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Dual Solar AC Charging System: A Review of Solar Photovoltaic Integration, Power Conversion and Electric Vehicle Charging Technology

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Abstract: *The increasing demand for electric vehicles (EVs) and sustainable transportation has created a need for reliable, economical and environmentally friendly charging infrastructure. Solar photovoltaic (PV) energy provides a promising solution by utilizing renewable solar power for electric vehicle charging. This review paper presents an overview of a Dual Solar AC Charging System, in which two solar photovoltaic sources are integrated to provide electrical power for AC charging applications. The system can be designed with solar panels, solar charge controllers, maximum power point tracking (MPPT), power conditioning circuits, an inverter and suitable protection devices. The paper reviews existing solar-powered EV charging technologies, AC charging configurations, power electronic converters, energy management techniques and the challenges associated with solar energy utilization. It also discusses the possible integration of battery energy storage and grid backup to improve charging reliability during low solar irradiance and nighttime conditions. The dual-solar concept aims to improve solar energy utilization, reduce dependence on conventional grid electricity and support sustainable electric mobility.*

Keywords: Solar Photovoltaic System, Dual Solar Charging, AC Charging, Electric Vehicle, MPPT, Solar Inverter, Renewable Energy, Battery Energy Storage System.

I. INTRODUCTION

The transportation sector is a major contributor to global energy consumption and environmental pollution. Conventional vehicles operate using fossil fuels, resulting in greenhouse gas emissions and air pollution. Electric vehicles have emerged as an alternative because they offer higher energy efficiency and the potential to reduce transportation-related emissions.

The increasing adoption of electric vehicles requires efficient and sustainable charging infrastructure. Conventional EV charging stations mainly depend on electricity supplied by the utility grid. As the number of electric vehicles increases, additional electricity demand may create pressure on existing distribution networks.

Solar photovoltaic technology offers an alternative method of generating electricity for EV charging. Solar panels convert sunlight directly into electrical energy without producing direct operational emissions. Integrating solar PV systems with EV charging stations can reduce grid energy consumption and improve renewable energy utilization.

A Dual Solar AC Charging System is considered in this paper as a configuration using two photovoltaic sources or solar panel groups to supply an AC charging arrangement through appropriate power conversion equipment. The two solar inputs may be connected through separate MPPT channels or suitable combined DC power conversion arrangements, depending on the system design.

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II. OBJECTIVES OF THE REVIEW

The major objectives are: (1) to study solar photovoltaic applications in EV charging; (2) to examine dual solar energy input for AC charging; (3) to review MPPT controllers; (4) to study DC-AC inverter technology; (5) to investigate battery storage and grid integration; and (6) to identify technical challenges and future research opportunities.

III. LITERATURE REVIEW

3.1 Solar Photovoltaic-Based EV Charging: Bhatti et al. presented a critical review of electric vehicle charging using solar photovoltaic energy. Their study examined grid-connected and standalone PV-based EV charging systems and discussed their technical and economic feasibility.

3.2 PV-Grid Integrated Charging Systems: Research published in Renewable and Sustainable Energy Reviews examined photovoltaic-based EV charging configurations, including PV-grid and standalone systems. The study discussed power converter topologies, MPPT techniques, charging mechanisms and energy management strategies.

3.3 Solar EV Charging Infrastructure: Alrubaie et al. (2023) reviewed solar photovoltaic-based EV charging stations by considering market development, technical requirements, distribution network implications and future challenges.

3.4 Standalone Solar Charging Systems: Recent research has examined standalone solar-powered EV charging stations with battery energy storage. These configurations require proper PV sizing, storage capacity and energy management to ensure reliable charging.

3.5 Power Electronic Converter Technologies: MPPT-based DC-DC converters extract maximum available power from PV panels, while inverters convert DC power into AC power for AC charging equipment.

IV. PROPOSED DUAL SOLAR AC CHARGING SYSTEM

The Dual Solar AC Charging System uses two solar photovoltaic sources to supply electrical energy to an AC charging output. Each PV array can be connected to an independent MPPT controller to extract maximum available solar power under different operating conditions. The controlled DC outputs are combined through a suitable DC bus arrangement and supplied to an inverter. The inverter converts DC electrical power into AC electrical power suitable for the intended charging equipment. Appropriate protection and monitoring are required for safe operation.

