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Analysis of Energy Management for EV Charging Stations powered by renewable energy sources

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ABSTRACT

This work presents an algorithm for managing energy at an electric vehicle charging station (EVCS) that takes techno-economic and environmental issues into account. The station is a hybrid, using solar power and biogas as its fuel sources. The suggested approach optimizes renewable energy usage and real-time charging prices for a 20-kW EVCS by managing power production, EV power consumption, charging times, and existing charging rates using a fuzzy inference system in MATLAB SIMULINK. When compared to current flat rate tariffs, the findings demonstrate that the suggested algorithm delivers reduced charge prices for both weekdays and weekends and cuts energy expenses by 74.67%. Greenhouse gas emissions are significantly reduced by the integration of hybrid renewables, and owners of charging stations have very short payback periods, making the project economical.

Index Terms: REnewable Energy, Electric Vehicles, Charging Stations, Fuzzy Logic.

I. INTRODUCTION

Rising worldwide energy consumption has hastened the depletion of fossil fuel reserves, which in turn has exacerbated already-existing environmental problems and accelerated the process of climate change. The transportation industry is a major source of global greenhouse gas (GHG) emissions, second only in importance to the energy sector, because of the rising use of fossil fuels [1]. Electric vehicles (EVs) provide a number of social, economic, and environmental advantages, and as a result, the governments of several nations are striving to transition from traditional to green transportation systems. Even though these electric vehicles don't use fossil fuels in their operation, they nonetheless end up using more fossil fuels than they would otherwise since they get their power from the grid that uses fossil fuels. Consequently, scientists all over the globe are working to find more cost-effective and environmentally friendly renewable energy sources in order to close the power demand-supply gap [2, 3]. Additionally, the absence of charging facilities hinders the quick adoption of electric vehicles as an affordable transportation option, particularly in developing nations. Thus, electric vehicle owners charge their batteries via their home's electrical outlet, resulting in a significant loss of power system efficiency and a worse profitability index [4]. Furthermore, due to their non-linear behavior, many EV chargers cause power quality issues when connected to the distribution grid. These issues include voltage fluctuations, harmonics, and power loss [5]. The distribution network's power quality issues are caused by EV charging techniques that are not coordinated and are inefficient [6]. Reformulating charging patterns [7], enhancing converter topologies [8], incorporating renewable resources [9], and employing energy management approaches [10] can all help with these issues. The most eco-friendly and economically viable option is to make use of the renewable resources that are already available. Additionally, it improves electricity quality while reducing strain on the utility system [11], [12]. Renewable power-generation infrastructure is expensive and has intermittent features, but these resources have grown in relevance due to their low maintenance requirements, minimal environmental impact, and cost-effectiveness [13]. But since renewable power supply is unpredictable and subject to change, using it to charge electric vehicles compromises system stability and security. The use of hybrid renewable resources at EV charging stations may circumvent these constraints [14]. As in other developing nations, there is a considerable number of operating battery-operated EVs in Bangladesh, but there is also a lack of charging infrastructure and regulations. Nevertheless, with an effective charging management system, Bangladesh offers great promise for harnessing renewable energy sources like solar and biogas to power electric vehicle charging stations (EVCSs) [15]. Solar energy is essential for power production, but it can only be successfully gathered during certain hours of the day [16]. When solar energy isn't available, biogas resources may step in and provide power [17]. Thus, combining these resources may lead to more efficient and dependable electricity production. Studies on renewable energy hybrid power production have shown that it is sustainable, efficient, and cost-effective [18], [19]. However, producing hybrid power for electric vehicle charging is greatly impeded by the absence of an energy management system.

TABLE 1. Literature related to the energy management system using various optimization methods.

Ref., year	Method	Contributions	Future Scopes
[27] 2020	Adaptive real-time dynamic programming	It reduces EV charging costs by up to 55% and 29% in summer and winter, respectively, by considering dynamic tariff, actual PV data, and vehicle parking behavior.	Only performed optimization for solar PV-based EVCS and neglected the departure time of EVs.
[28] 2021	Multi-objective particle swarm optimization	Proposed a flexible scheduling framework of PV-powered EVCS based on daily usage, including EV demand and the remaining state of charge of EV batteries.	Only analyzed daily scheduling operation and requires further analysis for a longer duration.
[29] 2020	HOMER techno-economic issues	Presents a grid-connected PV-battery system that reduces the EV charging cost and emission pollution.	Huge infiltration of renewables and EV charging patterns has not been considered.
[30] 2020	Mixed integer linear programming	The proposed model can reduce up to 78.3% of EV charging costs compared to the existing system by	Further research is required on EV charging behavior and the

		considering traffic route selection.	integration of renewables.
[31] 2020	Parameter adaptive differential evolution algorithm	Established coordinated scheduling of EV charging using a wind power system that increased wind power absorption and reduced the charging cost and GHG emission.	It only considers wind power systems and does not consider hybrid renewable energy resources.
[32] 2020	EV charging scheduling using Bayesian network	Demonstrated that solar PV-based EVCS minimizes charging costs by considering EV charging demand and solar output generation.	The charging period/duration and existing tariff have not been considered.
[33] 2021	NSGA-II-based method and Monte-Carlo method	It presented an optimization approach to lower charging costs than existing tariffs considering load demand, energy cost, and state of charge of an EV battery.	It integrates wind energy for EVCS, and hybrid renewables may consider for boosting utility grid strength.
[34] 2019	Dynamic programming and stochastic analysis	Proposed a novel energy management strategy to reduce charging costs using multi-source EVCS by considering DERs, stationary ESS, and V2G.	The EV charging behavior, such as charging duration and time of charging, is not considered.

