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Modeling of self hybrid system for charging vehicle h2v

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Abstract — **The production of electrical energy by photovoltaic systems is highly dependent on weather conditions. Therefore it should consider storing this energy to restore it during the day. This paper deals with the design and sizing of a photovoltaic system for recharging Lithium-ion batteries of an electric vehicle with electric power produced by photovoltaic panels. In this system, the power control is performed via a DC/DC converter (DC / DC buck), with a MPPT control. The evaluation performances are according to two modes : under degraded conditions and optimal conditions.**

Keywords — Photovoltaic energy - Photovoltaic system - DC/DC Converter - MPPT control - Recharge - Electrical vehicle - Battery

I. INTRODUCTION

Faced with the environmental, economic and political context, the integration of renewable energy from energy production becomes essential. Because of these many advantages, photovoltaic energy is one of the most promising solutions. However, the integration of photovoltaic systems in power generation is limited as the periods of injections on the network are not controlled. The addition of a storage element solves this problem, but a flow management in this new type of system becomes necessary [1].

II. BATTERIES IN ELECTRIC VEHICLES

For two centuries, the emissions of certain polluting gases from human activities have intensified the natural phenomenon of the greenhouse effect and leads to warmer temperatures on Earth. This phenomenon may have important consequences for climate and global ecosystems. The international community is mobilized to limit atmospheric concentrations of greenhouse gases, with the goal of halving global emissions by 2050 [2]. To do it, several solutions have been proposed by researcher and the Electric Vehicle is one of these sulutions.

An EV is a vehicle propelled by electricity, unlike the conventional vehicles on road today which are major consumers of fossil fuels like gasoline. This electricity can be either produced outside the vehicle and stored in a battery or produced on board with the help of Fuel Cells (FC’s) [3].

Promising for reducing CO_2 emissions, the storage technology on board needs to be improved: the poor performance, limited autonomy and the excessive price of prototypes are currently a real obstacle to the development of this solution. Only a few cities can make that choice for public transportation limited to urban travel. A development which implies in particular the development of recharging points.

Electric vehicles have a very limited autonomy, much lower than combustion vehicles. In addition, the charging time of batteries takes long hours, while a few minutes suffice to fill a tank of liquid fuel in a gas station. However, even if they are not spectacular, progress on the batteries are undeniable and the advent of the industry "Lithium" is probably in this sense, a notable event. Presumably, these advances now make it possible to develop a scale other than confidential electric vehicles for specific uses characterized by low daily mileages and periods of immobilisation long enough to allow battery charging. These include vehicle fleet to use highly specific (Post, EDF, some jurisdictions, deliveries or maintenance operations in urban areas ...).

III. BATTERIES TECHNOLOGIES AND RECHARGING TOPOLOGIES

A battery is a device which converts chemical energy directly into electricity. It is an electrochemical galvanic cell or a combination of such cells which is capable of storing chemical energy. The first battery was invented by Alessandro Volta in the form of a voltaic pile in the 1800’s. Batteries can be classified as primary batteries, which once used, cannot be recharged again, and secondary batteries, which can be subjected to repeated use as they are capable of recharging by providing external electric current [3].

TABLE I
DIFFERENT BATTERIES TECHNOLOGIES

	Lead Acid	Ni-Cd	Ni-MH	Li-Ion	Li-polymer
Specific Power (W/Kg)	80-150	150-400	200-1000	500-4000	315
Cycle Life	500	1350	1350	1000	+600

Batteries are more desirable for the use in vehicles, and in particular traction batteries are most commonly used by EV manufacturers. Traction batteries include Lead Acid type, Nickel and Cadmium, Lithium-ion/polymer, Sodium and Nickel Chloride, Nickel and Zinc.
Although some storage technologies could work for several applications, the most part of the different options is not economically applicable to different functional categories. Their assessment must be done on the basis of several parameters which establish their applicability: power level (nominal, pulsed), energy storage level (at different charge and discharge rates), memory effect, power density, energy density, overall cycle efficiency, life-time (number of cycles and performance), operative characteristics, environmental impact, recycle opportunity and costs, investment costs, maintaining costs. Table I summarize some of the commonly used batteries and their properties [4-5].
Most of batteries electrical vehicle need to incorporate onboard charger allowing the recharging of the battery anywhere there is an electric outlet. However, onboard chargers are limited in power output because of size and weight restrictions dictated by vehicle design. Offboard charges are limited in power output only by the ability of the batteries to accept the charge. While a high-power offboard charger needs less time to recharge batteries, the flexibility to charge at different locations is restricted.
In this work, we are interested to study this solution an example of batteries substitution where the battery can easily changed in a couple of minutes by a recharged one.

