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System Design for a Solar Powered Charging Network

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***Abstract*— In smart society, Home Photovoltaic System (HPS) was implemented with energy storages which can provide power for distribution grid. Conversely, the price of energy storages is high. By considering the various parameters in the smart city and limitations in the Renewable Energy Storages (RES) generation, it is significant challenge to optimize the charging service for the requirement for Electric Vehicles. In this paper, we propose the solar powered charging station using power management scheme. Here the power is generated from each charging station, which is efficiently utilized. This reduces the shortage of power in charging stations and is more convenient for charging the EVs in cloudy areas where there is less solar irradiance and temperature. The power management and conservation can be effectively monitored, and reduce the dependency on the grids. The installation and maintains of charging stations is comparatively less compared to the construction of power grids. As it is a conservation of solar to electricity the entire process is eco-friendly.**

***Index Terms*— Smart Society, Electric Vehicles, Power grids.**

I. INTRODUCTION

With the rapid growth of renewable energy like 'Solar Energy', 'Hydro Power', 'Wind Energy' in the smart society improves the energy efficient vehicular networks. Renewable Energy source is one of the energy entities for generation and storing [1],[2],[3],[4]. The consumed energy exchange energy with externally and internally entities like main grid to electric vehicles. The promising approach of EV is the less gas emissions with less fuel calamity [5]. EVs operate both in the mobile energy and flexible loads in the bidirectional power grid which indirectly reduces the peak valley differences [6]. EV annual growth of the 'International Energy Agency' will be more than 20% prior to 2020 [7]. It could be most cost effective in the power grid in the occurrence of SC [8],[9],[10]. Micro Grids systems powered with an DER which are small in number particularly in RES [11]. Theses micro grid serve a very minute geographic part of the SC. DER is powered with a variety of RES which are maintained by their aggregators [12], [13]. Demonstration of effective practical construction of RE generation system (i.e PV), is shown on the roof of building especially in cities areas [14]. Charging of EV frame work generally consists of 3 energy-parties: i.e., (i) main grid, (ii) EVs, (iii) micro grids. Conversely, in the literatures review only two interactions of micro grids with EVs or with main grid shown in [15],[16]. Hence it is a challenging task to design best charging system for both main grid and micro grids with providing hygienic energy with integration of RES and EVs for the SC. Due to the heavy malicious operations in the vehicle that threaten the user privacy such as fabrication, false information inoculation, node imitation and privacy seepage via malicious exploitations [17], [18].

In order to protect communication network trust-models are identified in opposition to cyber attackers and malicious operators. For the identification of the various malicious-operator to safe guard the charging system

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numerous authors have mentioned the integrated EVs with smart grid [19],[20],[21]. A solar charger is a charger that employs solar energy to supply electricity to devices or 10/38 They are generally portable. An electric vehicle charging network is an infrastructure sys charging stations to recharge electric vehicles. Many government, car manufacturers, and charging infrastructure providers sought to create networks.

Nomenclature

AC	Alternating Current
BC	Buck Converter
DC	Direct Current
DER	Distributed Energy Resources
EV	Electric Vehicles
EVCS	Electric vehicle charging station
HP	Hydro Power
HPS	Home Photovoltaic System
MG	Micro Grids
MPPT	Maximum Power Point Tracking
PV	Photo Voltaic
P&O	Perturb and Observer
PWM	Pulse Width Modulation
RES	Renewable Energy Storages
SC	Smart City
SOC	State of Charge

II. Related Work

A. Smart City

A speedy growth of energy system in the smart city, Zhang et al. implemented 3 party architecture with 2 consumer centered scheme ' involving with EVs' and 'SCs' for efficient energy scheme in SC [22]. Tushar et al. presents enticement based system for RES in SC to manage shared ability controller [23]. In order to reduce the electricity bill, Liu et al. proposed the novel energy scheme for SC by using entropy optimization method in smart house energy development [24]. For operational cost minimization, Tian et al. developed 2 level hierarchical frameworks for the micro grid society to smart environment [25]. Load forecasting and stochastic programming is adapted to EVs charging especially in office buildings with the integration of solar systems [26]. Lyapunov optimization scheme is implemented to apply power through renewable energy sources to EV with cost effectively [27].

B. Solar powered electric vehicle charging station for work places

Mouli, G. C., et, al. Proposes the electric charging vehicles at Netherlands using solar energy. Their experiment success with maximum energy with minimal PV panels. Their priority mechanism is proposed to facilitate the charging of multiple EV from a single EV-PV charger. The feasibility of integrating a local storage to the EV-PV charger to make it grid independent is evaluated. The optimal storage size that reduces the grid dependency be 25% is evaluated.

