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Hybrid Renewal Energy based on Electrical Vehicle charging Station

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A B S T R A C T

The fast increase in Electric Vehicles (EV) such Easy Bikes, Auto-Rickshaws, and Electric Bikes is a major contributor to the global energy issue. India, a rising nation, is likewise having issues as a result of excessive energy usage. Although cheaper modes of transportation and lower greenhouse gas (GHG) emissions are two of the advantages of electric vehicles, it is difficult to generate the enormous amounts of energy needed to charge the batteries on a daily basis. Additionally, Madhya Pradesh's lack of charging stations slows down travel times and increases costs for EV owners. Due to this, practically all EV owners unlawfully draw electricity from residential connections and pay their bills as residential consumers. Thus, there is a system loss in the electricity sector. Additionally, the non-linear features of EV chargers impact power quality by generating harmonics, creating voltage fluctuations, and resulting in power loss. This work focuses on the usage of readily available renewable energy for EV charging in order to address the issues raised before. As per Government of Madhya Pradesh "Government Wind Monitoring Scheme" choosing my project location **is Jomgodrani, district Dewas, Madhya Pradesh.** The site of Jomgodrani already installed wind energy plane for 13.05 MW by MP Winfarm Ltd., Bhopal have already established. But this station is not any charging station and it depend only on wing energy which is absent on rainy day & foggy environment. As Dewas has a great potential of wind resources and solar based Electric Vehicle Charging Station (EVCS) would increase the effective operational hours. This work investigates the feasibility of wind-solar based EVCS using HOMER Pro software.

Keywords:Key word: Renewable energy sources, Transportation, Tariffs, Charging stations, Electric vehicle charging

1. INTRODUCTION

As one of the world's largest automobile markets, India's country-wide electrification will be a turning point for the entire world and the country itself. Driven by the Indian government's push towards sustainable mobility, growing consumer demand for new technologies, and the emergence of private players with an interest in EV technology, the future of electric vehicles in India looks promising. However, the country continues to grapple with several challenges in its pursuit of full EV adoption, namely with the low number of charging stations and high upfront costs of EVs.India is among the top five markets worldwide for both private cars and commercial vehicles, making it one of the largest markets for two- and three-wheeled vehicles. JMK Research estimates that astonishing 455,733 electric vehicle (EV) units were sold in FY2022. The Ministry of Road Transport and Highways of India stated that as of July 2022, there were 1,334,385 electric vehicles operating in India. With the federal, state, and private sectors aggressively promoting more electrification of Indian roads, these figures are certain to rise. The following EV mix would be achieved in India by 2030, according to Union Minister Nitin Gadkari.

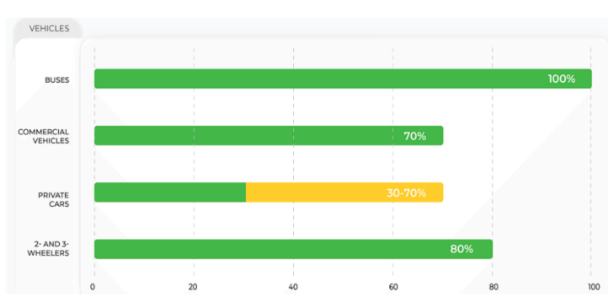

Figure 1.1 India sets ambitious targets for its EV ecosystem by 2030

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2. OBJECTIVES

The main goal of this dissertation is to analyze the feasibility with technical, financial, environmental and socio-economic aspects and design of a hybrid renewable energy based EVCS with energy management algorithm.

The following specific objectives will be taken into consideration in the present study:

i. To analyze the challenges and impacts of EVs on the power system;
ii. To identify the prospects of the solar and wind-based hybrid power generation scheme in India.
iii. To analyze the technical, financial, environmental and socio-economic feasibility of the proposed EVCS using HOMER Pro software;
iv. To design a model of proposed EVCS suitable for Bhopal near area that is Dewas, Madhya Pradesh, India.

3. RESEARCH METHODOLOGY

Electric Vehicle Charging Station (EVCS) basically connected with the utility grid for battery charging purposes. However due to sharp increasing in the EVs worldwide, it becomes a threat to the power sector. On the other hand, India has a great potential of renewable resources like solar, biogas, wind etc. But in this work only solar and wind-based hybrid generation is taken to analyze. In this chapter, the prospect of hybrid power generation through solar & wind energy is analyzed. Then, the feasibility assessment of the hybrid renewable energy based EVCS is performed according to the technological, financial and environmental aspects using HOMER Pro software 3.11.2. In addition, socio-economic aspects of this type of proposed EVCS is demonstrated.

3.1. *POTENTIAL OF RENEWABLE RESOURCES*

In this research, two types of renewable energy resources are proposed for the purpose of electricity generation, i.e., solar energy and wind energy.

3.2. *SOLAR ENERGY POTENTIAL IN INDIA*

India has a huge potential for solar energy. Every year, India enjoys around 3000 hours of sunshine. India's geographical surface receives around 5,000 trillion kWh of incident energy annually, with the majority of areas receiving 4–7 kWh per square metre each day. Solar photovoltaic power may be efficiently harnessed in India, offering enormous scalability. According to the National Institute of Solar Energy, India has a solar potential of roughly 750 GW, assuming that solar PV modules will cover 3% of the country's wasteland. Rajasthan and Gujarat have the greatest potential for solar energy.

