Towards an energy management system in solar electric vehicles

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***Abstract*— Electric vehicles (EV) are now a fertile field attracting increasing interest from researchers and manufacturers. Powered by regenerative electric power sources, this type of vehicle also offers advantages in terms of durability, CO2 balance especially with the mix of the electric and the benefit of renewable energies.**

This paper highlights a new approach to improve energy management in EV powered by solar energy (EVPSE). It aims to provide a conceptual model of the EVPSE system architecture, the definition of its components, their attributes and interactions with the charging infrastructure. Indeed, electric vehicle is a complex assembly that includes various parts like mechanical, electrical, control, pneumatic, electrochemical and management etc...

We propose in this work an energy management model developed based on a distributed parallel approach serving as a framework for simulation of strategies algorithms under constraints; taking into consideration the vehicle operating conditions. The system description is implemented on a simulation test-bed for simulating real scenarios.

The global objective of the energy management model proposed is to manage the compromises and the operating interactions between a considerable number of components: inverter, charger, converter, battery, braking system and/or driving elements and determine the optimal power balance.

A fully autonomous vehicle was developed to implement the model based on a modular electrical architecture, with a physical separation of the computer and the control panel. We simulate the vehicle in both conditions: driving state where the vehicle evolves on the road and carries out an imposed journey taking into account wind speed and slope, and then on load state where it's stationary and connected to a charging network.

Keywords*— *Solar vehicle, solar energie, microgrid, battery, inverter, energy management, MPPT;

I. Introduction

Electric vehicles can help reduce the dependencies on imported oil, help reduce the energy bills, reduce greenhouse gas emissions (1), improve air quality and reduce noise nuisance. Thanks to zero emissions at the exhaust.

In addition, electric vehicles can do more than mobility. Their batteries offer useful energy storage capacities to help regulate the electricity grid and develop renewable energies.

The commercialization of electric vehicles can be accompanied by energy services which can be economically valued and which make it possible to structure the supply of electromobility in return. To minimize its impact on the electrical network, it is essential to set up intelligent load management systems taking into account both the constraints of use and those of the network.

Electromobility is conceived as a full-fledged ecosystem that combines car manufacturers, charging operators, service providers, users, etc. It is a real sector whose economic relevance and environmental sustainability must be reflected in a systemic approach (2).

Electric Vehicles Associated with T.I.C. Can also contribute to the improvement of energy efficiency at national level by supporting charging modes coordinated with the capacities of the electricity network.

Thus, by imagining an exchange of data and information facilitated, EVs can be seen not only as vectors of mobility but also as contributors to the establishment of intelligent electrical networks.

In order to do so, it is essential to use, as much as possible, intelligent management of the load of EVs, so as to limit their impact on the network and the reinforcement needs of lines and transformer stations. Indeed, the batteries of electric vehicles offer possibilities for regulation of the electrical network, or smoothing of the tip, if they are used as energy storage. This "service" provided to the network could also be the subject of an economic valuation. Electric vehicles are thus a source of flexibility in electrical demand.

II. PROBLEM STATEMENT AND APPRACH

A. Problem statement

Solar vehicles, propelled wholly or partly by solar energy, are increasingly showing an increasing interest as a future alternative to the problems of urban mobility, especially with the technological developments in the field of photovoltaics.

Fig.1 shows a model of the electrical traction of the solar vehicle, including the photovoltaic panel as a source of electrical energy, the DC-DC converter whose function is to adapt the voltage level to the battery one, MPPT which serves to maximize the transfer of electrical energy between the panel and the battery and also acts on the control of the DC-DC converter, and finaly the battery with its management system of charge and discharge.

The mechanical part is made up of an engine with its driver, the mechanical transmission equipment and the wheels.

Depending on the state of charge of the battery determined by the SOC method (state of charge), and the availability of the energy sources: solar panel or the load point energy (DC Link).

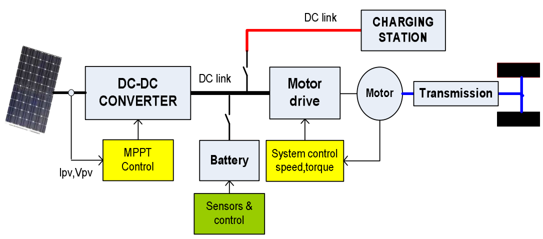

Figure 1 System description

B. Operating Modes

For the modelling approach of the energy management system we consider three operating modes namely:

1) Mode 1

This mode is active when the vehicle is moving or in parking (insulated), the electrical energy of the panels is used to charge the battery or directly to power the car's circuit, see Fig.2.