TABLE 1. ***(Continued.)*** **Literature related to the energy management system using various optimization methods.**

[35] 2020	Evolutionary particle swarm optimization	Reported a correlation between energy cost and control metrics by considering dynamic prices, EV charger type, and distribution network restrictions.	EV charging period/duration and renewable energy integration have not been considered.
[36] 2019	Approximate dynamic programming (ADP) and the evolution algorithm (EA.)	This study presented a cost reduction of over 50% compared to conventional charging by considering dynamic tariffs and charging demand.	Integration of renewables, time of charging, and duration have not been considered.
[37] 2020	Monte-Carlo simulation	Proposed a technique to determine an optimal number of charging points in EVCS and reduce the charging and waiting times.	It did not consider renewable energy integration and EV charging cost.
[38] 2019	Mixed integer non-linear programming	Improved the voltage profile and optimized power loss of the distribution grid by considering DERs and the number of EVs.	Only several EVs are considered, while the period and duration of charging are ignored.
[39] 2019	Mixed integer linear programming	It reduced EV charging costs by integrating PV systems.	EV charging patterns and other renewables have not been considered.
[40] 2018	Teaching-Learning Based Optimization	Proposed a PV-wind-battery hybrid system that minimizes energy costs considering EV power demand.	EV charging behavior, and charging period, i.e., peak/off-peak hour, have not been considered.

To improve dependability, it is necessary to analyze the uncertainties associated with renewable energy integration for electric vehicle charging [23]. When it comes to charging electric vehicles, hybrid systems that combine solar and biogas are more efficient than solo PV systems [18], [23]. Therefore, to make the most of renewable energy sources, an energy management system is necessary for charging electric vehicles. Studies on optimizing EVCS

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have taken into account factors such as location, EV power consumption, charging priority, and charging time [43], [47], and [50]. Additional study is needed to optimize EVCS taking into account the charging period (peak/off-peak hour), power output from renewables, EV power consumption, and real-time charging cost. This is important since most electric vehicles visit charging stations during peak hours. Congestion at charging stations and poor power quality caused by increased demand are consequences of charging EVs at fixed costs.

TABLE 2. Summary of fuzzy logic-based EVCS optimization approaches.

Ref., Year	Considered EV parameter	Contribution	Future Scopes
[43] 2020	EV battery state of charge, parking duration, and power availability	Proposed a fuzzy logic-based charging scheme for optimal power distribution to the EVs, reducing stress on the power grid.	This energy management scheme has not considered charging cost, speed, availability, and user satisfaction.
[44] 2019	EV waiting time	Fuzzy logic-based charging scheduling balances the charging request rate and reduces congestion in a charging station.	Other performance factors, i.e., charging cost, availability, speed, and renewable integration must be considered.
[45] 2019	Charging convenience, charging period, and cost	Fuzzy logic-based optimization is proposed considering user satisfaction, charging time, and cost.	Real-time charging costs and grid stress are not reflected.
[46] 2019	EV demand, time of use	Reduces charging costs, satisfies EV demand, and avoids overloading by considering the time of use, critical peak price, and real-time pricing.	EV waiting time and integration of renewables are not considered.

[47] 2019	EV battery SOC, arrival, and departure time, charging cost	It presents a charging priority identification method using peak power demand and charging cost.	Power availability, integration of renewables, and EV waiting time can be considered.
[48] 2018	Battery SOC, grid voltage, the charging period	Proposed a fuzzy logic-based charging approach considering charging time, battery SOC, and grid voltage.	Charging cost, availability of charging slots, and speed must be considered for optimization.
[49] 2018	Initial battery SOC, solar irradiance, and number of EVs	Presented fuzzy control-based EVCS by considering initial SOC, number of EVs, and solar irradiance.	EV waiting time and real-time price are not considered.
[50] 2017	EV power demand	It proposes a fuzzy optimization model to maximize the parking lot profit by satisfying EV owner requirements.	Renewable energy-based charging scenarios can be considered.
[51] 2017	Charging reservation time, electricity price	Demonstrated an optimization scheme based on charging reservation time, derivation of charging reservation time, and electricity cost.	The charging period (i.e., peak or off-peak hour) and integration of renewables can be considered.

such as those that operate distribution networks, own charging stations, and drive electric vehicles. Furthermore, there is a lack of environmental and techno-economic evaluations of energy management algorithms in the current literature [40], [46]. The following are the contributions to this study: 1. A review of the environmental problems caused by using fossil fuels and the need of finding renewable energy alternatives. 2. Emphasizing the possibilities of renewable energy sources like solar and biogas in Bangladesh, but also highlighting the problems and restrictions of electric vehicle charging in underdeveloped nations Third, a survey of the research on energy management algorithms for electric vehicle charging, paying special attention to algorithms grounded on fuzzy logic. 4. An energy management method supported by fuzzy logic that takes hybrid renewables into account while charging electric vehicles. 5. Evaluating the prospective energy management algorithm for electric vehicle charging from a techno-economic and environmental perspective Here is how the remainder of the paper is structured. In Section II, we learn about the renewable energy sources in Bangladesh and how far along the EVCS is. The suggested hybrid EVCS's conceptual design and cost estimate are then presented in section III. Section IV then shows an optimization technique for electric vehicle charging that makes use of solar and biogas resources, based on fuzzy logic. A case study of weekday and weekend consumption is included in Section V, which also gives the findings and discussion of the proposed EVCS. It goes on to detail the various renewable energy sources and their respective GHG emissions. Section VI concludes the study and discusses potential avenues for further study.