C. Optimal PV EV charging in workplace using PV

The integration of photovoltaic (PV) systems and electric vehicles (EVs) in the built environment including at workplaces, has increased significantly in the recent decade and has posed new technical challenges for the power system, such as increased peak loads and component overloading. Several studies show that improved matching between PV generation and EV load through both optimal sizing and operation of PV-EV systems can minimize these challenges. Fachrizal, R. et,al., presents an optimal PV-EV sizing framework for workplace solar powered charging stations considering load matching performances [30]. The proposed optimal sizing framework in this study uses a novel score, called self-consumption-sufficiency balance (SCSB), which conveys the balance between self-consumption (SC) and self-sufficiency (SS), based on a similar principle as the FI-score in machine learning. A high SCSB score implies that the system is close to being self- sufficient without exporting or curtailing a large share of local production. The results show that the SCSB performance tends to be higher with a larger combined PV-EV size. In addition to presenting PV-EV optimal sizing at the workplace charging station, this study also assesses a potential SC and SS enhancement with optimal operation through smart charging schemes. The results show that smart charging schemes can significantly improve the load matching performances by up to 42.6 and 40.8 percentage points for SC and SS, respectively. The smart charging scheme will also shift the combined optimal PV-EV sizes. Due to its simplicity and universality, the optimal sizing based on SCSB score proposed in this study can be a benchmark for future studies on optimal sizing of PV-EV system, or distributed generation-load in general. The depleting fossil fuel and growing environmental concern have opened the doors for clean and green energy development using renewable energy sources [31]. Grgic, D et, al investigates the pandemic impact on the electric vehicle (EV) monitoring framework designed for analyzing and tracking EV charging data in the Croatian electric vehicle charging station grid [32]. The developed framework encompasses multiple features of the EV charging grid behavior, notably: (1) global predictions of the utilized energy, (i) number of charging vehicles, (iii) total time spent while charging. In this paper, we analyze framework performance and key performance indicator (KPI) values during the pre-lockdown period, soft-lockdown period, and post-lockdown lift-off period to show how the pandemic situations and governmental lockdown regulations can impact EV grid performance and EV charging business. Li, C., Shan et, al proposes the technical and economic feasibility of hybrid solar photovoltaic (PV) and wind turbine (WT) power systems for environment-friendly electric vehicle (EV) charging stations at five different locations in China [33]. The HOMER Pro 3.14 software using a derivative-free algorithm has been used to search for the optimal scheme of the charging stations. The results show that the best solution considering renewable energy charging stations in the five regions is the hybrid PV/WT/battery EV charging station. Singh, A., et, al presents results from the design of a solar-powered EV charging station for an Indian context [34]. The analysis, based on the number of cars charged annually, the monthly variation in energy generation, the investment cost, and the decrease in carbon dioxide (CO2) emissions using different module technologies for six Indian cities, has been deliberated. The results indicate that an off-grid 8.1 KWp system with two days of battery autonomy has the fewest unused energy losses, with a good performance ratio (PR). It can completely charge around 414 vehicles of 30 kWh battery capacities annually. This would help to reduce annual CO2 emissions by approximately 7950 kg. The overall system has better energy generation and economy when mono crystalline modules are used.

III. SYSTEM MODEL

This section presents network model proposed in the work. The notations used in the network model are presented in the table 3.1. PV based Electric vehicle charging station has functional blocks pv array, MPPT, buck converter and battery. PV array converts the incident solar energy into electric current. For the simulation we are using is a battery to simulate the charging of an EV. The MPPT used in our system is P&O which is one of the most effective one. The buck converter is used for DC to DC conversion as the current generated by the PV cell is DC, which is the same form of current required to charge the lithium ion battery so there is no need for the conversion of current. This reduces the circuit complexity. Figure 3.1 shows the block diagram of electric vehicle charging station (EVCS) proposed in the system.

