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SOLAR WITH BATTERY STORAGE BASED DC CHARGING STATION FOR ELECTRIC VEHICLES

Kamal Prakash Yadav[1], Hemant patel[2]

[1,2]Department of Electrical and Electronic Engineering

[1,2]NRI institute of Information Science and Technology Bhopal, INDIA

kamalprakashee0026@gmail.com

***Abstract*— In this article, a renewable energy based Electric vehicle charging station (EVCS) is proposed which provides electricity to EV with the support of Battery storage system (BSS). Among all renewable energy sources, the solar PV system is best option because of abundance and easy to operation. However solar PV power fluctuates because of change in irradiance and temperature and it cannot generate constant power, therefore to compensate the power fluctuation a standby battery storage system is needed to meet up the power demand and maintain the reliability of the EVCS. Thereby, a DC micro grid system has been developed which consist of BSS along with the solar PV system and electric vehicle battery charger. The charging controllers are operated based on the concept of power balance, and constant current/constant voltage charging. Performance of the charging system is validated with simulation and experimental results.**

Keywords*— battery storage system, solar PV system, electric vehicle charging station, electric vehicle battery etc.

I. INTRODUCTION

In It is estimated that by 2022, EVs will be over 35 million in the World. The Indian government has set ambitious targets to accelerate the adoption of electric vehicles (EVs) due to potential of Electric Vehicles to reduce pollution along with many other advantages like high torque, easy speed control, and higher efficiency compared to the conventional ICEs. However, if all IC engines were to be replaced by EVs at large, then their high penetration causes heavy electricity demand to the power grid and the electric grid will collapse not being able to withstand the load demand [12, 13].In case of India-like countries, the main sources of electricity are fossil fuels. Currently (as of March 2020),62.8 % of total electricity of the country is being powered fossil fuel-based (coal, lignite, gas diesel) plants.

Adding to this, the transmission and distribution losses in the country on an average is around 22%, and in states such as Assam is as high as 38.2%[20, 21].However, with Demand increasing exponentially and the availability of fossil fuels decreasing at two-fold rate, the gap between the resource and the demand is widening at an alarming rate. One efficient approach to relieve the effect is to integrate local power generation such as RESs [18] into the EV charging infrastructure [16, 17]. Renewable energy installations such as solar energy panels generate zero emissions in their generation of electricity. taken advantage of it to its maximum extent, sunlight focused on the earth for 1 hour could meet energy demands of the whole earth for an entire year [22].

The system implemented in this paper incorporates a PV panel fed through boost converter and MPPT algorithm, bi-directional converter, buck converters and a BESS. While the energy generated by solar PV panel, during low solar irradiance conditions, is insufficient to meet the power demanded by the Electric Vehicle battery. Then BESS meets the required power demand. On the other hand, while the solar power generation is greater than the demand, the BESS stores the excess solar energy. Later, the system has been implemented in MATLAB/ Simulink to verify the system performance.

The design, and performance analysis of the proposed system using experimental studies are discussed in further sections of the paper. Figure 1 shows the block diagram of the proposed system. The boost converter uses MPPT algorithm and extract maximum solar power at all instants. The bidirectional converter helps in charging and discharging of the station battery depending on source - load power balance in addition to maintaining a constant 48 V bus at its higher voltage terminals. The buck converters step down the 48V to 36 V and charge at most EV batteries. The fast-charging method used here implements CCCV charging based on the SoC of the EV battery

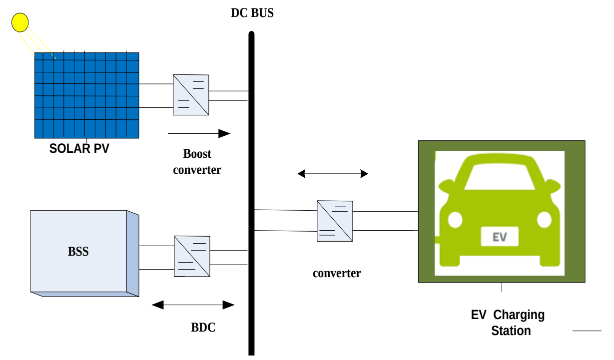

Fig. 1 Topology of the proposed electric vehicle charging station

II. DESIGN AND MODELING OF SYSTEM

A. The *Modeling of Solar Photovoltaic System*

A solar cell is represented by an equivalent model of the current source, diode, series resistance, and load. MPPT is an algorithm that forces the point of operation of the panel to be at the MPP. Perturb &Observe algorithm, which is the most-commonly used MPPT algorithm, uses a simple feedback arrangement and a few measured parameters (specifically V and I of PV panel). Several P-N junctions are fabricated in a thin semiconductor wafer and being exposed to sunlight, these P- N junctions absorb photon with a higher energy than the band- gap of the semiconductor and produce electron-hole pair. With an external load connected to the PV panel, a direct current (also known as Photocurrent) flow through it to balance out the number of holes and electrons in the semiconductor. An equivalent circuit for PV solar cell can be presented with a constant current source, a P-N junction diode, a series, and shunt resistor is shown in figure 2.