IV. Modelling and Sizing

A. Modeling of a photovoltaic cell and Sizing of the photovoltaic source

The mathematical model associated with a cell is deduced from that of a diode PN junction. It consists on the addition the photovoltaic current I_{ph} (which is proportional to the illumination), and a term modeling the internal phenomena. The current I in the output of the cell is then written :

$$I = I_{ph} - I_{0d}\left(e^{\frac{q(U+R_s I)}{kT}} - 1\right) - \frac{U+R_s I}{R_{sh}} \qquad (1)$$

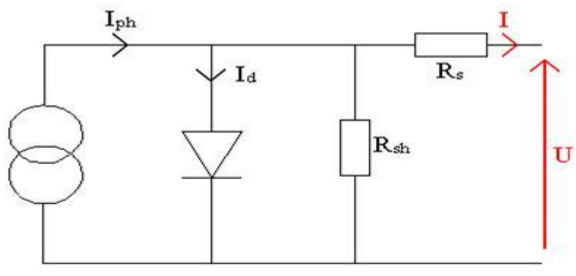


Fig. 1 : Equivalent circuit of a photovoltaic cell

The diode models the behavior of the cell in the darkness. The current generator models the current I_{ph} generated by illumination. Finally, the two resistors model the internal losses :

- Serial resistance R_s : models the ohmic losses of material.
- Shunt resistance R_{sh} : models the stray currents passing through the cell.

As the shunt resistor is much higher than the series resistance, we can neglect the current deflected in R_{sh}. We obtain :

$$I = I_{ph} - I_{0d}\left(e^{\frac{q(U+R_s I)}{kT}} - 1\right) - \frac{U}{R_{sh}}$$
(2)

The characteristics of the selected photovoltaic module are given in Table II.

TABLE II
CHARACTERISTICS OF THE PV MODULE

Max Power	Optimal Voltage	Optimal current	Efficiency
38.39W	22.2V	2.2A	10%

The sizing of the photovoltaic source is for the region of Biskra (South-East of Algiers), which receives a daily solar energy equal to 2712 Wh/m^2/day (worse case: month of December) [6].

TABLE III
SIZING OF THE PHOTOVOLTAIC SOURCE

Daily produced energy (kWh/j)	Total surface of the photovoltaic source (m^2)	Number of PV modules
26.6153	98.2	256

B. Characteristics of The Lithium-ion batteries pack

The characteristics of the Lithium-ion batteries pack are summarized in table IV.

TABLE IV
CHARACTERISTICS OF THE PACK OF LITHIUM-ION BATTERIES

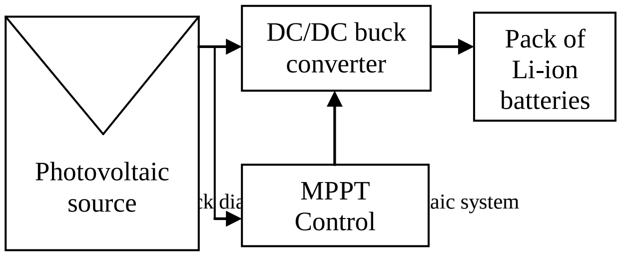
Pack voltage (V)	Rated Capacity (kWh)	Depth of discharge (%)
240	17.3	60

V. STRUCTURE OF THE PHOTOVOLTAIC SYSTEM

A. *Block diagram of the photovoltaic system*

Fig. 2 shows the block diagram of the photovoltaic system consisting of :

- A photovoltaic source, consisting of several photovoltaic modules, one module provides a power of 38.39W, a voltage of 17.45 V and a current of 2.2 A.
- A DC/DC buck converter with which is associated a MPPT control allows to operate the photovoltaic source to produce continuously the maximum of power.
- A Lithium-ion pack batteries supporting a voltage value lower than the optimal voltage of the photovoltaic source.



B. *The MPPT control*

The method of the conductance increment is chosen since it is adapted to the unstable weather conditions and does not present a risk of divergence from the maximum power point. In Fig. 3 shows the principle of the algorithm of increment of conductance.

