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Control strategy for a boost converter operating as a battery charger of photovoltaic-grid system for electric vehicles charging station

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***Abstract*—This work treats numerous limitations related to the charging station performance through the PV array including the dc-dc boost converter feeding a lithium-ion battery, which is presented as a storage battery of the charging station. The aim is to specify the control strategy of the power flux in the system using multiple optimization methods such as the MPPT algorithm and the voltage control loop for the dc-dc converter. However, the integration of the grid in this platform is also considered indispensable to build an efficient electrical pattern contains all the specifications required for the electric vehicle charging station, the limited power delivered by the PV system is also recognized as an energy constraint in this approach. On the other hand, the battery technology and the appropriate algorithm of the energy management system are made an important improvement to decrease the impact of the inconvenient concerns.**

Keywords-component; Electric vehicle, charging station, dc-dc converter, maximum power point tracking, battery storage bank, incremental conductance algorithm, voltage loop control.

I. INTRODUCTION

The predictable growth of electric vehicle provides highly significant solutions for many challenges facing the planet and the humankind as equal, for instance the lack of renewable energy sources production and the extreme use of petroleum fuel which lead us to a harmful environmental consequences. Moreover, the expensive cost of implement this green investment may still the only constraint for the projects owners although the short Return On Investment (ROI) rate that encourages the use of renewable energy in the industrial field in general and in particular charging an electric vehicle via charging stations [1], besides, Researchers and companies are made the involvement of electrical resources for charging EV more sophisticated and easier for the user's vehicle. However, the integration of different sources of energy (PV, Grid, Storage battery) in one platform must be take in consideration some facts that are mainly related to the frequent inefficiency and the instability of the PV power [2], and how the grid should respond to the external exchange of power between the CS that uses PV energy as a basic source and the grid utility as a back-up plan when the solar energy is unable to get the storage system of the CS fully charged [3].

Recent papers are focused on various modes of charging an EV i.e. AC and DC mode of electrical supply [4], the major factor that allows researchers to prefer the DC choice is the short charging time it offers, and also it requires less equipment e.g. the unnecessary use of extra rectifiers. Furthermore, the storage system of the EVCS is considered as a critical unit of the whole pattern, besides, a required characteristics must be available on the battery storage bank (BSB) of the CS and the EV battery. Moreover, the supercapacitor and the Lithium-ion technology are shown convenient results i.e. less weight and wider operating temperature range [5], additionally, they have to be faster to load and to accept higher recharge rate and others important characteristics to complete the smart architecture of the EVCS. The three different sources (PV, BSB, Grid) comprising the diagram illustrated in Fig. 1 are tied to a DC bus where the voltage is maintained stable due to the optimization management algorithms that control the power flow of each energy supply [6].

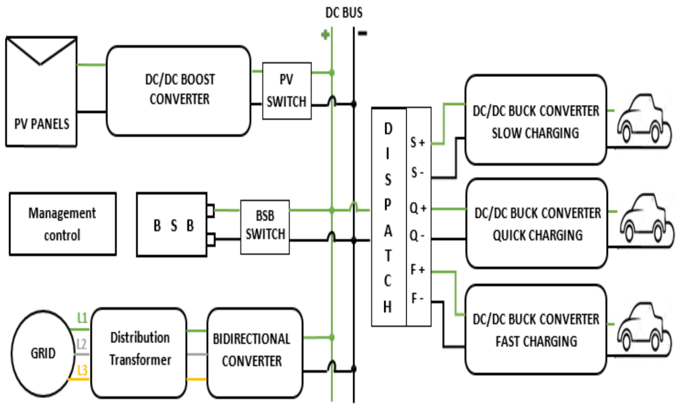

Fig. 1. Block diagram showing different scenarios of charging EV

The second part of the diagram depicts the three modes of charging an EV battery through a dc-dc buck converter that

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adapts the voltage output, besides, the converter offers a large power margin due to an accurate control system, each rated power matches a specific charging mode [7], which are described as follow: Mode-1: Slow charging (used for domestic, long-time EV parking), Mode-2: Quick charging (used for private, public location), Mode-3: Fast charging (used for public location) [8].

II. DESCRIPTION OF THE EVCS ARCHITECTURE

The integration of the photovoltaic-grid system (PVGS) on the EVCS is related to various factors that effect the CS yield as the choice of the appropriate technology of each part of the PVGS and the sophisticated design as well [9]. Furthermore, external inputs are considered important to complete the architecture, for instance the use of meteorological data, geographical position and the daily rated power of the CS [10]. However, this work describes the main structure using Matlab/Simulink software, the adopted technique is based on simulating separately each design of the general pattern that represents the EVCS [11].

