International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VI **Month of publication:** June 2021

DOI: https://doi.org/10.22214/ijraset.2021.35479

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VI Jun 2021- Available at www.ijraset.com

Design and Power Management of Solar Powered Electrical Vehicle Charging Station with Storage System

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Abstract: This paper represents as Global warming has led to the massive adoption of electrical Vehicles(EVs) which appear to be the simplest replacement to IC engines. Due to increased number of EVs within the road, charging of the vehicles with conventional fuel based grid isn't economical and efficient. Thus, a renewable energy based charging station finds immense potential and control for electric vehicle charging. An electric vehicle charging station integrating solar power and a Battery Energy Storage System (BESS) is designed for the current scenario. For uninterrupted power within the charging station a further grid support is additionally considered without becoming an additional burden to the grid. An efficient design of charging station with MPPT, PID and current control strategy is developed for the optimal power management between solar, BESS, grid with the EVs within the charging station. By taking dynamic charging needs of EVs, the planning of charging station is formulated and validated in MATLAB/Simulink.
Index Terms: Charging Station, Electric Vehicles, Solar, State of Charge (SOC), Battery EnergyStorageSystem

I. INTRODUCTION

Growing concern on global climate change because of green house gas emission has raised the necessity for alternate sources of energy with minimum pollution. It has contributed to the concept of electrification in transportation that has led to the rise in popularity of electrical Vehicles(EVs). But with the deployment of more EVs on the road, charging of the vehicle are going to be strenuous if electric grid power is employed . When more number of EVs are connected to the grid, it will unavoidably bring a huge impact to its function and control. Moreover, charging the EVs using the electrical grid powered by conventional energy sources gives no benefits. Thus, there is need for an efficient charging system for EVs utilizing the renewable energy sources. Solar energy is green and renewable, but the undependable gathered energy from the Photo-voltaic (PV) system and dynamic charging needs of individual EVs bring new issues to the efficient charging of vehicles from these sources.

Different charging strategy and power management for EV charging station are reviewed in the literature depending on the various energy sources and EV demand. In paper, solar powered charging station with battery storage system is explained. The approach introduces forecasted PV system and projection of EV pattern consistent with collected data. In charging scheduling for EVs by PV and Grid is given by reducing the total cost of the parking lot. With the real-time information about EVs, Model Predictive Control is applied for present time slot and projected information in the coming time slots. Prioritizing the EVs charging from the limited available solar energy is given in Feasibility of different types of PV and BESS charging for commercial, home and business has been explained in shows the solar powered e-bike charging station that provides AC, DC and contactless charging of e-bikes. The charging station has an integrated battery storage that provides both grid-connected and off-grid function. In paper, it shows the model of a grid connected rapid electric vehicle charging station ensuring power quality with reduced harmonics. The control of each vehicle charging is centralized and individual control is given to transfer energy from AC grid to the DC bus. Thus, for a well grounded charging station for EVs, the concept of utilising both the renewable energy and an energy storage system with additional grid support becomes very prominent in current scenario.

In the proposed work, an optimal approach for design and power management of Electric Vehicle charging station powered by solar PV and a Battery Energy Storage System (BESS) with AC grid is explained. The unreliability of solar and dynamic charging requirements of EVs are considered for the facility flow strategy. Solar PV acts because the primary source to charge all the connected EVs within the charging place. Since the facility from PV in the dark isn't there, A battery as an energy memory device is provided to charge the EVs connected within the charging station. Whenever there's a deficiency within the power output of solar or BESS to charge the EVs, required amount of power are going to be taken from the AC grid ensuring continuous operation of charging station throughout the day. The proposed system is formulated, designed and validated using MATLAB/Simulink.

