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Research Article

A Comprehensive Review of Electric Vehicle Charging Station with the Scope of Renewable Hybrid Energy and Fuel Cell Integration

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ABSTRACT

A renewable energy (RE) based system is a pollution-reductive and cost-effective solution while considering life cycle of RE system for electric vehicle charging stations (EVCS). In which solar photovoltaics, wind turbines, fuel cells, and biogas etc., are utilized to generate electricity that can be used in grid-tied or stand-alone charging stations. Due to a lack of grid access, stand-alone EVCS are promoted in tourist, rural and remote areas. The review article covers alternative modelling approaches in conjunction with EVCS standards for off-grid applications. Numerous modelling approaches are discussed for hybrid system selection, station location, and cost optimization while considering economic feasibility, as well as reviewing off-grid charging for EVCS. In addition, the uncertainty in the power system is described in selection strategies employed for the proposed EVCS, which adds to the charging problem. The RE-based EVCS can provide futuristic potential in the global automobiles and RE-based industries.

Keywords*:* Solar PV, Wind Turbine, Fuel Cell, Electric Vehicle charging system, Biogas, Standalone System

I. INTRODUCTION

The adoption of electric vehicles (EVs) in the recent globalized market is observed, which might be due to the prevention of the pollution and scarcity of fossil fuel, which is being used in the traditional transportation system as the primary source of internal combustion engines. Batteries, ultra-capacitors, and fuel cells are generally used in EVs as a power source, which is independent of fossil fuels and due to that environment is protected from harmful gases. The EVs use one or more of these sources as per the type of vehicle [1], As an evident from several articles that already described the detailed structure and configurations.

The role of the electric vehicle charging station (EVCS) is to supply of electric power by conversion, storage and transfer of the energy to the vehicle. Generally, the required energy to the EVs can be converted from solar photovoltaics (PV), wind driven generators, flywheels, biogas and hydrogen in all off-grid applications. All converted energies (in off-grid) or directly from grid can directly use to operate the vehicle or stored in batteries, fuel cells and capacitors used as standalone application.

Several difficulties must be overcome for EV to be competitive in the market. Another likewise includes battery cost, effective charging strategies, charging station interoperability, and the impact of EV integration on the grid. Furthermore, with the development of international standards and norms, universal infrastructures are required. As well as accompanying accessories, user-friendly software is important to the success of EVs over the next decade.[2]An AC bus connected to EV onboard charger;

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they are come up with AC/DC converter.[3] Power Converter provides rectification of power, power factor correction, voltage and current control and DC power to EV port.[4] A static charging system provides security like NO electric shock and cable loss. EV Charging Station load can be fulfilled by renewable energy. About 5-20% loss of power when converting into AC to DC. DC system used about 500VDC with 120A current.[5]

Figure 1 Electric vehicle charging station [6]

The following are some of the paper's significant findings: Numerous modelling methodologies have been defined to model and design the EV charging station. In addition, explain how various renewable energy sources can be integrated into off-grid charging station applications. This paper is structured as section 2 current scenario EV charging station, section 3 EV charging station standard, and section 4 describes various modelling techniques of the charging system. Section 5 indicates the various literature based on off-grid applications. The rest of sections 6 and 7 describe as discussion part and conclusion respectively.

II. CURRENT SCENARIO OF EVCS IN INDIA

The EV charging market in India is still in its early stages, thus the government is drafting new regulations and policies to encourage the widespread adoption of EVs in the country. An evolutionary initiative aimed at expanding charging stations beyond city limitations, hence contributing to the ecology that would allow EV use to develop in India. In India, most businesses are wired to the grid, and 15 Amp level 2 connectors are popular. Businesses and organisations located between 40 and 70 kilometres from cities are encouraged to set up 15 Amp charging stations. The goal is to provide out-of-town charging to allow urban EV owners to increase the range of their journeys.[4] EVs are at the forefront of technology advancements that have been developed to resolve environmental problems. EVs, especially in urban areas, have a considerable impact on air pollution reduction.