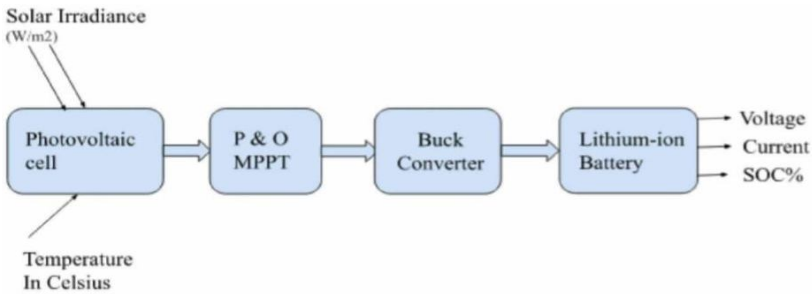

Figure: 1 System model of electric vehicle charging station

A. PV Array

A photovoltaic converts the visible light into direct current (DC). Photovoltaic cells are an integral part of solar-electric energy systems, which are becoming increasingly important as alternative sources of utility power. With our implemented software (MATLAB), the photovoltaic network takes irradiance and temperature as input and generates the corresponding voltage and output current concerning the given input. The radiance and temperature data are taken from 6 am to 6 pm a day because this is when the irradiance is enough for the photovoltaic array to provide sufficient output. Figure 3.2 shows the irradiance data in a day.

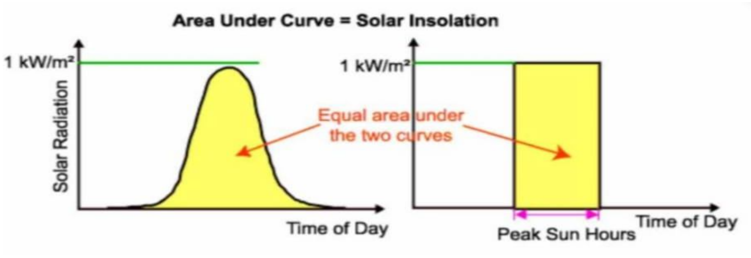

Figure: 2 Irradiance data in a day

B. MPPT charge controller

An MPPT is an electronic DC to DC converter that optimizes the match between the solar array (PV panels), and the battery bank or utility grid. They convert a higher DC output voltage from solar panels (and some windmills) to the lower voltage needed to charge the batteries. An MPPT takes that 17.6 volts at 7.4 amps and converts it down so that what the battery gets is now 10.8 amps at 12 volts. In the proposed system, the MPPT used is Perturb and Observer (P&O) Maximum Power Point Tracking. The P&O method is used to track the MPPT. In this technique, a minor disturbance is introduced to induce the power variation of the PV module. The PV output power is measured periodically and compared to the previous power. If the output power increases, the same process is continued, else the disturbance is reversed. In the proposed algorithm, the disturbance is provided to the PV module or the network voltage. The voltage of the PV module is increased or decreased to verify whether the power is increased or decreased. When a voltage increase results in a power increase, this means that the operating point of the PV module is to the left of the MPPT. Therefore, further disruption is necessary for the right to reach MPPT. Conversely, if an increase in voltage leads to a decrease in power, this means the operating point of the PV module is on the right of the MPPT and hence further perturbation towards the left is required to reach MPPT. The flow chart of the adopted P&O algorithm for the charge controller is given in Figure 3.3. When the MPPT charge controller is connected from the PV module to the battery, it measures the PVand battery voltages. Once the battery voltage is measured, it determines if the battery is fully charged or not. If the battery is fully charged (12.6V on the battery terminal), it stops charging to avoid overloading the battery. If the battery is not fully charged, the battery will start charging by turning on the BUCK converter. The micro controller will then calculate the existing power P at the output by measuring the voltage and current, and compare this calculated power to the previous measured power P. If Ps is greater than Paa. The PWM duty cycle is increased to extract maximum power from the PV panel. If Pew is less than Pou, the duty cycle is reduced to ensure the system moves back to the previous maximum power. This algorithm is easy to implement, simple, and cost- effective with great accuracy.

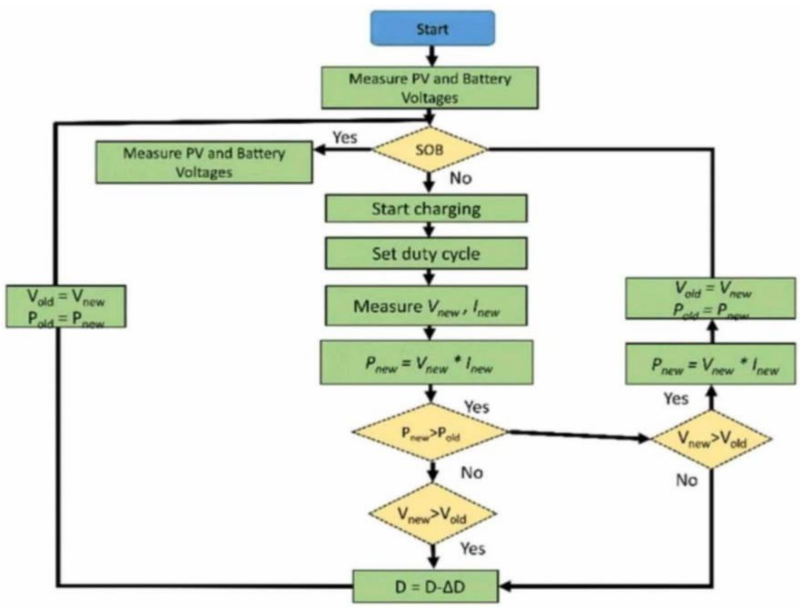

Figure: 3 Flow chart of Perturb and Observer Maximum Power Point Tracking.

