Von Mises results of wind turbine blade’s composites reinforced by diverse fibers sources under three different combined loading.

V. CONCLUSION

In this work the analysis of stress in wind blade was carried out, then the performance of some natural fibers was gathering. Based on the literature tensile testing carried out in different types of fibers and based on the present developed FEM process the mechanical behavior of the wind turbine blade were obtained from natural and synthetic fibers under combined stress condition. The FE simulation gives an important basis for comparison between natural sourced fibers and ordinary synthetic fibers in composite’s stress resistance of the wind turbine blades. It was observed that the mechanical behavior of the natural fibers has a prime importance in providing good resistance of the composite structure of the wind turbine blade to the combined loading stresses. The uses of cellullosic fibers in the structure of wind turbine blades bring a suitable resistance to the complex loading and sustainable environmental influence throughout achieving an efficient waste management practice. To confirm the reliability of the present investigation a future experimental work of the NFC wind turbine blade resistance to several combined loading conditions will be carried out.
REFERENCES


PARTICLE SWARM OPTIMIZATION (PSO) FOR PHOTOVOLTAIC GENERATOR OPERATING UNDER PARTIALLY SHADED CONDITIONS

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Abstract— This paper presents a detailed configuration of a photovoltaic solar system that aims to inject active power into an electrical network and a parallel active filter whose task is to eliminate the disturbances present in this network. This modelling allows us to conclude that the characteristics of a photovoltaic generator are affected by solar light, temperature and shading. Or, with partially shaded conditions, we have multiple maximums in the P-V and I-V characteristics and there are different techniques who’s defined to extract the maximum power point tracking (MPPT) as the perturb and observe (P&O) and the incremental of conduction (IncCond). But, these two algorithms fail to extract the global maximum power of the PV panel; however, they only extract the first maximum encountered either local or global. To resolve these problems, a technique based on particle swarm optimization (PSO) is studied and simulated under Matlab software. The results show that the PSO method has succeeded to overcome these difficulties and reach the global MPP.

Keywords— photovoltaic solar system, Matlab, particle swarm optimization (PSO), parallel active filter, maximum power tracking (MPPT), perturb and observe (P&O), incremental of conduction (IncCond).

I. INTRODUCTION

With the increasing interest about global environmental protection, the necessity to produce natural clean energy such as solar energy has received great concern as an alternative source of energy for the future, since it is clean, pollution-free and inexhaustible.

In Tunisia, most of the needed energy sources is imported from abroad. So, solar energy is one of the alternative energy. In addition of its excellent sunshine conditions, photovoltaic (PV) power generator is a good system to develop an important energy. In fact, if there is a good irradiance condition, the PV system can generate a maximum power efficiently, while an effective MPPT algorithm is used with the system.

Each type of PV module has its own specific characteristic corresponding to the surrounding condition such as temperature, irradiation and shading. Or, with partially shading, the P-V and I-V characteristics of PV panel show many maximums and this makes the tracking of maximum power point (MPP) a complicated problem. To overcome this problem, many maximum point tracking (MPPT) control algorithms have been presented such as perturb and observe (P&O), the incremental of conduction (IncCond), particle swarm optimization (PSO) and genetic algorithm as fuzzy logic (FL).

This paper describes the performance of PV module under shading conditions and PSO algorithm as a solution for MPPT and to command DC/DC converter.

II. SYSTEM CONFIGURATION

The system consists of a PV generator, DC-DC and DC-AC converters connected to an electrical network as shown on figure 1. The PSO base MPPT control is performed by adjusting the duty ratio of the DC-DC converter.

![Fig.1 system configuration](image)

III. PV MODULE

In a photovoltaic distributed generation, a solar cell is the smallest unit of a PV generator. The connection in series or parallel between cells make a PV module, and further a PV array.

A. Modelling of Solar Cell
PV cell is the basic component of PV module, it consists of a p-n junction fabricated in a thin layer of semiconductor. This cell is like p-n diode and their characteristics are also similar [1].

A solar cell equivalent electrical circuit can be represented by a single diode, as shown in fig.2, where the current source Iph is the generated current from the light, the diode saturation current is I0. Rs, series resistance, represents the various contact resistances in the system and Rp, parallel resistance, represents the leakage current of the semiconductor junction [2].

![Fig.2 Solar Cell Equivalent Model](image)

The mathematical model of this cell is given by the following expression:

$$I_{cell} = I_{ph} - I_0 \left( \frac{V_{cell} + R_s}{V_{oc}} - 1 \right) - \frac{V_{cell} + R_s}{R_p}$$  \hspace{1cm} (1)

Where I_{cell} and V_{cell} are the output current and output voltage of photovoltaic cell.

The table 1 resume all the notations of equation (1):

| I_{ph} | Parallel resistance |
| V_i | Diode ideality factor (1 < i < 2) |
| K | Boltzmann’s constant (≈1.38×10^{-23} J/K) |
| T | Temperature in kelvin |
| q | Electron charge (≈1.602×10^{-19} C) |

B. Modelling of PV Module

PV cell produce a small power, so to generate the required voltage and power, PV cells are connected in series and parallel to form modules, modules are grouped into panels and the connection between panels make us to build up the entire PV array which can generate the desired current-voltage (I-V) and power-voltage (P-V) characteristics [3].

![Fig.3 I-V curve](image)

![Fig.4 P-V curve](image)

The mathematical model of PV array is shown by the following expression:

$$I = N_p \times I_{ph} - N_p \times I_0 \left( 1 + \frac{i-1}{N_sv_i} \right) - \frac{V + i \times (N_s/N_p) \times R_s}{R_{oc} \times V_i + R_p}$$ \hspace{1cm} (4)

Where N_s and N_p are series and parallel solar cells. The series connection will increase the output voltage, instead of the parallel connection will increase the output current.

To simulate equation (4), we used MATLAB/SimPowerSystem.

The curves I-V and P-V are shown respectively on figure 3 and figure 4.

As shown in both graphs, we can illustrate 3 remarkable points:

- The point (Voc, 0), open circuit point, is the point where I-V curve meets axis and Voc which is the open circuit voltage of PV module reflects the voltage of the module in the night when there is no generation of current (I=0).
- The point (0, Ioc), short circuit point, is the point where
I-V curve meets the voltage axis and $I_{sc}$ which is the short circuit current is the greatest generated current value when the voltage is zero (V=0).

The point(Vmpp,Impp), the maximum power point where the PV module produce its maximum power ($P_{max}=Impp*Vmpp$). In this case, Impp and Vmpp are, respectively, the maximum operating current and voltage of PV module. Or, when we connect a PV module directly to a load, the operating point is the intersection between the I-V curve of the PV module and the load curve. However, this operating point does not, usually, meet the maximum power point (MPP) of PV module. Also, as the maximum power point depends on cell temperature and solar radiation, which vary randomly, its position is continuously changing.

Moreover, it is very important to establish that the PV module is operating at its maximum efficiency because the most problem with PV energy generation system is low efficiency [4]. For that reason, many algorithms are used to overcome this problem, here we talk about maximum power point trackers (MPPT).

In general, the MPPT is realized by interposing the current and voltage measurements, the MPPT algorithms generates the optimal duty ration (D), ensuring to conserve the electrical quantities (V, I and P) at values corresponding to the maximum power point [5].

C. Influence of solar radiation and temperature

To show the effect of solar radiation and temperature, we used the modeling of our PV module with MATLAB/Simulink and simulate it with different values of radiation and temperature as shown in I-V curves on figure 5/figure 7 and P-V curves on figure 6/figure 8.

Therefore, the I-V characteristics of a PV module depends strongly on solar radiation and temperature. As we can see in figure 5, the output current I of a PV module is extensively influenced by the variation in solar irradiance G, while the output voltage V stays almost constant. On the contrary, figure 7 shows that for a changing temperature the voltage varies widely while the current remains almost unchanged.

Furthermore, the P-V curve on figure 6 show how dependency of output power (P) on solar irradiance, and this proves the expected behavior of a device that transforms solar energy into electricity: the output power of a PV generator is considerably inflated for an increasing irradiance.

In the other side, figure 8 shows that the output power of PV module decrease by an increase in cell temperature. This can be explained by the dependency of the open circuit voltage (Voc) on the cell temperature as follows [6]:

$$V_{oc} = V_{oc,TC} + k_v(T - T_{TC})$$  \hspace{1cm} (5)

D. Shaded PV characterization

A PV array is composed of several PV modules connected is series and parallel, in order to produce the desired current and voltage. However, in real operating conditions, if the cells are slightly different or are not uniformly illuminated, we talk here about partially shaded conditions (PSC). A PV module is considered to be shaded if three or more of its cells are receiving lower than normal insolation [7].

In this case, the electrical behavior would be effected and the characteristics I-V will be influenced as shown in figure 9. Also, a new characteristic P-V as shown in figure 10.

It can be observed that number of peaks equal to the irradiance imposed for each shading pattern.
measure the optimal current matching to the maximum power.

- Power based methods, which are established on iterative algorithm to track continuously the MPP over the current and voltage measurement of the PV module.

Most of these algorithms are limited in partially shaded conditions, the presence of multiple peaks reduces the performance of the existing MPPT due to their inability to discriminate between the local and global maximum [10].

Over the years, many researches are developed to extract maximum power point under varying atmospheric conditions, but all of them are limited on shaded conditions, until the big revelation with the intelligent techniques. Among them, metaheuristics such as genetic algorithms (CA), particle swarm optimization (PSO), and shuffled frog leaping algorithms (SFLA) have validated their performance, in terms of robustness of MPPT, for various operational conditions in the case of partial shaded conditions [11].

A. Particle Swarm Optimization (PSO)

Inspiring by the social behavior of bird flocking and fish schooling, Eberhart and Kennedy developed the particle swarm optimization, in 1995.

A PSO algorithm controls a swarm of individuals (called particles) where each particle represents a candidate solution. Particles follow a simple behavior: imitate the success of neighboring particles and its own accomplished successes. The position of particle is consequently altered by the best particle in neighborhood, Pbest, in conjunction with the best solution found by the particle itself, Gbest.

To adjust the position of the particle, we use the following equation:

\[ x_{i}^{k+1} = x_{i}^{k} + v_{i}^{k+1} \]  

(6)

Where \( v_{i} \) is the velocity component and it represents the step size.

The velocity is calculated by using the following equation:

\[ v_{i}^{k+1} = w v_{i}^{k} + c_{1} r_{1} (P_{\text{best},i} - x_{i}^{k}) + c_{2} r_{2} (G_{\text{best}} - x_{i}^{k}) \]  

(7)

\( W \) is the inertia weight, \( r_{1} \) and \( r_{2} \) are random numbers between 0 and 1, \( c_{1} \) and \( c_{2} \) are the acceleration coefficients, \( P_{\text{best},i} \) is the personal best position of particle \( i \) and \( G_{\text{best}} \) is the global best position of particles [12].

B. Application of PSO

The purpose of our research is to apply PSO algorithm to solve the problem of P-V curve wherein multiple peaks MPPs present. So, due to the uniqueness of this problem, the standard version of PSO algorithm will be mutated to meet the practical detail of PV operating under partial shading conditions.

Figure 11 shows the flow chart of the suggested PSO based MPPT technique. To more explain the new algorithm, all steps are detailed as following:
1. (parameter selection) the identification of parameters is necessary in this step, and on our system the particle position is defined as the duty cycle value $d$ of the DC-DC converter, and the generated power $P_{pv}$ is chosen as the fitness value evaluation function. Also, according to the literature, the number of MPPs in P-V curve for PV modules is equal to the number of series connected PV cells [13]. So, the particle number $N$ is chosen as the number of the series connected cells in the PV module.

2. (PSO initialization) the initialization of particles can be placed on fixed position in the space randomly except that there is no information about the location of the GMPP. Consequently, the initialization of the particles should be around it, and according to [14], the presence of peaks on the P-V curve is almost at multiple of 80% of the module open voltage $V_{oc}$ -module. So, particles are fixed on $[D_{min}, D_{max}]$. $D_{min}$ and $D_{max}$ are, respectively, the minimum and the maximum duty cycle of the DC-DC converter.

3. (fitness evaluation) in view of maximizing the generated power $P_{pv}$, the fitness value function is chosen as $P_{pv}$, so to calculate it, the measurement and the filter of PV voltage, $V_{pv}$, and current, $I_{pv}$, is necessary.

4. (update individual and global best data) here, the algorithm compares the new fitness value of particle $i$ with the best fitness value in history $P_{best,i}$ and if the comparison is positive, then the algorithm set the current value as the new $P_{best,i}$ and choose the particle, with the best fitness value, of all the particles as the $G_{best}$.

5. (update position and velocity of each particle) after the evaluation of all particles, the velocity and position of each particle should be updated, with the new equations as following [14]:

$$V_{i}(k+1) = w(k) V_{i}(k) + c_1(k) r_1 (P_{best,i} - x_{i}(k)) + c_2(k) r_2 (P_{global} - x_{i}(k))$$

$$w(k) = w_{max} - \frac{k}{k_{max}} (w_{max} - w_{min})$$

where $w_{min}$ and $w_{max}$ are, respectively, the lower and upper bounds of $w$, and $k_{max}$ is the maximum admitted number of iterations.

$$c_1(k) = c_{1max} - \frac{k}{k_{max}} (c_{1max} - c_{1min})$$

$$c_2(k) = c_{2max} - \frac{k}{k_{max}} (c_{2max} - c_{2min})$$

where $c_{1min}$, $c_{1max}$, $c_{2min}$, and $c_{2max}$ are, respectively, the lower and upper bounds of $c_1$ and $c_2$.

6. (convergence determination) the MPPT algorithm will stop and produce the obtained $G_{best}$ solution, when two conditions will be reached, if the velocities of all particles become smaller then a threshold or if the number of iteration is attained.

Fig. 11 flow chart of PSO MPPT

V. PARALLEL ACTIVE FILTER

Nonlinear loads produce distorted current waveforms in the electrical network. Therefore, the injected harmonics have several impacts on the system and loads connected to system. As a solution to this solution, harmonic active filters are widely used in the system. Parallel active filter is a converter used in order to compensate current disturbances as harmonics, unbalance and reactive power. Various topologies and configurations have been developed for this filter that highlight different forms of its compensation tasks [14].

In this paper, the current reference for active power filter is generated using fast zero phase detection (FZPD). This method is very simple as it has less number of calculations compared to other typical methods.

VI. SIMULATION AND RESULTS

The proposed photovoltaic cells are not only able of providing extracted solar power to the power system. However, it also can considerably mitigate harmonic currents, which are peaked by non-linear loads. In consideration of establishing the effectiveness of the concepts discussed in this
paper, a simulation using the environment SIMULINK in MATLAB is done.

Figure 12 shows source voltage waveforms completely sinusoidal and balanced. Figure 13 shows the source current waveform deformed before filtering. Figure 14 presents the obtained current waveform. Figure 15 shows the reactive power is annulated with the active parallel filter.

![Fig.12 source voltage waveforms](image1)

![Fig.13 source current waveforms before filtering](image2)

![Fig.14 source current waveforms after filtering](image3)

![Fig.15 active and reactive power](image4)

**VII. CONCLUSION**

Photovoltaic power is, today, the favorable clean energy source. Therefore, to optimize its yield, we have proposed a direct connection of photovoltaic cells with parallel active power filter and MPPT based on PSO. From the results obtained, it is demonstrated that by applying the proposed system, photovoltaic power can be simply extracted by solar cells and injected into the grid by active parallel filter, which the principal duty is delivering the linear or nonlinear load with harmonic current and then controlled with the algorithm PSO to track the global maximum power point when multiple peaks exist in the P-V curve under partially shaded conditions.

Finally, and according to the obtained results, the proposed system seems to be an efficient solution but to upgrade it, we are studying to apply genetic algorithm to filter harmonic current.

**REFERENCES**


Enumeration of the Zeros of the Generalized Mittag-Leffler $E_{\alpha,\beta}(z)$ as Bargmann Functions

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Abstract

The Enumeration of the zeros of the function $E_{\alpha,\beta}(z)$ and their distribution are of fundamental importance and play a significant role in the dynamic solution and it has many applications in many scientific areas from mathematics, physics and communication. The aim of this paper is to enumerate the number of zeros of the solution of the Mittag-Leffler function $E_{\alpha,\beta}(z)$ as examples of Bargmann function with arbitrary order of growth. We find that for numerical calculation when $0 < \alpha < 2$ and $\beta = 1$ the number of zeros can be any finite number: 1, 2, 3, ..., not necessarily an odd number.

Keyword

Bargmann States, Mittag-Leffler Function, Numerical Enumeration of Special function, Mathematica program.

1 Introduction

The general theory of growth of an analytic function and the density of their zeros, is applied to the Bargmann function. An example of the Bargmann function has used the Mittag-Leffler function $E_{\alpha,\beta}(z)$ for the arbitrary complex argument $z$, and two parameters $\alpha, \beta \in \mathbb{R}$. The Mittag-Leffler function plays an important role in Mathematica model, its first formulation by the Swedish Mathematician [9] Magnus Greta Mittag-Leffler (1846 – 1927). The function became a relevant topic, not only from the pure mathematical point of view, but also from the perspective of its applications. The special function in this case is:

$$E_{\alpha}(z) = \sum_{m=0}^{\infty} \frac{z^m}{\Gamma(\alpha m + 1)} \quad \alpha > 0, z \in \mathbb{C}$$

And its general form:

$$E_{\alpha,\beta}(z) = \sum_{m=0}^{\infty} \frac{z^m}{\Gamma(\alpha m + \beta)} \quad \alpha > 0, \beta, z \in \mathbb{C}$$

In this paper we give a whole clarified description for the zeros of the solution of the Mittag-Leffler function $E_{\alpha,\beta}(z), 0 < \alpha < 2$. We find that the number of zeros can be any finite number: 1, 2, ..., not necessarily an odd number. The paper is organized as follows: Section 2 studied the Bargmann analytic representation and their growth of these function. Section 3 introduces the fundamental aspects of The Mittag-Leffler function and their states as Bargmann function. Section 4 The zeros of the Mittag-Leffler function as Bargmann function, are considered. Finally, Section 6 outlines the main conclusions.
2 The Bargmann analytic representation and Their growth.

There are several representation that use analytic function: The Bargmann representation is the most well-known one. In this section, we introduce the Bargmann analytic representation in the complex plane defined by the Glauber coherent state. The space of these functions is defined as the space of the entire functions with no singularities. The growth of an analytic function is characterised by its order and type [1], [4], [5],[14], [15], [16]. Let |k⟩ be an arbitrary state:

\[ |k⟩ = \sum_{n=0}^{\infty} k_n |n⟩. \]  

(1)

The normalisation condition is given below

\[ \sum_{n=0}^{\infty} |k_n|^2 = 1. \]  

(2)

The conjugate of |k⟩ is ⟨k| can be written as follows:

\[ ⟨k| = \sum_{n=0}^{\infty} k_n^* |n⟩. \]  

(3)

The Bargmann representation, [2],[6], for the state |k⟩ is represented by:

\[ k(z) = \exp \left( \frac{|z|^2}{2} \right) (z^*|k⟩ = \sum_{n=0}^{\infty} k_n z^n \sqrt{n!}. \]  

(4)

• The Bargmann representation for the number states |n⟩ is:

\[ k(z) = z^n \frac{1}{\sqrt{n!}} \]  

(5)

• The Bargmann representation for the coherent state |A⟩ is:

\[ k(z) = \exp (Az - |A|^2 / 2) \]  

(6)

Which is of order \( \rho = 1 \)

and type \( r = |A| \).

• The Bargmann function of the squeezed state |A; r, θ, λ⟩ is:

\[ k(z) = (1 - |r|^2)^{1/4} \exp \left( \frac{r^2}{2} z^2 + \beta z + \lambda \right) \]  

(7)

\[ \tau = -\tanh \left( \frac{1}{2} \right) \exp (-iθ), \quad \beta = A(1 - |r|^2)^{1/2} \]

\[ \lambda = -\frac{1}{2} r^* A^2 - \frac{1}{2} |A|^2. \]  

(8)

It has growth with order \( \rho = 2 \) and type \( \tau = \frac{1}{2} \tanh(\frac{3}{4}) \).

• State with the Mittag-Leffler function as Bargmann function |ψ, τ⟩ is:

\[ |ψ, τ⟩ = \sum_{N=0}^{\infty} \frac{1}{\Gamma(\frac{N}{\tau} + \beta)} \sum_{N=0}^{\infty} \frac{1}{\Gamma(\frac{N}{\tau} + \beta)} 2^{-N} |N⟩ \]  

(9)

when 0 ≤ \( \rho < 2 \), and also when \( \rho = 2 \) and \( r < \frac{1}{4} \), It has growth with order \( \rho = \frac{1}{4} \) and type \( \tau \) for any \( \beta \).

3 The Mittag-Leffler function as Bargmann function.

In this section it has introduce the Mittag-Leffler function as Bargmann function as example where the order of growth is fractional. The zeros of the Mittag-Leffler function are studied.

3.1 The Mittag-Leffler function

The Mittag-Leffler function is named after the great Swedish mathematician Gösta Magnus Mittag-Leffler (1846-1927). He has worked on the general theory of functions, studying the relationship between independent and dependent variables. The generalization of the Mittag-Leffler function was proposed by Wiman in his work [10] on zeros of function which is defined by the series:

\[ E_\alpha (z) = \sum_{m=0}^{\infty} \frac{z^m}{\Gamma(\alpha m + 1)} \quad \alpha > 0, z \in \mathbb{C} \]  

(10)

More generally, the Mittag-Leffler function with two parameters has the form:

\[ E_{\alpha, \beta} (z) = \sum_{m=0}^{\infty} \frac{z^m}{\Gamma(\alpha m + \beta)} \quad \alpha > 0, \beta, z \in \mathbb{C} \]  

(11)

Here z is a complex variable and \( \alpha, \beta \) are arbitrary positive constants. The function \( E_{\alpha, \beta} (z) \) is an entire function of the complex variable z.

Kilbas et al. studied the generalised Mittag-Leffler function with three parameters [7]. This function was also introduced...
by T.R Prabhaker in 1971[13];

\[ E_{x,\beta}(z) = \sum_{m=0}^{\infty} \frac{z^m}{m!} \left( \frac{\gamma}{\Gamma(\gamma)} \right) \] (12)

where \( \alpha, \beta \) are arbitrary positive constants, and \( \gamma \) is the Pochhammer symbol[13].

In some other applications, a generalized Mittag-Leffler function has four parameters, the following function was introduced by Dabashbashian [13], and is defined as follows:

\[ E_{\alpha,\beta}(z) = \sum_{m=0}^{\infty} \frac{z^m}{m!} \left( \frac{\gamma}{\Gamma(\gamma)} \right) \] (13)

where \( \alpha, \beta, \gamma \in \mathbb{C} \) and \( \eta \in \mathbb{N} \). When \( (\gamma)_{0} = 1 \) and \( (\gamma)_{m} = \frac{\Gamma(m+\gamma)}{\Gamma(\gamma)} \)

In the next section we provide details of some special properties of the Mittag-Leffler function.

