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SIMULATION AND ANALYSIS FOR SOLAR POWERED ELECTRIC VEHICLE CHARGING STATION BASED ON MPPT

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ABSTRACT:- The fast growth of electric vehicles (EVs) has produced a strong demand for capable and sustainable charging infrastructure. Conventional EV charging stations mostly depend on generated from fossil fuels, which contribute to environmental pollution and greenhouse gas emissions. Solar photovoltaic (PV) technology converts sunlight directly into electrical energy. The Electrical power generated by solar PV panels varies depending on environmental conditions such as solar irradiance and temperature. To develop the efficiency of solar PV systems, MPPT techniques are used. MPPT is a control method that continuously adjusts the operating point of the solar panel so that it can deliver maximum power under different environmental conditions. By using MPPT algorithms with power electronic converters, the performance and efficiency of solar energy systems can be significantly enhanced. In a solar-powered EV charging station, the energy produced by the PV array is processed through a DC-DC converter controlled by an MPPT algorithm. This paper analyze the value of the P&O MPPT algorithm for different load conditions and explores various modification to increase tracking accuracy. The integration of MPPT with power converters further improve system efficiency. The Simulation and tentative results show the possibility of implement P&O MPPT in real-world PV systems. The opportunity advancement in adaptive MPPT strategy will be essential in maximizing solar energy consumption.
Keywords: Solar PV Different Irradiations Simulink, EV Charging Station, MPPT, DC-DC Converter, MATLAB/Simulink, Renewable Energy.

1. INTRODUCTION The increase environmental concern and depletion of fossil fuels have accelerate the adoption of electric vehicles (EVs). According to the International Energy Agency, global EV sales have full-grown significantly in recent years, necessitating renewable-powered charging solutions [1]. Solar Photovoltaic (PV) systems are widely adopted due to their sustainability and small operating costs. PV output varies with solar irradiance and temperature [T]. Maximum Power Point Tracking (MPPT) algorithms are used to make certain maximum energy insertion from PV panels. This paper presents a simulation-based learn of a solar-powered EV charging station based MPPT-controlled DC-DC boost converter [3].

Solar Photovoltaic (PV) energy has emerge as one of the most promising renewable energy sources due to its large quantity, scalability, and environmentally friendly characteristics[4]. Integrating solar PV systems with EV charging stations reduces reliance on fossil fuels and reduced carbon emissions. However, the output power of PV systems is extremely nonlinear and depends considerably on solar irradiance and temperature variations [5]. These fluctuations generate challenges in extract maximum available power from the PV array [6].

The solar-powered Electric vehicle charging station in general consists of a PV array, a DC-DC converter, an MPPT controller and an EV battery system[7]. The DC-DC converter regulates voltage levels and ensures stable power transfer to the battery. Proper propose and simulation of such systems are necessary to estimate performance under different operating conditions before practical implementation [8].

This paper presents the simulation and analysis of a solar-powered EV charging station incorporated with an MPPT-controlled DC-DC boost converter [9]. The system is model and analyzed under varying irradiance and temperature conditions to calculate tracking efficiency, voltage stability, and charging performance [10]. The objective is to enhance energy utilization efficiency while ensuring reliable EV charging operation [11].

2. OBJECTIVES AND PROBLEM STATEMENT

Solar-powered EV charging stations offer a sustainable solution, numerous technical challenges limit their optimal performance:

1. **Nonlinear PV Characteristics:** The PV array exhibit nonlinear I–V and P–V characteristics, making it difficult to operate consistently at maximum power.
2. **Environmental Variability:** Rapid change in irradiance and temperature affect output power and charging stability.
3. **Inefficient Power Extraction:** Without MPPT control, important energy losses occur.
4. **Voltage Instability:** variation in PV output can cause unstable DC bus voltage, affecting EV battery charging.
5. **Dynamic Response Requirements:** EV charging systems have need of fast response to maintain efficiency and battery safety.

Solar-powered EV charging stations offer a many objectives are :

1. To model a solar PV array mathematically under varying environmental conditions.
2. To implement a DC-DC boost converter for voltage regulation.
3. To design and integrate a Perturb and Observe (P&O) MPPT algorithm.
4. To simulate the complete system in MATLAB/Simulink.
5. To evaluate system performance in terms of:
    - Power tracking efficiency
    - Voltage stability
    - Dynamic response under varying irradiance
    - EV battery charging performance
6. To analyze system behavior under different operating scenarios.

