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Solar Powered Ev Charging Station Using Mat lab

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Abstract: *This project focuses on the development of a simulation-based Electric Vehicle (EV) charging system using the MATLAB/Simulink environment, aimed at designing an efficient solar- powered charging solution. With the growing demand for electric vehicles, there is an increasing need for clean and sustainable energy sources to support charging infrastructure. The proposed system utilizes Solar Photovoltaic (PV) panels as the primary energy source to convert sunlight into electrical energy. Since the output of PV panels varies with solar radiation and temperature, a Maximum Power Point Tracking (MPPT) algorithm is implemented to ensure optimal performance, specifically using the Perturb and Observe (P&O) method, which continuously adjusts operating conditions to extract maximum power under varying environmental conditions. The generated solar power is then processed through a DC-DC buck converter to regulate the voltage according to EV battery requirements. A battery management system ensures safe and efficient charging by controlling voltage and current while monitoring the State of Charge (SOC). The integration of solar panels, MPPT controller, power converter, and battery system is modeled and simulated in MATLAB/Simulink to achieve stable and reliable performance. The results demonstrate effective tracking of the maximum power point and consistent charging output, highlighting that solar-powered EV charging is a practical, efficient, and eco-friendly solution that supports sustainable energy utilization and future green transportation systems.*

Key Words: *Lithium-ion battery, Lead acid battery, Electric Vehicle (EV), Perturb and observe (P&O), State of charge (SOC).*

I.INTRODUCTION

The modern world is witnessing a rapid rise in energy demand driven by industrial growth, population expansion, and technological advancements, traditionally met by fossil fuels like coal, oil, and natural gas, which are finite and environmentally harmful. These conventional sources contribute to pollution, global warming, and climate change, creating an urgent need for sustainable alternatives. Renewable energy technologies have emerged as effective solutions, with solar energy being particularly prominent due to its abundance, accessibility, and clean nature. Photovoltaic (PV) systems enable the direct conversion of sunlight into electrical energy, making solar power suitable for diverse applications. Simultaneously, the transportation sector is shifting toward electric vehicles (EVs), which offer a cleaner alternative by eliminating tailpipe emissions and reducing fossil fuel dependence. However, widespread EV adoption increases the demand for electricity, especially for charging infrastructure. Most existing EV charging stations rely on grid power, often generated from non-renewable sources, limiting environmental benefits. Therefore, integrating solar energy with EV charging systems is essential for true sustainability. This project focuses on designing and simulating a solar-based EV charging system using MATLAB/Simulink to efficiently utilize renewable energy for eco-friendly transportation.

II.MATERIAL AND METHODS

This project presents a simulation-based study on a solar-powered Electric Vehicle (EV) charging system developed using the MATLAB/Simulink environment. The work was carried out as part of an academic research project focusing on the design, modeling, and performance evaluation of a renewable energy-based EV charging infrastructure. The study aims to analyze the efficiency and reliability of integrating Solar Photovoltaic (PV) systems with EV battery charging under varying environmental conditions.

Study Design: Simulation-based study using system modeling.

Study Location: The study was conducted in a virtual simulation environment using MATLAB/Simulink tools for modeling and analysis of the solar-powered EV charging system.

Study Duration: The project simulation and analysis were carried out over a defined academic period.

System Size: The system consists of a Solar PV array, MPPT controller, DC-DC converter, and EV battery model.

System Design Calculation: The system parameters were designed based on standard PV characteristics, load requirements of EV batteries, and efficiency considerations. The Maximum Power Point Tracking (MPPT) was implemented using the Perturb and Observe (P&O) algorithm to optimize energy extraction. Converter design parameters such as duty cycle, switching frequency, and component values were calculated to ensure stable voltage output suitable for EV charging.

Components & Modeling Method: The system model includes a PV array to generate power, an MPPT controller to track maximum power, a DC-DC buck converter to regulate voltage, and a battery management system to monitor charging parameters like voltage, current, and State of Charge (SOC). The simulation was performed under varying solar irradiance and temperature conditions to evaluate system performance.