3.3. *SOLAR ENERGY PRESENT STATUS IN INDIA*

According to data presented in Parliament, 61GW of solar energy had been installed as of October 2022. Additionally, India has set a lofty goal to reach 175 GW of renewable energy capacity by the end of 2022, of which 100 GW was to come from solar energy, and 500 GW by the end of 2030. The largest expansion strategy for renewable energy exists right now.

India ranked third globally and second in Asia for new solar PV capacity. In terms of overall installations, it came in at number four (60.4 GW), passing Germany (59.2 GW) for the first time. Rajasthan and Gujarat, which accounted for 53% and 14%, respectively, of installations as of June 2022, were the top states for large-scale solar, followed by Maharashtra with 9%.

Between 2016 and 2019, China, the USA, and India were the top three countries in the installation of solar power facilities.

3.4. *WIND ENERGY IN INDIA*

Wind Energy in India has been the fastest-growing renewable energy source in the country. As the country has a vast coastline, Wind Power Plant in India is onshore and offshore. As of 30 September 2022, wind energy in India has an overall installed power capacity of 41.666 GW. Wind energy in India has a huge potential to fulfill the country's power needs and boost the economy.

The largest Wind Farm in India is the Muppandal Wind Farm in Tamil Nadu. Below mentioned are all the details of state-wise wind power plants in India. The article elaborates on complete details of the wind energy in India and the largest wind mills.

3.5. *CHOOSING LOCATION*

As per Government of Madhya Pradesh "Government Wind Monitoring Scheme" choosing my project location is **Jomgodrani, district Dewas, Madhya Pradesh**. The site of Jomgodrani already installed wind energy plane for 13.05 MW by MP Winfarm Ltd., Bhopal.

Therefore, in this study trying to best situation for installing 30 KW hybrid energy based electrical Vehicle station.

3.6. DESIGN OF THE OFF GRID CONNECTED HYBRID RENEWABLE ENERGY BASED EVCS

Figure 3.1 shows a grid connected hybrid powered Electric Vehicle Charging Station where the PV panel produces 30 kW power whose maximum power point is tracked by a MPPT. One Wind turbine and one Generator.

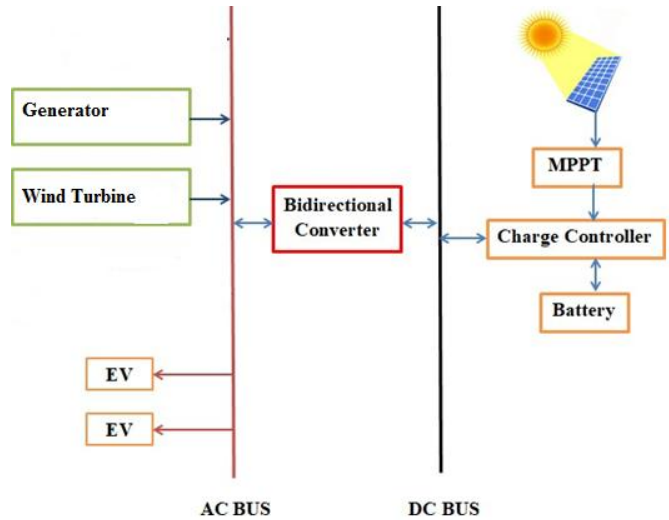

Figure 3.1Off Grid Connected Hybrid Renewable Energy Based EVCS

A charge controller regulates the voltage and current into the batteries. When the batteries are charged fully then it stops charging and sends the excess power to the converter. A bidirectional converter is used to convert the DC into AC. If the hybrid power is unavailable, the power comes from the national grid, especially during the off-peak period. Electric vehicles are charged from the AC bus through a charging apparatus.

3.7. DESIGN OF EVCS USING HOMER PRO SOFTWARE

HOMER is a free software application developed by the National Renewable Energy Laboratory in the United States. This software application is used to design and evaluate technically and financially the options for off-grid and on-grid power systems for remote, stand-alone and distributed generation applications. The HOMER (Hybrid Optimization of Multiple Energy Resources) model greatly simplifies the task of designing hybrid renewable micro-grid, whether remote or attached to a larger grid. HOMER's optimization and sensitivity analysis algorithms allow you to evaluate the economic and technical feasibility of a large number of technology options and to account for variations in technology costs, electric load, and energy resource availability.

Figure 3.2 shows the block diagram of EVCS designed by HOMER Pro software. In this demonstration, Generic flat plate PV, Generic 10kW Fixed Capacity Genset, Wind Turbine XzeresSkystream 3.7 [2.4kW], electric load (165.59 kWh/day), converter (30 kW) and battery storage Generic 1kWh Li-Ion [ASM] is used. This model uses the solar irradiation and temperature data from the National Renewable Energy Laboratory department.

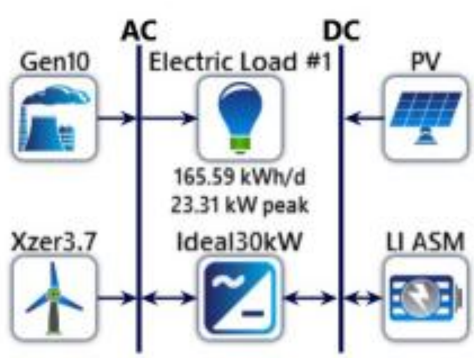

Figure 3.2Block diagram of EVCS designed by HOMER Pro software

The temperature curve and solar irradiation are given in Figure 3.3 and Figure 3.4 respectively. Figure 3.3 shows the temperature varies from 20^0C to 33^0C in Dewas. The average solar irradiation is 5.24 kWh/m^2/day as shown in Figure 3.4.

