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Solar Powered Charging Station for Electric Vehicle

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Abstract

As the demand for sustainable transportation continues to grow, the integration of renewable energy sources into Electric Vehicle (EV) charging infrastructure has become a vital focus. The concept and benefits of a solar-powered EV charging station proposed in this research, combines solar Photovoltaic (PV) technology with efficient charging infrastructure. The solar-powered EV charging station serves as an innovative solution that harnesses clean and renewable energy from the sun to charge electric vehicles. By leveraging solar PV panels, this charging station reduces reliance on traditional grid electricity, decreases carbon emissions, and promotes sustainable mobility. Furthermore, this study discusses the potential challenges and considerations involved in implementing a solar-powered EV charging station, including site selection, system sizing, grid interconnection, and maintenance requirements. It emphasizes the need for collaboration between renewable energy experts, charging infrastructure providers, and relevant stakeholders to address these challenges and drive the adoption of solar-powered EV charging stations. In conclusion, the abstract presents the solar-powered EV charging station as a sustainable and forward-thinking solution for promoting cleaner transportation. By leveraging solar energy, this charging infrastructure contributes to the reduction of greenhouse gas emissions, fosters energy resilience, and paves the way for a greener future in the realm of electric mobility. It is observed that the proposed system is more efficient than the existing system in terms of fast operation.

Keywords: PV array, MPPT, VSC, BOOST converter, BUCK-BOOST converter.

1. Introduction

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The cutting-edge 400 kW solar-powered Electric Vehicle (EV) charging station is a welcoming innovation. As the world shifts towards sustainable transportation and the adoption of electric vehicles continues to grow, this proposed charging station offers a reliable and environmentally-friendly solution for EV owners [1]. By harnessing the power of the sun and integrating advanced charging technology, provides a convenient and sustainable way to charge the electric vehicle [2].

The core feature of the charging station is its 400-kW solar power system. Through an array of state-of-the-art Photovoltaic (PV) panels, to capture solar energy and convert it into clean electricity [3]. This renewable energy is utilized to power the charging infrastructure, enabling it to charge the electric vehicle while minimizing reliance on traditional energy sources [4].

The importance of efficiency and convenience is a must when it comes to EV charging. The proposed charging station is equipped with multiple charging points, allowing several vehicles to charge simultaneously [5]. With high-speed charging technology, to ensure that the charging time is optimized, getting it back on the road quickly and conveniently [6]. In addition to efficient charging, the station incorporates a smart management system. This system optimizes the distribution of power among the charging points, taking into account demand and the availability of solar energy [7].

Opting the solar-powered EV charging station, makes a positive impact on the environment [8]. Relying on renewable solar energy, significantly reduces carbon emissions and minimize the dependency on fossil fuels. With each charge, it contributes to a greener future and help create a sustainable transportation system [9].

This work is committed to expanding the charging infrastructure network, forging partnerships with renewable energy providers, EV manufacturers, and local communities [10]. The aim of this research is to create a robust and accessible charging network that supports the growing number of electric vehicles on the road [11].

2. Existing System

The components of a 400-kW solar-powered EV charging station typically include:

2.1 Solar Panels

The core component of the charging station is a large array of solar panels. These PV panels capture sunlight and convert it into electricity. The number and size of the panels depend on the power output required for the charging station [12].

2.2 Inverter System

The inverter system is responsible for converting the Direct Current (DC) electricity generated by the solar panels into Alternating Current (AC) electricity that can be used for charging electric vehicles and other electrical devices [13].

