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Energy Management System for Electric Vehicle Charging Stations Using Hybrid Renewable Energy

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Abstract— In order to handle both techno-economic and environmental factors, this study presents an innovative energy management algorithm for a hybrid solar and fuel cell-based electric vehicle charging station (EVCS). In order to optimize real-time charging prices and improve renewable energy consumption, the current approach, which is intended for a 20-kW EVCS, makes use of a fuzzy inference system within MATLAB SIMULINK to manage power generation, electric vehicle (EV) power demand, and charging periods. Nevertheless, production instability could be a problem for this strategy. By replacing the fuzzy controller with an artificial neural network (ANN) controller, the suggested approach resolves this problem. Findings show that, in comparison to current flat rate tariffs, the ANN-based algorithm not only offers more steady outputs but also lowers energy costs, making it more affordable to charge for both weekdays and weekends. Furthermore, integrating renewable energy sources with hybrid technology greatly reduces greenhouse gas emissions. Due to the charging station owners' comparatively short payback periods, the idea is both environmentally friendly and financially feasible.

Keywords — Modified PR controller, Dual Mode Operation, Power Quality, ANN, Micro grid.

I. INTRODUCTION

The fast rise in the world's need for energy has caused fossil fuels to be used up and environmental conditions to get worse, which has led to global warming. Aside from the energy sector, the transportation business also releases a lot of greenhouse gases (GHG) into the atmosphere because it uses more fossil fuels. Several countries' governments are trying to use electric cars (EVs) to turn traditional transportation systems into green transportation systems. EVs have many benefits for society, the economy, and the environment. Although these electric vehicles (EVs) don't use fossil fuels directly, the energy they get from the grid that runs on fossil fuels makes them use more fossil fuels indirectly. To close the gap between the need for and supply of power, scientists around the world are working on cheap and environmentally friendly alternatives to renewable energy sources.

EVs are also not widely used as a cheaper way to get around because there are not enough charging sites, especially in developing countries. Because of this, EV users charge their batteries from their home connections, which causes a lot of system loss in the power sector and lowers the profitability index. Additionally, many EV chargers present power quality problems connected to the distribution grid, such as voltage fluctuations, harmonics, and power loss due to their non-linear behavior. These power quality problems within the distribution network are credited to uncoordinated and inefficient EV charging schemes. These problems can be fixed by changing the way charging works, making converter topologies better, adding renewable energy sources, and using different ways to handle energy. Utilization of the available renewable resources is considered the best method from techno-economic and environmental perspectives. It also eases the load on the power grid, which makes the power better.

Despite the high capital requirement and intermittent properties of the green power-generation infrastructure, these resources have gained considerable importance since they are cost-effective, environment-friendly, and require low maintenance. However, renewable integration for EV charging reduces the dependability and security of the systems due to the variability and uncertainty of renewable power generation. EV charging sites can get around these problems by using a mix of renewable energy sources.

A large number of battery-operated EVs are currently operational in Bangladesh, with no charging policy and insufficient charging stations, similar to the situation in other developing countries. However, Bangladesh offers considerable potential for the application of renewable resources such as solar and biogas energy, which can be utilized for power generation for EVCSs by using an efficient charging management scheme. Although solar energy is an important resource for electricity production, it can be harvested effectively only for a few hours a day. Conversely, biogas resources can produce electricity during the hours when solar energy is absent.

Hence, hybridizing these resources can help achieve reliable and efficient power generation. Research on hybrid power production using renewable resources has demonstrated its cost-effectiveness, energy efficiency, and environmental sustainability. However, the lack of an energy management system greatly hinders hybrid power generation for EV charging.

Energy management schemes allow maximum utilization of renewable energy with the lowest possible charging cost. Fuzzy logic-based algorithms are usually robust since they are not vulnerable to changes in the environment or incorrect commands. Additionally, fuzzy logic models are more suitable for intelligent systems due to their tendency to model human speech patterns and decision-making capabilities.

