



Study and Analysis of Electric Vehicle Charging Station with PV Cell Source

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ABSTRACT-

A standalone EV charging station powered by renewable sources presents a complex and often unreliable system due to the volatility of renewable energy. Typically, the most affordable and least maintainable renewable source is solar energy. Solar panels generate electricity based on solar radiation, which is unpredictable. In this paper, we propose a standalone EV charging station that uses solar panels combined with a BSM system to ensure power and voltage stability. The solar panels are designed with a bidirectional structure, which increases power generation by capturing solar radiation reflected off the back of the panel. The shift towards sustainable transportation is essential to reduce environmental impact, and electric vehicles (EVs) are at the forefront of this shift. Despite the environmental benefits, global EV adoption faces challenges such as new battery technologies, high costs, and inadequate charging infrastructure. This study considers the optimization of electric vehicle charging station (EVCS) locations as an important step towards increasing EV adoption rates. In addition, a comparative analysis of the performance of a conventional DC-DC bidirectional converter is performed. This analysis considers various factors such as ripple, turbulence and damping factors to identify better circuit topology. The complete analysis and simulation results are prepared using MATLAB's Simulink environment, using the 'Power System' Simulink library component.

Key Word- Electrical vehicle, Solar Photovoltaic system, Charging station, Backup battery.

INTRODUCTION

We are on the verge of an unimaginable environmental catastrophe as global warming concerns are rising and natural disasters are occurring. One of the major causes of global warming is the use of fossil fuels (coal, petrol or diesel) for power generation and transportation (domestic or commercial). These coal-based power plants and internal combustion engine vehicles produce high amounts of carbon gases (carbon monoxide and carbon dioxide) which are very dangerous for the environment [1]. Large amounts of these gases are the cause of most of the natural disasters around the world. To avoid further destruction in the future, we have to find better ways of power generation and transportation. To achieve this, replacing fossil fuel power plants is being considered.

Renewable electricity can be generated using solar panels, wind turbine farms, tidal energy, biogas plants, fuel cells, etc. These solar panels are installed in various series and parallel combinations to generate electricity at the required voltage and current levels. For more efficient power generation, regular solar panels are upgraded to bidirectional solar panels that generate power by reflecting solar radiation on the surface where the panels are installed [4]. This increases the efficiency of the solar generation unit for a specific area of the location. A DC-DC boost converter is connected to the solar panel array to increase the voltage and maximize power extraction, which is achieved by MPPT control [5].

Since the power and voltage from the solar generation unit are not constant (variable due to changes in solar radiation conditions), a stabilization device is required to stabilize the DC voltage. Therefore, BSM with high capacity battery pack in the DC link is introduced with a conventional DC-DC bidirectional converter [6,7]. Since there is no grid connection with the proposed topology, it represents a standalone system with renewable sources [8].

The battery bank of the BSM and the EV charging station are connected to separate bidirectional converters with charge and discharge control [9]. The bidirectional converters of EV charging stations can be either conventional DC-DC bidirectional converters or MAFB circuits. In previous studies, EV charging stations mainly adopt unidirectional charger modules that operate only in G2V mode. Most circuits consist of conventional DC-DC or PFC converters with uncontrolled diode rectifiers. PFC converters are considered a better option than simple DC-DC converters (boost and buck converters). Recognizing the urgency of reducing greenhouse gas emissions generated by the transport sector, which accounts for a significant share of total energy consumption, the European Union has highlighted the development of electric vehicles as a corrective measure [11]. On the other hand, the growing public awareness of environmental protection also drives the strong growth of electric vehicles [12]. However, despite their benefits and growing support worldwide, the global market penetration of electric vehicles remains relatively low, hindered by challenges such as immature battery technology, high initial costs, and inadequate charging infrastructure [13]. The widespread adoption of electric vehicles is associated with the presence of a strong charging infrastructure, which requires joint efforts from countries, regions, and municipalities. The establishment of such infrastructure is often considered a key

factor in increasing the adoption rate of electric vehicles. To address these challenges, location modeling for charging stations has become an important area of research, aimed at forecasting demand and optimizing the installation of charging facilities. Various methods such as genetic algorithms, integer programming, and geographic and statistical approaches have been used to determine the most suitable locations for charging stations [14].

