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The impact of a wind farm in the western Algerian network

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Abstract— **The detailed study of electrical power systems is a key element of many curricula in Industrial Technology. As a typical clean and renewable energy, wind power is becoming more and more widely used in electrical industry.**

This paper studies the impact of wind farm operation with doubly-fed induction generator (DFIG) connected to the west Algerian network 2012 from a different point of view. The important characteristics such as voltage profile and active power losses.

Keywords- Doubly-Fed Induction Generator (DFIG); wind farm; Algerian network2012; wind power

I. INTRODUCTION

In recent years, production, transport and consumption of electrical energy have been increasing due to industrialization, population growth and urbanization [1].

The fossil energy depletion, the global warming, gas emissions (CH4, PFC, HFC, N2O SF6, Methane, CO2), the acid rain… reinforce the idea of free polluted, economic and durable production of electrical energy. Renewable energy sources, especially the wind, as a non polluting energy and less expensive, have a key role to play in solving of all this problems [2].

The emergent pace of wind energy projects in various countries around the world has put wind energy at the forefront of the energy destiny. Among the various renewable energy resources, wind power is assumed to have the most favorable technical and economical prospects [3].

Algeria taking steps to develop large-scale wind markets. According to news released by the Global Wind Energy Council (GWEC) showing in figure1

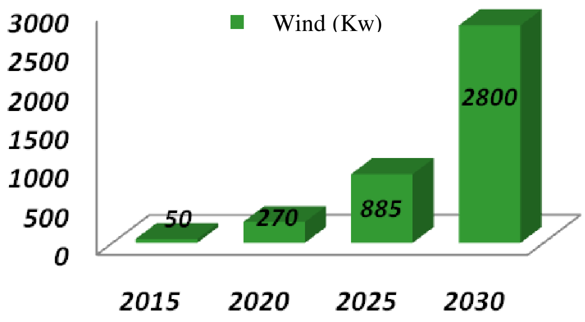

Figure1. The wind power has to install over the period 2012 – 2030

The west Algerian has good wind conditions the possibility to extend its current wind utilization greatly.

Since wind power must be placed where the wind conditions are good, most wind farms will be located far away from the load centers and in relatively weak networks with low short circuit power.

This work describes a study on the insertion of wind energy in the Algerian western network 2012, 400Kv, 220Kv and 60Kv. The principal goal is improved the transit of power, decreased the losses active and improved the voltage in this network by incorporating a wind farm with the use of a powerful tool for simulation which is the PSAT.

II. MODEL OF THE WIND TURBINE:

Wind speed *v*, applied to the blades of the wind turbine, involve its setting in rotation and creates a mechanical power on the turbine shaft, noted P_t and expressing by:

$$P_t = \frac{1}{2}.C_p(\lambda,\beta).\rho.S.v^3 \tag{1}$$

Where λ is defined by:

$$\lambda = \frac{\Omega_t.R}{v} \tag{2}$$

With:

λ: tip speed ratio representing the relationship between the linear velocity at the end of the blades of the turbine and the speed of the wind;

ρ: density of the air (roughly 1,225 kg/m3 with the atmospheric pressure at 15°C);

S: the circular surface swept by the turbine, the ray of the circle described being defined by the length of a blade;

Ω_t: rotor speed,

R: the rotor-plane radius;

The power coefficient C_P represents the aerodynamic output of the wind turbine and also depends on the characteristic of the turbine. This coefficient presents a theoretical limit, called limit of Betz, equal to 0,593 and which is never reached in practice.

In this paper, we will use an approximate expression of the coefficient of power according to relative speed λ and of the pitch angle β whose expression originates:

$$C_P(\lambda,\beta)=(0.35-0.00167).(\beta-2).\sin\left[\frac{\pi.(\lambda+0.1)}{14.34-0.3.(\beta-2)}\right]-0.00184(\lambda-3).(\beta-2)$$

Knowing the number of revolutions of the turbine, the torque C_t available on the slow tree of the turbine can thus be expressed by:

$$C_t = \frac{P_t}{\Omega t} = \frac{\pi}{2.\lambda}\rho.R^3.v^2.C_P(\lambda,\beta)$$

III. DFIG DYNAMIC MODELLING

A commonly used model for induction generator converting power from the wind to serve the electric grid is shown in Fig.2.The stator of the wound rotor induction machine is connected to the low voltage balanced three-phase grid and the rotor side is fed via the back-to-back IGBT voltage-source inverters with a common DC bus. The network side converter controls the power flow between the DC bus and the AC side and allows the system to be operated in subsynchronous and super synchronous speed. The proper rotor excitation is provided by the machine side power converter [4],[5].