Simulation Cases: The system was tested under different operating conditions, including varying solar radiation levels and load conditions, to analyze efficiency and stability.

Performance Evaluation: Key performance indicators such as output voltage stability, power efficiency, MPPT tracking accuracy, and battery charging characteristics were analyzed.

Grouping of Scenarios: Simulation scenarios were categorized based on irradiance levels and control strategies to compare system performance and validate the effectiveness of the proposed solar-powered EV charging system.

Inclusion criteria:
1. Simulation-based solar Electric Vehicle (EV) charging system developed using MATLAB/Simulink environment.
2. Solar Photovoltaic (PV) system models operating under standard and variable environmental conditions (irradiance and temperature).
3. Implementation of Maximum Power Point Tracking (MPPT) techniques, specifically the Perturb and Observe (P&O) algorithm.
4. Use of a DC-DC power converter (buck converter) for voltage regulation suitable for EV battery charging.
5. Inclusion of an Electric Vehicle battery model with defined parameters such as nominal voltage, capacity, and State of Charge (SOC).

Exclusion criteria:
1. Models not implemented or validated using MATLAB/Simulink.
2. Systems that do not use Solar Photovoltaic (PV) as the primary energy source for EV charging.
3. Charging models without incorporation of a Maximum Power Point Tracking (MPPT) algorithm.
4. Systems lacking a DC–DC power converter (e.g., buck converter) for voltage regulation.
5. Studies not including an Electric Vehicle (EV) battery model or battery management system (BMS).
6. Simulations that ignore variations in solar irradiance and temperature conditions.
7. Incomplete system configurations missing key components such as PV array, MPPT controller, converter, or load.
8. Models that do not evaluate essential performance parameters like efficiency, voltage stability, or State of Charge (SOC).
9. Purely theoretical studies without simulation or validation results.
10. Systems not focused on renewable energy integration or not relevant to sustainable EV charging applications.

Procedure methodology:

After the system design was finalized, a structured simulation framework was developed using MATLAB and Simulink to evaluate the solar-powered EV charging system. The model included a Solar PV array, MPPT controller using the P&O algorithm, DC–DC buck converter, and EV battery. Input parameters such as solar irradiance, temperature, and load conditions were varied systematically. Key outputs like voltage, current, power, and State of Charge (SOC) were monitored. The setup enabled analysis under realistic operating conditions.

All electrical parameters were measured under controlled simulation conditions to ensure consistency. The PV output was analyzed for different irradiance levels, and MPPT performance was evaluated for tracking efficiency. The DC–DC converter ensured proper voltage regulation for charging. Battery performance was assessed using SOC variation and charging profiles. The collected data were compared across multiple test scenarios.

System configuration details and component parameters were validated using standard design calculations. EV battery specifications such as voltage, capacity, and charging limits were predefined. Overall performance was evaluated based on efficiency, stability, and charging time. The results confirmed reliable operation under varying environmental conditions. The system demonstrates an effective and sustainable EV charging solution.

System Configuration and Operating Modes:
The designed solar-powered EV charging system was evaluated under three operating conditions:

Mode A – direct charging using PV with MPPT control
Mode B – regulated charging through a DC–DC buck converter
Mode C – controlled charging under variable irradiance conditions with intermittent operation.

These modes were implemented and analyzed using MATLAB and Simulink to study system performance and flexibility. The input solar parameters such as irradiance and temperature were simulated to represent real-time environmental variations after a steady-state initialization period. A virtual measurement system was used to record PV voltage, current, and power output. The EV battery charging characteristics were monitored continuously under each operating mode. All simulation processes were carried out using uniform system parameters and consistent modeling techniques to ensure accuracy. The PV system output, converter performance, and battery response were analyzed using standard electrical models. Key parameters such as output voltage, charging current, and efficiency were measured throughout the simulation. The power conversion process, including MPPT tracking and DC–DC conversion, was implemented using standard algorithms and validated models. The system ensured stable voltage output suitable for EV battery charging. Performance variation across different operating modes was analyzed to identify optimal charging conditions.