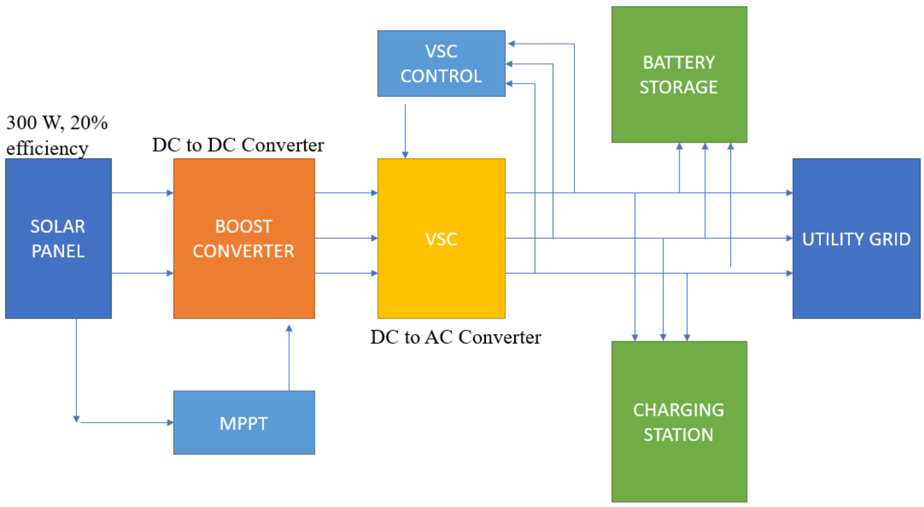

Figure 1. Block Diagram of Solar Powered Charging Station

2.3 Energy Storage System (Optional)

Some charging stations may include an energy storage system, such as batteries, to store excess solar energy for later use [14]. This allows for a more reliable power supply during periods of low sunlight or high demand.

2.4 Charging Infrastructure

The charging infrastructure consists of multiple charging points or stations equipped with connectors compatible with different types of electric vehicles [15]. These charging points provide the necessary power and communication interfaces for charging EVs.

2.5 High-Speed Charging Equipment

The charging station incorporates high-speed charging equipment capable of delivering a high amount of power to charge electric vehicles rapidly [16]. This ensures efficient and timely charging for EV owners.

2.6 Charging Management System

A smart charging management system optimizes the distribution of power among the charging points based on demand and available solar energy. It monitors energy consumption, adjusts charging rates, and provides remote monitoring capabilities to track charging progress and access charging data.

2.7 Grid Connection

The charging station is connected to the electrical grid to supplement solar power during periods of low sunlight or high demand. It allows for a continuous power supply and enables the export of excess energy back to the grid.

These components work together to create a comprehensive and efficient 400 kw solar-powered EV charging station, offering clean and sustainable charging solutions for electric vehicle owners as shown in Figure 1.

3. Proposed System

3.1 Maximum Power Point Tracking Control

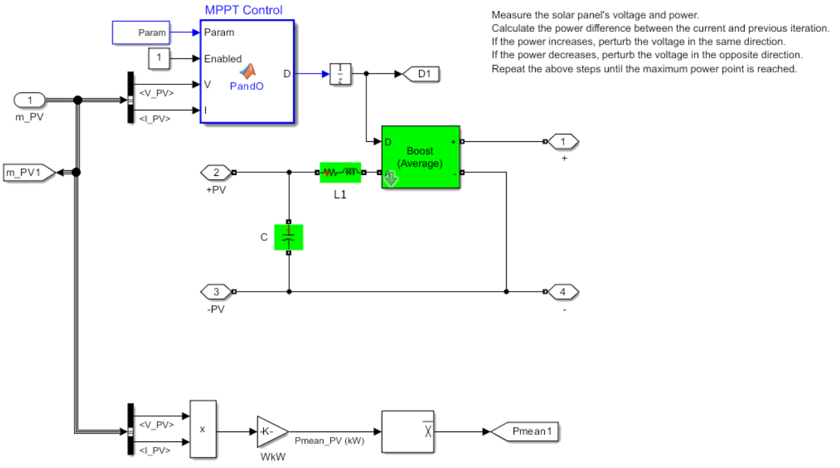

Figure 2. Maximum Power Point Tracking in MATLAB

Figure 2 shows the Maximum Power Point Tracking (MPPT) control is an essential component in a 400-kW solar-powered EV charging station to maximize the efficiency and output of the solar power system. How MPPT control is utilized in such a charging station has been discussed below.