C. BUCK converter

Buck Converter is a type of chopper circuit that performs a switch from the bottom of the installed DC signal. The combination of solid-state power electronics device with freewheeling diode the creates a connection with the low- pass LC filter to minimize current ripples or voltages. This assists in the production of controlled de output. The freewheeling diode is used to protect the circuit from unusual damage caused due to abrupt reduction in the current flowing through the circuit. It is also known as a Fly back diode and forms a connection across the inductor to remove the Fly back voltage generated across it.

D. Li-ion Battery

Lithium-ion cells have ability to store and release energy thousands of times. Each of those cells consists of two electrodes, a metal cathode and a graphite anode separated by a liquid electrolyte. While the battery is charging, lithium ions flow through the liquid from the cathode to the anode, filling up spaces between the graphite layers like wooden blocks fitting into a Jenga tower. Thus, in our work we are using a lithium-ion battery with a nominal voltage of 12v to simulate the charging of an electric vehicle. And the capacity of the battery is set to about Ah. Battery voltage and current are regularly monitored along with the battery percentage (SOC). Figure 3.6 shows the simulink model of single PV- charging station.

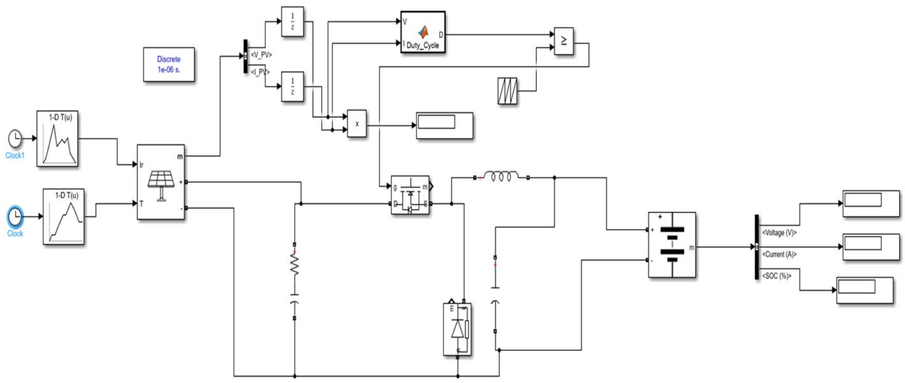

Figure 4: Simulink model of single PV- charging station

IV. PERFORMANCE EVALUATIONS

A. Simulation Setup

In simulation set up, for a single charging station, the modules are connected as follows initially the PV Array is connected to an MPPT Controller and the output of which is connected to a Buck converter which is a DC-DC step-down converter, and the output is connected to the Li-ion Battery where the power is stored and through a scope/display the Voltage Current and State Of Charge (SOC) % of the battery can be observed. In the same way, a number of charging stations are built and are connected to a centralized battery where power is stored and transferred back to a respective charging station based on EV traffic. The final network is constructed and connected through the transmission lines. Figure 4.1 shows the equivalent model of the entire circuit using Mat lab code.

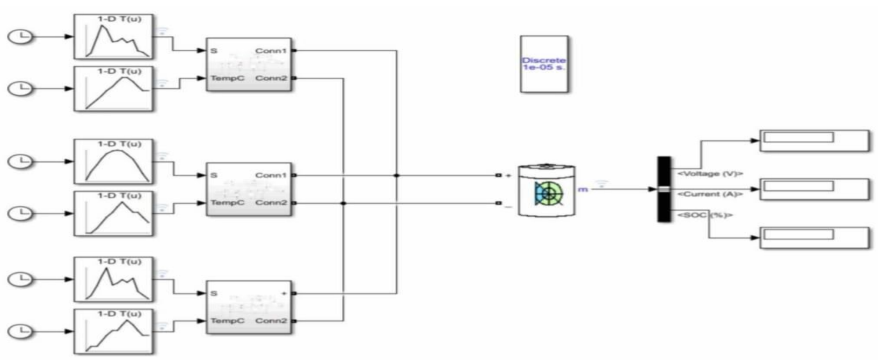

Figure 5: EVCS three network charging station

B. Input Parameters

The input is given to the PV Array as Solar Irradiance and surrounding Temperature as parameters. Figure 4.2 shows the datasheet, as well as a graphical representation of the Solar Irradiance and Temperature, collected on a real-time basis.