Additionally, different load and environmental scenarios were considered to evaluate system robustness. The energy utilization and charging efficiency were assessed for each case. The results demonstrate that the proposed system provides reliable, efficient, and sustainable EV charging under varying conditions, making it suitable for real-world renewable energy applications.

Statistical analysis:

Simulation data from the solar-powered EV charging system was analyzed using MATLAB tools. Descriptive measures such as average power, efficiency, and voltage stability were calculated. Performance comparison was carried out under varying irradiance and temperature conditions. MPPT efficiency was evaluated based on tracking accuracy and response time. Converter performance and Battery State of Charge (SOC) variation were analyzed.

III.RESULT

The simulation results of the proposed solar-powered EV charging system were obtained using MATLAB/Simulink and are presented through key performance waveforms. The State of Charge (SOC) of the battery shows a steady and linear increase from approximately 50% to 50.01%, indicating stable and continuous charging. This confirms that the system effectively transfers energy from the PV source to the EV battery without interruption.

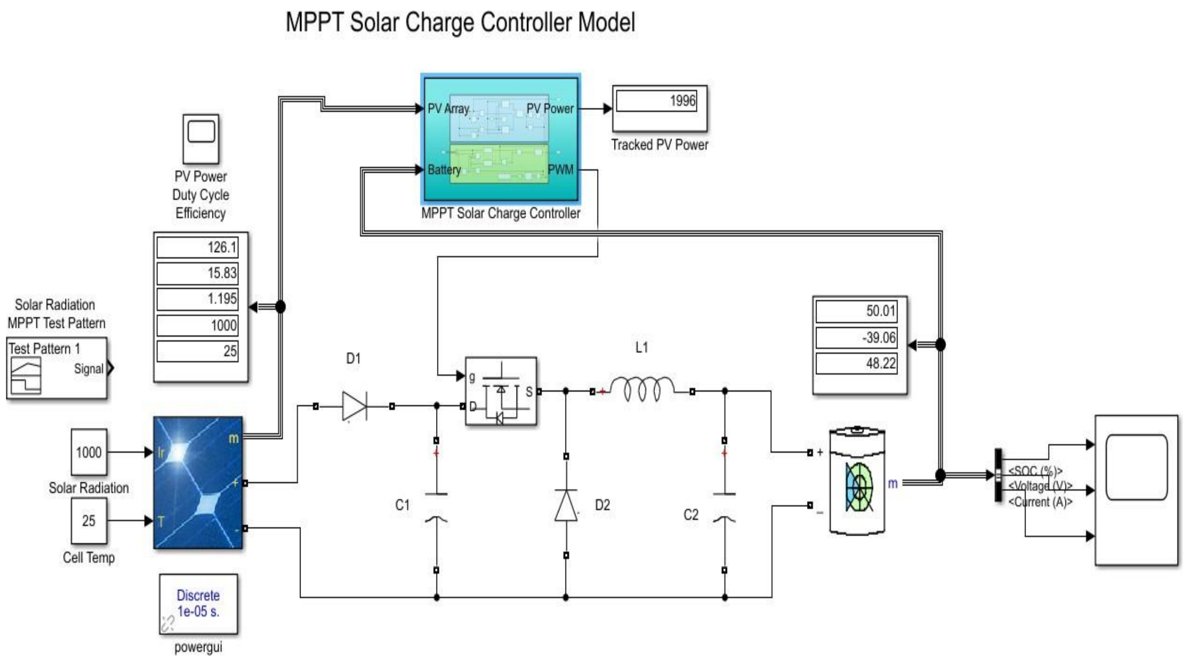

Fig. 1 Circuit Diagram

The PV system is modeled using the MATLAB/Simulink PV array block, incorporating irradiance and temperature as input parameters. Standard test conditions of 1000 W/m² and 25°C are used to evaluate performance. The generated voltage and current are monitored and supplied to the MPPT controller and DC–DC converter. A well-designed PV system ensures efficient energy generation and reliable EV charging operation.