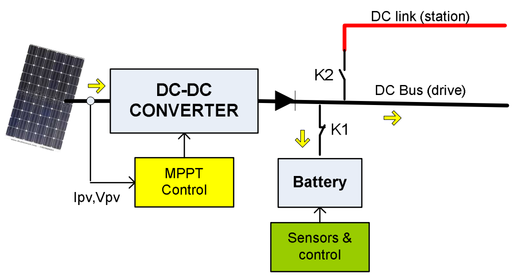

Figure 2 Operating mode 1

2) Mode 2

When the vehicle is connected to the charging station, and the battery is not full. Battery is then charged by both solar panels and the charging station which contribute to accelerate the charge process, see Fig.3.

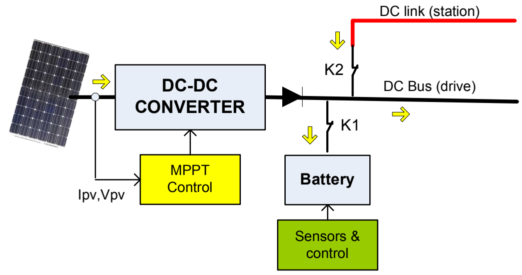

Figure 3 Operating mode 2

3) Mode 3

When the vehicle is connected to the charging station and the battery is full. The energy recovered from the solar panels of the vehicle can be used to charge the batteries of the charging station or used directly by a vehicle connected to the DC Link, see Fig.4.

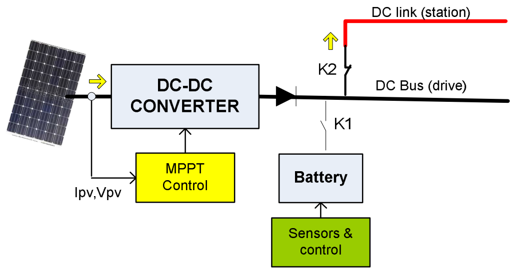

Figure 4 Operating mode 3

III. POWER MANAGEMENT SYSTEM

A. Photovoltaic battery charger

We modelled the charge of the battery as shown in fig.5 by the means of a DC-DC static converter (Boost) and a control based on the MPPT Perturb & Observe (PO) implemented on a DSP.

Based on the electrical data of the photovoltaic panel, the processor calculates the instantaneous power and decides, in relation to the old value of the stored power, the direction of the variation of the duty cycle of the DC-DC assembly so that the voltage of the panel is set to the optimum value giving the maximum power.

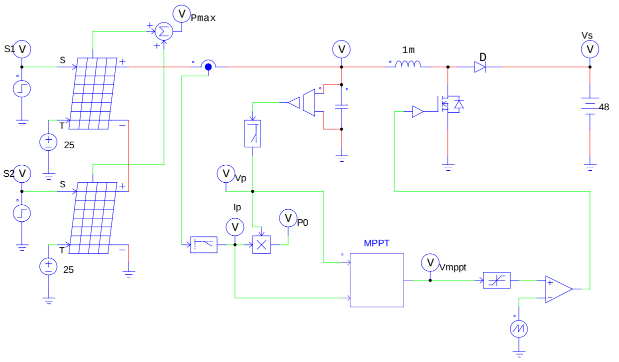

Figure 5 Battery charger electric model

1) *Photovoltaic panels*

Table 1 PV characteristics

Number of Cells Ns	36
Maximum Power Pmax	60W
Voltage at Pmax	17.1V
Current at Pmax	3.5A
Open-Circuit Voltage Voc	21.1V
Short-Circuit Current	3.8A