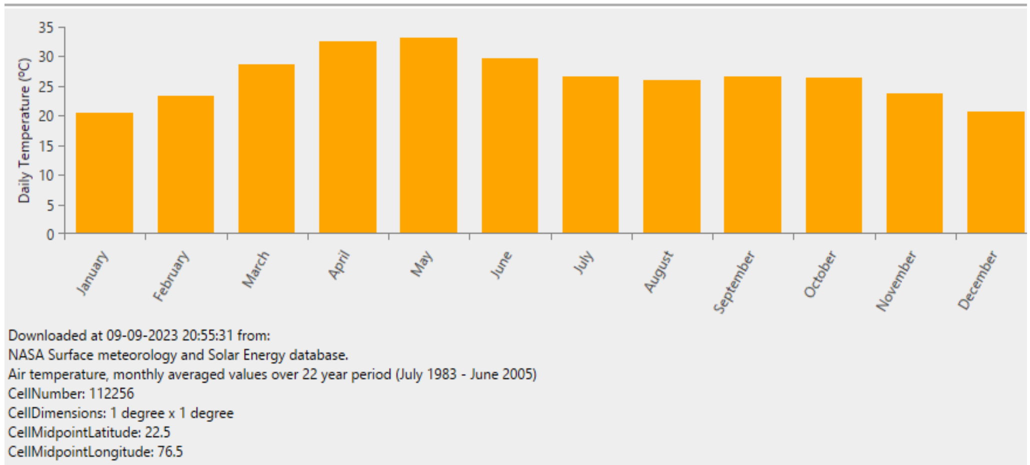

Figure 3.3Daily temperature at Dewas used in HOMER

Temperature affects the solar output energy production. In addition, a research performed on biogas production showed that, the 20^0C to 33^0C temperature acts solar generation.

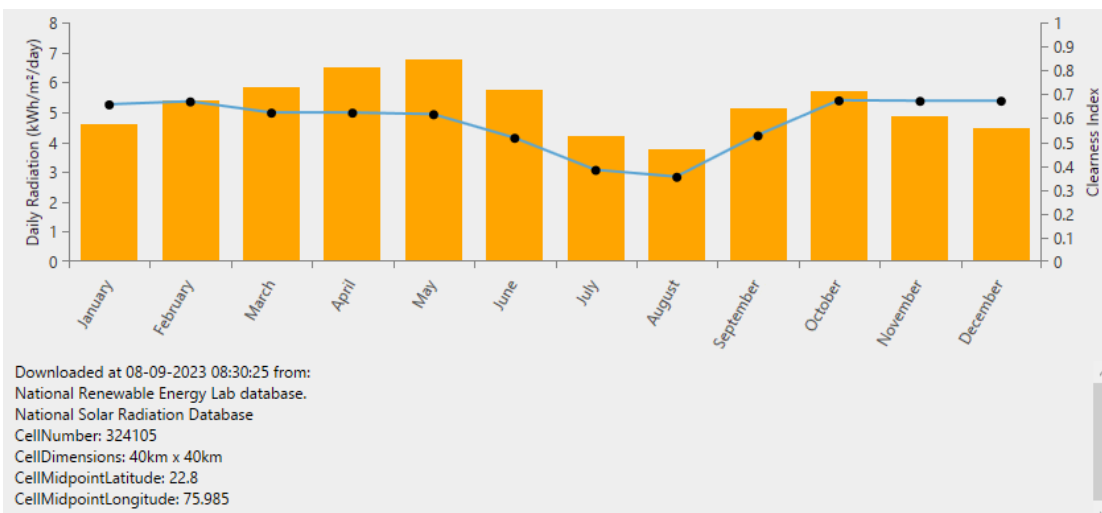

Figure 3.4 Solar irradiation profile used in HOMER

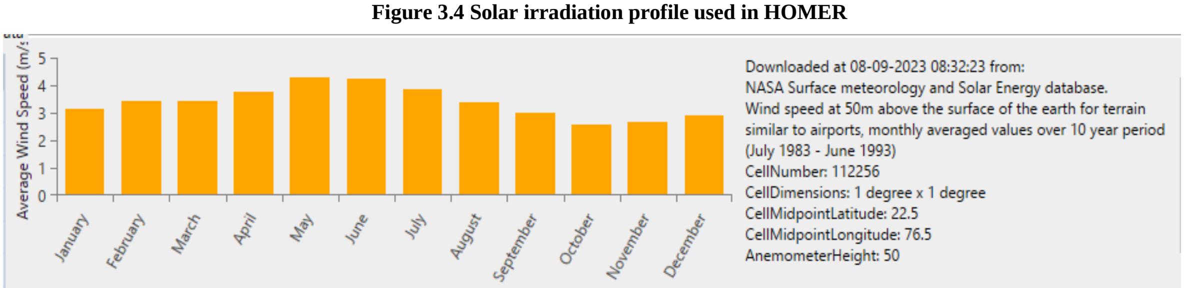

Figure 3.5 Wind flow used in Homer

The annual average wind speed is 3.39 m/s kWh/m^2/day as shown in Figure 3.5.