A. Battery of the CS and DC Bus

The lithium-ion battery technology has become widely used in the most performant storage system that required a specific characteristics e.g. fast charging, less self discharge, working under wider operating temperature range and accepts higher recharge rate [12]. The adopted battery is charged from the PV supply through the dc dc converter and it is controlled wisely to conserve its quality in the best conditions [13], as result, a long lifetime is ensured [14]. Moreover, the electrical behaviour of the battery is expressed using three different phases illustrated in the Fig. 2. Each state has been handled using a convenient sort of control e.g. MPPT algorithm, voltage loop control.

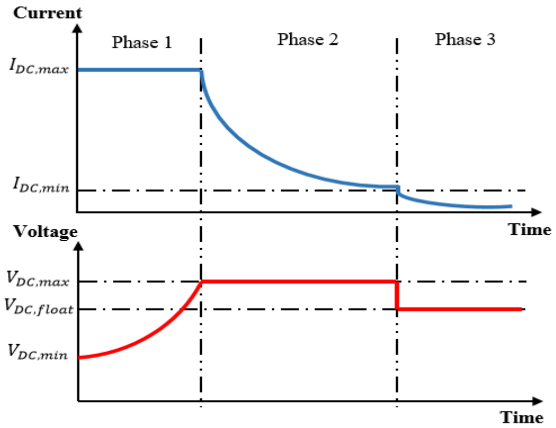

Fig. 2. Battery charging phases

B. Energy Management system

The necessity to enhance the power provided by the PV panels is ensured by the use of several MPPT techniques as the case of INC algorithm. However, the battery first phase is controlled using the adopted MPPT method by dint of the safety margin of the DC bus voltage which is betwixt the allowed minimum value V_{DCmin} and the overload maximum value V_{DCmax}, meanwhile the load current is fixed to the maximum charging current I_{DCmax} to avoid overheating and overstrain phenomena. Once V_{DC} achieve V_{DCmax}, means the battery is actually operating in the second phase where the CU is switching off the MPPT algorithm and adjusting the control voltage to the V_{DCmax} value. Nevertheless, the value of I_{DC} is kept increasing until it falls under I_{DCmin} where the third phase is reached, and in response the CU readjust the control voltage to a reduced value V_{Ref} , this reference voltage is able to avoid the deep self-discharge of the battery by generating a very small charging current [15].

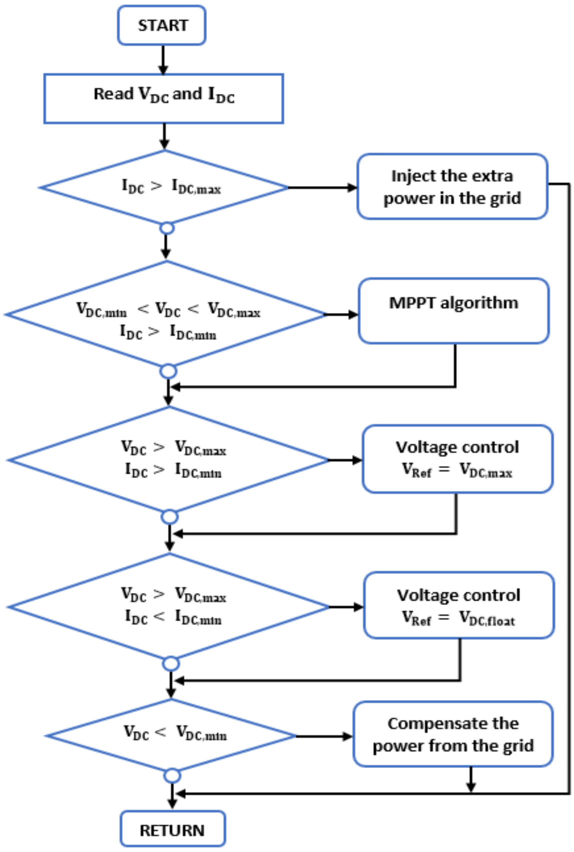

Fig. 3. Flowchart of the control strategy adopted for the charging DC bus through the BSB

The flowchart depicted in the Fig. 3 describes the main strategy of energy management system at the DC bus level, thus the algorithm requires also full data of the BSB as the maximum average of V_{DC}, I_{DC}. However, Fig. 4 shows the CS controller unit which commands the three energy sources switches.

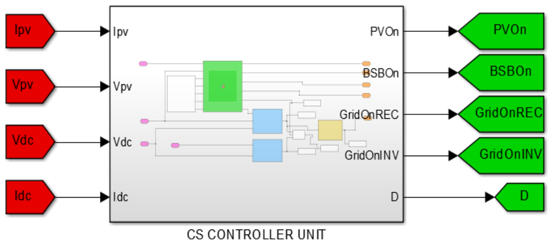

Fig. 4. CS controller unit of the PVGS

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III. SIMULATION RESULTS

The EVCS of the Fig. 7 requires a high performance storage system as the lithium-ion battery which is selected due its convenient characteristics, the accompanied settings of the battery are; 400 V /1 Ah. The DC bus storage system is charged from a PV prototype delivered 480 Wp. The validation results must match the earlier description, although, Fig. 5 depicts the meteorological scenario integrated in the PV model using signal building block in Matlab/Simulink.

