Design and implementation of dual-powered charging station for Electric Vehicle

1. Anjali Chandane

2. Rushikesh Tanpure 3. Dipak Badake 4. Omkar Tanpure 5. Pranav Chougule 6. Mr. Kishor P. Jadhav

1, 6 Assistant Professor, Department of Electrical Engineering, SKN Sinhgad College of Engineering Pandharpur, India

2,3,4,5 Student, Department of Electrical Engineering, SKN Sinhgad College of Engineering Pandharpur, India

Abstract : ***This project aims to develop a solar-powered electric vehicle (EV) charging station, harnessing renewable energy to provide sustainable, off-grid EV charging solutions. The system incorporates solar panels to capture sunlight, converting it into electrical energy via an inverter to power EV chargers. Energy generated by the solar panels is stored in a battery bank to ensure continuous availability, even when sunlight is limited. An integration with the Maharashtra State Electricity Board (MSEB) supply is included as a backup source to maintain operational reliability during low solar output. This hybrid approach combines renewable energy with grid support, enhancing efficiency and reducing reliance on non-renewable power sources. By leveraging solar power, the station reduces greenhouse gas emissions, aligns with green energy goals, and promotes clean transportation. The project demonstrates a scalable, eco- friendly model for sustainable EV infrastructure that can support the growing demand for EV charging facilities.***

Keywords - Renewable energy sources, Hybrid Power Supply, Solar Panel, Eco-Friendly Technology, Battery &Inverter.

INTRODUCTION

The increasing prevalence of electric vehicles highlights the need for reliable and sustainable charging infrastructure to support the shift from fossil fuel-powered transportation to clean energy mobility. As EV adoption continues to grow, addressing the environmental impact of charging stations has become a critical concern. Many conventional EV charging stations rely on electricity from the grid, often sourced from non-renewable energy, which contributes to greenhouse gas emissions and reduces the environmental benefits of EVs. To address these issues, renewable energy sources, particularly solar power, offer a promising solution.

This project proposes the design and implementation of a solar-based electric vehicle charging station, which harnesses solar energy to provide a more sustainable and environmentally friendly alternative to conventional grid-dependent charging stations. Solar power is one of the most abundant renewable energy sources, and by integrating solar panels into EV charging infrastructure, .The system is designed to capture sunlight through solar panels, convert it into electrical energy using inverters, and store it in batteries, ensuring that power is available for EV charging even during non-sunny periods or at night.

The key components of this solar-powered EV charging station include solar panels, inverters, a battery storage system, EV chargers, and a backup connection to the Maharashtra State Electricity Board (MSEB) power grid. Solar panels are responsible for capturing sunlight and converting it into DC (direct current) electricity. The inverters then convert the DC electricity into AC (alternating current) electricity, making it compatible with the EV chargers and other electrical systems. This electricity can either be used immediately for charging EVs or stored in battery banks for later use, depending on demand and solar availability.

One of the major advantages of this system is its ability to operate off-grid or as a hybrid setup with the grid as a backup source. In off-grid mode, the station is powered solely by solar energy and stored battery power, enabling independent and renewable charging. However, by incorporating a grid connection through MSEB, the system can seamlessly switch to grid power when solar energy generation is insufficient, such as during extended cloudy periods or high- demand scenarios. This hybrid setup ensures that the station maintains reliable operation, providing uninterrupted charging access for EV users.

In addition to promoting clean energy usage, this solar- based charging station also offers several economic and technical benefits. The reliance on solar power reduces the dependency on grid electricity, which can lower operational costs and protect against fluctuations

in energy prices. The battery storage system not only supports continuous charging during low-sunlight hours but also helps in energy load management, allowing the station to operate more efficiently and reduce strain on the grid during peak demand periods. This energy independence can lead to substantial long- term savings, particularly in regions with high electricity costs or unstable grid supply.

Environmental sustainability is a central focus of this project,By reducing the demand for grid power generated from fossil fuels, the solar-based EV charging station minimizes carbon emissions and supports a greener future for transportation. Furthermore, using clean, renewable energy contributes to air quality improvement and helps preserve natural resources, making it an ideal solution for urban and rural areas alike. This charging station model represents a proactive step toward sustainable urban planning and infrastructure development, where clean energy solutions become integral to everyday services.