II. CURRENT STATUS OF ELECTRIC VEHICLES AND RENEWABLE POTENTIAL IN BANGLADESH

More than one million electric vehicles (EVs)—including BEVs like auto-rickshaws, simple cycles, and minshuku—are presently operating in Bangladesh, according to a recent research [52]. From 100 to 160 Ah of electric charge is stored in each of the four or five 12 V batteries used in an electric vehicle. From a 220 V AC source, these electric vehicles' batteries are charged using a charger based on a switch mode power supply (SMPS). Because most electric vehicles don't run during the day, charging them at night is a disorganized mess that might cause accidents. There is currently no licensing scheme in place by the Bangladesh Road Transport Authority (BRTA) [53], even though electric vehicles are being adopted at a fast pace in the country.
As of recently, a new electric vehicle charging fee was put in place by the Bangladesh Electricity Regulatory Commission... Users are required to pay a demand charge of 0.4705 USD per kW per month in addition to a charging fee of 0.0906 USD per kWh. The widespread use of electric vehicles in Bangladesh makes the establishment of licensing laws and charging standards all the more urgent.

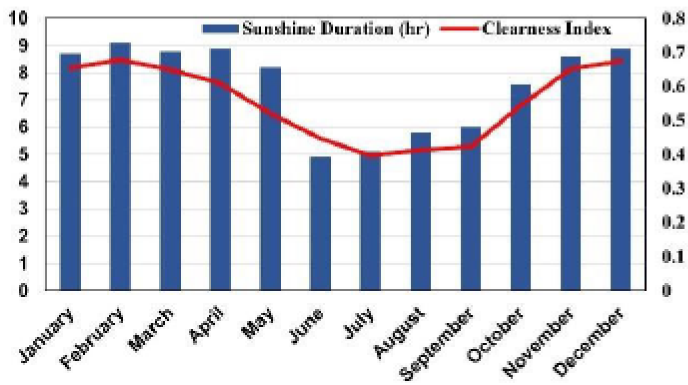

FIGURE 1. Month-wise solar radiation profile (Sunshine duration and Clearness index) in Bangladesh.

A. RENEWABLE SOURCES IN BANGLADESH: SOLAR BIOGAS

Rapid growth in Bangladesh's electrical generating industry has prompted the government to seek out renewable energy sources including solar, biogas, and wind in an effort to create a structure that is economical, efficient, and environmentally friendly. On a daily basis, Bangladesh receives around 5 kWh/m2 of insolation, and the amount of time that solar radiation is really effective is about 4 to 5 hours [54]. Solar power production in Bangladesh seems to be promising under this situation. There are 722.60 MW of installed capacity for power production that is based on renewable energy. This has led to the installation of over 65,000 solar household systems every year, for a total of 4.5 million [55]. Solar irradiation profiles for several locations of Bangladesh are shown in Figure 1 [56].
In addition, biogas resources, including animal and municipal solid waste as well as other biodegradable wastes, are abundant and may be used to generate energy. With such a big population, there is a great deal of potential for producing energy from garbage in Bangladesh, where the typical individual generates 0.5 kilogram of trash each year. In Keranigonj, Dhaka, there is a government-run biogas facility that is 1 MW in size. Installation of off-grid biogas plants around the nation is the responsibility of the Infrastructure Development Corporation Limited (IDCOL). Bangladesh still lacks the installation of solar biogas hybrid power plants, which might significantly improve the country's energy generating efficiency. Renewable energy in Bangladesh: what the future holds (Table 3).

III. DESIGN OF PROPOSED HYBRID RENEWABLE ENERGY-BASED EVCS

The planned electric vehicle charging station (EVCS) and its anticipated cost are detailed in this section using a conceptual

TABLE 3. Renewable energy prospects in Bangladesh [55].

Renewable source	Off-grid (MW)	On-grid (MW)	Total (MW)
Solar	346.58	142.1	488.67
Wind	2	0.9	2.9
Hydro	0	230	230
Biogas	0.63	0	0.63
Biomass	0.4	0	0.4

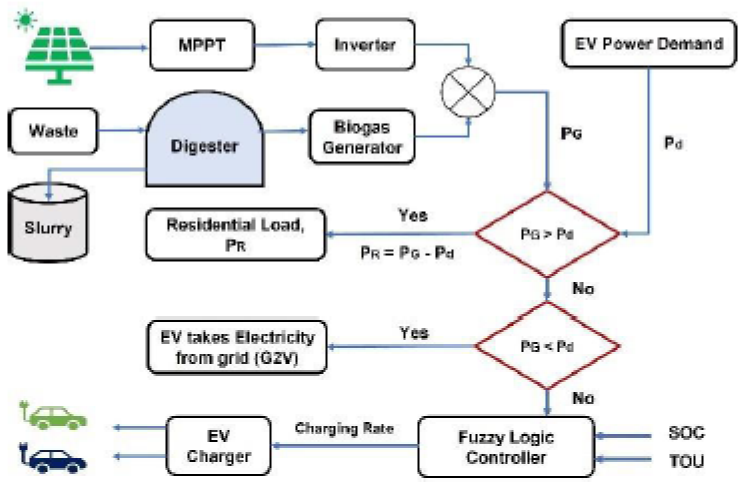

FIGURE 2. Conceptual block diagram of the proposed EVCS.

diagram of blocks. A power production system that uses solar energy and biogas is included into the planned charging station.

