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MODELLING AND SIMULATION OF SOLAR PV & CSP BASED E.V CHARGING STATION

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Abstract— Limited fossil fuels focused the entire world for developing new Renewable energy sources for electricity generation. In order to ensure secure and steady performance of power distribution network, it is essential to analyses the impact of EV charging stations on the power grid as well as possibility to make economical this system through solar roof top system. The prospective spread of electric vehicles (EV) and plug-in hybrid electric vehicles leads to the need for fast charging rates. Higher charging rates lead to high power demands, which cannot be supported by the electrical grid. Thus, the use of on-site sources alongside the electrical grid for EV charging is a rising area of interest. This paper proposes an innovative integrated bidirectional converter with a single-stage on-board charger to reduce the number of switches, size, and weight of the power electronic interfaces. However, the PV output power has an intermittent nature that is dependent on the weather conditions. Thus, battery storage is combined with the PV in a grid-tied system, providing a steady source for on-site EV charging in a renewable energy based fast charging station. Renewable energy based fast charging stations should be cost effective, efficient, and reliable to support the high charging rates demanded when a large number of EVs are connected to the electrical grid.

Keywords—EV, HEV, Power Charging, electrical vehicle to Grid,etc.

1. INTRODUCTION

The prospective shortage of fossil fuels and the current environmental challenges of reducing the greenhouse gases motivate the extensive research on EV systems. However, the research on EVs is highly impacted by the consumer willingness for switching from using conventional internal combustion engine vehicles to EVs as an alternate means of transport. This willingness is the main factor in predicting the future demand for EVs. So many authors concluded that the charging time is one of the main challenges that the EV industry is facing. Thus, this dissertation focuses on providing novel solutions for reducing the EV charging time by providing fast charging rates. Three levels of EV charging (shown in Fig. 1.1) are undergoing research and development in the US. The EV charging levels are classified according to their power charging rates.

Overnight charging takes place in level I, as the EVs are plugged to a convenient power outlet (120 V) for slow charging (1.5-2.5 kW) over long hours. The main concern of level-I is the long charging time, which renders this charging level unsuitable for long driving cycles, when more than one charging operation is needed.

Moreover, from the electrical grid operation point of view, the long charging hours at night overloads the distribution transformers as they are not allowed to rest in a grid system with high number of connected EVs. Level-II charging requires 240 V outlet; thus, it is typically used as the primary charging means for private and public facilities. This charging level is capable of supplying power in the range of 4 - 6.6 kW over a period of 3 - 6 hours to replenish depleted EV batteries. The time required is still the main drawback in this charging level.

Additionally, voltage sags and high power losses in an electrical grid system with a high penetration of level II charging are some of the challenges that are facing its widespread. Control and coordination in level II would reduce the negative impacts of level-II charging; however, this requires an extensive communication system to be adopted. In general, both levels-I and II require single phase power sources with on-board vehicle chargers. On the contrary, three-phase power systems are used with off-board chargers for level III fast charging rates (50-75 kW). The use of fast charging stations significantly reduces the EV charging time to less than half an hour for a complete charging cycle. Additionally, a widespread deployment of fast EV charging stations across the urban and the residential areas would eliminate the EV range anxiety concern. However, the high power charging rates required over a short interval of time for level-III impose a high demand on the electrical grid.

The current grid infrastructure is not capable of supporting the desired high charging rates of level-III. Thus, achieving fast charging rates while solely relying on the electrical grid does not only require the improvement of the charging system, but also the improvement of the electrical grid capacity. Additionally, drawing large amounts of current from the electrical grid will increase the utility charges especially at the peak hours and consequently will increase the system cost.


A) Level – I Charging B) Level – II Charging C) Level – III Charging

Figure 1.1. Three levels of chargers for EV charging stations

This method proved to be successful by simulation and experiment in charging EVs different amount of energy based on priority. Further investigation of this method can be carried out to reduce the charging cycle time, and study the effect of constant switching on the battery lifetime.