Fuzzy logic-based energy management schemes are generally used in EV charging station management due to their simplicity, flexibility in setting rules, and capability to model non-linear functions with a wide range of operating conditions. Several studies report optimal charging/ discharging scheduling offers EV user satisfaction with a dynamic pricing scheme considering solar and hybrid PV-Wind. The potential of hybrid renewables such as solar and biogas need to analyses for getting real-time charging rate for EV customers and reducing GHG emissions.

The current literature also considers V2G/V2V/V2H technology to transfer energy during peak hours. The use of these technologies helps EV customers and strengthens the utility grid. The fuzzy logic-based algorithm has received considerable interest in engineering applications due to its features such as decision-making, pattern recognition, identification, optimization, and control in developing countries, the EV charging stations are insufficient, leading to charging from residential connections, which shows considerable system loss and decreased profitability index. Also, power quality problems in the distribution network attributed to uncoordinated and inefficient EV charging methods.

Researchers have properly explored the EV markets for various geographical locations and identified potential barriers towards implementation of the same studied the effect of various government incentives on the market penetration of BEV in Australia. Created a simulation based model to compare various supportive and prohibitive scenarios to reduce the greenhouse gas emissions in New Zealand. Studied the impact of EV market growth on green-house gas emissions in United Arab Emirates. Did a comparative analysis of conventional diesel vehicles and EV to measure the actual GHG emissions and their reduction in Macau. A considerable amount of research is also available suggesting governments and local agencies with ideas and recommendations which may help overcome the EV barriers. The overpowering effect of barriers on the enablers often results in lower consumer acceptance and necessitates the need for further research to devise policy support specifically designed to the local and regional level.

It has been often noticed that importance of barriers tend to vary across different geographical and economic conditions. Berkeley et al. (2018) highlighted the presence of interrelatedness among the studied EV barriers through factor analysis and recommended focusing on the abridged set of barriers based on the strength of association among them to reduce the complexity of the problem. Reviewed the customer preferences and policy attributes of adopting EV. Hence the relative scarcity of study to provide quantitative support in explaining the strength of barriers and their interrelationship leaves enough scope for investigation.

There are various challenges to deploy Electric Vehicle Charging Station (EVSE). Day by day the numbers of vehicles are increasing on road and that requires more electrical power. This will pressurize the grid to supply more electrical power which can overload the grid and the generation of power will have to increase which if generated using fossil fuels will equally harm the environment as that of ICE vehicles. Apart from that, overloading of grid can cause voltage regulation issue, voltage fluctuation, increase in peak demand, reliability and efficiency of the system will decrease, thermal loading will increase and most important affect can be seen on load forecasting.

II. LITRATURE SURVEY

The ever-growing global worry on climate change caused due to vehicular greenhouse gas emission coupled with the depletion of natural resources is driving global economies towards the adoption of alternate fuel technology. Electric cars (EV) are positioned as an alternate green and clean technology which potentially can allow the efficient transition to sustainable low-carbon emission transportation system and preservation of natural scarce resources. Despite announcing favourable policy measures to encourage EV adoption, the multiplicity of possible barriers with mutual contact has resisted its penetration in several countries. Though researchers have identified the barriers, but the question “How EV barriers mutually interact among themselves?” has stayed largely unanswered in empirical research. Unpacking the relationship within barriers will empower manufacturers, lawmakers in strategic planning, and devising suitable measures in controlling the barriers. A mixed two-phased multi-criterion decision making (MCDM) tools are applied. Firstly, quantitatively BWM (Best-Worst Method) is applied in ranking and selecting the important barriers/sub-barriers. The obtained sub-carriers are then analyzed to build a mutual relationship using interpretive structural modelling (ISM). This study has been performed for the Indian EV context with a focus on technological, infrastructural, financial, behavioral, and external barriers [1].