### 3.2 Analytic properties of the Mittag-Leffler function

First of all, we have to mention that for \( \Re \alpha > 0 \) and arbitrary complex parameter \( \beta \), the Mittag-Leffler function \( E_{\alpha,\beta}(z) \) is an entire function of the complex variable \( z \). For particular values of parameters, the Mittag-Leffler function coincides with some elementary functions. A description of the most important properties of this function can be found in the third volume of the Bateman project [7],[8],[11],[9],[13]. In this case when using their series representations for some parameters. It is easy to see that:

\[ E_{0,1}(z) = \frac{1}{1-e^{-z}} \quad |z| < 1; \] (14)

\[ E_{\alpha,1}(z) = E_{\alpha,1}(z) = \sum_{m=0}^{\infty} \frac{z^m}{m!} \left( \frac{\gamma}{\Gamma(\gamma)} \right) \] (15)

\[ E_{\alpha,\beta}(z) = E_{\alpha,\beta}(z) = \sum_{m=0}^{\infty} \frac{z^m}{m!} \left( \frac{\gamma}{\Gamma(\gamma)} \right) \] (16)

And in general we can show some of this function as follows:

\[ E_{0,\beta}(z) = \sum_{m=0}^{\infty} \frac{z^m}{m!} \left( \frac{\gamma}{\Gamma(\gamma)} \right) \] (17)

\[ = \frac{1}{\sqrt{2\pi}} \sum_{m=0}^{\infty} \frac{z^m}{m!} \] (18)

As example:

\[ E_{1,3}(z) = \sum_{k=0}^{\infty} \frac{z^k}{\Gamma(k+3)} = \sum_{k=0}^{\infty} \frac{z^k}{(k+2)!} = \frac{1}{\sqrt{2\pi}} \sum_{k=0}^{\infty} \frac{z^k}{(k+2)!} \]

\[ = \frac{1}{\sqrt{2\pi}} \left[ e^{z} + \frac{z^2}{2} + \frac{z^3}{6} + \frac{z^4}{24} + \cdots \right] \] (19)

If \( \alpha, \beta > 0 \) then they take the formula[11].

\[ z^{\alpha} E_{\alpha,\beta+1}(z) = \frac{1}{\Gamma(\alpha+\beta)} \sum_{m=0}^{\infty} \frac{z^m}{m!} \] (20)

As example if \( \alpha, \beta > 0 \):

\[ z^{\alpha} E_{\alpha,\beta+1}(z) = \frac{1}{\Gamma(\alpha+\beta)} \sum_{m=0}^{\infty} \frac{z^m}{m!} \] (21)

3.3 The Mittag-Leffler states: States with the Mittag-Leffler function as Bargmann function

In this section we extend the construction of the states which is the Bargmann function with a given order \( \rho \) \( (\rho \text{ can be any values between 0 and } 2) \), also it can be \( \rho > 2 \) but then the function is not normalizable and given type \( \sigma \) by choosing the coefficients \( C_{N} \) in:

\[ C_{N} = \sum_{N=0}^{\infty} K_{N}|N\rangle \] (22)

\[ K_{N} = \mathcal{L}_{N}; \quad C_{N} = \frac{\sigma}{\Gamma(\rho)} \] (23)
$K_N = \frac{\pi^\alpha(N)!}{\Gamma{\left(\frac{\alpha}{\beta} + 1\right)}} \tag{26}$

where $L$ is a normalization constant given by the following:

$L = \sum_{N=0}^{\infty} \frac{\pi^\alpha(N)!}{\Gamma{\left(\frac{\alpha}{\beta} + 1\right)}} |N|^{-\alpha}$ \tag{27}

then we can write:

$|\rho, \sigma| = \sum_{N=0}^{\infty} \sigma^\alpha(N)! \frac{\pi^\alpha(N)!}{\Gamma{\left(\frac{\alpha}{\beta} + 1\right)}} |N|^{-\alpha}$ \tag{28}

$L$ is finite when $0 < \rho < 2$ and also when $\rho = 2$ and $\sigma < \frac{1}{2}$. The Bargmann function of this state $LE_{\frac{\alpha}{\beta}}(\sigma \hat{z})$ where $E_{ \frac{\alpha}{\beta}}(\sigma \hat{z})$ is the Mittag-Leffler function.

and we can write it as follows:

$K(z) = \sum_{N=0}^{\infty} K_N e^{N(z)} \hat{z}^N \tag{29}$

inserting Eq(23) in equation Eq(26) we get:

$K(z) = \sum_{N=0}^{\infty} L \frac{\pi^\alpha(N)!}{\Gamma{\left(\frac{\alpha}{\beta} + 1\right)}} e^{z^N N(z)} \frac{\pi^\alpha(N)!}{\Gamma{\left(\frac{\alpha}{\beta} + 1\right)}} |N|^{-\alpha} = \sum_{N=0}^{\infty} L \frac{\pi^\alpha N^\alpha}{\Gamma{\left(\frac{\alpha}{\beta} + 1\right)}} e^{z^N N(z)} \frac{\pi^\alpha N^\alpha}{\Gamma{\left(\frac{\alpha}{\beta} + 1\right)}} |N|^{-\alpha} = LE_{\frac{\alpha}{\beta}}(\sigma \hat{z}) \tag{30}$

We confine $z \in \mathbb{C}$ and consider the zeroes of the function $K(z)$ in Eq 27, where $E_{\frac{\alpha}{\beta}}(\sigma \hat{z})$ is the Mittag-Leffler function when $\beta = 1$. As an example we present extensive numerical calculation of the function $K(z)$ in the complex plane. We show a three-dimensional plot of the real and imaginary parts. $\rho$ can take all values between 0 and 2.

4 The Zeros distribution of the Mittag-Leffler function as Bargmann function

An entire function of fractional order can have infinitely many zeros. Also there are entire function which have few zero or no zeros, (e.g. the exponential function $[14], [16], [17], [18], [19], [20], [21]$). The Mittag-Leffler function which was given in Equations (10) and (11) is an entire function of order $\frac{1}{\alpha}$. Consequently, Mittag-Leffler function $E_{\alpha, \beta}(z)$ might have an infinite number of zeros with the possible exception when $\frac{1}{\alpha}$ is an integer. In this case, there may be a finite number of zeros, or an infinite number of zeros. We can show that with the excep-
5 Figures

In this section we generated some figures by aid of the methods described in the paper. We have considered numerical results presented in Fig (1), (2). The total numbers of the zeros in this case can be easily enumerated. In the special case where $\rho = 1$ the state Eq (25) is reduced to usual coherent states and when $\rho = 2$ the state Eq (25) is reduced to squeezed states.

The Mittag-Leffler function $E_{\alpha,1}(z)$ is equal to the exponential function $e^z$ and is only the function which has no zeros. In this section we calculate the zeros of polynomial approximations to $E_{\alpha,1}(z)$ using Eq (11) when $\beta = 1$ can be 2; 4; 6; ..., we demonstrate this procedure numerically for $\alpha$ increasing from $1.4 < \alpha < 1.99$ and where $z$ is real. In Fig (5),(6) and (7) we plot some curves of $E_{\alpha,1}(z)$. For example when the $\alpha = 1.567$, $E_{\alpha,1}(z)$ curve crosses the x-axis four times yielding two zeros, the next larger value of $\alpha$ when $\alpha = 1.759$, $E_{\alpha,1}(z)$ has six zeros, and when $\alpha = 1.957$, $E_{\alpha,1}(z)$ has more than ten zeros.

Figure 1: The zeros of the function $K_N(z)$ in Eq (27) with $N = 20$ in (a) for $E_{\alpha,1}(z)$ when $0 < \alpha < 2$, Polynomial approximation have been made, and their zeros may be fictitious.

Figure 2: The zeros of the function $K_N(z)$ in Eq (27), with $N = 40$ for $E_{\alpha,1}(z)$ in (b) when $0 < \alpha < 2$, Polynomial approximation have been made, and their zeros may be fictitious.
6 Conclusion

In this paper, we stated the Bargmann analytic representation in the complex plane. We also considered the growth of the Mittag-Leffler function as Bargmann function, and the parametric and analytic properties of the function. We also considered the zeros of the Mittag-Leffler function when $1 < \alpha < 2$. Furthermore, we considered the Bargmann function of the zeros of the function and we calculated the number of zeros for any value of $\alpha$ in the area of $0 < \alpha < 2$. The number of zeros can be any finite number.
References


[9] F. Mainardi, On some properties of the Mittag-Leffler function $E_\alpha(-t^\alpha)$, completely monotone for $t > 0$ with $0 < \alpha < 1$. Mathematical Physics (math-ph); arXiv:1305.0161 [math-ph].


[22] F. Mainardi, 'On Some properties of the Mittag-Leffler function $E_\alpha(-t^\alpha)$. Completely monotone for $t > 0$, with $0 < \alpha < 1$, Discrete and continuous dynamical systems, Vol 19, Sep 2014.

The Adomian decomposition method for Solving Batch Crystallization Models

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Abstract—A new semi analytic method is proposed for solving population balance equations (PBE). The PBE include the kinetic processes of nucleation, growth, aggregation and breakage.

The growth and aggregation attained high interest in chemical engineering and the dynamic behavior of crystals size distributions and in this finally they must be helpful in describing the dynamic behavior of any particulate system in which aggregation and growth are taking place.

The results obtained in all cases show that the predicted particle size distributions converge exactly in a continuous form to that of the analytical solutions.

Keywords—crystals; population balance equations; aggregation; growth; breakage.

I. INTRODUCTION

Crystallization is the process of solid formation in the form of crystals from a homogeneous solution. It is a solid-liquid separation technique in which the solute mass transfers from the liquid solution to a pure solid crystalline phase. The process is suitable for separations and purifications in pharmaceutical, chemical and food industries. For example, it is used in petrochemical industry for separation and purification of hydrocarbons, for manufacturing of polymers, and for the production of high valued chemicals and household products.

Analysis of a particle system desired to synthesize the behavior of the particle population and its environment by the behavior of individual particles in their local environment. It is described by the density of a suitable extensive variable, usually the number of particles, but sometimes (more correctly) by other variables such as mass or volume of particles. usual population balance equations (PBEs) expressing the conservation laws for hardware systems.

The population balance equation (PBE) is analogous to the mass and energy balance equations but provides more information to investigate and analyze the problem.

They were introduced in the field of chemical engineering by Hulbert and Katz (1964)[1] and later fully developed by Randolph and Larson (1988)[2]. However, their applications were limited due to a lack of computational power. Since high speed computers are available now, they became popular which is reflected by their use in several areas of chemical and biochemical engineering. PBE is a combination of different phenomena which contribute to the change in particles population.

In a number of diverse engineering fields used population balance equations (PBEs) such as emulsification, flocculation, crystallization, include polymerization, polymer degradation, aerosol, biological.

The object of this work is to present new technique Ademain decomposition method for solving certain forms of partial integrodifferential equations arising from (ADM) modeling population balances.

The Ademain decomposition method have attained high interest in applied mathematics and chemical engineering, because it allow solution of both linear and nonlinear functional equations without discretizing the equations or approximating the operators by such schemes as linearization or perturbation. The solution, when it exists, is found in the form of a rapidly converging series.

Comparison between the analytic solutions and the semi-analytique solutions that obtained by Ademain’s method indicates it can be accurately predicted by the proposed
method. In addition, the proposed method is easy to implement with few computational requirements.

II. THE POPULATION BLANCE EQUATIONS

In general, the population balance equation (PBE) is a well-established equation for describing the evolution of the dispersed phase. It represents the net rate of number of particles that are formed by breakage, aggregation, growth and could be written for a flow into a well-stirred vessel as [1-2]:

\[
\frac{\partial n(l,t)}{\partial t} + \frac{\partial (Gn(l,t))}{\partial l} = Q_{\text{net}} - n(l,t)\int_{0}^{\infty} \omega(l,l')n(l',t)dl' + \int_{0}^{\infty} \beta(lll')\Gamma(l')n(l',t)dl' - \Gamma(l)n(l,t) + \frac{l^2}{2} \int_{0}^{\infty} \omega(l|l^3-l'^3)|^{1/3} l' n(l',t)n((l^3-l'^3)^{1/3},t)dl'.
\]

III. THE ADOMIAN DECOMPOSITION METHOD

Since the 1980s, Adomian proposed a new and ingenious method for exactly solving nonlinear functional equations [3]. The method has been applied to many frontier problems in engineering, physics, biology, and chemistry among other fields [4]. The Adomian decomposition method (ADM) gives the solution as an infinite series usually converging to an accurate solution [5].

The general form of a differential equation be

\[ Fu = g. \]  

\[ F = L + R + N. \]  

(3) into (4) become

\[ Lu + Ru + N = g. \]

Where \( L \) is easily invertible operator, \( R \) is the remainder of the linear operator and \( N \) corresponds to the non-linear terms. We can write (4)

\[ Lu = g - Ru - Nu. \]

Multiple (5) by \( L^{-1} \) be

\[ L^{-1}(Lu) = L^{-1}g - L^{-1}(Ru) - L^{-1}(Nu). \]

Where \( L^{-1} = \int \cdots \int \cdots \int (\cdot)(d\cdot)^2 \) is the inverse of operator \( L \).

So (6) become

\[ u = u_0 - L^{-1}(Ru) - L^{-1}(Nu). \]

Therefore, \( u \) can be presented as a series

\[ u(\infty) = \sum_{n=0}^{\infty} u_n \]

The non-linear term \( N(\mu) \) will be decomposed by the infinite series of Adomian Polynomials \( A_n \)[6]

\[ Nu = \sum_{n=0}^{\infty} A_n, \]

\[ A_n = \frac{1}{n!} \frac{d^n}{dx^n} \left[ N \left( \sum_{l=0}^{\infty} \lambda_l u_l \right) \right]. \]

Y. Cherruault and al [7] has been studied the convergence of the Adomian decomposition.

IV. RESULTS AND DISCUSSION

1. Aggregation

A general description of aggregation with respect to length in any system can be expressed as follows[8], but with different aggregation kernels

\[ \frac{\partial n(l,t)}{\partial t} = \frac{l^2}{2} \int_{0}^{\infty} \omega(l|l^3-l'^3)|^{1/3} l' n(\cdot|\cdot)(l^3-l'^3,\cdot)dl'. \]

\[ -n(l,t)\int_{0}^{\infty} \omega(l|l^3-l'^3)|^{1/3} l' n(l',t)dl'. \]

1.1 Constant aggregation kernel

A constant aggregation kernel was adopted,

\[ \omega(l,l') = C. \]

In this case the initial condition at \( t = 0 \) is the exponential particle size distribution is given by:

\[ n(l,0) = \frac{3N_0}{l_0^7} e^{\left(\frac{-l^3}{l_0}\right)}. \]

Where \( l_0 = \frac{N_0 = 1} {1} \).

The solution by the ADM recursion scheme is given by:

\[ n_1(l,t) = \frac{1}{4} C l^2 e^{-3l^3} \left( l^6 - 12 \right) \]

\[ n_2(l,t) = \frac{1}{160} C^2 l^2 e^{-3l^3} \left( l^{12} - 60l^6 + 360 \right) \]
\[ n_1(t, l) = \frac{C^3 l^3 e^{-\frac{C}{C+2}} \left( 1 - \frac{Ct}{C+2} \right)^2 l^{3(2m-1)} (Ct+2)^{-m}}{\sqrt{Ct+2}} \Gamma(2m) \]  

\[ n_m(t, l) = \frac{12 e^{-\frac{C}{C+2}} \sinh \left( \sqrt{Ct} \right)}{\sqrt{Ct}} \sum_{m=0}^{\infty} n_m(l, t) = \frac{1}{\sqrt{Ct}} \frac{1}{\Gamma(2m)} \]  

which converges to the exact solution.

**Fig. 1:** The effect of the truncation of the series on the solution using \( n = 0 \) to 4 iterations and \( C = 1 \), using the exact solution as given by eq.(19) (ES continuous line) for the case of constant aggregation kernel.

### 1.2 Sum aggregation kernel

we use a sum kernel of the form \( \omega(l, l') = B_0 (l^3 + l'^3) \)

where \( l \) and \( l' \) are the sizes of particles and \( B_0 = 1 \). The initial particle size distribution is the same as given by equation (13)

The solution using the ADM is derived as follows:

\[ n_0(t, l) = 3l^3 e^{-\frac{C}{C+2}} \]  

\[ \frac{\partial n_0(l, t)}{\partial t} = \int_0^l \int_0^t \frac{\omega(l^3 - l'^3, l') n_0(l', t) n_0(l' - l'^3, t) dt'}{(l^3 - l'^3)^{3/2}} \]  

\[ n_m(l, t) = \frac{1}{\sqrt{Ct}} \frac{1}{\Gamma(2m)} \sum_{m=0}^{\infty} n_m(l, t) = \frac{1}{\sqrt{Ct}} \frac{1}{\Gamma(2m)} \sum_{m=0}^{\infty} \left( \frac{1}{l} \right)^m \left( e^{-\frac{C}{C+2}} \right)^m \]  

From which we calculate the solutions components

\[ n_1(l, t) = \frac{3}{2} B_0 t e^{-\frac{C}{C+2}} \left( t^6 - 2l^3 - 2 \right) \]  

\[ n_2(l, t) = \frac{1}{4} B_0 t^3 e^{-\frac{C}{C+2}} \left( t^{12} - 6l^9 - 3l^6 + 18l^3 + 6 \right) \]  

\[ n_3(l, t) = \frac{1}{48} B_0 t^5 e^{-\frac{C}{C+2}} \left( t^{18} - 12l^{15} + 12l^{12} + 120l^9 - 60l^6 - 168l^3 - 24 \right) \]  

\[ n_m(l, t) = 3l^3 e^{-\frac{C}{C+2}} e^{\frac{1}{2} \left( 1 - \frac{C}{C+2} \right)} \sum_{m=0}^{\infty} \frac{(l^3)^m \left( 1 - e^{-\frac{C}{C+2}} \right)^m}{(m+1)! \Gamma(m+1)} \]  

Using the above general term, the general summation is given by:

\[ n(l, t) = \frac{3 e^{-\frac{C}{C+2}} t^{\frac{C}{2}} e^{-\frac{C}{C+2}} \sum_{m=0}^{\infty} \left( l \right)^m \left( 1 - e^{-\frac{C}{C+2}} \right)^m}{l \sqrt{1 + e^{-\frac{C}{C+2}}}} \]  

\[ n(l, t) = \sum_{m=0}^{\infty} n_m(l, t) = \frac{1}{l} \left( \frac{3 e^{-\frac{C}{C+2}} t^{\frac{C}{2}} e^{-\frac{C}{C+2}} \sum_{m=0}^{\infty} \left( l \right)^m \left( 1 - e^{-\frac{C}{C+2}} \right)^m}{l \sqrt{1 + e^{-\frac{C}{C+2}}}} \right) \]
Fig. 2: The effect of the truncation of the series on the solution using \( n = 0 \) to 4 iterations and \( B_0 = 1 \), using the exact solution as given by eq.(26) (ES continuous line) for the case of sum aggregation kernel

1.3 Product aggregation kernel

The product aggregation kernel is given by

\[ \omega(l, l') = B_0 (l^3 l'^{3}) \]

where \( B_0 = 1 \). The initial distribution is the same as given by equation (13) The Adomian recursion scheme is given by:

\[ n_0(l, t) = 3e^{-l^3} \]

(27)

\[ \frac{\partial n_{m+1}(l, t)}{\partial t} = \int_0^l \int_0^{l'} \omega((l^3 - l'^3)^{1/3}, l') n_m(l', t) n_m((l^3 - l'^3)^{1/3}) \frac{l'^3}{(l'^3)^{2/3}} dl' dt - \int_0^l \left( n_m(l, t) \int_0^l \omega(l, l') n_m(l', t) dl' \right) dt. \]

(28)

\[ n_1(l, t) = \frac{1}{4} B_0 t e^{-l^3} \left( l^6 - 12l^3 \right) \]

(29)

\[ n_2(l, t) = \frac{1}{240} B_0^2 t^2 e^{-l^3} \left( l^{12} - 60l^6 + 360 \right) \]

(30)

\[ n_3(l, t) = \frac{B_0^3 t^3 e^{-l^3} l^4 \left( l^8 - 168l^6 + 5040l^2 - 20160 \right)}{40320} \]

(31)

Using the above terms, the general term is deduced as:

\[ n_m(l, t) = 3l^2 e^{-l^3} \left( \frac{\sqrt{\pi} 2^{-2m-1}(B_0 l^3)^m}{m! \left( m + \frac{1}{2} \right) (m+1)!} \right) \]

(32)

And the closed summation can be written as:

\[ n_m(l, t) = \sum_{m=1}^{\infty} 3l^2 e^{-l^3} \left( \frac{\sqrt{\pi} 2^{-2m-1}(B_0 l^3)^m}{m! \left( m + \frac{1}{2} \right) (m+1)!} \right) \]

(33)

Finally, this summation is reduced to:

\[ n_1(l, t) = 3l^2 e^{-l^3} F \left( \frac{3}{2}, \frac{1}{2}, \frac{1}{4} B_0 l^3 \right) \]

(34)

Where \( F \) is the hypergeometric function.

Fig. 3: The effect of the truncation of the series on the solution using \( n = 0 \) to 4 iterations and \( B_0 = 1 \), using the exact solution as given by eq.(34) (ES continuous line) for the case of product aggregation kernel

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page 198
2. Growth

A general description of growth with respect to length in any system can be expressed as follows:

\[
\frac{\partial n(l, t)}{\partial t} + \frac{\partial [Gn(l, t)]}{\partial l} = 0. \tag{35}
\]

linear growth rate. For the diffusion-controlled growth, the growth rate can be expressed as:[4]

\[
G(l, t) = \frac{a}{l} \tag{36}
\]

With the initial condition is the same as given by equation (13). We applied the ADM on the equation (36) can be written as:

\[
n(l, t) = -\int_{l_0}^{l} \left( \frac{\partial [Gn(l, t)]}{\partial l} \right) dt. \tag{37}
\]

We find the solution to Equation (37) by the ADM as follows:

\[
n_0(l, t) = 3l^2 e^{-3l}. \tag{38}
\]

\[
n_1(l, t) = 9at e^{-3l} - 3at e^{-l}. \tag{39}
\]

\[
n_2(l, t) = \frac{27}{2} a^2 t^2 e^{-3l} + \frac{27}{2} a^2 t e^{-3l} l - 3a^2 t e^{-l}. \tag{40}
\]

\[
n_3(l, t) = \frac{3a^3 t^3 e^{-3l}}{2l} + \frac{27}{2} a^3 t^3 e^{-l} l - 3a^3 t^3 e^{-l}. \tag{41}
\]

Hence, we calculate the general term as:

\[
n_m(l, t) = 3e^{-\left\{ l^2 - 2at \right\}^{m/2}} \left\{ \frac{l^m}{\Gamma} \right\} \tag{42}
\]

Then

\[
n(l, t) = \sum_{m=0}^{\infty} n_m(l, t) = le^{-\left\{ l^2 - 2at \right\}^{3/2}} \sqrt{l^2 - 2at}. \tag{43}
\]

3. Pure breakage

A general description of the breakage process can be written as follows[2]

\[
\frac{\partial n(l, t)}{\partial l} = \int_{l}^{\infty} \beta(ll') \Gamma(l') n(l', t) dl' - \Gamma(l) n(l, t). \tag{44}
\]

In this case the initial condition at \( t = 0 \) is the exponential particle size distribution:

\[
I_0 = \frac{N_0}{l}. \tag{42}
\]

So \( n_0(l, t) = 3l^2 e^{-3l}. \tag{45} \)

Therefore, the last form of particle breakage, which is suitable for applying the ADM method, is given by:

\[
n(l, t) = \int_{l}^{\infty} \beta(ll') \Gamma(l') n(l', t) dl' - \Gamma(l) n(l, t) dt. \tag{46}
\]

A power kernel for breakage process
\[
\Gamma(l) = a_0 l^3.
\]
(47)

And a uniform daughter distribution

\[
\beta(l | l') = 6l^3 / l'^3, 0 \leq l \leq l'
\]
(48)

The solution by the ADM recursion scheme is given by:

\[
n_1(l, t) = -3a t e^{-l^3} l^3 (l^3 - 2)
\]
(49)

\[
n_2(l, t) = \frac{3}{2} a^2 t^2 e^{-l^3} l^2 (t^6 - 4t^3 + 2)
\]
(50)

\[
n_3(l, t) = -\frac{1}{2} a^3 t^3 e^{-l^3} l^3 (t^6 - 6t^3 + 6)
\]
(51)

\[
n_m(l, t) = \frac{(-1)^m (3 e^{-l^3} a^m t^m (l^3 - m^3) - m)}{(m + 1)!} l^3 (l^3 - 2) + 3 e^{-l^3} l^2.
\]
(52)

the exact solution is given by summation the above general term and simplified to:

\[
n(l, t) = \sum_{0}^{\infty} n_m(l, t) = 3 e^{-l^3} (at + l)^2.
\]
(53)

Figure 1: The effect of the truncation of the series on the solution using \( n = 0 \) to 4 iterations and \( a = 1 \), using the exact solution as given by eq.(53) (ES continuous line) for the case of pure breakage.