2. PROBLEM IDENTIFICATION AND OBJECTIVES

The overall electric powertrain with a single integrated power electronic converter is illustrated in Fig. 1. In this structure, the charger and the bidirectional dc/dc converter share the same power stage as charging and propelling do not happen at the same time. As a result, overall cost, weight, and volume of the power electronic converter can be reduced effectively through reducing the number of switches, sensors, and large volume energy storage elements such as inductors.

Growing concern on climate change due to greenhouse gas emission has raised the need for alternate sources of energy with minimum pollution. It has contributed to the concept of electrification in transportation that has led to the increase in popularity of Electric Vehicles (EVs). But with the deployment of more EVs on the road, charging of the vehicle will be strenuous if electric grid power is used. 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 electric 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.

In this chapter, we propose a grid-assisted EV smart charging system. Different charging strategy and power management for EV charging station are reviewed in the literature depending on the various energy sources and EV demand. The approach introduces forecasted PV system and projection of EV pattern according to collected data. In EV 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

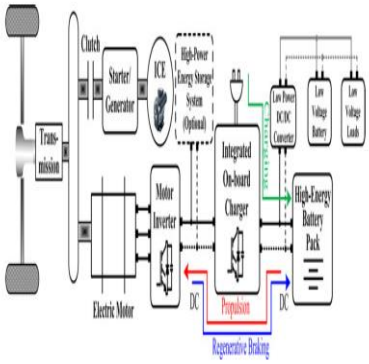

Fig. 2.1. System level structure of a parallel powertrain PHEV with on-board integrated battery charger

3. ELECTRICAL VEHICLE CHARGING SYSTEM

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 power flow strategy. Solar PV acts as the primary source to charge all the connected EVs in the charging place. Since the power from PV at night is not there, a battery as an energy storage device is provided to charge the EVs connected in the charging station. Whenever there is a deficiency in the power output of solar or BESS to charge the EVs, required amount of power will be taken from the AC grid ensuring continuous operation of charging station throughout the day.

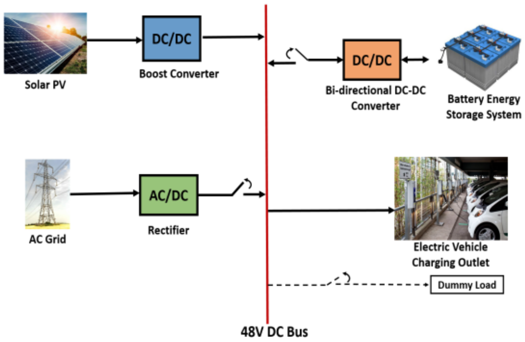

Fig. 3.1. Layout diagram of proposed charging station

Fig. 3.1 gives the block diagram of the proposed EV charging station. As per Bharat EV specifications, a 48V DC bus with 3kW power outlet for each EV is considered for the charging station. In this paper, a charging station with 5 power outlets for charging 5 EVs at a time is adopted for the design of proposed work.

The Overall System Architecture

The conventional architecture of a PV/battery grid tied system along with the power flow direction in the power electronic interfacing systems are shown in Fig. 3.2. However, the architecture of the PV/battery grid-tied system proposed here in this dissertation is configured based on the power flow management system findings.

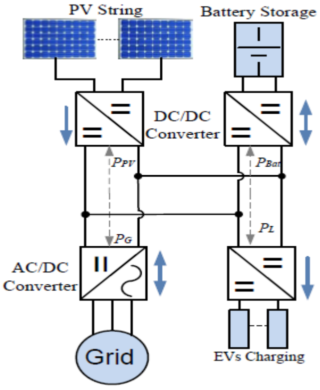

Figure 3.2 a conventional configuration for PV/battery grid tied systems

As can be shown in Fig. 3.2, the grid should be capable of supplying power to the DC system, which is composed of the storage batteries and the EVs. Consequently, the AC/DC rectifier is required to control the grid power factor that yields an efficient operation and a lower current stress.

$$SOC = \frac{(C_{\max} - C_{\text{used}})}{C_{\max}} \quad \ldots\ldots\ldots\ldots. (3.1)$$

Where C_{max} is the nominal rated C/3 capacity of the pack in A-h and Cused is the capacity of the pack in A-h that has been used since the pack was fully charged. C/3 is the capacity rating where the entire charge of the pack is discharged in 3 hours. The safe operating SOC range varies with different battery chemistries but is forced to stay over the constant range of 0.2 to 1 for this study. For most battery chemistries, the battery pack starts to be damaged at a SOC less than 0.2.