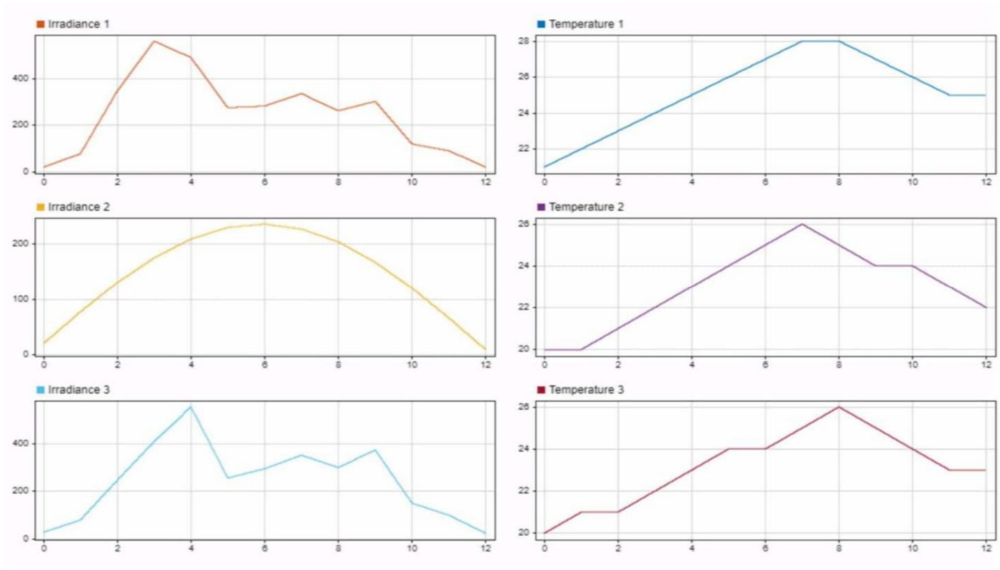

Figure 6. Graphical representations of inputs

	A	B	C	D	E	F	G
1	Time	Irr1	Irr2	Irr3	Temp1	Temp2	Temp3
2	6	21	20	28	21	20	20
3	7	78	77	79	22	20	21
4	8	347	130	246	23	21	21
5	9	561	175	409	24	22	22
6	10	491	209	555	25	23	23
7	11	276	230	256	26	24	24
8	12	283	236	295	27	25	24
9	13	336	227	352	28	26	25
10	14	263	204	300	28	25	26
11	15	303	167	374	27	24	25
12	16	120	120	150	26	24	24
13	17	91	66	99	25	23	23
14	18	21	9	23	25	22	23