3. Literature Review

Auther	**Method**	**Key Findings**
Singh et al. (2025)	P&O + IC	superior efficiency in hybrid renewable systems
Yahiaoui et al. (2024)	P&O, IC comparison	IC provides better MPPT tracking accuracy
Dahash et al.(2025)	P&O vs IC	PV output response depends on irradiance(G) and temperature (T)
Recent EV study(2026)	Hybrid MPPT	Compact THD and better EV charging output voltage

3.1 Solar PV Integration with EV Charging Stations

Solar PV systems provide an environmentally friendly solution to power EV charging stations. Researchers have established that standalone solar-based EV charging systems can achieve net zero energy operation, minimizing grid dependency and reducing carbon emissions. In grid-connected PV systems, energy management strategy and bidirectional converters are typically in use to balance grid interaction and renewable energy utilization. However, standalone designs remain critical for remote areas or locations with unreliable grid supply.

3.2 Maximum Power Point Tracking (MPPT) Techniques

MPPT techniques have been examined in the literature:

- **Perturb and Observe (P&O):** One of the most widely implements methods due to its simplicity and low computational requirement & it suffer from oscillations around the maximum power point and compact tracking performance under rapidly varying environmental conditions.
- **Incremental Conductance:** Improves tracking under dynamic conditions by compare incremental changes in current and voltage. Inc Cond reduce steady-state oscillations but is additional computationally intensive compared to P&O.
- **Fuzzy Logic and Neural Network MPPT:** Intelligent control technique have gained attention for improved adaptability and faster tracking. These methods influence machine learning or fuzzy inference to expect optimum operating points under complex environmental variations. Several comparative studies show that intelligent MPPT approaches can outperform classical methods in dynamic environments but at the cost of increased complexity and implementation challenges.

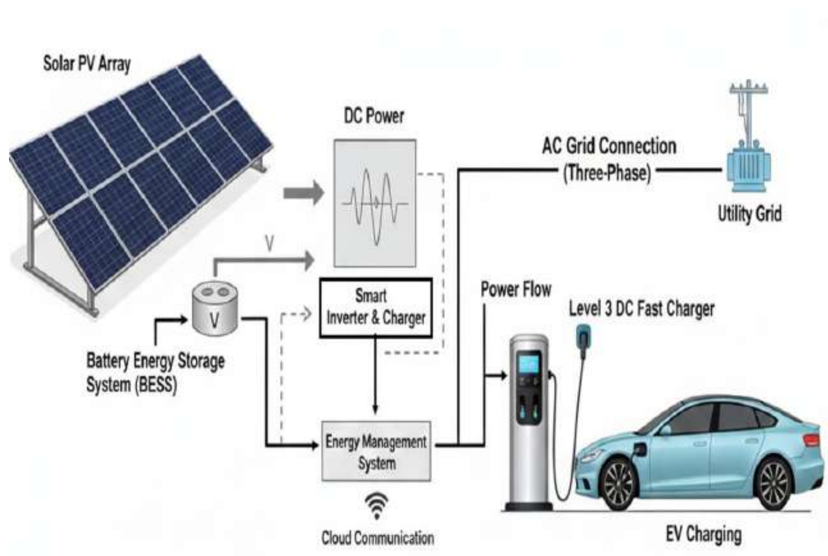
3.3 DC-DC Converter Topologies

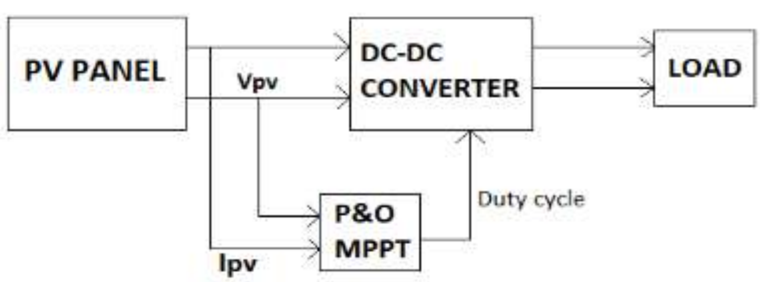
Proficient DC-DC conversion is critical for regulating PV output to suit EV battery charging profiles. The boost converter topology is commonly used to step up PV voltage to the required charging level. Researchers have also examine buck-boost and SEPIC converters to handle a wider range of irradiance conditions. Coupling the converter with MPPT control ensures maximum power withdrawal and stable DC bus voltage for EV charging.

