ENERGY MANAGEMENT SYSTEM FOR HYBRID RENEWABLE ENERGY- BASED ELECRIC VEHICLE CHARGING STATION

Dr.S.NARASIMHA Professor[1], A.Anjaiah[2]

Dr.S.Narasimha *Professor EEE, TKR College of Engineering & Technology (Autonomous), India*

A.Anjaiah, *Assistant Professor EEE, Tkr College of Engineering & Technology (Autonomous), India*

K.Veen, *UG student, EEE, TKR College of Engineering & Technology (Autonomous), India*

S.Saiteja goud, *UG student, EEE, TKR College of Engineering & Technology (Autonomous), India*

K.Omkar, *UG student, EEE, TKR College of Engineering & Technology (Autonomous), India*

T.Premkumar, *UG student, EEE, TKR College of Engineering & Technology (Autonomous), India*

Abstract -This paper introduces an energy management algorithm for a hybrid solar and biogas-based electric vehicle charging station (EVCS) that considers techno-economic and environmental factors. The proposed algorithm is designed for a 20-kW EVCS and uses a fuzzy inference system in MATLAB SIMULINK to manage power generation, EV power demand, charging periods, and existing charging rates to optimize real-time charging costs and renewable energy utilization. The results show that the proposed algorithm reduces energy costs by 74.67% compared to existing flat rate tariffs and offers lower charging costs for weekdays and weekends. The integration of hybrid renewables also results in a significant reduction in greenhouse gas emissions, with payback periods for charging station owners being ***relatively short, making the project profitable.***

***Keywords*—**Electric vehicle, electric vehicle charging station, fuzzy logic, renewable resources.

1. INTRODUCTION

The rapid increase in the global electricity demand has led to the exploitation of fossil fuel resources and adversely affected environmental conditions, resulting in global warming. Apart from the energy sector, the transportation industry contributes significantly to worldwide greenhouse gas (GHG) emissions due to increasing fossil fuel consumption. These EVs do not directly consume fossil fuel resources, the electricity supplied from the fossil fuel based electricity distribution grid indirectly increases their fossil fuel consumption.

Energy management schemes enable maximum utilization of renewable energy with the lowest possible charging cost. Fuzzy logic-based algorithms are typically robust since they are not vulnerable to changes in the environment or incorrect commands. Fuzzy logic-based energy management schemes are generally used in EV charging station management due to their simplicity, flexibility.

The potential of hybrid renewables such as solar and biogas need to analyze for obtaining real time charging rate for EV customers and reducing GHG emissions. The existing literature also considers V2G/V2V/V2H technology to transfer energy during peak hours . The use of these technologies benefits EV customers and strengthens the utility grid.

2. LITERATURE SURVEY

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 considering traffic route selection.	Further research is required on EV charging behavior and the 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.

3. BLOCK DIAGRAM

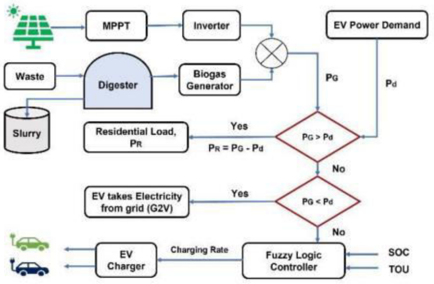

Fig: 1 Conceptual block diagram of the proposed EVCS

Fig. 2 presents a graphical representation of the proposed 20-kW EVCS, where the solar and biomass/biogas resources contribute equally (10 kW each) to the output hybrid power. The output power generated by the proposed EVCS is expressed as follows:

PGen = f (s,w) (1)

where ‘s’ and ‘w’ denote the solar Irradiation and waste inputs, respectively. The average duration of sunlight is typically eight hours, from 8:00 AM to 4:00 PM. Solar energy cannot be generated on rainy and foggy days. In such cases, biogas resources are used to produce electricity in the absence of solar energy. The waste material is first fed into the digester, which generates the biogas through fermentation. The biogas is then fed to the generator input to produce electricity. Additionally, the biogas system provides slurry, which is used as fertilizer and fish feed. When the EV demand exceeds the generated power of the charging station, excess power is obtained from the utility grid. In this case, a fuzzy logic controller is employed to optimize the charging cost for different EVs at different periods. The output-generated power availability, power demand of the EVs, charging period, and current charging rate are considered input variables. The charging cost and renewable utilization are regarded as the output variables.