For the stator:

$$v_{ds} = -R_s i_{ds} + (x_s + x_m) i_{qs} + x_m i_{qr} \tag{5}$$

$$v_{qs} = -R_s i_{qs} - (x_s + x_m) i_{ds} + x_m i_{dr} \tag{6}$$

For the rotor:

$$v_{dr} = -R_r i_{dr} + (1-\omega)((x_r + x_m) i_{qr} + x_m i_{qs}) \tag{7}$$

$$v_{qr} = -R_r i_{qr} + (1-\omega)((x_r + x_m) i_{dr} + x_m i_{ds}) \tag{8}$$

Where :

v_{ds}, v_{qs} : the direct and quadrate stator voltages.;
i_{ds}, i_{qs} : the direct and quadrate stator currents.
v_{dr}, v_{qr} : the direct and quadrate rotor voltages.;
i_{dr}, i_{qr} : the direct and quadrate rotor currents.
Rs, Rs : the stator and rotor phase resistances
x_s : inductance individual of the stator ;
x_r : inductance individual of the rotor ;
x_m : inductance mutuelle ;
ω : the electrical speed, $\omega = P_{dfig}.\Omega_{mec}$ and the P_{dfig} is the pair pole number.

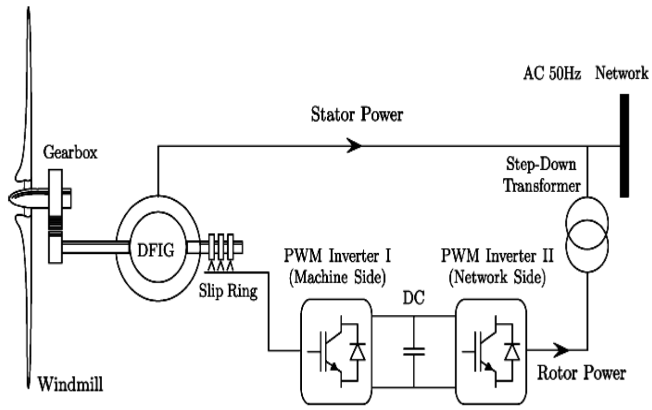

Figure2. Model of DFIG Wind Turbine

IV. ALGERIAN WIND POTENTIAL

12 identified zones (3 coastal, 4 in the central area and 5 in the south), set out again on a total surface of 906 200 km^2 in a twenty Wilaya.

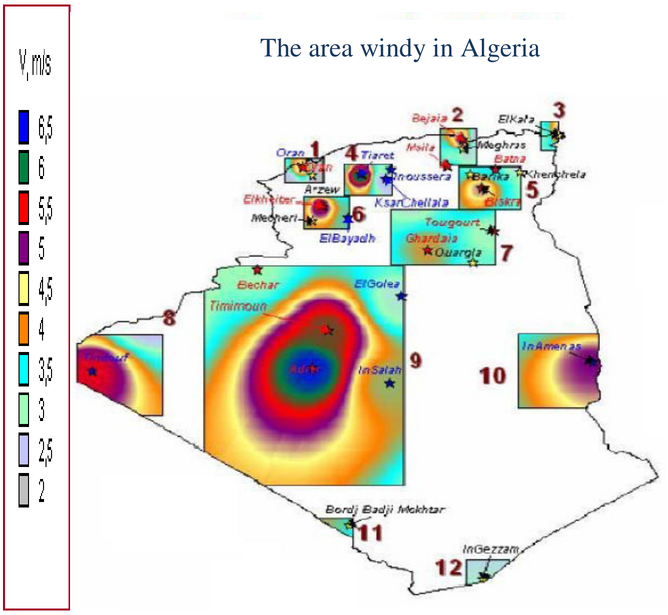

Figure3. The area windy in Algeria

For established a wind power turbine, a site should be chosen where the speed of the wind would provide energy necessary; we must thus make speed measurements of the wind in several sites. The Fig. 3 show an example of the areas been windy in Algeria according to the satellite data of the Laboratory of Wind energy CDER in 2011.