Another significant aspect of this project is its scalability and adaptability. The solar-powered EV charging station can be implemented in various locations and adapted based on energy demand, available space, and specific site conditions. Solar panels can be installed on rooftops, parking lots, or designated solar farms, allowing flexibility in deployment and enhancing accessibility for EV users. Additionally, as battery technology advances and solar panel efficiency improves, the station's performance and energy output can be upgraded to meet future demands without substantial overhauls, making it a scalable solution for communities, businesses, and government entities.

The integration with MSEB also enables a level of interoperability that could be essential for areas with intermittent sunlight or unpredictable weather patterns. By maintaining a connection to the traditional power grid, the station ensures reliability and user confidence, essential factors for widespread adoption. This feature is particularly beneficial in regions where solar energy alone may not consistently meet high charging demands, ensuring that users always have access to a dependable energy source for their vehicles. With the grid connection as a backup, the station provides a hybrid model that maximizes renewable energy utilization while mitigating operational risks associated with solar power alone.

LITERATURE SURVEY

A) Udaiyakumar S. , proposed "Solar powered EV charging station"

The paper published in April , 2024.

Udaiyakumar S.'s 2024 paper on "Solar Powered EV Charging Station" delves into the potential of solar energy as a primary power source for electric vehicle (EV) charging infrastructure. The study emphasizes the benefits of integrating photovoltaic (PV) systems, focusing on sustainability and reducing greenhouse gas emissions.

Udaiyakumar analyzes key technical aspects, such as the efficiency of solar panels, power management systems, and grid connectivity for reliable energy supply. His research also addresses potential challenges, like weather variability and peak load management, to ensure consistent energy availability. Moreover, the study proposes design and operational strategies to maximize energy capture and storage, aiming to make solar-powered charging stations viable on a larger scale. This work contributes valuable insights into achieving a cleaner, renewable energy-powered EV ecosystem.

B) Itamar Hasson & Bas van Donselaar , proposed "EV charging payments"

The paper published in June , 2023.

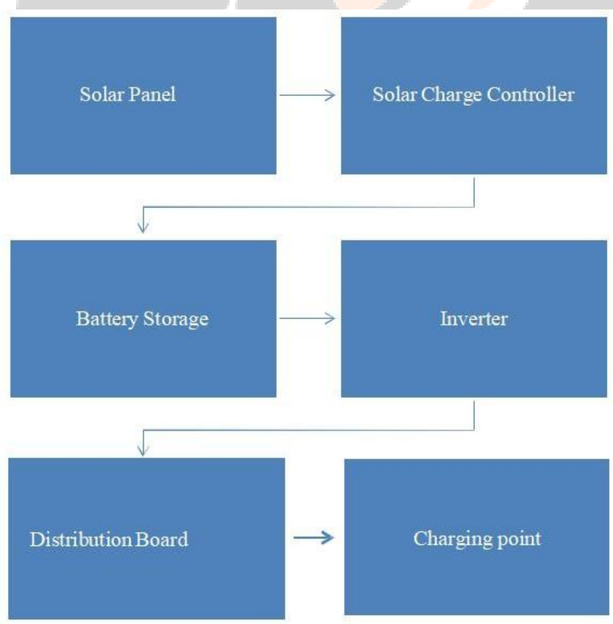
In their June 2023 paper, Itamar Hasson and Bas van Donselaar delve into the complexities of payment systems within the EV charging ecosystem, analyzing both existing and emerging models to make EV charging more user-friendly. They focus on improving payment flexibility through various models, such as subscription-based systems, on-demand payments, and dynamic pricing, to cater to diverse user needs. The study examines digital wallets, contactless cards, and mobile apps as means to enable seamless, secure transactions. It also highlights the potential for blockchain technology to enhance data security, enabling trustworthy transactions and reducing fraud risks. To support interoperability across networks, Hasson and van Donselaar propose standardized payment protocols, allowing drivers to access multiple charging networks with a single account. The authors ultimately argue that a simplified, user-centered payment process is key to accelerating EV adoption and achieving a well-connected EV infrastructure.

C) Joshi et al, proposed "Electric vehicle charging station"

The paper published in August 2021 .

