

PV Powered Charging Station for E-Vehicle

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Abstract: The rapid growth of electric vehicles has increased the demand for efficient and sustainable charging infrastructure across the world. In recent years, solar photovoltaic powered charging stations have emerged as an effective solution to reduce grid dependency and carbon emissions associated with conventional transportation systems. Most developed countries primarily focus on advanced charging infrastructure for passenger electric vehicles with high battery capacity and fast charging capability. The increasing adoption of electric mobility has encouraged the development of renewable energy integrated charging stations across various regions. This paper presents a detailed literature survey on electric vehicle charging infrastructure, battery specifications, charging standards, renewable energy integration, and region wise charging practices followed in Europe, Japan, China, Turkey, and India. The study also compares charging levels, battery voltage ranges, connector standards, charging power ratings, and charging duration for both two-wheeler and four-wheeler electric vehicles. Various published research works related to photovoltaic integrated charging stations, smart charging systems, and battery energy storage technologies are reviewed and analyzed. From the survey, it is identified that electric two wheelers require economical, low voltage, and decentralized charging infrastructure suitable for urban and semi urban regions. This review helps researchers understand the present development of renewable energy based charging infrastructure and highlights future directions for sustainable electric mobility and smart charging applications.

Keywords: Electric Vehicle, Solar Photovoltaic, Charging Infrastructure, Electric Two-Wheeler, AC Charging, Renewable Energy, Battery Energy Storage.

I. INTRODUCTION

The transportation sector is one of the major contributors to environmental pollution and greenhouse gas emissions throughout the world. The increasing usage of fossil fuel-based vehicles has resulted in severe environmental challenges such as air pollution, global warming, and depletion of conventional energy resources. To overcome these issues, electric vehicles have emerged as an effective alternative due to their high efficiency, reduced emissions, and lower operating cost. In recent years, governments and industries across the world have encouraged the adoption of electric mobility through various policies, subsidies, and charging infrastructure development programs.

The growth of electric vehicles has simultaneously increased the demand for reliable and efficient charging stations. However, the large-scale deployment of electric vehicle charging systems creates several challenges including grid overloading, voltage fluctuations, peak demand increase, and power quality issues. Therefore, renewable energy integrated charging stations are gaining significant attention among researchers and industries. Among different renewable energy sources, solar photovoltaic energy is considered one of the most suitable options for electric vehicle charging applications because of its availability, environmental friendliness, and simple installation.

Many developed countries such as Germany, Norway, Japan, and the Netherlands mainly focus on high power fast charging stations for passenger electric vehicles. These charging stations generally operate using battery systems above 300 V and charging power ratings above 20 kW. Different regions follow different charging practices depending on vehicle category, transportation demand, battery technology, and charging standards. Passenger electric vehicles generally operate using battery systems above 300 V and require both AC and DC fast charging infrastructure.

Recent studies indicate that integrating solar photovoltaic systems with electric vehicle charging stations can reduce grid dependency and improve sustainability. In addition, battery energy storage systems can improve charging reliability during low solar generation conditions. Several researchers have proposed photovoltaic integrated charging stations using grid connected and standalone configurations. Many existing studies focus on renewable energy integration, charging coordination, battery management, and smart charging strategies for electric vehicles.

This paper presents a detailed literature review on electric vehicle charging infrastructure and photovoltaic powered charging stations. The study analyzes global charging practices, battery specifications, charging levels, charging standards, and renewable energy integration techniques. Furthermore, this review highlights the importance of developing sustainable photovoltaic integrated charging infrastructure for future electric mobility applications.

II. GLOBAL EV CHARGING INFRASTRUCTURE ANALYSIS

The development of electric vehicle charging infrastructure varies significantly across different regions due to differences in transportation patterns, economic conditions, government policies, and energy availability. Developed countries mainly focus on high power fast charging systems suitable for passenger electric vehicles, whereas developing countries concentrate more on low power charging systems for light electric mobility applications.

1 European Charging Infrastructure

European countries such as Germany, Norway, France, and the Netherlands have established extensive electric vehicle charging infrastructure with strong government support and renewable energy integration. Most public charging stations in Europe are designed for four wheeler electric vehicles and use Level 2 AC charging and Level 3 DC fast charging systems. European charging stations commonly use Type 2 connectors for AC charging and CCS2 connectors for DC fast charging applications

Electric vehicles in Europe generally operate using battery systems ranging from 350 V to 800 V with battery capacities between 40 kWh and 100 kWh. Fast charging stations typically provide charging power ratings between 22 kW and 150 kW depending on the application. Several European countries are also integrating photovoltaic systems and battery storage systems into charging infrastructure to reduce carbon emissions and improve renewable energy utilization.