II. LAY OUT OF PROPOSED CHARGING SATION

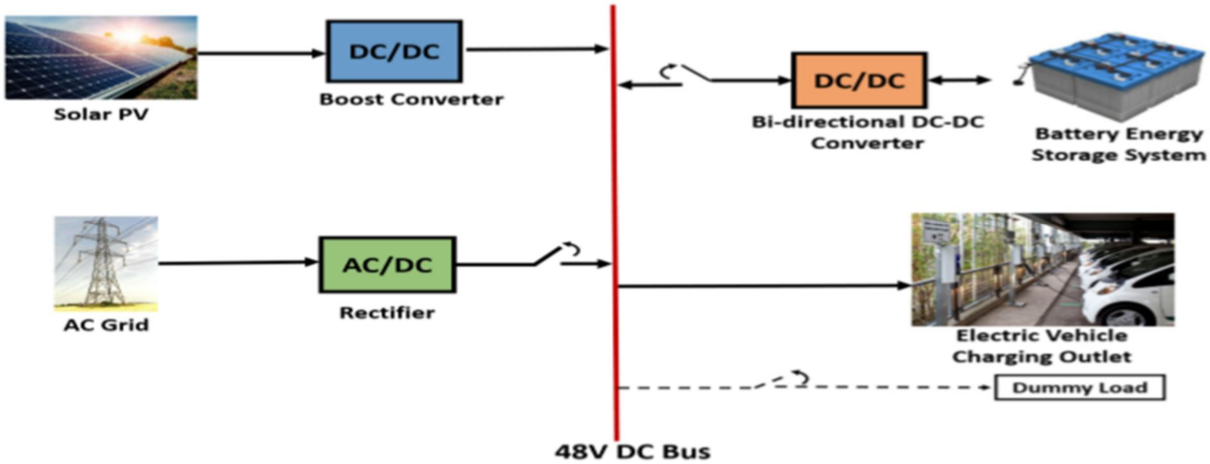

Fig .1 layout diagram

A. *Electric Vehicle as load*

A load of five electric vehicles, 48V, 28Ah with 0.5 hours to maximum 2 hours as charging time [9], is studied for the charging station. Charging requirements of incoming EVs varies time to time. The user can specify the State of Charge (SOC) limit, SOClt and the time required h hours for charging the EVs. The power requirement for charging all the EVs are calculated in terms of its SOC according to [10].The remaining SOC, SOCr required to charge the vehicle is calculated from time to time with the difference between SOClt and current SOC, SOCc.

SOCr = SOClt − SOCc

If EV battery voltage VEV and its Ampere-hour rating Ahrating is known, required energy EEV for each electric vehicle to be charged is given as

EEV = SOCrVEV Ah

The dynamic power required by the individual vehicle for charging in h hours is

PEV = EEV h − t

where t is that the time already covered by the EV for charging. Thus, the overall power needed for charging all the 5 EVs are often obtained by summation of (3).

For simulation study, it is assumed that the incoming EV has a minimum of 20% SOC in its battery.

B. *Solar PV with Boost Converter*

PV array of 250W at 37.3V as open circuit voltage is considered for the charging station design in MATLAB/Simulink. To step-up the PV array voltage, a boost converter is employed to urge the desired DC bus voltage as 48V. With boost converter efficiency as 90%, the solar PV is designed for a load of 5 EVs to charge from 20% to 100% SOC for 2 hours. Thus, a complete of 24 panels are required for the specified charging station.

C. *BESS with Bidirectional DC-DC Converter*

A battery energy storage system is employed to store the surplus power from the solar for charging the EVs at nighttime. A bidirectional DC-DC converter controls the charging and discharging operation of the BESS. Considering charge-discharge efficiency and bi-directional converter efficiency as 90%, for supplying maximum energy to the connected EVs for 2 hours, a 24V 350Ah BESS is used for the charging station. It is assumed that BESS maintains/ discharges to a minimum of 20%SOC and charges to a maximum of 95% SOC.

D. *Grid with Rectifier*

For additional power requirement for the charging station 230V AC grid is considered. In MATLAB/Simulink, a 230V AC source with a linear transformer is considered as grid to step down the voltage to 48V AC. A controlled rectifier is provided to convert the AC voltage to constant 48V DC bus voltage.