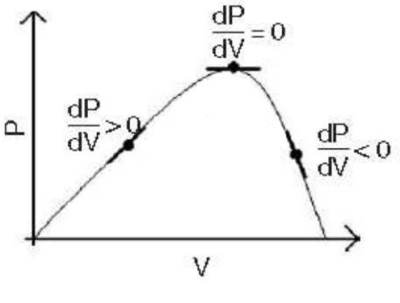


Fig.3 : Demonstration of dP / dV

Consider the notations V, I, P as variables related to the photovoltaic generator. The maximum power is achieved when :

$$\frac{dP}{dV} = 0 \quad (3)$$

To the left of this point, dP / dV is positive to the right of this point, dP / dV is negative.
Since P = I.V, differential calculus gives dP = V.dI + I.dV either in the maximum power point :

$$\frac{I}{V} + \frac{dP}{dV} = 0 \quad (4)$$

From measurements of I(t2),I(t1),V(t2),V(t1) and assuming that $dI \approx \Delta I = I(t_2)-I(t_1)$ end $dV \approx \Delta V = V(t_2)-V(t_1)$, we can calculate I/V+dI/dV and deduce the direction of maximum power point from the point of this operation. The direction of convergence is always known.

C. *Supervision system*

To regulate the process of charging of the storage element from the PV system , we used a supervision system based on the voltage of the pack and allows it to disconnect after a threshold voltage of 260V corresponding to the voltage of the pack when it is fully charged, in which case, it stops charging. For this, we consider the threshold voltage 236V corresponding to the voltage of the pack when fully discharged, recharge the battery pack begins from this threshold. The principle of the supervision system can be represented by the following diagram :

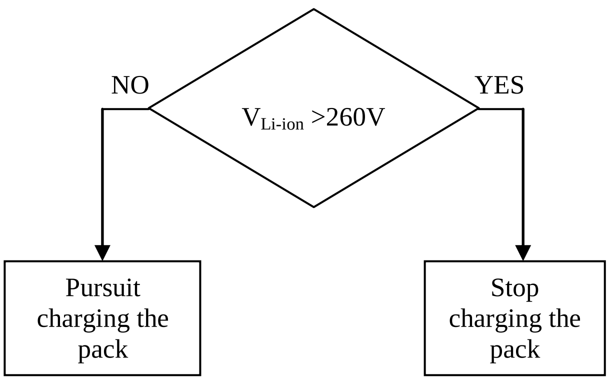


Fig. 4 : Principle of the supervision system

VI. RESULTS AND DISCUSSION

A. *Effectiveness of the method of increment of conductance*

The effectiveness of an MPPT algorithm is judged by its ability to track the maximum power but also its robustness in disturbed conditions. We conducted a series of tests with a significant variation in the sunshine for about ten seconds to test our algorithm.