3.8. TECHNOLOGICAL FEASIBILITY ANALYSIS

This research deals with the utilization of available renewable energy resources like solar and wind for the purpose of charging EVs in the area of Bhopal like Dewas M.P. The proposed EVCS consists of a PV module, Wind turbine and Generator for electric power generation. The HOMER Pro optimization software tool is used for designing and analysis of the economic analysis and sensitivity analysis. The average solar irradiation obtained from NASA is 5.24 kWh/(m^2·day). The daily, monthly and yearly load profile is shown in Figure. 3.6 where the daily estimated load is assumed as 165.59 kWh. The load varies during different seasons in Dewas. Every day 20-30 EVs can be a reasonable load for the charging station. Charging hours are inversely related to the state of charge (SOC) of the vehicles' batteries. In the proposed design, the electric power is supplied by the wind turbine when solar energy is unavailable to increase the effective operational hours to 8-10 h. The hybrid renewable energy generated by the PV module and wind turbine is supplied to recharge the EVs' batteries.

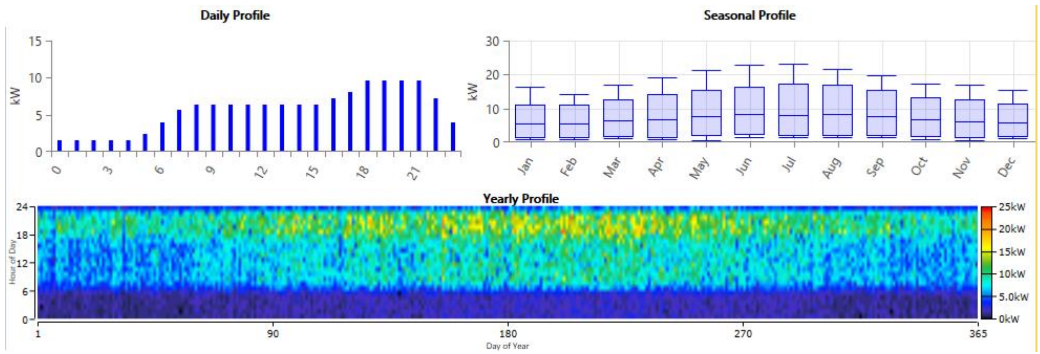

Figure 3.6 Load profile (daily, seasonal) used in HOMER

Every day 20-30 EVs can be recharged from this charging station according to the SOC of the vehicle battery. According to the configuration, this EVCS is capable of charging 8 EVs simultaneously. So, it is considered that all the EVs will arrive at different time interval in the charging station not altogether. In the case of holidays, when vehicle consumption decreases, excess energy can be sold to the national grid through vehicle to grid (V2G) technology. There is also an option for purchasing electricity from the grid in the case of rainy days or during periods of less wind energy. The electricity generated by proposed hybrid power generation scheme is then applied to EV charger which converts the power into constant DC Voltage.

3.9. ECONOMIC FEASIBILITY ANALYSIS

The total cost of installation and replacement gives the Net Present Cost (NPC) and O&M cost, respectively. The return of the investment is assessed by the term's payback period and annual cash flow summary. Finally, the Profitability Index (PI) is used to determine the feasibility study of the proposed charging station. It is assumed that an electric vehicle is used 26 days/month and consumes an average of 12 kWh daily for traveling 80 km, so 0.15 kWh electric power is required per km run. The monthly electric bill for charging an electric vehicle is about Rs. 3000. Solar radiation is available for producing electricity only for 5 to 6 h a day and wind energy available 15-20 h a day. Thus, the genset can generate electric power only during those hours, whereas, solar and wind are not providing the energy. Calculation of economic parameters is shown in Table 3.1.

Table 3.1 Economic parameters obtained from HOMER Pro software

Component Name & Size	Active Hours	Energy Production (kWh/Year)	Lifetime (Years)	Annual Cash-Flow	Payback Period (Year)	Profitability Index (PI)
Generic flat plate PV	5-6	2,47,433	25	Rs. 28,842	20	>1
XzeresSkystream 3.7 [2.4kW]	15-20	9,490	25	0	25	
Generic 10kW Fixed Capacity Genset	1-2	266	25	Rs. 10,661		

In Figure 3.7, the annual cash flow according to resource type is shown where PV is the highest contributor to the energy generation and Wind turbine and Generator are the next. For this charging station, the value of the profitability index is greater than one, which indicates the project is financially feasible.

The net present cost (NPC) for the proposed work is Rs. 739034.80 which is economically feasible. The operating cost of the proposed design is found as Rs. 16762.97 and the levelized Cost of Energy/kWh is found as Rs. 0.9464. The O&M cost is significantly lower in case of the proposed EVCS as there is less use of fuel like diesel.

The cost of energy in the proposed EVCS is less than that of a conventional grid-based charging station. Although it is difficult to bear the initial cost of installation of such an EVCS, it will be a profitable option after the payback period.