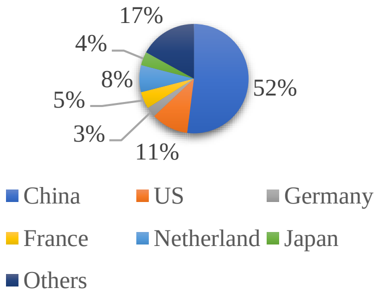

Figure 2 Percentage of the world's slow charging stations [7]

The calculation is made to compute CO_2 emissions from transportation, which account for 27% of total CO_2 emissions. India reported a 17 per cent rise in EV sales in the financial year 2019-2020, at the initial stage of EV penetration, due to the promising technology and efficient performance of EVs. Fig 2 and Fig 3 indicate the total percentage of publicly available slow and fast charging in various countries. It seems that about 50% of slow charging and 82% of fast charging are located in China.[7]

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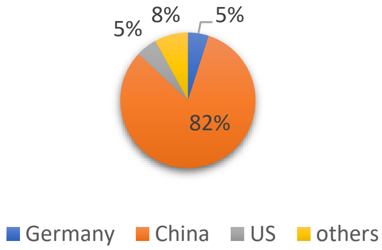

Figure 3 Percentage of the world's fast charging station [7]

III. EVSE STANDARD AND INFRASTRUCTURE

There are various types of EV charging stations available based on types of Power, a flow direction of power, based on the integration of renewable energy etc. There is main 3 types of EV Charging stations and systems classified below.

1) AC Conductive Charging System (Level 1)
2) AC conductive Charging System (Level 2)
3) DC conductive fast charging system
4) Inductive charging system (Wireless)

A. AC Charging System (Level 1)

Level 1 charging stations are slow charging stations with an output voltage of 120 VAC that require 10 to 12 hours to fully charge an electric vehicle battery. As shown in figure 4, A standard J1772 connector connects these charging stations to the EV port. Even though the cost of installation is low, the time it takes to charge an electric vehicle battery is longer. Level 2 charging stations were intended to address the issues of level 1 (slow) charging stations by reducing the charging time. [8]

B. AC Charging System (Level 2)

Level 2 charging stations are designed for use in both private and public locations. The EV's battery takes between 4 and 6 hours to fully charge. On the other AC side, the connector Society for Automotive Engineer (SAE)J1772 is used for level 2 charging stations. Although level 2 charging stations take less time than slow charging stations, it is still a considerable period when compared to filling conventional vehicles with fuel such as diesel or petrol.[8]

C. DC Charging System

As a result, the next level of charging station, known as the DC fast-charging station, is introduced. DC fast-charging stations have a voltage output of 500 V DC or higher. The 30 KWh battery of the vehicles is charged in around 30 minutes using a DC fast-charging station. DC fast-charging stations will cost between 5 and 10 lakhs to install. Another consideration for DC fast-charging stations is maintenance. The expense of running DC fast-charging stations is quite considerable.[9]

D. Inductive Charging System (Wireless)

Wireless power transfer is known as inductive charging. It provides electricity to devices by electromagnetic induction. Cars, charge systems, coil and safety systems all use inductive charging. The charging system needs to be perfectly aligned or establish electrical contact with a coil-to-coil contact otherwise some losses occur.

E. Charger Standard

All commonly available charging points are now conductive, which means that the power is provided by conductors, similar to how electricity is transported in an electrical outlet. Conductive stations are covered by SAE Standard J1772.

To ensure the capability of dc fast charger systems, many regulating boards have developed uniform protocols and couplers. The basic charger systems are listed in Table 2. There are IEC (International Electrochemical commission) standard, CHAdeMO standard, SAE (Society for Automotive Engineer) standard and Tesla's standard.