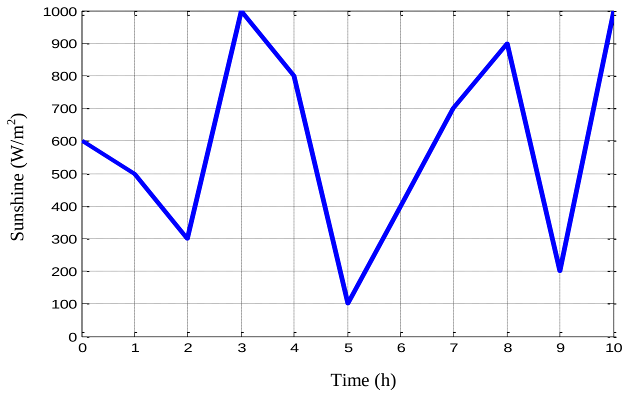


Fig. 5 : Profil of the sunshine test

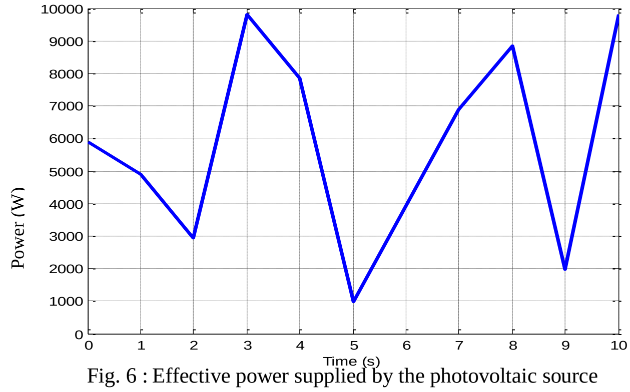


Fig. 6 : Effective power supplied by the photovoltaic source

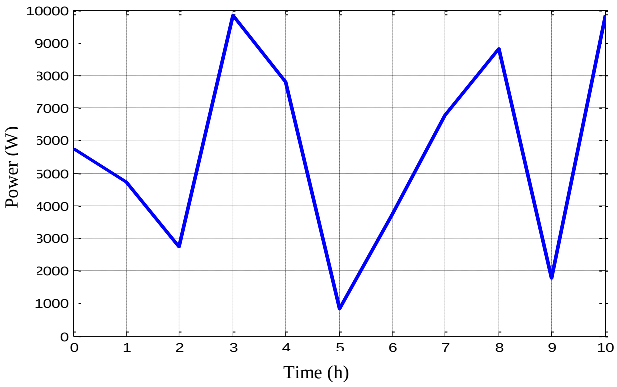


Fig. 7 : Maximum power that can be provided by the photovoltaic source

The average yield η_{mppt} is calculated from the average power supplied by the panels P_{pv_av}, and power theoretical maximum that can be provided by the panels P_{mpp} by [7]:

$$\eta_{mppt} = \frac{P_{pv\_av}}{P_{mpp}} \times 100\% \quad (5)$$

With the MPPT algorithm, we achieve an efficiency of 97.99% despite the sudden change of sunshine (from $800 W/m^2$ to $100 W/m^2$ in 1 hour).

B. Recharging of the batteries pack from the photovoltaic energy

Two profils of sunshine are concidered for the region of Biskra : profil under degraded conditions (month of December) and profil under optimal conditions (month of July). The daily profile is obtained by using measured data at regular intervals (one hour) throughout the day with clear sky.

a) Profil 1 : Under degraded conditions : month of December

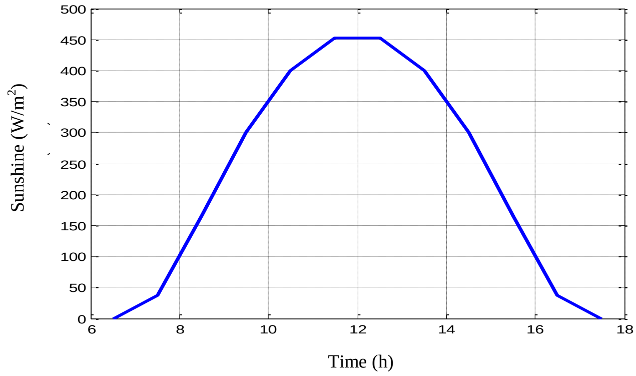


Fig. 8 : Profil of the sunshine in December in Biskra

By applying this profil, we obtain the following results in figure 9.

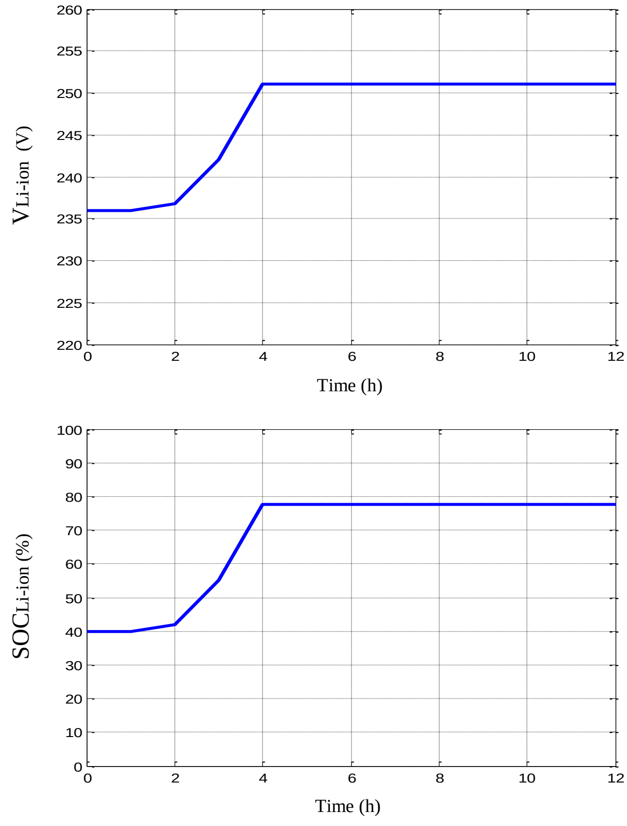


Fig. 9 : Batteries pack voltage and state of charge

Fig. 9 presents the batteries pack voltage and state of charge. The final state of charge is equal to 77.62%. Recharge time corresponding to this state of charge is 4 hours.

