IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

ISO 3297:2007 Certified ∺ Impact Factor 7.047 ∺ Vol. 10, Issue 5, May 2022

DOI: 10.17148/IJIREEICE.2022.10573

Photovoltaic Fed Portable Electric Scooter Charging Station for Academic Campus

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Abstract: The fast-growing global vehicle fleet is primarily responsible for global climate change and air pollution; the transportation industry emits about a quarter of all energy-related greenhouse gases, posing a bigger danger to the environment. Adoption of e-mobility solutions is a superior substitute for gasoline-powered internal combustion engine cars in this regard. A innovative option may be a sustainable e-scooter recharging port that is powered by a PV system. Because of the PV system's size limits, a single PV module must provide enough energy to recharge the e-scooter. This study discusses the design, analysis, and execution of an e-scooter PV charger.

Keywords: PV module, Zeta Converter, MPPT algorithm, Half-Bridge Inverter, PWM Controller, PI Controller.

I. INTRODUCTION

Climate change is one of the most pressing issues we face. The transportation industry alone is responsible for around 24% of worldwide CO2 emissions, roughly 29% of global energy demand, and 65 percent of global total oil consumption. As a result, the world around us becomes unstable, resulting in numerous pollutions that contribute to global warming. As a result, switching to e-mobility transports powered by renewable electricity is a necessary development in the transportation industry that helps to minimize greenhouse gas emissions. E-scooters are a low-cost, self-contained mobility solution that can park easily and share lanes normally reserved for bicycles. In metropolitan areas, the use of e-scooters facilitates the use of other modes of transportation (metro, bus, train, etc.), enhancing intermodality and minimizing the usage of private automobiles.

Photovoltaic and wind energy can help the transportation sector become more sustainable. A PV module may be used to recharge an e-scooter, lowering power usage and increasing efficiency. Access to the roof, wiring, and the inability to use the scooter while it is charging are the primary downsides of utilizing a PV charger. The development of charging facilities in tourist-friendly places, as well as the establishment of e-bike parking docks, are among the goals of the promotion and use of renewable energy in the e-mobility sector.

II. LITERATURE REVIEW

Energy usage has been quickly increasing in a number of countries. More over half of all petrol is utilized for transportation, with gasoline vehicles accounting for the greatest share. Automobile exhaust is the primary source of pollution in the environment. The development of electric cars is critical for reducing greenhouse gas emissions since the driving duration of 80% of vehicles is roughly 1 hour per day, according to data, and the energy stored is taken into account. The utilization of solar can help the transportation industry become more sustainable. A PV module may be utilized as a power source to recharge an e-scooter, lowering power usage and increasing overall efficiency.

In this research paper, the main objective of the development and usage of renewable energies in the e-mobility industry includes –
- To determine the preliminary needs and feasibility criteria for PV-powered EV charging stations that will result in increased PV benefits.
- Installation costs are low since there is no need to connect to the AC grid.
- It's transportable (Easy to move in urban and inter-urban environment).
- Multiple e-scooters may be charged at the same time.

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The main theme of this research paper is using the topology of converters, inverters, and controllers to set up a charging station for EV vehicles using the energy of PV modules. This proposed system consists of a PV module, Zeta converter, MPPT algorithm, Half-Bridge inverter, PWM generator, and PI controller. The information collected from the previous year's research paper led to the implementation of different techniques for this project in order to achieve the desired output.

