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OPTIMAL DESIGN OF GRID-CONNECTED SOLAR-WIND HYBRID SYSTEM FOR AN INSTITUTIONAL LOAD WITH EV CHARGING STATION

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ABSTRACT- Whenever it comes to energy resources, sustainability is a key issue. A sufficient amount of energy must be provided by our resources to meet our needs. Hybrid renewable energy systems are the answer to a reliable, affordable, and dispatchable integration of renewable energy. This project focuses on the feasibility and optimization of an on-grid hybrid system for an institutional load with an electric vehicle charging station. In this project, our goal is to develop a system that makes renewable energy sources more accessible on a smart grid and reduces the dependence of small remote communities on the grid. In addition to lowering the dependence upon the overburdened grid, the proposed system will also help developing countries reduce the cost of electricity with the help of environmentally friendly power generation techniques.

Key Words: on-grid system, renewable energy, solar panel, wind turbine, EV charging station.

1. INTRODUCTION

Over the past few years, fossil fuel reserves have become scarce, and climate change has led to greater reliance on renewable energy. A report from the Ministry of New and Renewable Energy in India reports that renewable energy contributes approximately 20% to the total energy consumption of the country. Wind and solar power generate the majority of the renewable energy share of India's electrical generation, while hydro, thermal and biomass power contributes a smaller share. Considering the recent advancements in power electronic storage devices and the declining costs of the components, solar and wind power have become dominant technologies for powering electrical loads in remote and off-grid locations.

Several different energy generation systems, such as renewable energy sources and their combination, together form the hybrid power system. Due to the advancement of renewable energy systems, depletion and exhaustion of nonrenewable energy sources and the rise in petroleum prices, hybrid renewable energy systems are becoming increasingly popular in remote areas. The main goal of hybrid power is to provide greater efficiency, balance, and sustainability of the system. It usually consists of two or more renewable energies used together. A hybridized renewable energy system also helps provide reliable, affordable, and dispatchable solutions to meet critical needs. From hybrid solar-wind to hybrid wind-hydropower systems, these renewable energy systems can provide "grid-quality" electricity with a power range of 1 kilowatt (kW) to several hundred kilowatts. Each hybrid power application is unique and can integrate numerous renewable energy sources, including wind and solar. Considering their efficiency, reliability, and long term performance, these systems can also serve as a backup plan for the public grid in the event of a blackout or weak grid, or as professional energy solutions such as telecommunication stations or emergencies. Globally, electric vehicles (EVs) are also being aggressively promoted as a way to reduce fossil fuel emissions and address environmental concerns (ECS). Furthermore, in recent years, an increase in plug-in hybrid EVs and EVs with battery packs has been observed. In an energy efficiency based system, EV integration is an interesting and challenging topic for research in terms of economic analysis and power management. An extensive review of various references provides an overview of the studies and advancements in EVs, along with their interaction with the grid, and their application. Various governments offer tax benefits for people to switch to EVs. In India, the government has planned for 'Only Electric Vehicles' initiative on the Road by 2030.

In this project, a small grid-connected solar-wind hybrid system with EV Charging Station is proposed for an institutional campus in Navi Mumbai, Maharashtra. The primary focus is to formulate a detailed analysis of a Solar-Wind Hybrid System incorporating EV Charging Station with a grid as the backup, which will include a full software model covering the electrical details using MATLAB Software and a software model covering the economic details using HOMER Software. Further, this project aims to minimize the power exchange with the grid. Our main objective is to help promote renewable energy sources in the smart grid and can reduce the dependence of a small community on the grid. Along with this, some of the basic objectives our project aims to achieve are

1. To obtain the least Levelized cost of electricity (LCOE) and present a feasible design model which will be cost-efficient and economically profitable for small institutions.
2. To deduce the component sizing of a solar-wind hybrid system that incorporates an EV charging station.
3. To reduce the reliance on the overburdened grid, particularly in developing countries with the help of this proposed hybrid model.
4. To raise awareness about the growing popularity of microgrids and electric vehicles.