Purpose of MPPT Control: The primary goal of MPPT control is to extract the maximum power available from the solar panels by continuously adjusting the operating point of the photovoltaic system. It ensures that the solar panels operate at their optimal voltage and current combination, regardless of changing weather conditions or variations in sunlight intensity.

MPPT Controller: The charging station incorporates an MPPT controller, which is responsible for monitoring the voltage and current output of the solar panels. The MPPT controller continuously analyses this data and calculates the ideal operating point that maximizes the power output from the solar panels.

Tracking the Maximum Power Point: The MPPT controller uses algorithms and feedback loops to dynamically track the Maximum Power Point of the solar panels. It adjusts the operating voltage and current of the solar power system to maintain the optimal operating conditions for power generation.

Variable Voltage Operation: The MPPT control adjusts the output voltage of the solar panels to match the optimal voltage required by the charging infrastructure and the charging process. This ensures that the solar power system is operating at its highest efficiency, minimizing power losses and maximizing the energy harvested from the sunlight.

Response to Environmental Changes: As environmental conditions change, such as variations in solar irradiance or panel shading, the MPPT controller continuously adapts to maintain the optimal operating point. It quickly responds to changes and dynamically adjusts the system parameters to extract the maximum power from the solar panels.

Integration with Charging Management System: The MPPT control is integrated with the overall charging management system of the EV charging station. It communicates with the charging management system to provide real-time information on solar power generation, available power, and adjustments made to optimize the charging process.

By incorporating MPPT control in a 400-kW solar-powered EV charging station, the system can effectively track and utilize the maximum power output from the solar panels, ensuring the efficient use of solar energy for charging electric vehicles. This control mechanism enhances the overall performance and effectiveness of the charging station, maximizing the benefits of solar power generation and promoting sustainable transportation.

3.2 Voltage and Current Control in VSC

In Voltage Source Inverter (VSI) control, voltage and current control are essential aspects that ensure the proper operation and regulation of the VSI in a 400-kW solar-powered EV charging station as shown in Figure 3. The voltage control scheme starts with generating a reference voltage waveform based on the desired output voltage requirements. The reference voltage waveform typically follows a sinusoidal waveform at a specific frequency.

Modulation Techniques: To generate the desired output voltage waveform, modulation techniques like Pulse Width Modulation (PWM) are commonly used. PWM varies the width of the switching pulses to approximate the reference voltage waveform.

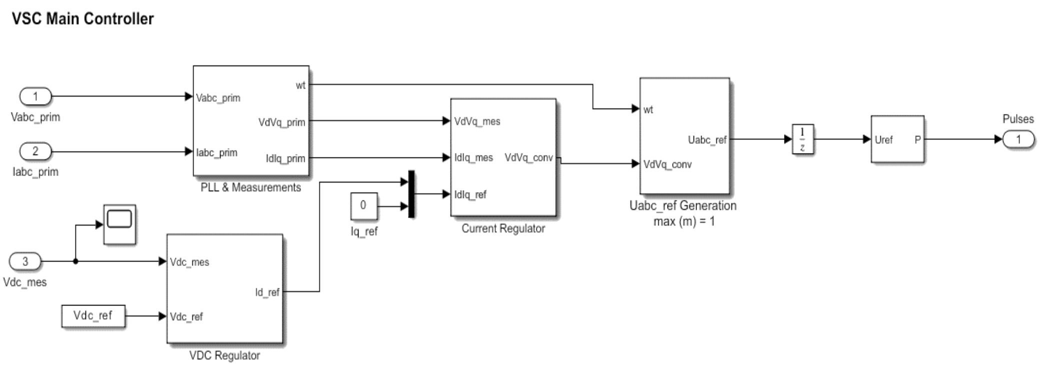

Figure 3. MATLAB model of VSC control

Comparators and Switching Signals: The reference voltage waveform is compared with a carrier waveform generated at a higher frequency. The comparison results in switching signals that determine the on and off states of the VSI switches.