These studies aim to minimize costs, reduce trip lengths, and consider the spatial distribution of charging demand based on available data and simulated scenarios. By 2030, the number of electric vehicles is expected to reach 120 million [15]. With the rapid growth of electric vehicles, the demand for charging infrastructure, which is crucial for their practical use, is projected to grow. The integration of electric vehicles into transportation systems and the consequent development of charging infrastructure bring complex problems. This situation may misrepresent the charging habits of electric vehicle users, leading to inaccurate location of stations. In this regard, this study first focuses on the demand-based location of electric vehicles. Then, it determines the station capacity by taking into account the types of charging units at the station relative to the number of electric vehicles introduced to the market. This work presents a sustainable and cost-effective model for selecting facility locations and determining their capacity [16].

This model focuses on selecting public areas, considering demand points and potential charging station locations to determine optimal charging station areas. Addressing the complexity of facility location challenges, the research presents a mathematical model based on the p-median problem to determine charging station locations without initial capacity estimation. The facility location model, determined using a genetic algorithm, follows simulation techniques to determine station capacity and the type and quantity of charging units at each station [17]. Based on the simulation data, the study evaluates station traffic density and develops various scenarios using Arena 14 software to optimize the type and quantity of charging units to minimize waiting time. are locations where EVs are parked and are candidate charging station points. Since CS1, CS2 and CS3 are close to each other, the intersection of the orange, purple and green circles in the figure is rich in charging resources and largely meets the charging demand of this area. However, the uneven distribution of charging sources brings some problems, such as difficulty in charging for users. If someone wants to charge an electric vehicle at DP2, it turns out that it is not suitable for charging electric vehicles.

LITERATURE REVIEW

Bhatti and Salam (2016) presented a PV-based EV charging station. It was developed due to the widespread availability of solar energy and the easy installation of PV power generation systems. Several articles have been published in support of PV-based charging stations. Tulpule et al. (2013) proposed a cost-effective PV-based charging station in a parking garage. The cost of this system is analyzed using parking rates, installation costs, and tax exemptions. It benefits the garage as well as the vehicle owner. In addition to this benefit, this system also contributes to reducing the charging burden from the grid and the penetration of RES in transportation. However, the authors did not present an economic analysis of this approach for other locations in terms of per unit cost and installation cost. Moreover, the grid is not available everywhere, which reduces the sustainability of the system. Similarly, Hernandez and Sutil (2016) presented a PVbased charging station that includes regenerative braking and battery storage to support the system structure during peak-load periods. The authors aim to utilize the maximum amount of RES and reduce the charging cost.

Similarly, Li et al. (2013) proposed a PV and wind-based CS with battery storage to control the fluctuation of power generation under changing environmental conditions. In this paper, they presented a SOC-based control method to address the problems caused by RES. However, they did not determine an accurate SOC estimation strategy for EV batteries. The above literature shows that a self-built/off-grid CS is a necessity in the current situation. However, the rapid growth of electric vehicles puts a burden on the grid. RES-based charging stations are required for the successful implementation of electric vehicles, especially in highways and remote locations. Therefore, a PV-based off-grid electric vehicle charging station is proposed. In order to make the proposed system sustainable, including battery storage is a suitable approach among the possibilities mentioned in the literature. The PV source integrated with the ESS is efficiently utilized under variable radiation conditions. Moreover, during the time of excess power situation or unavailability of electric vehicles, the ESS utilizes the maximum RES. Therefore, this system constitutes an efficient and environmentally friendly off-grid electric vehicle charging station.

Some preliminary conclusions are drawn from the above discussion which are as follows.

- In order to reduce the burden on the grid and facilitate the use of electric vehicles in remote locations, off-grid electric vehicle charging stations based on renewable energy sources have been introduced.
- The use of energy storage systems improves the reliability of off-grid electric vehicle charging stations. • The charging and discharging of the energy storage system is controlled based on PV radiation.

PROPOSED SYSTEM FRAMEWORK

The proposed off-grid EV charging station has three sub-sections: PV generation, EV charger, and ESS. The first section is the PV generation system consisting of a PV array, maximum power point (MPPT), and a boost converter. The PV array converts solar energy into clean electrical energy and provides voltage VPV and current IPV. The VPV and IPV are fed to the boost converter, which fluctuates due to changes in irradiance. Therefore, an MPPT strategy is proposed to handle the fluctuations of VPV and IPV. The MPPT extracts the maximum power PPV from the PV array and provides the corresponding operating voltage and current to the boost converter.