Electric Motor: - The electric motor, often referred to as simply the motor, converts' electrical energy from the battery pack to mechanical power into the CVT. The electric motor can also be used in reverse as a generator, converting mechanical energy from braking into electrical energy to be used to charge the battery pack. There are two main types of electric motors used in HEVs. The first is permanent magnet motors, using a permanent magnet to create the magnetic field needed to produce power. The second is an induction motor, which uses current to create the magnetic field. This study investigates only permanent magnet motors, the more common of the two in HEV applications.

Power Electronics: - Since the battery pack is basically a constant voltage device, a motor controller is needed to vary the current so that the motor produces the necessary torque. The power electronics are typically designed to the specific characteristics of the electric motor and are typically comprised of a microprocessor, power switching semiconductors, and a thermal management system.

4. PROPOSED TOPOLOGY

Operation and Control of Charging Station

Modes of Operation

Mode 1: PPV > Ptot and SOCBESS < max SOCBESS

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.

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.

Mode 3: PPV < PTot
Due to rain or cloudy condition, if the power harvested from the solar PV is lower than the power required by the EVs for charging, then the deficient power will be taken from the AC grid by connecting it to the DC bus.

Mode 4: PPV = 0 and SOCBESS > minSOCBESS
At night conditions, when there is no solar output, BESS provides energy for charging the EVS in the station by maintaining the minimum SOC in the battery.

Mode 5: PPV = 0 and SOCBESS < minSOCBESS
When the current SOC of BESS is less than its minimum SOC, then the required power for charging the vehicles will be taken from the AC grid by connecting it to the DC bus.

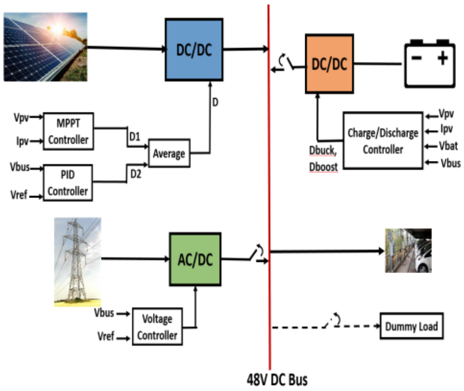

Fig. 4.1 EV charging station model with controllers

Here, two types of control such as for power management and for making the DC bus voltage constant are demanded for the presented work. Fig. 4.1 shows the model with adopted control topology for the charging station.

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 used for making the DC bus voltage constant at 48V.

DC bus voltage Vbus, is 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.

Current Control for Bi-directional Converter
Whenever there is excess power in the solar, the battery storage system is to be charged and at night this is to be discharged to supply power for the EVs. Here, current control strategy is adapted for the charging/discharging of the BESS. When the battery is charging, the duty ratio of the converter in Buck mode is given in below equations:-

$$I_b = \frac{P_{PV} - P_{tot}}{V_{bat}}$$

$$I_{charging} = \frac{P_{PV} - P_{tot}}{V_{bus}}$$

$$D_{buck} = \frac{I_{charging}}{I_b}$$

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 Dboost is given as the duty ratio.

$$I_b = \frac{P_{tot} - P_{PV}}{V_{bat}}$$

$$I_{discharging} = \frac{P_{tot} - P_{PV}}{V_{bus}}$$

$$D_{boost} = 1 - \frac{I_{discharging}}{I_b}$$

- Voltage Control for Rectifier

Using a PWM rectifier, voltage at DC bus is made constant at 48V by comparing it with Vbus and reference voltage 48V.

5. SIMULATION AND RESULT DISCUSSION

A lookup table of irradiance and temperature for a day is given as the data to the PV panel block in MATLAB/Simulink. Fig. 5.1 shows the extreme 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 selected PV array.