Source	Units	Estimated potential	Cumulative achievements as of 31-03-2007	Capacity factor	Potential generation (Bkwh)
Power from renewables					
Grid interactive renewable power					
Bio power from agro residues etc.	MW	16881	524.8	60%	88.72654
Wind power	MW	45195	7092	25%	98.97705
Small hydro (<25 MW)	MW	15000	1975.60	20%	26.28
Cogeneration (Bagasse)	MW	5000	615.83	60%	26.28
Waste to energy	MW	7000	43.45	60%	36.792
Solar	MW	50000	2.92	20%	88.72654

TABLE 2. Renewable energy prospects in india.

FUZZY LOGIC BASED ENERGY MANAGEMENT SYSTEM OF EVCS

The energy management algorithm has two objectives: minimizing the charging rate and maximum utilization of renewable resources. The objective functions can be expressed as follows: Min Charging and Max (Renewable Utilization) This objective function works under the following constraints: SOCmax ≥ SOCi ≥ SOCmin (2)

TD = (SOCmax − SOCmin) × CBatt η × Lch ; 0 ≤ TD ≤ 10 and LCh ∈ (1, 2) (3)

PGen ≥ PEVCS (4)

TD represents the charging duration measured in hours, which varies between 0 to 10 hours. LCh denotes the charging level. In this study, only Level 1 (3.7 kW) and Level 2 (6.6 kW) are considered since Level 3 charging (≥50 kW) is not available in the analyzed areas. The generated power, PGen, depends on the availability of renewable resources. It is also affected by the variation of the electricity prices in the proposed EVCS. The power limit is generally more useful when there is a diesel generator to meet extra power demand. The SOC limits are used to avoid EV battery degradation. Also, battery is mainly responsible to meet high/low ramp rate that mostly suits with SOC limits for more feasible EV charging. The power demand of the EV depends on the SOC and battery capacity. In the proposed model, the minimum SOC is considered 20%, and the maximum SOC is 80%. The battery capacity for the considered EVs varies from 8 kWh to 10 kWh. The proposed hybrid renewable generation enables the daily recharging of 15–20 EVs based on the initial SOCs. The self-generated power of the EVCS must be greater than or equal to the power demand of the EVCS. In such a case, renewable energy utilization becomes maximum. The charging duration, TD is the time required to recharge the batteries. The charging duration of the EV is expressed as follows:

TD = Tstop − T start − Tw (5)

where Tstart denotes the charge starting time, Tstop denotes the departure time, and Tw indicates the waiting time. The charging period lies between Tstart and the time of charging disconnection. The charging period, TC, is divided into peak and off-peak hours. The overall real-time charging cost is the function of the four input parameters: power availability, EV power demand, charging period, and existing tariff. It can be expressed as follows.

TC = PeakHour (5PM − 11PM)

Off – PeakhHour (11PM − 5PM) (6)

The real-time charging cost for the EVs, fc, depends on the current charging cost, r(t), SOC, battery capacity (CBatt), and duration of charging (TD).

EV arrives with low SOC increases power demand and cumulatively increases the overall power demand of the EVCS. The charging cost varies for different periods (peak/off-peak hours).fc is obtained from the definite integral within the interval from Tstart and Tstop, as shown below.

fc = Z Tstop Tstart (SOCmax − SOCi) × CBatt TD × r (t) dt (7)

Annual cash in-flow can be calculated according to the conventional energy price per kWh, CkWh multiplied by the total expected generation, PGen, from the EVCS. The payback period can be calculated using the following equation CCap and Crep indicates capital cost and replacement cost where Co&m represents operation and maintenance cost. The project lifetime is depicted by 'T' which differs for solar and biogas projects, affecting payback period. The payback period must be less than the project lifetime to be a successful project.