V. CONCLUSIONS

The solutions obtained by the ADM technique was infinite power series with appropriate initial conditions. The Adomain method is able to accurately predict the solution of PBE involving any combination of particle system process, that is, growth and aggregation. The proposed approach is free from stability and dispersion problems of other numerical methods such as the discretization.

The Adomain decomposition method was employed successfully for solving the particle population balance equations in batch crystallization models describing crystals size-dependent aggregation growth, and breakag.. The solutions obtained by the ADM technique was infinite power series with appropriate initial conditions. The method was found to produce good approximations to the exact solutions with their rapidly converging series for all the cases studied in this work.

References


Three dimensional simulation of magnetic field effect on natural convection of nanofluid

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Abstract— In the present work three-dimensional of natural convection heat transfer of water and nanofluid (Al\(_2\)O\(_3\)) in a differentially-heated cubic enclosure has been investigated numerically. The effects of fraction volume, Rayleigh number, Hartman number and inclination angle on natural convection heat transfer are analyzed. Method of solution is based on the finite volume method and an accelerated multigrid which has been tested and compared with previously published work on the basis of special cases and proved excellent agreements. The average Nusselt number increases with the increase of nanoparticles volume fraction at Ra=10\(^3\) for Al\(_2\)O\(_3\) water nanofluid. It is observed that the applying magnetic field results in a force opposite to the flow direction that leads to drag the flow and then reduces the convection currents by reducing the velocities. It has been noticed that the flow is affected by the number of Hartman and the inclination of the angle.

Keywords—natural convection, Heat transfer, Magnetococonvection, Nanofluids, three-dimensional, inclination angle.

I. INTRODUCTION

The natural convection of a conductive fluid in a closed cavity subjected to a magnetic field represents an adequate subject for scientific research. It is the challenge of many researchers during the past few decades. Natural convection is an effective procedure for many practical applications such as energy conservation, low noise and operating costs. Industries requiring natural convection are diverse. By way of example, mention may be made of nuclear reactors, cooling of electronic components, heat exchangers and solar collectors [1, 2, 3].

Natural convection in differentially heated inclined cavities was the subject of an important number of researches. To study the effect of this inclination on heat transfer and fluid flow, authors choose different ranges of angles.

Ravnik et al. [4] studied on the flow and heat transfer characteristics of the natural convection nanofluid flows in closed cavities. The simulations performed for Rayleigh number and three types of water-based nanofluids by using a three dimensional boundary element method based on flow solver. They have shown that the use of water-based nanofluids instead of pure water improves heat transfer. Sheikholeslami and Billahi [5] used the Boltzmann grid to study nanofluid natural convection inside a 3D enclosure in the presence of magnetic field. The Brownian motion was taken into account in the model used for the nanofluid coefficient of conductivity and viscosity. According to their results, magnetic field had a significant impact on natural convection heat transfer. In addition, the fluid convection decreased by increasing the Hartmann number. They also reported that, at a Rayleigh number of 10\(^3\), the heat transfer rate is highly dependent on the Hartmann number. However, this dependency is decreased at smaller Rayleigh numbers. Zhou et al. [6] performed a three-dimensional lattice Boltzmann simulation for mixed convection for nanofluid filled enclosure in presence of magnetic force. The influences of Rayleigh number, solid volume fraction of nanofluid, Hartmann number and Richardson number on the fluid flow and heat transfer are studied. They showed that the Adding nanoparticles of Al\(_2\)O\(_3\) into pure water improve natural convection heat transfer in a cubic cavity. However, the effect of convective heat transfer enhancement is more pronounced at low Rayleigh numbers. The enhancement will be weakened and even reversed at high Rayleigh numbers. (2) In contrast to Rayleigh number, the increase of Hartmann number decreases the heat transfer rate. This effect is more pronounced at high Rayleigh numbers. In addition, the influences of external magnetic field on heat transfer vary with different orientations.

Kolsi et al. [7] performed a computational study for 3D MHD natural convection inside a cubical enclosure with an inclined plate. They found an optimal inclination angle for the plate. The maximum heat transfer is formed when h = 180° but minimal value of average Nusselt number is changed according to nanoparticle addition into base fluid. Also, a minimum heat transfer value is formed at h = 270° almost for all cases. But effects of inclined plate became clearer for higher values of Rayleigh number. Heat transfer increases with increasing of Rayleigh numbers. Krnul and Gangawane [8] made a study on natural convection in a partially heated open ended square cavity subjegated to a magnetic field by using thermal lattice Boltzmann method (TLBM) based on single relaxation time (SRT) method. He showed that cavity with the applied
magnetic field at $Ha=45$ offers highest heat transfer restriction than other considered cases. Mahian et al. [9] performed a theoretical and experimental study on the Natural convection of silica nano fluids in square and triangular enclosures. Results indicate that the average Nusselt number could be estimated theoretically with the same trend and maximum difference of 4.5%.

Kolsi et al. [10] investigated the combined buoyancy-thermocapillary convection in 3D enclosure filled with Al2O3 nano fluid and showed that the increase of nanoparticle volume fraction causes heat transfer enhancement.

Purusothaman et al. [11] made a study on the 3D natural convection in a cubical enclosure with presence of thermally active heater and external magnetic field. The results show that the heat transfer rate and flow depended strongly on the strength of the magnetic field.

Bondareva et al. [12] investigated a numerical study on the natural convective heat transfer combined with melting in a cubical cavity filled with a pure gallium under the effects of inclined uniform magnetic field and local heater. It is mounted that an increase in the Hartmann number leads to suppression of the convective flow and heat transfer.

Al-Rashed et al. [13] studied the effect of magnetic field on natural convection inside a cubical cavity filled with CNT-water nano fluid. They found that for all the Rayleigh numbers the Bejan number increase by increasing nanoparticles volume concentration. Also, they noticed that the effect of angle of inclination on the total entropy generation is more sensible when $Ha =50$. Alsaaedy and al. [14] they carried out a bibliographic study on thermo-physical properties and thermo-magnetic convection of ferrofluid. They found that the thermal conductivity of a ferrofluid can reach 300 times that of the base fluid. Guir and al. [15] performed an experimental study for investigated the effect of various water based ferrofluid types on the heat transfer properties under the application of an external magnetic field. The results obtained showed that a higher solid volume concentration of magnetic nanoparticles enhances heat transfer rates. However, they observed that the effective thermal conductivity of the ferrofluid is reduced because of magnetization of the nanoparticles. Also, they observed that heat transfer rate was diminished with increasing magnetic field strength.

II. PHYSICAL MODEL AND NUMERICAL APPROACH

A. Physical Model

As shown in Figure 1, a three-dimensional cubic enclosure of side length $L$ filled with Al2O3-water nano fluid is considered $(Pr=6.2)$. The right sidewall of the enclosure is maintained at a constant hot temperature $T_H$, while the opposite wall has a constant cold temperature $T_C$. Four other walls of the enclosure are adiabatic. The nano fluid is assumed to be Newtonian, incompressible and the flow is laminar. The thermophysical properties of the base fluid (water) and Al2O3 nanoparticles are given in Table 1. The thermophysical properties of the nano fluid are taken to be constant except for the density variation in the buoyancy force, which is estimated by using the Boussinesq approximation. An external magnetic field is located at the center of the left hot wall which induced the magnetic convection at an angle of $\gamma$.

![Fig. 1. Physical model](image)

Table 1: Thermophysical properties of water and Al2O3 nanoparticles [16]

<table>
<thead>
<tr>
<th></th>
<th>Pure water</th>
<th>Al2O3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho(\text{Kg m}^{-3})$</td>
<td>997.1</td>
<td>3,970</td>
</tr>
<tr>
<td>$C_p(\text{Kg}^{-1} \text{K}^{-1})$</td>
<td>4179</td>
<td>765</td>
</tr>
<tr>
<td>$\nu(\text{m}^2 \text{s}^{-1})$</td>
<td>0.613</td>
<td>40</td>
</tr>
<tr>
<td>$\beta(\text{K}^{-1})$</td>
<td>$21 \times 10^3$</td>
<td>$85 \times 10^3$</td>
</tr>
<tr>
<td>$\kappa(\text{W m}^{-1} \text{K}^{-1})$</td>
<td>$1.74 \times 10^7$</td>
<td>$131.7 \times 10^7$</td>
</tr>
<tr>
<td>$\sigma(\Omega^{-1} \text{m}^{-1})$</td>
<td>0.05</td>
<td>$10^{-12}$</td>
</tr>
</tbody>
</table>

B. Numerical approach

Based on the above assumptions, the governing dimensionless equations for conservation of mass, momentum, and energy of the three-dimensional unsteady nano fluids magnetoconvection (MHD) flow can be written as follows:

Conservation of mass equation:

$$\frac{\partial U}{\partial X} + \frac{\partial V}{\partial Y} = 0$$

Momentum equation:

Projection according to (ox):

$$\frac{\partial U}{\partial \tau} + U \frac{\partial U}{\partial X} + V \frac{\partial U}{\partial Y} + W \frac{\partial U}{\partial Z} = -\frac{\partial P}{\partial X} + \nu_f \left( \frac{\partial^2 U}{\partial X^2} + \frac{\partial^2 U}{\partial Y^2} + \frac{\partial^2 U}{\partial Z^2} \right) + \frac{\sigma_f \mu_f}{\sigma_f^2} \rho \frac{H}{c} \sin(\gamma) \left( -U \sin(\gamma) + W \cos(\gamma) \right)$$

Projection according to (oy):

$$\frac{\partial U}{\partial \tau} + U \frac{\partial U}{\partial X} + V \frac{\partial U}{\partial Y} + W \frac{\partial U}{\partial Z} = -\frac{\partial P}{\partial Y} + \nu_f \left( \frac{\partial^2 U}{\partial X^2} + \frac{\partial^2 U}{\partial Y^2} + \frac{\partial^2 U}{\partial Z^2} \right) + \frac{\sigma_f \mu_f}{\sigma_f^2} \rho \frac{H}{c} \sin(\gamma) \left( -U \sin(\gamma) + W \cos(\gamma) \right)$$
\[
\frac{\partial V}{\partial \tau} + U \frac{\partial V}{\partial X} + V \frac{\partial V}{\partial Y} + W \frac{\partial V}{\partial Z} = - \frac{\partial P}{\partial X} + \frac{\nu_f \Pr}{\nu_f} \left( \frac{\partial^2 V}{\partial X^2} + \frac{\partial^2 V}{\partial Y^2} + \frac{\partial^2 V}{\partial Z^2} \right) \\
\sigma_f \frac{\partial P}{\partial \tau} H a^2 V
\]  
(3)

Projection according to (\(oz\)):

\[
\frac{\partial U}{\partial \tau} + U \frac{\partial U}{\partial X} + V \frac{\partial U}{\partial Y} + W \frac{\partial U}{\partial Z} = - \frac{\partial P}{\partial X} + \frac{\nu_f \Pr}{\nu_f} \left( \frac{\partial^2 U}{\partial X^2} + \frac{\partial^2 U}{\partial Y^2} + \frac{\partial^2 U}{\partial Z^2} \right) \\
- \frac{\beta_f \Pr}{\beta_f} H a^2 \cos(y)(U \sin(y) - W \cos(y)) 
\]  
(4)

Energy equation:

\[
\frac{\partial \theta}{\partial \tau} + U \frac{\partial \theta}{\partial X} + V \frac{\partial \theta}{\partial Y} + W \frac{\partial \theta}{\partial Z} = \frac{\sigma_f}{\alpha_f} \left( \frac{\partial^2 \theta}{\partial X^2} + \frac{\partial^2 \theta}{\partial Y^2} + \frac{\partial^2 \theta}{\partial Z^2} \right) 
\]  
(5)

In order to cast the governing equations into a dimensionless form, the following dimensionless parameters are introduced:

\[
Ra = \frac{g(T_H - T_C)H^3 \beta_f \Pr}{\nu \alpha_f} ; \quad Pr = \frac{\nu_f}{\alpha_f} ; \quad Ha = \frac{\sigma_f}{\mu_f} \sqrt{H a^2}
\]

The average Nusselt number (\(Nu_{avg}\)) is defined in the heated wall as:

\[
Nu_{avg} = \frac{K_f}{K_f} \int_0^1 \frac{\partial \theta}{\partial Y} |_{Y=0} dX
\]

III. RESULT AND DISCUSSION

The presented results in this work are obtained by using a finite volume home FORTRAN code, named NASIM and developed by the second author which use multi-grid solver explained in details in previous works [17].

In this section, we will adopt the multi-grid solver to study the natural convection of nanofluids in partially heated cubic enclosures with temperature-dependent properties. Numerical simulations are performed for wide ranges of different parameters.

Fig.2. Variation of Nusselt number at different volume fractions.

(a) 20\(^{\circ}\), (b) 30\(^{\circ}\), (c) 60\(^{\circ}\), (d) 90\(^{\circ}\) at Ra=10\(^3\).

Fig.3. Comparison of the stream line velocity for various inclined angles (a) 0\(^{\circ}\), (b) 30\(^{\circ}\), (c) 60\(^{\circ}\), (d) 90\(^{\circ}\) at Ra=10\(^3\).

Fig.4. Comparison of the average Nusselt for various Hartman number at Ra=10\(^3\) and \(\gamma=45^{\circ}\).
Fig. 5. Effects of inclination angle (a) $Ha=0$, (b) $Ha=15$, (c) $Ha=30$, (d) $Ha=60$ on isotherms ($Ra = 10^5$, $\phi=1\%$, $\gamma=45^\circ$).

Fig. 6. Velocity profiles through a centre of the Y=0.5 plane for natural convection in a differentially heated cubic cavity for different Hartman number.
Fig. 7. Velocity vectors for various inclined angles: (a) 0°, (b) 15°, (c) 30°, (d) 45°, (e) 60° and (f) 75° at $Ra=10^3$ and $\phi=1\%$.
In order to study the effects of the external applied magnetic field on heat transfer, a series of simulation tests were performed within a partially heated cubic cavity. Figure 2 shows the effects of volume fractions of nanoparticles on the natural convection heat transfer of nanofluids in a cubic cavity. Four simulation cases, namely, \( \varphi = 0, 2\%, 4\%, 8\% \), at \( Ra=10^5 \) have been realized. It is observed that the addition of nanoparticles in the base fluid improves the heat exchange rates in the fluid and consequently leads to the improvement of the energy transfer. For pure water and Al\(_2\)O\(_3\)–water nanofluids, Figure 3 presents the stream line velocity for various inclined angles at \( \theta=0 \) and \( Ra=10^5 \). It has been shown that the speed of the flow is affected by the angle of inclination. Figure 4 illustrates the variation of average Nusselt number with Hartmann number at Rayleigh numbers 10\(^3\). As can be seen in the figure, the increase of the Hartmann number increases the heat transfer rate. It is interesting to see that this fact is not valid for \( Ha=60 \) and \( Ha=30 \). For lower Ha numbers, the magnetic forces are weaker so the flow is not totally under the influences of these forces. Figure 5 presents the effects of Hartmann number on isotherms. It is observed the isotherms become parallel to the side wall as Hartmann number increases. It is due to the increase of Hartmann number leads to increasing Lorentz force, which results in the domination of conduction heat transfer. The comparison of profiles for \( Ra=10^3 \) and \( \theta=45^\circ \) for water and nanofluids is shown in Figure 6 the influence of the magnetic field on the velocity of the flow is observed by the change in the number of Hartman. The decreased velocity results in decreased convective heat transfer. Figure 7 presents velocity vectors for nanoparticle concentration of 1% at \( Ra = 10^5 \). When the inclined angles increase, the buoyancy force divide into vertical and horizontal forces throughout the cavity. Therefore, the shapes of the streamlines change from circular to elliptical forms. Hence, the alteration provokes the heat transfer process in the cavity to ameliorate or reduce.

IV. CONCLUSIONS

In this paper, natural convection of Al\(_2\)O\(_3\) water nanofluids in a cubic cavity in the presence of magnetic field are numerically investigated. The effects of nanoparticles volume fraction Rayleigh number, Hartmann number, and inclination angle on the flow and heat transfer characteristics have been examined. The following conclusions can be drawn.

1. Adding nanoparticles of into pure water improves natural convection heat transfer in a cubic cavity.
2. In contrast to Rayleigh number, the increase of Hartmann number decreases the heat transfer rate. This effect is more pronounced at high Rayleigh numbers.
3. The influences of external magnetic field on heat transfer vary with different orientations.

References


IMPLEMENTATION OF SMART BUILDING
(a Complete End to End Solution for Smart Building System)

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Abstract—Communication and information technology created a great impact on the way we live, it had changed our life style a great deal, it opens new track to human to invite methods to combine services and systems with the new technology.

In this context Smart Building which is a mixture between application of communication, programming, and control systems became a popular perspective to applied on different types of buildings whether through conducting, services, systems or the three combined.

This work aims to study this type of buildings and the possibility of controlling their resources easily through using the smart devices and also the possibility of controlling the buildings remotely through the internet.

Also “Mind wave Mobile Headset” has been used to read the brain signals (EEG signals) to use them in controlling the building through program loaded on Arduino device.

Keywords—Arduino, Smart building, Mind wave.

I. INTRODUCTION

A smart building is a structure that uses automated processes to automatically control the building’s operations including heating, ventilation, air conditioning, lighting, security and other systems. It uses sensors, actuators and microchips, in order to collect data and manage the systems according to a business’ functions and services.

This work aimed to design and build a smart building which can be controlled entirely through a smart device. In addition it will be controlled by an Electroencephalography (EEG) signal.

This work contains a web application to control the building through any smart device from anywhere via the internet. It also contains a new innovation “mind wave mobile headset” which is put on the head of a human and takes the mind signal, interoperrated and converted it to an electrical signal used to control the building utilities through an Android application.

This work is organized as follows: Section II covering the main concepts of the Smart Building and its components. Section III representing the implementation of the Hardware connection and the Software of the work. Then the automation hierarchy of smart building is discussed in section IV, V and VI. Section VII contains experimentmentation Model for The Smart Building. While section VIII representing Practical Case to Control The Smart Building. Finally section IX drawing the major conclusions from this work and providing some topics that need further investigation and development.

II. SMART BUILDING

Smart buildings are sometimes referred to as ‘automated buildings’, 'intelligent buildings' or buildings that incorporate smart technology. It is a term used to describe buildings that include technologies such as [1]:

- Automated systems.
- Intelligent building management systems.
- Energy efficiency measures.
- Wireless technologies.
- Digital infrastructure.
- Adaptive energy systems.
- Networked appliances.
- Data gathering devices.
- Information and communications networks.
- Assistive technologies.
- Remote monitoring.

A smart building uses sensors, actuators and microchips, in order to collect data and manage it according to business’s functions and services. This infrastructure helps owners, operators and facility managers to improve asset reliability and performance, which provides comfort, security, energy efficiency (low operating costs) and convenience at all times, also optimizes how space is used and minimizes the environmental impact on buildings.

Today, buildings are complex concatenations of structures, systems and technology. Over time, each of the components inside a building has been developed and improved, allowing building owners to select lighting, security, heating, ventilation and air conditioning systems independently.

Making a smart building begins by linking core systems together such as lighting, power meters, water meters, pumps, heating, fire alarms and chillier plants with sensors and control systems and then connecting the building automation system to enterprise systems. At a more advanced stage, even elevators, access systems and shading can become part of the system [2][3].
Integration is enabling facility executables to reap smart-building benefits, both in new construction and also by gradually transforming existing buildings into smart buildings.

Installation of smart products give the building and its occupants various benefits the same benefits that technology and personal computing have brought to us over the last years, convenience and savings of time, money and energy.

A. Benefits of Smart Building

Creating or transforming a building into a smart building is beneficial for both the owner and the organization working within. In general Smart building strategy can reduce energy costs, increase the productivity of the facility staff, improve building operations, support sustainability efforts ... etc. The most important benefits of smart building are summarized in the following points:

- The ability to control the building.
  It provides good control of internal conditions of the building, in addition to the possibility of controlling and monitoring the entire building remotely.

- Reducing operating costs.
  Smart buildings are usually highly efficient buildings where operating costs are significantly lower than similar buildings, intelligent monitoring and control of energy-intensive systems such as HVAC and lighting help reduce costs.

- Fast and effective service.
  Smart building technologies give building management professionals the tools they need to better serve users. Accessing building systems via the Internet makes it easier for users to assess real-time conditions, detect problems, and monitor building performance off-site, and problems are identified early and solved immediately.

- Web-based security system.
  A Web-based security system which can be used in smart building allows security personnel to be able to view live video from surveillance cameras on a laptop or portable device.

- Enhanced life safety and security.
  The operators in the smart building are more aware of what’s happening in the building, this enables them to efficient lighting controls and efficient HVAC, which leads to contribute to preservation of their life cycle to the total smart building.

- Compatible with existing buildings.
  Automation systems can be applied on even old buildings. There is no need to establish a new building instead.

- Providing significant benefits to building owners and end-users, also increasing the level of comfort and time saving.

- Smart buildings are more effective to operate, and offer so much potential for future efficiencies.

B. Smart Building Component

There are main parts and components that make the building become smart and distinguished from normal building.

- Hardware

Smart buildings need the ability to recognize what's happening with an environment (inside and outside a building), needs something like human senses. For this purpose smart buildings are equipped with sensors and meters. So, a building can determine light intensity, inside and outside temperature, detect a gas leak and so on.

Besides observing the environment, a building also should be able to change its state. For this purpose "smart" buildings are equipped with devices and actuators that can control various engineering systems like lighting, heating, air conditioning.. etc [4].

- Software

Sensors and meters provide only raw information. A smart building needs to extract useful information, learn from this information, make decisions and even predict status of environment and people activities. It is done by special software which is an artificial intelligence of a building [4].

Software is a vital part of any smart building, and the target systems comprises all parts of the buildings and all pieces of building equipment that have a direct or indirect impact on the energy of the building. This includes all appliances that consume, generate or store energy [4].

- Network

To allow the building to act as a whole a communication network is required. It connects all devices to each other and with the artificial intelligence component. It is the nervous system of a building [4].

III. IMPLEMENTATION OF SMART BUILDING “PRACTICAL PART”

In this work, two different methods have been used to control the smart building. The first was to control the smart building by using a Mindwave mobile headset, while the second was to control the smart building by web application.

The automation hierarchy of smart building consists of three levels as shown in Fig.1. These levels are field, automation and management levels, where the field and automation levels are shared for both methods in management level.
1. Automation Hierarchy of Smart Building

The main reason for using two methods to control the smart building is to provide more than one option for controlling the building in flexible and easy way and to commensurate with most segments of society as well as to reduce the cost.

Web application provides the possibility of controlling the building and monitoring its condition via the Internet or a local network by using any smart device that has a web browser, It also provides the possibility of controlling the building remotely from anywhere.

While, the Mindwave mobile headset is a new innovation and has been used in this work to be used by a certain class of society such as people who have physical impairment, it provides easy way for them to control the building, And it also can be used by anyone.

This work also contains the Arduino controller and some components such as fans, IEDs, sensors .. etc, to build a model that simulates a real building. Components will be controlled by the Arduino controller that receive orders either by Android application which is considered as an interface for the Mindwave mobile headset or Web application.

IV. FIELD LEVEL

The lowest level of the automation hierarchy is the field level, which includes the field devices such as actuators and sensors. The task of the devices in the field level is to send or receive data to or from automation level and this data may be both binary and analog.

At the field level, interaction with the physical world takes place. Environmental data are collected (measurement, counting, metering) and transformed into a representation suitable for transmission and processing. Likewise, parameters of the environment are physically controlled (switching, setting, positioning) in response to commands received from the system.

In the practical implementation of the work a set of equipments and component have been linked with the Arduino microcontroller and controlled by it, when it receives an order from the web application or Mindwave Mobile Headset via the android application or through some of sensors.

V. AUTOMATION LEVEL

Automation level is for control, Operation and monitoring the equipments and component in field level based on orders that are received from Management Level.

The Arduino Mega 2560 has been used in this work as a controller which connects field level with management level.

Arduino communicates with “the software of hardware controller” which in turn communicates with Smart Building Database and send orders to the Arduino controller based on the saved data in this database.

