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Experimental and Simulation of Advanced Solar Powered Electric Vehicle Charging Station

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***Abstract* - The main aim of this simulation is to design such a charging station which is coupled with solar energy for urban cities. Simplified EV load models are developed by considering different commercial EV model which is available in the market. This article presents the design aspects and practical implementation of the modern solar-assisted level-2 electric vehicle charging station which is controlled by a Type-1 vehicle connector. The designed model is developed in MATLAB/Simulink environment, the circuit operations examined and its methodological model is derived to study the parametric design features. Furthermore, the complete hardware setup has developed to test the performance of the power factor correction under the steady-state condition with respect to variation in load for the input of 3 kW, 230 Vrms at 1-phase, 50 Hz rated, and to produce a 48 V buck converter dc output. The PV system modelling depends on the components of the block that comprises the connection under a PV framework, i.e., solar panel, MPPT controller, charge controller, battery, solar hybrid inverter, 5-level PFC rectifier, buck converter, EV charger, and EV battery as a load.**

Keywords: Converter topology, electric vehicle (EV), EV charging infrastructure, solar photovoltaic (PV), solar panel, MPPT controller PFC rectifier, BUCK converter PI controlled, EV battery.

I. INTRODUCTION

In electric vehicles (EVs), batteries are mostly used as a main energy source in many applications. Interest in batteries for EVs can be traced back to the mid-19th century when the first EV came into existence. Today, since EVs can reduce gasoline consumption up to 75%, EV batteries have gained renewed attention in the vehicle market. Boston Consulting Group has reported that, by 2020, the global market for advanced batteries for electric vehicles is expected to reach US $25 billion, which is three times the size of today's entire lithium-ion battery market for consumer electronics EV and HEV'S are subject to battery technology management system for the battery. So a battery management system (BMS), is the connector between the battery and the vehicle, it plays a very important role in improving battery performance and optimizing vehicle operation in a safe manner. Pure-electric and plug-in hybrid electric vehicles, hereafter denoted as Plug-in Electric Vehicles (PEVs), are more and more running on the roads. Therefore environmental pollution and energy consumption of the thermal vehicles. PEV batteries are recharged from the utility by help of either a house connection or a recharging bollard.

Different types of Electric Vehicles (EVs) are being developed as an option to the Internal Combustion Engines (ICE) vehicles, for example, Battery Electric Vehicles (BEV), Plug-in Hybrid Electric Vehicles (PHEV), and Fuel Cell Electric Vehicles (FCEV) ,in its different configurations. EVs are more popular, as demonstrated by the numerous vehicles recently made available in the market by almost all automakers. The main energy storage systems of these vehicles are the electrochemical batteries, the ultra capacitors and the full-cells. However, taking into account nowadays limits of energy storage of those technologies, the vehicles have limited range autonomy. Different energy storage systems configurations can be implemented; however, the electrochemical batteries still are the most used technology to store energy. Nevertheless, they are usually used in conjunction with ultra capacitors to store energy during transient moments, as during the vehicle regenerative braking. Actually, the ultra capacitors are used in this way to receive a significant amount of energy in a short time, and to provide this energy to the next acceleration, or to help charging the batteries.

The electrical power grids were not designed for this new type of load, which corresponds to the batteries charging systems of EVs, therefore the impact caused by the proliferation of EVs cannot be neglected. The challenge is to rebuild the electrical power grids, as early as possible, as "smarter" as possible, and the most environmentally friendly as possible. To achieve these targets arise the Smart Grids, which are not used as a single technology or device, but rather as a vision of a distributed electrical system, supported by reference technologies, as integrated communications, Power

Electronics devices, Energy Storage Systems (ESS), and Advanced Metering Infrastructures (AMI). The Smart Grids intend to reduce the energy costs, and simultaneously to achieve a sustainable balance between production and consumption, increasing the reliability of the power grids and the power quality of the electrical energy delivered to the loads.

II. LITERATURE SURVEY

In [1], the design and practical implementation of the modern solar-assisted level-2 electric vehicle charging station is controlled by a Type-1 vehicle connector is proposed. The designed model is developed in MATLAB/Simulink environment, the circuit operation is examined and its methodological model is derived to study the parametric design features. The complete hardware setup has developed to test the performance of the power factor correction under the steady-state condition with respect to variation in load for the input of 3 kW, 230 Vrms at 1-phase, 50 Hz rated, and to produce a 48 V buck converter dc output. The 6.4 kW solar photovoltaic (PV) charging station, installed at the Centre of Advanced Research in Electrified Transportation building parking area in Aligarh Muslim University campus. As, the controller circuit is simulated in PROTEUS software and a prototype model is tested in the lab. The study is performed on a 10 kWh lithium-ion battery pack on a bright sunny day at standard test condition of the solar panel.

The battery management system (BMS) is a critical component of electric and hybrid electric vehicles. The purpose of the BMS is to guarantee safe and reliable battery operation. To maintain the safety and reliability of the battery, state monitoring and evaluation, charge control, and cell balancing are functionalities that have been implemented in BMS. As an electrochemical product, a battery acts differently under different operational and environmental conditions. The uncertainty of a battery's performance poses a challenge to the implementation of these functions. Paper [2] addresses concerns for current BMSs. State evaluation of a battery, including state of charge, state of health, and state of life, is a critical task for a BMS. Through reviewing the latest methodologies for the state evaluation of batteries, the future challenges for BMSs are presented and possible solutions are proposed as well.

The battery the executives' framework (BMS) is a basic part of electric and half and half electric vehicles. The reason for the BMS is to ensure protected and solid battery activity. To keep up with the security and dependability of the battery, state checking and assessment, charge control, and cell adjusting are functionalities that have been executed in BMS. As an electrochemical item, a battery acts diversely under various functional and natural conditions. The vulnerability of a battery's exhibition represents a test to the execution of these capacities. Paper [2] addresses worries for current BMSs. State assessment of a battery, including condition of charge, condition of wellbeing, and condition of life, is a basic undertaking for a BMS. Through auditing the most recent systems for the state assessment of batteries, the future difficulties for BMSs are introduced and potential arrangements are proposed also.