A. The EVCS's Conceptual Block Diagram

The 20-kW EVCS is shown in Fig. 2, where the solar and biomass/biogas resources provide 10 kW each to the hybrid power output. Here is how the planned EVCS expresses the power output:

$$P_{Gen} = f\ (s, w) \qquad (1)$$

where's' stands for solar irradiation and 'w' for waste inputs. On most days, you can expect to see the sun from eight in the morning until four in the afternoon. On cloudy or rainy days, solar power cannot be produced. When solar power isn't an option, biogas resources are turned into electricity. First, the trash is put into the digester, where it undergoes fermentation to produce biogas. The next step in turning the biogas into power is to feed it into the generator. Slurry is another byproduct of the biogas system that finds application in the agricultural and aquaculture sectors. The charging station draws electricity from the utility grid when the demand for electric vehicles is higher than the power it can produce. Here, a fuzzy logic controller is used to minimize the cost of charging various electric vehicles at different times. Considered input factors include the availability of output-generated power, the power requirement of the EVs, the charging duration, and the current charging rate.

TABLE 4. Cost of hybrid renewable energy-based EVCS.

Items and specifications	Capital cost (USD)	Replacement cost (USD)	O & M cost/year (USD)	Lifetime (years)
PV (10 kW) (37 × 275 W)	10000	5000	10	25
Biogas generator (10 kW)	2000	1000	50	5
Digester (2 × 4.8 m^3, 1 × 3.2 m^3)	5000	2800	1100	5
Bidirectional converter (10 kW)	2000	1000	2	5
Charging assemblies (12V, 100 Ah- 5 Pcs)	200	100	50	5

The output variables are the cost of charging and the usage of renewable energy sources. The proposed EVCS will be cost-estimated in Section B. The planned charging station's total cost includes the initial investment, replacement cost, and operating and maintenance expenses for the hybrid renewable energy system. Solar photovoltaic systems (37 modules, 10 kW, 275 kW), biogas generator, three digesters (4.8 m3, 4.8 m3, and 3.2 m3), bidirectional converter, batteries, charging assemblies, and so on are the main components needed for this charging station. The size and rating of the solar panels and methane digesters are chosen according to what is commercially available [18]. Here are the costs and advantages of the planned charging station, as shown in Table 4.

IV. FUZZY LOGIC-BASED ENERGY MANAGEMENT SCHEME

The energy management system and optimization model for electric vehicle charging stations (EVCS) that use hybrid renewable resources are detailed in this section. A number of objective functions are considered by the optimization algorithm, which may seek to maximize or minimize them.

The EVCS Energy Management System

Both reducing the billing rate and making the most of renewable resources are goals of the energy management algorithm. These are the possible ways to represent the objective functions:

$$Min\left(C_{Charging}\right) \text{ and } Max\left(Ren_{Utilization}\right)$$

This objective function works under the following constraints:

$$SOC_{max} \geq SOC_i \geq SOC_{min} \tag{2}$$

$$T_D = \frac{(SOC_{max} - SOC_{min}) \times C_{Batt}}{\eta \times L_{ch}};$$

$$0 \leq T_D \leq 10 \; and \; L_{Ch} \in (1, 2) \tag{3}$$

$$P_{Gen} \geq P_{EVCS} \tag{4}$$

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The charging period, denoted as TD, may range from zero to ten hours. The charging level is represented by LCh. Since the places under consideration do not have access to Level 3 charging (≥50 kW), this research just takes Level 1 (3.7 kW) and Level 2 (6.6 kW) into account. The PGen, or produced power, is contingent upon the accessibility of sustainable resources. Variation in power costs within the planned EVCS also impacts it. When a diesel generator is available to handle peak demand, the power limit becomes much more valuable. To prevent deterioration of EV batteries, the SOC limits are used in this article. Additionally, for more practical electric vehicle charging, the battery is primarily responsible for meeting the high/low ramp rate that typically matches with SOC restrictions. Electric vehicle power consumption is proportional to state-of-charge and battery capacity. The suggested model takes a 20% SOC as a minimum and an 80% SOC as a maximum. For the EVs that are being examined, the battery capacity ranges from 8 kWh to 10 kWh. According to the early SOCs, the planned hybrid renewable power can recharge 15-20 EVs each day. The EVCS's power demand and its self-generated power must be at least equal. Under these conditions, the use of renewable energy sources reaches its peak. The time needed to recharge the batteries is known as the charging duration, or TD. What follows is an expression for the EV charging duration:

$$T_D = T_{stop} - T_{start} - T_w \qquad (5)$$

The charge beginning time is Tstart, the departure time is Tstop, and the waiting time is Tw. The time it takes to go from Tstart to the point when charging is disconnected is called the charging period. There are two halves to the charging time, TC: the peak and the off-peak. Four factors—power availability, EV power consumption, charging duration, and current tariff—determine the total real-time charging cost. The following is one way to put it.