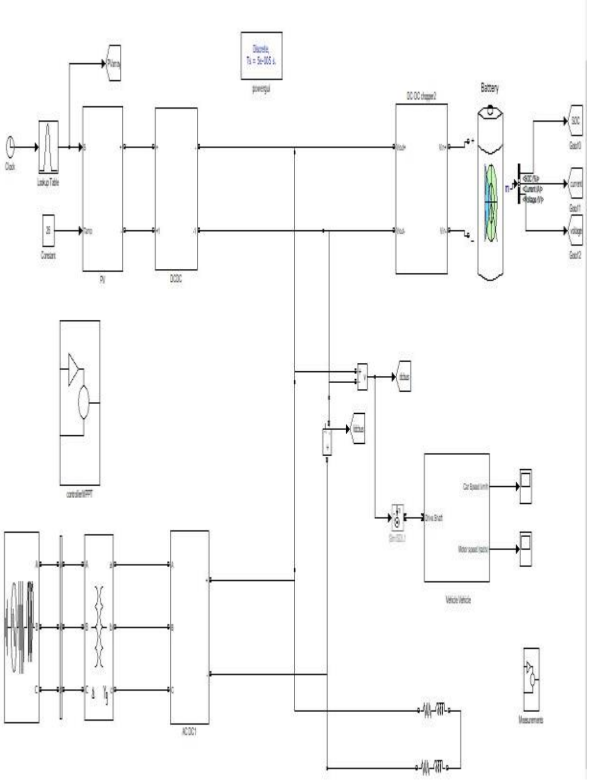

Fig 5.1- Proposed system using Matlab-Simulink

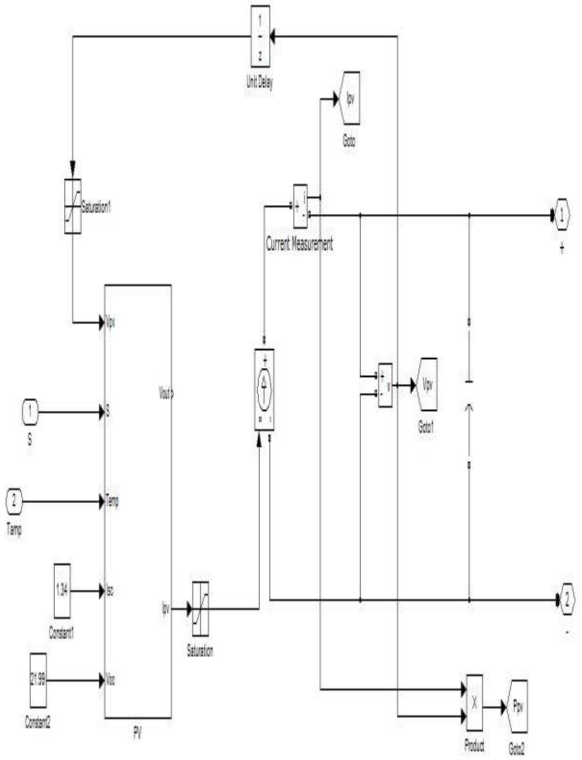

Fig 5.2- Matlab Simulation of Solar PV system

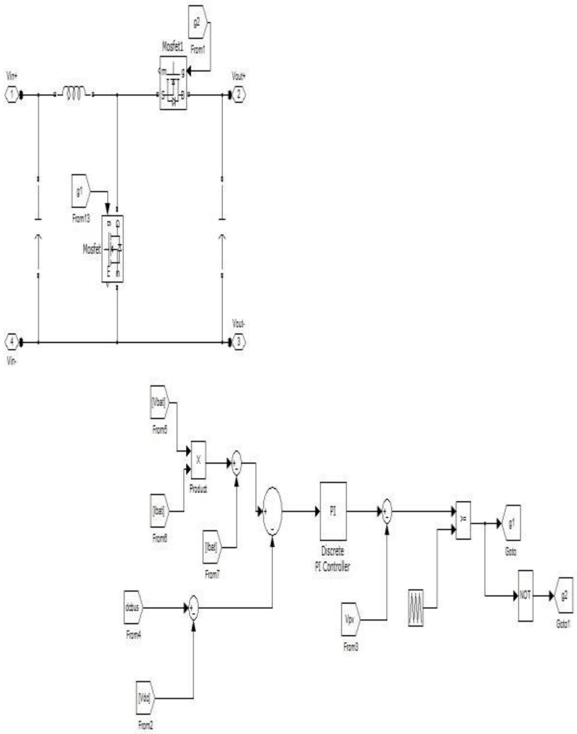

Fig 5.3- DC to DC Chopper Control for E.V

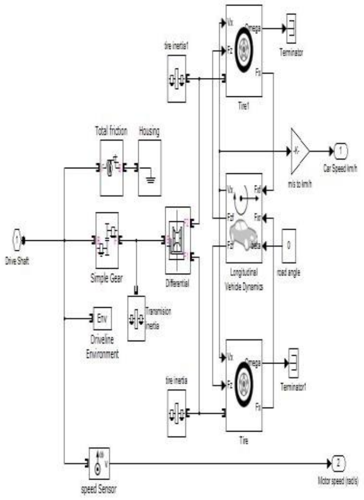

Fig 5.4- Matlab Simulation of E.V Model

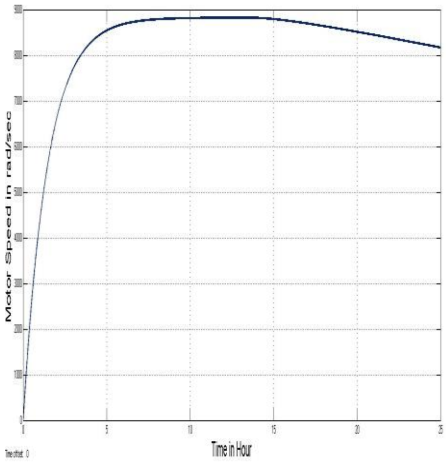

Fig 5.5- Motor Speed in Rad/Sec

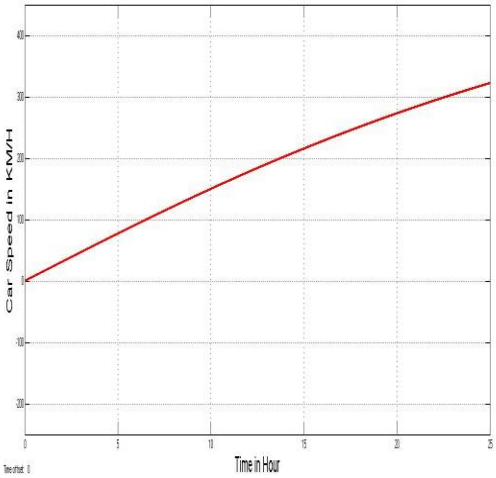