The main aim of [3] is to charge our battery smartly by using electric supply as well as solar energy for electric vehicle. In this paper is to charge our battery smartly and also discharger it properly without fail to our battery and charging circuit. For proper charging we are using balancing method and for charging of this battery we are using three different modes each mode has its own benefits. Battery energy storage effectively stabilizes the electric grid and aids renewable integration by balancing supply. The importance of such storage is specially crucial in more populated urban areas, where traditional storage techniques like pumped hydroelectric energy storage and compressed-air energy storage are not feasible [4].

Paper [5] presents a Hierarchal Cascaded Multilevel Converter (HCMC) for continuous uniform SOC operation. The proposed HCMC has a hybrid structure of half-bridge converters and H-bridge converters and the voltage can be cascaded to reach a high level at two hierarchical levels: the half-bridge level and H-bridge level. The converter has the features of high voltage and high power application capability and modular design for cost reduction and reliability improvement. Continuous uniform SOC operation can be achieved via the proposed converter without adding additional balancing circuits. Simulation studies have been carried out to verify the performance of the proposed converter.

Paper [6] analyzed the characteristics, advantages and disadvantages of cell balancing methods. Table 1 compared passive balancing methods and active balancing methods based on their advantages and disadvantages. A passive cell balancing method normally uses a low current. Therefore, its energy transmission efficiency is low because of its low heat dissipation although it requires long balancing time. A passive method is a suitable technique for portable tools and low power systems. An active balancing method has higher energy transmission efficiency and shorter balancing time than a passive cell balancer. Therefore, an active cell balancing method is a suitable technique for uninterruptible power supply (UPS), energy storage system (ESS) and electrical vehicle (EV).

Mouli et al [7] investigated the possibility of charging battery electric vehicles at workplace in Netherlands using solar energy. Data from the dutch meteorological institute is used to determine the optimal orientation of pv panels for maximum energy yield in the Netherlands. The seasonal and diurnal variation in solar insolation is analysed to determine the energy availability for ev charging and the necessity for grid connection. Due to relatively low solar insolation in Netherlands, it has been determined that the power rating of the pv array can be oversized by 30% with respect to power rating of the converter. Various dynamic ev charging profiles are compared with an aim to minimize the grid dependency and to maximize the usage of solar power to directly charge the ev.

III. PROPOSED SYSTEM

The main aim of this paper is to analyze the potential for zero carbon car travel by exploring whether: Zero carbon personal car travel is technically possible and affordable, and can be achieved in the next five years; and Zero carbon personal car travel compares to present transport systems, when considered their cost, co-benefits, attractiveness and convenience.

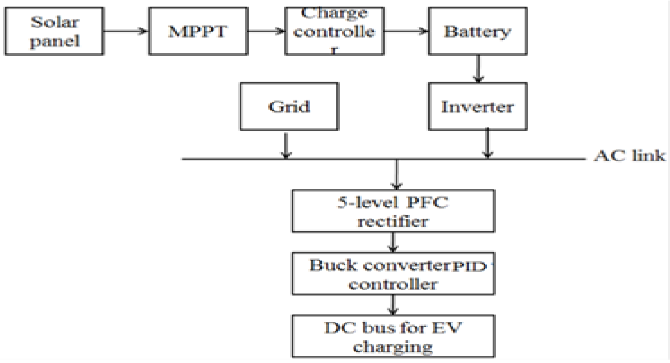

Figure 1: Architecture of proposed system

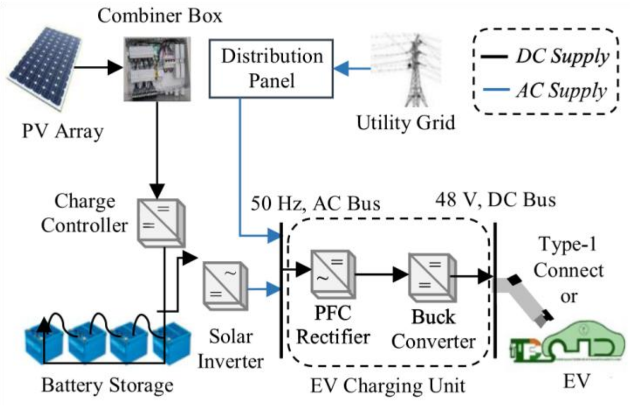

Figure 2: Diagram showing the block elements of the SPVCS

The work implies to break down the potential for zero carbon vehicle travel by investigating whether: Zero carbon individual vehicle travel is more conceivable and reasonable, and can be completed the following 5 years ; and Zero carbon individual vehicle head out visualizes well to introduce transport frameworks, by considering their expense, accommodation, engaging quality and co-benefits. Fig. 1 Diagrams shows the square schematics of the proposed charging framework. The charging station is given from two sources utilized for re-energizing the vehicles left under a shed, viz., the normal utility lattice power and sun oriented PV-based power. Hence, the charging station supplies the sun based capacity to the vehicles coming for charging by using sunlight based energy during the day time and the regular framework power in the night hours.

The PV system modelling depends on the components of the block that comprises the connection under a PV framework, i.e., solar panel, MPPT controller, charge controller, battery, solar hybrid inverter, 5-level PFC rectifier, buck converter, EV charger, and EV battery as a load. Power Factor Correction (PFC) shapes the input current of the power supply to be in synchronization with the mains voltage, in order to maximize the real power drawn from the mains. In a perfect PFC circuit, the input current follows the input voltage as a pure resistor, without any input current harmonics.

