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"Review of solar-powered electric vehicle charging systems"

Bhavik P. Kapade
Student, Electrical Engineering Department, Govt. College of Engineering Amravati, India

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ABSTRACT-The rising global demand for electric vehicles (EVs) has led to a growing need for efficient charging stations on a worldwide scale. Traditional charging stations, which rely on the electric grid, are placing significant strain on the existing infrastructure. To tackle this issue, it is essential to embrace non-conventional energy sources, such as solar photovoltaic systems. This article presents a comprehensive examination of charging stations that utilize solar energy to charge EVs. It explores various components and systems, including storage systems, batteries, controllers, converters, and battery exchange stations. By harnessing solar power, these charging stations provide a sustainable and environmentally friendly solution for EV charging. The paper serves as a valuable resource for readers, offering valuable insights into the implementation of photovoltaic charging stations for electric vehicles. Furthermore, it proposes potential solutions to the challenges encountered by conventional charging infrastructure.

Keywords: Solar; Renewable Energy, Electric Vehicle; Charging Station.

I. INTRODUCTION

In recent years, climate change has gained significant attention due to the emissions of greenhouse gases that contribute to its occurrence. Consequently, there is a growing recognition of the necessity to explore alternative energy sources that have minimal environmental impact. One response to this concern is the concept of electrification in the field of transportation. Electric Vehicles (EVs) have gained popularity as a means to reduce greenhouse gas emissions originating from transportation activities. Unlike conventional vehicles relying on gasoline, EVs operate using electricity, which can be generated from renewable sources like wind or solar power. As a result, EVs emit minimal to no pollutants, establishing them as a significantly cleaner option for the environment.

In addition to their positive environmental impact, electric vehicles (EVs) present several advantages compared to traditional vehicles. Firstly, they offer a quieter and smootherdriving experience, enhancing passenger comfort. Secondly, operating costs are typically lower as electricity is generally cheaper than gasoline. Lastly, EVs require less maintenance, resulting in potential time and cost savings for drivers. These advantages have contributed to the increasing popularity of EVs in recent years. Major car manufacturers now offer electric models, and governments worldwide provide incentives to promote their adoption. Undoubtedly, electric vehicles play a crucial role in combating climate change, despite the existing challenges such as the need for expanded charging infrastructure. It is worth noting that charging EVs with conventional energy sources does not offer any environmental benefits, as it merely transfers pollution from the tailpipe to the power plant. Hence, many EV owners choose to utilize renewable energy sources like solar panels to power their vehicles.

Innovative charging solutions are being explored to ease the pressure on the grid. These include V2G (Vehicle-to-Grid) technology, which allows electric vehicles (EVs) to supply electricity to the grid during peak hours, helping to stabilize the grid and prevent power cuts. went smoothly. Furthermore, smart charging systems provide another effective approach by optimizing charging schedules based on the presence of non-conventional energy sources. These systems can be intelligently configured to prioritize charging during low-demand hours, reducing pressure on the grid.

The demand for electric power has significantly increased due to the use of electric vehicles (EVs) on a global scale. The electric vehicle market has experienced significant growth, as evidenced by the increasing number of electric vehicles on the road. In 2010, there were only a limited number of electric vehicles, but by 2017 that number has grown to around three million. Moreover, by the beginning of 2019, the number of electric vehicles has reached about 6 million units

[1]. Different charging strategies and energy management approaches for EV charging stations are documented, considering different energy sources and the unique needs of electric vehicles. One particular study, introduces the concept of a solar charging station equipped with a battery storage system [2]. This article explains how photovoltaic (PV) solar panels and battery energy storage systems (BESS) are used to charge electric vehicles at a charging station. Photovoltaic solar power serves as the primary source of power to charge all connected electric vehicles. However, to solve the shortage of solar energy generated at night, the battery acts as an energy storage system to facilitate the charging of electric vehicles during these hours.

When energy is generated by solar panels or stored in is insufficient to charge an electric vehicle (EV), the charging station will replenish the necessary power from the AC network. This guarantees a seamless charging process, ensuring that the connected EVs are always charged regardless of the availability of solar energy or the capacity of the battery storage system. By integrating solar PV, BESS, and the AC grid, the charging station creates a dependable and sustainable solution for EV charging.