b) Profil 2 : Under optimal conditions : month of July

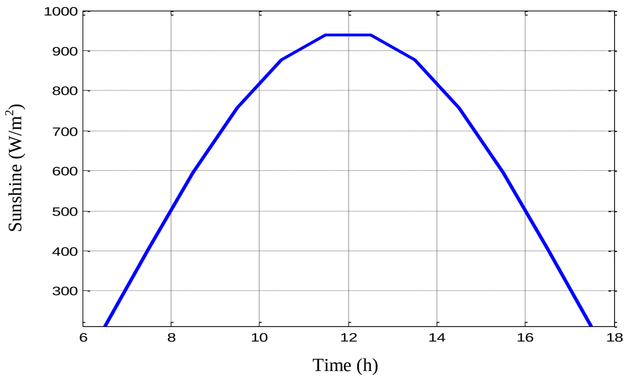


Fig. 10 : Profil of the sunshine in July in Biskra

By applying this profil, we obtain the following results in figure 11.

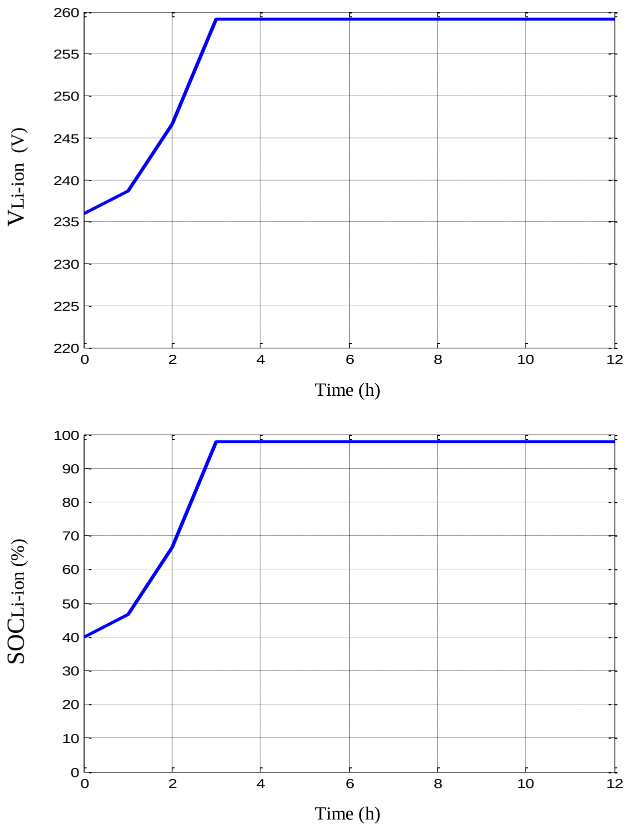


Fig. 11 : Batteries pack voltage and state of charge

Fig. 11 presents the batteries pack voltage and state of charge. The final state of charge is equal to 97.81%. Recharge time corresponding to this state of charge is 3 hours.

VII. Conclusion

In this paper, the design, sizing and performances of a photovoltaic system used to recharge Lithium-ion batteries are given. This system use a DC/DC buck converter with which is associated a MPPT control allows to operate the photovoltaic source to produce continuously the maximum of her power. It was shown that the algorithm MPPT used tracks the maximum power point even in disturbed conditions. During a day of system operation, the batteries pack is recharged at 77.62% for 4 hours (during a day of the month of December) and 97.81% for 3 hours (during a day of the month of July). From different results, we can conclude that :

- The regulation of the charging process of the storage element is provided by the supervision system,
- The model of the PV source is accurate and reflects the variation of illumination and temperature,
- The MPPT algorithm tracks the maximum power point even under disturbed conditions,
- More is sunshine, greater is state of charge of the batteries pack and less is time of recharge of this pack.

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