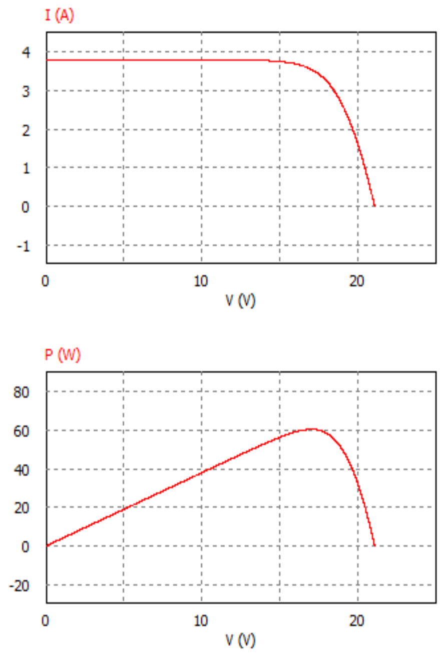

Figure 6 I-V and P-V characteristics

2) *MPPT algorithm*

Perturb and Observe (P&O) algorithm was use to track maximum power:

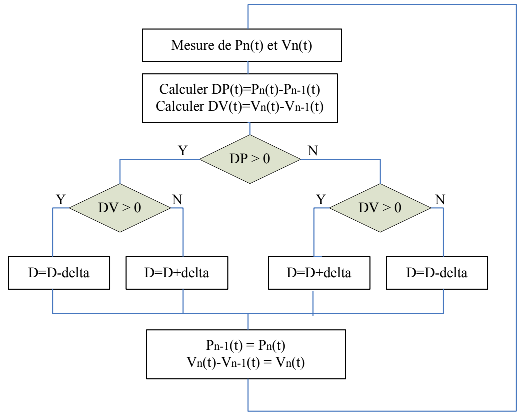

Figure 7 P&O MPPT algorithm

The simulation is performed for a panel temperature 25 °C and an abrupt change of irradiation from 1000W/m² to 500W/m².

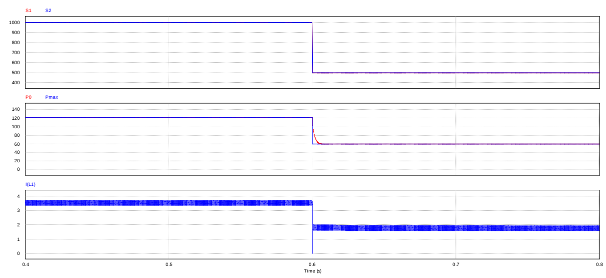

Figure 8 Graphs for a variation of the irradiation from 1000W/m² to 500W / m²

Fig.8 shows the simulation of the MPPT algorithm behaviour under different irradiation levels. Besides the DC-DC converter always operates in continuous mode with a low current ripple IL.

3) *Partial shading Behavior:*

In the case of partial shading on the photovoltaic panels mounted in series, there is a marked decrease of the extracted power (3) and appearance of hot spots on the cells.

Fig.9 shows the power decrease after a reduction of irradiation in the second panel from 1000W/m² to 500W/m² , respectively from 90W to 65W.

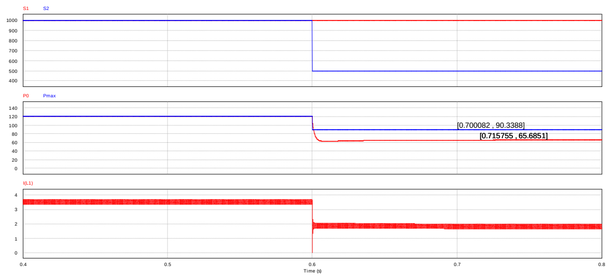

Figure 9 Partial shading simulation

We then propose the use of a DC-DC circuit with its own MPPT control circuit, for each panel. The assembly is given in Fig.10:

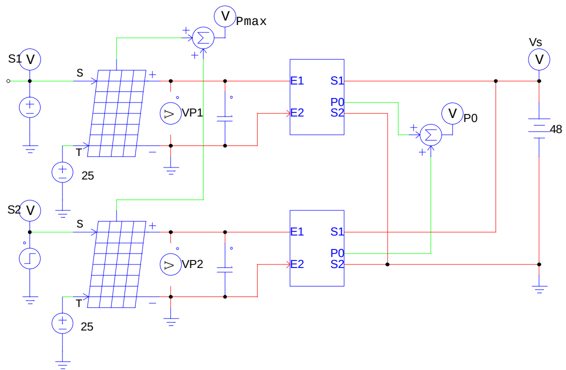

Figure 10 MPPT for each Photovoltaic Panel

B. Motor drive modelling and simulation

This part presents the model and the simulation of the permanent magnet synchronous machine and its control system. It's the traction motor of the solar vehicle with a voltage 60V and a power 3kW.