Voltage Regulation: The switching signals control the VSI switches to regulate the output voltage. By adjusting the width and timing of the switching pulses, the VSI can maintain the desired voltage level, compensating for load variations and providing a stable output.

Current Sensing: Current control requires measuring the output current flowing through the VSI. Current sensors, such as current transformers or shunt resistors, are used to provide feedback on the actual output current. A current control loop generates a reference current signal based on the desired output current level. This reference current is compared with the actual current to determine the control action.

Current Control Loop: The current control loop typically employs a Proportional-Integral (PI) controller. The PI controller compares the reference current with the actual current and generates a control signal that adjusts the width and timing of the switching pulses to maintain the desired current level.

Current Regulation: By continuously adjusting the switching pulses, the current control loop ensures that the output current closely follows the reference current. This enables precise control of the charging current provided to the electric vehicles, facilitating safe and efficient charging operations. Both voltage and current control in a VSI work together to maintain the desired output voltage and current levels, ensuring stable and regulated power delivery in a 400-kW solar-powered EV charging station. The control schemes employed can be further enhanced with advanced control techniques, such as predictive control or cascaded control, to improve performance and response times as shown in Figure 4.

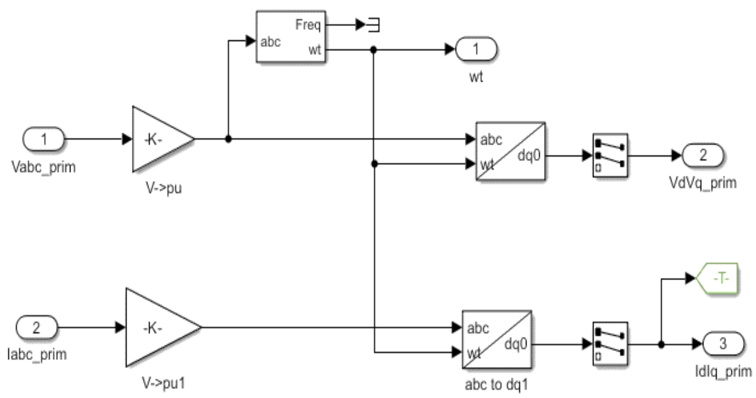

Figure 4. Voltage and Current Conversion

4. Working

The working of a 400-kW solar-powered EV charging station involves several steps and processes. An overview of how such a charging station typically operates has been elaborated below.

a) Solar Power Generation:

The charging station consists of a large array of solar panels installed on rooftops or ground-mounted structures. These solar panels capture sunlight and convert it into DC electricity through the PV effect.

b) Energy Conversion:

The DC electricity generated by the solar panels is then directed to an inverter system. The inverter system converts the DC electricity into AC, which is the standard form of electricity used in homes and commercial buildings.

c) Power Distribution:

The AC electricity produced by the inverter system is distributed to the various components of the charging station, including the charging infrastructure and other auxiliary systems.

d) Charging Infrastructure:

The charging infrastructure consists of multiple charging points equipped with connectors compatible with different types of electric vehicles. These charging points are connected to the power distribution system and are capable of providing the necessary power for charging EVs.

e) Charging Process:

When an electric vehicle is connected to a charging point, the charging process begins. The charging station communicates with the vehicle to establish the charging parameters, such as charging rate and duration. The power from the charging infrastructure is then transferred to the electric vehicle's battery system through the charging cable and connector.

f) Smart Charging Management:

A smart charging management system oversees the charging process. It optimizes the distribution of power among the charging points based on demand and the available solar energy. The system constantly monitors energy consumption, adjusts charging rates dynamically, and ensures efficient utilization of the solar-generated power.

g) Grid Connection and Energy Storage (if applicable):

In situations where solar power generation is insufficient or the demand exceeds the available solar energy, the charging station can draw additional power from the electrical grid to supplement the charging process. Similarly, if the charging station has an energy storage system, such as batteries, it can utilize the stored energy to meet the changing demands during periods of low sunlight or high demand.