PV SYSTEM

A photovoltaic system, also called a PV system or solar power system, is a power system designed to provide useful solar energy through photovoltaics. In simple terms, PV systems are similar to other electrical generation systems, but the equipment used is different from conventional electromechanical generation systems. However, the principles of operation and interfacing with other electrical systems remain the same and are governed by a well-established body of electrical codes and standards. While a PV array generates electricity when exposed to sunlight, many other components are required to properly manage, control, convert, distribute, and store the energy produced by the array.

DC TO DC CONVERTER

A DC-to-DC converter is an electronic circuit or electromechanical device that converts a source of direct current (DC) from one voltage level to another. It is a type of electrical power converter. Power levels range from very low (small batteries) to very high (high-voltage power transmission).

AC TO DC CONVERTER

An AC to DC converter converts an AC input into a DC output. The average power transferred from the AC source to a DC load is 100 ohms. The AC to DC converter is called a rectifier. The peak reverse voltage is the maximum reverse voltage that can be applied to a diode when it is not conducting.

BATTERY CHARGING CIRCUIT

A battery charger, or charger, is a device used to supply energy to a secondary cell or battery that is used to power an electrical device. A smart charger delivers a relatively small amount of current, enough to counteract the battery's self-discharge during long periods of inactivity. Battery electric vehicles, also known as BEVs, and often referred to as EVs, are fully electric vehicles that are powered by batteries and do not have a gasoline engine. Battery electric vehicles store electricity on board with high-capacity battery packs. Their battery power is used to power the electric motor and onboard electronics. BEVs do not produce the harmful emissions and hazards that traditional gasoline-powered vehicles produce. BEVs are charged from an external power source. Electric vehicle (EV) chargers are classified according to the speed at which they can recharge the EV battery. The classifications are Level 1, Level 2, and Level 3 or DC fast charging. Level 1 EV charging uses a standard household (120V) outlet to connect to an electric vehicle and takes about 8 hours to charge an EV for about 75-80 miles.

Level 1 charging is typically done at your home or workplace. Level 1 chargers are capable of charging most EVs on the market. Level 2 charging requires a dedicated station with 240V power. Level 2 chargers are typically found at workplaces and public charging stations and can charge a battery for up to 75-80 miles in 4 hours.

Level 3 charging, DC fast charging, or rapid charging, is currently the fastest charging solution on the EV market. DC fast chargers are found at dedicated EV charging stations and can charge a battery for up to 90 miles in 30 minutes.

SIMULATION MODEL

Arena simulation software is designed as an advanced tool for predicting, verifying, and validating system or process strategies for improved and optimized operational performance. The software uses discrete event modeling to optimize these complex processes. The software uses a flowchart modeling approach in which various process variables are defined based on predefined or userspecified statistical functions or distributions. The software is capable of accurately modeling any variable process, including processes characterized by limited resources and complex interactions.

Its ability to present the simulation study of the entire process in 2D or 3D visualizations greatly aids in the interpretation of simulation results. In addition, the software is adept at handling multiple variables over time, allows for various statistical analyses, and produces comprehensive reports detailing all results. The query system is designed to estimate the number and types of charging stations needed to meet the charging requirements of electric vehicles. The system includes various inputs, including electric vehicles and charging stations. The system is supposed to determine the optimal number of electric vehicle charging stations and the specific types of charging modules needed to efficiently service electric vehicles. The system includes several key elements, such as stations, vehicles, and charging modules, all of which interact to influence outcomes such as vehicle waiting time. This time is affected by the capacity of the charging stations and the types of charging modules used. The system is parameterized by the number of electric vehicles, charging stations, and charging modules. Its performance is evaluated based on metrics such as the occupancy rate at the station, the number of vehicles waiting for service, and the waiting time of these vehicles. The output of the system is the number of electric vehicles that meet their charging needs.