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TABLE I VARIOUS CHARGING STANDARD

Sr	Organization	Standard	Details
1	IEC	IEC61851	General Charging Requirements
		IEC62196	Plug, Sockets and Connector requirements
2	SAE[9]	J2293	EV and offboard charging
		J1772	Standard conductive charging
		J1766	Safety Requirements
3	CHAdeMO[9]	D001-002	Battery Characteristics
		D707-709	Battery testing
		D107-105	Conductive Charging
4	IEEE[10]	P15747	For different aspect of grid connection

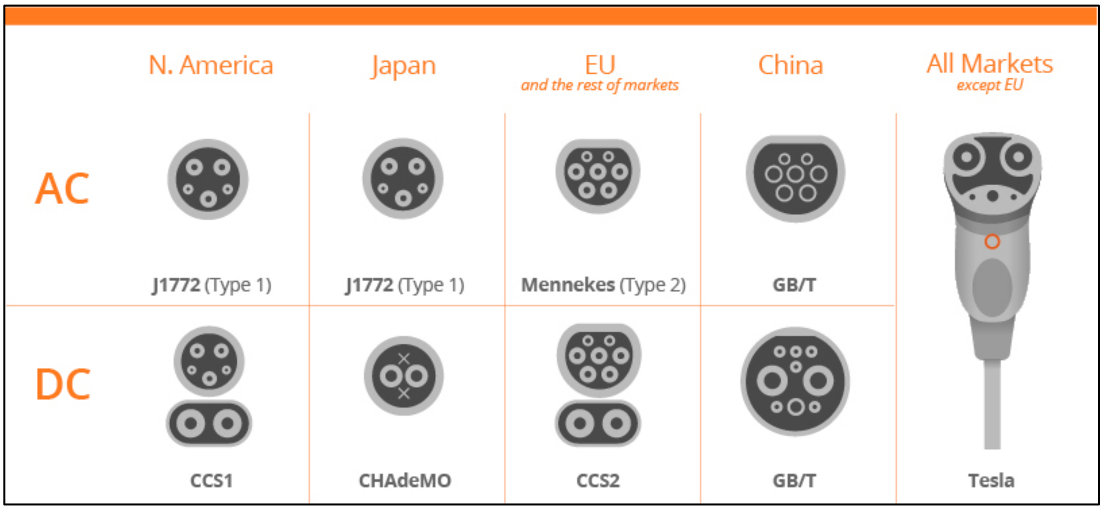

Figure 4 Various charging chargers [11]

In India Hyundai Kona, Suzuki, Honda and Nissan leaf are used as CHAdeMO chargers, whereas Hyundai, BMW, Ford, Kia, TATA, and Renault used CCS chargers in EVs. Tesla used its superchargers in EVs. Table 2 indicates EV battery capacity and the charging techniques used. As well as table 3 indicate that summary view of the EV charging system used by current manufacturers.

TABLE II VARIOUS EVS AND THEIR BATTERY CAPACITY [12]

Manufacture	Battery capacity (Kwh)	Charging system
Mahindra XUV 300	30.2	DC & AC
Tata Altroz EV	30	DC & AC
Maruti WagonR	50	DC
Nissan Leaf	30	DC & AC
Hyundai Kona	39.2	DC & AC

TABLE III SUMMARY OF AN EV CHARGING SYSTEM

Charging System	Charger Location	Power Level	Power rating	Charging Time	Use	Vehicle Technology
AC Level 1	On Board	120V, 15A	1.2 to 1.8 KW	14-16 h	Home	Bike, Auto EV
AC Level 2	On Board	240V, up to 80A	3.1 to 19.2 KW	6-8 h	Private or Public	EV
DC Fast Charge	Off Board	500VDC, 120A	25- 100 KW	0.30- 1 h	Commercial, Public station	EV

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IV. VARIOUS EV MODELLING TECHNIQUES

Modelling ensures that a mathematical representation of the system is properly designed, analyzed, and optimized, allowing for the observation of the effect of changes in the system variables. The performance of the system components determines the design of the Hybrid Renewable Energy (HRE) system. Through appropriate modelling of the individual system, the system can achieve better performance at a lower cost. [13]

In hybrid systems, optimization strategies based on mathematical modelling aid in the resolution of difficult issues. Many research has been carried out to solve the issues with standalone systems, and the majority of these studies have produced encouraging outcomes in terms of cost reduction and better system reliability. A consider a variety of modelling methodologies used in hybrid system-based power generation for off-grid applications.[3]

When the problems involve objective functions that are not continuous and/or differentiable, these optimization techniques have a limited scope increase. The Linear Programming (LP), Linear Programming Model (LPM), Dynamic Programming (DP), Genetic Algorithm (GA), Multi-Objective Programming (MOP), Hybrid Optimization of Multiple Energy Resources (HOMER), Multi-objective goal programming, and Multi-Input Linear Programming (MILP) are some of the traditional optimization methods used in hybrid energy systems. Another like, Hierarchical Optimization Model (HOM), Particle Swarm Optimization (PSO), Fuzzy Logic System (FLS), and Artificial Deep Neutral Network (ADNN) are various optimization techniques. [5]Those are all discussed further below.

