Modeling and Simulation of a Hybrid Energy Source based on Solar Energy and Battery

Asma MESKANI¹, Ali HADDI², Mohamed BECHERIF³

¹Innovative Technologies Laboratory
ABDELMALEK ESSAÂDI University, (ENSA) Tangier, Morocco
²FCLAB FR CNRS 3539, FEMTO-ST UMR CNRS 6174,
University of Technology of Belfort-Montbéliard, France
³meskani.asma@gmail.com
²haddi.ensat@gmail.com
³mohamed.becherif@utbm.fr

Abstract— With the increasingly prominent energy crisis and environmental pollution caused by automobiles, the solar energy, as a new and clean energy, has attracted much attention. In this paper, a novel topology of hybrid generator with a PV energy conversion system with a battery in a DC-coupled structure is adopted to solve the problem and replace Fuel Cells, which have important diesel fuel consumption and high energy costs. In the proposed system, the PV Source represents the main source, the DC link and battery the transient power source. This latter can absorb or supply power peaks. Finally, the proposed system is verified by the results of simulation.

Keywords— Solar Energy, Hybrid generator, PV, Battery, DC-coupled structure

I. INTRODUCTION

More likely than not, getting a vehicle from point "A" to point "B" involves combustion of a fossil fuel, a process that emits gasses and affects the environment. According to the U.S. Environmental Protection Agency, more than half of the air pollution in the world is caused by mobile sources, primarily automobiles. Further contributing to the pollution potential of cars is the fact that they are filled with numerous fluids, which can harm the environment in the cases of leakage or improper disposal.

One solution to the current emissions problems that we face is the Hybrid vehicles, as they offer lower emissions than gasoline automobiles. Fuel cell (FC) technologies are expected to become a suitable substitution for conventional power generators and grid utility for residential applications, as they are more efficient and environmentally friendly in comparison with other conventional power generators. However, in order to provide power demand of a residential load, it may be required to over design fuel cell power module which is not economically advisable. Furthermore, due to the sluggish dynamic response of fuel cell in transient events, there will be load following problem. [1] Not to mention diesel fuel consumption and energy costs that makes FC less effective.

In such cases, a renewable energy, such as PV Panel, has been incorporated in order to overcome these problems. [2] In an electric vehicle using a single energy source, the necessary power is transferred from the permanent source, the PV Panel for example, to the load. The permanent source must frequently supply or absorb the picks of power resulting from the accelerations and the braking. This double uses of the permanent source, as energy source and as power source, is strongly penalizing: the losses and the weight are increased and the lifetime of the energy source is reduced. [3]

One solution to this problem is the hybridizing of the source with a battery which manages the power picks. Hence the permanent source can only supply the average power which insures the vehicle’s energetic autonomy. The battery system provides power to the vehicle during periods of peak power demand such as vehicle acceleration or traveling at a high constant speed.

Fig. 1 The price for PV systems has decreased by more than 60% in the last 3 years. Fuel costs for diesel generators are constantly rising. Source: Juwi Group ASIA Pacific: Quantifying Commercial Benefits of Fuel Saver Systems
Hybrid sources allow dissociating mean power sizing from peak transient power sizing, the aim being to reduce in volume and weight. [4] [5]

In this paper a hybrid power source using PV Panel and battery supplying a load is proposed to make the system highly efficient and reliable. In a first step, a dynamic modeling of the overall system is given. Secondly, a description of the components of the proposed system is provided. Finally, simulation results in presence of DC Bus voltage changes and load resistor disturbances, using Matlab-Simulink, are presented.

II. DYNAMIC MODELING

The converter topology for the renewable hybrid system is depicted in Fig. 2.

![Fig. 2 PV/Battery hybrid system configuration](image)

A. MODELING OF PV PANEL

A photovoltaic PV generator consists of an assembly of solar cells, connections, protective parts, supports etc. Solar cells are made of semiconductor materials (usually silicon), which are especially treated to form an electric field, positive on one side (backside) and negative on the other (towards the sun). When solar energy (photons) hits the solar cell, electrons are knocked loose from the atoms in the semiconductor material, creating electron-hole pairs. If electrical conductors are then attached to the positive and negative sides, forming an electrical circuit, the electrons are captured in the form of electric current (photocurrent).

The model of the solar cell can be realized by an equivalent circuit that consists of a current source in parallel with a diode (Fig. 3).

![Fig. 3 Equivalent circuit diagram of a solar cell](image)

\[
\begin{align*}
I &= I_{PV} - I_0 \left( e^{\frac{qU}{kT} - 1} \right) \\
U &= \frac{kT}{q} \ln \left( 1 - \frac{I_{PV}}{I_0} \right)
\end{align*}
\]

Where:
- \( k \) - Boltzmann constant (1.3806 10-23 J/K);
- \( T \) – reference temperature of solar cell;
- \( q \) – elementary charge (1.6021 10-19 As);
- \( U \) – solar cell voltage (V);
- \( I_0 \) – saturation current of the diode (A);
- \( I_{PV} \) – photovoltaic current (A).

The model of solar photovoltaic power system has been developed in Matlab/Simulink as shown in Fig. 4.
B. BATTERY

The battery has the characteristics of high energy density and relatively low power density. The internal resistance is the major factor for the limited discharging and charging current capability. The internal equivalent series resistance has different values under charging and discharging operating conditions. The charging and discharging efficiency are nonlinear functions of current and state of charge (SOC). The battery can be modeled as an equivalent circuit such as a voltage source and an internal resistor. [4] [9]

B. THE MAXIMUM POWER POINT TRACKING

Even with higher efficiency, the goal remains to maximize the power from the PV system under various lighting conditions. Maximum Power Point Tracking (MPPT) is used to obtain the maximum power from this system. [11]
In order to archive the maximum power point (MPP) of the PV array, it is necessary maintain it at their optimum point operating. The MPP varies with the solar radiation and the temperature. The characteristic curves specify a unique operating point at which maximum possible power is delivered. At the MPP, the PV system operates at its highest efficiency. [12]

There are many different approaches to maximizing the power from a PV system. The method that has been adopted is the Perturb and Observe (P&O) MPPT Algorithm.

The perturbation and observation method has been widely used because its simple feedback structure and fewer measured parameters which are required. It operates by periodically perturbing (incrementing or decrementing) the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the power is increasing the perturbation will continue in the same direction in the next cycle, otherwise the perturbation direction will be reversed. The flowchart of this method is represented by Fig. 9. [13] [14]

The output voltage and current with perturb and observe technique are shown by Fig. 10 (a) and Fig. 10 (b) respectively.
IV. SIMULATION RESULTS

Fig. 11 shows the response of the system to the DC Bus voltage reference changes $V_D$ & $V_{DC}$. The DC Bus voltage tracks well the reference. A very low overshoot and no steady state error are observed.

Fig. 12 shows the battery voltage and current $V_B$ & $I_B$ response in presence of the DC Bus voltage variation. The battery supplies power to the load in the transient and in the steady state no energy is extracted since the battery current is nul.

It can be seen from Fig. 13 that the battery supplies and absorbs the transient peak power.
V. CONCLUSION

A dynamic modeling of a hybrid source system composed of a PV source and a battery source is presented. An encouraging simulation result has been obtained exhibiting also the robustness of the proposed controllers towards load resistor variations.

Many benefits can be expected from the proposed structure such that supplying and absorbing the power peaks by using a battery which also allows recovering energy. At the same time, this can reduce significantly the harmonics on the line.

REFERENCES