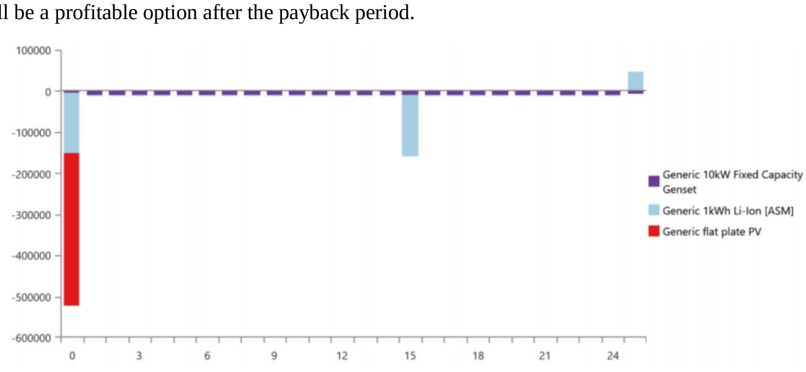

Figure 3.7 Annual cash flow by resources

3.10. ENVIRONMENTAL FEASIBILITY OF THE PROPOSED EVCS

Electric vehicles have several key benefits, including reduction of GHG emissions, fumes and noise pollution which are hazardous to the environment. Environmental benefits of the proposed EVCS are the reduction of carbon dioxide emissions and other pollutants. In this system, the amount of CO_2 emission found 270 kg/yr. The Carbon Monoxide 2.04 kg/yr. Unburned Hydrocarbons 0.0745 kg/yr. Particulate Matter 0.124 kg/yr. Sulfur Dioxide 0.663 kg/yr. Nitrogen Oxides 2.32 kg/yr. In the proposed EVCS, yearly CO_2 emission is about 270 kg/yr whereas for the same demand grid-based charging station produces 25708.80 kg of CO_2 or Biogas by 8,837.40 kg.

4. RESULT AND DISCUSSION

Electric Vehicle Charging Station optimization for minimizing charging cost is the main purpose of this research. In the present energy scenario of Dewas, charging electric vehicles leads to a huge consumption with increasing system loss. EV owners are also in a big trouble for being less number of charging stations throughout the district/state. On the other hand, charging cost is very high when the electric vehicles are charged from the commercial line. Due to solve these problems, fuzzy optimization technique is employed in this research. Fuzzy “if-then” rule-based strategy is used in this optimization system. The membership functions are defined according to the data for the current battery electric vehicles of Dewas. The surface view of the charging rate, power availability, power demand, time of charging and duration of charging is discussed in this section.

4.1. Electrical Summary

As per annual production summary the Generic flat plate PV generate 247433 kWh/yr and Wind turbine 490 kWh/yr whereas Genset only generate 266 kWh/yr as shown in Table 4.1 and Figure 4.1. This is clear that the energy production by renewal resources is very high.

Table 4.1 Production Summary

Component	Production (kWh/yr)	Percent
Generic flat plate PV	2,47,433	99.7
Generic 10kW Fixed Capacity Genset	266	0.107
XzeresSkystream 3.7 [2.4kW]	490	0.197
Total	**2,48,188**	**100**

From Table 4.2 consumption by AC Primary Load 100% this is clear that only power consumed by load and no losses. The total annual consumption as per load is 60,407 kWh/yr whereas total production is 248188 and only 247433 kWh/yr power generate by PV solar that means the excess electricity 1,82,735 kWh/yr is unused so it can be sold out to grid and get cash back.

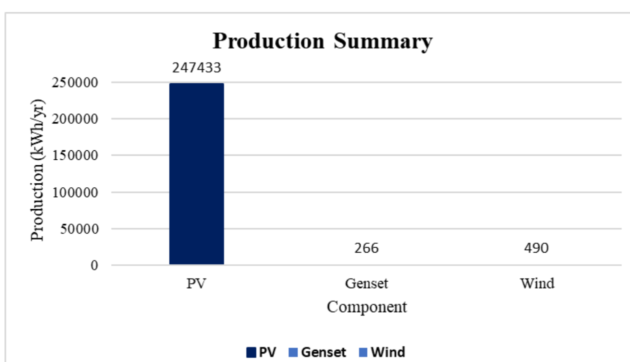

Figure 4.1Annual Production Summary

Table 4.2 Consumption Summary

Component	Consumption (kWh/yr)	Percent
AC Primary Load	60,407	100
DC Primary Load	0	0
Total	**60,407**	**100**

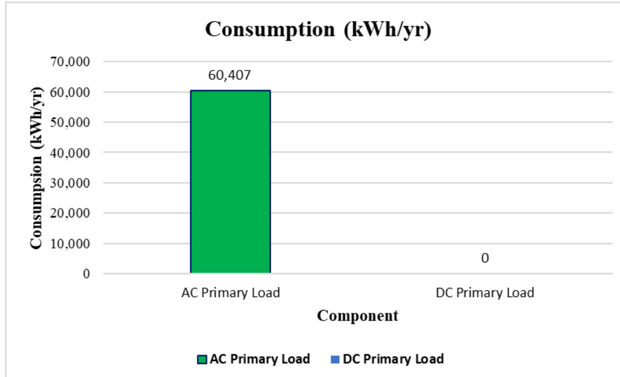

Figure 4.2 Annual consumption summary

Table 4.3 Excess and Unmet

Quantity	Value	Units
Excess Electricity	1,82,735	kWh/yr
Unmet Electric Load	34.8	kWh/yr
Capacity Shortage	57.0	kWh/yr

4.2. Electric summary of Generator

The Electric summary of Generator is shown in Table 4.4. From Table 4.4 Electric production 266 kWh/yr, mean Electric Output is 4.67 kW, Minimum Electric Output 2.50 kW and Maximum Electric Output is 10.0 kW.