Ramkumar et al.[14] developed a linear programming model to meet the energy needs of undeveloped nations, and used the objective function to calculate the total annual cost of the system. LP was developed to evaluate the economic feasibility of the Hybrid Renewable Energy Systems (HRES). Ascione et al.[15] presented energy demand for renewable energy system and optimize using MATLAB and Energy Plus software panel, Thermal solar system and heat pump used for in this literature as a renewable energy system. MOP optimization is used for the design of renewable energy integrated systems with constraints of investment cost and energy demand. With the simplex technique, Aregawi [16] developed a set of various equations for determining production activities within a certain period. LPM is used for improving performance, profit and cost, while working within several resource limitations like machine-hours, man-hours, money, material etc defined by an organisation.

Ali-Mohammad et al.[10] optimized allocation of protective devices, and distributed energy resources using the HOM method. Furthermore, depending on the data and probability table, different cumulative functions can be utilized for arriving time, leave time, and travelling distance. HOM is a method of optimization in which the problem is divided into several levels of hierarchy as shown in figure no 5. A difficult problem is separated into simpler sub-problems in hierarchical optimization, and each level is optimized individually. It's also used to define the load of an EV charging station.

Pablo et al[17] suggested the PSO approach to minimize the cost of a Hybrid EV charging station. In addition, the author applied a Photovoltaics (PV) and Fuel Cell (FC) system to create a low-cost hybrid renewable energy system. PSO is a computational method for optimizing a problem by iteratively attempting to improve a solution in terms of a specific quality measure. In comparison to other deterministic algorithms, it was able to achieve the optimum solution with a very low processing cost.

Ekren et al.[18] proposed design and optimization of wind-solar hybrid energy-driven charging station as shown in figure no 6. Although the concept that the sizing study was completed for a specific location at Izmir, Turkey. The data and technique may be applied anywhere in the world by modifying the solar and wind energy statistics. HOMER software is used for the optimization of various renewable energy sources including cost, sensitivity analysis, etc. HOMER system is used for the analysis of on-grid as well as off-grid applications.

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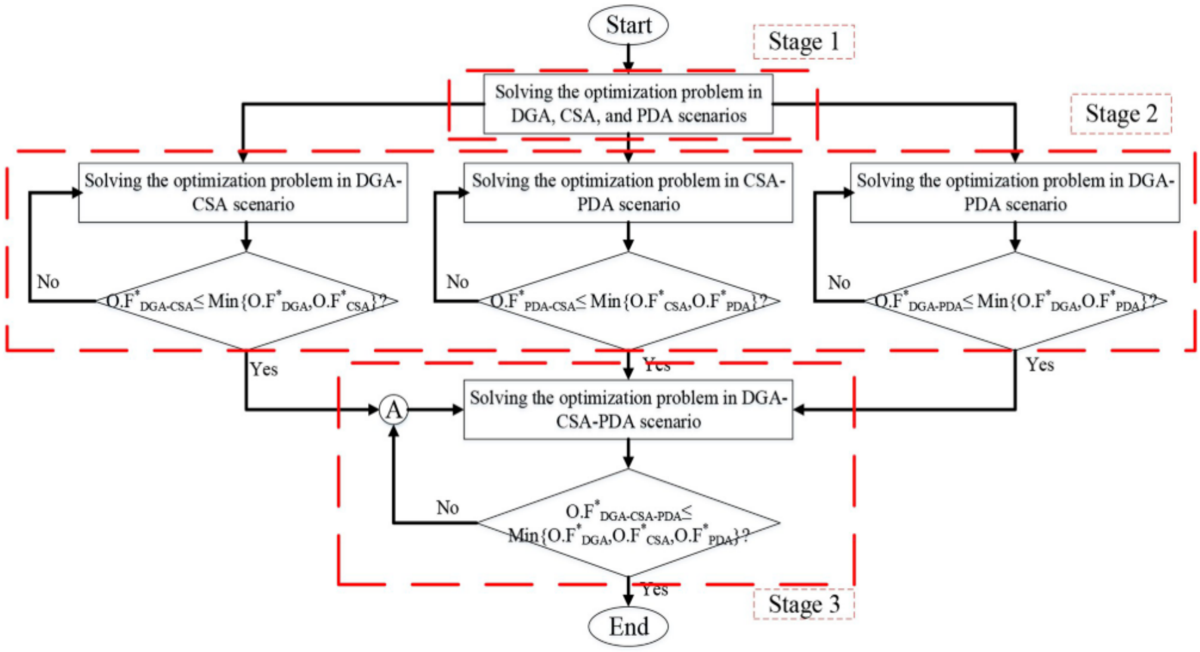