IV. DESIGN OF ELECTRIC VEHICLES CHARGING STATION

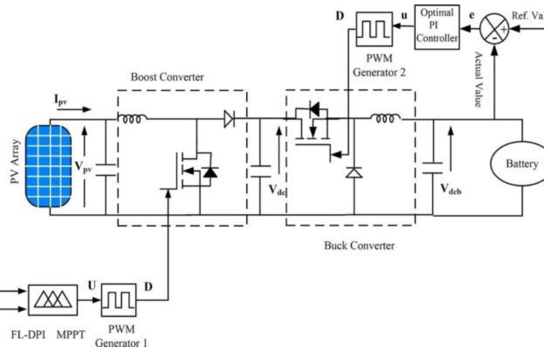

Figure 3: Circuit Design for EV battery

1. Solar energy

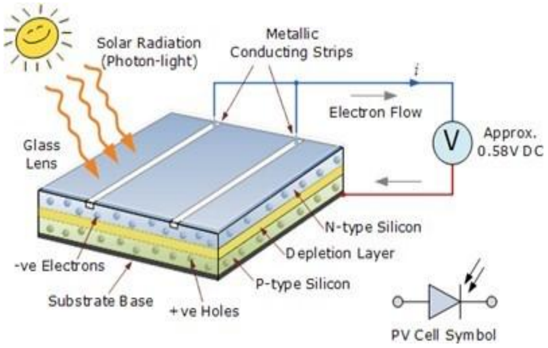

Figure 4(A): Solar power from sun

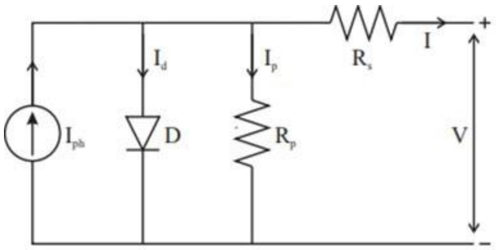

Figure 4(B): Single Diode Model

The PV cell converts the solar energy into the electrical energy. The energy conversion process of the PV module may be realized electrically by using a single diode or two diode equivalent models. The single diode model as shown in 3.Fig. below has been considered for the simulation in the presented work, because it is easier to implement and has low complexity when compared to the two-diode model.

At the output terminals of PV module, the current I may be expressed by Eq. (1).

$$I = Iph - Id - Ips \quad \ldots\ldots (1)$$

Where Id and Ips in (A) are the currents flowing through diode shunt resistance. The current due to incident photon energy Iph in (A) is given by Eq. (2).

$$Iph = (I_{sc,n} + K_1 dT)\,\frac{G}{Gn} \quad \ldots.. (2)$$

Isc, n is the short circuit current at nominal conditions of 1000 (W·m−2) and 25 (◦C). KI is the short circuit current temperature coefficient. The dT, expressed as dT = T −Tn, is the difference between the operating temperature T and nominal temperature Tn in (K). G and Gn in (W·m−2) are the irradiations at the normal operating condition and nominal condition. The current flowing through the diode is expressed as in Eq. (3):

$$I_d = I_0\left[exp\left(\frac{V+IRs}{V_t a}\right) - 1\right] \ldots.. (3)$$

I0 in (A) is the diode reverse saturation current and the V in (V) is the output voltage of PV module. The diode ideality factor will be represented by a and its value lies in the range of 1 to 2. RS in (Ω) is the series resistance of the PV module. The thermal voltage Vt in (V) of the PV module is given by Eq. (4):

$$Vt = \frac{NSkT}{q} \quad \ldots.. (4)$$

Where NS represents the number of series cells in a PV module. k is the Boltzmann constant (1.3806503 · 10−23 J·K−1) and q is the charge of the electron (1.60217646·10−19 C). The I0 is expressed as in Eq. (5):

$$I_0 = I_{0,n}\left(\frac{Tn}{T}\right) exp\left[\frac{qEg}{ak}\left(\frac{1}{Tn} - \frac{1}{T}\right)\right] \ldots.. (5)$$

Eg in (V) stands for the bandgap energy of the p-n junction material and its value is 1.12 eV for polycrystalline silicon at 25 ◦C. I0,n in (A) is the diode reverse saturation current and is expressed as in Eq. (6):

$$I_{0,n} = \frac{I_{sc,n}}{exp\left(\frac{V_{oc,n}}{aV_{t,n}}\right) - 1} \quad \ldots.. (6)$$

Voc, n and Vt, n in (V) are the open circuit voltage and thermal voltage at nominal conditions. The current in shunt resistance is represented as in Eq. (7):

$$Ips = \frac{V + IRS}{Rp} \quad \ldots. (7)$$

2. MPPT protocol

Maximum Power Point Tracking (MPPT) methods are used in photovoltaic (PV) system to continually maximize the PV array output power which generally depends on solar radiation and cell temperature. MPPT methods can be roughly classified into two categories: there are conventional methods, like the Perturbation and Observation (P&O) method and the Incremental Conductance (IncCond) method and advanced methods, such as, fuzzy logic (FL) based MPPT method. This paper presents a survey of these methods in order to analyse, simulate, and evaluate a PV power supply system under varying meteorological conditions. Simulation results, obtained using MATLAB/Simulink, show that static and dynamic performances of fuzzy MPPT controller are better than those of conventional techniques based controller. 3. BUCK converter by using PI controlled.