Table 4.4 Generic 10kW Fixed Capacity Genset Electrical Summary

Quantity	Value	Units
Electrical Production	266	kWh/yr
Mean Electrical Output	4.67	kW
Minimum Electrical Output	2.50	kW
Maximum Electrical Output	10.0	kW

Table 4.5 shows the Genset Fuel Summary. From Table 4.5 Fuel Consumption by Genset is 103 L in a year and Specific Fuel Consumption 0.389 L/kWh. The Fuel Energy Input 1018 kWh/yr that means Mean Electrical Efficiency 26.1 %.

Table 4.5 Generic 10kW Fixed Capacity Genset Fuel Summary

Quantity	Value	Units
Fuel Consumption	103	L
Specific Fuel Consumption	0.389	L/kWh
Fuel Energy Input	1,018	kWh/yr
Mean Electrical Efficiency	26.1	%

Figure 4.3 shows the Genset output.

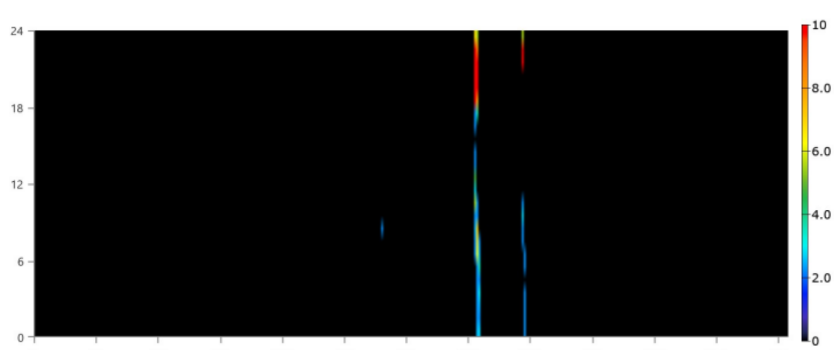

Figure 4.3 Generic 10kW Fixed Capacity Genset Output (kW)

4.3. *Electric summary of Generic flat plate PV*

Table 4.6 Generic flat plate PV Electrical Summary

Quantity	Value	Units
Minimum Output	0	kW
Maximum Output	146	kW
PV Penetration	409	%
Hours of Operation	4,404	hrs/yr
Levelized Cost	0.117	₹/kWh

Figure 4.4 shows the annual summary of Generic flat plate PV Output (kW). From Table 4.6 the maximum output of the PV is 146 kW, PV penetration 4.9%, Hours of Operation 4404 hrs/yr and Levelized Cost 0.117 ₹/kWh which is very low.

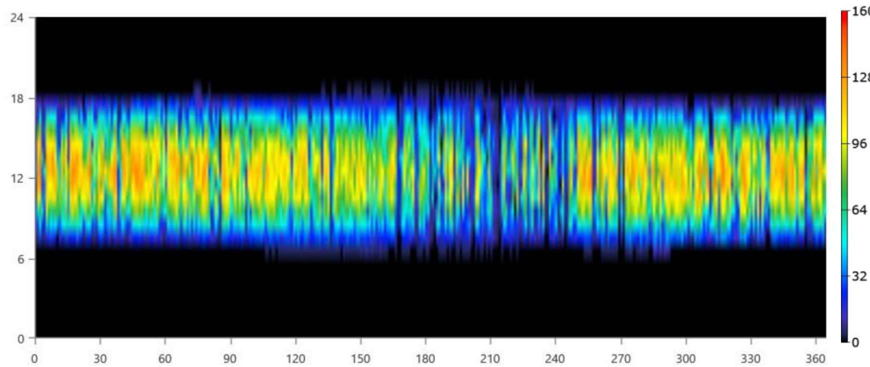

Figure 4.4Generic flat plate PV Output (kW)

4.4. *Electric summary of Wind Turbine*

From the Table 4.7 Minimum Output is 0 kW, Maximum output 2.17 kW,Wind Penetration 0.810 %, Hours of Operation is 3678 hrs/yr and Levelized Cost is 0 ₹/kWh which is very low. Figure 4.5 represent the electric output for one year from the wind turbineXzeresSkystream 3.7 [2.4kW].

Table 4.7XzeresSkystream 3.7 [2.4kW] Electrical Summary

Quantity		Value	Units
Minimum Output		0	kW
Maximum Output		2.17	kW
Wind Penetration		0.810	%
Hours of Operation		3,678	hrs/yr
Levelized Cost		0	₹/kWh

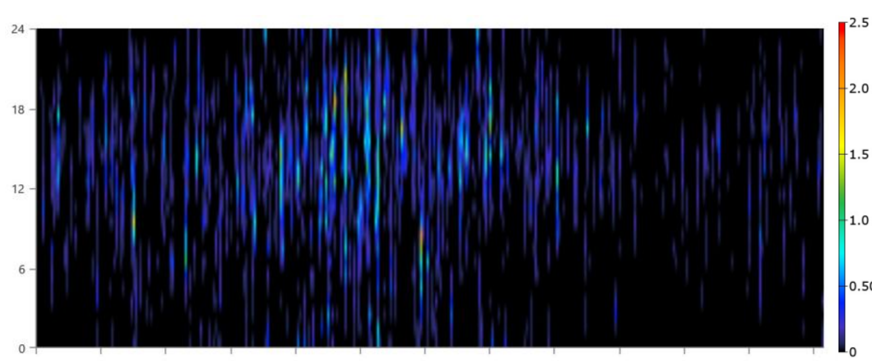

Figure 4.5XzeresSkystream 3.7 [2.4kW] Output (kW)

4.5. Storage: Generic 1kWh Li-Ion [ASM]

From Table 4.8 Li-Ion Battery have Average Energy Cost 0 ₹/kWh, Energy In 31,119 kWh/yr, Energy Out 28,558 kWh/yr, Storage Depletion 64.5 kWh/yr, Losses 2,625 kWh/yr and Annual Throughput 29,807 kWh/yr. The graphical representation shown in Figure 4.6.

