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Sustainability Assessment of Hybrid Powered Electric Vehicle Charging Stations- A Review

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Abstract – *This review paper explores the the demand for electric vehicles (EVs) continues to rise, the sustainability of their charging infrastructure becomes crucial. This study presents a comprehensive assessment of hybrid-powered EV charging stations, integrating renewable energy sources with conventional grid power. The primary objectives include evaluating the environmental impact, economic viability, and social implications of such hybrid systems.*

The review Environmental impacts, including carbon emissions and resource depletion, are quantified to assess the ecological footprint of hybrid charging stations compared to traditional counterparts. Economic models incorporate initial investment costs, operational expenses, and potential revenue streams to determine the financial sustainability of these hybrid solutions.

The social dimensions, considering factors such as accessibility, community engagement, and job creation associated with hybrid EV charging stations. The findings aim to guide policymakers, industry stakeholders, and urban planners in making informed decisions towards a more sustainable and resilient future for EV infrastructure.

Keywords: **Hybrid Powered, PV-grid charging station, Electric vehicle charging, smart grid, Vehicle to grid, Bidirectional DC converter, Energy storage unit**

I. INTRODUCTION

The rapid growth of electric vehicles (EVs) has brought about a paradigm shift in the transportation industry, steering it towards a more sustainable and environmentally friendly future. As the EV market expands, the demand for efficient and eco-friendly charging infrastructure becomes increasingly crucial. In response to this need, hybrid powered electric vehicle charging stations have emerged as a promising solution, integrating renewable energy sources with traditional grid power to enhance sustainability.

This paper provides Hybrid powered charging stations combine various energy inputs, such as solar, wind, and grid electricity, to provide a reliable and resilient charging infrastructure for electric vehicles. This innovative approach aims to address both the rising energy demand for EV charging and the imperative to reduce greenhouse gas emissions associated with transportation.

The sustainability assessment of hybrid powered electric vehicle charging stations involves a comprehensive evaluation of their environmental, economic, and social impacts. This assessment considers factors such as energy efficiency, carbon footprint, economic viability, and community engagement to gauge the overall sustainability of these charging stations.

A. Types of Electric Vehicle and Electric Vehicle Charging Station (EVCS)

The EVs among various developed technologies have gained tremendous attention as an alternative technology that is becoming a part of the modern transport system. The EVs are mainly classified into three types, based on the source of electricity for the propulsion of the vehicle, namely:

(a) Hybrid electric vehicles (HEVs)
(b) Plug-in electric vehicles (PEVs)
(c) Fuel cell electric vehicles (FCEVs).

HEVs utilize two propulsion technologies, i.e., an electric propulsion system and internal combustion engine. This is done to achieve better fuel economy, low emission, longer drive range, etc., when compared with conventional internal combustion engine vehicles. PEVs include BEV and PHEV. The BEV operates on an electric propulsion system and is powered 100% by rechargeable batteries. PHEV primarily runs on an electric propulsion system powered by a battery, but it also has a gasoline engine to be used as a backup when the battery gets completely discharged. FCEVs operate on an electric propulsion system and uses fuel cell technology instead of the battery, or in combination with a battery or super capacitor as the power source. Figure 1 shows the detailed classification of types of EV.

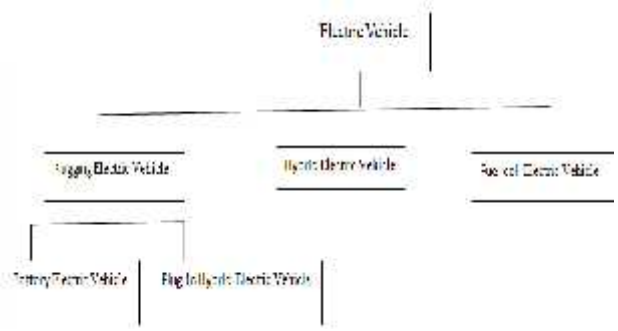

Figure 1 Types of electric vehicles

An EVCS is an integral part of EV charging infrastructure. It is also known as electric vehicle supply equipment (EVSE). It supplies electrical energy to EVs for charging from different energy sources

II. LITERATURE REVIEW

Anand Kishorbhai Patel et.al. (2023) - The seamless integration of electric vehicle (EV) charging infrastructure with solar heating technology holds great promise for revolutionizing sustainable transportation. This research delves into the effectiveness of solar thermal collectors, emphasizing their pivotal role in optimizing energy generation. By harnessing sunlight for both indoor heating and EV charging, this innovative approach reduces reliance on conventional grid electricity and curtails greenhouse gas emissions. The study underscores the importance of advanced materials and coatings through an assessment of collector absorptivity, transmissivity, and thermal conductivity [01].

Ashish Kumar Karmaker et.al. (2023) - A plagiarism-free energy management algorithm has been developed for a hybrid solar and biogas-based Electric Vehicle Charging Station (EVCS), taking into account both techno-economic and environmental considerations. This algorithm, tailored for a 20-kW EVCS, employs a fuzzy inference system in MATLAB SIMULINK. It effectively oversees power generation, EV power demand, charging periods, and current charging rates to optimize real-time charging costs and enhance renewable energy utilization. The outcomes demonstrate a remarkable 74.67% reduction in energy costs when compared to conventional flat rate tariffs, offering more economical charging expenses for both weekdays and weekends [02].