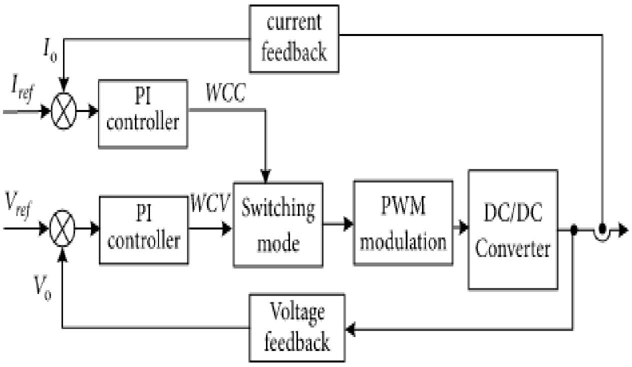

Figure 5: BUCK converter by using PI controlled

Constant current and constant voltage switching charging control method is as shown in Figure 4. In the constant voltage stage, the output voltage Vo is compared with the reference voltage Vref. The error is obtained by the PI controller and the modulation signal on simulation is obtained. Similarly, the modulation signal in MATLAB can be obtained.

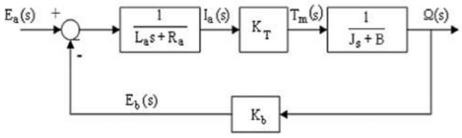

Figure 6: PI controller

A variation of Proportional Integral Derivative (PID) control is to use only the proportional and integral terms as PI control. The PI controller is the most popular variation, even more than full PID controllers. The value of the controller output u(t)u(t) is fed into the system as the manipulated variable input.

$$e(t) = SP - PV$$

$$u(t) = u_{bias} + K_c\, e(t) + \frac{K_c}{\tau_I}\int_0^t e(t)dt \qquad \text{….. (1)}$$

The ubias term is a constant that is typically set to the value of u(t)u(t) when the controller is first switched from manual to automatic mode. This gives “bump less” transfer if the error is zero when the controller is turned on. The two tuning values for a PI controller are the controller gain, KcKc and the integral time constant τIτI. The value of KcKc is a multiplier on the proportional error and integral term and a higher value makes the controller more aggressive at responding to errors away from the set point. The set point (SP) is the target value and process variable (PV) is the measured value that may deviate from the desired value. The error from the set point is the difference between the SP and PV and is defined as e(t)=SP−PV.

3. PFC rectifier

A low power factor is caused by the presence of displacement or distortion in the signal. The negative effect of displacement on the power factor is relatively simple to solve, because capacitors drag the phase forward, while inductors drive it back. If a system’s current wave is lagging behind the voltage, you can simply add a capacitor with the right impedance to the circuit, and the current wave’s phase will be pulled forward until it is in phase with the voltage (Figure 6).

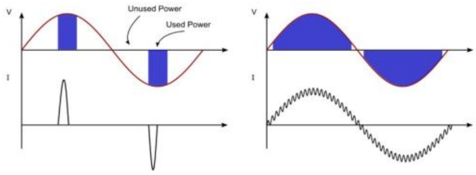

Figure 7: Low PF Power Transmission with No PFC (Left) and Power Transmission with Corrected Power Factor and PFC (Right)

4. Result and MATLAB simulation

MATLAB Simulation of "Design and Simulation of an Advanced Solar-Powered Electric Vehicle Charging Station" is shown in fig 7. It consists of charge controller, inverter, rectifier, PI controller and distribution panel, respective results of this part is explained in next sections.