Fig 5.6- Car Speed in Km/H

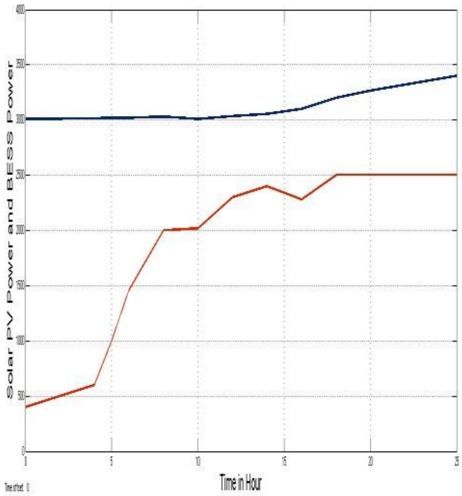

Fig 5.7- Solar PV and BESS Power

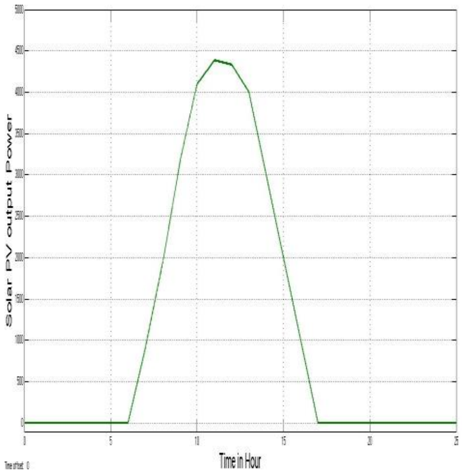

Fig 5.8-Maximum power harvested from the PV array

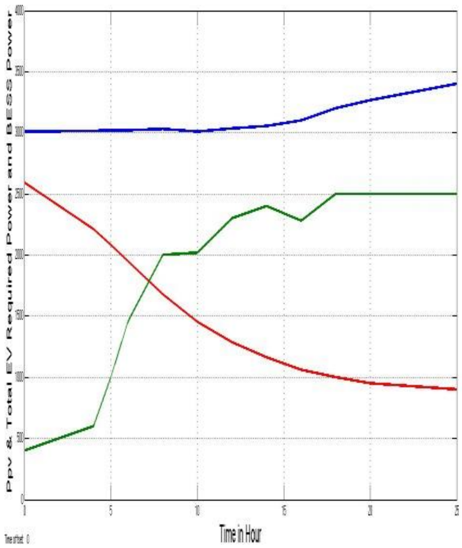

Fig 5.9-Power from solar and total power required for EVs and BESS power for case 1

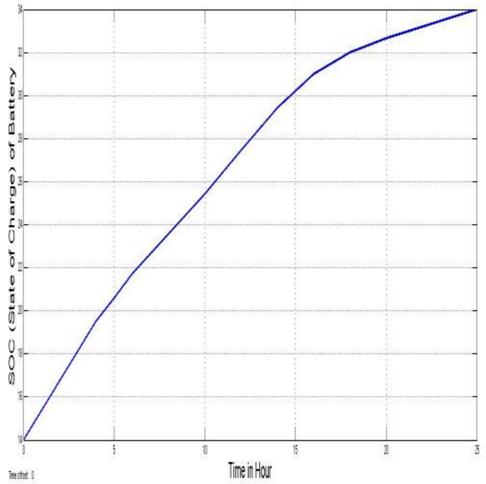

Fig 5.10-Electric Vehicle charging for case 1

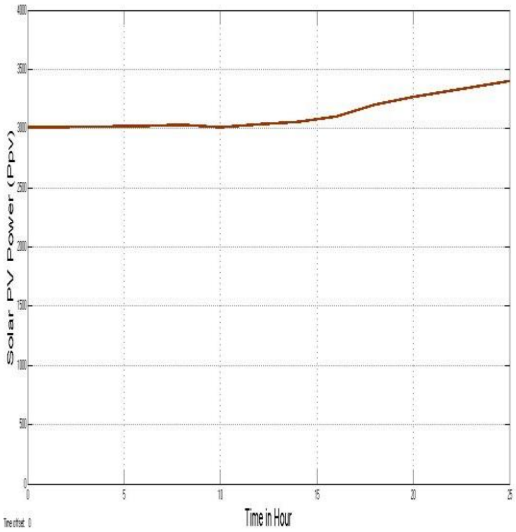