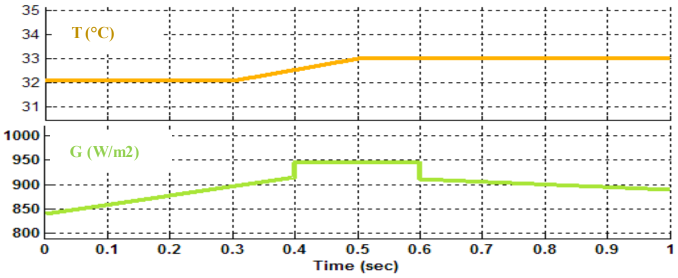

Fig. 5. Meteorological scenario of solar irradiation and temperature

The PV model contained two panels mounted in series, Fig. 6 illustrates the voltage curve of the prototype system, where the output DC bus voltage aims to maintain 400 V due the electrical characteristic of the battery and the controller unit.

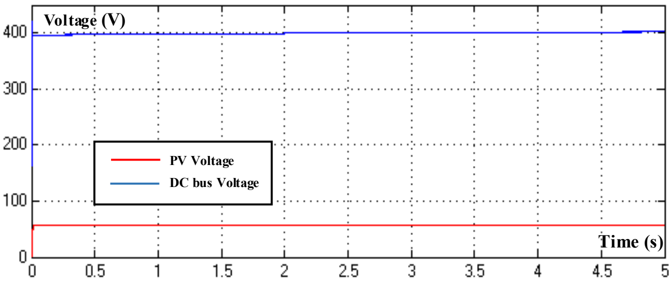

Fig. 6. DC bus voltage of the system verses time

The energy losses of the boost converter decrease the power yield of the system. Furthermore, the power curve and the current variations at the boost output are shown in the Fig. 8 and in the Fig.9 respectively which are representing the charging process of the BSB, in the meanwhile the CS controller unit is selecting and implementing the appropriate algorithm i.e. the INC MPPT or the voltage loop control.

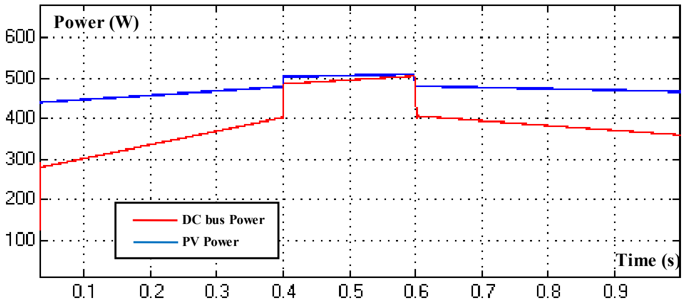

Fig. 8. DC bus power of the system verses time

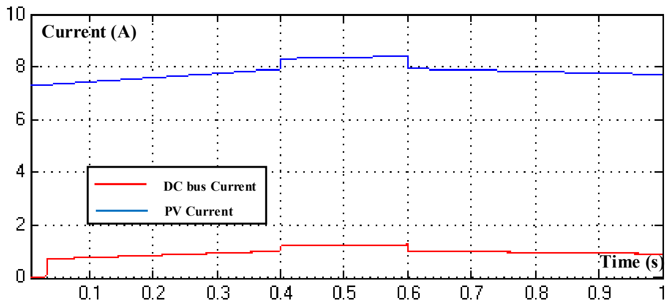

Fig. 9. DC bus current of the system verses time

The validation results of a stand-alone PV system is tested. The reaction of the grid is also exanimated with a scenario of charging the BSB from two different sources i.e. PV and Grid.