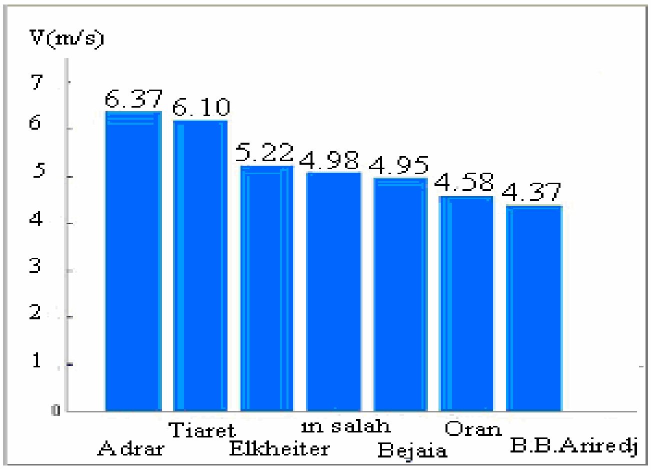

figure 4. Comparison between the average speed of windy sites [6]

V. APPLICATION

The objective of this article, is to apply the calculation of the power flow by the method of Newton-Raphson for the Western network Algeria 400 /220KV and 60KV, while inserting to him the power wind by using a topicality tool for simulation (software PSAT).

PSAT is a very convivial tool for the users of information and planning system for the power system, first because it's free, second for their precision.

The network represented by the fig. (5) includes:

- 102 bus;
- 07 production bus;
- 03 compensation bus ;
- 92 consummation bus ;
- 138 lines

The calculation of the power flow is a stage necessary to be able to compare our results. It is performed first for the determination of the initial conditions of the system before the insertion of the power wind. Indeed, it makes it possible to find the voltages in the different nodes and subsequently transmitted powers injected and losses.