Table 4.8 Generic 1kWh Li-Ion [ASM] Result Data

Quantity	Value	Units
Average Energy Cost	0	₹/kWh
Energy In	31,119	kWh/yr
Energy Out	28,558	kWh/yr
Storage Depletion	64.5	kWh/yr
Losses	2,625	kWh/yr
Annual Throughput	29,807	kWh/yr

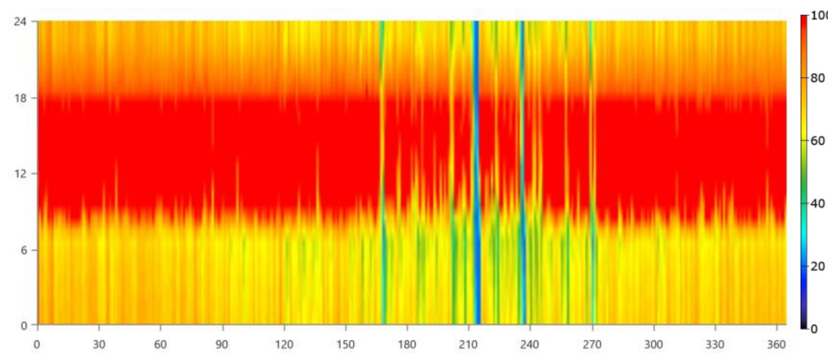

Figure 4.6 Generic 1kWh Li-Ion [ASM] State of Charge (%)

4.6. Converter: Ideal Power Grid-Resilient 30kW

The 30kW Convertor is used for Converting energy AC-DC and DC-AC. From Table 4.9 the Convertor Hours of Operation 8,750 hrs/yr, Energy Out 59,656 kWh/yr, Energy In 62,142 kWh/yr and the Losses of convertor is 2,486 kWh/yr.

Table 4.9 Ideal Power Grid-Resilient 30kW Electrical Summary

Quantity	Value	Units
Hours of Operation	8,750	hrs/yr
Energy Out	59,656	kWh/yr
Energy In	62,142	kWh/yr
Losses	2,486	kWh/yr

4.7. Fuel Summary

Total fuel consumed by generator is 103 L in a year and Average fuel consumption 0.283 L/day which is very low. Table 4.10 shows the diesel consumption statics and

Table 4.10 Diesel Consumption Statistics

Quantity	Value	Units
Total fuel consumed	103	L
Avg fuel per day	0.283	L/day

Figure 4.7 represent the Average Electric Production from the Hybrid renewal Electric Vehicle charging station. Table 4.11 Renewable Summary of the prosed work.

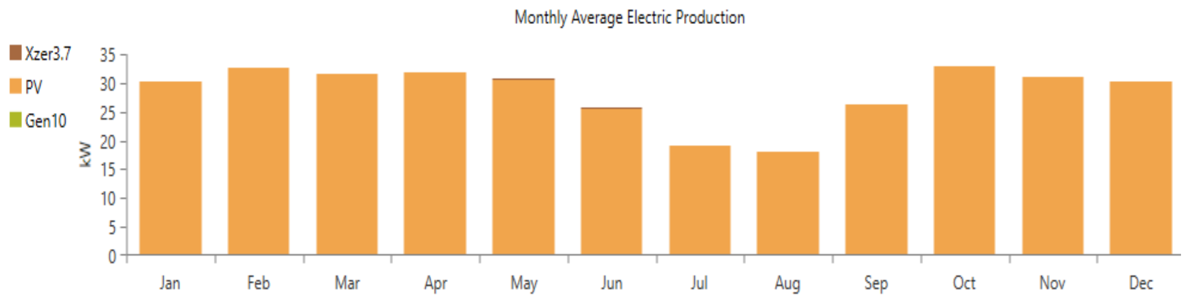

Figure 4.7 Monthly Average Electric Production

Table 4.11 Renewable Summary

Capacity-based metrics	Value	Unit
Nominal renewable capacity divided by total nominal capacity	93.8	%
Usable renewable capacity divided by total capacity	92.4	%
Energy-based metrics	Value	Unit
Total renewable production divided by load	410	%
Total renewable production divided by generation	99.9	%
One minus total nonrenewable production divided by load	99.6	%
Peak values	Value	Unit
Renewable output divided by load (HOMER standard)	6,657	%
Renewable output divided by total generation	100	%
One minus nonrenewable output divided by total load	100	%