To set up a PV-fed EV charging station, the first thing is to identify the load ratings from which the PV module ratings are fixed. When it comes to PV modules during low or non-sunny times, irradiation may vary and there may be fluctuations in the amount of energy produced. To counter that, various converters such as Buck converters, Boost Converters, Zeta Converters, etc. are available on the market, which will step up the output voltage of the PV module. In this project, the research-made Zeta converter was chosen as an ideal converter due to its efficiency (94%), high response time compared to other converters, and ability to produce accurate waveforms from input to output. Another problem arises when, during the fluctuation in irradiation conditions, to step up the output voltage of the PV module, one has to control the switching of the Zeta converter. This can be achieved by using controllers. A Maximum Power Point Tracking (MPPT) controller is used to track the Maximum Power Point (MPP) for the voltage and current sent from the PV module. MPP is achieved by using the Perturb and Observe (P & O) algorithm, which is commonly used in many systems and will produce the required duty cycle for the switching of the Zeta converter. Therefore, the Zeta converter will step up the voltage from the PV array and send it to an inverter. In this case, a half-bridge inverter is used to convert DC voltage to AC voltage. This AC voltage is given to the load as an output voltage. However, another problem arises when the load voltage is not obtained as desired. When this type of variation occurs in the load voltage or output voltage, one has to tune the inverter circuit. This can be achieved by giving PWM pulses to the MOSFETs of the inverter. Therefore, a PWM generator is used for this purpose. In addition to that, for getting the desired output voltage, the obtained output voltage is given to the PI controller, which generates a reference voltage for the PWM generator to produce the desired pulses for the MOSFET of the inverter. Furthermore, the output on the load is obtained as desired.

This review represents a solar charging station for various electric vehicles, which is commonly used to eliminate the need of nonrenewable energy to charge for all intents and purposes electric automobiles, which is rather significant. This research creates a model that effectively integrates solar power plants with electric vehicles to minimize pollution emissions from the power generating and transportation sectors.

III. METHODOLOGY

The proposed system consist of a PV module, Zeta converter, MPPT algorithm, Half-Bridge inverter, PI controller, PWM generator for setting up an EV charging station.

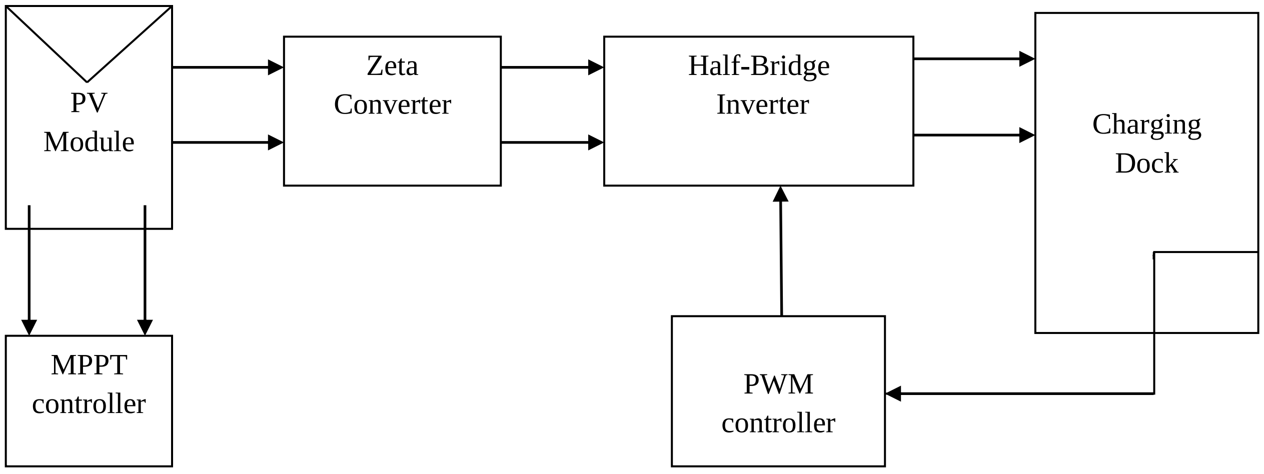
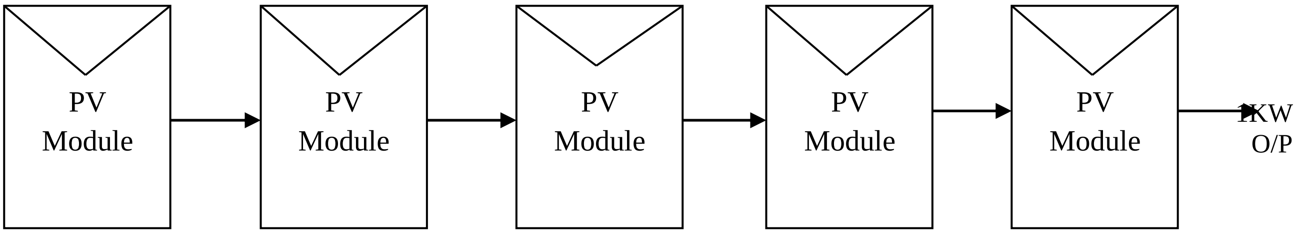