Figure 5 Flow chart of the HOM method [10]

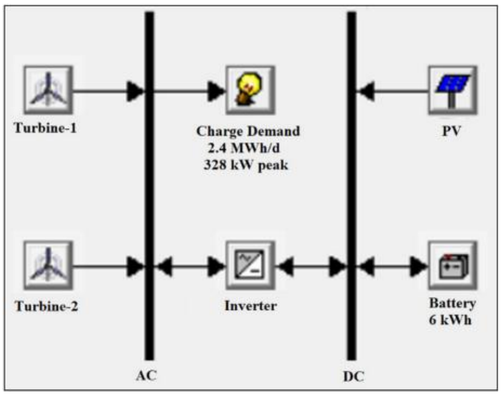

Figure 6 System architecture in HOMER Software[18]

Vendoti et al.[19] used the Genetic Algorithm (GA) method for modelling and optimising OFF grid renewable energy systems in the rural area. The author used PV, WT and FC as a renewable energy system and optimize using HOMER and MATLAB software. For constraint-based optimization issues, a is used. To build a new sample, the GA performs several computations in each iteration based on population size, selection technique, and crossover & mutation rate. GA is also created using MATLAB software. Abdulbaset et al[20] proposed a hybrid PV and FC system based on DNN. A PV system simulation model was constructed and modelled with MATLAB using a DNN-based MPPT method. The DNN controller creates rules and restrictions to ensure optimum fuel flow for a fuel cell system, and the author achieves relatively minimal error in the voltage and current of the FC system using the DNN system. DNN is a type of neural network that is used to solve problems in the power system, such as smart PV and fuel cell systems. PV voltage, current, and duty cycle were some of the variables used by DNN. The simulation of DNN is shown in figure 7.

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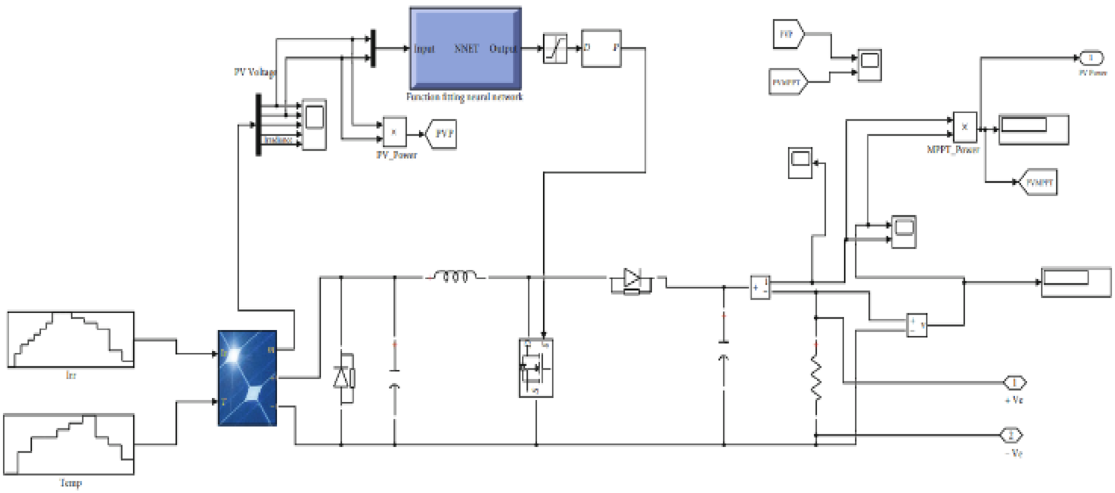