The basic terms of charging station like charging station types, levels. To overcome these challenges, different technologies are discussed along with brief introduction of lithium ion batteries charging methods and Battery Management System (BMS). Since, Indian Government is concentrating towards environmental friendly ecosystem and as per its goal to reduce carbon emission from the transport sector, deployment of EV's and installation of EVCS is the biggest concern. Since, government has reduced the tax on EV's and providing subsidy for putting charging station, this is an easy task. Hence, in this paper certain directions by the Ministry of Power and Ministry of Housing (Government of India) is discussed [2]. Which can help an individual to set up a charging station at their end.

A method to manage electric vehicles charging behaviors in order to reduce its effects in grids [3]. The research summarized the charging patterns of electric vehicle users, based on charging profile observations from advance metering system at first. The method distinguished supervision free user patterns and established a novel schedule strategy to reduce grid peak power demand. The strategy is based on ‘valley filling’ concept while also consider cutting down the total interference time of users’ charging process. The general grid impacts of vehicle charging before and after the adoption of the proposed strategy is simulated and compared.

Bridgeless adapter based EV (Electric Vehicle) battery charger is created and developed in this work. It offers low cost and high power density based charging option for EV. This

charger incorporates less number of devices operating over one switching cycle, which reduces the additional conduction loss caused by a diode bridge rectifier of conventional charger and hence, improves the charger efficiency [4]. During constant current and constant voltage regions, the instructions for battery charging, are synchronized by a fly back converter. The suggested charger draws a sinusoidal current from AC mains along with the total harmonic distortion (THD) in supply current is reduced to the limits as per the IEC 61000-3-2 standard.

The home photovoltaic (HPV) system integrated with energy storages can give power to the distribution grid which may be reliable and free from HPV intermittency effects. However, this is always linked with the high cost of energy storages. On the other hand, the growth of electric cars (EV) in the market has a potential to place the distribution grid in a high risk as the EV owners may charge the EV battery on demand which may cause an unexpected increase in the evening and power quality problems. This paper suggests an efficient energy management approach for the HPV systems to power the electric vehicle battery (EVB) charging facility while utilizing the EVB as an energy storage system (ESS) that can mitigate the HPV impacts and allow the growth of HPV systems in power grids. This research is meant for electric vehicles (EVs) that are compatible with the dc fast charging CHAdeMO standard. The operation strategy of the HPV-EVB charging system is built in such a way that the EVB is either charged efficiently by the HPV or by the distribution grid. The suggested energy management strategy will help to reduce the unexpected peak power demand, and can help in the implementation of the vehicle-to-grid (V2G) to improve the stability of the grid during peak load. In addition, the EVB can provide power to the important loads in the home when there is a loss of power supply from the grid. In the proposed system, the HPV, the grid, and the EVB converters share a shared dc bus. Both the simulation and experimental results show that the proposed energy management of the HPV-EVB system can reduce the impacts of the high penetration of EVs and HPVs on power delivery grids and can effectively improve the self-consumption of the HPV systems [5].

Current EU 2050 climate commitment sets an 80e95% GHG reduction goal. To meet this goal, the EU must make continued progress towards a low-carbon society. Renewable energy sources and electric car play an important role for a gradual transition [6]. The power grid faces a challenging future due to intermittency and the non-dispatch able nature of wind and solar energy production, but flexibility needs can migrate from generation to load, with the growth of demand-side resources and storage technologies. A novel grid method is presented and evaluated in this research for the optimal integrated operation of renewable resources and electric car to increase penetration of renewable energy. It is suggested a distribute control system to manage a charge and discharge strategy to support mismatching between load and renewable generation thru V2G technology. Demand response, peak saving and related services are introduced to keep a reliable power quality, stable frequency and flatten load profile.