Fig.1. Block Diagram

III. I. PV Module



In this proposed system, the PV module consists of five series-connected PV arrays of maximum power (W) 225V each, which will produce voltage at a maximum power point (Vmp) of 29.3V and current at a maximum power point (Imp) of 7.66A. The solar irradiation is set at 1000 W/m2 and the cell temperature is set at 25 deg. C. Therefore, the maximum power generated from this module during ideal conditions is about 1 KW.

III. II. Zeta Converter

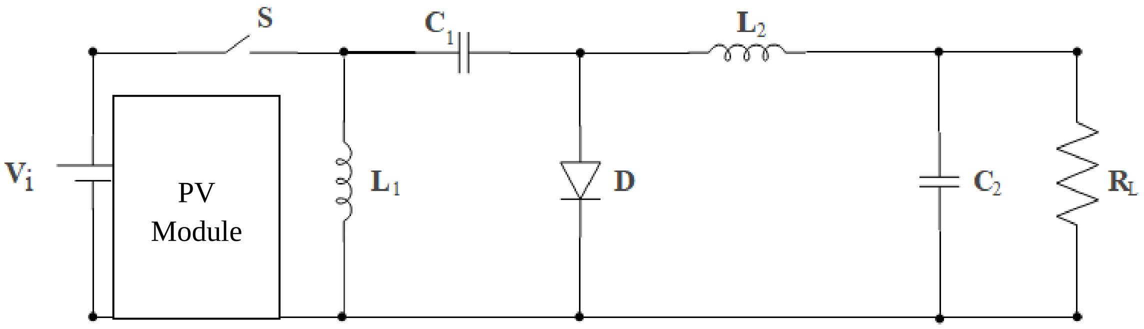


Fig.2. Circuit Diagram of Zeta Converter

The Zeta converter is also known as the inverting Sepic converter**.** It is made up of a MOSFET, two inductors, two capacitors, and a diode. The MOSFET acts like a switch, ON and OFF when the PWM pulses given to the MOSFET that determines the output voltage are adjusted. At first, nothing is turned on, nobody is charged, and nobody's power goes to anyone, but when the MOSFET is turned on, the current tries to flow in the inductor L1 direction. In the starting phase, it opposes the flow of current because it acts as a high resistance compound. After some time, its impedance decreases and the current starts increasing. During this time, the inductor stores the energy. Now the MOSFET is turned off and it induces a flyback voltage, which has a magnitude of

$$V = L \times \frac{di}{dt}$$

Where, L = inductance of the inductor
$\frac{di}{dt}$ = change in current over time

The current direction remains unchanged, the diode becomes forward biased, and the capacitor C1 begins charging through the inductor. Through the work, the voltage of the inductor is DC, but the current provided to the inductor L1 is not constant DC. It decreases continuously, so the capacitor C1 acts as a shock socket. During these cycles, there is no power provided to the load. In the process of the next cycle, the MOSFET is turned on again, and the inductor gets charged. The capacitor discharges power to the load and charges two inductors, L1 and L2. In the next cycle, the MOSFET is turned off. Now the inductor is charging the capacitor and also the inductor L2 is charged. So inductor L2 induces flyback voltage and starts providing power to the load. This is the working principle of the zeta converter.