With the growing demand for electric vehicles (EVs) and the popularity of EV charging stations, research institutes and energy providers are proactively addressing the problems arising from the increasing load on the grid. local electricity. In this regard, photovoltaic sources have emerged as a highly promising remedy, presenting the opportunity to ease the strain on local electricity networks and offer essential assistance to the expanding EV charging infrastructure [2].

Conventional charging stations often result in disturbances to the stability of the electrical grid due to factors such as harmonics, fluctuations, and voltage interruptions [3]. Conversely, the Resonant Current Injection (RCI) method offers several benefits, including enhanced efficiency, lowered system costs, and simplified installation [4]. Furthermore, RCI-based facilities require fewer power conversion stages compared to alternating current (AC)-based facilities[5].

II. ENERGY STORAGE AND FAST CHARGING SYSTEMS

Extensive research has revealed the potential consequences of uncontrolled loads, which can put additional stress on transformers, power lines and overall power supplies. To address this challenge, several studies have proposed the implementation of fixed energy storage systems and fast charging technology. These energy storage solutions aim to ease the pressure on charging configuration and reduce operating tariff by powering e-car during peak hours [6]. In addition, energy storage plays an important role in improving the stability of electric vehicles by providing sufficient power for emergency situations and ensuring reliable access to charging stations. .7).

Extensive research has been conducted to investigate the benefits associated with the integration of fixed energy storage systems and fast charging technology. However, to make the most of these benefits, it is important to decide the optimal size of the energyaccumulator. This optimization process considers diverse factors, such as energy tariffs, projected EV adoption rates, and the load profiles of electric vehicles [8]. By carefully analyzing these variables, it becomes feasible to determine the ideal size of the energy storage system, thereby maximizing the efficiency and effectiveness of the entire charging infrastructure.

Fast charging stations (FCSs) offer a remedy to the lengthy charging procedure, which has been a significant obstacle in the widespread acceptance and implementation of electric vehicles (EVs) [9]. By enabling swift recharging comparable to the refueling process at traditional gas stations, fast charging technology addresses the demand for efficient turnaround times. This aspect plays a pivotal role in extending the driving range of EVs, as strategically located FCSs can be found along travel routes.

The offboard fast charging module plays a crucial role in fast charging stations, delivering a power output of 35 kW. Operating at high current and voltage levels, typically ranging from 20-200 A and 45-450 V, respectively [10], this module requires careful deployment in supervised centers or stations. This ensures the safe operation and efficient management of the infrastructure, considering the substantial power levels involved.

III. STORAGE BATTERY AND CONTROLLER

Solar-powered batteries offer an effective resolution to tackle the difficulties arising from unreliable grid electricity, which includes irregular charging and discharging cycles and intermittent full-charging periods. Extensive research has investigated various battery types to meet these specific needs. Notable subcategories of battery accumulator, such as lead-acid batteries, lithium-ion batteries, and flow batteries, have been identified as suitable options for solar energy

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extraction [11].In order to efficiently use the excess energy generated by the photovoltaic system, a central control unit is required to redirect the power to the battery, as shown in Figure 1. The use of the controller in Photovoltaic applications have become the subject of extensive research [12]. The researchers emphasize the importance of improving the efficiency of solar power generation through the implementation of technologies such as peak power point tracking (MPPT) and pulse width modulation (PWM)[13]. These technologies play an important role in optimizing energy production and improving the overall efficiency of the solar power system.