h) User Interaction and Payment:

The charging station provides user interfaces for EV owners to initiate and monitor the charging process. These interfaces may include touchscreens, mobile apps, or RFID cards. EV owners can select the desired charging options, monitor the charging progress, and receive charging status notifications. Payment systems, such as credit card readers or mobile payment platforms, enable secure and convenient transactions for charging services.

i) Safety and Maintenance:

The charging station incorporates various safety features to ensure safe and reliable charging operations. These features include ground fault protection, overcurrent protection, and surge protection. Additionally, the station may have monitoring systems to track the performance of solar panels, inverters, and charging equipment, allowing for proactive maintenance and troubleshooting.

By integrating solar power generation, smart charging management, and user-friendly interfaces, a 400-kW solar-powered EV charging station provides efficient and sustainable charging solutions for electric vehicle owners, reducing reliance on fossil fuels and contributing to a cleaner and greener transportation system.

5. Simulation and Results

5.1 Simulation Model

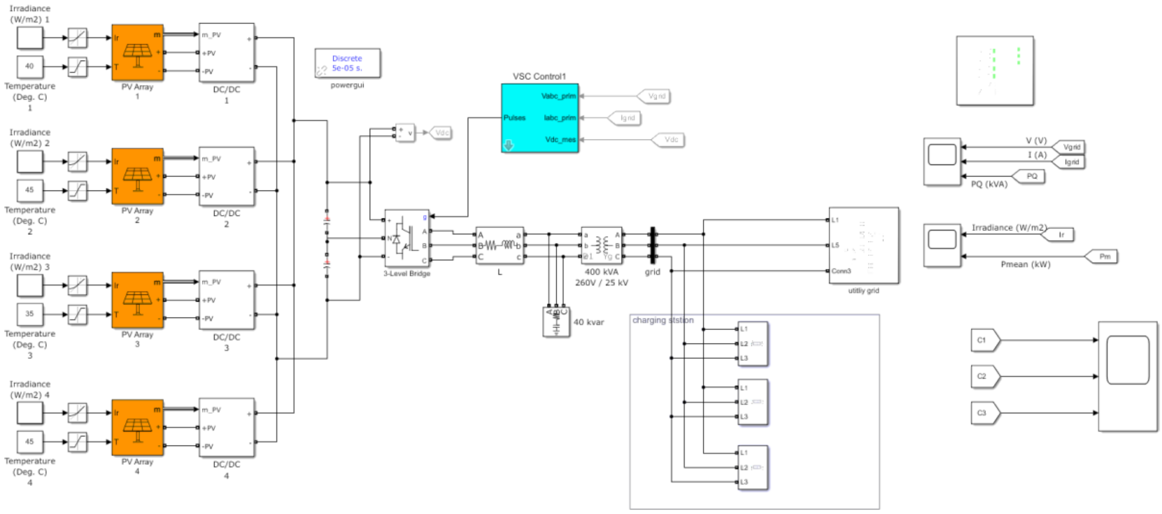

Figure 5. Model of 400 kW Solar Powered Charging Station for Electric Vehicle

Modelling the solar PV system defines the PV panel characteristics, such as efficiency, maximum power output, and temperature coefficients as shown in Figure 5.