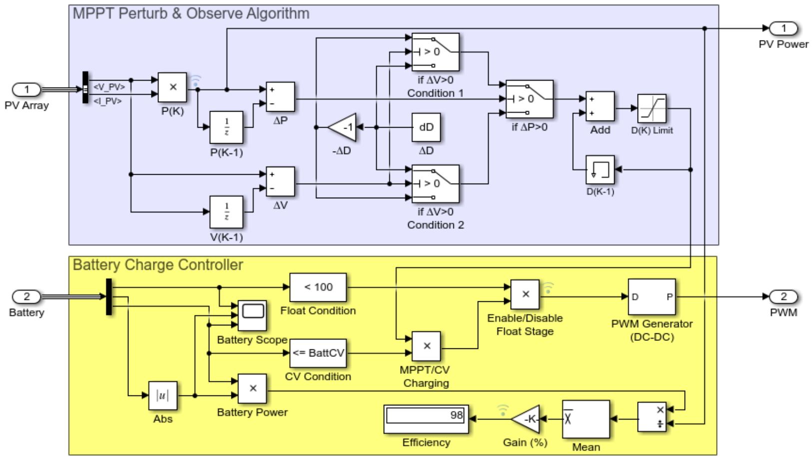

Fig. 2 MPPT Block

The P&O MPPT is commonly used in many small and medium commercial solar PV charge controller and grid connected inverter due to its tracking effectiveness and simplicity of implementation. The MPPT algorithm track the maximum power of the PV array and output its duty cycle relevant to the tracked maximum power to the battery charge controller. The algorithm observes the power changes and perturbs the PV panel operating voltage by changing the duty cycle to the converter switching device which in turn changing the effective input resistance (2) of the buck converter. It then observes again if it reaches the maximum power and this process repeats itself indefinitely. The implementation of the MPPT Perturb & Observe Algorithm in Simulink is shown in Fig. 4. It is implemented using only Simulink blocks without using any scripting code. Each block is labelled with its function with respect to the flowchart. The P&O MPPT algorithm takes in voltage and current reading from the PV array, the previous sample (K-1) function is carried out by the unit delay block. The three if-else conditions of the P&O algorithm are carryout by the condition switch block, the ΔD block allows the user to set the perturbation step size of the duty cycle, the duty cycle increment and decrement function are carried out by an adder with a memory block D(K-1) feedback loop. The D(K) limit block limit the duty cycle exceeding the range between 0.4 to 0.6. The output of the duty cycle is connected to the battery charge controller section. The PV power output is also connected to the battery charge controller for conversion efficiency computation.

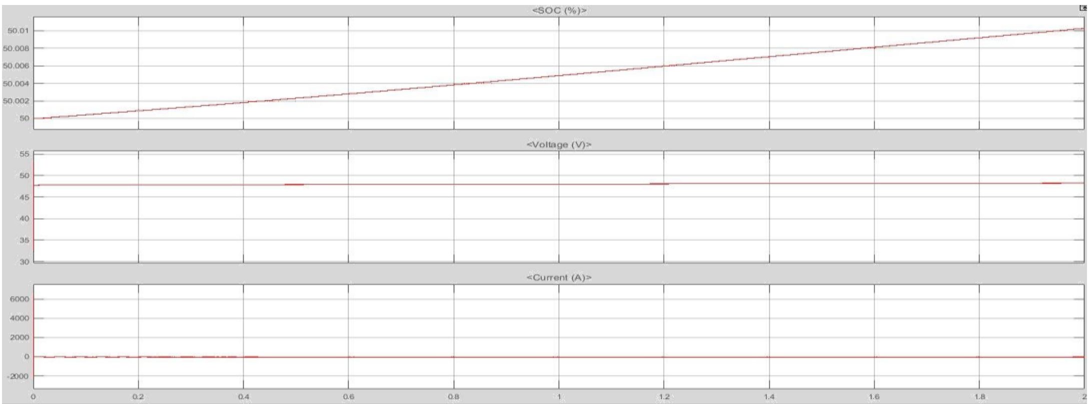

Fig.3.1 Lead acid battery with parameters soc ,voltage, current with respective time