Many studies conducted in Europe focus on smart charging strategies, vehicle to grid technology, and renewable energy integrated charging stations. Researchers have also investigated grid stability, load balancing, and coordinated charging techniques for reducing peak demand conditions caused by large scale electric vehicle penetration.

2 Japanese Charging Infrastructure

Japan is one of the leading countries in electric vehicle charging technology and fast charging infrastructure development. Japanese charging stations mainly use the CHAdeMO charging standard for DC fast charging applications. The majority of public charging stations in Japan are designed for four wheeler electric vehicles operating with battery voltages between 300 V and 600 V.

Fast charging systems in Japan generally operate with charging power ratings between 20 kW and 100 kW. Japanese charging infrastructure mainly focuses on compact installation, urban charging reliability, and disaster resilient energy systems. Several charging stations integrate solar photovoltaic systems with battery storage systems to provide reliable charging support during emergency situations.

Although Japan has advanced charging infrastructure for passenger electric vehicles, comparatively fewer charging systems are specifically designed for low power electric two wheelers. However, the increasing adoption of light electric mobility systems is creating new opportunities for low voltage charging infrastructure development.

3 Chinese Charging Infrastructure

China has become one of the largest electric vehicle markets in the world with extensive deployment of both two wheeler and four wheeler electric vehicles. Chinese charging infrastructure supports a wide range of electric mobility systems including passenger vehicles, buses, scooters, and electric bicycles. The country mainly uses the GB/T charging standard for AC and DC charging applications.

Passenger electric vehicles in China generally operate using battery systems between 300 V and 600 V with charging power ratings ranging from 7 kW to 120 kW. At the same time, electric two wheelers commonly operate using 48 V to 72 V battery systems with charging power requirements below 2 kW.

China has also implemented large scale battery swapping and distributed charging systems for electric two wheelers in urban regions. Several research works conducted in China focus on photovoltaic integrated charging stations, smart charging control, energy management systems, and battery swapping infrastructure.

4 Turkish Charging Infrastructure

Turkey has shown significant growth in electric vehicle adoption and charging infrastructure development in recent years. The charging stations installed in Turkey mainly use Type 2 and CCS connector standards similar to European charging systems. Most charging stations are designed for passenger electric vehicles with charging power ratings between 7 kW and 50 kW.

Renewable energy integrated charging systems are also receiving increased attention in Turkey due to rising energy demand and environmental concerns. Researchers have proposed several photovoltaic based charging systems integrated with distributed renewable generation and battery storage systems. However, electric two-wheeler charging infrastructure is still in the developing stage compared to passenger vehicle charging networks.

5 Indian and Southeast Asian Charging Infrastructure

India and many Southeast Asian countries are rapidly expanding electric vehicle adoption through government policies and charging infrastructure development. Electric scooters and motorcycles are widely used for daily transportation because of their affordability, lower energy consumption, and suitability for urban traffic conditions.

Electric two wheelers in India generally operate using 48 V to 72 V battery systems with battery capacities between 1.5 kWh and 4 kWh. Most charging systems use AC charging with charging power ratings between 0.5 kW and 2 kW. Bharat AC and domestic charging interfaces are commonly used for low power charging applications.

Due to the high population density and increasing electricity demand, decentralized renewable energy-based charging systems are highly suitable for Indian conditions. Several researchers have proposed solar photovoltaic powered charging stations with battery energy storage systems to reduce grid dependency and improve charging reliability. Compared to fast charging systems used in developed countries, low power AC charging systems are more economical and practical for electric vehicles applications in India.

III. ELECTRIC VEHICLE BATTERY TECHNOLOGIES

Battery technology plays an important role in electric vehicle performance, charging duration, driving range, and overall system efficiency. The selection of battery technology mainly depends on factors such as energy density, charging capability, cost, safety, and lifecycle.

Initially, lead acid batteries were commonly used in electric vehicles because of their low cost and simple charging requirements. However, lead acid batteries have low energy density, larger weight, and shorter lifespan compared to modern battery technologies. Nickel metal hydride batteries were later introduced to improve energy density and performance.