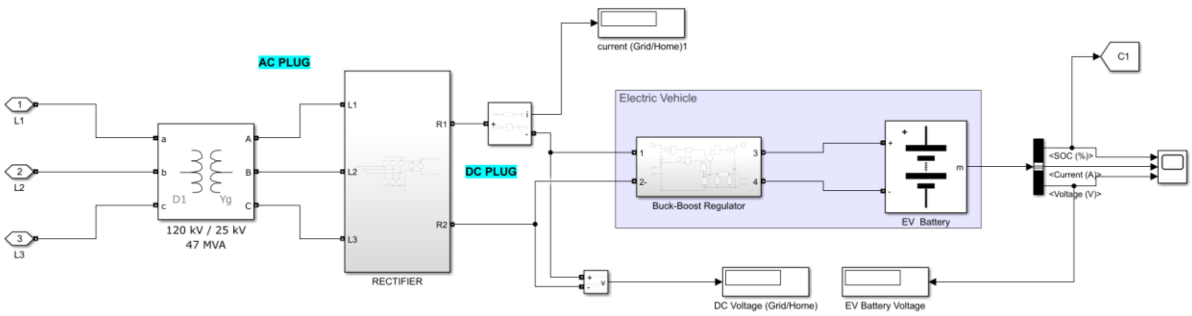

Figure 6. Integrated EV Charging Station

MATLAB's mathematical functions and equations are utilized to model the solar irradiance variations throughout the day and year based on geographical location and time. The incorporated shading effects, temperature variations, and other factors that affect the PV system's performance are shown in figures 5 and 6.