III. II. I. Design Calculation of Zeta Converter

$$V_{mpp} = 146.5\ v$$

$$P_{mpp} = 1122.19\ w$$

$$I_{mpp} = \frac{P_{mpp}}{V_{mpp}} = \frac{1122.19}{146.5} = 7.66\ A$$

$$D = \frac{V_{dc}}{V_{dc} + V_{mpp}} = \frac{325}{325 + 146.5} = 0.69\ A$$

$$I_{dc} = \frac{P_{mpp}}{V_{dc}} = \frac{1122.19}{325} = 3.453\ A$$

$$L_1 = \frac{(D \times V_{mpp})}{(f_{sw} \times \Delta I_{L2})} = \frac{(0.69 \times 146.5)}{(30 \times 10^3 \times 7.66 \times 0.06)} = 7.33 \times 10^{-3} \cong 8\ mH$$

$$L_2 = \frac{(1-D) \times V_{dc}}{(f_{sw} \times \Delta I_{L2})} = \frac{(1-0.69) \times 325}{(30 \times 10^3 \times 3.453 \times 0.06)} = 16.209 \times 10^{-3} \cong 17\ mH$$

$$C_1 = \frac{(D \times I_{dc})}{(f_{sw} \times \Delta V_{C1})} = \frac{(0.69 \times 3.453)}{(30 \times 10^3 \times 325 \times 0.1)} = 2.444\ \mu F \cong 3\ \mu F$$

$$C_{2,min} = \frac{I_{dc}}{(6 \times \omega_{min} \times \Delta V_{dc})} = \frac{3.453}{(6 \times 2\pi \times 50 \times 325 \times 0.1)} = 56.3653 \times 10^{-6} = 57\ \mu F$$

III. III. MPPT Controller

The main objective of the Maximum Power Point Tracking (MPPT) controller is to step up the irradiance changes and maintain the systems at Maximum Power Point (MPP). The system's power is reduced when the irradiance declines, leading the converter's output power to decrease, which leads to the system's efficiency loss. But, by using the MPPT algorithm, the system will be able to maintain constant efficiency for the overall system. Therefore, to achieve MPP, the Perturb and Observe (P & O) algorithm is used, which will produce the desired duty cycle for switching control of the Zeta converter.

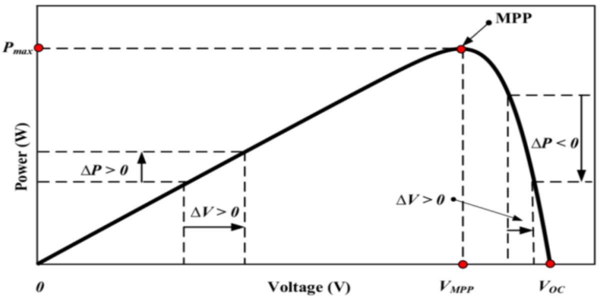


Fig.3. Waveform Illustrating Maximum Power Point (MPP)

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III. III. I. Flowchart of P&O MPPT Controller Algorithm