4.1 Main Components: Solar PV panels convert solar radiation into DC electrical energy; MPPT controllers optimize the operating point of the PV arrays; DC-DC converters regulate the DC voltage; a DC bus combines regulated power from both solar inputs; optional battery storage stores excess energy; a DC-AC inverter converts DC power into AC electricity; an AC charging unit provides the charging interface; and protection devices provide overcurrent, overvoltage, short-circuit and earthing protection.

4.2 Working Principle: Solar panels generate DC power. Both solar sources feed their respective MPPT controllers, which adjust their operating points to maximize available solar power. Regulated DC outputs are supplied to a common DC bus through suitable power conditioning circuits. The DC-AC inverter converts DC power into AC power, which is supplied to compatible charging equipment. Battery storage or grid backup, if incorporated, can support the load when solar power is insufficient. Charging voltage and current must be controlled according to the connected EV charging equipment specifications.

4.3 Block Diagram: Solar PV Array 1 + Solar PV Array 2 → MPPT Controllers → DC-DC Power Conditioning → Common DC Bus → DC-AC Inverter → AC Charging Unit → Charging Load. Optional battery storage and grid backup can be integrated using suitable converters and protection arrangements.

V. POWER ELECTRONIC CONVERSION TECHNIQUES

5.1 Maximum Power Point Tracking: PV maximum power changes with solar irradiance and temperature. MPPT controllers help panels operate near their maximum power point. Common methods include Perturb and Observe (P&O), Incremental Conductance (INC), fuzzy logic and AI-based MPPT.

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5.2 DC-DC Converter: DC-DC converters regulate the voltage generated by solar panels. Boost, buck or buck-boost converters may be selected according to the required DC bus voltage.

5.3 DC-AC Inverter: The inverter converts DC energy into AC energy. A suitable pure sine-wave inverter is preferred for AC charging applications. It must be rated according to charging power and incorporate appropriate electrical protection.

VI. AC CHARGING TECHNOLOGY

In AC charging, the charging station supplies controlled AC power to the vehicle, while the vehicle's onboard charger converts the AC supply into DC power for battery charging. The system generally consists of an AC supply source, EV supply equipment (EVSE), charging cable and connector, communication and control arrangement, onboard charger and battery management system. Charging rate depends on supply voltage, current rating and onboard charger capacity. The design must comply with applicable EV charging safety and electrical installation requirements.

VII. ADVANTAGES OF THE DUAL SOLAR AC CHARGING SYSTEM

The system uses renewable solar energy for charging applications and can reduce electricity drawn from the utility grid. Two solar inputs can allow flexible PV array configuration, while MPPT controllers improve solar energy extraction. Additional solar capacity or battery storage may be incorporated subject to system design. The concept can be adapted for suitable EV charging and other AC loads.

VIII. TECHNICAL CHALLENGES AND LIMITATIONS

Solar generation depends on sunlight intensity and weather. Initial installation costs may be high, and improper PV array matching can reduce performance. Conversion losses occur in MPPT controllers, DC-DC converters and inverters. Battery storage adds cost and maintenance requirements. Safe AC charging requires suitable protection and compatible charging equipment. Dust, shading and high temperatures can also reduce system performance.

IX. FUTURE SCOPE

Future development may include IoT-based monitoring, AI-assisted MPPT, battery energy storage, automatic source selection, intelligent energy management, grid-connected hybrid operation, improved inverter efficiency, smart charging based on solar availability and experimental prototype evaluation.

X. CONCLUSION

This review paper has examined the concept and technological aspects of a Dual Solar AC Charging System for sustainable electric vehicle charging applications. Integrating two photovoltaic sources with MPPT controllers, DC-DC converters and a DC-AC inverter provides a possible configuration for utilizing solar energy in AC charging applications. Solar-based EV charging can reduce dependence on conventional grid electricity and support renewable energy integration. System performance depends on solar irradiance, PV array sizing, converter efficiency, inverter capacity and energy management. Further work should focus on prototype development, simulation, experimental testing, efficiency measurement and cost analysis to validate practical performance.

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