4. System configuration & block diagram

The system consists of:

1. Solar PV Array
2. MPPT Controller
3. DC-DC Boost Converter
4. DC Link Capacitor
5. EV Battery Model
6. Load Controller





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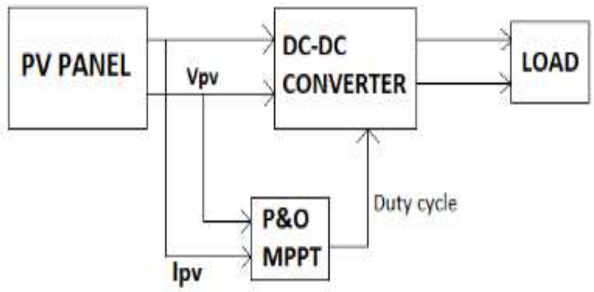

Figure:1 - Solar power MPPT system block diagram

Description of Each Block

1. Solar PV Array

The Solar Photovoltaic (PV) array converts solar energy into electrical energy. The output power depends on:

- Solar irradiance (W/m²)
- Temperature (°C)

2. MPPT Controller

The Maximum Power Point Tracking (MPPT) controller ensures that the PV array operates at its Maximum Power Point (MPPT). In this learn, the Perturb and Observe (P&O) algorithm is implementing. Functions:

- Calculated PV voltage and current
- Measured output power
- Adjusts duty cycle of DC-DC converter
- Maximizes energy insertion

3. DC-DC Boost Converter

The boost converter increases the PV voltage to the required EV charging voltage.

Boost Converter equation:

$$\mathbf{V_{out} = V_{in}/(1-D)}$$

Where:

- D = Duty cycle
- V_{in} = PV voltage
- Vout = Output voltage

4. DC Link Capacitor

The DC link capacitor:

1. Minimized voltage ripple

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2. Stabilizes DC bus voltage
3. Ensures smooth power transfer to EV battery

5. EV Battery

The EV battery:

1. Receives synchronized DC power
2. Charges according to voltage and current control
3. Represents the EV load in simulation

Battery parameters considered:

1. Nominal voltage (e.g., 48V or 72V)
2. State of Charge (SoC)
3. Charging current limits

1. MATLAB/Simulink Model :-

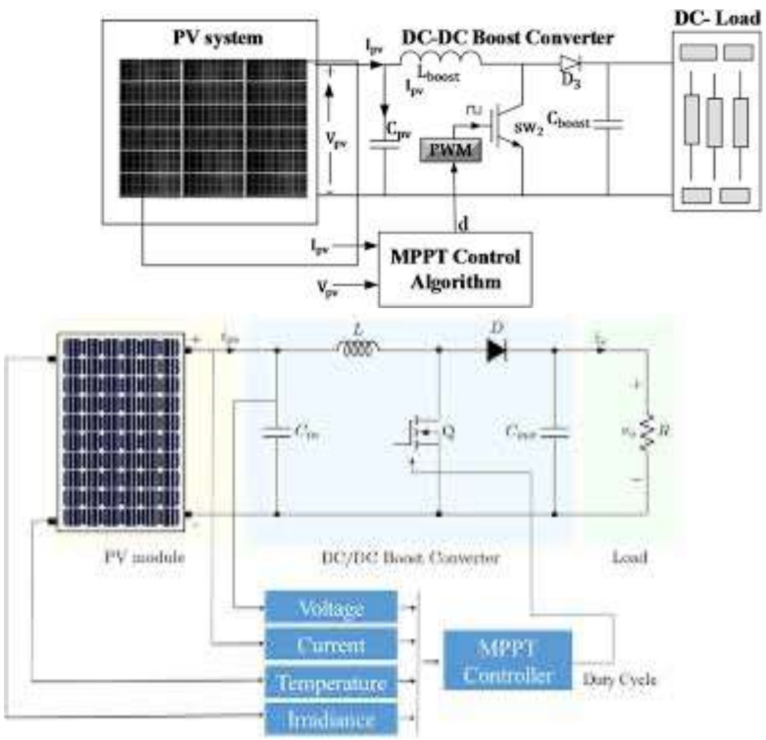

Figure:2- Proposed PV –powered EV charging station with the battery storage system