Figure 7 Simulation DNN algorithm of PV system [20]

Yun et al[21] distinguished the Robust Optimization Model (ROM) approach with PV and FC systems. For uncertainty variation of EV charging, the author compares robust and deterministic cases and optimizes the system. One of the most effective and successful techniques for dealing with uncertainty in a model is ROM. The method's theory is to investigate a model's robustness in the presence of the highest level of uncertainty penetration, and then deliver the final ideal outcomes based on the various durability rates for off-grid charging stations.

Mirhassani et al.[22] proposed two drive classes for EV charging: home to office and intermediate for conventional EV charging. In addition, several charging locations for EV owners were determined using mathematical formulas. Bendor Decomposing Algorithm (BDA) has been used to solve optimization problems like vehicle routing, traffic problems, and charging station positioning Alireza et al[23] implemented a scheduling strategy based on policies such as First Come, First Serve, Smart Charging, and Quality of Service. This will save the user time and allow for faster charging. The Smart Scheduling Model (SSM) is known for determining the best charging schedule for electric vehicles to maximize revenue and user satisfaction.

FLS model in PV Maximum Power Point Tracking (MPPT) system with hybrid configuration was presented by Subramanian et al.[24] In addition, MATLAB software was utilized to define the FLS model with the PSO system. FLS is in form of a truth-value real number between 0 and 1. It's used to deal with the concept of partial truth, where the truth value can be somewhere between 100% true and 100% false. Table 4 summarizes the modelling techniques.

TABLE IV SUMMARY OF MODELLING TECHNIQUES

Techniques	Used for	Application	Merits	Limitation	Software Used
LP [14]	PV-WT-BG	Economic feasibility	Easy due to probability analysis	The renewable system sometimes affects the performance	Manually
MOP [15]	PV-WT	Determine production	Improve the decision making	Time-consuming and less transparent	Energy Plus
LPM [16]	BG-BM	Improving performance	Provide possible and practical solutions	Planning problems and other activities can't measure quantitative terms	Manually

HOM [10]	PV-WT-DG	Selection for a hybrid system	Increase the reliability in hybrid system selection	Increase complexity with an increasing number of variables	MATLAB
PSO [17]	PV-WT-BM	Charging Quality	Easily find out the optimization problem	Some modifications are required.	HOMER
HOMER [18]	PV-WT-BG	Cost optimization	Easily design and optimise of system	Require very accurate data for correct result	HOMER
GA [19]	PV-WT-BG	Constraints based	Efficient techniques for approximate solution	Time-consuming and require hard working	MATLAB HOMER
DNN [20]	PV-FC	Power system	Good for analyses of power system	Very Complex System	MATLAB
ROM [21]	PV-FC-EVSE	Uncertainty of charging	Using input and output data easy to define uncertainty problem	Require accurate data for the exact result of uncertainty	General Algebraic Modelling System (GAMS)
BDA [22]	EVSE	Location of Charging station	Easy for solving a multi-objective formulation problem	Various constraints based	AIMMS with CPLEX Solver
SSM [23]	PV-WT-BG	Scheduling of EV	Effectively provide a various EV scheduling system	Faces problems when heavy traffic	MATLAB
FLS [24]	PV-WT-FC	Control system	Easily constructed, flexible and allow modification of the rule	Completely dependent on human	MATLAB

All of the above modelling methodologies apply to a variety of hybrid renewable energy systems, including PV, WT, FC, biogas (BG), and biomass (BM). All strategies are applied for the optimization issue as specified above in table no. 4 for both off-grid and on-grid charging stations. Generally, MATLAB software is used for the various algorithm, simulation and modelling techniques. HOMER is also used on-grid and off-grid power generation techniques with consideration to renewable energy sources like PV, WT, FC, Biogas and Hydrogen systems. HOMER suggest the load analysis as well as the cost of the system, per unit kWh cost and total net present cost.