In their August 2021 paper, Joshi et al. provide a detailed examination of electric vehicle (EV) charging station infrastructure, focusing on strategic placement and optimization to enhance network accessibility and efficiency. They assess factors like traffic density, proximity to urban centers, and accessibility to renewable energy sources to determine ideal station locations. The study also evaluates energy management techniques, such as load balancing and smart grid integration, to handle fluctuating power demands and minimize grid strain. The authors propose a hybrid model using renewable energy sources, like solar and wind, to reduce dependency on conventional power. Additionally, they highlight the importance of interoperability between charging networks to support a seamless user experience.

METHODOLOGY



which is especially useful in EV stations where reflective surfaces can increase energy yield. This design helps capture additional sunlight from the ground, boosting output by up to 30% over traditional panels. Additionally, the half-cut cells improve resilience to shading, as shaded sections don't affect the entire panel's performance. Although they are slightly more expensive, the higher energy output and durability lead to a faster return on investment, making them an optimal, sustainable choice for commercial EV charging setups.

Solar Charge Controller:-

Solar Panel:-

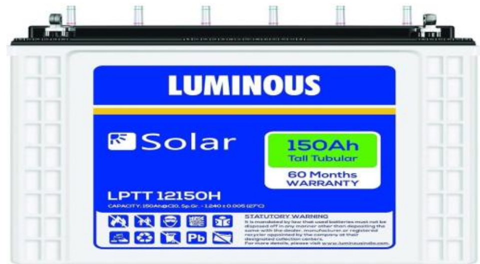
Block diagram

Solar Panel

It is essential for managing the flow of electricity from solar panels to batteries in electric vehicle (EV) charging stations, ensuring efficient and safe charging. This device regulates the current to prevent overcharging or deep discharge, which helps maintain battery health and extend battery life. It also optimizes power usage by adjusting the charging rate based on battery capacity and the amount of solar energy available, making the system more efficient. Most solar charge controllers used in EV stations feature maximizes energy capture from the solar panels by constantly tracking the optimal voltage and current. This is crucial in EV applications where consistent and rapid charging is needed. Additionally, charge controllers offer safety protections against short circuits, overheating, and reverse polarity, making them a reliable and essential component in solar-powered EV charging stations.

Battery:-

Mono half-cut bi-facial solar panels are highly effective for electric vehicle (EV) charging stations, thanks to their high efficiency and dual-sided energy capture. Made from mono-crystalline cells, they offer superior performance, even in low-light conditions, and the half-cut cell design reduces power loss by minimizing resistance. The bi-facial nature of these panels enables them to generate power from both the front and back,



Lead-acid batteries, though less common in modern electric vehicle (EV) charging stations, are sometimes used due to their lower cost and reliable performance in specific applications. These batteries are durable, easy to recycle, and capable of delivering high bursts of power, which can be useful in managing the fluctuating energy demands of EV charging. meaning they take up more space and may need replacement more frequently. Lead-acid batteries are best suited for smaller stations or those with less frequent charging needs, as they are heavy and have slower charging speeds. Despite these limitations, their affordability and simplicity make them a viable option for budget-conscious installations, especially where renewable energy storage is only needed for short-term backup.

Inverter:-

energy sources to various charging points. It acts as a central hub where electricity is controlled, protected, and directed to different components within the station, including chargers, lighting, and auxiliary systems. Equipped with circuit breakers, fuses, and safety devices, the distribution board safeguards the entire setup by preventing overloading, short circuits, and other electrical faults, enhancing both safety and reliability. For solar-integrated stations, it also manages the input from inverters and ensures seamless switching between solar and grid power as needed. Additionally, distribution boards allow for monitoring and easy maintenance of power distribution, making them vital for efficient and safe operations in EV charging infrastructure.

Payment Gateway:-

A solar inverter is a crucial component in electric vehicle (EV) charging stations powered by solar energy, as it converts the direct current (DC) generated by solar panels into alternating current (AC), which is required by most EV chargers. This conversion enables the seamless integration of solar energy with the charging station's power system, ensuring efficient energy flow to charge vehicles. They also provide grid management functions, allowing the charging station to draw power from or send excess energy back to the grid, which is especially useful in peak demand times. Additionally, solar inverters help with system monitoring, safety functions, and even battery management if the station has a storage system, making them integral for efficient and reliable EV charging.