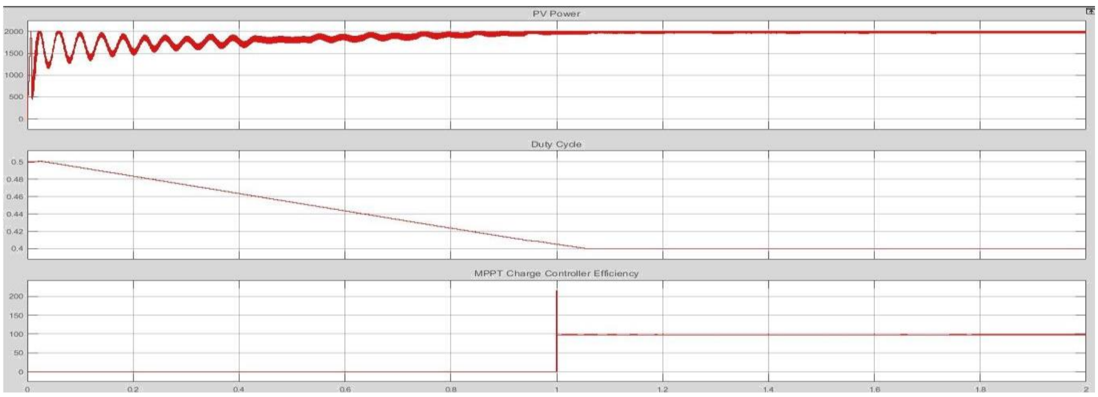

Fig.3.2 Lead acid battery with parameters of power, duty cycle, efficiency with respective time

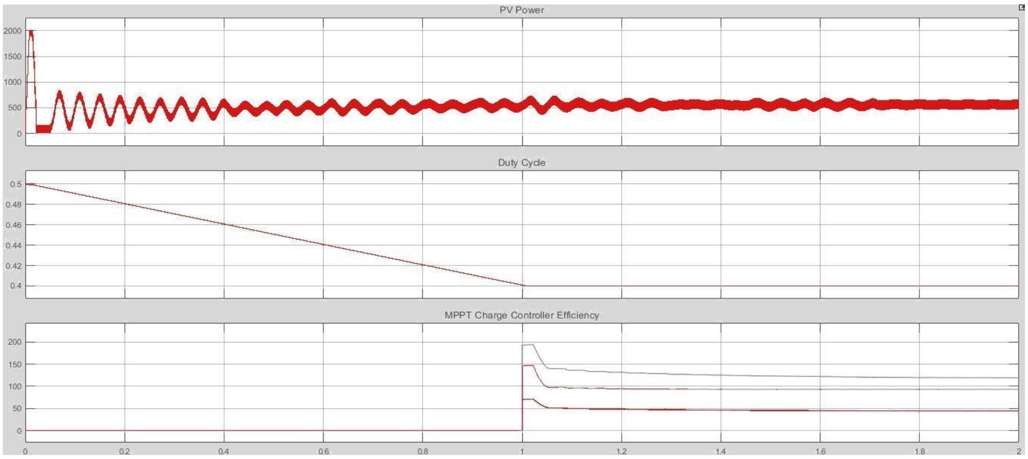

Fig.4.1 Lithium ion battery with parameters of power, duty cycle, efficiency with respective to time