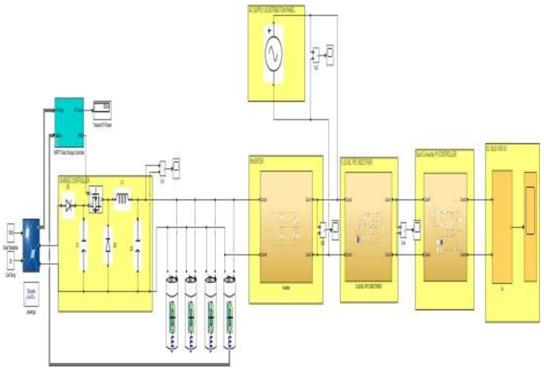

Figure 7: MATLAB simulation

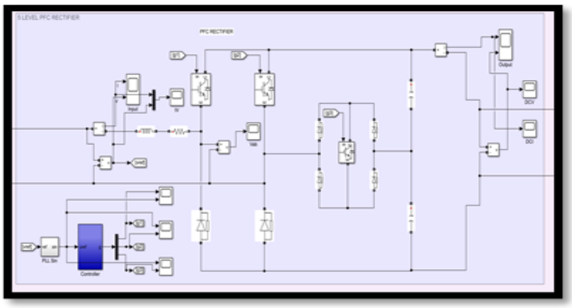

Figure 8: 5 Level PFC Rectifier

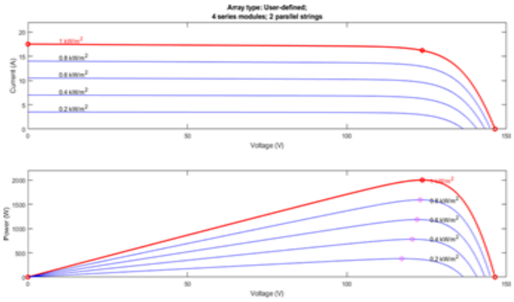

Figure 9: SOLAR Panel input

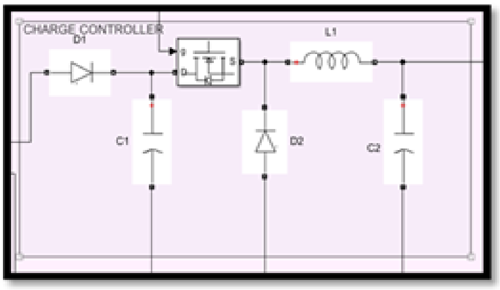

Figure 10: Charge Controller

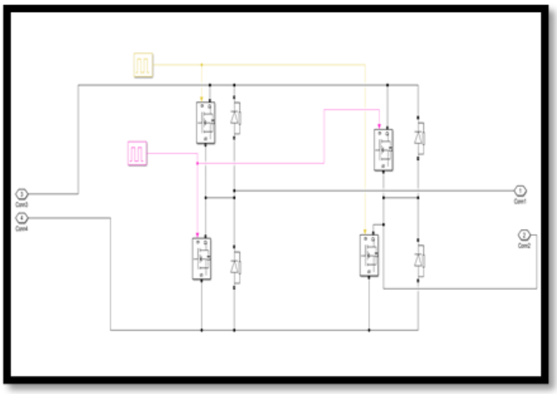

Figure 12: Inverter

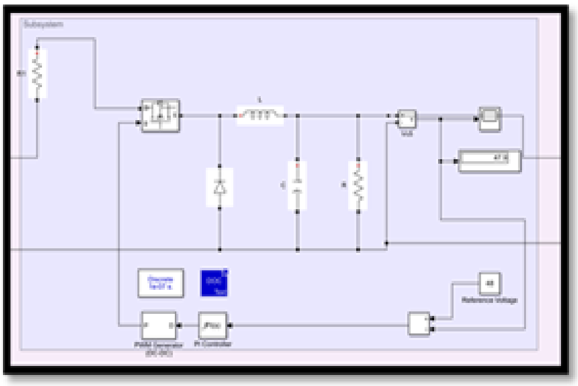

Figure 13: Subsystem

V. RESULTS

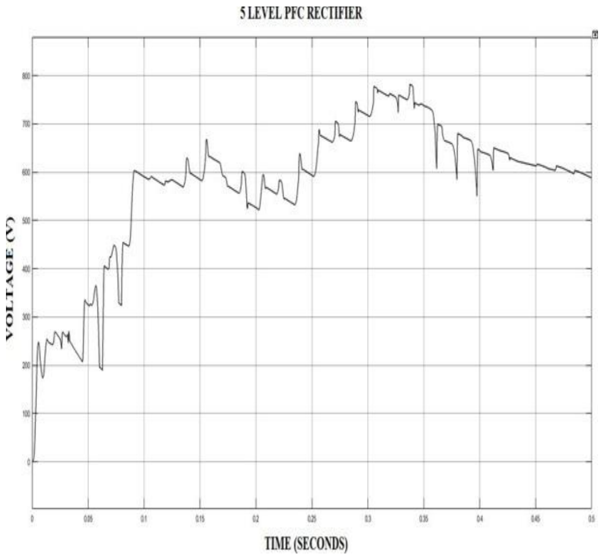

Figure 14: Five level PFC rectifier output

Output voltage of 5-level PFC rectifier is given in fig 14. High power factor or PFC rectifiers are one of the mostly used equipment in the industries. The main concerns of such converters are the unity power factor operation and low harmonic distortion of the input AC waveforms that can be ensured by generating a DC voltage higher than the grid peak voltage amplitude, which makes use of switching devices inevitable. A cascaded PI controller has been designed to regulate the output DC voltage and to ensure the unity power factor mode of the input AC voltage.

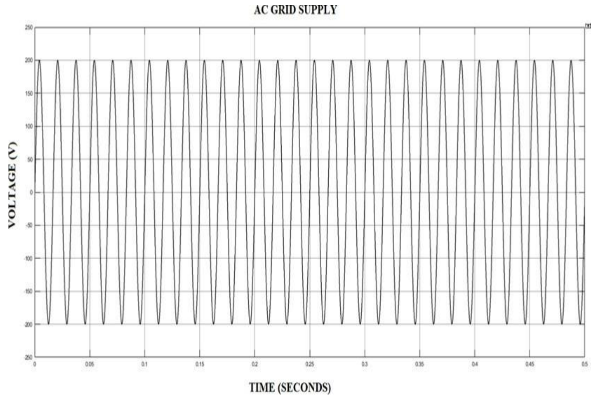

Figure 15: AC grid supply

The voltage and current output of solar panel showed changing of current and power with respect to change in voltage. We have used solar panel of 4 series modules with 2 parallel strings for simulation.