A novel stand-alone charging station (CS) powered by a combination of solar and wind energy in presence of a fuel cell (FC) system is designed and constructed for charging plug-in hybrid electric vehicles (PHEVs). The built CS is high-efficient due to putting to practical use a proposed novel variable step-size maximum power point tracking (MPPT) scheme applied to both photovoltaic (PV) and wind parts of the CS. The main defect of a standalone CS is its necessity to battery banks which not only are expensive but also provide short lifetime due to a considerable number of daily charge and discharge imposed to them in a CS. This problem has been solved in this study by

utilizing an FC system as supporting power source playing two roles. First, whenever PV and wind power production is less than charge demand, the FC system produces extra electric energy required. Second, whenever PV and wind power production is more than charge demand, the electrolyser of the FC system produces hydrogen by absorbing extra electric power available in the system. Thus, the FC structure acts as a high capacity storage device in continuously regulating charging power to instant charge demand [7].

Increasing the use of Electric-Vehicles (EV) is regarded as a step in the right way to reduce air-pollution and carbon emissions. However, a dramatic rise of EV and charging stations has raised voltage quality and harmonic distortion issues that affect the performance of integrated renewable power sources (wind and solar) and smart-grid electrical transmission networks [8]. This research models an integrated electric-vehicle charging and battery storage system working in the presence of unpredictable wind and solar power sources. The aim is to allow the design of an electrical control system that develops the correct duty cycle to stabilize and regulate the voltage at the DC/DC power conversion station. Simulations are run to evaluate energy management by the proposed control system.

Electric Vehicles (EV) are adding new dimension in the transportation sector as well as consuming huge electric power. Although, it becomes very popular due to numerous benefits such as- limits fossil fuel consumption, increases the environmental sustainability through low GHG emission, less sound pollution and cost-effective transport medium. However, EV adoption in Bangladesh becomes very challenging due to several barriers. This paper aimed to explore the potential factors that will be the challenges for EV adoption in the context of Bangladesh [9].

Since 2003, over 4.1 million Solar Home Systems (SHSs) have been installed in Bangladesh, adding to a rise in energy access in rural Bangladesh from 26% to 68.9% and saving about 200,000 tons of emissions every year. However, there are large regional discrepancies in SHS uptake hitherto overlooked by academic study. Using Rogers's Diffusion of Innovation (DoI) theory as the theoretical framework, this paper explores how different levels of literacy, wealth and cosmopolitanism effect SHS installations at the district-level in Bangladesh. Whilst it has been argued in previous research that education, financial means and regional inter- and intra-connectivity are important factors in SHS distribution, this paper concludes that, at a district-level, this is overshadowed by the influence of Participating Organizations (POs) who distribute the SHSs [10]. This finds that POs are effective mobilizers of customer demand, advocating closer public-private partnerships in the deployment of clean energy solutions. The study also finds that large districts where grid expansions may be more costly are positively associated with SHS uptake showing that SHSs are a viable alternative to grid electricity in rural areas.

III. CONCLUSION

The dual mode of operation from grid integrated to grid isolated and vice versa has taken place seamlessly without the presence of the distortion or spikes during transition.

. Additionally, the model can be applied for solar radiation and temperature prediction, energy estimation, energy management in smart homes and cities, and forecasting solar radiation and temperature.

Looking ahead, the future scope of solar PV MPPT based on ANN appears promising, presenting various avenues for research and development. One potential option is studying the use of reinforcement learning algorithms to further optimize

MPPT control in solar PV systems. Additionally, integrating AI-based control systems with power electronics equipment, such as DC–DC converters and inverters, could boost overall system efficiency. Advancements in sensors and data collecting systems offer the potential to produce more sophisticated and accurate ANN models for MPPT control. Furthermore, studying hybrid control algorithms that incorporate multiple AI- based methodologies could lead to increased performance in solar PV MPPT. The suggested work delivers significant insights but has limits. Firstly, it focuses primarily on six unique ANN algorithms, potentially restricting the understanding of the overall algorithmic ecosystem. Secondly, the evaluation is based on certain performance parameters, which may not capture all elements of algorithm performance. Additionally, the study focuses primarily on solar PV systems, disregarding other renewable energy sources.

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