A. Smart Building Controller

A controller (also known as a control panel or control unit) is a device, historically used mechanical, hydraulic, pneumatic or electronic techniques often in combination, but later in the form of a microprocessor or computer, which monitors and physically alters the operating conditions of a given dynamical system [5].

A Control Unit (CU) directs all input and output flow, and it is considered as the processor brain because it issues orders to just about everything and ensures correct instruction execution.

The Arduino Mega2560 Fig2 is a microcontroller board has 54 digital input/output pins (15 of them can be used as PWM outputs), 16 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, and a reset button.

2. The Arduino Mega 2560

Code of the Arduino board has been wrote by using the Arduino IDE. This code defines the operating way to the Arduino board. In other words, how the board will control the electrical component based on the received orders from the USB port or via bluetooth connection, also based on the received data from sensors.

- Arduino Flow Chart

The Arduino gives orders for equipment and electronic components that have been connected with it based on the commands and data that the Arduino received from the Web application and android application as shown in first flow chart in Fig3, or received from sensors as shown in second flow chart in Fig4.
B. Smart Building Database

A database management system (DBMS) is a software system for creating and managing databases. The DBMS provides users and programmers with a systematic way to create, retrieve, update and manage data [6].

The DBMS essentially serves as an interface between the database and end users or application programs, ensuring that data is consistently organized and easily accessible, it is actually a tool used to perform any kind of operations on data in database, also it provides protection and security to database [6].

Smart Building Database has been created by using SQL server, then it has been connected with web application and “the software of hardware controller”. This database consists of a set of tables contain data for the smart building.

The main table in this database called switches, it consists a set of fields. Each field stores specific data for equipment as following:

- Switch_Name field contains the name of component.
- Switch_Status field contains the current status of component if it’s on or off (true or false).
- Switch_Changed field become ‘true’ during the process of changing the status of the component.
- SwitchData field contains the data of sensors.

The data for equipment and devices which is controlled by applications are stored in switches table as shown in Fig5.

5. Switches Table

The web application stores any changes occurs in the Switches Page in switches table and the software of hardware controller communicates with database every second to see if there any changes in the status of switches to send them to smart building controller via the serial port.

The web application also generates a set of tables in database to store user data (the user name and password) to make user able to log in for Switches Page.
VI. MANAGEMENT LEVEL

The management level is the top level of the automation hierarchy, it provides web and terminal services for operation and monitoring.

At this level, information from the entire system is accessible. A unified interface is presented to the operator for manual intervention. Access to automation level values is provided, including the modification of parameters.

Management Level in this work includes two methods to control the smart building. Mindwave mobile headset with android application and the web application. They will be discussed in more details in next subsections.

A. First Method “Mindwave Mobile Headset and Android Application”

Mindwave Mobile headset as shown in Fig6 is a wireless device used to record the EEG signals, then it sends a corresponding data of the brain waves to the device connected with it via bluetooth connection [7].

The headset uses eSense meters for Attention and Meditation. The meter value for each type of eSense is reported on a relative eSense scale of 1 to 100.

Given that the Attention can be controlled through a focus, two actions have been chosen in practical implementation of the work “single and double blinking” which they give different range of values on eSense scale.

The headset records low frequencies of single blinking and gives small values on eSense scale while higher frequency is recording when the Human blinks his eyes twice and the values will be higher on eSense scale.

Android application as shown in Fig7 is designed to communicate with the headset and it acts as an intermediary between the Mindwave Mobile Headset and the smart building controller “The Arduino”. It takes advantage of these values in order to send commands to the Arduino.

Android mobile which contains this application, receives signals from the Mindwave Mobile Headset via bluetooth connection and it also sends orders to the Arduino via bluetooth connection.

B. Second Method “Smart Building Web Application”

A web application “web app” is a software program that is stored on a remote web server and delivered over the Internet through a browser interface. Unlike traditional desktop applications, which are launched by operating system. It will make it independent of operating system, place, and used hardware.

Web application is used to control the smart building by using any device from anywhere via the Internet.

Web application has several advantages over desktop applications. They run inside web browsers which mean it will operate in any device has a web browser rather than the operating system, so it can considerably lower the costs because of reduced requirements on the end user system.

In this work, Smart building web application has been created by using ASP.NET MVC framework and C# language via Microsoft visual studio.

After the creation of web application as shown in Fig8, it has been published in a local web server, and can be opened and used by any smart device exist on the same network of the local Web server by writing the URL (http://localhost_smartBuilding/) of the application in the device’s browser.
The Smart Building Web Application consists of four pages (Home Page, About, Contact, Switches).

C. Comparison Between the Two Methods

Table 1 compares the two methods in the management level of smart building to clarify the difference between them and their specifications.

<table>
<thead>
<tr>
<th>Comparatives</th>
<th>First Method Mindwave Mobile headset and Android Application</th>
<th>Second Method Smart Building Web Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements</td>
<td>Mindwave headset and Android device</td>
<td>Any device has web browser</td>
</tr>
<tr>
<td>Access method to the controller</td>
<td>Bluetooth connection</td>
<td>Wifi connection</td>
</tr>
<tr>
<td>Provision of services</td>
<td>Used by any one, even if the user has physical impairment</td>
<td>Provides friendly interface for web browser users</td>
</tr>
<tr>
<td>Possibilities</td>
<td>Controls appliance of the smart building</td>
<td>Controls appliance of the smart building and knows the status of some sensors</td>
</tr>
<tr>
<td>The cost (for user)</td>
<td>Higher cost</td>
<td>Lower cost</td>
</tr>
</tbody>
</table>

VII. EXPERIMENTATION MODEL FOR THE SMART BUILDING

Designing and implementation an experimentation model for smart building as shown in Fig 9 has been done to apply the idea of the work.

VIII. PRACTICAL CASE TO CONTROL THE SMART BUILDING

As a practical case to control the component in smart building, this section will explain the way to open "LED 2" by using the two methods.

A. Using The First Methods

The following steps clarify how to open the LED 2 by using the Mindwave Mobile headset and Android Application:

- Operating the headset and putting it on the head where the sensor arm resting on the forehead above the eye.
- Establishing Bluetooth setting to connect the mobile with the headset and the Arduino board.
- Changing the focus to LED 2 button by blinking the eye as one blink to reach the targeted button.
- Selecting the LED 2 button by blinking the eye as double blink.
- Closing it by following the same previous steps.

After doing these steps the LED will operates as shown in Fig 10. These steps also can be apply for all other equipments.

Sometimes, some delay occur to implement this process due to the nature of human eye, because blinking is a semi-autonomic rapid closing of the eyelid which means in some cases the headset will not record the range of blinking frequencies.

B. Using The Second Methods

The following steps clarify how to open the LED 2 by using the web application:

- Opening the web application by writing the URL (http://localhost.smartBuilding/) of the application in the device's browser.
- Opening Switches page by login to the page via entering the email and Password.
- Pressing the edit button that located next to LED 2 switch.
- Changing the current status of it, then pressing on save button to save the change.

After doing these steps the LED will operates as shown in Fig 10. These steps also can be apply for all other switches.

9. Experimentation Model for The Smart Building
IX. CONCLUSION & FUTURE WORK

A. Conclusion

The idea of the smart building has been implemented in this work, where the work has been done in three levels of the Automation Hierarchy (field, automation and management levels) as following:

- In the management level

Two different methods have been implemented to control the smart building. The first was a Mindwave mobile headset, and the second was a web application.

- The Mindwave mobile headset is a new innovation that has been used to control the building via Android Application which in turn acts as an intermediary between the Mindwave Mobile Headset and the smart building controller "The Arduino".
  Two range of the EEG signals are used and the Android application takes advantage of these frequencies in order to send commands to the Arduino.

- Smart building web application has been created to control the building and monitoring its condition by using any device from anywhere via the Internet or a local network.
  As an experiment for the smart building web application, it has been published in a local web server, and can be opened and used by any smart device exist on the same network of the local Web server.

B. Future work

We are looking to implement our work in real case in the future, this requires to develop the work in several parts, such as:

- Publishing the web application on web server to be used by any device via the internet.
- Creating more applications for the Mindwave mobile headset compatible with other operating system rather than the Android.
- Using other types of controllers have more ability than Arduino board, that can be used to control the appliances of real building.

REFERENCES
1. Smart buildings http://www.designingbuildings.co.uk/wiki/Smart_buildings (October, 15th 2017)
2. Enterprise IOT Insights (What is a smart building and how can it benefit you?) http://industrialiotsg.com/20160725/5g-smart-building-tae31-tae99 (October, 15th 2017)
5. Controller (control theory) https://infis.io/infis/OnXovpiizW3WknF1nKLwH1CnI.72vedxi0kDDP1mXWo8uce/wiki/Controller_(control_theory).html (October, 15th 2017)
Comparative Study of the Performance of Two Heating Ways in the Greenhouse Production

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Abstract— This paper study the efficiency of the deployment in Tunisia of the Ground Source Heat Pump (GSHP) system and of a solar air heater with latent storage (SAHLS) for heating mode application. A pilot GSHP system using conic ground heat exchanger and a SAHLS were installed and experimented in the Research and Technology Center of Energy (CRTEn), Borj Cedria, northern Tunisia. The status of geothermal and the solar air collector energies and their utilization are pointed out, the evaluation of both systems is examined for air heating. Their effect in the growth rate and yield of tomato are also studied. The main results show that the SAHLS gives the appropriate microclimate for plants under greenhouse in comparison with GSHP: high night temperature and low relative humidity. This leads to earliness of 2 weeks and a good quality and quantity of fruits represented by high relative growth rate, high phenolic compounds and a high quantity of marketable fruits.

Keywords— Solar air collector, heat pump, yield, greenhouse, fruits

I. INTRODUCTION

Worldwide, tomato (\textit{Solanum lycopersicum}, L) represent one of the most popular and extensively consumed vegetable crops [1]. Besides to its economic importance, this species can serve as an experimental model for the study of fruit development [2]. Otherwise, growing conditions influence its productivity and quality even under greenhouse. The major environmental factors that affect the growth and the precocity of production of greenhouse plants are carbon dioxide, light, humidity and temperature. Temperature affects photosynthesis, respiration. It intervenes in the growth rate, flowering and earliness of maturity.

In Tunisia, one of the major problems encountered in greenhouses is the control of the internal climate. The lack of heating has unfavorable effects on the precocity of production. Moreover, natural resources are considered as rare specially in Tunisia [3] while the energy requirement is increasing continuously. Various types of heating systems used in the conventional greenhouses utilize the fossil fuels. Indeed, the increasing of the price of the fossil fuels raises the production cost and reduces the income of farmers [4]. Consequently, it is necessary to replace the current conditioning units with new technologies better energy efficiency, based on renewable energies. Henceforth, we should aim towards the use of renewable energy such as solar and geothermal energy to compensate this need.

So, to provide an amount of heat nocturnal use, a new Solar Air Heater with Latent Storage Collector (SAHLS) using spherical capsules as a packed bed absorber and a geothermal system using a geothermal Heat Pump and a conic basket geothermal heat exchanger were designed and realized in the Research and Technology Center of Energy (CRTEn) in Tunisia and used for heating the greenhouse. The status of geothermal and the solar air collector energies and their utilization are pointed out, the evaluation of the GSHP as well as the SAHLS systems is examined for air conditioning. There is little information about the effects of climatic conditions generated by these heating systems used in greenhouses on tomato fruit quality produced. This study underscore the range of suitability of each heating system for plants grown under greenhouses using them.

Therefore, to get a clear picture of suitable technology to improve performance and to minimize greenhouse in terms of energy requirements and costs, the state of the plant behavior under greenhouse heated with two different technologies will be discussed in this research. Thus, the work is aimed to control crop production, the improvement of the yield and of the visual quality and the nutritive value of the greenhouse-grown tomato fruits.

II. MATERIALS AND METHODS

Three insulated greenhouses were used. They were designed and constructed to investigate a comparative study. The first is considered as a reference named (IG) (Fig 1a). The second is using a solar air heater with latent storage collector (SAHLS) and was named IGHLS (Insulated Greenhouse with Latent Heat System), shown in (Fig 1b). The third is using a heat pump system and named IGHP (Insulated Greenhouse with Heat Pump) (Fig. 2).

A. Experimental Greenhouse Design and Site Description

The experimental setup has been installed at the Research and Technology Center of Energy in Borj Cedria, on the Mediterranean coast of North Africa, near the city of Tunis in Tunisia, with the following coordinates: Latitude 36°, 43’ N and Longitude 10°, 25’.
The three experimental small chapel-shaped greenhouse occupies each one a floor area equal to 14.8 m². The greenhouse wall and roof oriented to the south are covered by glass plates thickened of 3mm. Sidewalls are built by sandwich panels thickened of 0.4m and the northern roof thickened of 0.6m. The slopes of the southern wall are equal to 30° and of the southern roof is 33°. The greenhouse was equipped with a centrifuge fan controlled by a differential thermostat. When the temperature inside the greenhouses exceeds the optimal growth temperature of the plant (28 °C), the fan operates.

B. Experimental Setup and Methodology

The new SAHLS was used as a mean to heat the interior environment of the greenhouses during the nighttime.

During the sunshine period, the charging process, a fraction of the total solar radiation received inside the greenhouse is absorbed by the black packed bed absorber of the SAHLS. The absorbed thermal energy is stored as sensible and latent heat forms into the collector. In the sunset and during the night, the greenhouse air temperature drop causes by a radiation heat exchange in the IGHLS. In this time a fan blows air across the PCM capsules and extracted the stored heat into the IGHLS, so the discharging process is done.

For the third greenhouse, the heating system essentially consists of two components which are geothermal Heat pump and two conic basket geothermal heat exchangers (Fig.2). The geothermal heat pump unit used is a reversible water-to-water Ageo CIAT type, which is considered as an individual heater (Fig.2b). The geothermal heat pump is equipped with two circulating pumps, one for hydraulic circuits and the other for external hydraulic circuits (Geothermal heat exchanger in the form of conical buried basket) and internal (the exchanger in the floor of the greenhouse and the suspended one). The two Conic Basket Geothermal Heat Exchanger (CBGHE) represented in (Fig.2a), are installed vertically at 3m depth in the ground. To evaluate the performance of the installed geothermal system for greenhouse heating, the greenhouse is equipped with a multilayer heat exchanger system (Fig.2c).

C. Measurements

1) Plant Growth and Fruit Classification: During the culture, every two days, plant height and diameter of stem were measured. Ten plants were selected in order that the dates of flowering and the number of inflorescence and flowers will be recorded. The date of fruits’ maturity is also recorded.

To obtain the cumulative yields and to evaluate fruit quality, the harvested tomatoes were also categorized into marketable fruits and other non-marketable fruits (undersized <50 g). All yield fractions were counted and weighed separately.

2) Chlorophyll Content and Photosynthetic Parameters: Chlorophyll content of the youngest fully expanded leaves was estimated at midday. Chlorophyll content index (CCI) were measured at random points (n=8-10) using an Opti-Sciences CCM-200. The photosynthetic rate is typically measured by determining the net CO₂ fixation rate [5]. The photosynthetic rate was determined using a Li-Cor handheld photosynthesis system (Li-Cor 6200, Li-Cor Nebraska, USA). The photosynthesis rate (A), transpiration rate (E) and intercellular CO₂ concentration (Ci) of the tomato’s leaves from the corresponding sites were determined at 9:30 h–11:30 h on a sunny day.

3) Determination of Phenolic Compounds: To investigate the contents of phytochemical compounds, three replicates containing three tomatoes were dried by lyophilization. The chemical analyses regarding the determination of the contents of secondary plant compounds, in the homogenate of each replication were performed in triplicate.

Plant powder (1g) was stirred in 10ml of 80% methanol. After 30 min of magnetic stirring and standing for 24h at 4 °C in the dark, the mixture was filtered through ashless filter paper. The extract obtained is finally stored at 4 °C in the dark for assay.

The phenolic compounds were extracted following the method outlined by [6]. The determination of total flavonoids is done according to the method of [7]. Lycopene content in tomato samples was extracted using the method outlined by [8].
III. RESULTS

A. Climatic Conditions

Figure 3 shows that, at the heating phase of the SAHLS, the inside air temperature of IGHLS is with an average value of 15.44 °C. This temperature decreases gradually as the heating system operates. It reaches an average value equal to the ambient temperature when the stored thermal energy dropped. For the IGHP, diurnal and nocturnal temperature were lower than that under IGHLS and IG due to the effect of shading done by the multilayer heat exchanger system. The two heating systems, the SAHLS and the GSHP, allow a temperature elevation of 1.5 °C and 0.67 °C, respectively in comparison with the conventional greenhouse.

For the relative humidity, it is higher inside IGHP than inside IG and IGHLS at night due to dehumidification done with the solar air collector by its outlet air temperature.

![Image](image_url)

Fig.3 Ambient air temperature and relative humidity and inside the experimental greenhouses as a function of days (15th-16th February, 2014).

B. Gas Exchange Measurements and Chlorophyll Content

Table 1 shows the photosynthetic capacities and transpiration of the tomato under the microclimatic conditions of experimental greenhouses. When grown under IGHLS, a significant stimulation in net photosynthesis (A) followed by a significant increased transpiration (E) were observed. A drop in stomatal conductance (gs) and in the intercellular CO₂ (Ci) was showed for the plants under this greenhouse in comparison with IGHP. Under IGHP, the net photosynthesis was 15.10molCO₂ m⁻² s⁻¹ followed by a lower value under IG. The stomatal conductance and the Ci were the highest at this investigation. The lowest values were shown under IG.

The chlorophyll content was higher under IGHLS as compared with IGHP and IG with 17.81, 15.70 and 14.02 g mg⁻¹ FM, respectively (Fig.4). It is chlorophyll which allows the photosynthetic reaction. As chlorophyll is less abundant in IGHP, more light is needed to produce enough sugar to the life of the plant.

![Image](image_url)

Fig.4 The chlorophyll content in different experimental greenhouses, (IG) Insulated greenhouse as a reference, (IGHLS): Insulated greenhouse equipped with a solar air collector and IGHP which is insulated greenhouse heated via a heat pump.

<table>
<thead>
<tr>
<th></th>
<th>Cl (µmol mol⁻¹)</th>
<th>E (mmol H₂O m⁻² s⁻¹)</th>
<th>gs (ms⁻²)</th>
<th>A (mol CO₂ m⁻² s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IG</td>
<td>219.0±61.54</td>
<td>3.24±0.48</td>
<td>0.21±0.05</td>
<td>14.86±3.73</td>
</tr>
<tr>
<td>IGHLS</td>
<td>226.8±27.35</td>
<td>3.94±0.20</td>
<td>0.30±0.03</td>
<td>18.88±2.30</td>
</tr>
<tr>
<td>IGHP</td>
<td>389.7±95.95</td>
<td>3.09±0.56</td>
<td>0.42±0.10</td>
<td>15.10±0.20</td>
</tr>
</tbody>
</table>

C. Influence of Microclimate

1) In the Growth Rate and Flower Number: Temperature strongly affected both relative growth rate of diameter and the height stem: RGRd and RGRh (Fig.5). According to the difference between the night temperature determined for both systems, it is suggested that RGRH of plants under IG was relatively stronger affected than RGRh of the plants grown under greenhouses with heating systems. It is around 0.034 mm day⁻¹ against 0.038 and 0.040 for IGHP and IGHLS, respectively. Furthermore, it is shown that plants of IGHLS are favored by the high value of RGRd (0.024 mm day⁻¹) in comparison with IGHP or IG.
It is shown in Fig.6 that the number of flowers per plant is the highest in plants grown under IGHLS. From 31 January until 20 February, the number of flowers was similar under the different greenhouses, peaked in the second period from 20 February until 22 March and become again similar at the third period (in April). The number reaches at average 7, 5.4 and 3.5 flower plant⁻¹ under IGHLS, IGHP and IG, respectively in the second period.

3) In Phytochemical Compounds: Biochemical analysis showed that the phenolics levels in the fruits of plants grown under IGHLS was significantly higher than those of IG and IGHP with values of 14.65, 10.99 and 7.79 mg EAG g⁻¹ DW, respectively (Fig.7).

For the flavonoids and the tannins, the fruits of IGHLS still have the high level reaching a value of 2.21 and 1.11 mg BC g⁻¹ DW (Fig.8).
The lycopene values show that fruits of IGHLS enjoy the highest one against those of IGHP and IG. It reach 0.020, 0.013 and 0.007 µg g-1 DW, respectively (Fig.9).

![Figure 9: Effects of microclimatic conditions on lycopene in tomatoes of IG, IGHLS and IGHP. IG Insulated greenhouse as a reference. IGHLS: Insulated greenhouse equipped with a solar air collector and IGHP which is insulated greenhouse heated via a heat pump.]

III. DISCUSSION

In this study, a decline in photosynthetic capacity accompanied by a reduction in gs, C1 and E in the IG (Table I) was found, indicating that this response is one of the reasons for the low night temperature. The same results were observed in mango [9] and Tomato [10] treated with low night temperature. They demonstrated that photosynthesis is reduced in days following cold nights. Indeed, low night temperature treatment caused a substantial reductions in photosynthetic capacity in tomato [10].

Temperature is a key factor that regulates the photosynthetic processes of plants [11]. This parameter was enhanced by the night heating under IGHLS (Table I) which is in agreement with the experimental warming in both species P. asperata and A. faxoniana, which indicated that night warming could accelerate photosynthesis by increasing chlorophyll concentration and apparent quantum efficiency [12]. In a consistent way with our findings (Fig. 4, Table I), [13] indicated that low temperature forms a stress decreasing chlorophyll biosynthesis, photosynthetic rate and carbohydrate metabolism which result in a reduction of crop yield (Table II) and quality. At the physiological level in tomato, some negative impacts were also observed: low night temperatures of 6 or 9 °C led to an irreversible reduction in the photosynthetic rate and stomatal limitation of CO2 supply [10].

Hastened development of tomato plants found in IGHLS has been reported to the increasing night temperature. Yet, decreasing night temperatures to 11 °C at average has been reported to decrease stem elongation of tomato (Fig. 5). Many researchers reported that a direct effect on plant growth, development and morphology was awarded to temperature [14]. Others indicated that the difference between day and night temperature involved in the control of stem elongation and thus height [15]. This is in consistent with earlier literature on poinsettia when lower night temperatures have decreased size and number of bracts [16].

Otherwise, according to [17], light and temperature inside the greenhouse represent factors which create a particular microclimate with significant effects on growth, development and crop productivity. Therefore, although night-warming increased average diameter and had no significant effect on average plant height and stem base diameter of both species P. asperata and A. faxoniana [12]. The reduced number of flowers was shown under IGHP and IG (Fig.6) as found by [18], when the number of flower trusses of ‘Money-maker’ was reduced by the low night temperature regime.

The lower light intensity received as well as the low night temperature reached by plants in the greenhouse heated via heat pump was the cause of the lower content of phytonutrients in the fruit (Fig.7, 8, 9) which was supported by [19] who described that the phytonutrients accumulation are strongly affected by the intensity, duration and quality of light. Reference [20] suggest that temperature in the greenhouse, season production and lighting conditions inside the greenhouse, affect lycopene biosynthesis or accumulation process. They prove that higher temperatures observed in the glasshouses allowed a greater biosynthesis of lycopene.

In our study, we found that the solar air system is most efficient for heating the interior of the greenhouse without secondary effect than the heating system via heat pump which hinder plants by shading done from the exchangers. It’s consistent with previous works which reveal that shading reduce the intensity of solar radiation and the greenhouse air temperature [21] and consequently reduces the quality of the fruit [22].

It is proven for Tunisian climatic conditions that PCM assisted solar air heaters can maintain the internal air temperature of 15 °C for greenhouses, which is ideal for tomato planting [23]. Reference [24] found that PCM utilization in the insulated greenhouse with latent system is capable to keep the internal temperature at the level of 15 °C at night while the temperature outside reaches 8 °C. However, the combined system has several characteristic benefits. It is suitable from both economic and technical points of view and can be used instead of conventional systems [25].

IV. CONCLUSIONS

Since greenhouse climate control is aimed to increase production, this control could also improve the visual quality and nutritive value of the greenhouse-grown tomato fruits.