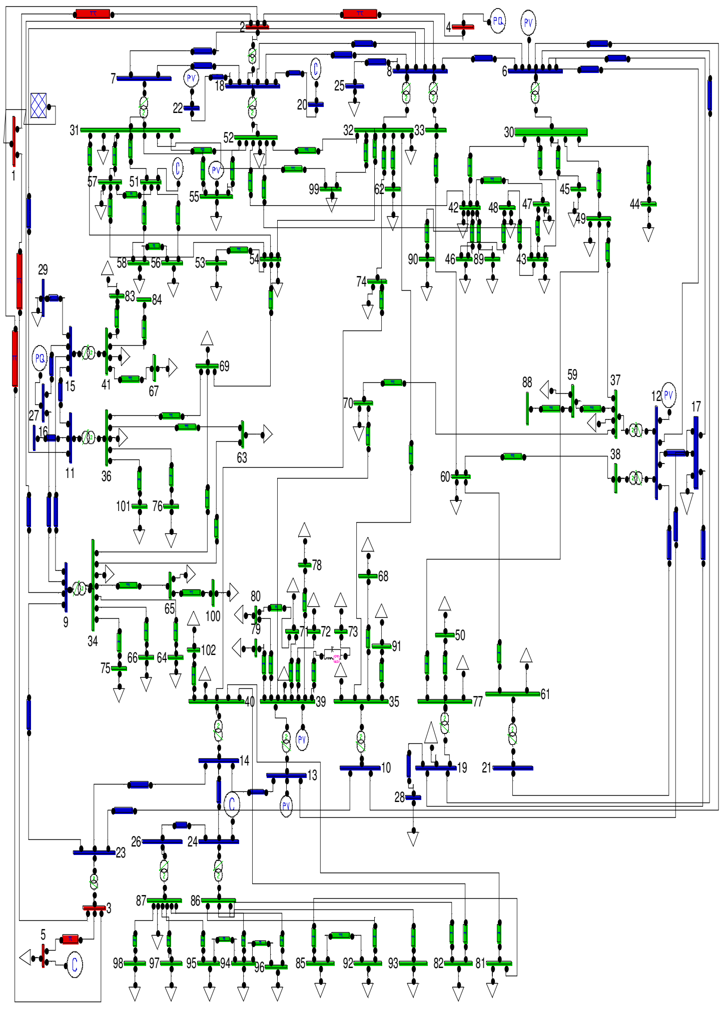

Figure5. Diagram of the West-Algeria (2012) network, inserted in PSAT

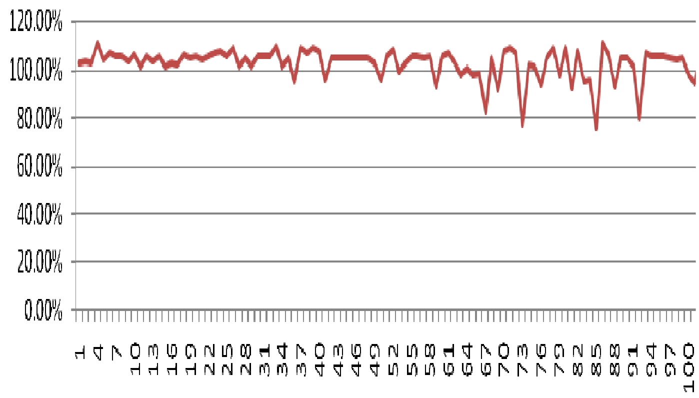

Figure6.Nodal voltages of the network West-Algeria 2012

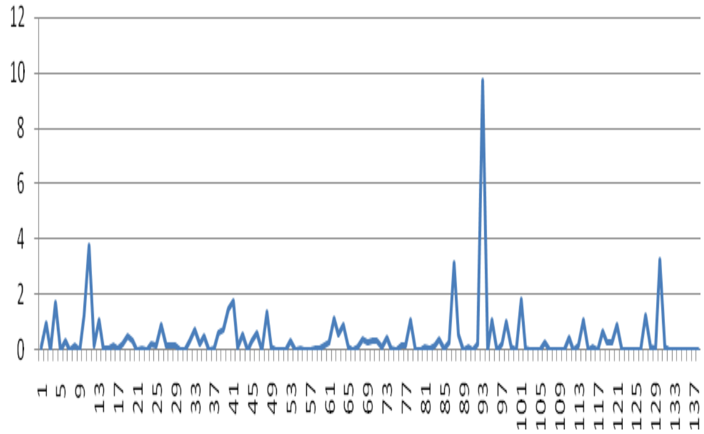

Figure7. Active losses of the West-Algeria (2012) network

TOTAL GENERATION
REAL POWER [MW] 1747.2815
REACTIVE POWER [MVar] 540.929

TOTAL LOAD
REAL POWER [MW] 1689.01
REACTIVE POWER [MVar] 658.751

TOTAL LOSSES
REAL POWER [MW] 58.2715
REACTIVE POWER [MVar] -117.822

A. *Problematic of the network West-Algeria*

According to the results of the power flow preceding as indicated in figures 6 and 7, we can conclude that this network contains two problems, the first it is the transit of power especially in the longest lines such as Bechar- Naama and Naama- Saida, the second problem it is the fall and overvoltage especially on the level of bus 4, 73,85 and 88. Bus N°73, which exists on the side of the wilaya of Tiaret, records the low voltage and greatest quantity of the active losses. Then it is necessary to solve this problem using the renewable powers precisely wind power. Then we must insert a wind power in the network West-Algeria, but when we will install this device? Which are the parameters of adjustment of this device?

B. *The emplacement of the device*

The emplacement of the wind farm is conditioned by two criteria, first is internal related to the problems of this network, and the second related to the climatic condition of the area where one goes installed this device.

According to the study of the power flow of the western network Algerian 2012 without the insertion of the device and as the study of the areas been windy in Algeria, one can say as the ideal site of this farm is on the level of the area of Tiaret or the speed of the wind to reach 6.78 m/s during the month April 2011 to see figure 8.