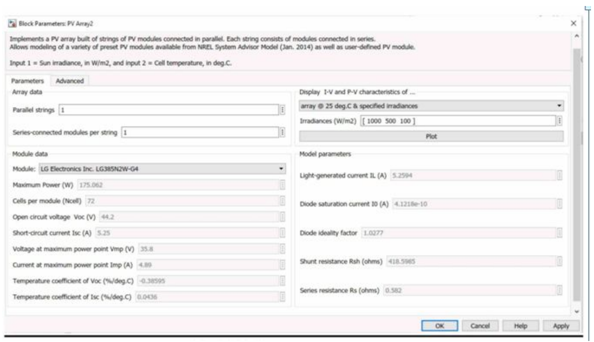

Figure 7: Datasets of input parameters

Figure 8: PV array parameters

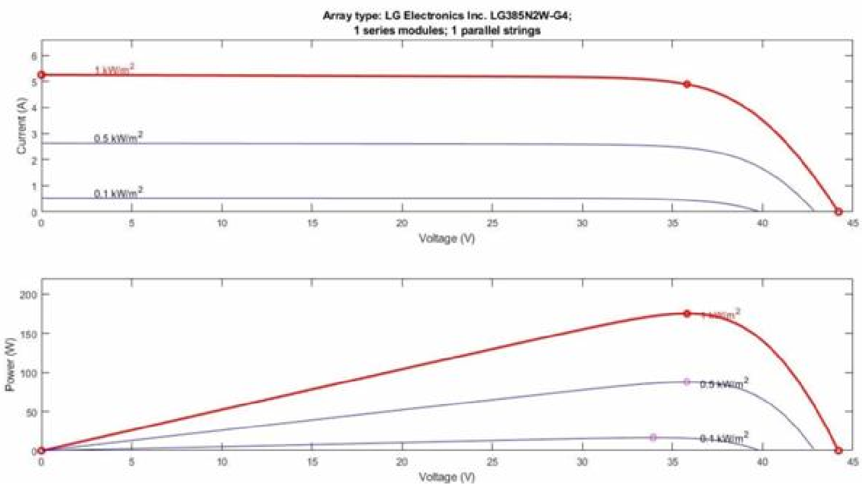

Figure 9: VI and VP characteristics of PV array

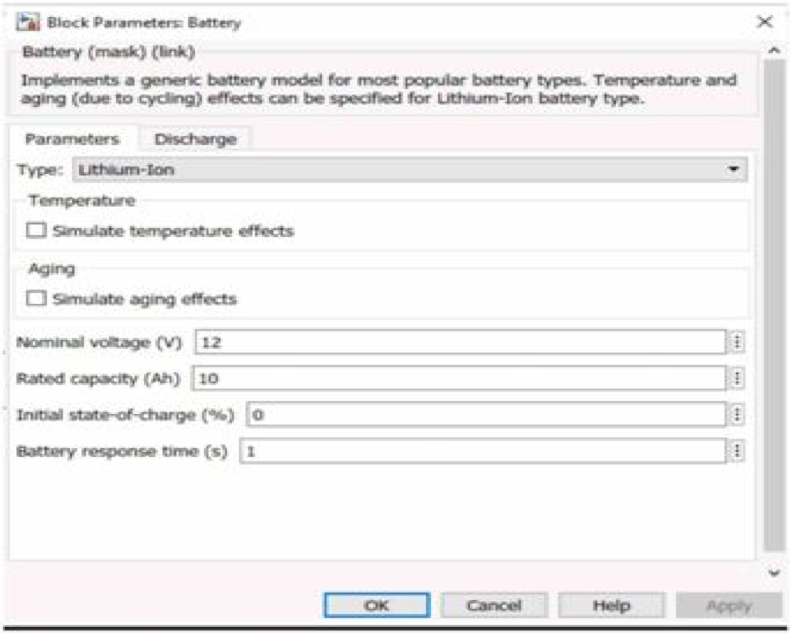

Figure 10: Battery parameters

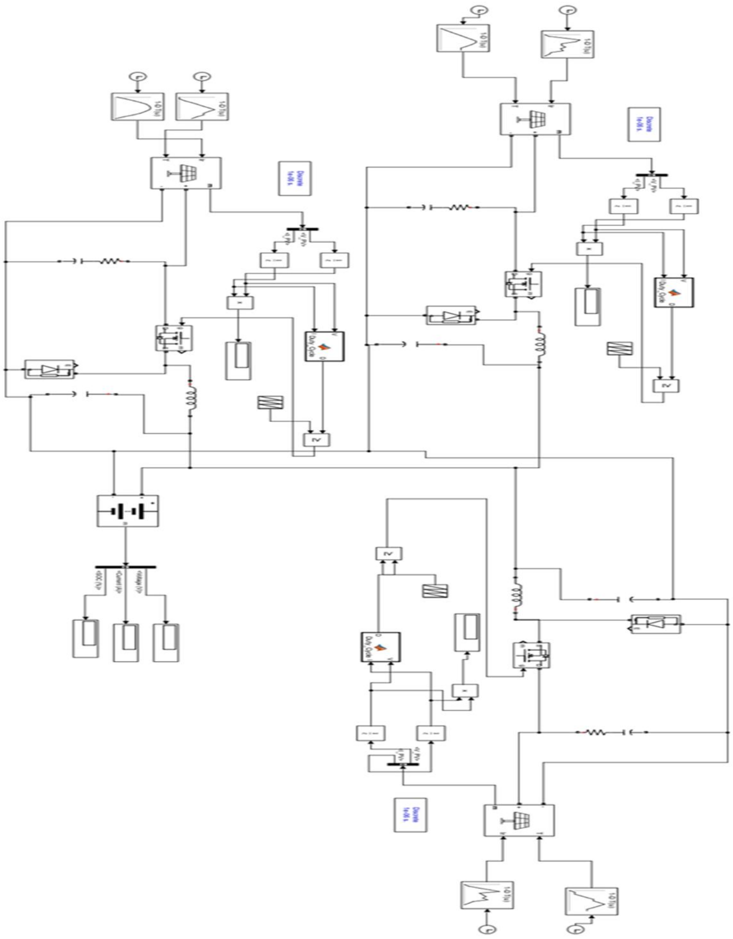

Figure 11: Circuit of PV based EV charging station network

C. Outcome

The outcome of the software implementation of a single charging station is observed, the current produced to charge the battery is minimal. The aim is to create a network of charging stations to significantly increase the power and current produced by the circuit and effectively transfer the power to the required charging station and receive the power if required.