III. MODES OF OPERATION

1) *Mode 1:* PPV > Ptot and SOCBESS < maxSOCBESS If the delivered power from the solar PV is more than the required power of all the connected EVs, then the EVs will be charged to its SOClt using the solar power only. If the current SOC of BESS is lower than its maximum SOC, then the surplus power from the solar is used to charge the BESS by connecting it to the bus
2) *Mode 2:* PPV > Ptot and SOCBESS maxSOCBESS With the power from the solar, EVs are charged but if the SOC of BESS reaches its maximum, then it is disconnected from the grid and dummy loads are connected for the power balance
3) *Mode 3:* PPV < Ptot, Due to rain or cloudy condition, if the facility harvested from the solar PV is less than the facility required by the EVs for charging, then the deficient power will be taken from the AC grid by connecting it to the DC bus.
4) *Mode 4:* PPV = 0 and SOCBESS > minSOCBESS. At night conditions, when there's no solar output, BESS provides energy for charging the EVS within the station by maintaining the minimum SOC within the battery.
5) *Mode 5:* PPV = 0 and SOCBESS < minSOCBESS When the current SOC of BESS is less than its minimumSOC, then the required power for charging the vehicles will be taken from the AC grid by connecting it to the DC bus.

Here, two sorts of control like for power management and for creating the DC bus voltage constant are demanded for the presented work. Fig. 2 shows the model with adopted control topology for the charging station.

A. *MPPT and PID Control for Boost Converter*

For obtaining the maximum power from the solar, Maximum Power Point Tracking (MPPT) using Perturb and Observe (P&O) method is adopted in this system. Using P&O method, if the power is more, the voltage is adjusted in that direction until power no longer increases. The duty ratio for the converter obtained by P&O method is noted as D1. Here a PID controller is employed for creating the DC bus voltage constant at 48V. DC bus voltage Vbus measured and considered with the desired voltage and the obtained error is given to the PID controller. D2 gives the desired duty ratio from the PID controller. The average of the 2 duty ratios, D1 and D2, is fed to the boost converter for getting the utmost power from the solar by keeping the DC bus voltage constant.

B. *Current Control for Bi-directional Converter*

Whenever there's excess power within the solar, the battery storage system is to be charged and in the dark this is often to be discharged to provide power for the EVs. Here, current control strategy is tailored for the charging/discharging of the BESS . When the battery is charging, the duty ratio of the converter in Buck mode is given .When in boost mode, BESS discharges to supply power for charging for all the EVs in the charging station. For boost mode of operation in bidirectional converter Dboostis given as the duty ratio.