Distribution Board:-

A distribution board in an electric vehicle (EV) charging station is essential for managing and distributing power from the main supply or solar

The Bolt Earth payment gateway in electric vehicle (EV) charging stations provides a streamlined, secure method for users to pay for charging services. Integrated into Bolt Earth's EV charging network, it allows users to initiate and complete transactions digitally via the Bolt Earth mobile app,using digital technique The payment gateway is designed for quick, contact-less payments, enhancing convenience for EV drivers. With secure encryption and real-time processing, it ensures that users' financial data is protected, and transactions are verified instantly. Bolt Earth's payment gateway also enables station operators to track usage, revenue, and user preferences, which supports efficient operations and insights into customer behavior. This system simplifies the charging experience, making it accessible and user-friendly for EV owners.

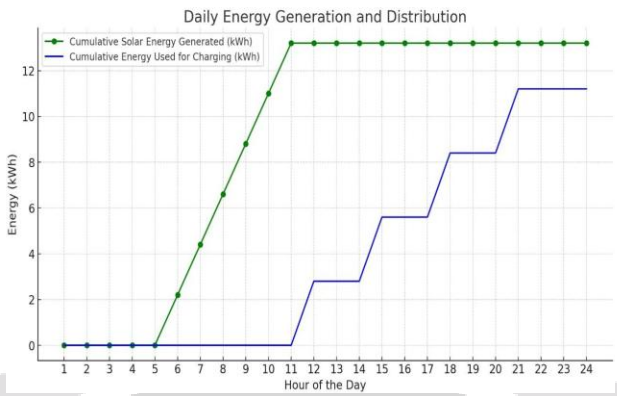
Equipment	**Specification**
Solar Panel	48v,555watt (Mono-half cut bi-facial)
Battery	12v,200Ah (Lead acid)
Inverter	5.2kw (Solar inverter)
charger	24v,36v,48v,60v output 230v I/P (universal charger)
Charge Controller	8-72v,1040watt

Table:Specification of Equipment

4) Battery Sizing for storage:

Battery Capacity (Ah) = voltage * Battery Current
=48*200
=9.6Kw

RESULT & DISCUSSION



CALCULATION

1) Solar Panel Size and capacity:

Calculate the average solar irradiance for your location (e.g. 6 hours of peak sunlight per day).
Solar panel output = No. of solar panel * solar panel Watt
= 4*555
= 2220 W
= 2.2kw/h

Daily solar panel output = solar panel output * hours
=2.2*6
=13.2kw

2)Two-Wheeler Battery Capacity:
Determine the average battery capacity of the two- wheeler you'll be charging (e.g. 48V, 60Ah).
Energy required per charge = Battery Capacity (Ah) × Battery Voltage (V)
For a 48V, 60Ah battery:
Energy = 48V × 60Ah = 2.8 kWh

3) Daily Usage:
Estimate the number of two-wheeler you expect to charge per day.
For example, if you plan to charge 4 two-wheeler daily: Total energy required per day
= 4 × 2.8 kWh
= 11.2 kWh

- Green Line (Cumulative Solar Energy Generated)*: This line shows the accumulation of energy generated by the solar panels over the day, peaking after 6 hours of sunlight.

- Blue Line (Cumulative Energy Used for Charging)*: This line represents the cumulative energy usage for charging two-wheeler, distributed in intervals starting midday.

CONCLUSION

In conclusion, hybrid charging stations, utilizing both solar energy and the main power grid, present a sustainable and efficient solution . This dual-source approach offers enhanced reliability, reduced dependence on conventional energy sources, and lowered carbon emissions, aligning with global efforts toward clean energy adoption. By integrating renewable solar power with grid support, hybrid charging stations can ensure continuous availability of power, even during peak demand periods or low- sunlight conditions. The proposed hybrid system not only optimizes energy use and minimizes operational costs but also enhances the environmental impact of EVs, making electric mobility a more feasible and eco- friendly choice. Further research and development of hybrid charging technologies will be crucial in addressing challenges such as energy storage, grid compatibility, and cost-effectiveness, driving widespread adoption and supporting the transition toward a sustainable future in transportation.

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