Fig 5.11- Solar PV extracted Power

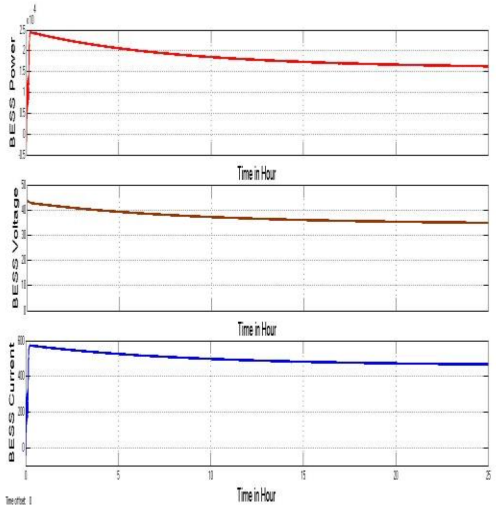

Fig 5.12- BESS output Parameters

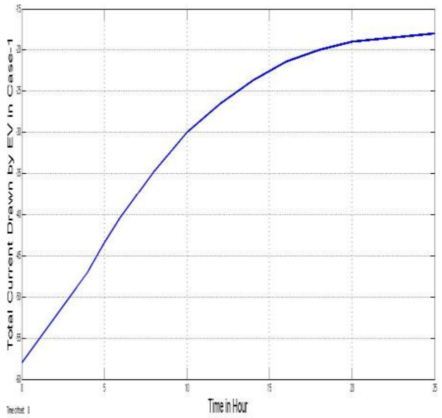

Fig 5.13-Total current drawn by EVs for case 1

6.4.2 Case-II

In this work, for considered 2 hours of operation, solar output increases from 3050W to 4000W. In simulation study, the power needed 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 is shown in below Simulation Results.