2. LITERATURE SURVEY

'Optimal Design of Solar-Wind Hybrid System Using Teaching-Learning Based Optimization Applied in Charging Station for Electric Vehicles'
Amangaldi Koochaki, Mohammad Divandari, Islamic Azad University, Aliabad Katoul, Iran, Ebrahim Amiri Electrical Engineering Dept, University of New Orleans, New Orleans, USA, Oleksandr Dobzhanskyi Electrical Engineering Dept, North-West University.

This paper exhibits an optimal design of the solar-wind hybrid system with energy storage for the Electrical Vehicle Charging System (EVCS). Optimization is done on the number of solar panels, wind turbines, batteries to minimize the energy production cost. The cost of the system consists of initial investment and maintenance costs. By using Teaching Learning Based Optimization (TLBO) the cost function is optimized.
We have reviewed three modes: only solar, only wind and hybrid system working through this paper, which gave us the following results. Solar and wind individually were not electrically efficient, which means its LPSP increases, resulting in an increased cost of electricity. Thus, the solar-wind hybrid was the only effective option for optimal sizing and decreased cost of electricity. The result of this paper shows that the proposed method has a good performance in designing a hybrid generation system of EVCS.

'Design, Analysis and Optimization of a Hybrid Microgrid System Using HOMER Software: Eskişehir Osmangazi University Example'
ipek Çetinbaşa, Bünyamin Tamyüreka, Mehmet Demirtaşb, Faculty of Engineering and Architecture, Department of Electrical and Electronics Engineering, Eskişehir Osmangazi University, Eskişehir, Turkey.*

This paper presents the design, performance analysis, and optimization of a hybrid microgrid for the hospital complex located on Eskişehir Osmangazi University (ESOGU) campus using HOMER software. The electricity consumption of the hospital and solar energy generated by the campus over one year were collected and used in the design of microgrids.
From this paper, we understand the various factors that affect our hybrid model's system performance and economic feasibility. These factors are namely, increase in demand, PV module failure, wind turbine failure, grid interruption/mains outage. With the help of this paper, we were able to optimize and design our hybrid model using HOMER software with the least cost of electricity and increased system performance. We were also able to review microgrid analysis that reflects the realistic operation of microgrids over its 25-years of service time.

'Off-grid Electricity Generation with Renewable Energy Technologies in India: An Application of HOMER'
Rohit Sen The Energy and Resources Institute, New Delhi India and Subhes C Bhattacharyya Institute of Energy and Sustainable Development De Montfort University Leicester LE1 9BH, UK.
This project aims to propose the best hybrid technology combination for electricity generation from a mix of renewable energy resources to satisfy the electrical needs in a reliable manner of an off-grid remote village, Palari in the state of Chhattisgarh,

India.
This project helped us understand the two main aspects of HOMER analysis; Pre-HOMER and Post-HOMER analysis. The Pre-HOMER analysis gave us a complete idea about the electrical summary of our hybrid system and helped us in the component selection. The Post-HOMER analysis gave us the economic and cost feasibility summary for the project. It helped us optimize and design our project to make it more cost-efficient and a greater alternative to on-grid connection. This paper also shows that a hybrid combination of renewable energy generators is sustainable, techno-economically viable and environmentally sound. The only drawback was as the system is off-grid, during the time of system failure there will be no backups available leading to blackouts.

'Designing a Competitive Electric Vehicle Charging Station with Solar PV and Storage'
Ilhami COLAK, Ramazan BAYINDIR; Ahmet AKSÖZ ,Eklas HOSSAIN and Sabri SAYILGAN, Istanbul Gelisim University, Istanbul, Turkey.