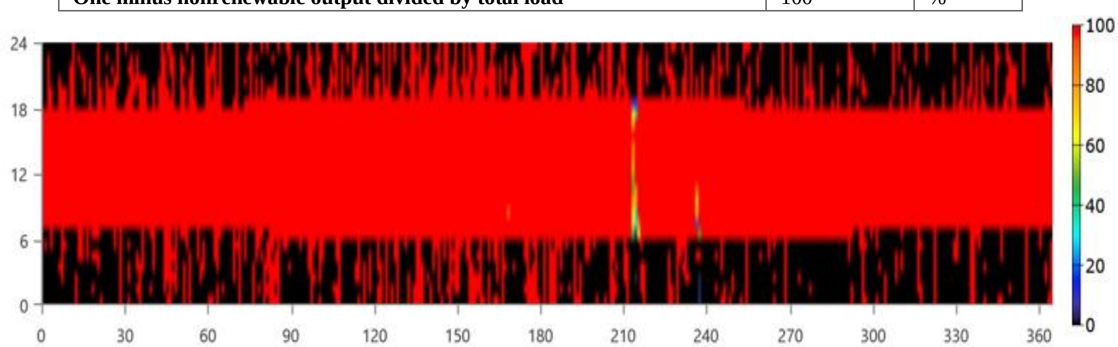

Figure 4.8 Instantaneous Renewable Output Percentage of Total Generation

Figure 4.8 represent the Instantaneous Renewable Output Percentage of Total Generation. Figure 4.9 shows the Instantaneous Renewable Output Percentage of Total Load. Figure 4.10 shows the 100% Minus Instantaneous Non-renewable Output as Percentage of Total Load.

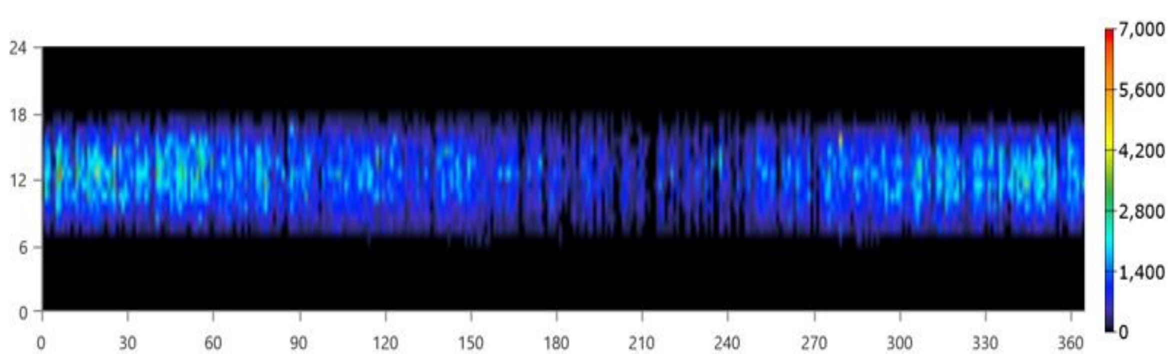

Figure 4.9 Instantaneous Renewable Output Percentage of Total Load

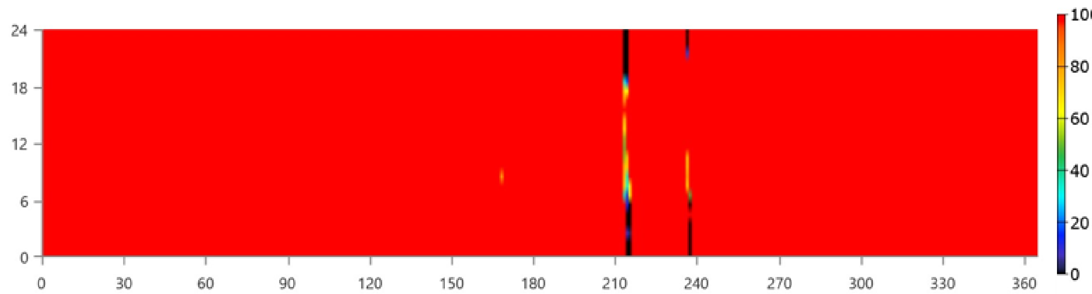

Figure 4.10100% Minus Instantaneous Non-renewable Output as Percentage of Total Load

5. CONCLUSIONS

Growing popularity of Electric Vehicles opens a new sector in the field of transportation. It is a user & environment friendly and cost-effective mode of transportation. The whole research aimed to design, develop and optimization of Electric Vehicle Charging Station using solar and wind energy resources.

This research identifies the main challenges of the EV adoption in Dewas/Bhopal during the SWOT analysis such as- lack of charging infrastructure, high charging cost & time, no governmental policy, less investment and technological barriers etc. Finally, the negative impacts of the existing EVCS onto the utility grid, distribution station by affects power quality.

In this work design a hybrid renewable electrical vehicle charging station based on Solar and Wind energy resources. Assume the location **Jomgodrani, district Dewas, Madhya Pradesh** for generation the electricity for the proposed work

For the study purpose taking 30 kW EVCS an example for the designing the proposed work. For the simulation of prosed work taking HOMER Pro. 3.11 software environment.

Taking both the data of charging rate from our prosed station and charging rate by Madhya Pradesh Electricity Regulation Commission (MPERC) and optimized charging rate using Fuzzy algorithm-based optimizer with help of MATLAB R-2023a.

FUTURE WORKS

This research mainly identified the renewable resources and tested the feasibility of these resources for electric vehicle charging.

You can use the other resources like the solar and biogas resources for the electric charging station.

Another future suggestion for experimental investigation will be carried out if sufficient funding is found. The environmental affects upon acceptance of Electric Vehicle charging infrastructure all over the country will be analyzed.

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