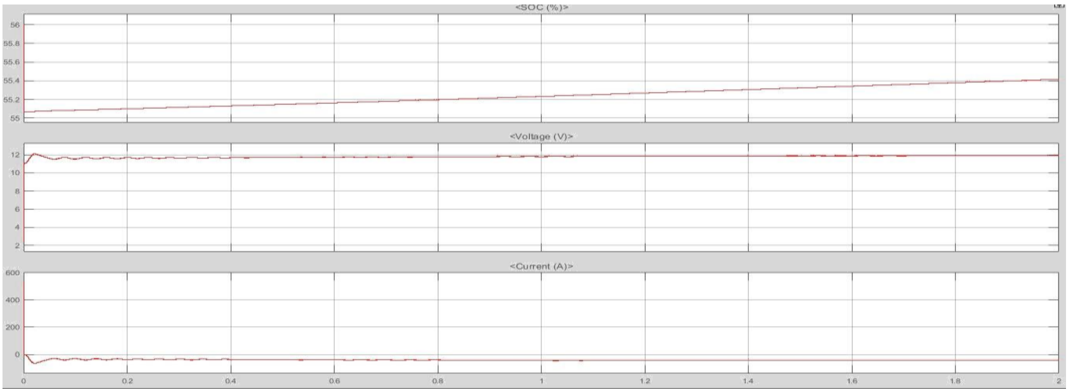

Fig.4.2 Lithium ion battery with parameters of soc, voltage, current with respective time

Comparison between Lead-acid Battery and Lithium-ion Battery:

Parameter	Lead-acid Battery	Lithium-ion Battery
Initial Cost	Very low (best for budget projects)	High upfront cost
Availability	Easily available everywhere	Limited in some regions
Technology Simplicity	Simple design, easy to implement	Requires complex Battery Management System (BMS)
Safety	More stable, less risk of thermal runaway	Risk of overheating/fire if mismanaged
Recycling	Highly recyclable (~95%)	Recycling is complex and less widespread
Overcharging Tolerance	Can tolerate slight overcharging	Sensitive, requires strict control
Cold Temperature Performance	Performs better in low temperatures	Performance degrades in cold conditions
Surge Current Capability	Excellent for high current	Limited surge capability

IV.DISCUSSION

The increasing adoption of electric vehicles (EVs) has created a significant demand for sustainable and efficient charging infrastructure. Conventional grid-based systems often depend on fossil fuels, reducing the environmental benefits of EVs. This has led to growing interest in renewable energy-based charging solutions. Among these, solar energy stands out due to its abundance and eco-friendly nature.

Solar Photovoltaic (PV) systems provide a clean and renewable source of energy for EV charging applications. However, their performance is highly dependent on environmental conditions such as solar irradiance and temperature. This variability necessitates the use of intelligent control techniques. Efficient energy extraction becomes critical for ensuring reliable system operation.

In this study, a solar-powered EV charging system was developed using MATLAB and Simulink. The system integrates a PV array, MPPT controller, DC–DC converter, and EV battery. The Perturb and Observe (P&O) algorithm was used for maximum power tracking. This approach enables continuous optimization of power output under dynamic conditions.The simulation results demonstrate that the MPPT controller effectively tracks the maximum power point. It adapts quickly to changes in irradiance and temperature conditions. This leads to improved energy utilization compared to conventional methods. As a result, the overall efficiency of the system is significantly enhanced. The DC–DC buck converter plays a vital role in regulating the output voltage. It ensures that the voltage levels are suitable for safe EV battery charging. Stable voltage output contributes to improved system reliability. The converter also minimizes power fluctuations during operation.

Battery performance was evaluated using parameters such as State of Charge (SOC) and charging characteristics. The SOC showed a steady increase under different operating conditions. This indicates efficient energy transfer from the PV system to the battery. Proper battery management ensures safe and optimized charging. The findings of this study are consistent with previous research on renewable energy-based EV charging systems. Similar studies have highlighted the importance of MPPT and power electronic converters. These components significantly improve system performance and efficiency. The proposed model aligns well with these established results.Overall, the study confirms that solar-powered EV charging systems are a practical and sustainable solution. They reduce dependence on fossil fuels and lower environmental impact. The proposed system demonstrates reliable performance under varying conditions. This work supports the development of future green transportation technologies.

V.CONCLUSION

This project demonstrates an efficient solar-powered EV charging system designed and simulated using MATLAB/Simulink. The integration of PV panels, MPPT (P&O) algorithm, and DC–DC converter ensures optimal power extraction and stable battery charging. The results confirm reliable performance under varying conditions. Overall, the system provides a sustainable and eco-friendly solution for future EV charging applications.

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