In this context, the use of different heating systems involve installation and operational costs which the user has to bear. However, each system has some advantages and limitations, which the user has to think of before going for the installation. Thus, from our study we can define the special solar air collector as a greenhouse facility which can be used for dehumidification processes and to produce plants with the thermal stored energy. It gives the appropriate microclimate for plants under greenhouse in comparison with GSHP. The produced energy excess can also be used to cover the basic
load for night heating inside greenhouses. Under the greenhouse heated with this solar system, we found a high RGRh and RGRd, an earliness of production with 2 weeks and a good quality and quantity of fruits represented by high phenolic compounds and a high quantity of marketable fruits. As regards the other heating system via the heat pump, it is desirable to find a solution for heat exchangers in order not to interfere brightness which acts negatively on the growth of plants. Overall performance of a greenhouse coupled with any heating system is influenced by several interrelated parameters.

These findings should not be interpreted as meaning that solar air heating system should replace heat pump heating system in Tunisia. The performance for both systems is strong and the heat provided can satisfy the demand. The results do suggest that more attention might be directed toward improving greenhouse heating system via heat pump installation. So, we can prove that the solar air heater with latent storage system is an effective method to achieve a suitable environment for crop growth and to enhance crop productivity and quality out of season.

ACKNOWLEDGEMENT

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REFERENCES

Determining Hansen Solubility Parameters by StefanisPanayiotou Method for Fatty Acids Extraction by Petrochemical and Green Solvents

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Abstract –In recent years, research in the field of green solvents has focused on the search for agro-solvents to reduce the use of petroleum solvents, although they are very efficient and of a lower cost. Several innovations towards green solvents have been developed: solvent-free extraction technology, the use of water as an alternative solvent, the use of ionic liquids.

Bio- or agro-solvents are an alternative that presents less risk and danger to the environmental impact than petroleum solvents. Terpenes, considered as solvents, are renewable, an interesting alternative to typical solvents. They are found in the essential oils and oleoresins of fruit and aromatic plants. \( \alpha \)-pinene is a monoterpene likely to be an interesting alternative. It is the main constituent of turpentine oils of most conifers and a component of wood oils, leaves and bark of a wide variety of other plants such as rosemary, parsley, basil, mint, lavender, sage and ginger.

In our study, we focused first on the determination and comparison of Soxhlet extracting fatty acid content of food matrices: peanut seeds, soybeans, sunflower seeds and olives (chemlal), using \( \alpha \)-pinene as green solvent in substitution of n-hexane as petrochemical solvent.

No significant qualitative or quantitative difference could be highlighted between the different extracts. This allows us to conclude that the proposed solvent, \( \alpha \)-pinene, is effective and valid for the recovery of oils and fats in oilseeds, and can then be a definite alternative to n-hexane. Even if its boiling temperature is higher than that of n-hexane (excess energy required for its heating), the fact that the recycling rate of \( \alpha \)-pinene is almost total (90\% against 50\%) makes it more interesting, more reliable and safer for the environment.

We then considered the determination of \( \alpha \)-pinene and n-hexane solvent power on fatty acids of used matrices. We applied the predictive method of Hansen solubility parameters, parameters determined by StefanisPanayiotou approach.

Keywords- \( \alpha \)-pinene, green solvent, fatty acid extraction, Hansen parameter.

I. INTRODUCTION

During the last years, research in the field of green solvents has focused on the search for agro-solvents to reduce the use of petroleum solvents, although they are very efficient and of a lower cost. Several innovations towards green solvents have been developed: solvent-free extraction technology, the use of water as an alternative solvent, and the use of ionic liquids.

Bio- or agro-solvents are an alternative that presents less risk and danger to the environmental impact than petroleum solvents. Terpenes, considered as solvents, are renewable. They are then an interesting alternative to typical solvents. We found them in the essential oils and oleoresins of fruit and aromatic plants. The \( \alpha \)-pinene is a monoterpene likely to be an interesting alternative. It represents the main constituent of turpentine oils of most conifers, and a component of wood oils, leaves and bark of a wide variety of other plants such as rosemary, parsley, basil, mint, lavender, sage and ginger.

II. VEGETABLE MATERIAL

Oilseeds (peanut seeds, soya and sunflower) used for fatty acid extraction were bought on the local market. The olives (chemlal) were harvested at Ighil Ali (Bejaia, Algeria).

III. SOLVANT

The solvents used for this study are \( \alpha \)-pinene, a bio-solvent and n-hexane, a petrochemical solvent. Their properties are described in Table 1.
### Table 1

<table>
<thead>
<tr>
<th>Properties</th>
<th>n-Hexane</th>
<th>α-Pinene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical structure</td>
<td>![Chemical structure image]</td>
<td>![Chemical structure image]</td>
</tr>
<tr>
<td>Molecular weight (g/mol)</td>
<td>86.17</td>
<td>136.26</td>
</tr>
<tr>
<td>Specific gravity (25°C)</td>
<td>0.65</td>
<td>0.874</td>
</tr>
<tr>
<td>Viscosity (cP, 25°C)</td>
<td>0.32</td>
<td>1.293</td>
</tr>
<tr>
<td>Boiling point (°C)</td>
<td>68.74</td>
<td>156-158</td>
</tr>
<tr>
<td>Refractive Index</td>
<td>1.3723</td>
<td>1.4636</td>
</tr>
<tr>
<td>Solubility in water (wt% 25°C)</td>
<td>0.00123</td>
<td>Insoluble</td>
</tr>
<tr>
<td>Dielectric constant (20°C)</td>
<td>1.89</td>
<td>2.76</td>
</tr>
<tr>
<td>Flash point (°C)</td>
<td>23</td>
<td>32</td>
</tr>
<tr>
<td>Surface tension, dyne/cm (25°C)</td>
<td>18.4</td>
<td>25.3 ± 3.0</td>
</tr>
<tr>
<td>Odour</td>
<td>Petroleum</td>
<td>Turpentine resin</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>Top</td>
<td>Low</td>
</tr>
<tr>
<td>Renewable</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Toxic</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

### IV. Experimental Protocol

The Soxhlet extraction of the oils using n-hexane and α-pinene was carried out according to the standard procedure (ISO 659-1998) [4] and illustrated in Fig. 1.

For each testing n-hexane, mass of the sample is 30 g and volume of solvent is 300 mL. After 8 hours of extraction, the distillate in the flask was concentrated to dryness with a vacuum rotary evaporator; the flask is then cooled to room temperature in a desiccator and weighed to the nearest milligram.

The Soxhlet extraction using alpha-pinene was also performed according to the above standardized method. The recovery of oil was carried out using a Clevenger distillation of a mixture (oil+alpha-pinene), a method suggested by Virot et al. for lipid extraction by d-limonene [5].

![Fig. 1 Extraction procedure representation using α-pinene and n-hexane](image)

Thus, once extraction with alpha-pinene was achieved, 150 mL of distilled water was added to the mixture (extracted oil+alpha-pinene) in the flask. Then, the flask was connected to a Clevenger apparatus and a condenser. At the end of distillation, two binary mixtures consisting of two immiscible phases were obtained: the first one (water/oil) in the distillation flask, and the second in the Clevenger glassware composed of water and alpha-pinene. The recovery of the different phases was performed by simple phase separation. The water and alpha-pinene were re-used, after checking that lipid was not detected in the Clevenger phases. Fig. 1 describes the various stages of the extraction by alpha-pinene.
All extractions, both using n-hexane or alpha-pinene, were performed in triplicate, and the mean values were reported.

Qualitative and quantitative aspects have been considered in the results treatment [6].

V. CHROMATOGRAPHIC ANALYSES

In order to check if alpha-pinene undergoes degradation during the extraction of oils, the samples of alpha-pinene, pure and recovered after extraction, were analyzed by gas chromatography (GC) coupled with mass spectrometry (MS). GC–MS analyses were carried out in a Shimadzu QP2010 (Kyoto, Japan) gas chromatograph. The gas chromatograph was equipped with a CP-Wax (52 CB) capillary column 30 m x 0.32 mm x 0.5 μm (Varian, Walnut Creek, CA, USA). The velocity of the carrier gas (He) was at 47 cm/second.

Flow rate was held at 1.69 mL/minute and the column head pressure was 20 kPa. Samples were injected (2μL) with a split mode (ratio 1:15) and the injector temperature was set at 250°C. The oven temperature was increased from 60°C (1 minute) to 180°C at a rate of 20°C/minute, then increased from 180° to 230°C at a rate of 4°C/minute and held at 230°C for 15 minutes.

The mass spectra were recorded at three scans per second between 50 and 400 amu. The ionization mode was electron impact (EI) at 70 eV. Identification of common fatty acids was performed using the NIST®98 [US National Institute of Standards and Technology (NIST), Gaithersburg, MD, USA] mass spectral database.

FAMEs were analyzed by using an Agilent (Kyoto, Japan) gas chromatograph equipped with a flame ionization detector (FID). The detector temperature was 300°C. The other analytic conditions including the column type and column temperature, the injection temperature, split ratio, carrier gas and the linear velocity were the same as those in the GC–MS analysis. FAMEs were identified by retention time and comparison with purified FAME standards (Sigma Co. St Louis, MO, USA).

VI. IISSIP METHOD

The Hansen solubility parameter method is based on the δ solubility, which is divided into three main components: the first component δd relates to so-called “dispersion” forces of London (non-polar interactions), the second δp is related to the Keesom polarity forces (between permanent dipoles), finally the last δh represents the hydrogen bonding forces and more generally interactions involving electronic exchanges. Debye forces (between induced dipoles) are generally low in absolute value and neglected.

Hansen thus obtains a three-dimensional space (Fig.2) in which all liquid or solid substances can be located.

![Diagram](https://via.placeholder.com/150)

Fig.2 Three-dimensional representation of Hansen’s solubility parameters

A point represents the combination of interactions that ensures the cohesion of the substance (Eq. 1).

\[
\delta^2 = \delta_d^2 + \delta_p^2 + \delta_h^2
\]

(1)

For any solid substance to be soluble in a liquid, or for two liquids to be miscible, their situation in space must be close, that is, their solubility parameters should be close. Thus, compounds that have similar Hansen parameters have high affinity.

In this configuration, the previously described dissolution condition is extended to all three parameters. The factor to be minimized then becomes:

\[
A^2 = 4(\delta_{d1} - \delta_{d2})^2 + (\delta_{p1} - \delta_{p2})^2 + (\delta_{h1} - \delta_{h2})^2(2)
\]

A: distance between compounds 1 and 2

The presence of the factor 4 in front of the dispersion parameters is motivated by the desire to make the system more symmetrical, the dispersion values being generally very low [7].
In other words, for two substances to be miscible, it is necessary that their three solubility parameters are identical or very close.

The nonpolar interactions, which correspond to the δd component, concern all the molecules since they are attributable to the atoms that constitute them. Indeed, a nonpolar molecule also has electrons that can cause a momentary imbalance of the distribution of charges in the surrounding molecules, thus inducing a temporary dipole moment.

Even if they change constantly, these induced dipoles generate attractive forces all the more large as the molecular mass is high (high number of electrons). For saturated aliphatic hydrocarbons, for example, the London interactions are the only attractive interaction, which results in a vaporization energy equivalent to cohesion energy.

The second parameter of partial solubility δp is related to polar interactions, excluding hydrogen bonding. There are forces of electrostatic attraction between the polar molecules, the positive pole of the one attracting the negative pole of another. Interactions related to orientation forces between permanent dipoles are called Keesom forces [8].

The third parameter of partial solubility δh is related to interactions involving a hydrogen bond between a hydrogen atom with a positive partial charge and a strongly electronegative atom.

All these forces of attraction can be classified according to their intensity:

**Hydrogen bonding forces > London Force> Keesom Force.**

The method developed by the Greeks Stefanis and Panayiotou is recent [9]. These authors used modern statistical methods to process Hansen's data and developed three linear equations, from a two-step linear regression, to calculate each of the solubility parameters:

\[ Y = \sum_{i} N_{i} C_{i} + W \sum_{j} M_{j} D_{j} \]  

(3)

Ci corresponds to the first order contributions of a group i appearing N times in a molecule.

Dj corresponds to the possible second order contributions of a group j appearing M times in a molecule.

W is equal to 1 or 0, respectively if the test compound has or not second order contributions.

Y is a linear function that can correspond to δd, δp or δh.

These properties have many applications in the chemical, pharmaceutical and food industry, as well as in the protection of the environment [10].

The values calculated by the Stefanis-Panayiotou method are in agreement with Hansen's experimental values. The number of functional groups used to decompose the molecular structures is large, which makes the method recognized as one of the most accurate for the calculation of the three solubility parameters (HISiP Software, 2010).

The computation of the relative energy difference (RED) allows to determine the miscibility force between a solvent and a solute (Eq. 4).

**RED = A/R**  

R: radius of Hansensolubility sphere

HISiP software offers different ways to calculate Hansen's solubility parameters. We can quote for instance Beerbower, Hoy, Van Krevelen [7-8, 11-12] and more recently, Stefanis and Panayiotou [9] and Yamamoto (HISiP Software, 2010).

**VII. RESULTS AND DISCUSSION**

The extractions results of the different matrices are presented in Table 2 and Fig 3. The oil yields of the α-pinene extractions are slightly higher than those obtained with n-hexane. This difference, also emphasized by Liu et al. [13] and Virot et al. [5], is certainly due to the slightly more polar nature of α-pinene relative to n-hexane which would cause a greater solubilization power for triglycerides. In addition, the diffusion is improved thanks to the higher boiling temperature of α-pinene, which decreases the oil viscosity.

**TABLE 2 OIL CONTENT OF THE DIFFERENT MATRICES OBTAINED BY SOXHLET EXTRACTION WITH N-HEXANE, α-PINENE**

<table>
<thead>
<tr>
<th>Food matrix</th>
<th>n-hexane (%)</th>
<th>α-pinène (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peanuts</td>
<td>39.5 ± 0.23</td>
<td>42.3 ± 0.29</td>
</tr>
<tr>
<td>Soya</td>
<td>19.5 ± 0.29</td>
<td>21.1 ± 0.20</td>
</tr>
<tr>
<td>Sunflower</td>
<td>52.6 ± 0.20</td>
<td>67.2 ± 0.21</td>
</tr>
<tr>
<td>Olive Chemial</td>
<td>22.6 ± 0.16</td>
<td>24.5 ± 0.24</td>
</tr>
</tbody>
</table>
Fig. 3 Fatty acids’ yields of different oils extracted by two used solvents.

Results show that recycling rate of alpha-pinene, which is close to 90%, is significantly higher than that of n-hexane, which reached 50%. In addition, the GC and GC/MS analysis of alpha-pinene recovered after extraction does not show any important degradation.

After extraction, fatty acids were converted in FAMEs and analyzed by GC–MS. The results also given in Fig. 3-5 indicate that fatty acids extracted by both solvents are equivalent in terms of compounds identified and relative proportions.

Peanuts (Fig. 4) and olives (Fig. 7) oils contain a majority of monounsaturated fatty acids (MUFA’s) including oleic acid (C18:1), the main component.

Whereas soya (Fig. 5) and sunflower (Fig. 6) oils are richer in polyunsaturated fatty acids (PUFAs) with linoleic acid (C18:2) the principal compound.

Fig. 4 Fatty acids’ composition of Peanuts oils extracted by two solvents.

Fig. 5 Fatty acids’ composition of Soya oils extracted by two solvents.
In order to calculate the Hansen solubility parameters (HSP), the decomposition of the studied molecule into functional groups predominates. The knowledge of the chemical structure of the compounds studied is very important.

The solubility parameters calculated by the HSPlP software are presented in Table 3.

<table>
<thead>
<tr>
<th>Solvent name</th>
<th>δd</th>
<th>δp</th>
<th>δh</th>
<th>RED pinene</th>
<th>RED hexane</th>
</tr>
</thead>
<tbody>
<tr>
<td>a-pinene</td>
<td>16.9</td>
<td>1.9</td>
<td>2</td>
<td>0</td>
<td>0.8</td>
</tr>
<tr>
<td>Hexane</td>
<td>15.2</td>
<td>3.1</td>
<td>4.7</td>
<td>0.8</td>
<td>0</td>
</tr>
<tr>
<td>Palmitic C16:0</td>
<td>15.8</td>
<td>2.3</td>
<td>5.4</td>
<td>0.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Margaric C17:0O</td>
<td>15.9</td>
<td>2</td>
<td>5</td>
<td>0.39</td>
<td>0.45</td>
</tr>
<tr>
<td>Stearic C18:0</td>
<td>15.9</td>
<td>1.7</td>
<td>4.6</td>
<td>0.42</td>
<td>0.5</td>
</tr>
<tr>
<td>Eicosanoid C20:0</td>
<td>15.9</td>
<td>1.7</td>
<td>3.8</td>
<td>0.61</td>
<td>0.67</td>
</tr>
<tr>
<td>behenic C22:0</td>
<td>15.9</td>
<td>0.4</td>
<td>3</td>
<td>0.67</td>
<td>0.87</td>
</tr>
<tr>
<td>Palmitoleic C16:1</td>
<td>16.3</td>
<td>1.9</td>
<td>5.9</td>
<td>0.28</td>
<td>0.69</td>
</tr>
<tr>
<td>Oleic C18:1</td>
<td>16.3</td>
<td>1.3</td>
<td>5.1</td>
<td>0.64</td>
<td>0.72</td>
</tr>
<tr>
<td>Gadoleic C20:1</td>
<td>16.3</td>
<td>0.7</td>
<td>4.3</td>
<td>0.71</td>
<td>0.82</td>
</tr>
<tr>
<td>Linoleic C18:2</td>
<td>16.7</td>
<td>0.9</td>
<td>5.6</td>
<td>0.94</td>
<td>0.96</td>
</tr>
<tr>
<td>Linolenic C18:3</td>
<td>17.2</td>
<td>0.5</td>
<td>6.2</td>
<td>0.12</td>
<td>0.25</td>
</tr>
</tbody>
</table>

RED = 0 perfect solvent. 0 < RED < 1 good solvent. RED > 1 bad solvent

The results in Table 3 show that for all fatty acids REDpinene is lower than REDhexane, which is itself less than 1. This means that α-Pinene and n-Hexane are good solvents for fatty acids extraction and that α-Pinene is better than n-Hexane.

In order to more easily compare the values obtained by the algorithm, the diagram representing δp as a function of δh was analyzed (see Fig. 8).

We notice that the fatty acids grouped together and representing an inverted “L”, cover an area between 0.4 and 3.1 Mpa⁻¹ for the attraction force δp, and between 2 and 6.2 Mpa⁻¹ for the hydrogen bonding force δh. The group is located near α-Pinene. We can also notice that the hexane is quite far from the group.
Fig. 8: Hansen solubility parameters representation in the two-dimensional space $\delta_p \delta_s$, using StefanisPanayiotou method

VIII. CONCLUSION

The study carried out for the determination of oils and fats in oilseeds shows that the results obtained with the two solvents are comparable, allowing to conclude that $\alpha$-pinene is effective and valid and can substitute n-hexane. The fact that the recycling rate of $\alpha$-pinene is almost total (90% against 50% for hexane), makes it a more reliable and safer alternative for the environment, despite its higher boiling point than that of n-hexane (surplus energy required).

The computation of Hansen parameters is a good approach for determining the solubility of a compound relative to a solvent. The results obtained show that $\alpha$-pinene is an adequate solvent for fatty acids extraction, confirming hence the experimental results.

REFERENCES


A New Criteria for Evaluating Quality Educational Websites

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Abstract— This paper presents how the criteria for quality of education website have impact on education operation by generated a new reliability criterion to enhance quality of these websites this research focused on the importance the structure of educational website application and the building architecture of these websites if free of faults with compared the it’s fault tolerant, so the establishment of these sites without a censor lost confidence and credibility in many locations, and therefore appeared to assess the sites and measured to ensure its credibility.

Keywords—Reliability ; Website Quality ; Fault Tolerance ;

I. INTRODUCTION

Referring to refere [1] kapon study (kapoun, 1998) indicated that there were five criteria for evaluating web pages in general, namely, accuracy, responsibility, objectivity, modernity and moderation [2]. king’s study (1998), which described the main pages of twenty-two hundred libraries in the library research association, he tested the site's introduction and design, and divided its result into seven sections: backgrounds, title, end, body, page and numb steps to access the library page from the organization's sites and the domain name provided on the server the Clausen study [3](Clausen, 1999) is one of the distinctive studies that confirms the sites library on the internet must be overwhelmed by the high-quality services and sources that are offered for users, the Clausen division criteria that can be achieved into six sets design, structuring, information, quizzes, navigation, technical impression, and general assessment. the criteria for this study were applied to three sites of academic libraries in Denmark the urgent need to further evaluate the websites of libraries on the internet to develop the uses of technologies information and uses of clients as the study indicated the need for library sites to update at regular intervals to maintain location and objectives focused on the Readability of educational.

II. WEB QUALITY

The reliability for web application and functionality of websites are described briefly in the following points:-

A. Reliability for web application: can be defined as the probability of failure-free web operation completions. we define web failures as the inability to correctly obtain or deliver information, such as documents or computational results, requested by web users. this definition conforms to the standard definition of failures as being the behavioral deviations from user expectations [4]. based on this definition, we can consider the following failure sources: host, network, or browser failures, that prevent the delivery of requested information to web users. these failures are similar to failures in regular computer systems, network, or software, which can be analyzed and assured by existing techniques [5].

B. Functionality of websites: [6] functionality - a set of attributes that bear on the existence of a set of functions and their specified properties. the functions are those that satisfy stated or implied needs. reliability - a set of attributes that bear on the capability of software to maintain its level of performance under stated conditions for a stated period of time

III. RELAIZING OF RELIABILITY WEB SITES

To access a high-quality website, there must be a direct link between the processes and the product "website" in software science, the individual skills and experience gained by system developers are often the basis for high-quality websites so that is important prudent to take quick decisions in building the websites of the institutions and companies, which in such a case that we offer related to the sites that are particularly destructive educational the main objective of this evaluation is to estimate how much defect the web site may contain from a lack of cohesion and bladder in the construction where all the largest size of the site and the marquee has increased the complexity and the tendency of its components to error so should be consider the in the following points:-
A. relebate Components in Series

If the components are arranged sequentially, the website will work .

< operation1 > < operation2 < operation3 > <operation4 > \rightarrow \text{operation} \ldots \text{N }>

B. software quality factors:

all of these measuring bellow lead us for [7] software quality factors which are following :

Correctness:
- Accuracy, completeness of required output
- Up to datedness, availability of the information
Reliability
- Maximum failure rate
Efficiency
- Resources needed to perform a software function
Integrity
- Software system security, access rights
Usability
- Ability to learn, perform required task

IV ANALYZING WEB FAULTS FOR RELIABILITY EVALUATION

for testing websites to butting the factor of reliability criteria select more than 200 education web location witch divide in the top 10 of the rank universities for more than 20city taken from the (Web Metric.com) rank website. the test collected the main elements in quality misusing as following :

- Language use
- Number of error
- time execution

A. evaluteing web site

The test quality is based on two main things as clarified in the following points:

- **Time excitation** : it's time The Internet browser waits while the page is reloaded or the web pages are loading.
- **number of error** : website error in the computing world to commit flaws in the design phase of the software or while writing it in a programming language. This error often results in bad or unexpected performance.

The study was based on a set of hypotheses aimed mainly at learning the effect of quality in the marketing of educational web site . The hypotheses of the study were formulated as follows:

1. There is a relationship between safety and quality of educational websites.

2. There is a relationship between marketing strategy and the quality of educational websites

V. BASICS of RELIABILITY ANALYSIS

Both the failure information and the related workload measurements provide us with data input to various software reliability models [8], [9]. The output of these models can help us evaluate the Web software reliability and the potential for reliability improvement. Two basic types of software reliability models are: input domain reliability models (IDRMs) and time domain software reliability growth models (SRGMs) [9], [10]. IDRMs can provide a snapshot of the Web site’s current reliability. For example, if a total number of f failures are observed for workload units, the estimated reliability R according to the Nelson model [11], one of the most widely used IDRMs, can be obtained as:

\[ R = \frac{(n-f)}{n} = 1 - e \]

Where r is the failure rate, which is also often used to characterize reliability. When usage time ti is available for each workload unit i, the summary reliability measure, mean-time between failures (MTBF), can be calculated as:

\[ MTBF = \frac{1}{f} \sum i \]

When the usage time ti is not available, we can use the number of workload units as the rough time measure. In this case,

\[ MTBF = \frac{n}{f} \]

Cascading style sheets (CSS) is a language that applies presentation (styling, layout, animation) to markup content (such as html, xhtml, svg or xml). It is one of the main components of the open web platform. CSS allows you to style your content through a set of selectors and properties [12, 14].