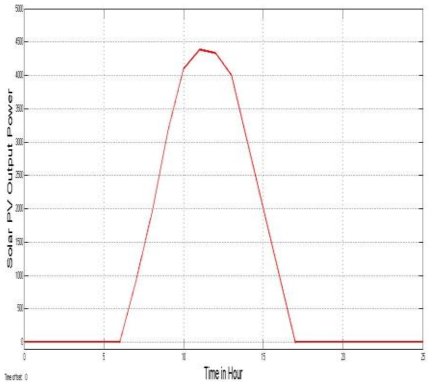

Fig 5.14- Maximum power harvested from the PV array

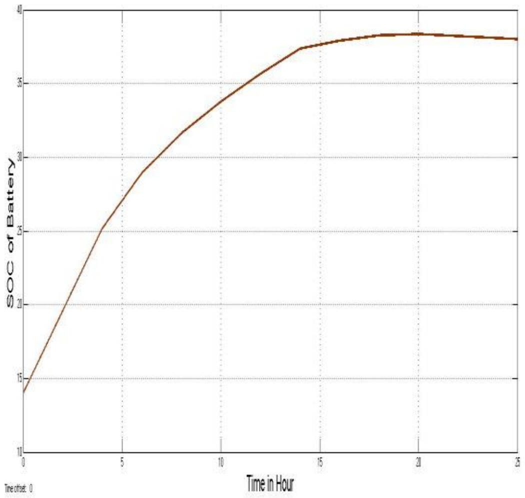

Fig 5.15- Electric Vehicle charging for case 2

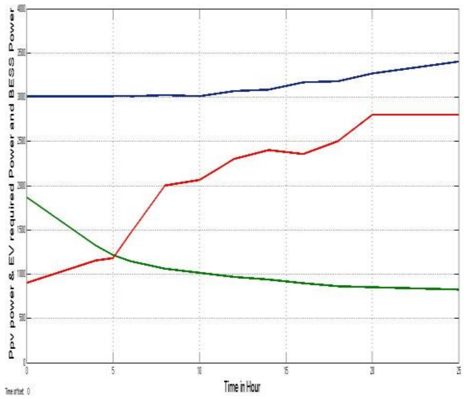

Fig 5.16-Power from solar and total power required for EVs and power BESS for case 2

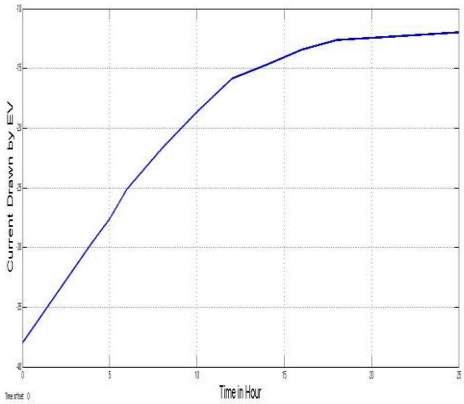

Fig 5.17-Total current drawn by EVs for case 2

6. CONCLUSION

This paper discussed Time-multiplexing method, a strategy to charge EVs from solar energy. The integration of various energy sources (besides the PV), for example fuel cell, wind turbines and stand–by battery to the smart grid and grid stability is also a possible area to be investigated. Although this integration increases the capital cost, it may be economical when long term running cost is considered. These are interesting topics that provide exciting further research opportunities in this area. The operation of charging station as standalone generator with good quality of the voltage, has been verified by the presented results. Matlab Simulation is successfully done for the proposed system with different operating modes and case study analysis. The Matlab Simulation of Electrical Vehicle Charging station based on Solar PV is successfully developed with multiple sources of Fuel cell and Main utility grid supply.

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