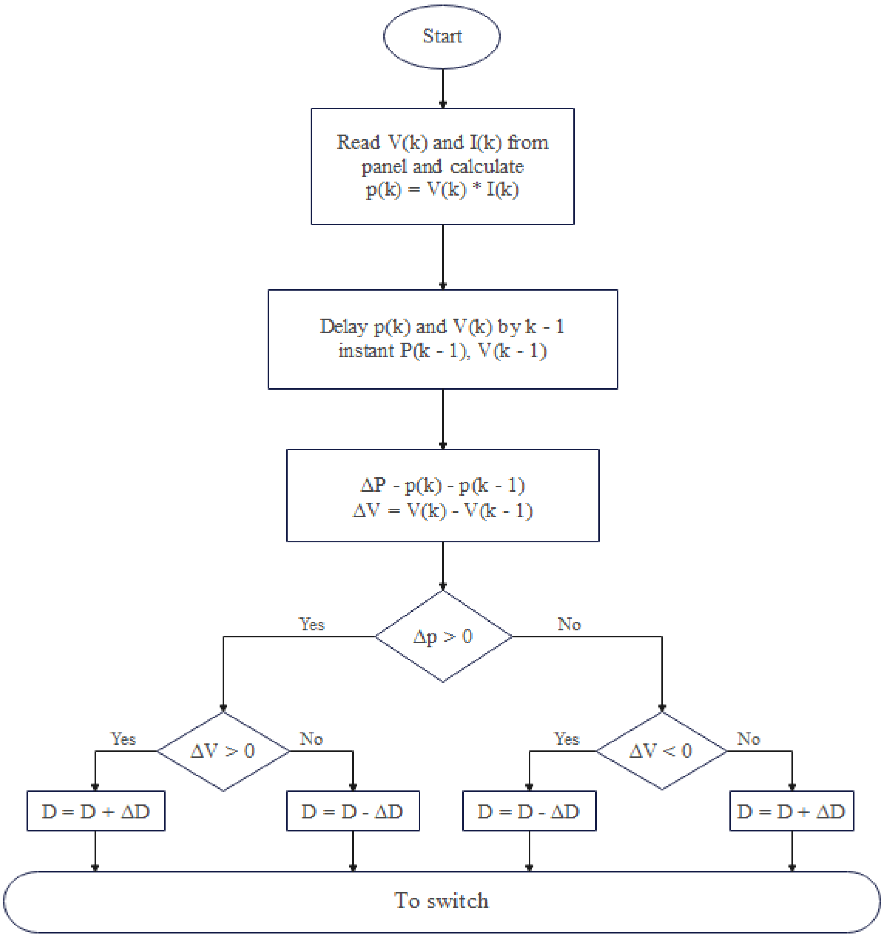

Fig. 4. P&O Algorithm Flowchart

It is the easiest MPPT approach to use. Only voltage is measured in this approach, making it simple to implement. The power output of the system is tested using this approach by altering the provided voltage. It is the easiest MPPT approach to use. Only voltage is measured in this approach, making it simple to implement. The power output of the system is tested using this approach by altering the provided voltage. Initially, the instantaneous voltage V (k) and current I (k) from the PV module are received by the MPPT controller. According to the P & O algorithm study, the instantaneous voltage V(k) and current I(k) are multiplied , which gives power P(k) (i.e., P(k) = V(k) * I(k)). Then the power P(k) is compared with previous sampling interval P(k-1) which implies ΔP = P(k) – P(k-1), similarly the voltage V(k) is compared with previous sampling interval V(k-1) which implies ΔV = V(k) – V(k-1). The obtained ΔP is checked to see if P > 0 and ΔV > 0. If both the conditions are satisfied, then the slope is left in the side region and approaches MPP. The duty cycle is varied as D = D + ΔD. If ΔP > 0 and ΔV < 0, then the slope is in the right-side region and approaching MPP, then the duty cycle varies as D = D - ΔD. A similar process takes place when ΔP < 0 condition occurs. If ΔP < 0 & ΔV < 0 conditions are satisfied, then the slope is on the left side region and going away from MPP, then the duty cycle is varied as D = D - ΔD. If ΔP < 0 and ΔV > 0, then the duty cycle is varied as D = D + ΔD. Therefore depending on the instantaneous voltage and current, the duty cycle is varied and given to the MOSFET of the Zeta converter for switching control to step up the output from the PV module.