5.2 Simulation Result

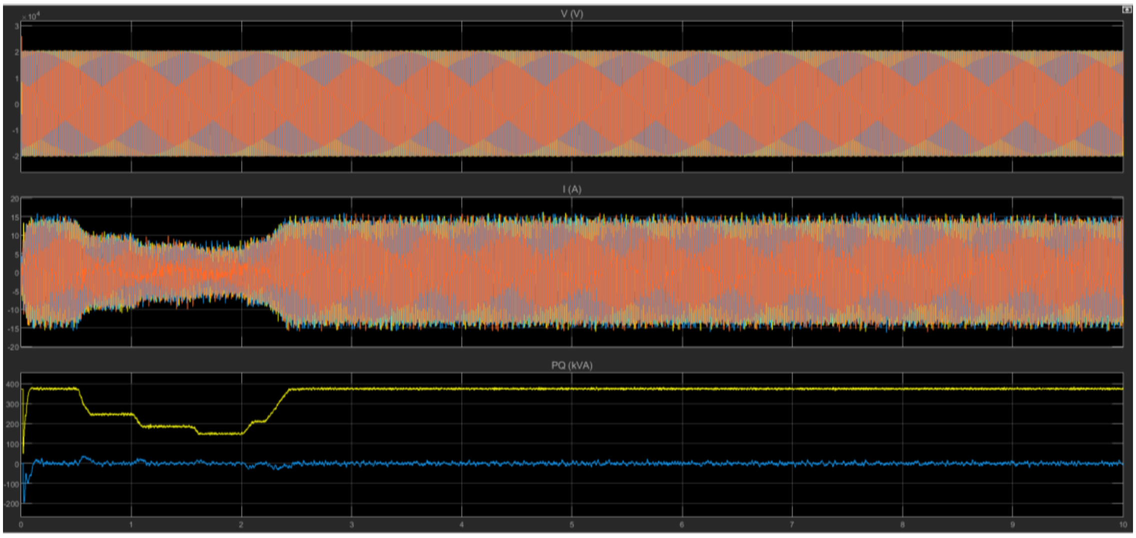

Figure 7. Output for 400 kW Solar Powered Charging Station for Electric Vehicle

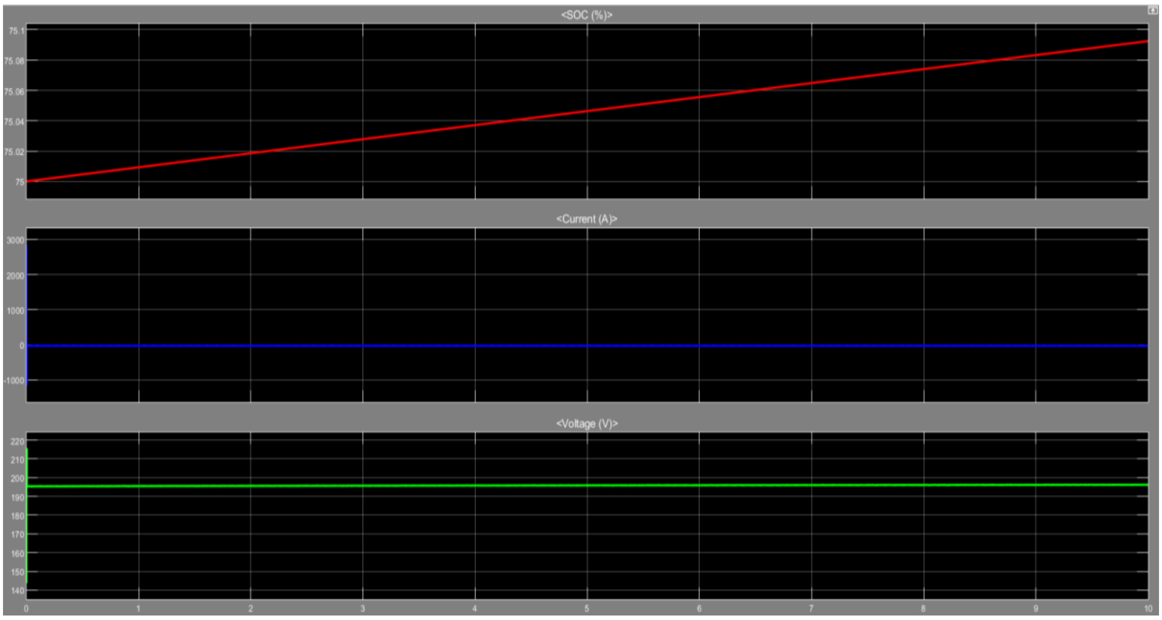

Figure 8. Output for Charging Station with Electric Vehicle in Charging Mode

6. Conclusion

In conclusion, the development of a 400-kW solar-powered charging station using MATLAB offers numerous benefits and opportunities. MATLAB, a widely used programming platform, provides a comprehensive set of tools and functionalities that enable efficient design, analysis, and optimization of the charging station. By harnessing the power of solar energy, the 400-kW charging station contributes to a sustainable and eco-friendly transportation ecosystem. It reduces reliance on fossil fuels, lowers greenhouse gas emissions, and promotes the adoption of Electric Vehicles (EVs) as a clean transportation option. Through MATLAB, various aspects of the charging station are modelled, simulated, and optimized. The design process involves sizing and configuration of the solar photovoltaic system, determination of the optimal energy storage capacity, and layout planning of the charging infrastructure. MATLAB's capabilities allow for accurate performance analysis, considering factors like solar irradiance, ambient temperature, load demand, and charging efficiency. Furthermore, MATLAB facilitates grid integration and power management strategies. It enables the development and testing of control algorithms for bidirectional power flow, voltage regulation, and power quality control. By optimizing power management, the charging station can efficiently utilize solar energy, balance the power exchange with the electrical grid, and participate in demand response programs.

The integration of a 400kW solar-powered charging station offers environmental, technological, and economic advantages. It reduces greenhouse gas emissions, enhances EV charging efficiency, provides energy resilience, supports a decentralized energy system, and contributes to job creation and energy security. These factors make solar-powered charging stations an attractive and sustainable solution for meeting the growing demand for EV charging infrastructure.

In summary, the utilization of MATLAB for the design, analysis, and optimization of a 400-kW solar-powered charging station enhances the efficiency, reliability, and sustainability of the charging infrastructure. It enables accurate modelling, simulation, and control of various components, ensuring optimal utilization of solar energy, seamless grid integration, and economic viability. This comprehensive approach contributes to the advancement of clean transportation systems and paves the way for a greener future.

References

[1] G.R. Chandra System. (2021). Design for a solar powered electric vehicle charging station for workplaces.

[2] Muhammad Majid Gulzar, (2020). An Innovative Converter Less Solar PV Control Strategy for a Grid Connected Hybrid PV/Wind/Fuel-Cell System Coupled with Battery Energy Storage.

[3] A Gayathri. (2019). Solar Based Charging Station for E-Vehicle.