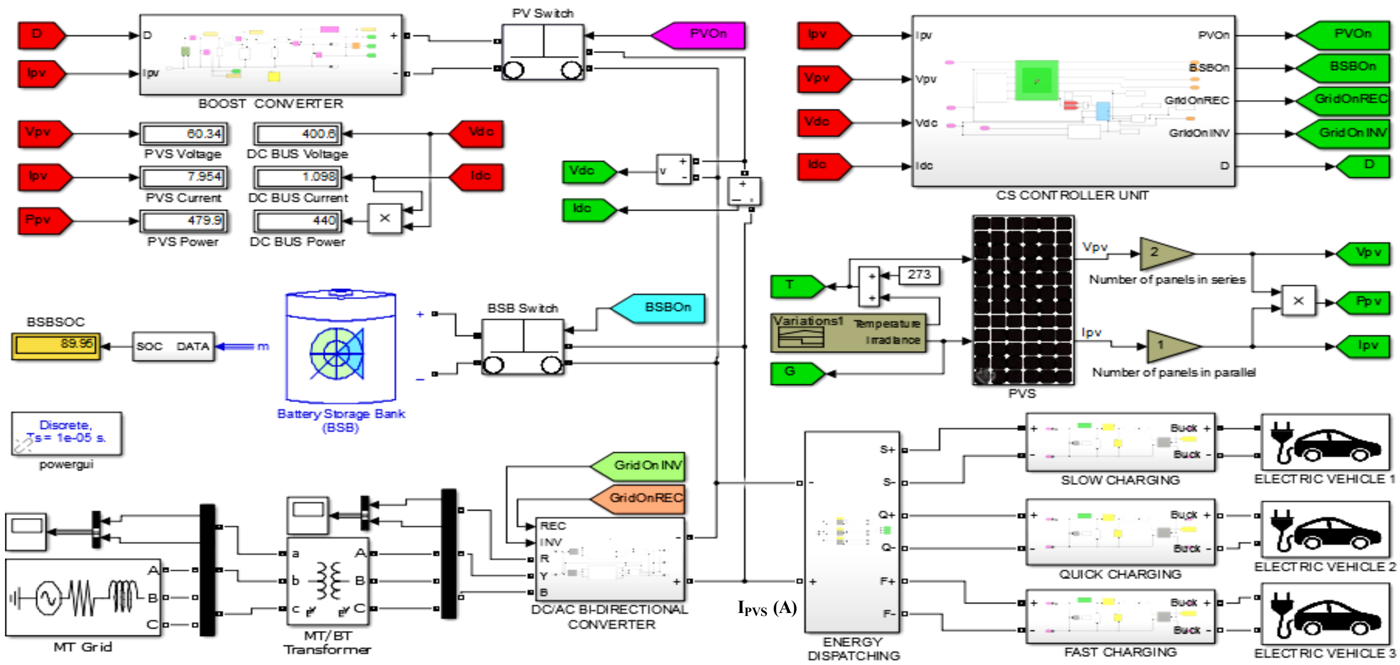

Fig. 7. PVGS for the CS Battery in Matlab/Simulink

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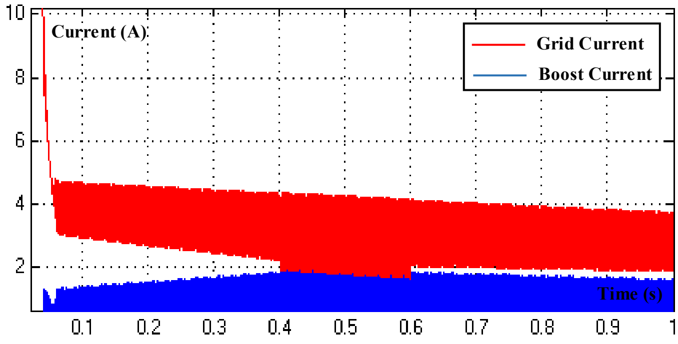

Fig. 10. Charging currents of the system verses time

The complementarity of energy between the Grid and the PV is clarified in the fig. 10, where the three switches; BSBOn, PVOn and GridOnRec are Closed ON.

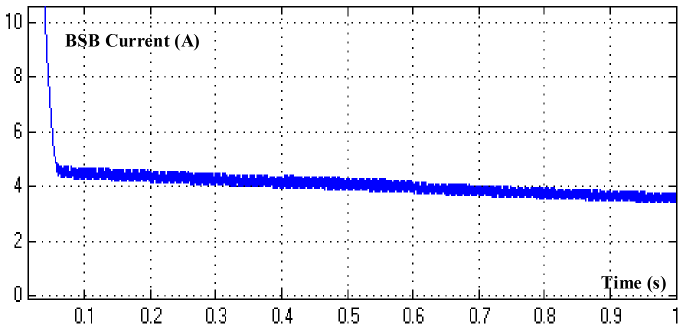

Fig. 11. BSB current of the system verses time

The BSB is under charging phase as shown the current curve in the fig. 11. Further, the current consumed by the storage system of the CS is decreased due to the increasing value of the BSBSOC.

IV. CONCLUSION

In this paper, the main strategy of maintaining the DC bus voltage value fixed is described taking into account several constraints for the CS system e.g. the extraction of maximum power from the PV panels and keeping the best lifetime yield for the charging station batteries, the intelligent algorithm contains two different sort of control i.e. MPPT method and voltage loop control which are implemented in the CS controller unit. Moreover, simulation results show constantly reactions to the input variations such as the temperature and the irradiance. This work aimed to establish a smart compromise between the three different sources of energy including the reaction of the Grid in the EVCS, besides, the technical purpose is to ensure various charging scenarios to feed an EV battery.

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