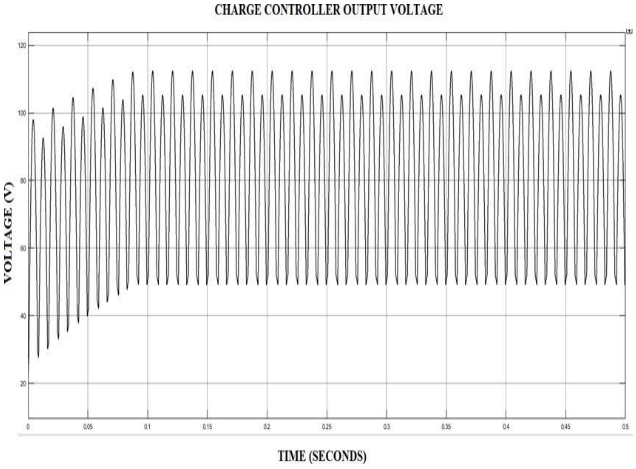

Figure 16: Charge controller output voltage

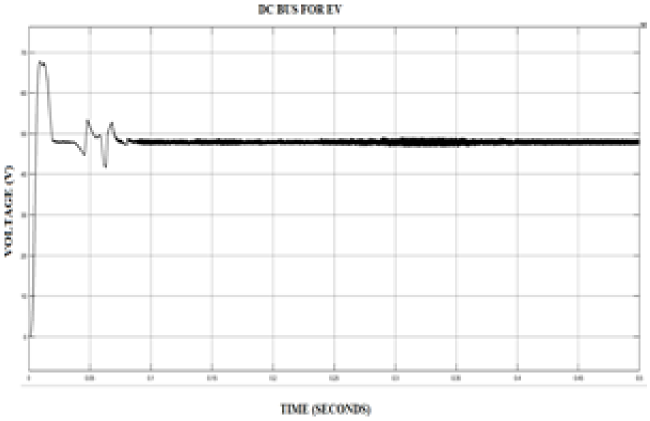

Figure 17: DC Bus for EV

Hardware Setup

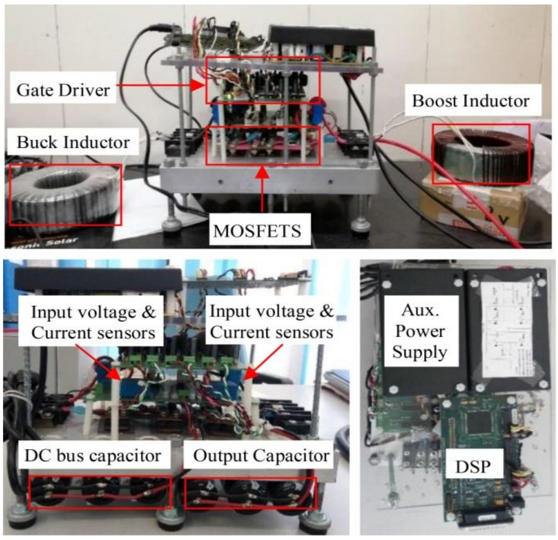

Figure 9: Hardware setup and components of the battery charger circuit

B. Operating Sequence of the PWM-Based Vehicle Charging Controller

The charging sequence and its related system activities are specified by the CCS protocol. Light emitting diode (LED) indicators viewed easily from a distant location could make the owner to determine the EVSE status. Hence, through these colored indicators, the following mentioned states of charging can convey easily (see Table II):

1) The charging station is active, i.e., ac supply is available;
2) The connector is connected to the vehicle, i.e., not charging but connected mechanically;
3) Charging starts, i.e. in progress through electrical connection;
4) Fault or alarm condition.

PWM-Based Charging Control Strategy Based on the CCS Standard [21]

Total Resistance between CP-PE	Open circuit	2700 ohm (Ω)	880 ohm (Ω)	240 ohm (Ω)		
Resistors R2 + R3 2740 Ω	-	- 2740 Ω	1300 Ω 2740 Ω	270 Ω 2740 Ω		
Voltage Measured: CP PE	+12 V	+9 V ±1 V	+6 V ±1 V	+3 V ±1 V	0 V	-12 V
State of charging	State A	State B	State C	State D	State E	State F
Charging status	standby	Vehicle detected	Ready (charging)	With ventilation	No power	Error

The converter tracks the input voltage, so the output current looks like a sine wave with a frequency of 50Hz. However, this current waveform still looks very different from a pure sinusoid, so it will logically have a large number of harmonic components. Because these harmonic components are multiples of the switching frequency, which is much higher (50kHz to 100kHz) than the 50Hz fundamental, they will be very effectively filtered out. This significantly increases the power factor, which is why some switching power supplies reach PF values of up to 0.99.

PFC techniques are broadly divided into passive (static) PFC, partial-switching PFC, and active (switching) PFC. Passive (static) PFC inserts a reactor in series with a power supply. Depending on the capacity of the power supply, a large reactor is required. Therefore, passive PFC is commonly used for low-capacity power supplies. Partial switching PFC is widely used in combination with a voltage doublers rectifier for the power supplies of 100-VAC inverter air conditioners and other home appliances.

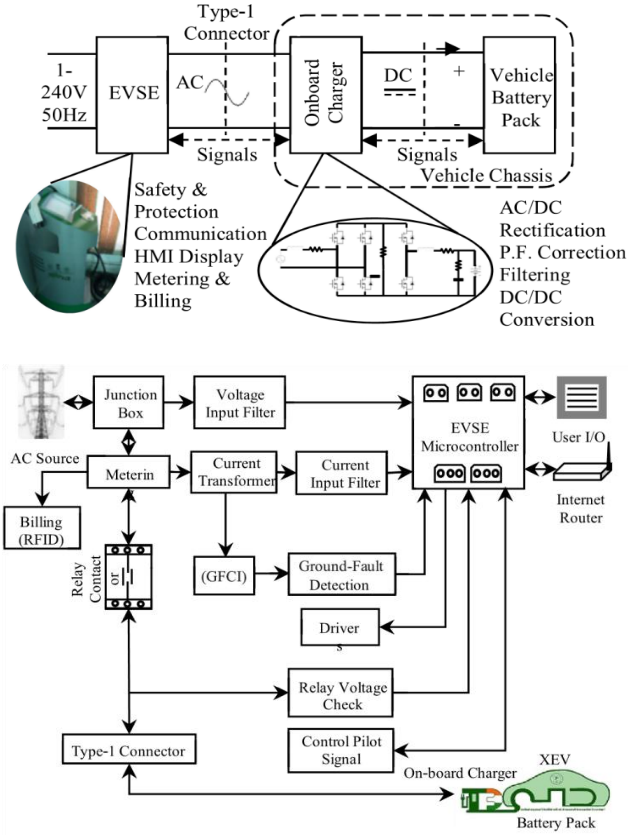

Figure 8: Vehicle charging control architecture block schematic

Fig. 5 shows the charging controller circuit schematics. Various functions are performed through the EVSE by using the relays of high power rating in the circuit. For safely operating the relay, a driver with a suitable protection circuit should be applied [20] as the following:

1) An over current relay (solid state type) for short circuit and overload protection. An electronic contactor switch for latching-up the connector with the supply.
2) A controller circuitry which interfaces the on board charger and provides line-to-ground fault protection (see ground fault circuit interrupter (GFCI) in Fig. 5).
3) Displays and indicators on the peripheral to show the alarm status and help the users to understand the working sequence.
4) Connecting cable from the EVSE to the onboard receptacle in the vehicle chassis.
5) A female connector (conductive type) to plug in to the male counterpart on the vehicle.