V. ELECTRIC VEHICLE CHARGING STATION INTEGRATION WITH OFF-GRID

There are various types of charging stations classified based on system integration.

1) On-Grid (Grid-Tied)
2) Off-Grid
3) Hybrid (Combination of On and Off-grid)

Modelling an HRE system is a difficult task that requires the creation of mathematical models for each component. Various optimization approaches must be used to optimise the mathematical models of renewable energy sources.[25] Renewable energy resources are found in nature at random and, to create a standardised framework, these resources are combined to create a hybrid system configuration that meets the energy needs of customers in remote places. The number of power conversion stages and losses in power supplied to the load/utility are reduced when power conversion circuits and controllers are properly interfaced to the AC or DC bus.

In this study, Electric Vehicle Supply Equipment (EVSE) or Electric Vehicle Charging Station (EVCS) review is based on various renewable energy systems to reduce the dependency on conventional fuel. EVCS is used for both purposes of AC and DC charging of Car, Bus, Motorcycle and trucks etc. [26]

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A. Components of On-Grid EVCS
As system power sources, EVCS are directly connected to the grid. Due to the increased number of EVs, the grid load and power demand may increase. Electric vehicles can be charged using both AC and DC charging systems.
B. Components of off-grid renewable energy sources
There is the various renewable energy system used in EV charging systems listed below.
1) *PV system:* PV panels with charger controllers, converters, and battery backup systems make up a PV system. A DC electricity is generated from a PV system. PV systems are divided into two categories: grid-connected and stand-alone.
2) *Wind Energy system:* Wind turbines extract energy from the wind and use a generator to turn mechanical rotation into electricity. AC electricity was generated by a wind turbine. The term "wind farm" refers to a group of wind turbines.
3) *Fuel cell:* A fuel cell is an electrochemical cell that uses hydrogen and oxygen to produce energy through a redox process. FCSs differ from batteries in that they require hydrogen and oxygen as fuel. There are several types of fuel cells available, including Proton Exchange Membrane, Solid Oxide Fuel Cell, and Alkaline Fuel Cell.
4) *Biogas and biomass*: Biogas is a mixture of methane and carbon dioxide-containing gases. It is made from animal waste, agricultural waste, food waste, and sewage waste. It is one form of renewable energy source for electricity generation.
C. Hybrid EVCS:
Hybrid systems connect with both grids as well as renewable power sources. When power demand is high from the grid side electricity can be sent via renewable sources and vice versa. A hybrid system cost higher than a grid-tied system. [27]
D. DC Charging System Connect with HRES:
The dc renewable energy resources may be connected to a dc bus line to which the dc loads are attached in a dc charging system, whether directly or via a DC-DC converter. AC-DC converter attaches the ac renewable energy to the same dc bus link. Using a dc/ac converter, that system's layout can also provide ac power to ac loads. A bi-directional converter can connect the storage system to the dc bus line to deliver dc power to the dc loads in accordance to demand.[28]
E. AC Charging system Connect with HRES:
An ac renewable energy generation may be connected to a power frequency ac bus line to which the ac loads are linked in a power frequency ac-coupled arrangement, whether direct or through an ac/ ac power converter. A dc/ac power converter connects the dc renewable energy to the same bus line.[27]
F. HRES system integrates with EVCS:
Hasan Fathabadi[27] presented a wind-powered novel grid-connected electric vehicle charging station with V2G functionality. MPPT technology is utilized on a vertical 10KW axis wind turbine. For EV charging, a DC-DC boost converter was used to create a DC fast-charging system. As indicated in figure no 8, Chellaswamy et al[29] used MATLAB software to model PV and Wind energy-based EV charging. For the 10 DC charging system points, two unidirectional PV converters and six bidirectional wind turbine converters were used. Three DC-AC inverters are used to supply excess electricity to the grid.