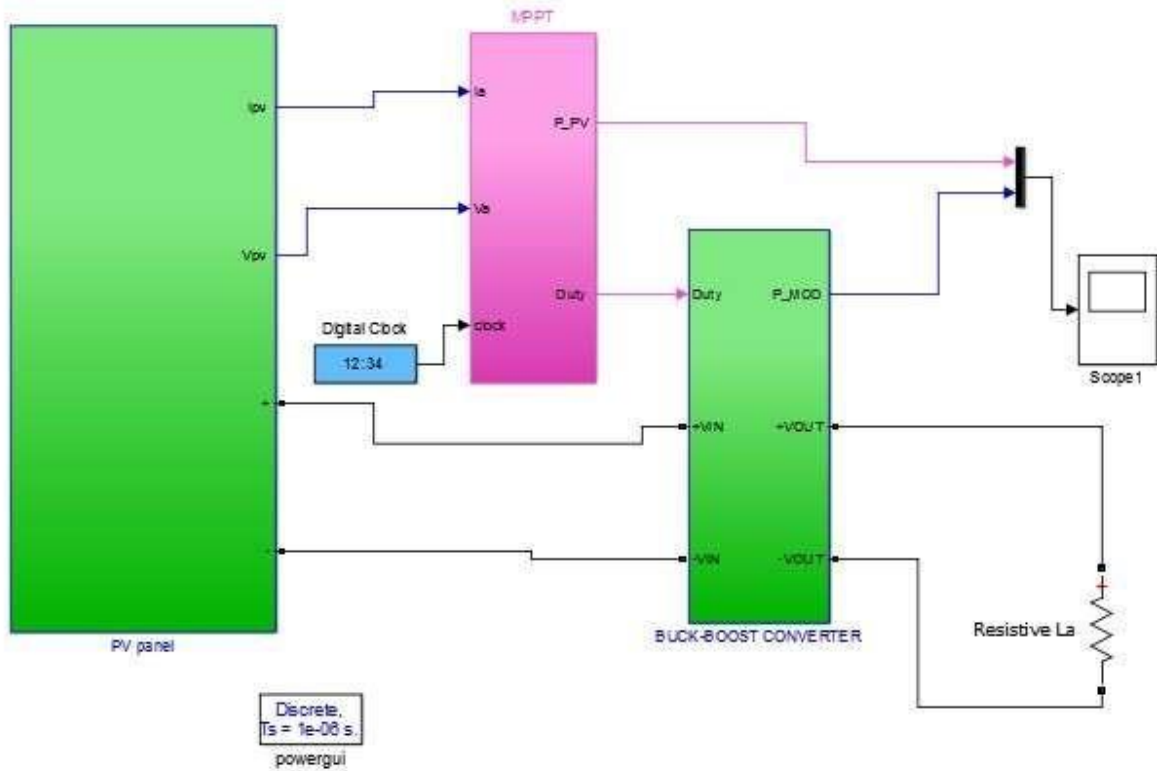


Figure 1. PV cell modal with resistive load

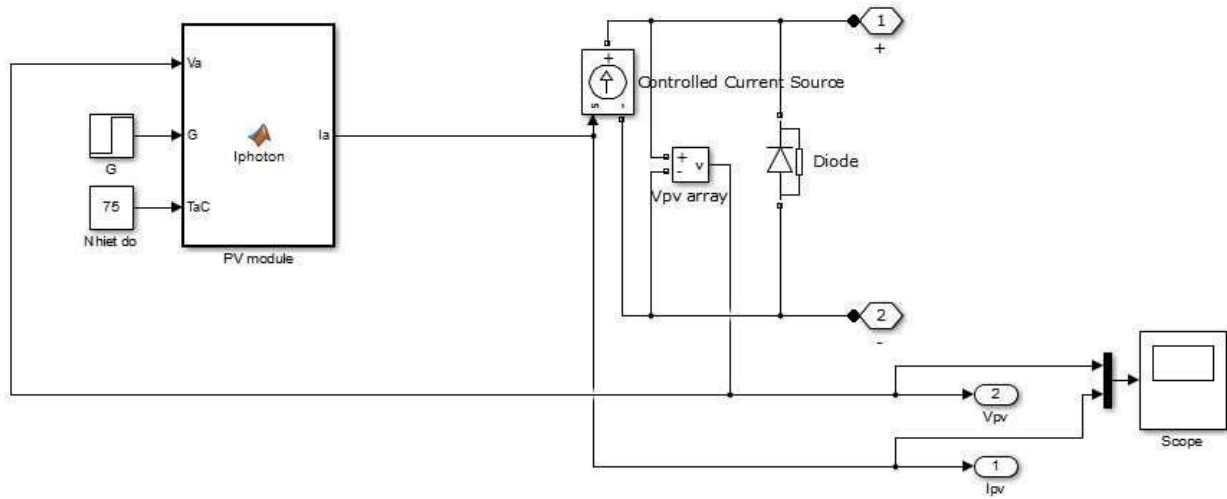


Figure 2. PV cell modal with controlled current source

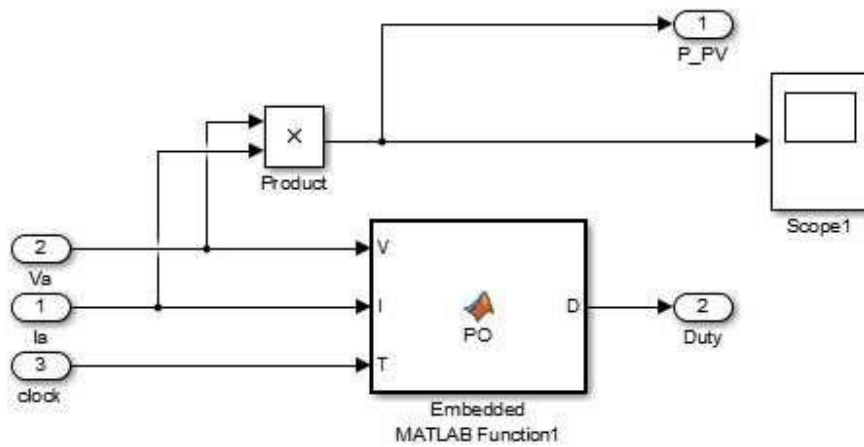


Figure 3. Embedded MATLAB Fuction

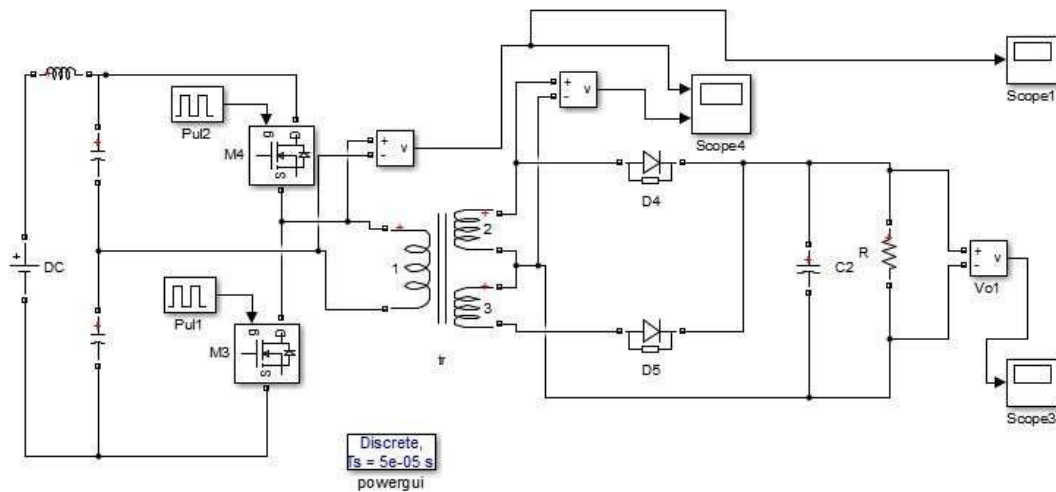


Figure 4. Power supply modal for EV battery charging system

Linear Transformer (mask) (link)

Implements a three windings linear transformer.

Click the Apply or the OK button after a change to the Units popup to confirm the conversion of parameters.

Parameters

Units pu

Nominal power and frequency [Pn(VA) fn(Hz)]:
[200 10000]

Winding 1 parameters [V1(Vrms) R1(pu) L1(pu)]:
[50 0.002 0.0005]

Winding 2 parameters [V2(Vrms) R2(pu) L2(pu)]:
[30 0.002 0.0]

☒ Three windings transformer

Winding 3 parameters [V3(Vrms) R3(pu) L3(pu)]:
[30 0.002 0]

Magnetization resistance and inductance [Rm(pu) Lm(pu)]:
[500 500]

Measurements None

OK Cancel Help Apply

Figure 5. Power supply parameter

DC Voltage Source (mask) (link)

Ideal DC voltage source.