$$T_C = \begin{cases} PeakHour\ (5PM - 11PM) \\ Off - PeakHour\ (11PM - 5PM) \end{cases} \qquad (6)$$

Factors such as state of charge (SOC), charging duration (TD), battery capacity (CBatt), and current charging cost (r(t)) determine the real-time charging cost (fc) for electric vehicles. The total power demand of the EVCS is increased when an EV comes with a low state of charge, which in turn raises power consumption. There is a set charge for both peak and off-peak times in the case study region, but the charge changes for other periods. Below, we can see that fc is produced by taking the definite integral inside the interval from Tstart to Tstop.

$$f_c = \int_{T_{start}}^{T_{stop}} \frac{(SOC_{max} - SOC_i) \times C_{Batt}}{T_D} \times r\,(t)\,dt \qquad (7)$$

Multiplying the entire anticipated generation, PGen, from the EVCS by the conventional energy price per kWh, CkWh, yields the annual cash in-flow. The return upon investment

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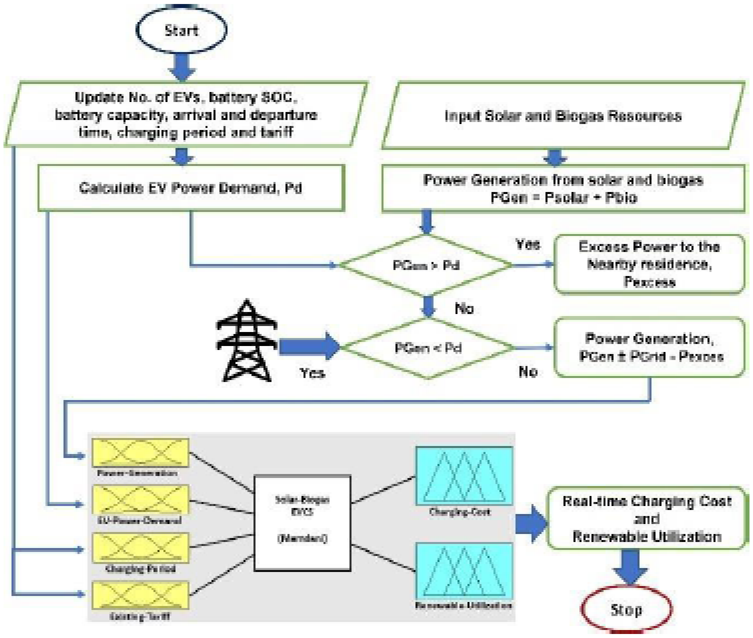

FIGURE 3. Proposed energy management system for EVCS.

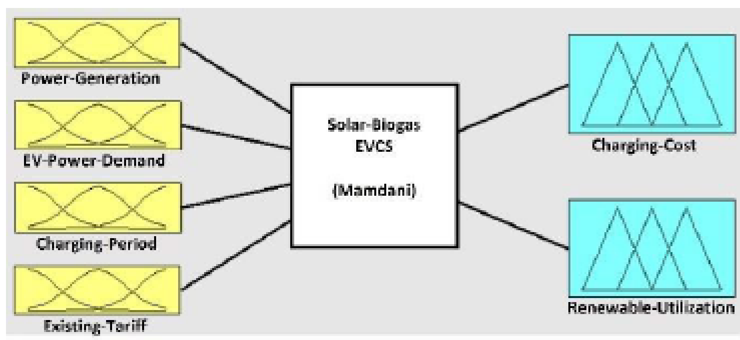

FIGURE 4. Fuzzy (Mamdani) optimization model for EVCS.

period can be calculated using the following equation (8).

$$PBP = \frac{C_{cap} + C_{rep} + C_{o\&m}}{P_{Gen} \times C_{kWh} \times T} \tag{8}$$

The capital cost and replacement cost are denoted by CCap and Crep, respectively, while the operation and maintenance cost is represented by Co&m. For solar and biogas projects, the project lifespan is represented by 'T,' which impacts the payback period differently. For a project to be considered successful, its payback period should be shorter than its lifespan.

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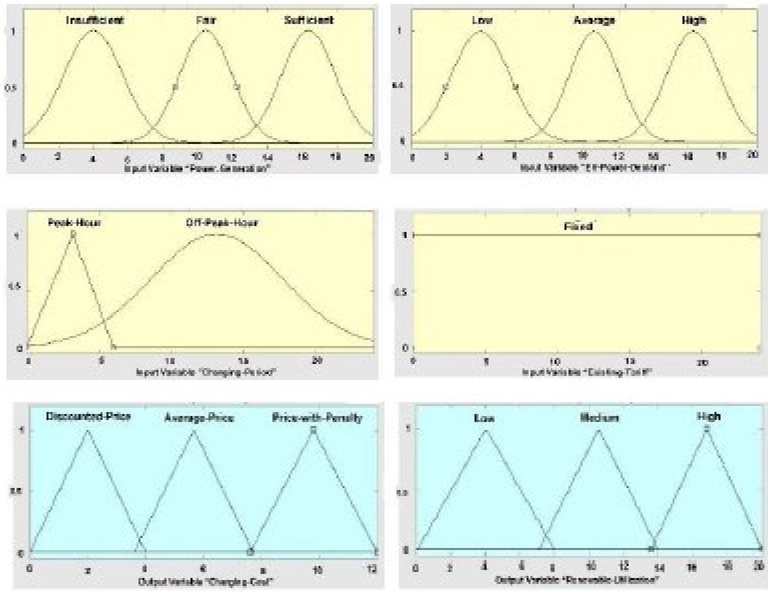

FIGURE 5. Input variable and output variables with membership functions.