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III. IV. PI Controller

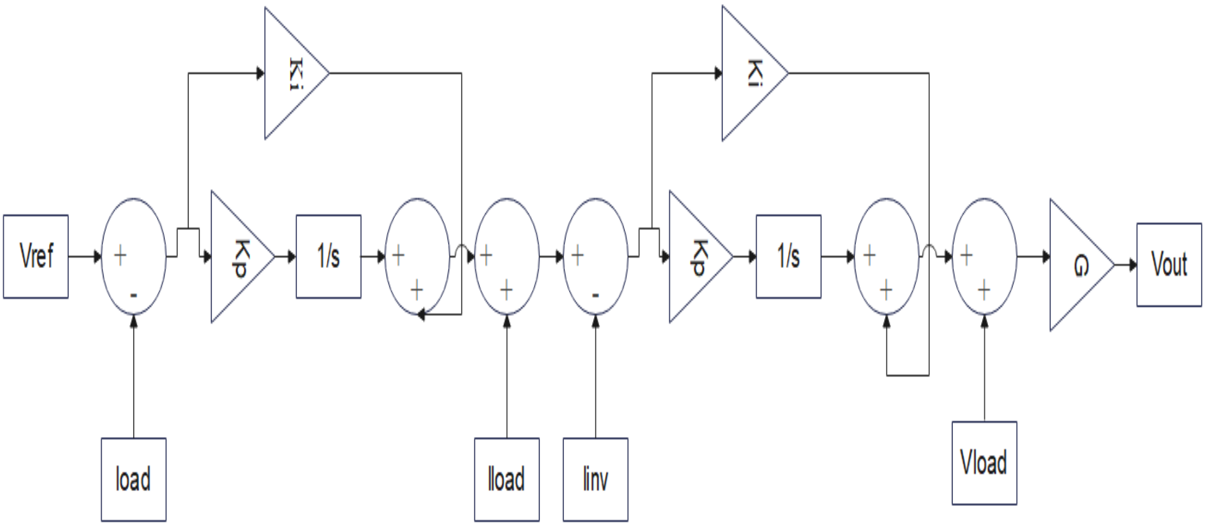


Fig.5. PI Controller

PI means proportional and integral controller, which is a typical approach in control systems for correcting for inaccuracy between the commanded set point and the actual value via feedback. In the proportional-integral controller, both proportional and integral controllers are used to govern the system. This combination of two separate controllers results in a more efficient controller that removes the drawbacks of each of them individually. Introducing the PI controller into the control system significantly reduces the system steady-state error without impacting system stability, and it also reduces the rise time. It is useful to change the magnitude, and it lags the output. The purpose of the PI controller is to prevent large disturbances in the operation process.

In this proposed system, a PI controller is used in order to generate a reference voltage (Vref), which will be given to a PWM generator that generates the required PWM pulses for the MOSFET's of the inverter in order to obtain the desired voltage for the load.

III. V. PWM Controller

It means pulse width modulation. It controls the different electronic devices. The power supply is turned on and off at a predetermined frequency and pulse width. It changes the pulse width of the control signal. The power delivered to the load is controlled. It achieves the constant voltage battery charging by modulating the duty cycle ratio of the switches' MOSFET. The current from the solar panel tapers according to the battery's state and recharging demands via a PWM controller. When the battery voltage hits the regulation set point, the PWM algorithm gradually reduces the charging current to the battery to prevent it from overheating. by ensuring that the PWM was sensitive to the system changes, preserving stability under all conditions, and improving the PV power source's switching. It also has high efficiency and low power loss.

In this proposed system, a PWM controller is used to generate PWM pulses required for the switching of MOSFET's in a Half-Bridge inverter. The reference voltage (Vref) from the PI controller is taken as the input voltage of the PWM controller and the desired PWM pulses are generated for the switching of inverter MOSFET's.