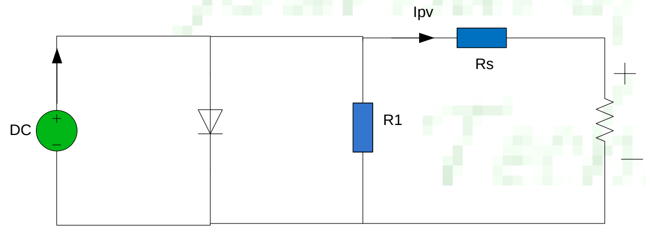

Fig. 2 Equivalent model of solar cell

Equations can determine the current output of the PV circuit. These equations are used for the modeling of PV.

$$I_{pv} = n_p I_{ph} - n_p I_{sat} \times \left[e^{\left(\left(\frac{q}{AkT}\right)\left(\frac{V_{pv}}{n_s} + R_s I_{pv}\right)\right)} - 1 \right] \ldots (1)$$

B. Battery Storage system:

The modeling of battery depends on two important parameters i.e., State of charge (SOC) and terminal voltage (V_b). In case of BSS, we are focusing on terminal voltage (V_b).

$$V_b = V_0 + R_b . i_b - k . \frac{Q}{Q + \int i_b dt} + A . e^{(B \int i_b dt)} \quad \ldots . (4)$$

Where: V_0= open circuit voltage of the battery, i_b = battery charging current, Q = battery capacity, A = exponential voltage, R_b = internal resistance of the battery, k = polarization voltage and B = exponential capacity. Constant current / constant voltage (CCCV) is a combination of CC (constant current) charging and CV (constant Voltage) charging. The charger limits the amount of current to a reference level until the battery reaches a value of SoC. The charging current then decreases as the battery becomes fully charged. This system allows fast charging without the risk of over-charging and is widely used in EV charging. The battery normally charges with a constant current which is approximately 20 % of the battery capacity. If the battery reaches a SoC greater than 90% then it goes to CV mode of charging and in this mode, the change in duty maintains the battery voltage constant. The methodology is as depicted in Figure 3.

III. DC BUS VOLTAGE CONTROLLER

C. Fuzzy Logic Based Pi Voltage Controller:

PID controller has the limitation of parameter tuning and it cannot change its parameters simultaneously for each different condition. Therefore, it fails to provide the best optimal response for every condition Hence, FLC provides it.

FLC has various advantages such as working with imprecise inputs, not needing an accurate mathematical model, and handling nonlinearity [8].

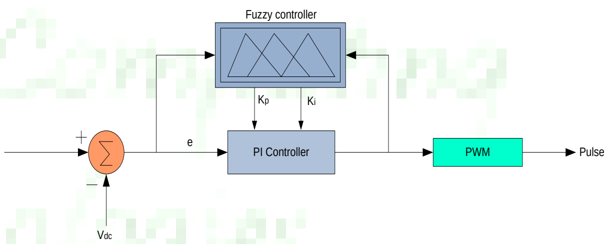

Fig. 3 Fuzzy based PI controller

On the other hand, fuzzy logic controller has the ability that if you define the rules for all the conditions separately, then it will provide the best response for each condition every time, which means it will provide best optimal response as compared to PID controller. The conventional PI controller adjusts its values of K_p and K_i according to the changes in conditions. Hence, by developing the rule base for fuzzy logic system, the parameters will be modified automatically not manually this will increase the performance of controller within a wide range.

In above table, rules are developed using the error and the input where the gains of proportional and integral are proportional to each rule they work accordingly to the rules. Hence, the fuzzy gives the better response than given by PI controller.

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IV. SI MULATION RESULTS

D. *With conventional PI controller:*

DC bus voltage with conventional PI controller is shown in Fig.4. Initially, voltage was having oscillations and settling after a long time. For a crucial EV load, voltage must be constant with less settling time as well as less oscillations. Figure 5(a), (b) and (c) shows that battery voltage, current and SOC of BSS.