- Solar PV array generates DC power.
- MPPT controller detects maximum power point.
- Duty cycle of boost converter is adjusted.
- Boost converter regulates output voltage.
- Stable DC power is supplied to EV battery.
- Battery charges efficiently under varying irradian

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6. Perturb and Observe (P&O) MPPT Algorithm

Steps:

- Compute PV voltage and current.
- Estimate power.
- Evaluate with previous value.
- Adjust duty cycle accordingly.

Advantages:

- Simple realization
- small computational cost

Disadvantages:

1. Oscillation around MPPT
2. Slow under rapid irradiance change

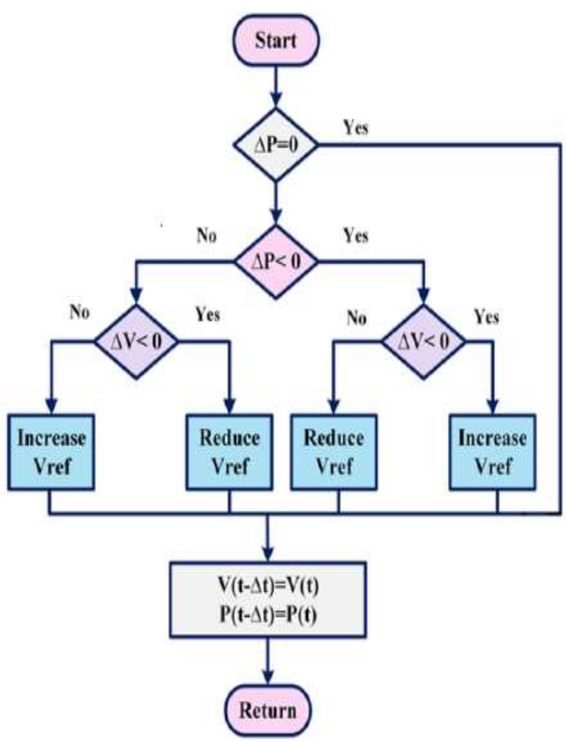

Figure:3- P&O MPPT Algorithm

7. Simulation model discrimination:-

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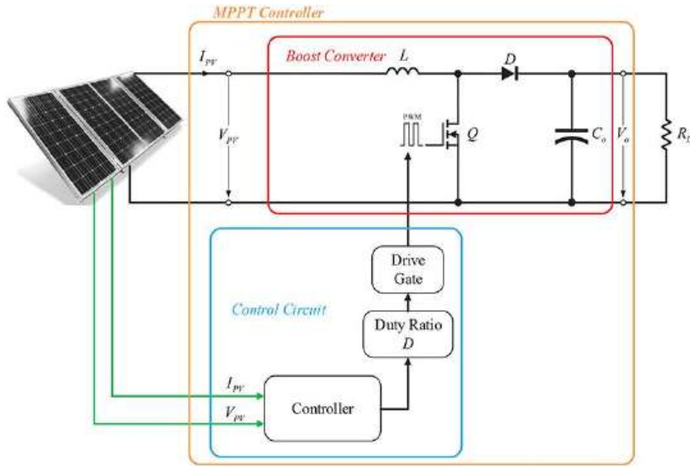