A. Modelling and Simulation of Controller Circuit

The communication and signalling circuit is simulated in PROTEUS software based on Arduino Nano, we can use any microcontroller for the PWM, the reason for using Arduino is that it is very versatile and easy to program When we give run command to the software, the circuit simulated based on Arduino coding accordingly as follows Table III depicts the sequence of states depending on the charging condition of Table II, and Fig. 13 shows only blinking LED state (i.e., charging state).

B. Lab Prototype Model

The prototype hardware setup in the lab sides Described here. The results obtained from PROTEUS simulation and a consecutive hardware implementation show that the proposed controller can detect all six states as required for proper operation of the charger.

The experimental setup is developed in the EV Hardware In-the-Loop Lab established at CARET in AMU campus.

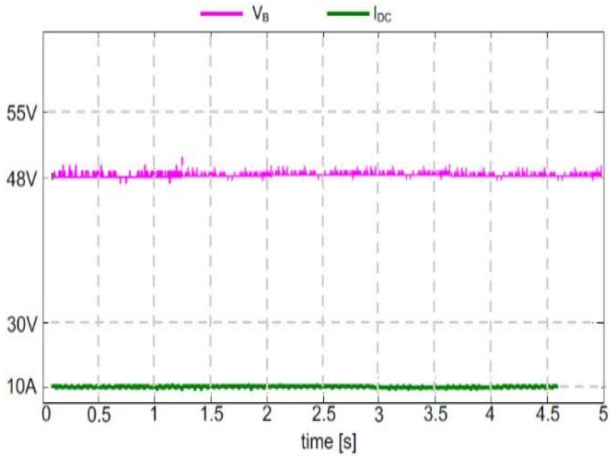

Figure 10: Experimental waveforms representing the load variation response of a dc–dc converter (buck) in the charging mode

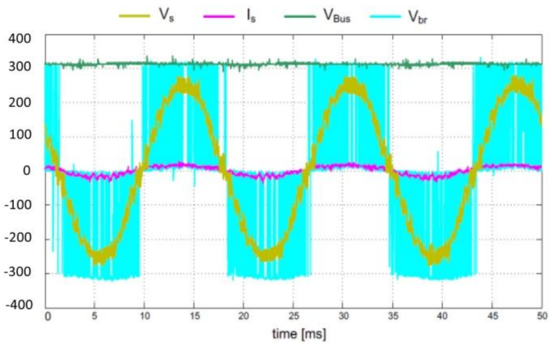

Figure 11: Experimental waveforms of the PFC stage

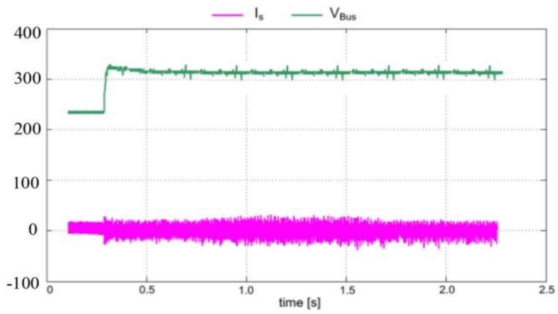

Figure 12: Experimental waveforms representing the load variation response at the ac–dc converter stage

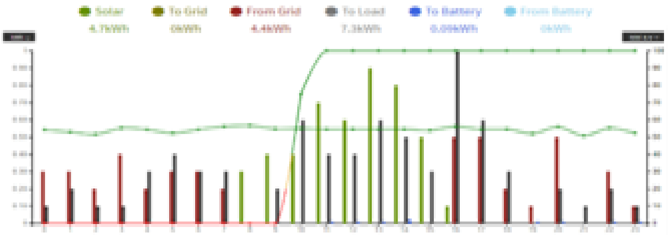

Figure 13: Graphical representation of various charging parameters, viz. SOC, solar grid, etc

VI. HARDWARE IN THE LOOP AND EXPERIMENTAL VERIFICATION

Considering the design given in the earlier sections, the charger circuit used in the EV (see Fig. 8) could be realized practically as depicted in Fig. 16.

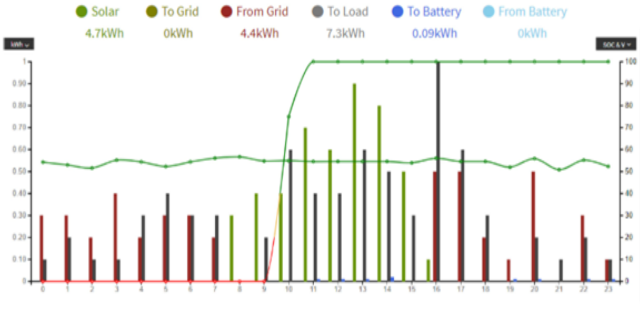

Figure 20: Graphical representation of various charging parameters, viz. SOC, solar grid, etc

The sensor feedback input has been executed through the DSP TMS320F2812 board. The voltage and current sensors are LV20-P 500V and LA100-P 100A, respectively. Microsemi MOSFET switches APT100M50J, 500 V, and 100 A rated are triggered through VLA513 at 60 kHz frequency, IGBT-Powerex drivers. An ac voltage regulated supply is supplying the voltage input to the electronic dc (output) load. The whole feedback controller has been executed digitally in the DSP.

The current and voltage output waveforms in this operation mode (charging) of the dc/dc second stage buck converter under dynamically changing load conditions is shown in Fig. 17. Here, in the charging mode, the second stage manages the dc inductor current IDC constant through the current controller, when the load (resistive in this case) changes.

The second stage dc/dc bidirectional converter works in the buck operating mode to reduce the voltage at the dc bus (VBUS) to the level of the voltage of the battery terminal (VB). In the ac/dc rectifier operation, the PWM converter in the boost mode maintains the PFC (in an active mode).