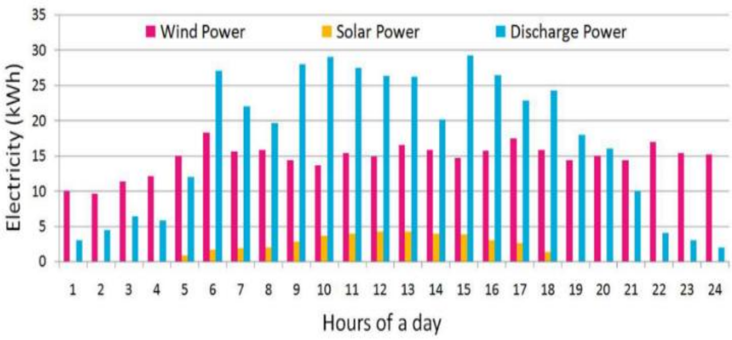

Figure 8 PV and Wind based charging station load curve

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Karmaker et al.[30] have a 10 KW solar system and three 10 KW biogas generators with a battery bank system. For the HRE system, the author employed a DC charging system and analysis in HOMER software. In addition, the author's proposed model reduced CO_2 emissions by 34.68 %. Hasan Fathabadi[31] created an EVCS for a Plug-in Hybrid Electric Vehicle that incorporates solar panels, wind turbines, and fuel cells. To ensure uninterrupted EV charging, the author includes a 12 KW solar array, a 10 KW wind turbine, and a 5 KW fuel cell system.

As shown in fig. no 9, Onur Elma [32] presented a DC fast-charging system that integrates renewable energy sources such as PV and wind turbines. To deliver excess electricity to the grid, the author employed a DC-AC converter. With Concentrating PV, Biomass, and multiple storage units Abdulla et al[33] created a grid-independent, renewable energy-based, and standalone charging station. Fuel cells consisting of H_2, NH_3, and PCM are utilized to provide continuous charging during the night and in adverse weather situations.

Figure 9 Literature proposed charging station [18]

TABLE V SUMMARY OF ABOVE STUDIES

Sr No	Energy Source	Charging System	Connection
1	Wind	DC	Both with V2G
2	PV- Wind	AC and DC	Off Grid
3	PV-WT-BG	DC	Off Grid
4	PV-WT-FC	DC	Off Grid
5	PV-Wind	AC and DC	Both, Excess sent to Grid
6	PV- Biomass	DC	Off Grid

VI. REMARKS AND DISCUSSION

As the number of electric vehicles on the road increases, more EV charging stations are needed. End-of-cycle pollution is reduced by grid-Independent EV charging. Many renewable energy sources, such as sunlight, wind, and tidal energy, are available for free. We need to include renewable energy sources in electric vehicle charging stations to reduce pollution and system load. Off-grid electric vehicle charging stations used renewable energy sources in a hybrid renewable energy system. Incorporating renewable energy sources in diverse combinations, such as solar wind. Biomass-wind, and other renewable energy sources.

PV and wind systems are now expensive, but they are necessary for the future to minimize greenhouse gas emissions. As previously said, there are a variety of strategies that may be used to build and develop off-grid charging stations. The position of the charging station is an essential parameter, and it can be optimized using the Bendor algorithm. HOM technique and HOMER software were used to select a hybrid system and optimize costs respectively. PSO and ROM methods have been utilized to improve charging quality and uncertainty in charging optimization. Overall, off-grid EV charging stations are a future necessity that will require some form of subsidy or exemption to be implemented more quickly.

VII. CONCLUSION

Due to developments in renewable energy technologies that improve system efficiency, hybrid renewable energy system-based power generation has been recognized as a practical and cost-effective power generation solution in off-grid applications. A review of the related components of the hybrid renewable energy system for off-grid applications has been conducted in this paper. Off-grid applications such as villages and remote areas require a hybrid renewable energy system. The numerous hybrid system optimization and sizing strategies have been summarized. We've also seen that two more renewable energy systems are being employed to improve load management, lower the risk of power outages and reduce grid load. Various researches are being conducted, but there are still some gaps that must be addressed to create a new HRE system combination.

Standalone has installed any space where there is grid not available like remote area, village etc. As well standalone has no bad environmental impact and not produced toxic gases like CO, and NO_X. Off-Grid Energy application has a very effective and less payback period for great efficiency. Based on various modelling techniques improve system performance and eliminates uncertainty, high cost and High energy loss. Various sizing and optimization techniques include study for off-grid application on the renewable charging station.

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