Muhammad Bashar Anwar et.al. (2022) - Fueled by advancements in technology and a growing global emphasis on sustainability, the embrace of electric vehicles (EVs) is experiencing an upswing. The widespread adoption of EVs stands poised to revolutionize the transportation sector, triggering profound implications for energy and electricity systems. This shift presents new possibilities for substantial load growth. However, unregulated EV charging has the po tential to strain existing grid infrastructure, posing challenges in terms of operation, reliability, and planning at both the bulk and distribution levels.

ctively managing EV charging holds the key to addressing these challenges and unlocking additional value [03].

Hoda Fakour et.al. (2022) - Examining the feasibility of utilizing solar photovoltaic (PV) systems to fulfill the energy requirements of an electric vehicle (EV) charging station within a public carport in Kaohsiung, Taiwan, holds global significance. This approach can be universally applied to advance the configuration of PV arrays and the selection of sites for PV development, particularly with carport-mounted PVs contributing to national renewable energy and low-carbon objectives. The outcomes affirm the practicality and sustainability of employing solar canopies for parking spaces in comparable regions, highlighting the substantial potential for utilizing renewable energy in expansive urban parking lots.Given that the research site is situated in one of southern Taiwan's premier tourist destinations, financial benefits for vehicle owners were investigated. This involved examining the impact of various carbon tax proposals and parking fees on the profitability of vehicle owners. The analysis indicates that PV-powered carports could potentially offer greater benefits to vehicle owners than home charging, especially in the presence of carbon pricing. The implementation of a carbon tax, which could offset CO2 emissions from the electrical grid, enhances the attractiveness and advantages of these renewable charging stations [04].

Youssef Krim et.al. (2021) –The initiation of electric vehicle (EV) sales experienced a notable surge, underscoring the crucial need for accessible charging station infrastructure. This study aims to evaluate the significance and advantages of integrating photovoltaic (PV) technology into EV charging infrastructures, employing efficient energy management facilitated by a microgrid. This microgrid incorporates PV panels on rooftops or car parking shades, EV charging terminals, electrochemical stationary storage, and a connection to the public grid. The objective is to define the economic viability, feasibility, and initial prerequisites for this system, preventing grid overload and ensuring a substantial share of clean energy. The proposed methodology is outlined through the creation of a techno-economic tool for local stakeholders, structured into three phases **[05].**

Nuri Cihat Onat et.al. (2021) - Sustainable development hinges significantly on transportation and mobility choices. This study aims to explore the broader social, economic, and environmental ramifications of various vehicle technologies in the United States. The technologies under scrutiny encompass conventional gasoline, hybrid, plug-in hybrid (with varying all-electric ranges), and fully battery electric vehicles (BEVs). A total of 19 sustainability indicators at the macro level are assessed under two scenarios: one where electric vehicles rely solely on the existing U.S. power grid without additional infrastructure and another where they are exclusively charged through solar charging stations The comprehensive analysis spans all life cycle stages, encompassing material extraction, processing, manufacturing, operation, and the end-of-life phases for

both vehicles and batteries **[06].**

Phap Vu Minh et.al. (2021) - The study conducted a comprehensive analysis of PV-powered Electric Vehicle (EV) charging stations, considering different solar radiation conditions in Vietnam. The research utilized HOMER Grid software to determine the optimal system configuration, ensuring a plagiarism-free rewrite. The findings indicated a direct correlation between solar irradiation levels and the reduction in the Net Present Cost (NPC), Cost of Energy (COE), and operational expenses. Consequently, higher solar irradiation enhanced the investment efficiency of PV-powered EV charging stations. The study's results revealed consistent proportions of solar power and grid power in the overall electricity generation for EV charging stations in Da Nang and Ho Chi Minh. This consistency persisted across two scenarios due to the determination that a maximum PV system capacity of 50 kW remained the most optimal configuration. However, the scenario for Hanoi presented a shift in optimal configuration, transitioning from a 50 kW PV capacity in scenario 1 to a slightly reduced 45 kW in scenario 2. This adjustment led to decreases in solar power output, excess solar power, and renewable fractions for Hanoi in scenario 2 compared to scenario [07].

III. METHOD

Sustainability assessment methods typically involve evaluating the environmental, economic, and social impacts of a system. In the context of hybrid-powered electric vehicle charging stations, some common aspects that might be considered include:

Environmental Impact:

Energy source: Assess the environmental impact of the energy sources used to generate electricity for the charging stations. Consider renewable energy sources like solar or wind power.

Life cycle analysis: Evaluate the environmental impact throughout the life cycle of the charging station, including manufacturing, installation, operation, and disposal.

Economic Viability:

Cost analysis: Assess the economic feasibility of the charging station, including initial installation costs, operational costs, and potential revenue streams.

Return on investment (ROI): Evaluate the financial returns over time to determine the economic viability of the charging station.

Social Impact:

Accessibility: Evaluate the accessibility of the charging station to different communities and demographics.

Job creation: Consider the potential for job creation in the installation, maintenance, and operation of the charging station.

IV. CONCLUSION

In this paper has provided the sustainability assessment of hybrid-powered electric vehicle (EV) charging stations reveals a multifaceted perspective on the environmental, economic, and social aspects of these infrastructure projects. This assessment encompasses the integration of renewable energy sources, energy efficiency, economic viability, and the overall impact on the community.

The sustainability assessment of hybrid-powered electric vehicle charging stations underscores the importance of a holistic approach, considering environmental, economic, and social factors. A successful charging station should not only provide a clean and efficient energy source but should also contribute positively to the community and align with broader sustainability goals. Continuous monitoring, adaptation to evolving technologies, and community involvement are key elements for ensuring the long-term success and positive impact of these infrastructure projects.

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