IV. SIMULINK MODEL AND DISCUSSION

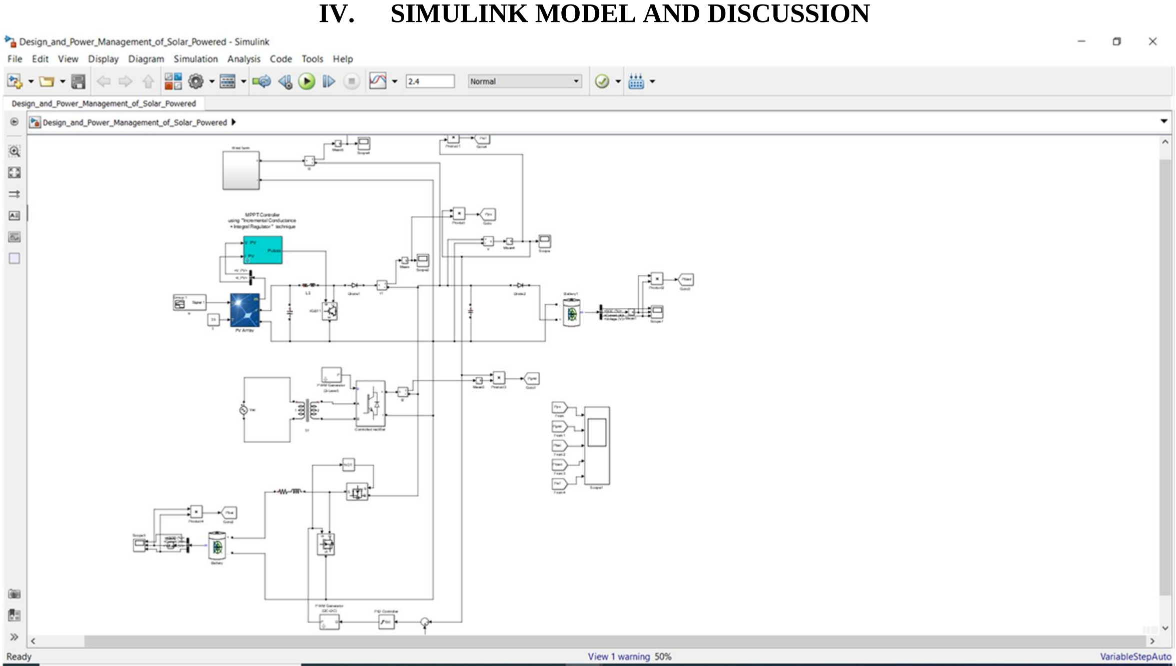

Fig .2 SIMULINK Model LabVIEW block diagram

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To study about simulation, 2 cases of EV requirements were investigated. In case 1, five EVs are connected to charge from 20% to 95% SOC for two hours. Case 2 explains the need of two EVs to charge from 50% SOC to 95% SOC, 1 EV to charge from 80% to 95% SOC and a couple of EVs to charge from 30% to 95% SOC are used.

A. Mode 1

A lookup table of irradiance and temperature for every day is given because the info to the PV panel block in MATLAB/Simulink. Fig. 3 shows the acute power obtained from the PV array by MPPT for the corresponding data.

A maximum of 4500W at peak time is obtained from 24 parallel connected solar panels of the chosen PV array.In this work the time of study is taken into account 2 hours of operation, solar output increases from 3050W to 4000W. In the study of simulation, the power used for charging all the five EVs at a time is obtained as 2688W to 980W for case 1 and 1780W to 600W case 2 respectively.

The battery of EV charging from 20%, 30%, 50% and 80% to 95% SOC is shown in Fig.for case 1 and 2 respectively. The EVs are charged from their current SOC, SOCc to 95% SOC in 2 hours.

The current used from the bus to charge the EVs is given in Fig below. At 40 minutes, for case 1, SOC of EV is charged from 20% to 70% with 6.5A at an influence of 1500W thus validating the equation (3). the entire current required for charging all the EVs at a flash of 40 minutes just just in case 2is given by 1000W/48V = 20A denoting the power balance. Since the EV battery is charging, this is denoted as negative.

As in mode 1, the power produced by the solar is more compared with power needed for all EVs, BESS is connected to the DC bus for charging. BESS are often charged till it reaches the utmost SOC using the excess power. In case 1, with excess power 400W to 2400W, the BESS charges from 20% to 33% SOC and just in case 2, the surplus power 3100W-1800W = 1200W charges the BESS from 20% to 40% SOC as shown in Fig below.

B. Mode 2

In mode 2, BESS will be disconnected and dummy loads will be connected to the system for maintaining power balance. In simulation study, it's obtained that, PPV ˇPT ot + Pdummyas shown in Fig below. The dummy loads are connected to the system for maintaining power balance within the planning of charging station. In practice, this excess power from the solar are often utilised for any residential or commercial purpose.

C. Mode 3

Since the PV power may be a smaller amount , switch closes and AC grid is cascaded to the system. Night hours of solar output is taken for simulation purpose.

Considering the rectifier efficiency, Pgrid ˇPTot - PPV , i.e. 2688W-1700W = 1000W as in Fig. 10 for case 1 and represents for case 2. the present drawn from the grid for both the cases. Current taken from the grid varies from 25A to 10A just just in case "> just in case "> just in case "> just in case 1 and nearly 5A in case 2.

D. Mode 4

BESS discharges from its maximum SOC 95% to just about 89% drawing 55A and 35A for case 1 and case 2. Current used from the BESS for charging the EVs is shown in fig below. The duty ratio is calculated for the bidirectional converter's boost operation.

E. Mode 5

With BESS state of charge 35% to discharging nearly 20%, the power within the storage system is a smaller amount than the power needed to charge all the EVs. Grid supply is connected to the system and deficient power is sapped. Graphs below shows the discharged BESS and depicts the facility drawn from the grid.