IV. SIMULATION AND EXPERIMENTAL RESULTS

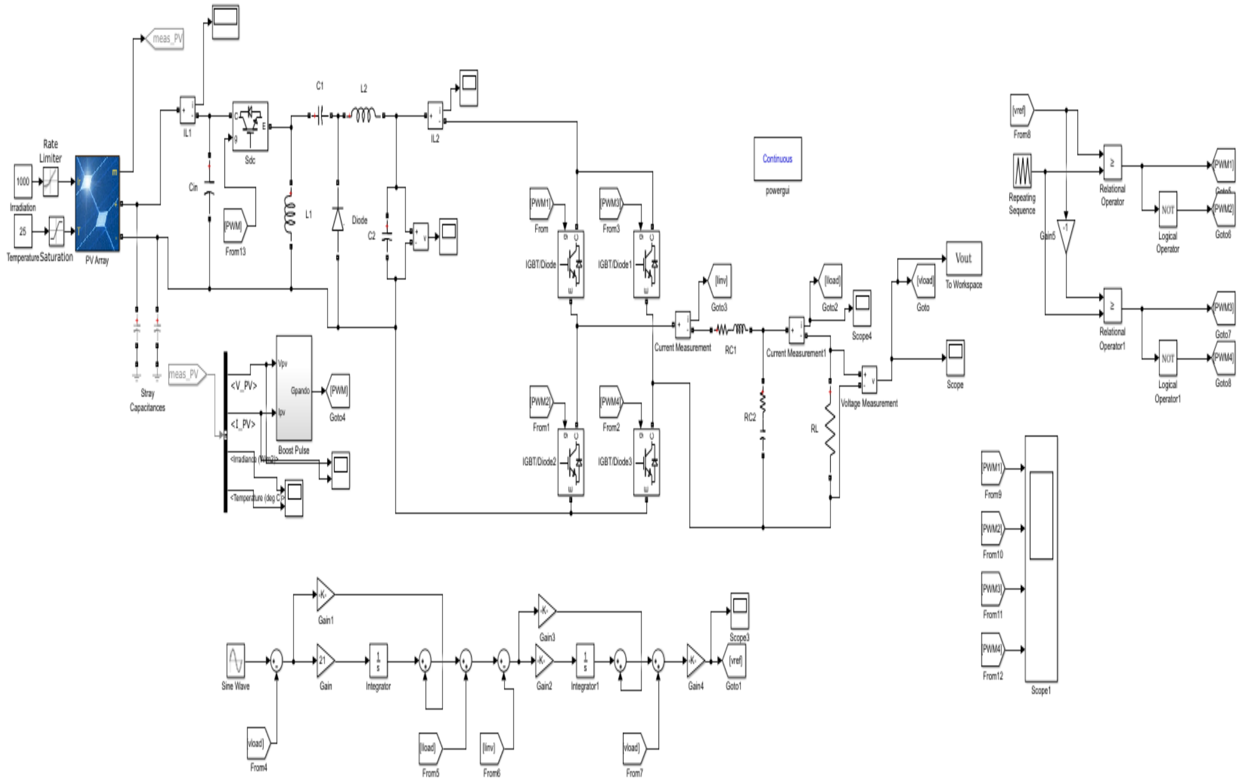
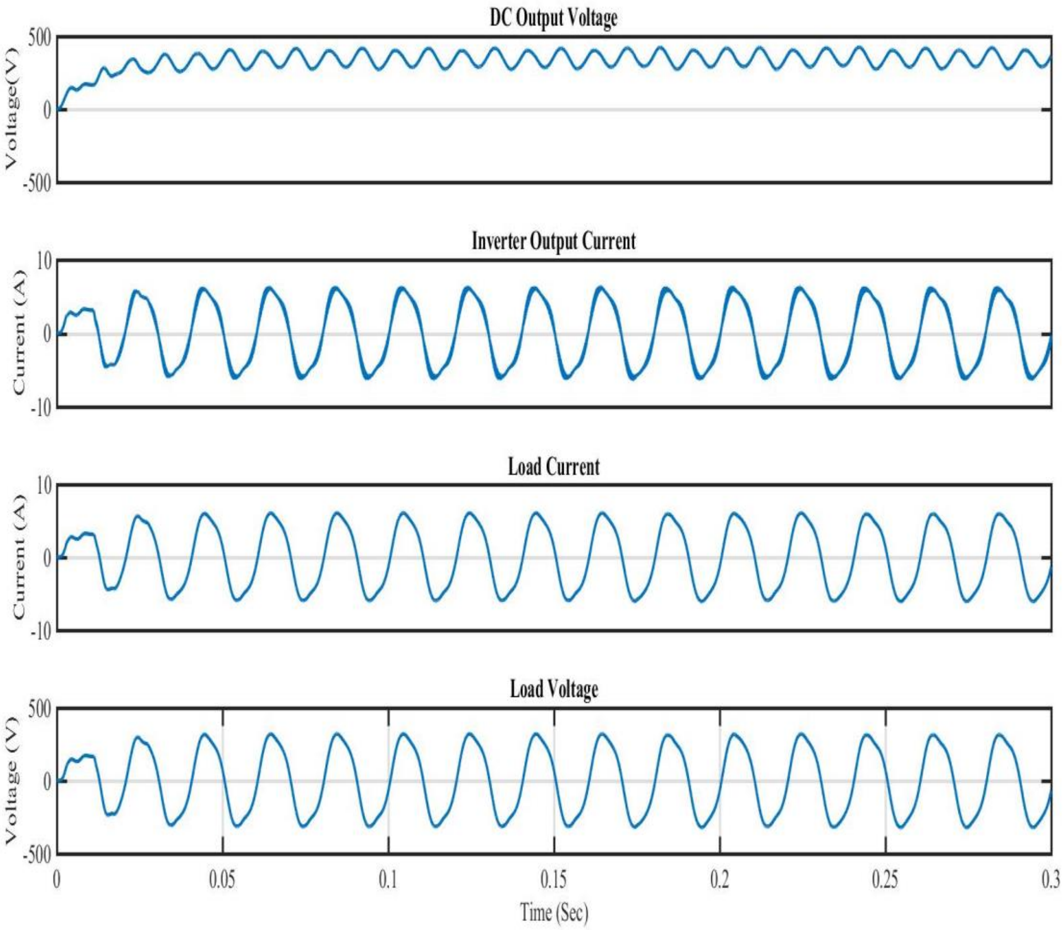