- **first version**: the CSS 1 recommendation was described by Hikon wium lie and Bert bos, and first published in 1996.
- **current stable version**: the CSS 2 recommendation was first published in 1998, but was not completely finished until 2011, despite being effectively stable for a number of years before that. Several modules from css3 are also stable as of the time of writing (Dec 2012).

from CSS can do the validate to many of the educational website from accesses to the trailer and defect of the website then valid these website if have the reliable characterize to access to the high quality level.
the most educational websites are written by HTML pages, and they seem to display okay, but there are a few things not quite right with them. to ensure that these pages and evaluating the quality level most measuring them by reliability technical’s measuring [15, 16].

VI. FAULT TOLERANCE FOR RELIABILITY MEASURING

The work in this paper is based on the creation of a new standard for measuring reliability. This criterion was issued based on the study and analysis of the percentage of errors in the websites programming in those sites. The sample of the study was based mainly on educational sites such as universities. We examined this phenomenon, which included more than 100 websites and achieved the amount of error by CSS validation [11, 15].

In Section 5 we presented previous models through which the reliability of Web applications was measured based on the number of failure rate occurred. But in this work, it is based on Errors rate occurred, and not every errors is a measure of the unreliability of the site and not of its quality. There are errors that are allowed for the system to be highly resilient in all environments. This standard is known [13] fault tolerance

In the construction of the websites there are very little errors do not trust the reliability of the pages and not on quality, but that the increased reduction may expose those sites to the risk of being unreliable and quality.

To build web page need of the thousands, hundreds of markups in thousands of lines in this work was extracted how much size errors in. to know the reliability and quality of these websites through use of the MODE of error Table 1 the error type for fault -tolerance .

Table 1 Illustrates type fault -Tolerance in HTML language

<table>
<thead>
<tr>
<th>NO</th>
<th>TYPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>end-tag-with-attributes</td>
</tr>
<tr>
<td>2</td>
<td>duplicate-attribute</td>
</tr>
<tr>
<td>3</td>
<td>eof-in-script-html-comment-like-text</td>
</tr>
<tr>
<td>4</td>
<td>missing-attribute-value</td>
</tr>
<tr>
<td>5</td>
<td>missing-whitespace-between-attributes</td>
</tr>
<tr>
<td>6</td>
<td>missing-whitespace-between-doctype-public-and-system-identifiers</td>
</tr>
<tr>
<td>7</td>
<td>nested-comment</td>
</tr>
<tr>
<td>8</td>
<td>noncharacter-character-reference</td>
</tr>
<tr>
<td>9</td>
<td>null-character-reference</td>
</tr>
</tbody>
</table>

Fault Tolerance Reliability Measuring (FTRM) is depending of the MODE of error observing from the website if the value is one of the types in table 1 so the website is reliable .the figure present the rate of website error this result occurred from the CSS validation software of variant educational website.

From the following chart we discover the percentage of allowed errors based on the type of it and these errors do not constitute risk to the feasibility of its quality cause in more than 2000 line to build those websites we may find between 20-25 mistakes allowed and the compiler avoid These implementation process. So you consider them to be reliable and no risk in the quality of the these websites in the validity, but either when the number of the fault tolerance errors is vary high and observe the warring of faults from different types of warring error so the quality of the websites is very low and the rate of the error is more then 29 or over of 30.

![Fig. 1 Rate of Reliability Error](image1)

![Fig. 2 Illustrates the Rate of Time Execution](image2)

to builder websites need the thousand or hundred of markups line And the number of lines of the marquee is based on the time of implementation and monitoring mistakes in figure 2 show the rate of the time execution of websites of some universities base on the line of markups and tags on HTML language.
VII CONCLUSION

By analyzing the unique problems and challenges for the Web environment, we have developed an approach for Web software reliability evaluation based on information extracted from existing Web server logs. By using existing tools to extract usage information, we have kept the additional effort for implementing our approach to a reasonable level. We developed utility programs in CSS to analyze Website error.

Assessing the operational reliability for Websites: When used with fault tolerance to estimate failure rate to get the reliability, and the quality must be in concepts of error-free Software and concentrate on complex activities and used to complete in time. As discussed in the previous sections of this paper the Software quality attributes, principles, factors and its methods are implemented in the early stages of reliable websites, because of this activity the web developer get the knowledge about the websites what it needs going to develop, it may reduce the rework and failures of the websites. Nowadays all the software development industries are implementing the SQA component to get quality software.

REFERENCES

Feasibility Study of Grid Connected Photovoltaic Power Plant
In the Southern of Tunisia

Drissi Hanen, Jalel KHediri, Massimo Gori, Luca Gregori, Begnis Francesco

Abstract— World energy consumption is rising due to population growth and increasing industrialization. Traditional energy resources cannot meet these requirements with notice to their challenges, e.g., greenhouse gas emission and high lifecycle costs. Renewable energy resources (RES) are the appropriate alternatives for traditional resources to meet the increasing energy consumption, especially in electricity sector.

This paper investigated the potential operation of PV plant Grid connected system in the northernmost city in Africa, city of Tozeur in the South of Tunisia, this region is characterized by High ambient temperature in the summer and high solar irradiance potential. This study presents a feasibility analysis. For this we have choose to work with one of the most powerful tools for this purpose is Hybrid Optimization Model for Electric Renewable (HOMER) software that was developed by National Renewable Energy Laboratory (NREL), United States, with the implementation of an excel application to simulate the impact of representative PV generators with and without ESS (energy storage system) functions. Homer has widely been used by many researchers around the world. The system is optimized by this software and Excel application using Tunisia global irradiation and the Tunisian load profile, the electricity tariffs and the photovoltaic system components are modeled according to the Tunisian market.

Keywords— Grid-connected PV system, technical analysis, Homer software, excels application ...

I. INTRODUCTION:

Among the RES technologies, solar energy technologies have shown a significant advancement and maturity for power generation. Solar photovoltaic (PV) technology, which directly converts the sun irradiation into electricity, is one of the fastest growing RES technologies worldwide. Recently, the solar PV modules’ prices have dropped by 80% since 2009 and are anticipated to keep falling [1].

In the near future, the applications of solar photovoltaic systems will certainly play a contentious role in the development of countries. Solar photovoltaic systems are generally categorized into stand-alone and grid-connected systems. In stand-alone photovoltaic power systems, there is no connection to the utility grid and the systems are usually categorized into two main sub-groups: direct-coupled system without storages (batteries) and standalone system with storages. However, in some cases, other types of energy systems such as gas, steam, and wind or micro-hydro generator systems are used in the supporting of stand-alone photovoltaic systems; this configuration is called a hybrid system. On the other hand, grid connected photovoltaic power systems which are directly connected to the utility grid have recently experienced a rapid growth worldwide and have become more popular especially in developed countries.

In the context of diversifying its energy mix for power generation, improving the level of independence from fossil fuels, and enhancing the enormous potential of renewable energy resources (solar and wind), The Tunisian Company of Electricity and Gas (STEG) has started the development of the wind energy sector since the year 2000 through the construction of the first 54 MW power station in Haouaria, then a second power station at the end of 2013 at Bizerte (Kehabta-Metline) with an overall power of 190 MW.
STEG recently elaborated a new plan of action, within the context of the Tunisian Solar Plan (PST), which stipulates the construction of solar and wind power plants by 2020 with an overall power of the order of 300 MW in wind energy and 67 MW in photovoltaic solar energy. STEG then began its first project for the construction of a 10 MW photovoltaic (PV) solar power plant in Tozeur. This plant will be located on a site next to the Tozeur-Nafta road near the 150/33 kV (STEG) transformer station on an area of 22 ha. The programmed power is 10MW with the possibility of extension in the future.

PST: The Tunisian Solar Plan (PST) is a long-term strategy that follows the goal of diversifying the energy mix, which is currently based on 95 percent of natural gas.

This strategy foresees the reduction of the share of natural gas to only 50% in 2030 thanks to a massive deployment of renewable energies and the entry into the production of carbon-based electricity. The PST envisages a contribution from renewable energies of about 30% of electricity production by 2030, including 15% for wind, 10% for photovoltaic (PV) solar and 5% for solar concentrating (PSC) [2].

![Graph](image1.png)

Fig.1 Evolution of installed capacity as provided in PST [1]

The third of the renewable production (2887 GWh) is made available by photovoltaics, which corresponds to 1,510 MW of capacity installed in 2030. For 2020, photovoltaic capacity reaches 540 MWp and produces 1030 GWh according to the PST. In calculations, the capacity factor is estimated to be constant at 22 percent for all the installations.

![Graph](image2.png)

Fig.2 Evolution of the installed PV capacity as provided in PST [2]

The objective of this work is to investigate the techno-economic viability of solar PV plant-grid connected energy system in a location in the south of Tunisia. This system may not only improve access to reliable supply of electricity, but can also reduce dependency on diesel generator systems.

Many research papers studied the techno-economics of PV systems based on off-grid [3–14] or grid-connected settings [16–24]. The grid connected systems are intended to supply power generated by RES into the electric grid.

II. SELECTED SITE:

This plant will be located, in the southern of Tunisia, on a site next to the road Tozeur-Nafta near the transformer station 150/33 kV (STEG) on an area of 22 ha. The scheduled power is 10 MW with the possibility of extension in the future.

Latitude and longitude coordinates for Tozeur: 33.9185° N, 8.1229° E. This region is characterized by High ambient temperature in the summer and high solar irradiance potential.

![Map](image3.png)

Fig.3 Tunisia Map

III. HOMER DESCRIPTION:

HOMER (Hybrid Optimization Model for Electric Renewable) is a computer optimization model developed by the U.S. National Renewable Energy Laboratory (NREL) to assist the design of micro-power systems and to facilitate the comparison of power generation technologies across a wide range of applications.

HOMER models a renewable energy system’s behavior, its life-cycle cost and allows to choose optimal design options based on technical, economical and environmental criteria. Many resources such as WT, PV array, fuel cells, converter, batteries, and conventional generators are modeled in
HOMER also simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. Required input data for simulation with HOMER.

A. HOMER INPUTS Data:
To judge the feasibility of the grid connected PV system, technical and economical evaluation criteria can be applied, so HOMER requires six types of data for simulation and optimization including meteorological data, load profile, equipment characteristics, and search space, economic and technical data.

HOMER first assesses the technical feasibility of the system and whether it can meet the load demand, technical feasibility depends mainly on the load energy consumption and the available area to place the photovoltaic modules. These data are described in details in the following subsections.

B. Economic data:
The economical parameters are calculated. The calculation assesses all costs occurring within the project lifetime, including initial set-up costs which is the total installed cost of that component at the beginning of the project, component replacements within the project lifetime, operating and maintenance cost (O&M) and the purchasing power costs (PPC) from the grid.

1) Annual real interest rate:
The real discount rate is used to convert between one-time costs and annualized costs. HOMER calculates the annual real discount rate from "Nominal discount rate" and "Expected inflation rate" inputs. HOMER uses the real discount rate to calculate discount factors and to calculate annualized costs from net present costs.

The annual real interest rate is related to the nominal interest rate by the equation given below which Homer uses [25]:

$$i = \frac{i' - f}{1 + f}$$  \hspace{2cm} (1)

Where i the real discount rate, i'=nominal discount rate (the rate at which we could borrow money), and f the expected inflation rate.

2) Net present Cost:
The life cycle cost of the system is represented by the net present cost (NPC) which is the present value of all the costs that it incurs over its lifetime, minus the present value of all the revenue that it earns over its lifetime, HOMER calculates the total NPC by summing up the total discounted cash flows in each year of the project lifetime. REF HOMER HELP
It was calculated according to the following equation:[ 25]

$$c_{NPC} = \frac{TAC}{CRF}$$  \hspace{2cm} (2)

Where TAC is the total annualized cost ($/year) (which is the sum of the annualized costs of each system component) and CRF is the capital recovery factor given by [25]:

$$CRF_{i,n} = \frac{i(1+i)}{(1+i)^N-1}$$  \hspace{2cm} (3)

Where N is the number of years and i is the internal rate of return (%) which is the nominal discount rate that corresponds to a net present cost of zero for projects.

3) Levelized cost of energy:
As techno-economical evaluation criterion. COE represents the unit cost of the energy produced by the system and can be calculated by dividing the total annualized cost by the annual produced energy as follows[25]:

$$COE = \frac{TAC}{E_{pr}}$$  \hspace{2cm} (4)
Therefore, among different measures of the economic value of an investment, an appropriate economic analysis payback period, and the internal rate of return ($I_{	ext{IRR}}$) can guarantee the profitability of the investment in photovoltaic systems.

C. Solar radiation and clearness index:

The meteorological data for our system are solar radiation and temperature which are fed into the software in the form of monthly averages or time series data. HOMER uses these inputs data to calculate the output power of PV array.

The figure below shows the daily radiation and clearness index for every month of a year, the solar radiation data inputs on the left axis and the solar radiation’s clearness index on the right axis. Solar radiation varies with time and season.

![Fig.5 Global horizontal solar radiation of Tozeur](image)

The radiation data is obtained by the PVGIS software. The figure shows that the irradiation is maximum in summer (July) and very low in winter (December). PV system designed to supply entire load considering the worst month solar radiation, which will deliver sufficient energy during rest of the year. The global horizontal solar radiation in Tozeur ranges from 5kWh/m²/day to 8kWh/m²/day and the annual average of the solar radiation is estimated to be 6.47 kWh/m²/day which make it an ideal location for photovoltaic application and enough to generate the required power for the area.

The clearness index is a dimensionless number between 0 and 1 indicating the fraction of the solar radiation striking the top of the atmosphere that makes it through the atmosphere to strike the Earth’s surface.

HOMER calculates the clearness index from the global horizontal radiation (GHI). The following equation defines the monthly average clearness index [25]:

$$K_i = \frac{H_{	ext{ave}}}{H_{0,\text{ave}}}$$  (5)

Where:

- $H_{\text{ave}}$ is the monthly average radiation on the horizontal surface of the earth [kWh/m²/day].
- $H_{0,\text{ave}}$ is the extraterrestrial horizontal radiation, meaning the radiation on a horizontal surface at the top of the earth's atmosphere [kWh/m²/day].

D. Load profile:

Load profile of each region is the most important factor in the simulation and optimization. These real data are fed into HOMER as time series data. However, in some regions especially remote and rural areas that the real load consumption data are not available, the load profile should be forecasted with notice to the specification of that region. These data are fed into HOMER as daily profile and HOMER uses them in power balance constraint.

![Fig.6 The annual average electrical load of Tunisian people](image)

This figures 06 and 07 shows for each day of 2016 three values, the mean power, and the maximum and minimum load. The Tunisian power system has its peaks during summer. The Load data showed that the average daily energy consumption is 47,587.61 kWh/d and the peak demand is 3,403 kW in August. The required consumption is not the same over the year. The peak loads depends on the season since the day length changes.
Fig.7 the Monthly average Load profile of Tunisian people

E. Energy purchase and sellback price:
Tunisian power grid is managed by the Tunisian Company of Electricity and Gas (STEG) .The load considered in the area is domestic in nature. The tariff of electricity for domestic consumers in Tunisia which is a fixed rate is about 0.167d/kWh which is equal to 0.07£/kWh and to US dollar of $0.08/kWh. The “feed-in-tariff” or sellback price for renewable energy less than 20 MW in Tunisia has multiple rates which are set by Decision of the Minister of Industry, Energy and Mines in 2 June 2014 are mentioned in the table below:

<p>| TABLE I |</p>
<table>
<thead>
<tr>
<th>FEED-IN-TARIFF FOR RENEWABLE ENERGY IN TUNISIA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
</tr>
<tr>
<td>Day</td>
</tr>
<tr>
<td>Morning Peak summer</td>
</tr>
<tr>
<td>Peak evening</td>
</tr>
<tr>
<td>evening</td>
</tr>
</tbody>
</table>

IV. SYSTEM COMPONENTS:
The design of the grid-connected PV system was modeled using HOMER. Which it consists of a PV array and an inverter. Typically, PV panels are mounted at fixed orientation. However they can be made to “track” the sun in order to maximize the incident solar radiation and HOMER has the feature to include PV tracking. The function of the PV array is to extract solar energy from the sun and convert it to DC voltage. The generated voltage is converted to AC by the inverter. The surplus photovoltaic electricity is sold to the grid, and in case of insufficiency of photovoltaic energy, the country uses the grid to meet the lack of power. This system will be studied with and without storage bank. The Battery bank is only charged by the excess electricity from PV array after fully supplying the load. This is called “load following strategy”.

A. PV ARRAY:
The photovoltaic modules used in the feasibility study are the STP 230-20 Wd by SUNTECH Company. The Optimum Operating Voltage of each module (Vmp) is 29.8 V and the optimum operating current Ip, pis 7.72A (from Datasheet), the lifetime of the photovoltaic modules are estimated to 25 years. The peak power to be installed is given by the following formula:

$$P_c = \frac{B_t}{\eta_{inv} * E_i}$$

(6)

Where : $P_c \text{ The peak power(kW)}$, $B_t \text{ The daily needs for electricity (kWh)}$, $\eta_{inv} \text{ The Inverter efficiency(%) }$, $E_i \text{ The irradiation (kWh/m^2)}$ .
The provisional number of modules is therefore calculated as follows:

$$N_{\text{panels}} = \frac{P_c}{P_{(c,unit)}}$$

(7)
The designed PV is rated to 10MW (10000 kW) and this is the base electricity supply for the system. It has 43470 modules with each proposed module rated at 230 W. The total area that can be occupied by all the modules of the array is 71800 m².

The cost for a 1kW PV module was assumed to be 2600 dt/kw equal to $1170/kW. The replacement cost for a 1kW PV module was assumed to be $0 because system’s lifetime is assumed to be 25 years so panels will not be replaced. The Operating and Maintenance cost was assumed to be 52 dt/year equal to $233/year. HOMER calculates the power output of the PV array using the equation from Homer files [25]:

\[ P_{pv} = f_{pv} y_{pv} \frac{H_s}{H_g} \]  

(8)

Where, \( f_{pv} \) is the PV derating factor, \( y_{pv} \) the rated capacity of the PV array (kW), \( H_s \) the global solar radiation (beam plus diffuse) incident on the surface of the PV array (kW/m²), and \( H_g \) is 1 kW/m², which is the standard amount of radiation used to rate the capacity of the PV array.

According to fig 08 from Homer software, it was observed that the production of total PV output power is in the range of 6000–8000 kW at the local solar irradiation varies between 0 and 1.2kW/m².

B. converter:

A grid connected inverter is required for PV system to maintain the flow of energy between DC photovoltaic generation and AC load and power grid. The inverter plays a vital role in the operation of the grid connected PV system. Inverters have special features adapted for use with the grid connected PV systems that make the system more robust such as MPPT [27], automatic synchronization with the grid, anti-islanding protection, and high conversion efficiency.

The grid connected inverter efficiency is defined as the ratio of output AC power to input DC power and can be expressed as the following equation:

\[ \eta_{inv} = \frac{E_{AC}}{E_{DC}} = \frac{\int P_{AC} \, dt}{\int P_{DC} \, dt} \] 

(9)

Where \( E_{AC} \) is the AC output electrical energy, \( E_{DC} \) is the DC input electrical energy, \( P_{AC} \) is the AC output power, and \( P_{DC} \) is the DC input power. The inverter used in this system is SUNNYCENTRAL 1000MV by SMA Company, it is assumed that the inverters have a maximum efficiency between of 98% and 98.2%, and 10 years lifetime, it is rated at 1000 kVA AC output power based on 1100 kVA DC input power from PV array. The maximal input current of the inverters 2500A.

The output grid voltage of the inverter is rated to 3-phase 20 kV/ 50 Hz.
C. Battery Bank:

The battery bank is a collection of one or more individual batteries. A battery was modeled as a device capable of storing a certain amount of DC electricity at fixed round-trip energy efficiency, with limits as to how quickly it can be charged or discharged, how deeply it can be discharged without causing damage, and how much energy can cycle through it before it needs replacement.

HOMER assumes that the properties of the batteries remain constant throughout its lifetime and are not affected by external factors such as temperature. Battery Parameters are:

1) Battery Capacity

The battery capacity is the amount of energy that could be extracted from the battery bank from the fully charged state to the zero charge state; it is measured in Ampere hours (Ah). The battery capacity changes depending on factors such as age, rate of discharge or temperature. High ambient temperatures cause internal reactions. Therefore, many batteries lose capacity quicker in hotter climates. On the other hand, extremely cold climates may stop the discharge of the storage by freezing the electrolyte.

2) State of Charge (SOC)

The state of charge is the percentage amount of energy stored in the battery with respect to the nominal battery capacity. The latter parameter is mainly used to reveal the current amount of power stored and to evaluate the performance of the battery.

3) Charging and Discharging rate

The amount of power extracted/added from/to the battery per unit time; it is measured in Amperes.

4) Battery Efficiency

The battery efficiency is described in two ways: the Columbic and voltage efficiency. The cumbic efficiency is the ratio of the amount of power that enters the battery when its charges versus the amount of power that can be extracted from the battery when it discharges. The voltage efficiency is the discharged voltage average versus the charged voltage average. More generally, the roundtrip efficiency is the energy extracted from the battery versus the energy sent into the device.

In order to study the behavior of PV power plants from techno-economical points of view, the feasible sites in Tunisia to install is a 10 MWp PV-grid connected power plant are selected. The main geographical and meteorological data are tabulated in the supplementary part of the study as mentioned before.

V. Analysis of a 10 MW PV grid-connected for January and July

A. Analysis of a 10 MW PV grid-connected without energy storage (Results with HOMER) for January and July:

Data recorded collected during January and July 2016 for weather and total radiation will be presented (Homer).

An average hourly variation of local solar irradiation to the production of PV output power during 7:00–18.00 for January 2016. From previous Figs it was found that the production of total PV output power is in the range of 1500–4000 kW at the local solar irradiation varies between 0 and 600 W/m².

It can be concluded that the production of PV output power is a function of solar irradiation and module working temperature. It increased with increasing solar irradiation and decreased with increasing module working temperature as explained in previous work [28]. These mean that solar irradiance and module working temperature play important factors in order to estimate energy production and degradation of the PV system. We can observe that the hourly global parameters performance of PV plant is more significant between 10.00 and 15.00 h. The PV power production takes the maximum value at 12.00 and equal to zero at night so that local consumers have to buy electricity from grid to feed their needs, which illustrate the effect of weather conditions on the efficiency of PV panels and the relations between the radiation and the output power of PV panel [28]. The surplus photovoltaic electricity is sold to the grid, and in case of insufficiency of photovoltaic energy, the country uses the grid to meet the lack of power.

Fig.10 data recorded during January 2016
Same during July, only the production of total PV output power change in the range of 6000–8000 kW at the local solar irradiation varies between 0 and 1000 W/m². We can observe also that the hourly global parameters performance of PV plant are more significant between 10.00 and 16.00 h. The PV power production takes the maximum value at 12.00 and equal to zero at night from 19h. Compared with the configuration of grid only in previous work, this configuration has higher initial capital and total NPC. This is because the total NPC includes the initial capital and replacement cost of inverter, initial capital of PV and operation and maintenance (O&M) cost.

The tables below gives Balance over PV plant lifetime project for 25 years taking into account the variable tariffs for electricity bying from grid. Annual Electricity Generation & Consumption statics are shown in Table II.

In this particular study, the overall net present cost (NPC) is achieved as $2900. The payback duration for proposed power system is achieved as 20.2 years which provide almost 21 long years of exclusive income for a period of 25 years. For this case PV productibility reduction due to PV aging was assumed to 0.9% per year.