Parameters

Amplitude (V):
260

Measurements None

OK Cancel Help Apply

Figure 6. Input power supply for EV battery charging system

RESULTS AND DISCUSSION

This section presents a MATLAB simulation model of a solar system consisting of an MPPT voltage, a irradiance constant, two converters, a shunt diode, and a block to display their results. The main obstacles to the global adoption of electric vehicles are the high costs associated with electric vehicles, their limited range, and the charging infrastructure. With the advancement of electric vehicle battery technology and the expansion of the electric vehicle market, it is necessary to establish charging stations that meet the energy needs of these vehicles. The strategic location of such charging facilities requires comprehensive coordination with the planned charging demand and traffic patterns.

In addition, the design and layout of charging stations should be done with an in-depth analysis of the local power distribution network to ensure operational efficiency and sustainability. In the strategic planning process for charging infrastructure, it is necessary to integrate these facilities into the city's development strategy and road network. The service range of each charging station should be determined based on EV criteria. Furthermore, it is crucial to anticipate future EV adoption patterns and technological innovations during the planning phase, ensuring that the installation infrastructure is flexible and can adapt to evolving patterns.

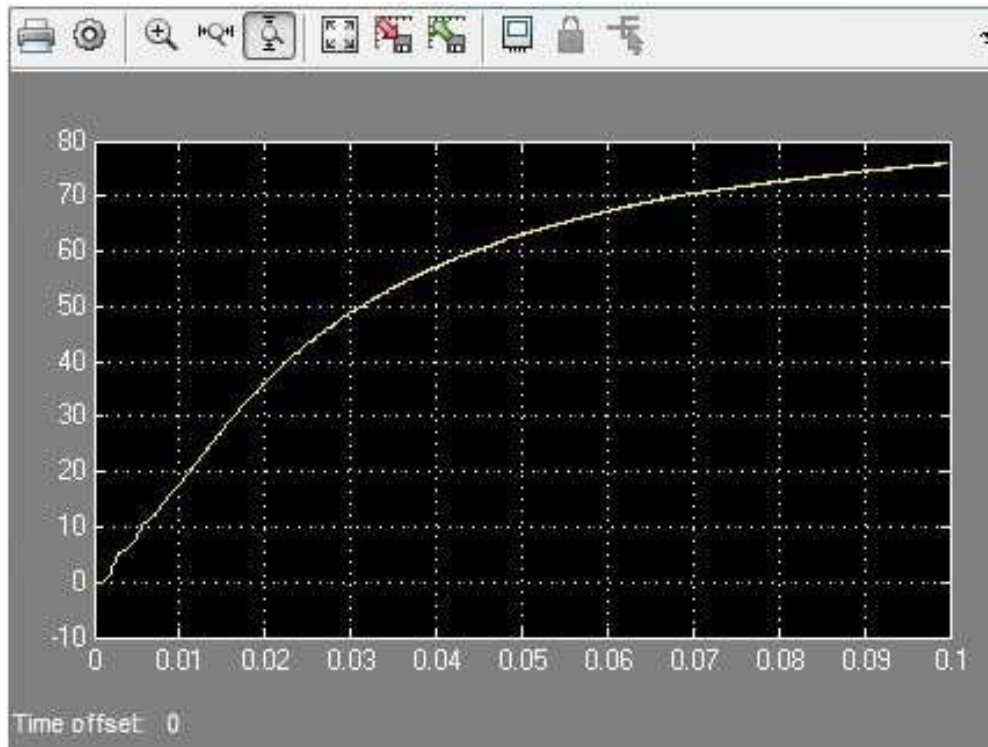


Figure 7. Output power supply from MPPT

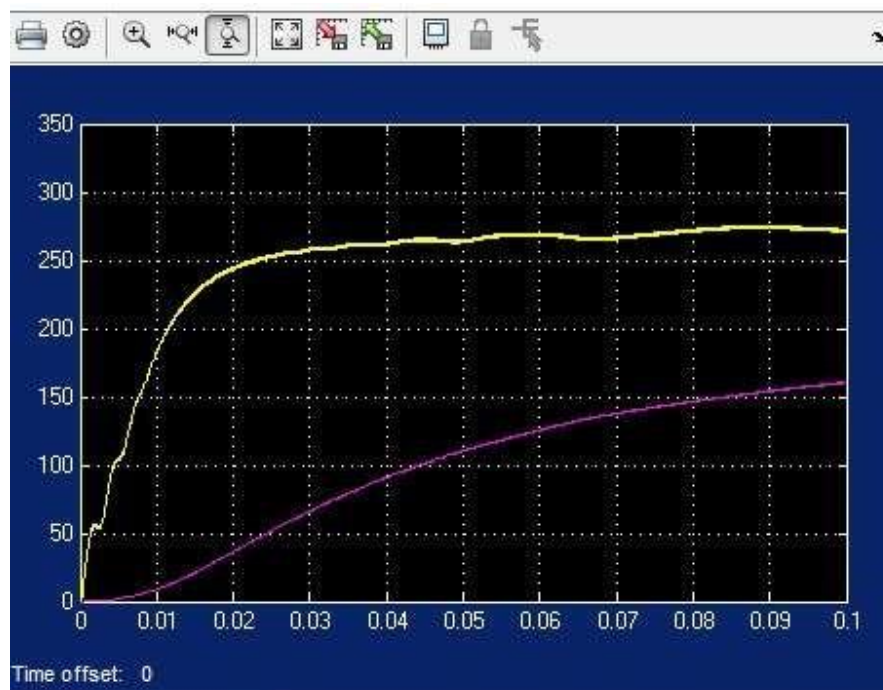


Figure 8. Output power supply from PV cell and MPPT with convertor system