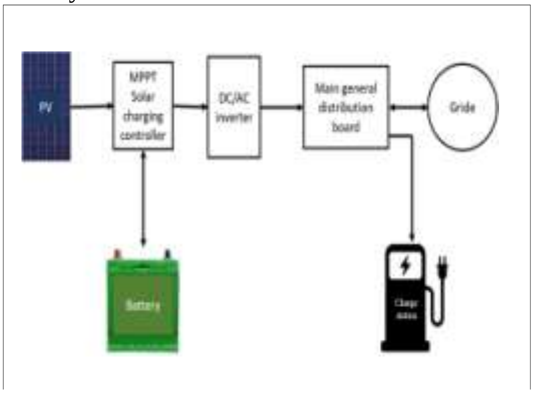

Figure 1. EV charging infrastructure with solar PV charger

IV. CONVERTERS

In the field of solar conversion, photovoltaic (PV) panels are integrated with DC/DC converters to allow precise control of complete power point tracking. Furthermore, the AC-DC converter facilitates bidirectional energy conversion from DC to AC and vice versa [14]. The mains power is AC, so it needs to be converted to DC to charge the electric vehicle. This transition takes place before charging or during energy transfer from the network to the electrical network. Therefore, converters play an important role in achieving balanced energy conversion in photovoltaic systems [15]. Extensive research has been conducted on many types and requirements of converters. For example, string inverters combine panels with micro- converters, while central inverters combine separate inverters and energy-optimized micro- converters, requiring additional monitoring. fig. The power optimizer performs an important function by continuously adjusting the connected load to optimize the overall efficiency of the PV array, thus ensuring maximum system efficiency [16].

V. BATTERY SWAPPING STATION

Battery Swap Station (BSS) is a system that allows electric vehicle (EV) owners to swap depleted batteries with fully charged batteries at dedicated stations. The implementation of BSS offers a number of notable benefits, one of which is extremely fast battery change times. Tesla, a well-known electric vehicle manufacturer, has achieved the impressive achievement of replacing electric vehicle batteries in just 90 seconds. Another important benefit of BSS is the ability to ignore loads during peak demand times, effectively reducing strain on the grid [17].

BSS provides various additional advantages, including effective cost management, extended battery lifespan, and reduced energy consumption. However, there are certain drawbacks to consider. One notable drawback is the substantial investment needed to build and maintain these stations. The infrastructure required for BSS occupies significant space, which can be challenging in densely populated areas. Additionally, the battery management system employed in BSS may not guarantee absolute battery safety. Despite these drawbacks, the benefits of BSS, such as rapid battery exchanges and the ability to avoid peak demand, make it an appealing option for specific EV charging scenarios.

VI. OPTIMAL PLANNING

Estimating and obtaining accurate charging requirements for electric vehicles (EVs) is a complex and challenging task. It is difficult to determine the exact optimal charging schedule due to the many factors at play. V2G technology in toll station planning Another group of research papers focuses on Battery swap Stations (BES) as a solution to meet charging needs for electric vehicles. By reviewing the literature in the field, valuable insights can be gained on the renewable energy integration and V2G technology, as well as the role of BES in the broader EV charging ecosystem.

Charging station planning involves significant challenges due to a variety of factors, such as the availability of renewable energy sources, uncertainty about traffic demand, complex site design, and more. complexity and energy schedule management considerations. These considerations include aspects such as the availability of renewable sources, peak hours on the grid, and the integration of vehicle-to-grid (V2G) systems. Addressing these complex issues requires establishing a planning framework that links long-term decisions (such as location, size, and hours of operation) with short-term operational options (including the use of grid supply, energy storage, V2G use, and renewable energy integration). In the field of fast charging stations, access to all data becomes important. Designers need access to data about electric vehicles on the transportation network, including factual data and real-time charging demand. Harnessing the gathered data enables the development of innovative data-driven approaches that can optimize the performance of charging stations. Table 1 provides an overview of studies that have adopted a data-driven approach in their research efforts.

In addition, when considering energy system planning models for charging stations in the built environment, it is important to prioritize standardization, interpretability, scalability, flexibility, and data reconfiguration capability [18]. These characteristics ensure that planning models can effectively adapt to changing needs and dynamic conditions in the built environment.

Study	Modelling Methods	Origin	Terminal Type
[19]	Stochastic-programming	Grid,PV-Array	Charging Station
[20]	Mixed-integerlinear programming (MILP)	Grid, Wind, vehicle - grid (V2G)	Charging Station
[21]	Two-stage stochastic Mixed-integer linear programming (MILP)	Grid, PV-Array	Battery Swapping Station & Charging Station
[22]	Two-stage stochastic Mixed-integer linear programming (MILP)	Grid, wind, V2G	Charging Station
[23]	Stochastic-Optimization	Grid, Wind	Charging Station
[24]	Probabilistic-Model	Grid,PV-ArrayWind,	Charging Station
[25]	Two-stage stochastic Mixed-integerlinear programming	Grid, PV-Array	Battery Swapping Station

Table 1. Planning of Charging station

VII. OPTIMAL SIZING

In recent years, the transportation sector has seen a significant increase in the use of electric vehicles (EVs), fueled by advances in battery technology and electric powertrains, to establish a sustainable transport system. However, with the increasing number of electric vehicles, the demand for electric charging is also increasing, putting more pressure on the electric system [27]. To address this challenge and promote the integration of Renewable Energy Sources (RES) in charging stations, capacity upgrades and expansions are essential in power distribution systems.