**TABLE II SIMULATION RESULTS OVER 1 YEAR**

<table>
<thead>
<tr>
<th>Load consumption</th>
<th>MWh/year</th>
<th>%</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy produced by PV plant</td>
<td>17369</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy from PV consumed by load</td>
<td>14025</td>
<td></td>
<td></td>
</tr>
<tr>
<td>in real time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy from PV to grid</td>
<td>7982</td>
<td>57%</td>
<td>46%</td>
</tr>
<tr>
<td>Energy from PV to battery</td>
<td>6043</td>
<td>43%</td>
<td>35%</td>
</tr>
<tr>
<td>Energy from battery to Load</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Total Energy from PV to load (incl. battery)</td>
<td>7982</td>
<td>57%</td>
<td>46%</td>
</tr>
<tr>
<td>Battery cycle</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Revenue on avoided electricity from grid</td>
<td>cycle/year</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Revenue on exceeding PV production to grid</td>
<td>MWh/year</td>
<td>1.59</td>
<td>1, 61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MWh/year</td>
<td>0.75</td>
<td>0, 75</td>
</tr>
</tbody>
</table>
### TABLE III

**Balance Over PV Plant Lifetime (25 Years) - Case A: Variable Tariff for Electricity Buying from Grid**

<table>
<thead>
<tr>
<th>year</th>
<th>0</th>
<th>1</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>21</th>
<th>23</th>
<th>25</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load consumption MWh/year</td>
<td>17 369</td>
<td>17 369</td>
<td>17 369</td>
<td>17 369</td>
<td>17 369</td>
<td>17 369</td>
<td>17 369</td>
<td>17 369</td>
<td>17 369</td>
</tr>
<tr>
<td>Energy produced by PV plant (MWh/year)</td>
<td>17 424</td>
<td>16 805</td>
<td>16 062</td>
<td>15 352</td>
<td>14 674</td>
<td>14 542</td>
<td>14 281</td>
<td>14 025</td>
<td></td>
</tr>
<tr>
<td>Energy from PV consumed by load in real time (MWh/year)</td>
<td>8 243</td>
<td>8 203</td>
<td>8 152</td>
<td>8 098</td>
<td>8 042</td>
<td>8 030</td>
<td>8 007</td>
<td>7 982</td>
<td></td>
</tr>
<tr>
<td>Energy from PV to grid (MWh/year)</td>
<td>9 181</td>
<td>8 602</td>
<td>7 911</td>
<td>7 254</td>
<td>6 632</td>
<td>6 512</td>
<td>6 275</td>
<td>6 043</td>
<td></td>
</tr>
<tr>
<td>Energy from PV to battery (MWh/year)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Energy from battery to Load (MWh/year)</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>Total Energy from PV to load (incl. battery) (MWh/year)</td>
<td>8 243</td>
<td>8 203</td>
<td>8 152</td>
<td>8 098</td>
<td>8 042</td>
<td>8 030</td>
<td>8 007</td>
<td>7 982</td>
<td></td>
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<tr>
<td>Battery cycle (cycle/year)</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<tr>
<td>Battery cumulated cycle (cycle)</td>
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<td>0</td>
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<tr>
<td>PV CAPEX (Md)</td>
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<td>Battery CAPEX (Md)</td>
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<tr>
<td>Revenue on avoided electricity from grid (Md/year)</td>
<td>1.64</td>
<td>1.63</td>
<td>1.62</td>
<td>1.61</td>
<td>1.60</td>
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<td>Revenue on exceeding PV production to grid (Md/year)</td>
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<td>0.99</td>
<td>0.91</td>
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<td>PV O&amp;M (Md/year)</td>
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<tr>
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<tr>
<td>Net Cash Flow (Md)</td>
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<td>2.18</td>
<td>2.09</td>
<td>1.99</td>
<td>1.91</td>
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<tr>
<td>Discounted Net Cash Flow (Md)</td>
<td>-26.44</td>
<td>2.15</td>
<td>1.71</td>
<td>1.28</td>
<td>0.96</td>
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<td>-24.28</td>
<td>-16.81</td>
<td>-9.60</td>
<td>-4.20</td>
<td>-0.15</td>
<td>0.53</td>
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<td>DPT calculation [years]</td>
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<td>NPV (Md)</td>
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<td></td>
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<td>DPBT (years)</td>
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<td></td>
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</table>

**B. Analysis of a 10 MW PV grid-connected with energy storage (Results with excel) for January and July**

This section investigates the potential of using battery energy storage systems in the public distribution grid, to defer upgrades needed to increase the penetration of photovoltaic’s (PV). The potential of battery energy is to support the operation of public distribution grids gains rage systems (HESS) wide interest [26], [27]. This study performed a techno-economic assessment of grid-connected PV system. The system is considered interactive with the grid and with battery storage. A presentation of weather data analysis was provided and different configurations of this system were considered, i.e. battery removed from the system.

The study concluded with cost of electricity appearing to be higher per Kwh for the GCPV system more than utility electricity. The author attributes such results to high taxes and governmental subsidies on electricity.

![](image.png)
Fig. 13 Data recorded during January 2016 (with storage Bank) using excel application.

Fig. 14 Data recorded during July 2016 (with storage Bank) using excel application.
VI. CONCLUSIONS

This study performed a design and techno-economic evaluation of a Grid-connected PV system in Tozeur city, with a size of 10 MW. The numerical simulation was made using Homer Software and an excel application. The optimum array size is 230 Wp with around 43470 modules to satisfy the 10 MW. The system has a payback period of 21 years and a CoE of 0.81USD/kWh. The system is feasible and shows great promise for the city of Tozeur.

To conclude, this study further enriches the body of knowledge about the feasibility, technical performance, and economic aspects of grid-connected solar PV with different time adjustments. Nevertheless, several possible limitations need to be considered. Moreover, the effect of different models of solar PV with different temperature coefficients and their effect on power generation, NPC, and LCOE are investigated. In the future research, a comparative performance analysis of off-grid and grid-connected designs for various locations with different metrological conditions will be investigated. Moreover, hybrid systems such as solar-wind-biomass could be integrated to examine the optimal design.

ACKNOWLEDGMENT

The first author would like to thank CESI (Milan) and RES4MED (Rome) for the financial support under their internship program. Also, the authors express sincere appreciation to Tunisian Company of Electricity and Gas (STEG) for providing the required data.

REFERENCES

SMART BUILDING
Using Web Application
(Second Controlling Method)

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Abstract—As technology advances, there is an increasing demand for the internet to allow us to control every facet of our lives, usually from apps on our phones or our smart devices. Whether we are able to remotely turn on our heating, set timers on our lights to ensure they are shining, etc.

This work aims to study the possibility of controlling the smart building using Web Application to provide User Friendly Interface and Remote Connection through the internet or intranet.

Smart building web application is an example of what's possible with based Internet of Things projects.

This paper describes part of an integrated project for implementation of smart building controlled by several ways, which is considered as a Second Method to control the building.

Keywords—Web application, C# language, ASP.NET, Smart building.

I. INTRODUCTION

Today, Smart buildings are complex concatenations of structures, systems and technology. Over time, each of the components inside a building has been developed and improved, allowing building owners to select lighting, security, heating, ventilation and air conditioning systems independently.

There is a possibility to develop a practical way to control the whole building more easily. As well as the possibility of controlling the devices and equipment inside the building remotely from anywhere, and to identify the current state of the building.

A Property Management Software is an online program or software designed for residential or commercial property management. It is an effective and easy-to-use tool.

Property management systems are utilized by homes, hotels, conference centers and organizations...etc. Some property management software can integrate with applications already running.

They can be based online, or hosted internally on the current computer systems of the building. Property management systems can be used to manage single or multiple properties simultaneously. These softwares help people to know the real state of the building. It is a quick response application that can store each detail of the whole building.

The Web Application is considered as one of the Property Management Software.

This work aims to design and use the Web Application to control the building through any smart device from anywhere via the internet. as shown in Fig1.

![Intelligent Building Diagram]

1. Intelligent Building Diagram

This work is organized as follows: Section II covering the main concepts of the Web Based Application. Section III representing important information about Programming Language C#. Then the ASP.NET Web Application is defined in section IV. Section V contains the practical part of Smart Building Web Application. Finally section VI drawing the major conclusions from this work.

II. WEB BASED APPLICATION

The Web Application has been created and used in this work to control building appliances by any smart device from anywhere.

A web application “web app” is a software program that is stored on a remote web server and delivered over the Internet through a browser interface. Unlike traditional desktop applications, which are launched by operating system. It will make it independent of operating system, place, and used hardware.

Web applications are the ultimate way to take advantage of today's technology to enhance organizations productivity and efficiency. Web application gives an opportunity to access the information from anywhere in the world at anytime. It also facilitates us to save time and
money and improve the interactivity with the customers and partners.

Web apps have several advantages over desktop applications. Since they run inside web browsers, developers do not need to develop web apps for multiple platforms because the appearance is dependent on the browser rather than the operating system, also they do not need to distribute software updates to users when the web app is updated. By updating the application on the server, all users have access to the updated version.

Additionally, the data you entered into a web app is processed and saved remotely. This allows to access the same data from multiple devices, rather than transferring files between computer systems.

A. Advantages of Web Apps

Web-based applications offer a range of advantages over traditional desktop applications:

- **Web Application are accessible anytime, anywhere, via any smart device with an Internet connection.**

- **Web based applications are far more compatible across platforms than traditional installed software [1].**

- **Installation and maintenance becomes less complicated.**

- **The upgrades for web application are only performed by an experienced professional to a single server, the results are more predictable and reliable [2].**

- **Web based applications can considerably lower the costs because of reduced support and maintenance, lower requirements on the end user system.**

- **The web application takes a couple of minutes to set up, it just need the URL, a user name, and password.**

- **There are many technologies can be used for building web-based applications, depending on the requirements of the application, such as the newer Microsoft .NET platform uses Active Server Pages, SQL Server and .NET scripting languages [2].**

- **Web applications do not need the storage space on Users' computers because most of the information is stored somewhere on a server.**

B. Types of Web Apps

Web app development is not limited to only smartphones or tablets. It is designed to run on any browser, work on desktop computers, laptops or mobile devices. In this subsection, the different types of web applications will be classify.

The classification is based on how web apps show the content it provides. These can be categorised into 6 different types of web applications [3]:

1) **Static web application:** Web app displays very little content and is not very flexible like professional portfolios or digital curriculums

2) **Dynamic web application:** More complex. Have an administration panel (called CMS) from where administrators can correct or modify the app’s content including text and images.

3) **Online store or e-commerce:** Enable electronic payments via credit cards, PayPal or other payment methods.

4) **Portal web app:** Lets you access several of its sections or categories through a home page like forums, chats, email, browsers.

5) **Animated web application:** Use Flash technology. Present content with animated effects.

6) **Web application with a ‘content management system’:** Very common among content pages: personal blogs, corporate blogs, professional blogs, news pages, articles, media, etc. Examples could be WordPress, Joomla, and Drupal.

Each kind of web application has its strengths and weaknesses, but they ultimately remain to be a website. They are not native apps, no matter how similar they may be in appearance to these (this will depend on the web app’s design, not on its development). we will have to comply with regulations on cookies and strengthen the app’s security against possible hacker attacks — in a similar way as needs to be done with websites.

C. The Way The Web application function

Most web applications are based on the client-server architecture where the client enters information while the server stores and retrieves information. Web applications can provide the same functionality and gain the benefit of working across multiple platforms.

The Fig 2 details the three-layered web application model [4]:

- **The first layer is normally a web browser or the user interface.**

- **The second layer is the dynamic content generation technology tool such as Java servlets (JSP) or Active Server Pages (ASP).**

- **The third layer is the database containing content and customer data.**

2. The three-layered web application model
A user goes to their browser, types in a website and hits Enter. The browser goes out and finds the internet-facing computer that the website lives on and asks the server for the specific page. The server responds to the request by sending some files over to the browser. The browser executes those files and shows something to the user [5].

Activities involved from making a ‘user request from the browser’ to ‘getting response back to the browser’ can be divided into five steps:

1) User requests the app from the browser.
2) Browser sends request to the server.
3) Server finds the request and generates the requested app as a response to the request.
4) Data is returned in response to the request.
5) then the browser replaces view with the data sent as response from the server.

III. PROGRAMMING LANGUAGE C#

The programming language has been used to program the smart building web application is C#.

C# (pronounced "C sharp") is a programming language that is designed for building a variety of applications that run on the .NET Framework. C# is simple, powerful, type-safe, and object-oriented language. The many innovations in C# enable rapid application development while retaining the expressiveness and elegance of C-style languages [6].

C# can be used to create Windows client applications, Web services, distributed components, client-server applications, database applications, and much more. Visual C# provides an advanced code editor, convenient user interface designers, integrated debugger, and many other tools to make it easier to develop applications based on the C# language and the .NET Framework [6].

Visual Studio is one of the programs that can be used to design programs written through C Sharp language, because it includes C#. ( The Visual Studio has been used in this work to develop a web application for the Smart Building ).

Windows is the dominating Operating System on client computers. The best GUI frameworks for Windows applications is Winforms and WPF together with .NET Framework. The best programming language to work with the .NET Framework and it's APIs is C# [7].

C# is designed to work with Microsoft's .Net platform. Microsoft's aim is to facilitate the exchange of information and services over the Web, and to enable developers to build highly portable applications. C# simplifies programming through its use of Extensible Markup Language (XML) and Simple Object Access Protocol (SOAP) which allow access to a programming object or method without requiring the programmer to write additional code for each step. Because programmers can build on existing code, rather than repeatedly duplicating it, C# is expected to make it faster and less expensive to get new products and services to market [8].

IV. ASP.NET WEB APPLICATION

ASP.NET (originally called ASP+) is the next generation of Microsoft's Active Server Page (ASP). It is an open source web framework for building modern web applications and services. With ASP.NET we can quickly create web sites based on HTML, CSS and JavaScript, scale them to millions of users and easily add more complex capabilities [6].

ASP.NET is a unified Web development model that includes the services necessary to build enterprise-class Web applications with a minimum of coding. ASP.NET is part of the .NET Framework, so that it provides access to all of the features of that framework. For instance, we can create ASP.NET Web applications using any .NET programming language and .NET debugging facilities [8].

The ASP.NET application codes can be written in any of the following languages [9]:

- C#
- VisualBasic.Net
- Javascript
- J#

ASP.NET is used to produce interactive, data-driven web applications over the internet. It consists of a large number of controls such as text boxes, buttons, and labels for assembling, configuring, and manipulating code to create HTML pages.

A. Frameworks of ASP.NET

ASP.NET offers three frameworks for creating web applications: ASP.NET Web Forms, ASP.NET MVC, and ASP.NET Web Pages. All three frameworks are stable and mature, and we can create great web applications with any of them [6].

Each framework targets a different type of application. Which one we choose depends on a combination of the web development experience and which is the best fit for the type of application we're creating [6].

All three frameworks will be supported, updated, and improved in future releases of ASP.NET.

The ASP.NET MVC framework has been used to create the smart building web application by C#, so it will be discussed in more details in this section.

B. ASP.NET MVC:

ASP.NET MVC ( That we used in our project ) is a part of the ASP.NET web application framework and is included with Visual Studio.

The Model-View-Controller (MVC) architectural pattern separates an application into three main components: the model, the view, and the controller. The ASP.NET MVC framework provides an alternative to the ASP.NET Web Forms pattern for creating Web applications. The ASP.NET MVC framework is a lightweight, highly testable presentation framework that is integrated with existing ASP.NET features [6].
By dividing the application into the Model(M), Views(V), and Controllers(C), ASP.NET MVC can make it easier to manage complexity in larger applications, also it works well for Web applications that are supported by large teams of developers and Web designers who need a high degree of control over the application behavior.

In addition, MVC was designed to be extensible, providing power developers the ability to customize the framework for their application needs.

The MVC framework includes the following components as shown in Fig3 [6]:

- **Models**: Model objects are the parts of the application that implement the logic for the application's data domain. Often, model objects retrieve and store model state in a database. For example, a Product object might retrieve information from a database, operate on it, and then write updated information back to a Products table in a SQL Server database.

- **Views**: Views are the components that display the application's user interface (UI). Typically, this UI is created from the model data. An example would be an edit view of a Products table that displays text boxes, drop-down lists, and check boxes based on the current state of a Product object.

- **Controllers**: Controllers are the components that handle user interaction, work with the model, and ultimately select a view to render that displays UI. In an MVC application, the view only displays information, the controller handles and responds to user input and interaction. For example, the controller handles query-string values, and passes these values to the model, which in turn might use these values to query the database.

3. **The MVC framework**

C. **Integrated Development Environment**

For all the software and web developers, the right tool for the job can really make all the difference. However, Integrated Development Environment suites (IDE) tend to offer a richer code editing experience that can include extras like wizards, debug mode and color coding... etc. One of the most famous IDE used to develop Web application is Microsoft Visual Studio.

*Microsoft Visual Studio* used by Any Developer, to Any App and Any Platform, it is an integrated development environment (IDE) from Microsoft. It is used to develop computer programs for Microsoft Windows, as well as a complete set of development tools for building ASP.NET Web applications, XML Web Services, web sites and mobile applications [10].

Visual Studio supports different programming languages include Visual Basic, Visual C#, and Visual C++ and so on, which enables tool sharing and cases the creation of mixed-language solutions. In addition, these languages use the functionality of the .NET Framework, which provides access to key technologies that simplify the development of ASP Web applications and XML Web Services [6].

There are many versions of Microsoft Visual Studio and the latest version is Visual Studio 2015+, which has been used in our project to develop a web application for the Smart Building. The Fig4 shows the GUI of the Microsoft Visual Studio.

4. **Microsoft Visual Studio**

V. **PRACTICAL PART “SMART BUILDING WEB APPLICATION”**

Web application is used to control the smart building by using any device from anywhere via the Internet.

Web application has several advantages over desktop applications. They run inside web browsers which mean it will operate in any device has a web browser rather than the operating system, so it can considerably lower the costs because of reduced requirements on the end user system.

In this work, Smart building web application has been created by using ASP.NET MVC framework and C# language via Microsoft visual studio.

After the creation of web application, it has been published in a local web server, and can be opened and used by any smart device exist on the same network of the local Web server by writing the URL (http://localhost/smartBuilding/) of the application in the device's browser.
A. The Interface of The Smart Building Web Application

The Smart Building Web Application consists of four pages (Home Page, About, Contact, Switches)

1. Home Page

Home Page as shown in Fig5 is the first interface of the web application, it contains the name of the application.

7. Web Application (Contact Page)

4. Switches

This page as shown in Fig8 contains an index includes a set of switches that allow us to control equipments and components in the building, in addition to the knowledge of the current status of this equipment.

5. Web Application (Home Page)

2. About

This page contains a brief explanation about the basic idea of smart buildings, as well as a simplified explanation about the idea of this application as shown in Fig6.

8. Web Application (Switches Page)

To open Switches page must first log in by entering the email and Password as shown in Fig9.

6. Web Application (About Page)

3. Contact

This page contains our contact information to communicate with us for any queries as shown in Fig7.

9. Web Application (Log in Page)
To change the current status of any switch, we must click on the edit button that located next to each switch in the index as shown in Fig8.

After pressing the edit button, edit page as shown in Fig10 will appear and Allows us to change the status of the switch.

**B. Web Application Flow Chart**

Smart Building Web Application provides "User Friendly Interface " to control the smart building from any smart device.

The flow chart in Fig11 is clarifying how the web application works and how it communicate with database, as well as how to communicate with smart building controller.

10. Web Application (Edit Page)

11. Web Application Flow Chart
VI. CONCLUSION

A web application “web app” is a software program that is stored on a remote web server and delivered over the Internet through a browser interface.

Web application has several advantages over desktop applications. They run inside web browsers which mean it will operate in any device has a web browser rather than the operating system, so it can considerably lower the costs because of reduced requirements on the end user system.

In this work the Smart Building Web Application is designed to control the smart building by using any device from anywhere via the Internet.

The Smart Building Web Application consists of four pages (Home Page, About, Contact, Switches).

After the creation of web application, it has been published in a local web server, and can be opened by writing the URL (http://localhost/smartBuilding/) of the application in the device’s browser.

REFERENCES


2. The benefits of web-based applications http://www.magicwebsolutions.co.uk/blog/the-benefits-of-web-based-applications.htm (October, 15th 2017)

3. Types of Web Apps https://en.yeeply.com/blog/6-different-kinds-web-app-development/ (October, 15th 2017)


8. C# (C Sharp) http://searchwindevelopment.techtarget.com/definition/C (December, 1st 2016)


L’impact énergies renouvelables dans la planification urbaine, l’exemple de Bechar ville

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Résumé :
Le présent travail brigue de concéder une vision sur l’impact de l’intégration des énergies renouvelables dans la planification urbaine : stratagème, pour lequel l’Algérie opte depuis les dernières décennies, en guise de garantir le développement dans le domaine d’architecture et d’urbanisme. Elle adopte en effet, depuis le début des années 90, ce qui est désigné par le Plan Directeur d’Aménagement et d’Urbanisme (PDAU) et le Plan d’Occupation des Sols ‘POS, en tant qu’instruments de planification régissant le cadre de vie d’une population allant grandissant.

Cause à effet, d’une croissance urbaine sans précédents, ce surcroît de la population engendre une construction exponentielle des immeubles d’habitations et, un accroissement notable du nombre de véhicules, mais pas seulement, il provoque au truchement de tous ce qui s’en suit, le réchauffement de l’espace urbain, agrémenté de la rareté d’espaces verts, et l’usage des matériaux de construction dont le béton incommodant au milieu aride.

Or, le secteur de l’habitat, à priori au premier plan des préoccupations, est devenu de plus en plus énergivore. Les suites et préjudices à l’environnement, nécessitent une prise en charge dans un avenir proche, étant lourds d’impact. Raison pour laquelle, la production urbaine et architecturale s’inscrit dans la priorité des objectifs des gestionnaires. Dès lors, les architectes s’imposent inéluctablement dans la quête d’une démarche, à même de concourir au développement économique durable du pays.

Qui dit développement durable, insinue tacitement un environnement plaisant, prenant en charge les conditions du milieu climatique, socioculturel,…

Mots clés
Énergies renouvelables, planification urbaine, développement durable, milieu aride.
Planning sustainable urban development in Bechar city
Planning sustainable urban development in Bechar city

1. Introduction

The Extreme Value Theory is an area of statistics dedicated to develop models and techniques that estimate the behavior of rare events that in some cases have catastrophic results. The climate knows, and will continue to know of the peremptory as upheavals attest to these scientific results of the GIEC (Intergovernmental Group of experts on climate change). The extra frequency and importance of extreme weather events (whose: waves of heavy heat, wind storms, floods,...etc) probably threatens human settlements and natural resources; threatening the safety and the health of men, in a word: human life and its development, including economic stability.

If the damage climates undergo the city, the built environment, and people are increasingly expanding, what about when contexts Saharan where excessive temperatures, violent sands and floods, catastrophic and unpredictable winds make this environment already hostile, difficult to live?

As 'a space of social relations' (Roncayolo; M., 1992), the city brings together the men with their daily... their dreams, by promoting the encounter and Exchange. The oasis goes beyond local aspirations, since it is managed by mechanisms for exchanges. It is subject to geographical, historical, religious and economic contingencies. These links sate relational expectations of isolated and disparate companies over this vast area of the Sahara.

The exchanges necessary Saharan worldwide, is carried by camel, and made prosperous territories. So if Sahara means "desert", he dedicates ‘the relationship of humanity to the Earth’ (Bergue, 2002). Traveled by explorers, tour operators, it is not empty. Network oasis that has stalked along valleys of a life at the heart of the Sahara, but also reflects a society that resists the severe conditions of the environment: water scarcity, harsh climate, vast desert expanses, fragile ecosystem.

South of the Algeria is a vast region as rough and fragile, hostile only attractive where a significant number of human settlements (Ksar & palms) are formed over time despite unfavorable conditions. In this geographical area, three fundamental elements interact to produce habitat, the Palm Grove, so the oasis. It’s human, water and Palm. Each oasis constitutes a cultural area, in which we find the product of a collective experience, characterized by its codifications, its solutions and its way of doing.