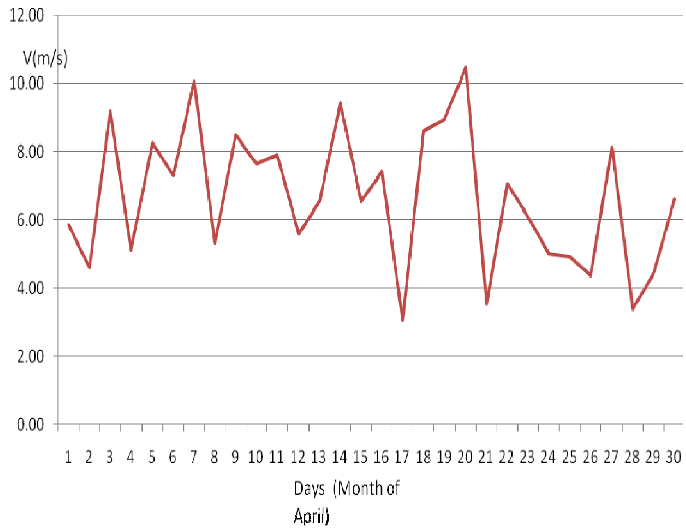

Figure 8. The speed of the wind recorded in the area of Ksar chelala in Tiaret during the month of April 2011.

C. *Parameters of the wind power*

The wind was modelled as distribution of Weibull already proposed by F.Milano (2005) by taking account of nature made up of the wind which included the average [7].

TABLE I. WIND MODEL PARAMETERS.

Nominal wind speed/ air density	15m/s /1.225Kg/m3
Filter time constant/sample time	4s,0.1s
Weibull constant C & K	20,2
Ramp constants [*tsr, ter , Awr*]	5s,15s,1m/s
Gust constants [*t sg, t eg, A wg*]	5s,15s,0m/s
Turbulence constants [*h, Z0 ,df ,n*]	50m,0.01,0.2Hz,50

TABLE II. DFIG PARAMETERS.

[MVA,KV,Hz], kWs/kVA	[600 69 60], 3pu
[Rs,Xs] [Rr,Xr] Xm	[0.01 0.10] [0.01 0.08] 3.00 pu
Kp, Tp, Kv, Te	[10pu 3s], 10pu, 0.01s
Pole, Gear Ratio,	[4 1/89]
Blade length and number	[75.00m 3]
Pmax, Pmin; Qmax, Qmin	[1.00 0.00]pu; [0.7 -0.7] pu
No of generators	300Nos

D. The insertion of the wind farm

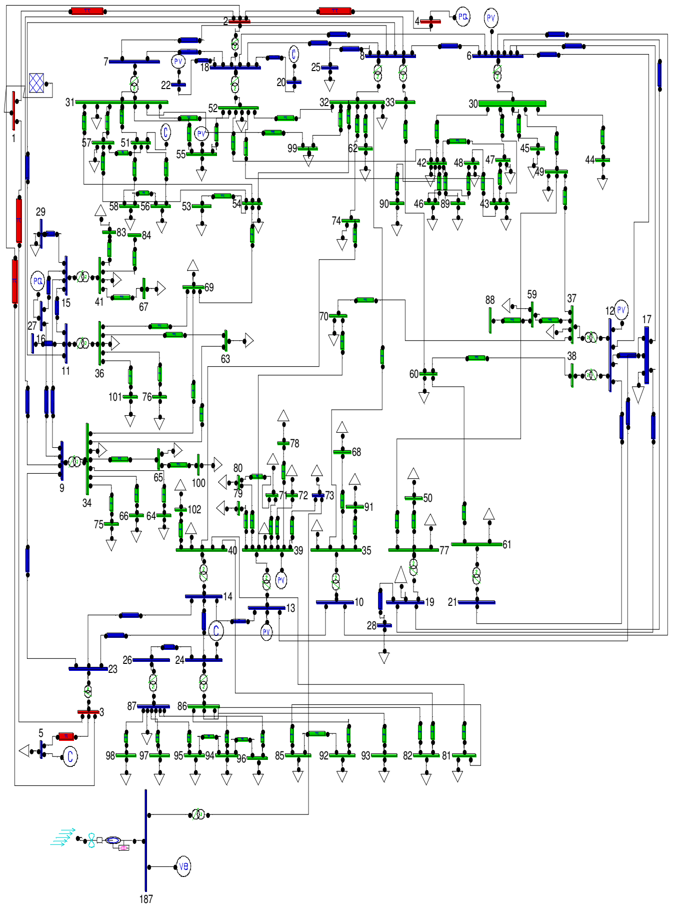

Figure 9. West-Algeria (2012) network with wind farm

The calculation of the power flow of the system with insertion of device in the sit chosen, the results obtained are in figures 10 and 11.