V. ANALYSIS OF RESULTS AND CASE STUDY

A fuzzy "if-then" rule-based method is used by the suggested optimization system. The data of the existing battery EVs in Bangladesh is used to determine the membership functions. The fuzzy rule viewer with 18 rules applied is shown in Fig. 6. The fuzzy rule viewer provides a numerical representation of the relationship between input variable changes and output variable changes. The optimization strategy's rule organization may also be seen with the use of a fuzzy rule viewer. Factors affecting output include hybrid power generation, electric vehicle power consumption, charging time, and current tariff. During both peak and off-peak hours, the current rate remains constant. It is clear that the charge rate changes for various intervals while using this rule viewer, however.

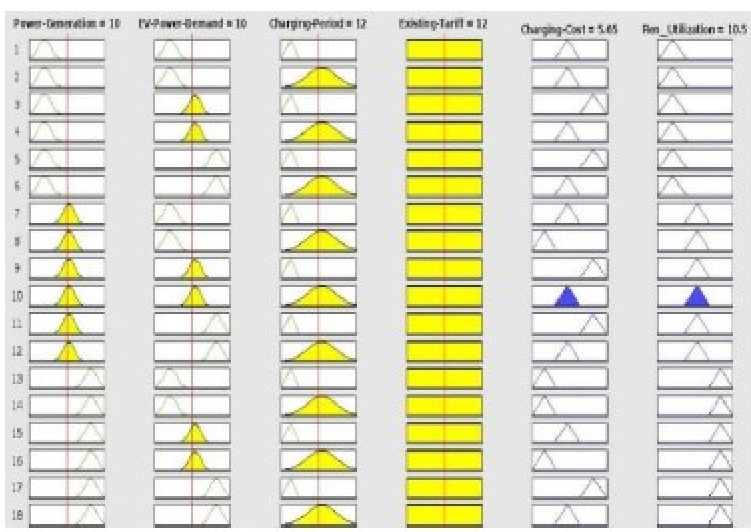

FIGURE 6. Fuzzy rule viewer.

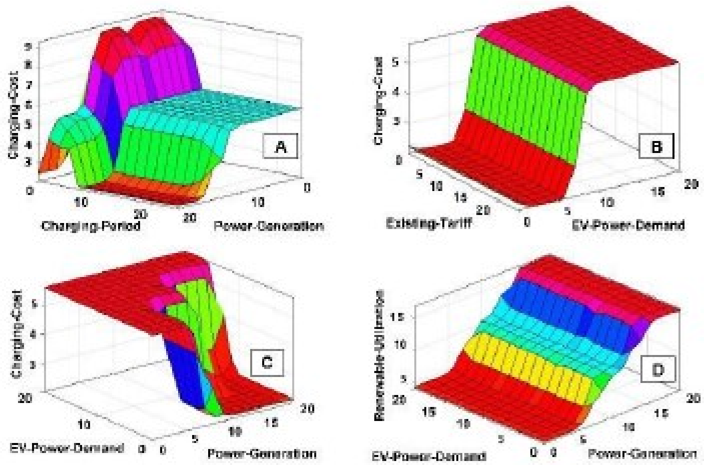

FIGURE 7. Surface view of output and input variables. (A) Surface view of Power-Generation, Charging-Period, and Charging-Cost, (B) Surface view of EV-Power-Demand, Existing-Tariff, and Charging-Cost, (C) Surface view of Power-Generation, EV-Power-Demand, and Charging-Cost, (D) Surface view of Power-Generation, EV-Power-Demand, and Renewable-Utilization.

To reduce the expense of charging electric vehicles, the suggested fuzzy-based optimization takes solar and biogas resources into account. Several variables affect the amount of time it takes to charge an electric vehicle's battery, including the driver's arrival and departure times, the vehicle's capacity, the degree of charging, the driving range, and the battery's current state of charge. Flat rate tariffs are available to EV consumers via conventional EVCS. So, power quality issues arise during peak hours since EV consumers show up at EVCS at random. Not to mention that EVCSs powered by solar energy can keep EVs juiced up all day long. Consequently, EVCSs that use solar biogas and have variable charging rates encourage consumers to charge their EVs at off-peak times when the prices are cheaper. Electric vehicle charging stations that use solar biogas also lower greenhouse gas emissions and lessen reliance on the electric grid. Figure 7 (A), (B), (C), and (D) show the fuzzy inference system's input and output variables in a three-dimensional surface perspective.