This paper proposes a design of a model for a PV based electrical vehicle that forecasts total power output under particular conditions of Ankara city. First PV cell parameters are determined and then PV arrays are formed including cells designed to calculate cumulative effect. Using actual irradiation and temperature values this paper tries to catch an approximation of output power for future needs. It also intends to give an efficient, applicable and cost-effective model of PV-based EV Charging Station.
From this paper, we were able to understand the design and architecture of PV-based EVCS. It used a Buck Converter with a PI Controller to give an optimal input to the EV battery. Similarly, we have used a Boost Converter with PID Controller to meet our electrical requirements and obtain stable operation. We have also reviewed how SOC and SOP affect the battery charging capability.

'Design and Simulation of a Fast Charging Station for PHEV/EV Batteries'
G. Joos and M. de Freige, Jr and M. Dubois, Department of Electrical Engineering, McGill University and Laval University.

The paper proposes a fast-charging station using a flywheel energy storage and a supercapacitor as energy storage devices. Design issues and simulation results for a typical Level III charger are presented. This paper helped us review various battery storage technologies and also helped in the selection of a battery storage device for our project. Understanding the different levels of charging stations and the performance requirements of the electric vehicle charging stations could have become easy with this paper. We have also been able to select an optimal level of charging for our electric vehicle charging station model.

3. PROJECT PLANNING

A. CONSTRUCTIONAL OVERVIEW

According to the project requirements, the block diagram was designed on HOMER. AC and DC lines are connected by buses. The AC bus carries the college load. DC buses receive EV load. It consists of three main sources. In the first place, there is the utility grid connected to the AC bus. A PV flat plate that is connected to the DC bus is also a very important source. On the AC bus is the third component, the wind turbine. The dual converters are connected to both AC and DC buses so that both types of output can be converted to meet the demand of the various loads. To control the entire system, HOMER uses its controller. If all sources fail, the DC bus is connected to a battery.