[4] Aqib Shafiq. (2018). Solar PV-Based Electric Vehicle Charging Station for Security Bikes.

[5] Sheridan, S. C., & Lee, C. C. (2018). Temporal trends in absolute and relative extreme temperature events across North America. Journal of Geophysical Research: Atmospheres, 123(21), 11-889.

[6] Arjun, K. G., Pruthviraj, B. G., Chethan, K. Y., & Rashmi, P. (2017, May). Design and implementation of peltier based solar powered portable refrigeration unit.In 2017 2nd IEEE International Conference on Recent Trends in Electronics, Information & Communication Technology (RTEICT) (pp. 1971-1974). IEEE.

[7] Rokde, K., Patle, M., Kalamdar, T., Gulhane, R., & Hiware, R. (2017). Peltier based eco-friendly smart refrigerator for rural areas. International Journal, 7(5).

[8] Sonkhede, P. G., & Pathrikar, A. (2016). Portable thermoelectric refrigeration system for medical application. International Journal of Innovative Research in Computer and Communication Engineering, 4(3), 3190-3195.

[9] Anandakumar, H., & Umamaheswari, K. (2017). Supervised machine learning techniques incognitive radio networks during cooperative spectrum handovers. Cluster Computing, 20(2),1505-1515.

[10] Ganesamoorthy Rajkumar and Srinivasan Sekar. (2022)"An improved intermittent power supply technique for electrostatic precipitators" Energy Harvesting and Systems.

[11] Kannan, G. P., & Usha, S. (2022). Critical Review on and Analysis of Solar Powered Electric Vehicle Charging Station. International Journal of Renewable Energy Research (IJRER), 12(1), 581-600.

[12] Rouhani, M., Ardakanian, O., & Musilek, P. (2022, July). Robust Sizing of Solar-Powered Charging Station with Co-located Energy Storage. In 2022 IEEE Power & Energy Society General Meeting (PESGM) (pp. 1-5). IEEE.

[13] Titus, F., Thanikanti, S. B., Deb, S., & Kumar, N. M. (2022). Charge scheduling optimization of plug-in electric vehicle in a PV powered grid-connected charging station based on day-ahead solar energy forecasting in Australia. Sustainability, 14(6), 3498.

[14] Yap, K. Y., Chin, H. H., & Klemeš, J. J. (2022). Solar Energy-Powered Battery Electric Vehicle charging stations: Current development and future prospect review. Renewable and Sustainable Energy Reviews, 169, 112862.

[15] Turan, M. T., & Gökalp, E. (2022). Integration Analysis of Electric Vehicle Charging Station Equipped with Solar Power Plant to Distribution Network and Protection System Design. Journal of Electrical Engineering & Technology, 17(2), 903-912.

[16] Varun, S., & Bhongade, S. (2022). Solar Power Charging of Electric Vehicle Along with the Implementation of Vehicle-To-Grid (V2G) Technology. In Planning of Hybrid Renewable Energy Systems, Electric Vehicles and Microgrid: Modeling, Control and Optimization (pp. 809-825). Singapore: Springer Nature Singapore.

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K B Sen was born in the year of 1998 in Pandalam, India. He received his BE in 2020 and MTech degree in 2022 from Sree Buddha College of Engineering, Alappuzha. Now, he is pursuing post graduate program in EV system design and development in Skill-Lync, Chennai. He has published 3 articles in journals and have a deep knowledge in Electrical machines and renewable sources.

Rajkumar Ganesamoorthy was born in the year of 1989 in Virudhunagar, India. He received his BE degree in 2010 from Shanmuganathan Engineering College and and MTech in 2012 from Dr.M.G.R University. He worked as an Assistant Professor in Nehru College of Engineering and Research Centre and is now working as a Senior Associate Project Engineer in Skill-Lync. He is also pursuing PhD in Hindustan University, and is a Research Scholar in Hindustan Institute of Technology and Science, Chennai. He has published more than 45 articles in journals and have a deep knowledge in renewable sources.