The motor is powered through a three-phase inverter that controls the current in the motor to adjust the speed at a given setpoint. The DC bus of the inverter is derived from the battery, see Fig.11.

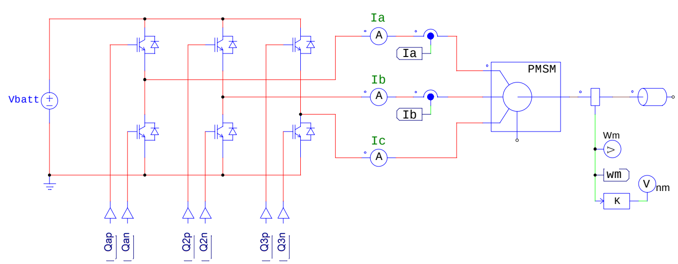

Figure 11 Motor drive model

Simulation for the following data is presented below Fig.12:

Resistant torque: 2N.m

Setpoint speed: 1000 rpm

Engine:

Stator resistance $Rs = 2.875\ \Omega$

$Ld = 0.0085$ H

$Lq = 0.0085$ H

Number of pairs of poles: 4

Moment of inertia: $J = 0008\ kg.m^2$

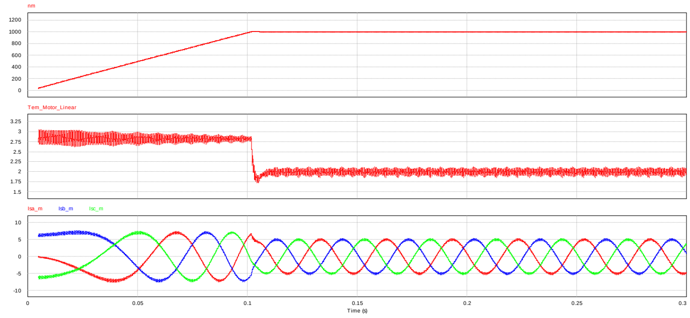

Figure 12 Motor drive simulation

C. Model implementation

The solar vehicle energy management system was implemented on a prototype based on a DSP platform (Digital Signal Processing)

Decision-making regarding the state of connections of the various components of the system is made on the basis of state detection "connected yes or no to the charging station", and the state "battery charge level".

The flowchart Fig.13 presents the algorithm for managing the different operating modes of the solar vehicle:

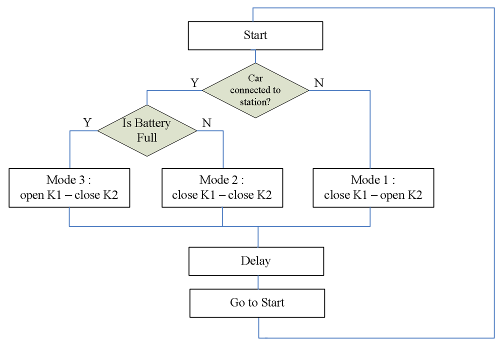

Figure 13 Flowchart of modes management

D. Experimental equipment

We present in this section some photos of the equipment under test in the laboratory: Solar car (Fig. 14), motor and drive controller (Fig. 15), DC-DC converter and DSP control board (Fig. 16).

Figure 14 - Picture of solar car

Figure 15 Motor with drive controller

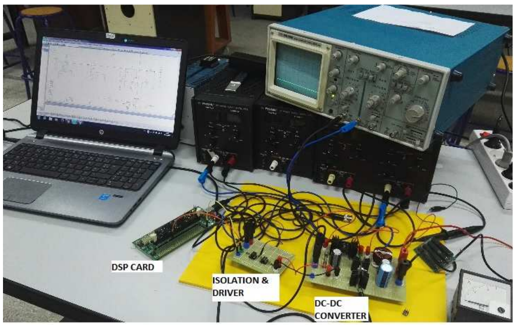

Figure 16 DC-DC converter with DSP Card

IV. CONCLUSION

In this paper a model of the management system of the electric energy of solar vehicles was proposed on the basis of the modelling and the simulation of the different components of the latter.

This model has been implemented on a DSP platform for the validation of simulation results.

The prototype will be tested on an urban solar car for validation in real conditions; this is the subject of work in progress.

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