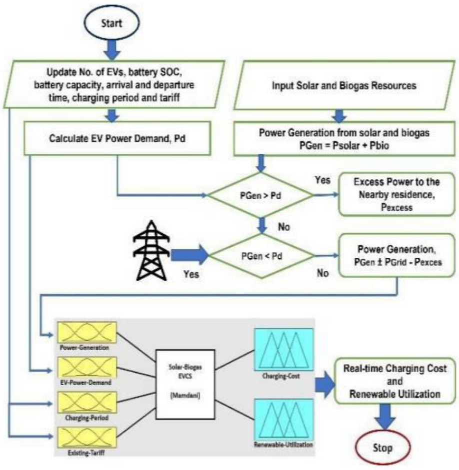

FIG:2 proposed energy management system for EVCS

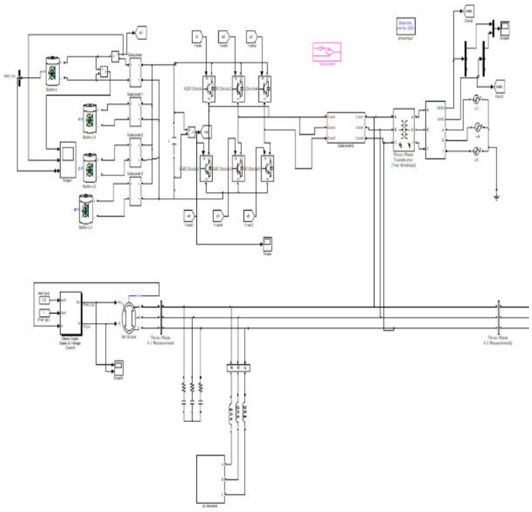

Fig: 3 MATLAB Simulink diagram of proposed system

6. CONVERTER

A bidirectional converter is proposed for converting DC to AC and vice versa. There are two types of resources , biogas generators and solar panels . Biogas generators produce ac power and solar panels produce DC power . therefore, a converter is essential to convert DC to AC as a most of the EVs are charged by an ac system .

7. MPPT CONTROL

The MPPT is pronounced as the Maximum Power Point Tracking (MPPT), it is used to track the maximum available power from the system under certain conditions, in this circuit the main use of MPPT control is to extract the maximum power from the solar power generation system and wind power generation system. This makes the system to work efficiently, and it increase the charging efficiency and power output of the system. A common or a single MPPT control system is used in the circuit for both generating systems.

8. RESULT:

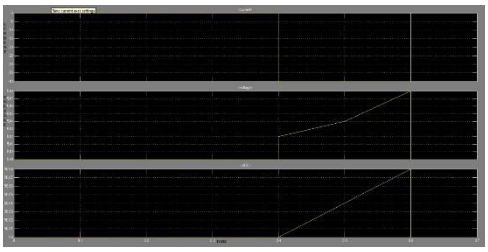

Fig:4 output wavewforms of voltage ,current and SOC

Fig: 5 output waveforms of voltage and current at Grid

9. CONCLUSION

The growing popularity of EVs opens new avenues for research on renewable integration. This study aimed to design and develop an optimization algorithm for an EVCS using solar and biogas/biomass resources. Additionally, the considerable potential presented by renewable resources for electricity generation in off-grid areas is explored in this study. The proposed approach is helpful for effectively utilizing the available renewable resources to reduce GHG emissions and the stress from the distribution grid due to EV charging. The fuzzy optimization algorithm optimizes the charging cost based on the power availability, EV power demand, charging period, and existing tariff while the renewable utilization becomes maximum. It demonstrates that the hybrid renewable energy-based EVCS presents a lower energy cost, especially during off-peak hours, which can inspire EV owners to recharge the batteries during such a period. Also, it reduces power quality problems during peak hours due to lesser demand. Furthermore, it reduces the daily charging cost by 46.15% and 55.22% on weekdays and weekends, respectively, compared to the average cost.

It demonstrated that CO2 emission from the proposed EVCS is 54.86% lower than that of the conventional grid-based EVCS when 84% of the renewable resources are integrated with the EVCS. Accordingly, with shares of 52.50% and 20.10%, renewable resources reduce GHG emissions to 34.28% and 13.12%, respectively. This study primarily focuses on applying solar and biogas resources in a hybrid mode for EV charging and developing an effective energy management system for the proposed EVCS.

In the future, the experimental analysis will be performed to validate and observe the real-time performances. Furthermore, the environmental effect of implementing the proposed EV charging infrastructure throughout the country, which is of considerable research interest, will be analyzed in detail. The optimization of the proposed hybrid renewable energy-based EVCS can be achieved using other algorithms, such as particle swarm optimization (PSO), the genetic algorithm (GA), and the GA-PSO algorithm, for better results. The performance comparison of these algorithms for EVCS optimization presents considerable research potential. The proposed optimization approach can be implemented to establish a sustainable charging infrastructure worldwide. Lastly, a new scheme can be designed as a bidirectional energy transfer facility similar to a smart grid for the EVCS, known as the V2G (Vehicle to Grid) technology. During blackout and peak hour periods, the EVs can transfer energy to the utility grid through this scheme. This study contributes significantly to the sustainable development of power system networks and the transportation sector, and the proposed strategy presents various techno-economic and environmental benefits.

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