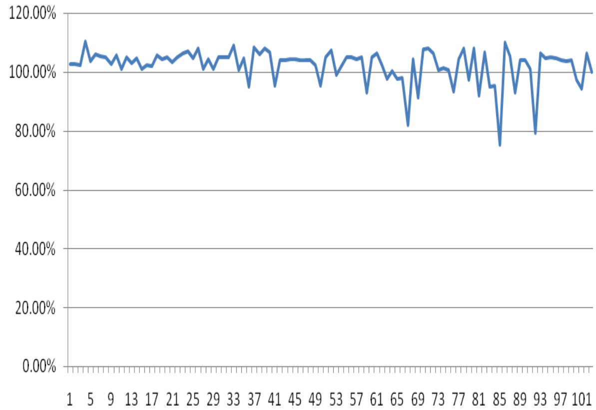

Figure10. Bus voltage of the West-Algeria (2012) network, with wind farm

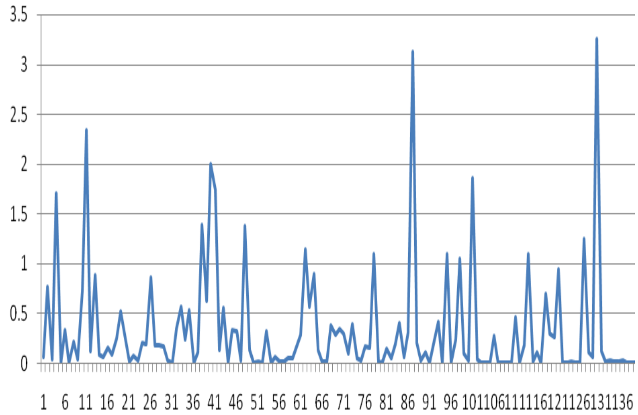

Figure11. Active losses of the West-Algeria (2012) network, with wind farm

TOTAL GENERATION

REAL POWER [MW] 1734.714
REACTIVE POWER [MVar] 495.2116

TOTAL LOAD

REAL POWER [MW] 1689.01
REACTIVE POWER [MVar] 658.751

TOTAL LOSSES

REAL POWER [MW] 45.704
REACTIVE POWER [MVar] -163.5394

E. Interpretation of the results

TABLE III. RESULTS COMPARISON

Results	Without wind	With wind	Better

	farm	**farm**	**emplacement**
Active losses [MW]	58.2715	45.704	Tiaret
Voltges in node 73 [¨%]	76.58	100.65	Tiaret

According to the results obtained table (III) we notices that the total losses of the system decreased by 58, 2715 MW to 45,704 MW, That is to say a profit of 12, 5675 MW. This reduction is obtained thanks to the site of device wind farm in the bus 73 which corresponds to the optimal site. This last is not arbitrary because, we chose it among other sites by respecting the criteria of insertion of the controller.

In addition, it Is noticed that the voltages are improved, the overvoltage of bus 73 increases by 76.58% been able to 100.65 it is due to the implantation of the wind farm on the level of these area.

CONCLUSION

The principal goal of this article was presented by a test to formulate a model of the western network Algerian 2012.
In this model was includes all the power stations used in this area for the production of electrical energy, as well as simulation was illustrated by the use of one of the most recent software which is software PSAT. This last was applied for such a system complicated without any failure or instability in simulation.

Through this article a wind farm was inserted in the western network Algerian 2012 to improve not only the production cost and transport but also to improve quality of service of this real network by the reduction of the active losses and improve the quality of the voltage. In addition, the results obtained could decrease the production which will influence the overall costs of the network, without forgetting the environmental impact.

ACKNOWLEDGMENT

Through this article we could know the utility of the wind farm in the power system by the improvement of the power flow and the improvement of the voltage quality.

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