Sizing and efficiently operating charging stations to reach the growing demand for e- cars (EVs) poses a significant challenge. Many studies have been carried out to address these difficulties, some of which are presented below. For example, one study implemented a wind- solar hybrid energy source in the design of an EV charging station. The software HOMER (Optimized Modeling Combined for Electrical Renewable Energy) was used to decide the appropriate size of the non- conventional energy source and allocate power to the loads. A total of 843,150 kWh was generated by the wind turbine and photovoltaic panels, making it possible to recharge five EV's in one hour with an annual energy production of 200 kW.

Essentially, a scientific demonstration has been created within the MATLAB environment to optimize the scale and capacity allotment of the wind vitality framework in coordination with the EV battery swapping station. The use of the differential evolution (DE) algorithm allows for optimal results in terms of size and capacity allocation [28]. Several studies have been conducted to address challenges related to the growing demand for EV charging, the integration of non-conventional energy sources, and the optimization of charging station design and operation.

To meet the energy needs of electric vehicles (EVs) and maintain the energy balance of the system, a hybrid approach combining a 200-kW wind turbine with a 10 kW charger and discharger was used. This combination has effectively met the energy demand for the journey of electric vehicles. Through the analysis of energy fluctuations in different periods, it is determined that the selected components and their power variations offer reasonable and optimal solutions to meet the energy demand of electric vehicles.

In addition, the multi-objective optimization problem determining the optimal size of electric vehicle charging stations and renewable energy sources (RES) was solved by the differential evolution algorithm (DE). MATLAB is used to evaluate the effectiveness of different methods on different grids. The results show that the voltage profile has improved and the optimal size of the EV charging stations has been achieved. In addition, a mixed optimization algorithm combining Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) was implemented to determine the optimal size of the RES and satisfy the loading needs of the RES. By using the algorithm, we can get the most suitable size solutions for RES and meet the charging requirements of electric vehicles.

These studies demonstrate the application of sophisticated optimization algorithms and hybrid system concepts to optimize the scale of non-conventional energy sources and electric vehicle charging stations while simultaneously meeting demand. effective electric vehicle (EV) energy.

VIII. ENERGY CONTROL AND MANAGEMENT

Integrating non-conventional energy charging stations into the grid poses various challenges, including grid integration and volatility issues. Charging operations, especially at fast charging stations, can cause significant inconvenience with regard to power quality and required time. It is therefore essential to effectively manage the loading behavior to minimize the impact of these challenges.

Researchers have conducted analyses on electricity generation to calculate performance indicators related to grid-supplied electricity, revealing significant fluctuations in CO2 emissions. This highlights the importance of having accurate knowledge of operational parameters for the effective management of smart grids. Managing electric vehicle (EV)charging behavior becomes critical to smoothing renewable energy fluctuations, optimizing grid peak demand, and achieving efficient charging characteristics.

The available literature includes many studies examining the effects of network load. Green et al. explore the consequences of electric vehicles (EVs) on the distribution network, while Amini et al. discuss the impact of extensive charging infrastructure on total system damage. Probabilistic modeling was used to analyze the incremental impact of electric vehicle charging on the distribution network[21].

These studies emphasise the significance of controlling EV charging behaviour to lessen its effects on the grid, decrease variability in the production of renewable energy, enhance grid performance, and guarantee effective resource utilisation.

IX. CHALLENGES OF RENEWABLE ENERGYBASED CHARGING INFRASTRUCTURE

A. Power quality:

Renewable energy production can cause power quality problems. The unpredictable and fickle nature of wind and solar power makes renewable energy production non-deliverable and susceptible to significant fluctuations. These power quality issues significantly affect the reliability and stability of renewable energy conversion systems, highlighting the important role of the renewable energy conversion interface (RCI).

The modular nature of renewable generators poses a significant challenge when it comes to power quality in the Renewable Energy Conversion Interface (RCI). Power quality is widely recognized as an important factor that can have a significant impact on RCI reliability and stability. Effectively addressing power quality issues is essential to ensuring an efficient and reliable renewable energy system and maintaining the overall stability of the grid[24].

