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Renewable Energy with Battery Storage based Charging Station for Electric Vehicles

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***Abstract*—Now a days, electric vehicles (EVs) have attracted much attention owing to their use of clean energy. Large progress in lithium-ion battery has propelled the development of EVs. However, the challenge is that growing number of EVs leads to huge demand in electric power, which will aggravate the power grid load. This leads to an exploration for alternative and clean sources of energy to charge EVs. This project implements solar energy system to erect a charging station for EV application. The charging station employs multi-port charging by providing a constant voltage DC bus. 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

I. Introduction

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

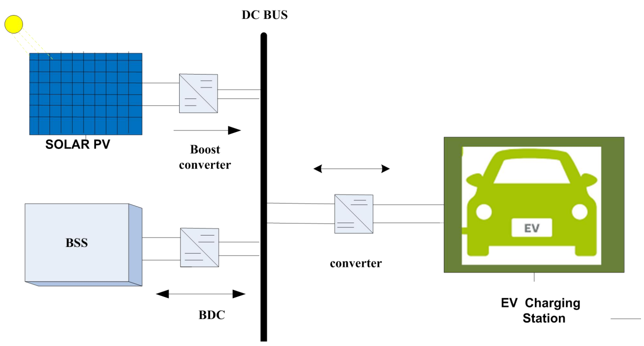

Fig. 1 Topology of the proposed electric vehicle charging station

II DESIGN AND MODELING OF SYSTEM

A. 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

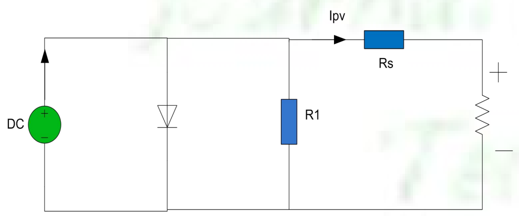

Fig. 2 Equivalent model of solar cell

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

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

B. Battery Storage system:

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

$$V_b = V_0 + R_b . i_b - k . \frac{Q}{Q + \int i_b dt} + A . e^{(B \int i_b dt)} \quad \text{.... (2)}$$

Where: V0= open circuit voltage of the battery, ib = battery charging current, Q = battery capacity, A = exponential voltage, Rb = internal resistance of the battery, k = polarization voltage and B = exponential capacity.

III. CHARGE DISCHARGE CONTROLLER OF BATTERY:

A. CCCV MODE OF CHARGING

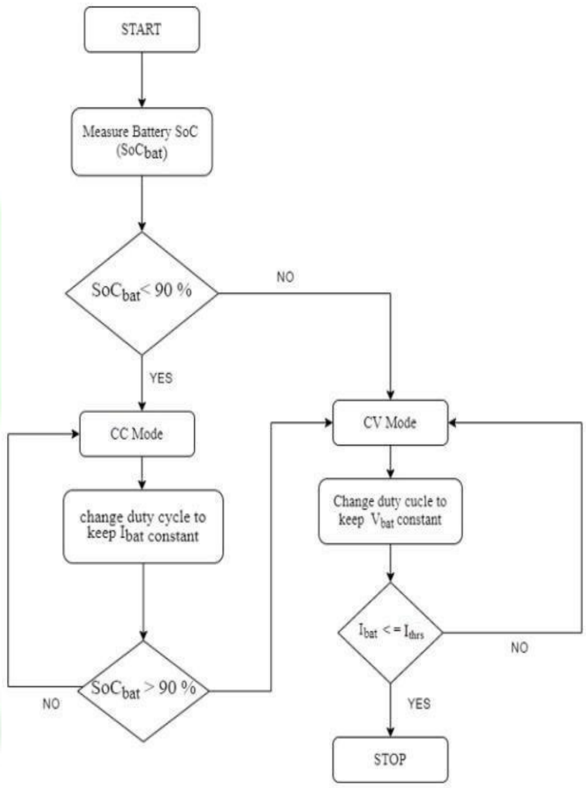

Fig.3 CCCV mode of charging algorithm

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.

IV. SIMULATION RESULTS

The proposed Solar Charging Station can charge upto three E-Bikes of capacity 36V, 12Ah. A constant DC Bus is maintained with a voltage of 48V. Station Battery is connected through a Bidirectional converter, which decides mode of operation of Station Battery i.e either charging or discharging based on solar power supplied at that instant. Figure 5 shows the power balance in the system. When three vehicles were charging from the station, the station battery was discharging power. When one of the batteries entered CV mode, the power consumed by that battery became minimum and hence a drop in total Vehicle power is observed. The behaviour of station battery under lower value of solar irradiance (around 200 W/m2). When the solar irradiance is less, the EV batteries are charged up by the station battery.