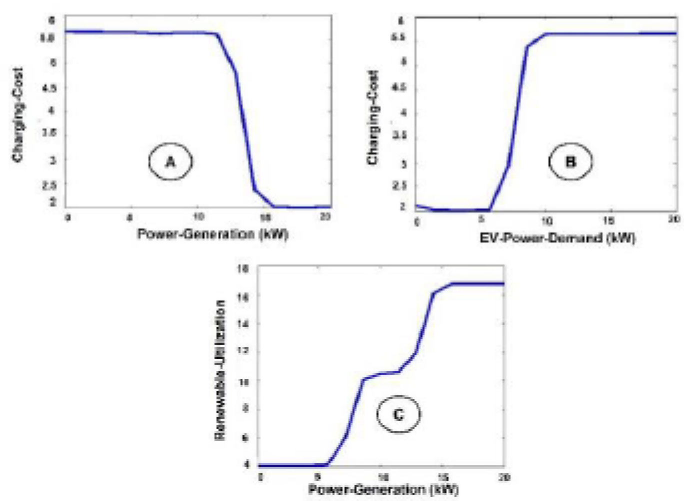

FIGURE 8. Variation of input and output variables. (A) Variation of Charging-Cost against Power-Generation (B) Variation of Charging-Cost against EV-Power-Demand (C) Variation of Renewable-Utilization against Power-Generation.

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The difference between renewable usage and electricity production is seen in Fig. 8 (C). The inadequacy of power availability is a sign that the solar and biogas resources are not functioning at their best, as the projected EVCS relies on these resources to generate electricity. More power production to enable EV charging is achieved via expanding renewable integration, because the planned EVCS mostly relies on these resources. So, when renewable resources are plentiful, electricity availability is greater, and the corresponding

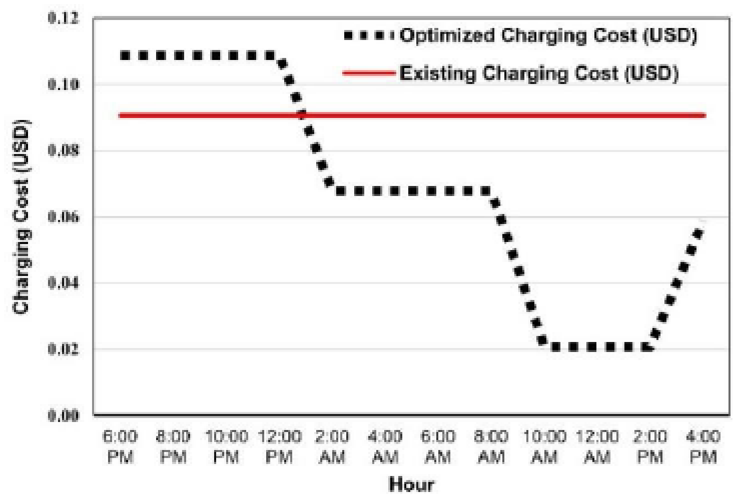

FIGURE 9. Fuzzy logic-based dynamic charging rate compared with existing flat rate tariff in Bangladesh.

expense associated with charging. Charging during peak hours is more important than offpeak hours in the proposed EVCS that is based on fuzzy logic. Charging an electric vehicle's battery using a standard EVCS in Bangladesh will cost between 1.41 and 1.7647 USD on average. The Bangladesh Energy Regulatory Commission has established a power tariff that includes a battery charging cost of 0.0906 USD per kWh of energy use. But for various charging periods, battery capacities, and EVCS power availability, the optimization of the suggested EVCS based on hybrid renewable resources offers dynamic tariff rates. Optimal billing costs are introduced by the suggested strategy, as seen in Figure 9. The examined EVs had battery capacities ranging from 8 to 10 kWh. According to the early state-of-charge calculations, the proposed EVCS can recharge the batteries of fifteen to twenty EVs every day with its twenty kilowatts of electricity.

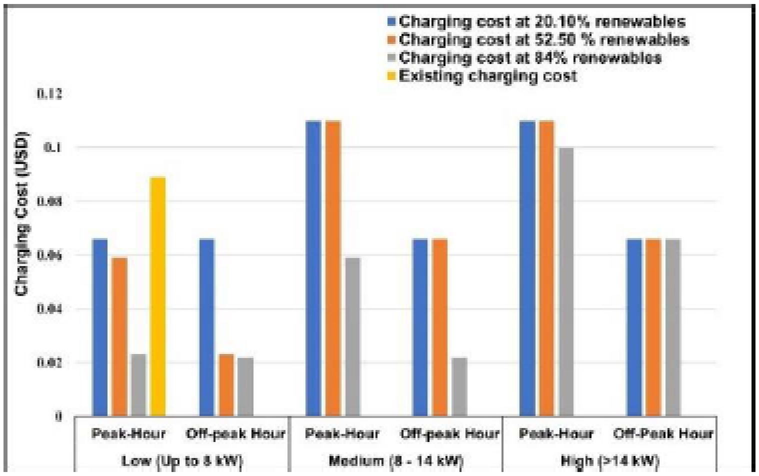

FIGURE 10. Comparison of charging costs at different renewable penetration scenarios with existing charging costs.