By the adopted voltage control algorithm, the voltage of the DC bus was found as varying from 47.86V to 48.13V maintaining the 48V DC bus voltage limits. With the proposed design, it shows the uninterrupted continuous operation of the presented charging station working throughout the day.

By keeping the utmost power needed for all EV as constant at 2688W, the power management between solar, BESS and grid with the EV is shown describing all the modes of operation. Power from the PV, power drawn from the grid, dummy loads power with power demanded by all the EVs are plotted with state of charge of BESS. This shows the validation of the system that it are often adopted for more EV demand and parking capacity.

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V. SIMULATION GRAPH RESULTS

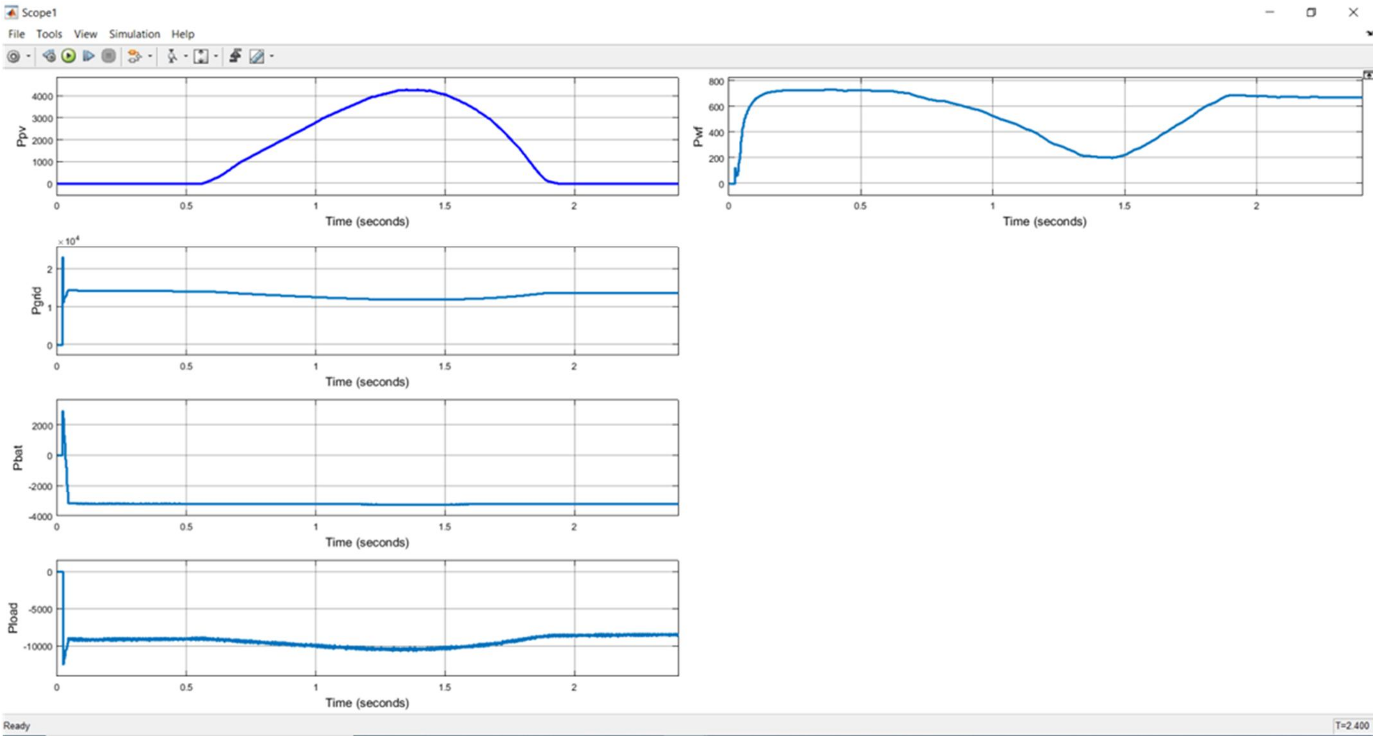

Fig. 2 Graph Shows That Power Produced By Various Renewable Sources At Differnt Time