Figure4:-simulation model solar PV system for EV charging station

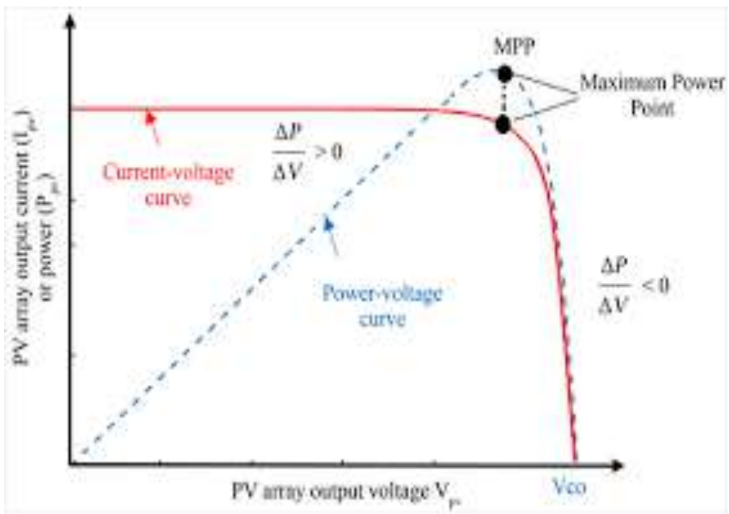

Figure:5-simulation & analysis of Powered EV charging based on MPPT

8. Results & Discussion:- The Perturb and Observe (P&O) MPPT algorithm effectively tracked the maximum power point under dynamic irradiance changes. Main Observations

1. Tracking time: < 0.06 seconds
2. Steady-state oscillations: Minimal (±1–3%)
3. Tracking efficiency: 95–97%

Parameter	**Without MPPT**	**With MPPT**
Energy Utilization	Minimum	Maximum
Power Loss	Maximum	Minimum
Charging Time	Higher	Reduced
Overall Efficiency	~78%	~95%
Power Utilization	80–85%	96–98%
Voltage Stability	Moderate	High

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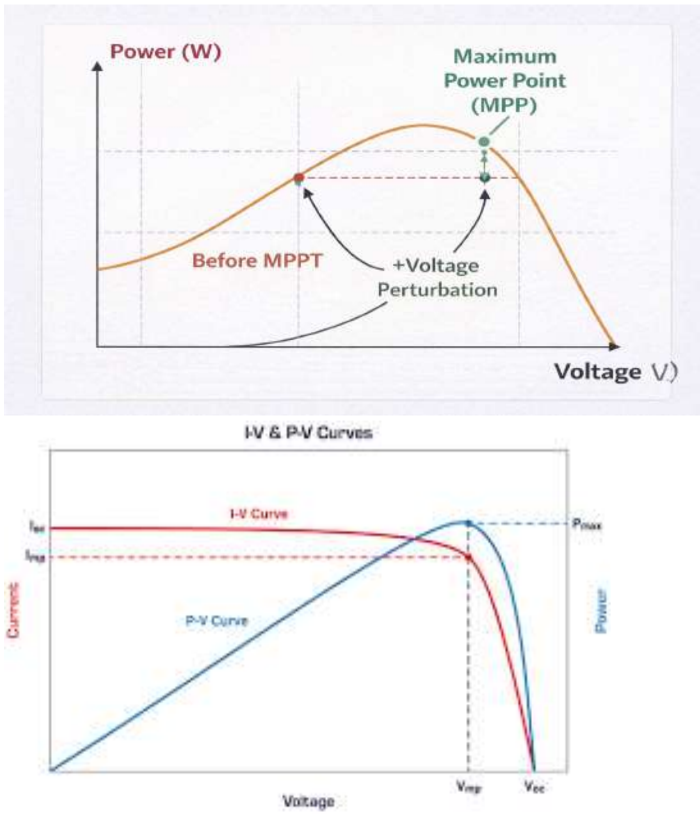

Figure:6 - PV curved for MPPT

Figure:7- **Simulation output waveforms of a DC–DC converter** solar Electric-Vehicle charging / MPPT

9. Conclusion: -The Simulation and Performance examination of a solar-powered EV charging station integrated with a Maximum Power Point Tracking (MPPT) controller. The results confirm that:

1. The MPPT algorithm effectively tracks the maximum power point under varying solar irradiance conditions.
2. The DC–DC boost converter maintains stable DC output suitable for EV battery charging.
3. The overall system efficiency improves significantly with MPPT execution.

4. Charging time is compact due to optimal utilization of available solar energy.
5. The proposed system enhances reliability, stability and sustainability of EV charging infrastructure.
6 The converter capably transfers energy from Photo-Voltic to load.

7. The Current output waveforms confirm correct switch function.
8. System maintains stability subsequent to transient oscillation period.
9. The proper for incorporation with MPPT algorithms.

FUTURE WORKS:-

1. Performance of Incremental Conductance MPPT for superior tracking accuracy.
2. Incorporation with battery energy storage system (BESS).
3. Real-time hardware substantiation using DSP/FPGA.

11. Applications

1. Smart cities & Remote/off-Smart grid locations
2. Public Solar EV charging stations
3. Renewable energy optimization

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