Currently, lithium-ion batteries are widely used in electric vehicles because of their high energy density, lower weight, faster charging capability, and improved lifecycle performance. Lithium-ion batteries are commonly used in both electric two wheelers and four wheelers. Most electric two wheelers use lithium-ion battery systems operating between 48 V and 72 V, while passenger electric vehicles generally use battery systems above 300 V.

Several battery chemistries are used in electric vehicle applications including lithium iron phosphate, lithium nickel manganese cobalt oxide, and lithium titanate batteries. Lithium iron phosphate batteries are widely preferred for electric two wheelers because of their thermal stability, safety, and longer cycle life.

Battery management systems are also important in electric vehicle applications for monitoring battery voltage, temperature, charging current, and state of charge. Proper battery management improves charging safety and extends battery lifespan.

IV. EV CHARGING LEVELS AND STANDARDS

Electric vehicle charging systems are generally classified into Level 1, Level 2, and Level 3 charging based on charging power and charging duration.

A. Level 1 Charging

Level 1 charging is the simplest charging method and generally uses domestic AC supply. Charging power is usually

below 2 kW and charging duration is comparatively longer. Electric two wheelers commonly use Level 1 charging because of their smaller battery capacities and lower charging requirements.

B. Level 2 Charging

Level 2 charging provides higher charging power compared to Level 1 charging and is commonly used for passenger electric vehicles. Charging power generally ranges from 3.3 kW to 22 kW depending on the charging system configuration.

C. Level 3 DC Fast Charging

Level 3 charging, also known as DC fast charging, provides very high charging power ranging from 20 kW to more than 150 kW. These charging systems are mainly used for highway charging stations and commercial charging hubs.

Different countries use different connector standards for electric vehicle charging applications. European countries mainly use CCS2 and Type 2 connectors, Japan uses CHAdeMO connectors, China uses GB/T standards, and India uses Bharat charging standards for low power charging applications.

V. PHOTOVOLTAIC INTEGRATED EV CHARGING STATIONS

Solar photovoltaic integrated charging stations are receiving increasing attention due to their environmental benefits and reduced grid dependency. In photovoltaic powered charging systems, solar panels convert sunlight into electrical energy which can be directly supplied to the electric vehicle battery or stored using battery energy storage systems.

Several researchers have proposed grid connected and standalone photovoltaic charging systems for electric vehicle applications. Grid connected systems provide reliable charging support by utilizing both solar energy and utility grid supply. During low solar generation conditions, the utility grid acts as a backup power source.

Battery energy storage systems are also integrated with photovoltaic charging stations to improve charging continuity and energy management. Energy storage systems can store excess solar energy generated during daytime and utilize it during nighttime charging conditions.

Researchers have also investigated smart charging techniques, energy management algorithms, and power converter topologies for improving charging efficiency and reducing system losses. DC DC converters such as boost converters are commonly used for voltage regulation in photovoltaic charging systems.

Photovoltaic integrated charging stations provide several advantages including reduced carbon emissions, improved renewable energy utilization, reduced operating cost, and lower dependency on fossil fuel based power generation. However, challenges such as intermittent solar generation, installation cost, and charging coordination still require further research.

VI. CONCLUSION

This paper presented a comprehensive literature survey on electric vehicle charging infrastructure, battery technologies, charging standards, and photovoltaic integrated charging stations. A detailed region wise analysis of charging infrastructure practices followed in Europe, Japan, China, Turkey, and India was discussed. The study identified that developed countries mainly focus on high power fast charging systems for passenger electric vehicles, while Asian countries predominantly require low power charging systems for electric two wheelers.

The reviewed literature indicates that photovoltaic integrated charging systems can significantly improve charging sustainability and reduce dependency on conventional utility grids. However, comparatively fewer studies focus on low power photovoltaic charging systems specifically designed for electric two wheelers. Therefore, developing economical and renewable energy-based charging stations for electric vehicles is an important research direction for future sustainable transportation systems.

The presented survey provides useful insights into global charging infrastructure development and highlights the significance of photovoltaic powered charging systems for future sustainable transportation applications.

VII. FUTURE SCOPE

Future research can focus on implementing practical photovoltaic powered AC charging stations for electric two wheelers with improved energy management and charging coordination techniques. Battery energy storage systems can

be further optimized for improving charging continuity during low solar generation conditions. Smart charging methods integrated with Internet of Things based monitoring systems can also be implemented for efficient charging control and energy utilization. In future developments, photovoltaic powered charging stations can be expanded for public charging applications and integrated with smart grid systems for sustainable urban transportation..

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