Fig.6. MATLAB Simulation Model

The above model is the MATLAB simulation circuit for the implementation of a PV-fed EV charging station made from research and applications of various research and journal papers. In this model, the PV module is used as an input source, which will convert solar energy to electrical energy and send it to the Zeta converter. The Zeta converter is used to step up the output energy (power) produced from the PV module during changes in irradiance. Therefore, to achieve this, the instantaneous voltage and current are given to the MPPT controller where the P&O algorithm technique is used to produce the required duty cycle for the DC-DC PWM generator integrated within the controller. This PWM generator generates PWM pulses for the switching control of the Zeta converter, and the step-up process takes place. The step-up voltage is then given to a half-bridge inverter where the DC-AC conversion takes place. The AC voltage is given to the load, or in this case, the charging dock, to charge the EV vehicle. However, if there are any changes in the voltage that is given to the load or if the desired voltage is not supplied from the inverter, the output voltage (Vo) is taken and given to a PI controller, where the controller converts the output voltage (Vo) into a reference voltage (Vref), which will be given to a PWM generator to generate PWM pulses. Finally, the PWM pulses are given to the half-bridge inverter and the desired output for the load is obtained.

IV. I. Simulation Result Waveforms



V. CONCLUSION

This research paper presents a solar charging station for various electric vehicles, which is commonly used to avoid using nonrenewable energy sources to charge for all intents and purposes electric automobiles, which is rather significant. This research creates a model that effectively integrates solar power with electric vehicles to minimize pollution emissions from the power generating and transportation sectors.

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