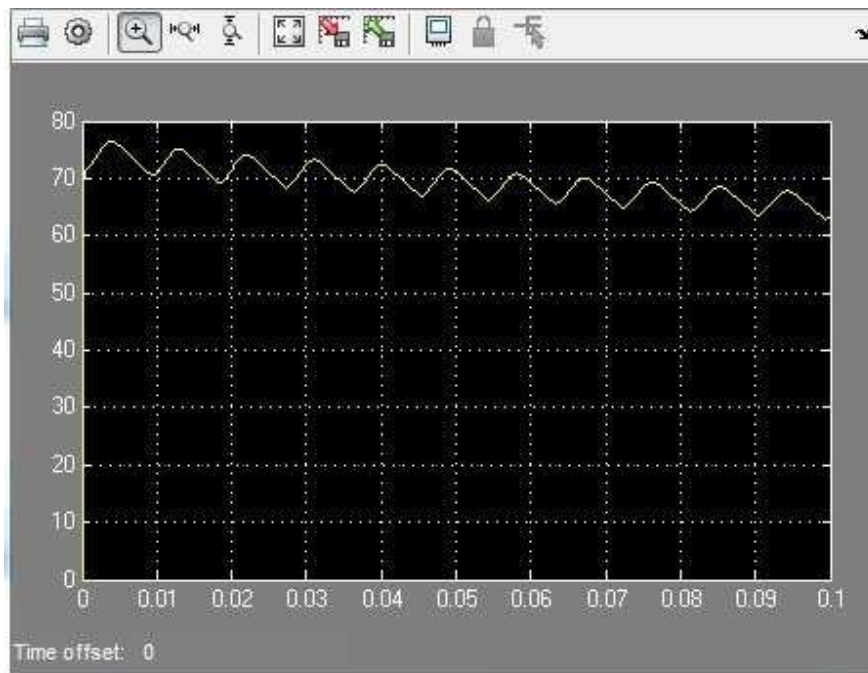


Figure 9. Output power supply for EV battery charging system

A renewable energy-based electric vehicle charging station with a typical DC-DC converter and MPPT circuit is modeled in MATLAB Simulink. The “Electricity” sections in the Simulink library include all sources, power electronics, and passive elements. The simulations of the models are performed with the same system rating of all modules and yield all results. In the designed model, the solar irradiance (I_r) varies at different times, the output power of the panels. The initial simulation time is set to 0 seconds I_r 1000W/m², and this value decreases to 500W/m² in 0.5 seconds. As the power of the solar panels increases, the I_r value increases to 800W/m² in 1.5 seconds. The power, voltage, and current plots of all modules as a function of I_r are presented below. The plots show the performance of the modules for different values of I_r .

CONCLUSIONS

A renewable energy-based EV charging station with a BSM system is successfully modeled using MATLAB Simulink software and “electricity” blocks. The maximum power is extracted from the solar panels using the P&O MPPT method, which charges the EV batteries or stores the energy in the BSM after considering the local load requirements. The EV charging station consists of three charging units, each connected to an EV battery via a conventional two-way converter. These EV charging circuits are later upgraded to a MPPT circuit, enhancing the battery performance. The primary port of the MPPT is connected to the DC link, while the secondary ports are connected to the EV batteries.

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