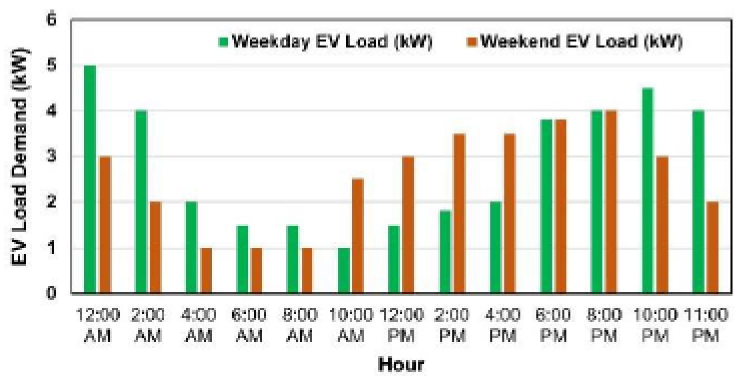

FIGURE 11. Daily EV load profile.

maximizes the use of renewable resources. In addition, the EV scheduling technique is improved by this energy management algorithm, which leads to higher customer satisfaction. Furthermore, environmental sustainability is greatly enhanced by minimizing greenhouse gas emissions in comparison to the traditional utility grid-based EVCS.

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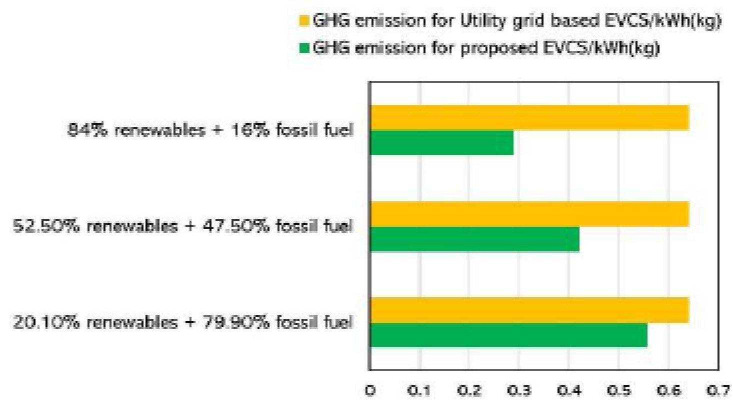

FIGURE 12. Comparison of GHG Emission from conventional utility-based EVCS and proposed EVCS.

Saturdays and Sundays it's 0.079 USD per kWh. When compared to the average cost, the fuzzy optimization-based EVCS lowers charging expenses by 46.15% during the week and 55.22% on weekends. The distribution network is impacted by EV charging because of the significant energy consumption. Charging electric vehicles at times of high demand causes voltage fluctuations and power outages in the distribution network. The power infrastructure and customers may both profit from charging electric vehicles during off-peak hours. In Bangladesh, the hours between 11 PM and 5 PM are considered off-peak, whereas the hours between 5 PM and 11 PM are considered peak. During off-peak hours, the charging rate is lower than during peak hours since there is less demand for electricity.

TABLE 5. Economic parameters from the proposed EVCS.

System	Annual energy generation (kWh)	Lifetime (years)	Annual cash in-flow (USD)	Payback period (years)
PV	15350	25	1880	10.1
Biogas	24820	5	3040	3.27

VI. CONCLUSION

New opportunities for studies on renewable integration arise as a result of the increasing demand for electric vehicles. An optimization technique for a solar-powered, biogas-or biomass-powered electric vehicle charging station (EVCS) was the primary focus of this research. Furthermore, this research delves into the immense potential of renewable resources for power production in locations without grid access. To lessen the burden on the distribution grid from charging electric vehicles and to cut down on greenhouse gas emissions, the suggested method is useful. In order to maximize renewable usage, the charging cost is optimized by the fuzzy optimization algorithm taking into account the following factors: power availability, electric vehicle power consumption, charging time, and current rate. To encourage EV users to recharge their batteries during off-peak hours, it shows that hybrid renewable energy EVCS have a lower energy cost overall. As a bonus, lower demand during peak hours means fewer power quality issues. In addition, compared to the average cost, it lowers the daily charge cost by 46.15% during the week and 55.22% on weekends. By including 84% renewable resources into the EVCS, it was shown that CO_2 emissions from the suggested system are 54.86% lower than those from the standard grid-based system. In this way, renewable resources cut GHG emissions to 34.28% and 13.12%, respectively, with shares of 52.50% and 20.10%. The main goals of this research are to design an efficient energy management system for the EVCS that is being considered and to employ solar and biogas resources in a hybrid mode for charging electric vehicles. We will verify and monitor the real-time performances via experimental analysis in the future. The planned nationwide EV charging infrastructure has piqued a lot of interest from researchers, so we'll make sure to examine its potential environmental impact thoroughly. Alternative algorithms, including GA-PSO, particle swarm optimization (PSO), and genetic algorithm (GA), may optimize the suggested hybrid renewable energy-based EVCS. There is a lot of room for investigation into comparing the algorithms' performance in the context of EVCS optimization. A sustainable charging infrastructure may be set up all over the globe by using the suggested optimization technique. Finally, V2G (Vehicle to Grid) technology allows for the development of a novel system that functions as a smart grid-like bidirectional energy transfer facility for EVCS. Electric vehicles may contribute to the utility grid's energy supply during times of outage and high demand. With its many eco-friendly and economically advantageous features, this research makes a big splash in the world of sustainable transportation and power system network development.

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