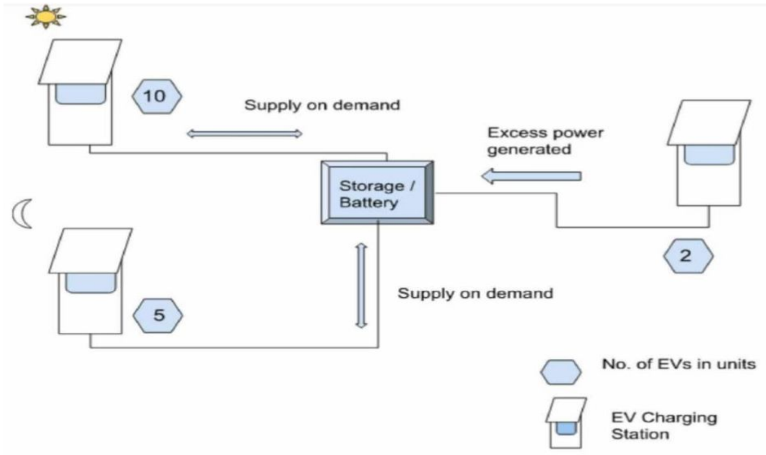

Figure 12: Final implementation of the proposed work

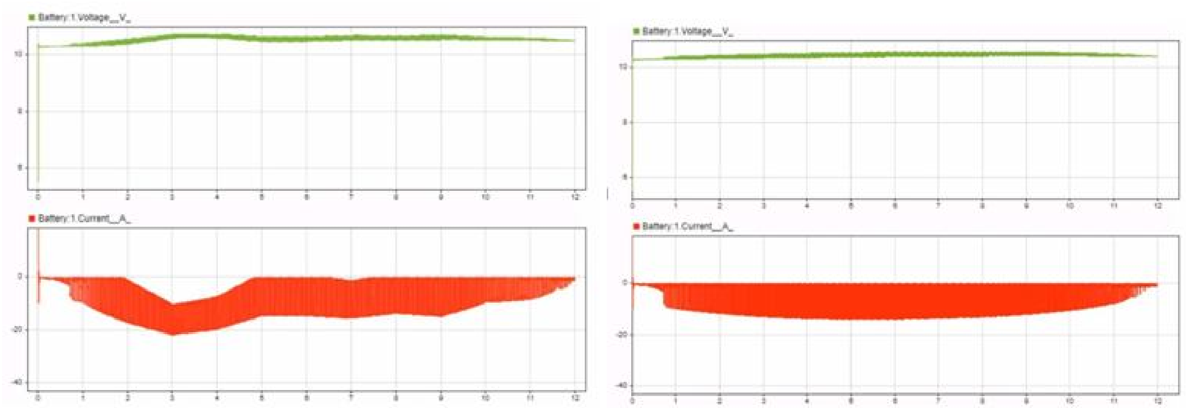

Figure 13 (a): Shows the voltage and current from the output of charging station 1   Figure 13 (b): Shows the voltage and current from the output of charging station 2

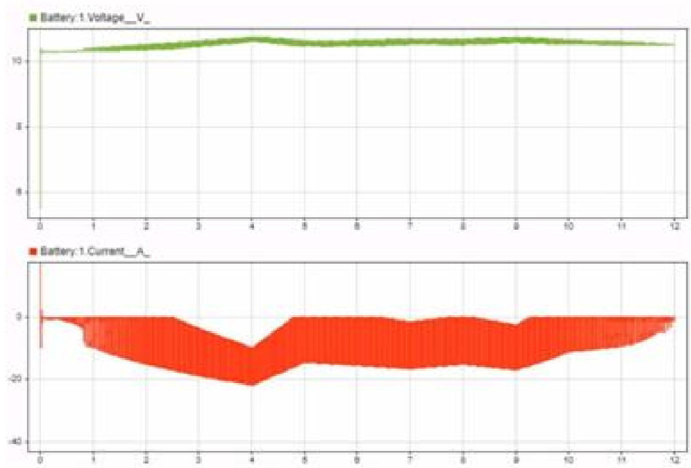

Figure 13 (c): Shows the voltage and current from the output of charging station 3

The figures 4.11 and 4.12 clarifies that voltage is constant in respective charging stations. The only parameter that varies is the current and slow charging is achieved, further by combination of all the three networks fast charging and efficient centralized battery is built and constructed.