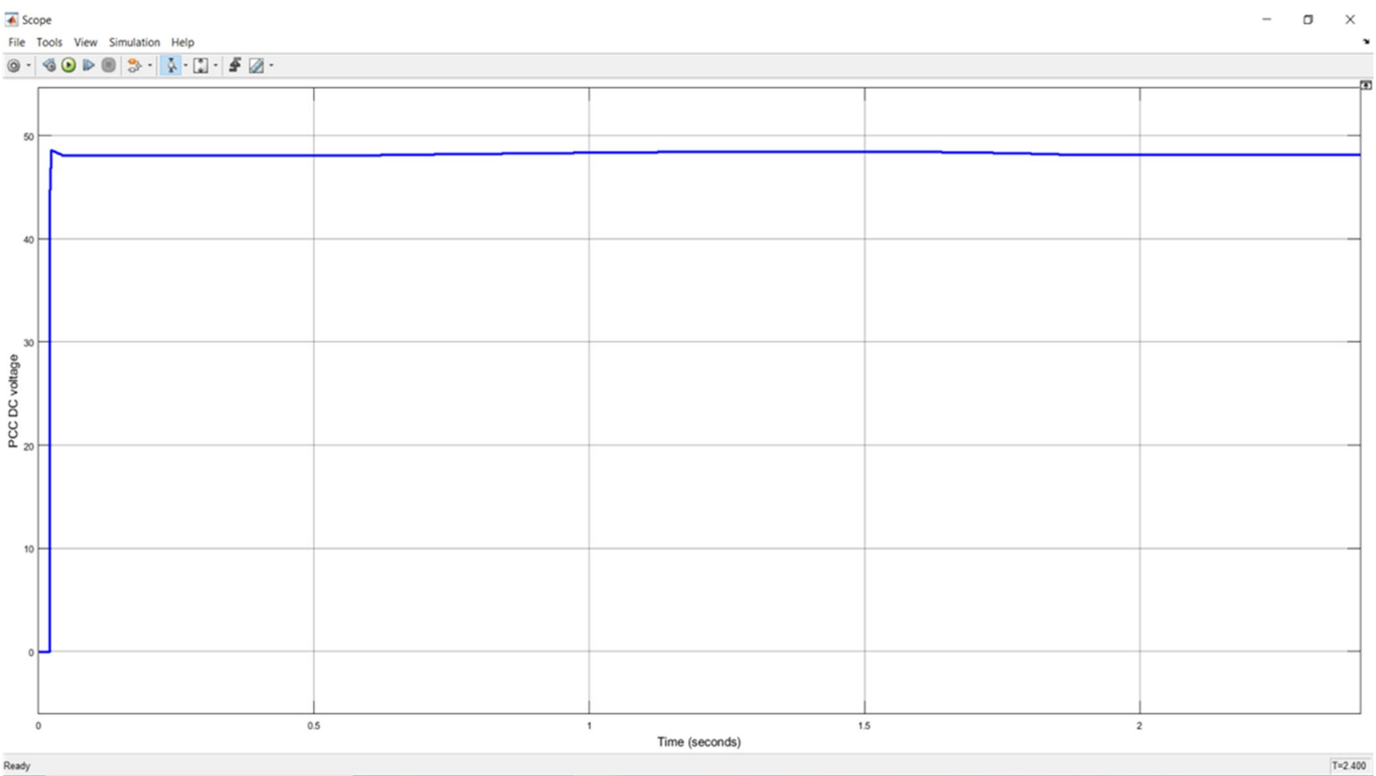

Fig. 3 Graph Shows That Entire System Maintaining Constant Votage

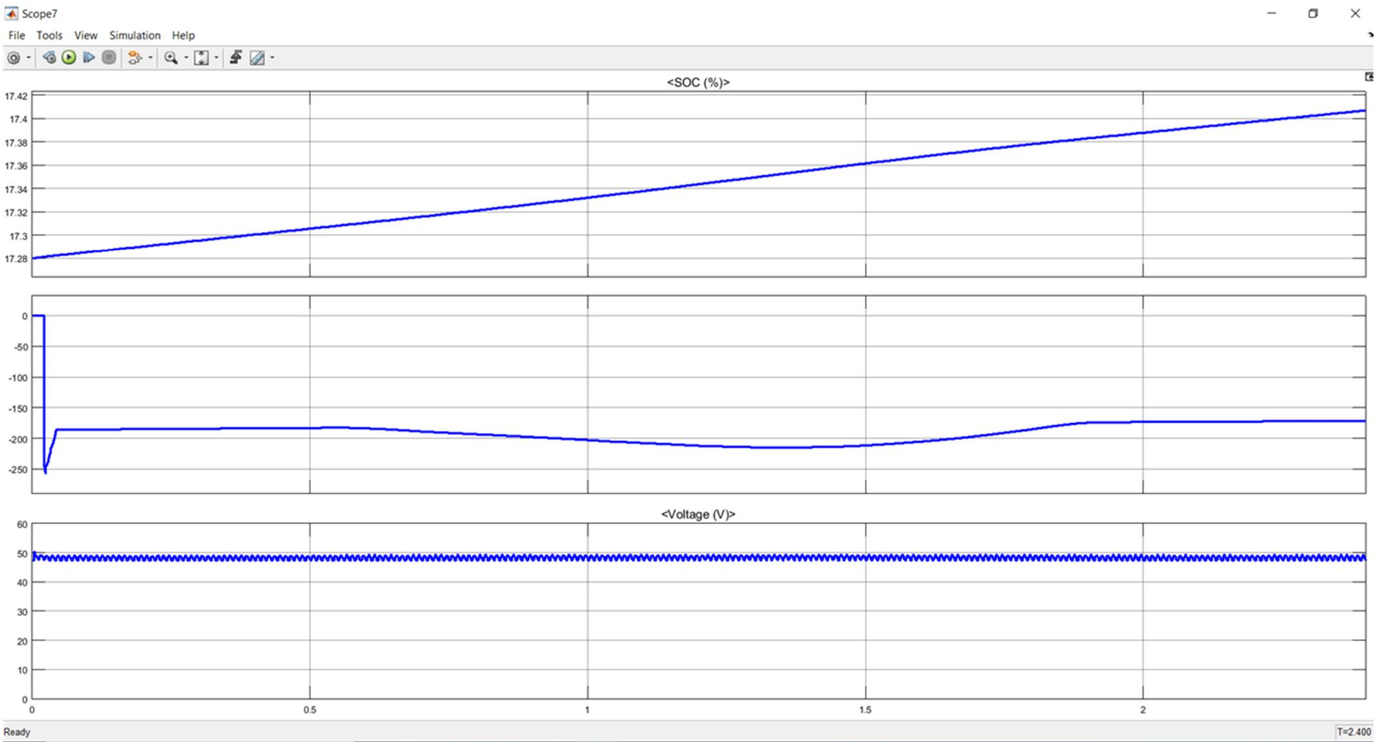

Fig. 4 Graphs Show Entire System Maintains Same Voltage When The Load Is Connected And When The Battery Is Charging.

VI. CONCLUSION

With the rapid growth of EVs on the road, the charging of EVs possess as a critical issue. A charging station with renewable energy sources like solar, battery storage system with additional grid support gives a promising solution for satisfying charging requirements of all EVs connected throughout the day. Using PID, current control and voltage control required amount of power is obtained by maintaining the DC bus voltage constant for the entire station. This design and its power management of the proposed station is made understood and validated in MATLAB/Simulink considering 5 different modes of operation and studying 2 cases of EV requirement thus making the design and algorithm robust. This can be adopted in large power rating and capacity for providing because the power outlet for EVs at workplace or parking zone .

VII. FUTURE SCOPE

In future with the help of this project we can buit a EV charging station at our own premices and various parking lot by maintaining same voltage across the system without any disturbances. We can also reduce the per unit cost of electricity as we use renewable energy sources.

VIII. ACKNOWLEDGEMENT

We would like to express our sincere thanks to our project supervisor Asst.Prof.Mr. S. Ramu, Department of Electrical Engineering, Sreenidhi Institute of science and Technology for his constant support, timely help, guidance, sincere co-operation during the entire period of my work. We are grateful to him for the problem solving part in the various phases of the project.

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