The PWM pulses from the DSP board deals with the actuation of various switching appropriately in +ve and −ve half cycles of the voltage input. Fig. 18 demonstrates the experimental waveforms in a PWM boost PFC stage. Similarly, the results are shown in the simulation of Fig. 11, the controller keeps up the PFC and, therefore, the input voltage and current are in the same phase.

Moreover, as calculated by (17), the dc bus voltage fluctuates double the fundamental frequency. Here, the power factor is 0.93. The PFC corrected it from 0.72. Because of the ac power supply internal impedance, the switching phenomena are replicated in the input side voltage waveform. In addition, hence, a little increment in the THD value is caused.

Fig. 19 shows how the ac/dc rectification stage responds to the variation in the load. For this situation, a compensator (feed forward) is additionally executed in the controller algorithm. Because the PFC has average mode multiloop current control, the voltage at the dc bus (VBUS) is kept steady, yet the variation in the load must be seen by the variation in the magnitude of the input side current waveform.

The energy management controller is used for display and real-time monitoring of the plant, as shown in Fig. 1 via Ethernet cable as explained in Section II. In Fig. 20, different parameters of the SPVCS are shown graphically.

6.1 Various component parameters

Solar panel: We have used solar panel of 4 series modules with 2 parallel strings for simulation. It is used to charge battery of electric vehicle.

Type of Product :	Polycrystalline Solar Panel
Rated Power Range :	1-30 W
Watt :	5 W
Voltage at Pmax (V) :	8.3 V
Module Voltage :	6 V

Battery: battery is charged from solar panel. Electric vehicles use lithium-ion batteries of various designs, similar to those used in cell phones and laptop computers, only on a much larger scale. Lithium-ion batteries have a high energy density and are less likely than other types of batteries to lose their charge when not being used. An EV's battery capacity is expressed in terms of kilowatt-hours, which is abbreviated as kWh. More is better here.

- Voltage- 12V
- Battery Capacity- 1.3Ah
- Terminal Standard F3-TAB 187E
- Operation Temperature
  - Charge 0°C (32°F) - 40°C (104°F)
  - Discharge -20°C (-4°F) - 50°C (122°F)
  - Storage -20°C (-4°F) - 40°C (104°F)
- Capacity 25° (77°F)
  - 20 hour rate (0.165A) 1.3AH
  - 10 hour rate 1.17AH
  - 5 hour rate 1.04AH
  - 1 hour rate (1.98A) 0.78AH

Charge controller circuit: A solar charge controller is fundamentally a voltage or current controller to charge the battery and keep electric cells from overcharging. It directs the voltage and current hailing from the solar panels setting off to the electric cell.

- Solar panel rating: 50W (4A, 12V nominal) (open circuit voltage: 18 to 20V)
- Output voltage range: 7 to 14V (adjustable) (not recommended for 6V applications)
- Max power dissipation: 16W (includes power dissipation of D3)
- Typical dropout voltage: 1.25V @ 4A
- Maximum current: 4A (current limiting provided by solar panel characteristics)
- Voltage regulation: 10mV (no load to full load)
- Battery discharge: 1mA (Chinese controls discharge at typically 5mA)

H-bridge inverter: The half-bridge inverter consists of two diodes and two switches which are connected in anti-parallel. The two switches are complementary switches which means when the first switch is ON the second switch will be OFF similarly, when the second switch is ON the first switch will be OFF.

Rectifier: High power factor or PFC rectifiers are one of the mostly used equipment in the industries. The main concerns of such converters are the unity power factor operation and low harmonic distortion of the input AC waveforms that can be ensured by generating a DC voltage higher than the grid peak voltage amplitude, which makes use of switching devices inevitable.

- Three-Phase Input 208 VL-L 60 Hz, Output 600-V DC Nominal, 1.2 KW
- Three-Phase Input 400 VL-L 50 Hz, Output 700-V DC Nominal, 2.4 KW
- 50-kHz Pulse Width Modulation (PWM) Switching
- Greater Than 98% Peak Efficiency
- Less Than 2% Total Harmonic Distortion (THD) at Full Load and Low Line

Buck converter: A cascaded PI controller has been designed to regulate the output DC voltage and to ensure the unity power factor mode of the input AC voltage. The output of Buck converter is 15V DC. Buck inverter is control using PI controller and design in Arduino software.

6.2 Results of hardware

There are two modes in the system

Mode 1. Solar powered system: While the running system in the day light system runs on power from solar panels. In this mode the power from the solar panel is fed to the inverter after boosting it. Then after rectifier action power is converted to DC 15V, so that electric vehicle battery can be charged.

Mode 2. Grid connected system: Grid gives AC supply using Rectifier it is converted to DC. The converted DC supply is such that it gives 15V so that one can easily charge the electric vehicle battery.

VII. CONCLUSION

In this paper, we have developed and simulated the solar model, Charge controller model, Buck converter Model, PFC model, different PI controller and also inverter grid control. Maximum Power Point Tracking (MPPT) methods are simulated for photovoltaic (PV) systems to maximize continually the PV array output power which generally depends on solar radiation and cell temperature. 5 Level PFC Rectifier model is simulated to give correct output which is filled controlled for battery charger. By using above parameters, we can develop the battery management system also.

In our simulation we have set the point voltage to 48 constant to charge the vehicle. So in the output we get two states the first state is transient stage in which the voltage varies and the second is the constant state were the voltage does not vary and is set to constant at 48 voltage for charging the vehicles. Thus, using solar plant and EV model we have generated a electric vehicle charging station. In this simulation we have used solar panel of 4 series model with two parallel strings for simulation. Thus, we have found the peak point using the current voltage graph. EV charging promotes the self-consumption of PV and these results in increased PV revenues when feed-in tariffs are lower than retail electricity price. Thus the dual benefit of lower fuel cost and emission make EV charging from PV to be both economical and environmentally beneficial. If in case, sunlight is not available then one can use power from electricity board, making it uninterrupted power supply.

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