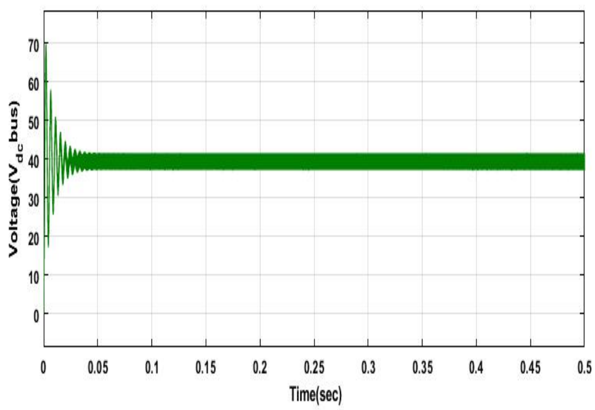

Fig. 4 DC Bus Voltage

The voltage and current in the result shows that battery is getting discharged and initially SOC of BSS is 70% as shown in figure.7(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.

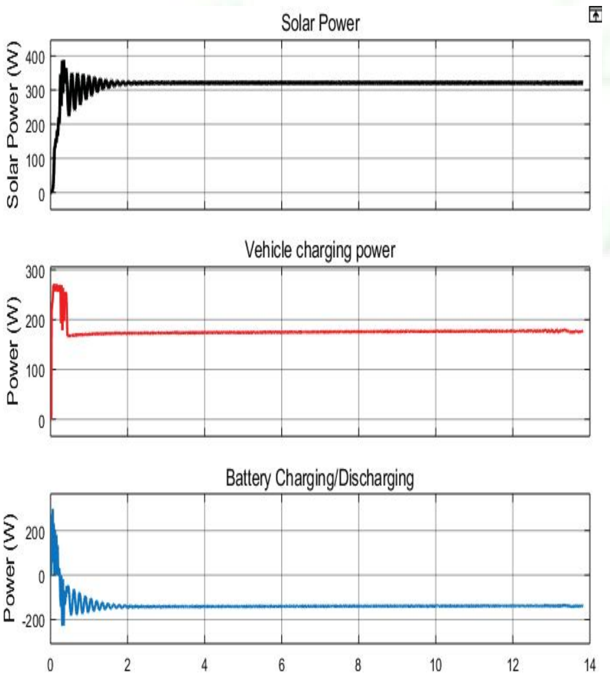

Fig. 5 (a) Solar output power **(b)** battery charging power **(c)** EV battery charging power

Figure.8 (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.

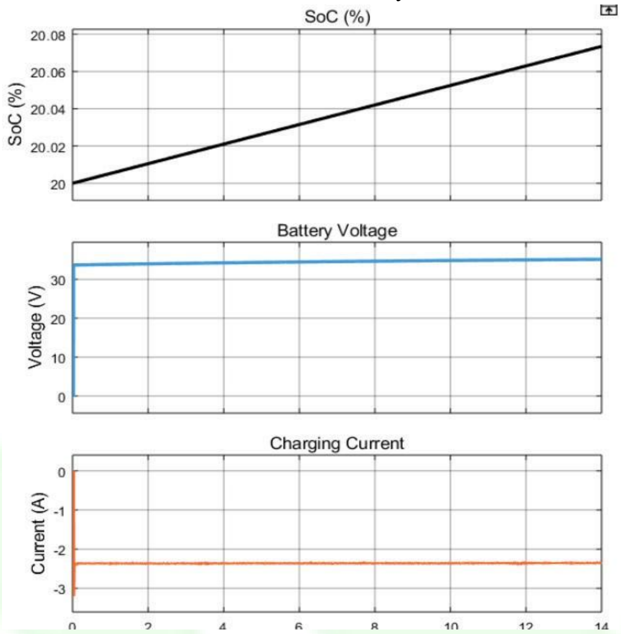

Fig. 6 (a) SoC of EV battery **(b)** battery nominal voltage **(c)** EV battery charging current

Figure 6 shows the charging of station battery due to excess power available from solar panel. The SoC of the battery is seen to rise gradually when it charges.
It is to be noted that the rate of increase in SoCs and the Voltages is the same for both batteries since the same magnitude of current charges both the batteries

Hence, it can be concluded that the station battery

- Discharges when the PV power is lower than that required by the vehicles charging
- Charges when the Solar power exceeds that required by the vehicles
- Maintains a constant DC bus across the ends of the boost converter.

V.CONCLUSIONS

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. 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

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