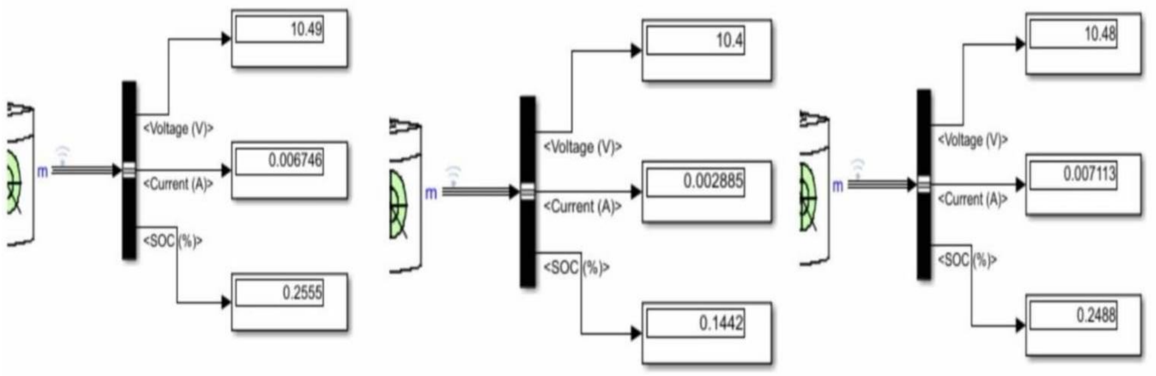

Figure 14 (a)

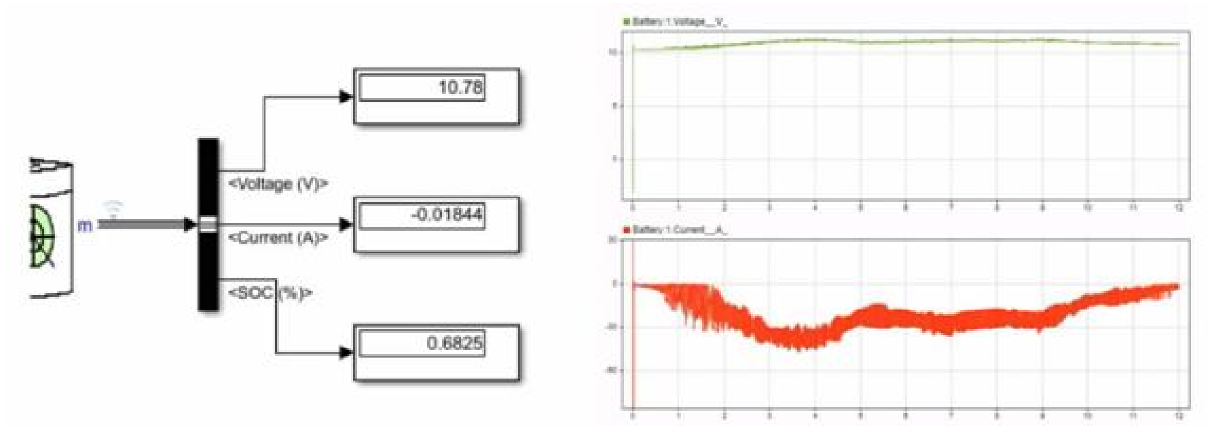

Figure 14 (b): Centralized battery output

Figure 4.9 (a) and (b) represents the output of the combined charging stations where maximum current and power is obtained and desired results and efficiency of the centralized battery is achieved. From the above graphical representations it clearly shows the current is infect negative because of charging the battery as we are supplying the current for charging of battery hence, the current obtained at battery terminal is negative.

V. CONCLUSION AND FUTURE SCOPE

The charging station network is designed to obtain the maximum efficiency of the output current from the centralized battery. There is also an option of storing the excess charge generated from each charging station. As compared to other works our proposition is towards effective energy distribution to the areas having less solar irradiance. This technique can be implemented and utilized effectively in the cases where there is more EV traffic and high demand of charging by means of routing power from less traffic area. In the future scope for a solar-powered charging station network is to revolutionize the way we charge our devices and vehicles while promoting sustainability and reducing our carbon foot print, clean and renewable solar-powered charging stations.

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