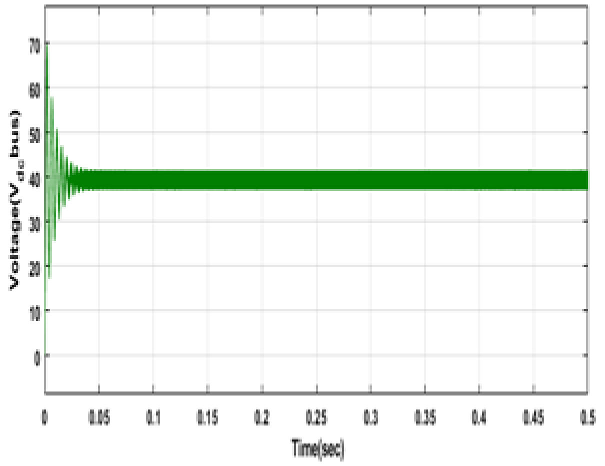

Fig. 4 DC bus voltage with conventional PI controller

The voltage and current in the result shows that battery is getting discharged and initially SOC of BSS is 70% as shown in figure.5(c). By reviewing the voltage and current waveforms, power is positive here, and it clearly shows that BSS behaves as source for the load that is EV battery. And the SOC is getting continuously decreased.

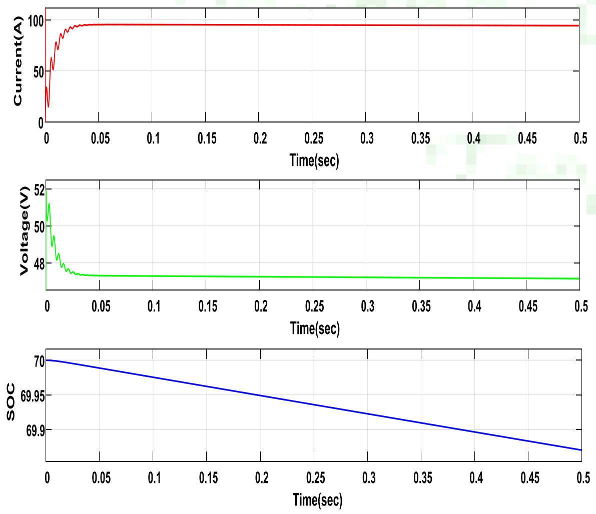

Fig. 5 (a) Electric Vehicle Current in Ampere **(b)** Electric Vehicle Voltage in volts **(c)**State of charge of EV battery

Figure.6(a), (b) and (c) consists Voltage, Current and State of Charge of EV battery. The voltage and current waveform clearly show that EV battery is charging hence, SOC is being increased. Initially SOC of EV battery was 20% as shown in figure 8(c) and it is continuously increasing.

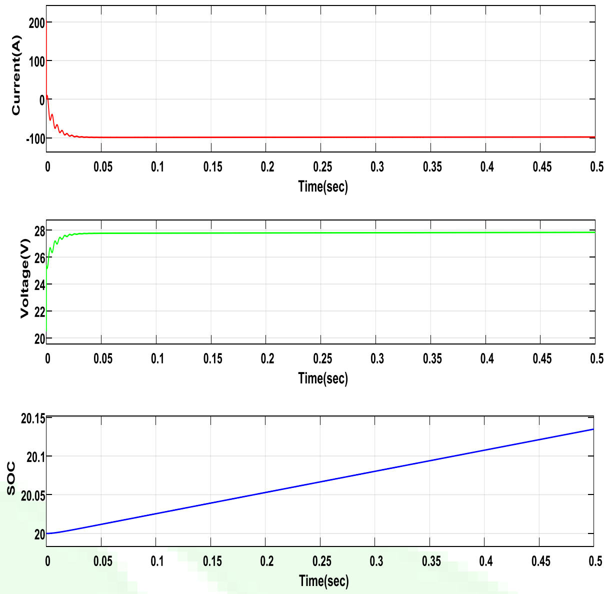

Fig.6 (a) Electric current of BSS **(b)** electric voltage of BSS **(c)** State of charge of BSS

E. With fuzzy logic controller:

Figure 7 is showing the DC voltage which is improved by using fuzzy logic controller than in PI controller. There is less fluctuation in the voltage thereby replacing the conventional PI controller.