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B. Stability:

Ensuring the stability of the power system includes important aspects such as restoring the system after a power failure and maintaining voltage and frequency control. However,stability issues can arise when dealing with excess power generated from renewable energy sources and the use of battery storage, which can pose a risk to the interface. Therefore, effective system stability management is extremely important to ensure optimal performance and proactively deal with any potential instability.

Preserving power balance is a crucial element within the Renewable Conversion Interface (RCI) due to the inherent unpredictability and variability of renewable energy sources. The fluctuating nature of renewable power generation can disrupt power balance within the RCI, requiring meticulous management and resolution. By implementing appropriate control mechanisms and strategies, the power system can maintain a balanced and stable operation, effectively mitigating the uncertainties associated with renewable energy sources.

C. Charging prices:

As renewable energy sources continue to gain traction, the cost structure is shifting towards more capital-intensive investments. To ensure the economic viability of renewable energy integration, planning companies must consider long-term energy prices. However, it is important to note that utility programs that offer renewable energy-based electric vehicle charging are currently limited in availability and are primarily focused on residential customers.

To serve a wider audience of electric vehicle users, including heavy-duty drivers, individuals at work, and retail customers at public charging stations, a variety of approaches are needed. It is important to develop strategies and programs that can effectively meet the charging needs of these distinct customer segments. By expanding the availability and accessibility of renewable energy-based electric vehicle charging, a more comprehensive charging infrastructure can be established to more effectively support the vehicle market. Electricity is developing.

D. Locations:

Significant research has been conducted to assess the feasibility of utilizing medium- and large-scale wind turbine farms to fulfil the energy demands of EV charging infrastructure. However, it has been observed that urban areas are not conducive to the installation of windturbines due to the limited availability of open spaces. The presence of tall structures in urban environments disrupts the wind flow, thus impeding the effectiveness of wind energy systems.

Moreover, certain city regulations impose restrictions on the entry of heavy-duty vehicles into urban areas during specific hours, making it impractical to install charging infrastructure in such locations. Therefore, it is more feasible to focus on suburban or rural areas to meet the charging needs of medium- and heavy-duty vehicles.

However, the deployment of renewable energy charging infrastructure in urban areas presents specific challenges. For example, multi-unit residential buildings face barriers related to parking, building restrictions, and administration. Therefore, careful planning of the location and timing of charging stations becomes crucial to ensuring the efficient deployment of urban renewable energy charging infrastructure. These critical factors must be considered for the successful deployment and operation of a renewable energy charging infrastructure.
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X. CONCLUSIONS

However, the deployment of renewable energy charging infrastructure in urban areas presents specific challenges. For example, multi-unit residential buildings face barriers related to parking, building restrictions, and administration. Therefore, careful planning of the location and timing of the charging station becomes crucial to ensuring the efficient deployment of urban renewable energy charging infrastructure. These critical factors need to be considered for the successful deployment and operation of a renewable energy charging infrastructure.

Despite the challenges, wind and solar power offer viable options for electric vehicle charging infrastructure. By integrating these renewable energy sources with electric vehicles, vehicle-to-grid (V2G), and energy storage systems (ESS), it is possible to establish a sustainable renewable charging infrastructure (RCI) through microgrid planning for the power grid. Effective RCI planning involves addressing a number of issues, including the availability of renewable resources, uncertainty about traffic demand, complex site design, and other factors. affect hourly energy management, such as the availability of non-conventional sources, grid peak hours, and V2G integration technology.

The document highlights the importance of conducting research that leverages real-world data to improve strategies for controlling, scaling,

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and managing renewable energy charging infrastructure in real time. Establishing efficient interactions between infrastructure and long- range electric vehicles is essential to enabling smart charging and discharging strategies. Inaddition, charging pricing methods should be expanded beyond existing limited utility programs focused primarily on residential customers to include heavy vehicles and retail customers at charging stations. public.

In conclusion, the integration of renewable energy sources into EV charging infrastructure presents both opportunities and challenges. However, through proactive measures such as thorough planning, the implementation of efficient control strategies, and the establishment of inclusive charging programs, we can overcome these obstacles and promote the widespread adoption of renewable energy-based charging infrastructure. By doing so, we contribute to the realization of a sustainable future.

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