The oasis is a settlement around water generator of culture. The oasis is an artificial ecosystem founded and maintained by humans through careful management of natural resources on three strata: the herbaceous stratum (gardens), the shrubby stratum (fruit trees) and the trees stratum (palms). The environment submitted to the extreme aridity requires the movement of surface water as an essential condition for the maintenance of a plant density important

GEOGRAPHICAL CONTEXT OF THE COMMUNE OF BECHAR

1.1. GEOGRAPHICAL LOCATION

Béchar is located in the South-West of Algeria. Its geographical location near the western Border and the role of north / south hinge of the southern slope of the Saharan Atlas give it a strategic position as a commercial and military crossroads of the south-west. Its current status as capital of aWilaya (department), makes it today the main agglomeration of the region encompassing the wilayas of Bechar, Adrar and Tindouf. Béchar is crossed by the national road n ° 6 considered as a main axis, connecting it to the big cities of the North and the South of the country.

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Figure 1– panorama on the splendor of the Saharan vernacular property Taghit in Bechar/ Algeria. Source : Authors
Planning sustainable urban development in Bechar city

2. PHYSICAL AND REGIONAL FRAMEWORK

The commune of Béchar fills a space of 5050 km². It is crossed from the North-East to the South-West by Oued Béchar (river) - probably an old tributary of the Oued GUIR- Fed by the flowing waters of the Jebel Grouz, which drains, with its tributaries, a basin of 150kms.

It is mainly bounded:
- On the north by the Djebel GROUZ,
- On the south / east by the Western Erg,
- On the west by the Hammada of the GUIR,
- In the east is Djebel MEZARIF and Hammade Bet-Touadjine

As for the agglomeration of Béchar, it is limited by:
- On the north / west by two parallel ridges called respectively Barga El Gaada and BargassidiHamed Ben Bouziane- adopting the leadership of the Oued,
- To the south / east, at a distance of about 15 kms, by the Djebel Béchar

The site presents various physical elements which together form two main parts:
- The first part forms a triangle, formed by Djebel Antar and the lower part the most flat and highest. The Oued (river) passes through the middle of this triangle, hence, forming two well distant fringes, one flattened and elevated towards the north and the west, the other more or less flat and elevated towards the east.

The second part is composed of the same elements structuring the first, in which the relief is more or less rugged towards the south. Nevertheless, it forms a trapezium, which is as a small base limit of the first part and the great base of the Hamada of Gui towards the south.

The site thus presented has favored the implantation of the city since the conditions of life allow it: water, defense system, fertile land. The city, subsequently settled in the flattest part and obeyed the existing linear conformation: the Oued (river).

Evolution of the population at the new census 2008-
Evolution and dispersion of the population (77-2008)

Figure 3: Geographic map of the evolution of habitat density, source URBAT Town of Béchar

Figure 4 : location map of the city of Béchar, source URBAT 1996

Figure: situation of the agglomeration
Planning sustainable urban development in Bechar city

THE SPACE DEVELOPMENT OF THE CITY OF BECHAR

2.1. INTRODUCTION

The urbanization of Béchar has passed, through its long history by different civilizations. The site has been inhabited since ancient times as evidenced by the presence ruins of the ancient ksour and the old Ksar which is still existing. It was characterized by the saharan civilization with its habitat and its oasis agriculture, by the nomadism that occupied its nearest surroundings and the caravan trade of which it represented a place of stage.

2.2. BECHAR PRES-COLONIAL:

1. Pre-Islamic period (before the 7th century)

During that period, no writing or vestige gives information on possible phoenician implantation in the are of Béchar and in the South of Algeria. After the ruin of the commercial hegemony, and the conquest of the Numidyi Mauritanian kingdoms, Rome settled strongly in the new provinces. The mines that existed in Niger, Senegal, Guinea since the Iron Age, proves that a trading system occurred and was real in the west of Africa long before the trans-Saharan medieval trade. The TRANSSAHARIANS were existing that is why, Mr. RAYMOND reconstructed their probable itinerary on a map. It clears two main roads: FAZAH KAWAR in the east of the Algerian south connecting CARTAGE to Mali passing through. The region of TOUAREG. The second FAZAH GAO in the west linking Morocco to GAO, passing through Mauritania.

2. Muslim dynasties (7th century AD)

The Eastern Algeria was part of the Abbassides empire whereas, the west of Maghreb belonged to the kingdom of the Idrissides. Fez was its capital. In 1912, the Muslims of Spain brought about the dismemberment of the Almohad empire which replaced the local dynasties. But in spite of the conquests (FOUTOUHATES), and the management of the great country (Arab Maghreb), no document or index has been found giving clear proof of the existence of the region of Bechar.

3. Turkish Period (1505-1830)

The Spanish fleet attacked several coastal cities, such as Mers-El-Kébir (1505), Oran (1507), Algiers (1509), Tenes and Mostaganem (1511). In order to hold out against the Spanish attacks, the muslims of Algeria appealed to the Turkish corsairs whose leader Khair-Eddin extended his rule over all the coast. During the Deys’ regime in Algeria, the Turks had small detachments. They occupied several Oasis. It was then during a period of drought that lasted 40 years that the Day of Tiemcen, Caliph Abdel Malek (1550), sent missionaries to search for water across the region. One of these missionaries brought him in a gourd some delicious and fresh water, discovered in the Sahara. The Dey told him "you are a BACHCHAR," meaning an announcer. He gave the name of BECHAR to that particular area. Since the discovery of that place, a series of urban facts have occurred: The settlement of "OuledNoceir" in Béchar. Then and later, there was the settlement of SidiMhamed Ben-Bouziane, a holy man. He and his tribe had cultivated the palm grove and had bored wells as well.

Then, during that time, the Trans-Saharian route that linked Tafilalet (egSijilmasa, Morocco) and the southern Algerian Gouraya, Touat to S habil Africa was born while passing through the Bechar’s region.

Bechar became an important trading point at the place called "Place des Chameaux". SidiMhamed Ben-Bouziane deserted the region of Béchar and moved to Kenadsa (about 20km west of Bechar), where he founded a Zouia, a sort of an islamic monastery or brotherhood. Meanwhile, there was the construction of a Ksar south of the place called "Place des Chameaux" in the left fringe of the river and near the palm grove at the end of the fourteenth century. It is the actualKsar (palace). Of Bechar. The Kasr of Bechar, the oldest nucleus of Bechar, was built by the servants of the zaouia of Kenadsa. It is endowed with two cemeteries: one in the south near the Kasr’s south door, thus, forming a barrier of growth, the other in the north-west. This Ksar (palace) is organized and structured with a mosque in the middle, the Houader’s square, and hierarchical paths overlooking houses. The communication with the outside world was made through three main gates,
Planning sustainable urban development in Bechar city

one in the west, the other in the north-east and the last in the south.

So we can say that before 1903, the site of Bechar was occupied by the old ksar which is still existing today. It was part of a series of ksur (palaces) that characterized the area. The Ksour, villages consisting of a concentrated accommodation, such as fortresses, presenting a typology and a technique of construction which had been used extensively along the northern Sahara strip and which the Muslim civilization had strongly contributed to spread.

Close to the Ksar, there is the Camel Square, which has become the meeting place for commercial caravans where the Kaourians were making their trading exchanges with the nomads and other itinerants of the caravan routes.

figure 6; photo of « Square of the camels 1903

Figure 7: The city of Bechar before 1903, source URBAT.
Planning sustainable urban development in Bechar city

2.3. Colonial period

France, which had colonized Algeria since 1830, entered the south and to Bechar precisely and only in 1903. Why did the French push their conquest to the Sahara, and specially to Bechar? In history, the trans-Saharan railway awaits its historism following the meanderings of its evolution. The idea of the railway was launched by the French in 1960. It fueled all polemics until the last moment of the Algerian War of Independence. At the same time of course, to be feasible under a political will to any test.

The period 1903-1917: French penetration and construction of the railway:

In 1903, the French took possession of Bechar, site and strategic node from a military point of view. They set up a fortified redoubt north of the Kasr. Two poles of the future growth of the city of Bechar are thus defined. On the one hand, the Old Kasr with the aboriginal population and on the other the military barracks (the redoubt) in a strategic position of control, alongside the most important sources of water and communication.

In 1905, the railway connected Béchar to the north of Algeria. A few years later, in 1917, a new European quarter, "the village" was born close to the Kasr and extended from the Camels' square to the Redoubt.

The period 1917-1940: is the one of the growing role of the city with the exploitation of the coal mines and the construction of the trans-Sahara. The greatest urban expansion of the city took place between the two wars, when Bechar became a military base, and a node of communication towards the Saharan South.

For example, large companies such as the Trans-Sahara for the exploitation of the riches of the Saoura and Touat regions, which made the trail that reached Gao in Niger and a good part of which will be used for the national road N° 6.

In this period, the French population is twice as large as the local population. The economic and administrative role of Béchar has an obvious impact on the organization of the territory in general, and on the urban development of the city in a particular way. However, the growth of the city is in harmony with the natural and social environment.

However, afterwards, a major fact had come to shake this harmony and thus the urban structure of the city. Indeed, the French administration favored the local ownership of land, tribal and common property to facilitate the sale to French settlers.

The period 1940-1958:

the new expansion (Béchar-Djédid and la Barga) with the extension of the railway line:

In 1940 the railway was extended to Abadla to serve the coal mines. In 1942 a new railway linked the city of Béchar to the port of Ghazaouat, through Morocco as part of the project "Mer-Niger" with ambition to bring the Mediterranean into the Niger by a railway.

Large-scale projects such as the new Bechar railway station and a power station south of Béchar with a neighborhood of 1,600 workers in Bidon II, 7 km from Béchar (currently Béchar-Djédid) were being built.

During the 1950s, the city asserts itself more as a military and administrative one. Thus, a large residential area is made to the west of the city near the mountain ridge "la Barga" of which it bears the same name.

This expansion is aggravated by the exodus of the inhabitants of the Kasr of the Saoura and the sedentarization of the nomads in the town of Bechar. The current structure of the latter with the main poles of our days is beginning to emerge:

1. In the center of the city the first European quarter outside the barracks along the axis of Lutaud's square (ex-place of the camels) until the redoubt, to which is grafted the new district of the Barga.

2. Between these two sets, a depression "Chaabat towards the south, with a precarious accommodation sheltering thekoursians of the exodus,

3. In the north-west, around the railway station, a neighborhood housing Moroccans and Spaniards from the workforce of the construction of the railway,

4. And in the east, the Dédbaba district, which welcomes nomads who settle down, including the Ouled-Djerir who settled on their former gardens, to which would be added other migrants from the ksour of the valley of the Saoura.

post-independence period: strengthening the tertiary sector

The city of Béchar is experiencing a rapid and uncontrolled expansion characterized mainly by the exaggerated zoning practice. There was the construction of new housing parks, 220 housing district in the Barga, 622 housing district,
Planning sustainable urban development in Bechar city

halfway between Béchar city and the Electric central district, as well as other neighborhoods such as SNTV, Debdaba (east side), in BécharDjedid. Add to this the construction of bridges and the renovation of the city center which is unfinished.

We take notice of the permanence of the places, the line of transsaharienne growth, the Ksar the route of the historical center.

The town of Béchar counts, despite the departure of the Europeans, almost 34000 inhabitants. The Closure of the coal mines has affected Kenadsa’s economy, and the one of Bechar, however, thanks to the exploitation of natural gas, the State and through several plans has injected equipments, including, specially school and health, as well as basic infrastructure and networks.

The town of Béchar has been formed and transformed along the history, following a clear and permanent structure composed mainly of the major nodes of articulation and routes of gradual connections.
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Figure

Map of Bechar 1903

Figure the

Map of Bechar 1936

colonial civilians settlement 1936
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Figure: Different growth plans of the city of Bechar, source: Magisterium in Urban Planning, Ben Mohammed T, 2005.
Figure 23: The distribution of the housing estates in Béchar’s department.
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CONCLUSION

The phenomenon of urban sprawl is evident, like all Algerian cities, with an increasingly rapid urbanization but also anarchic. The town of Béchar is characterized by a linear growth along the two banks of the Oued( river ), knowing that the western side of the city faces a natural barrier of size which is the mountain ridge of the Barga, and in its continuation and along the latter, an artificial urban barrier represented by the area occupied by "the 3rd military region".

This logic of growth, led to two conurbations, one in the north with the Ouakda's borough, and the other to the south with the BécharDjedid Quarter. On the other hand, in addition to the growth and mutations experienced by these two urban entities, with that of the main popular district of Debab in, other poles have emerged without any spatialization, let a global vision of urban management, such as ZHUN( urban lodging zone), the Blue Zone, and Supra-area facilities such as university or hospital, to the south or the pole of the road of Lahmar in the north, created outside the urban perimeter, more particularly with the new university cluster, a large social housing program, and other facilities as well.

Indeed, the city of Béchar is prey to a real "urban breakdown ", expression, borrowed once again to a study prepared by ANAT Algiers in 1996, entitled Control of the growth of Béchar's city ". This complete disorder in which the city evolves is in fact the result of arbitrary and spontaneous interventions since the post-independence period, in particular.

The sustainable development is a project which has been scheduled in all developed countries thanks to international negotiations about ecological risks for the protection of natural capital. The Algerian government shows a high interest in the principles of sustainable development, implementing for example residents' participation (Boukarta 2011) aiming at the realization of durability and enhancing the quality of cities and neighbourhoods. Yet, with the isolation of the elected representatives and the local authorities, mediocrity and failure of plans are inevitable. To illustrate, bechar is one example of this failure. In this city, we find a disproportionate and an uncontrolled urbanization process which delays the institutional, technical and urban administrators from intervening, and that result in the multiplication of environmental damage within urban spaces (Madani 2002).

The crisis of 1980s and the total disengagement of the government to act and find solutions to decentralization, the population, in particular neighbourhood's residents, claim their right to be involved in the management of affairs of the city. Therefore, does the mode of normative and centralized management come to its end? Is it the era of neighbourhood governance that leans a multitude of actors and emphasizes the role of the mediators, the mobilization of the social agents and the research for a compromise between divergent interests? Among the present neighbourhood committees in bechar, how many among these are really active? How many are they interested in the living environment, neighbourhood changes and the future? However, the world we will leave to future generations will depend on our success or our failure to deal with climate change. If we win this battle, we will preserve the resources of our planet, while also opening huge economic prospects for sustainable development. Accordingly, we need to consider a resilient, secure, and sustainable city and collect a reflection at the same time taking into account economic, social, environmental, cultural, political factors and governance impacting urban environmental.
Planning sustainable urban development in Bechar city

Bibliography

[1] Planning sustainable urban development in Bechar city
[34] Lagane J. 2013. Les défis de la durabilité urbaine en Méditerranée. Aix Marseille, Presses universitaires d’Aix Marseille. (In French)
[35] Loughough H. 2014. La ville algérienne:
Planning sustainable urban development in Bechar city


MOROCCAN WEARABLE ARTIFICIAL KIDNEY (MorWAK):
REQUIREMENT AND USE CASE DIAGRAMS

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Abstract — The aim of this work is to characterize a portable ultrafiltration system allowing the treatment of hypervolemia encountered mainly in situations of End-Stage Renal Failure (ESRD) and Congestive heart failure (CHF). Indeed, changing needs and better understanding of the Pathophysiology of uremia and understanding the limitations of current ultra-filtration techniques have been challenged by the design of MorWAK overcoming the drawbacks of current techniques of liquid extraction extracorporeal way. The MorWAK device will be described according to a functional approach by the requirement and use case diagrams. Structural and behavioural approaches will be the subject of future studies.

Keywords — MorWAK - ESRD - CHF - Hemodialysis - Ultrafiltration - Functional Approach - Requirements Diagram - Use Case Diagram

I. INTRODUCTION.

Extracorporeal fluid extraction techniques, used in the treatment of hyper-volemia mainly encountered in End-Stage Renal Failure (ESRD) and Congestive heart failure (CHF) situations require hospitalization in an intensive care unit and the use of costly and bulky machines driven by a highly skilled workforce [1] - [2]. These are survival techniques rather than real alternatives to the physiological functioning of the native kidney which functions 24 hours a day. In order to improve the quality of life of dialysis patients, reduce cardiovascular morbidity and mortality mainly [3], prevent and correct the metabolic complications of kidney disease, the research team Engineering and Biomedical has developed the portable device MorWAK (Moroccan Wearable Artificial Kidney) [4] allowing the simplification of procedures for the treatment of hyper-volemia, that is defined by the increase in extracellular volume. Our team is affiliated to the Laboratory of Cellular, Molecular, Inflammatory, Degenerative and Oncological Pathophysiology (LPCMIDO) of the Faculty of Medicine and Pharmacy of Casablanca in Morocco. The critical study of current extracorporeal fluid extraction techniques as well as the assessment in 2015 of the carbon printfoot of the dialysis activity at the Ibn Rochd University Hospital Center in Casablanca demonstrated that only the development of portable hemodialysis technologies seems to be the medium- and long-term outcome to dramatically reduce the suffering of patients with ESRD and the disastrous impact of one of the most expensive and polluting health care activities on the planet.

II. TOOLS AND METHODS

To satisfy the need, you have to know it. To understand it, it must be expressed in terms of functions. To identify the functions it is necessary to have the methods and tools of analysis.

During this study, we will use a number of problem solving tools to better explain the need and characterize the MorWAK device.

A. ISHIKAWA DIAGRAM

This diagram will be used to group by category the causes that may cause a problem. In our case, it is a critical study of dialysis as it is currently done in intensive care centres with the aim of improving the quality of life of dialysis patients [5].
B. FUNCTIONAL SPECIFICATIONS

The functional specification presents all the functions grouped by family. Each function is characterised by a number of assessment criteria with their levels and flexibility. The functions are ordered by importance. [6].

C. SOFTWARE Modelio SA - SysML

Maintaining the consistency and compliance with the specifications of multidisciplinary systems requires a modelling language that makes it possible to group together in a model all the trades, specifications, constraints and parameters of the entire system. Systems Modeling Language (sysML), which approaches design using the notion of blocks, is best suited to the MorWAK device. [9].

D. REQUIREMENTS DIAGRAM

This functional diagram will describe the requirements of the functional specifications. Each requirement expresses an ability or constraint to be met by the system. A requirement may express a function to be performed by the system or a condition of technical, physical, reliability, safety, ergonomics, esthetics performance [7].

E. USE CASE DIAGRAM

This functional diagram highlights the functional interactions between the actors and the system studied. It precisely delineates the system being studied and describes what the system will do without alluding to the technological solutions adopted. [8].

III. HEMODIALYSIS IN CENTRE: THE PROBLEM

Hemodialysis was introduced in the 1950s as a renal replacement technique. The first works of Willem Johan Kolff have made it possible to set up hemodialysis generators: bulky devices requiring prior water treatment but which have also saved thousands of lives. It is primarily intended for patients with chronic end stage renal failure [10]. This is the most used technique for this indication in the world. Indeed, after more than sixty years of use, few changes have been made to the basic principle [11]. The main improvements have been in accessories such as the addition of performance monitoring tools such as ionic dialysis or blood volume monitoring modules to almost all generators.

Hemodialysis is a heavy and very expensive technique. It undermines the health budget in all countries regardless of their GDP. Access to this type of treatment is therefore very limited in developing countries [12]. The high technicality of hemodialysis requires a particular organization. It is very often carried out in a centre where a machine is "made profitable" by its use for several patients in the same day. Whereas the ideal solution seems to be that each patient should have a "personal" or "individual" machine. This would make the technique overpriced and therefore inaccessible for the vast majority of patients.

IV. RESULTS

The multidisciplinary Engineering and Biomedical research team is aware of the various needs in dialysis field. It includes the improvement of the quality of life, the reduction of morbidity and mortality, the prevention and correction of the metabolic complications of kidney disease. Then, we developed MorWAK (Moroccan Wearable Artificial Kidney), a portable device that simplifies hemodialysis procedures.

![Initial Needs Diagram](image1.png)

![MorWAK SADT Model](image2.png)

MorWAK is therefore defined as a set of solidarity and organized elements to meet the expectations raised by ESRD patients.

The set of functions allows to identify the limits of the MorWAK, the elements which constitute it and its frontier including all the elements necessary for its functioning in all its phases of use.

The Incoming Work Material (IMW) contains:
- Patient in ESRD.
- Electrical energy.
- Drug.

The Outgoing Work Material (OWM) consists of:
- The dialysis patient.
Solid and liquid waste.
The data files.
Real-time information on the progress of the purification operation.

The energy (W), setting (R), control (C) and operating (E) parameters allow the user to customize the purification operation.

A. NEED IDENTIFICATION

The main causes affecting patient’s quality of life are grouped into five main families (5M) as follows [5]:

- **Machine (Dialyzer):** The machine is profitable by its use for several patients in the same day.
- **Material:** The dialysis of an individual greatly reduces its autonomy and socio-professional performance. The life of the patients is rhythmic (3 times 4 hours per week); which restricts their movements in addition to drastic food restrictions.
- **Manpower:** the quality of service depends on the qualification of the personnel controlling the dialysis equipment.
- **Method (process):** the quality of service depends on the qualification of the personnel controlling the dialysis equipment.
- **Medium:** it is at the origin of the expansion of previously known pathologies (manual transmission in dialysis centers) and the emergence of new diseases associated with dialysis.

B. FUNCTIONAL SPECIFICATIONS

The critical study of current extracorporeal purification techniques has made it possible to draw up a not exhaustive list of requirements specifying the capacities or constraints that the MorWAK must satisfy. [8]

In order not to weigh down the presentation, we have grouped the requirements:

- Functional requirements.
- Technical requirements.
- Security requirements.
- Environmental requirements.
- Interfacing requirements.
- Practical requirements.
- Marketing requirements.
- Energy requirements.

These requirements constitute the technical functional specifications of MorWAK. The criteria and levels of appreciation of the functions and constraints specified by the requirements will appear in the requirements diagrams. [6]

In the following, each requirement category will be treated separately.

C. REQUIREMENT DIAGRAMS

Each of the previously defined requirements will be broken down into several unit requirements:

**Functional requirements:**

These requirements describe the extracorporeal treatment function for which the system is designed.
Security requirements:
These requirements highlight the dangers involved in using the device for better protect the patient.

![Image of MorWAK Security Requirements](image1)

Figure 5: MorWAK Security Requirements

Environmental requirements:
Respect for the environment is imperative; the device must produce minimum solid and liquid waste.

![Image of MorWAK Environmental Requirements](image2)

Figure 6: MorWAK Environmental Requirements

Interfacing requirements:
The use of a Human Machine Interface (HMI) is essential to allow a better interaction with the MorWAK.

![Image of MorWAK Interfacing Requirements](image3)

Figure 8: MorWAK Interface Requirements

Practical requirements:
Users are not necessarily technicians, which is why MorWAK must be easy to use and intelligent enough to manage risk situations independently.

![Image of MorWAK Practical Requirements](image4)

Figure 9: MorWAK Practical Requirements

Energy requirements:
The portability of MorWAK requires better management of electrical energy. The technological solutions thus adopted must not be energy-intensive.
A portable hemodialysis device has been published on the WIPO website under number WO2017/164722 [4].

The characterization of the MorWAK was the main result of the critical study of the current techniques of extracorporeal purification. A prototype satisfying the maximum requirements of the functional specifications was built. In vitro tests were carried out on whole bovine blood units using our first prototype. The results will be published soon. The animal tests are ongoing and will test the reliability, efficacy and safety of MorWAK.

**Marketing requirements:**

The cost of the device and its estimation functions will influence its marketing. Great attention must be focused on the choice of technological solutions.

**D. Use case diagram**

All features visible from outside the MorWAK represent its use cases that can be summarized in four major families of features as shown in Figure 11.

**V. DISCUSSIONS**

The first research works of the Engineering and Biomedical team concerned research on optimal volume control means and portability in hemodialysis.

A first patent concerning a portable hemofiltration device (MorWAK1) has been published on the WIPO website under the number WO2016/072826A1 [13]. A second patent for a
REFERENCES


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