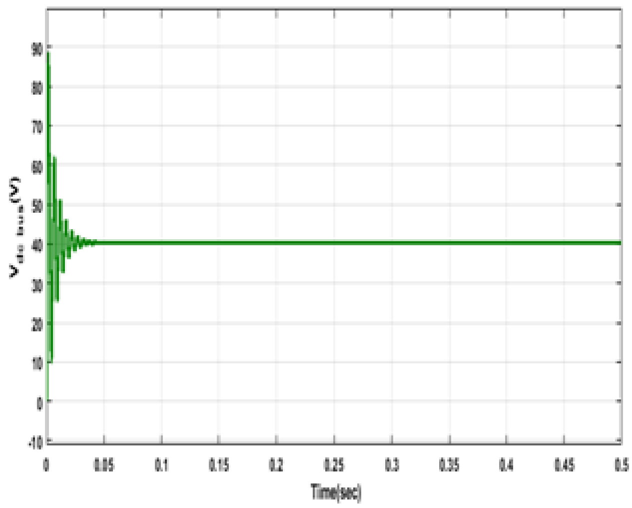

Fig.7 DC bus voltage

Figure 8 shows the battery voltage, current and SOC of BSS. The voltage and current in the result shows that battery is getting discharged and initially SOC of BSS is 70% as shown in figure.8(c). By reviewing the voltage and current waveforms, power is positive here, and it clearly shows that BSS behaves as source for the load that is EV battery. And the SOC is getting continuously decreased.

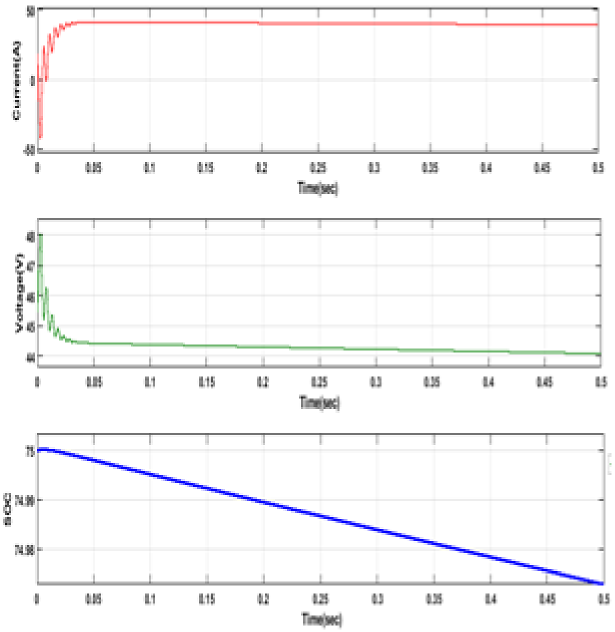

Fig.8 (a) Electric current of BSS **(b)** electric voltage of BSS **(c)** State of charge of BSS

Figure.9 (a), (b) and (c) consists Voltage, Current and State of Charge of EV battery. The voltage and current waveform clearly show that EV battery is charging. Hence, SOC is being increased. Initially SOC of EV battery was 20% as shown in figure 9(c) and it is continuously increasing.

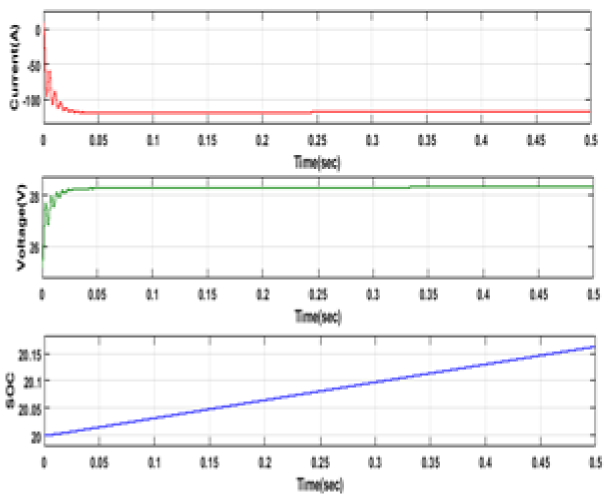

Fig.9(a) Electric Vehicle Current in Ampere **(b)** Electric Vehicle Voltage in volts **(c)**State of charge of EV battery

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V. CONCLUSION

The Electric vehicles (EVs) help a lot reduce GHG gases and global warming. But these vehicles will add additional burden to the power system network and their demand also varies throughout the day. In addition, in rural areas, the accessibility to electricity is very less, so it is preferred to utilize renewable sources in an effective manner. The effectiveness of this EV charging station is analysed by means of simulation model studies and experimental testing under various scenarios like changing solar irradiance and change in the initial SOC. System performance is found to be satisfactory.Electric vehicles (EVs) help a lot reduce GHG gases and global warming. But these vehicles will add additional burden to the power system network and their demand also varies throughout the day. The objective of EV, noise free and pollution free environment. This paper helps to propose a green energy based electric vehicle CS and also ensure the constant DC bus voltage with the help of fuzzy based PI controller which will also improve the battery life span. Fuzzy based PI controller is better than conventional PI controller it is also verified with the help of MATLAB results in our proposed work.

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