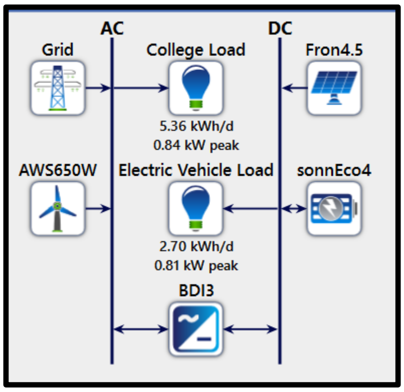

Fig-4: HOMER based circuit diagram

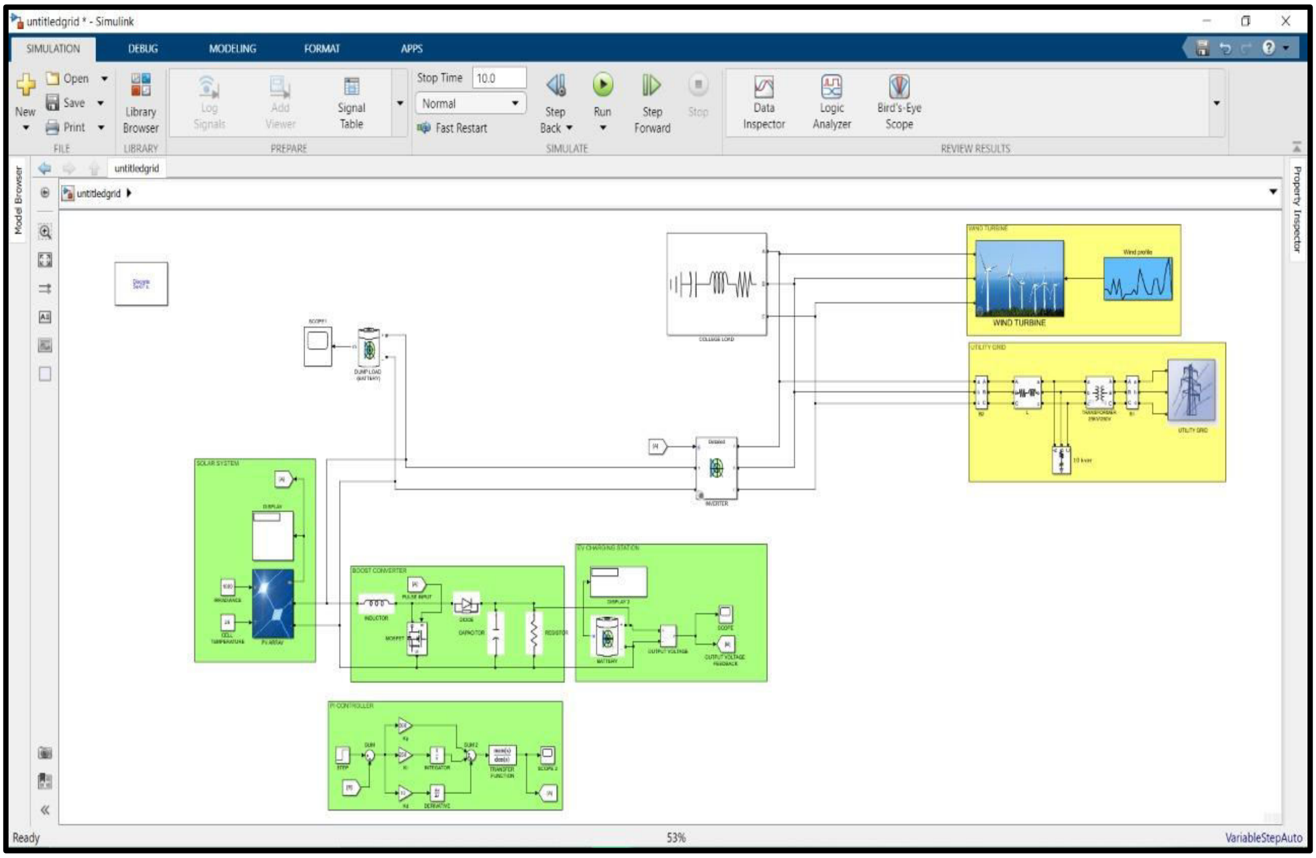

Fig-5: Main circuit diagram for the project

This circuit diagram was constructed using the SIMULINK software on MATLAB. On the AC bus, the Utility grid and Wind Turbine are connected, as shown in the illustration. Load from institutions is connected to the AC bus. DC bus consists of PV flat plate, EV load, and battery. Temperature and irradiance are the inputs to the PV. To remove the unwanted ripples in the DC output of the PV, the DC output is first fed into the BOOST converter and then into a PID controller. Therefore, the battery of the EV is charged by the obtained output. Although the PV is a DC-powered system, the Institutional Load is an AC-powered system. It is necessary to install an inverter to convert DC into AC. The wind turbine's output is AC, so it is directly supplied to the Institutional Load.

B. WORKING OVERVIEW

The working of this project will be explained in three different parts. (1) DC System (2) AC System (3) Loads

DC System

Two subsystems are involved PV Flat plates and batteries. PV Flat Plates are made up of photovoltaic cells. Direct conversion of solar power to electricity is performed by photovoltaics. Photovoltaic cells operate on the photovoltaic principle. Photons are absorbed by the flat plate and free electrons are released when exposed to light. This phenomenon is called the photoelectric effect. Based on the principle of the photoelectric effect, the photovoltaic effect produces direct current electricity. A photovoltaic cell converts sunlight into direct current (DC). However, a single photovoltaic cell cannot produce enough electricity. The photovoltaic modules or solar panels are created by mounting many of these cells on a supporting frame and getting them electrically connected. The Institute receives a portion of the output of this solar panel and the remaining goes to electric vehicles. Gradually, the solar panels charge the battery using the DC line as soon as they begin to produce electricity. This battery is used in the case when all the sources including the grid fail. It is only used in an emergency. A display connected to the PV can display the PV's output, as shown in the circuit diagram.

AC System

It consists of two subsystems Grid and the Wind Turbine. It is a network that delivers electricity to consumers. A power grid is made up of generator stations, transmission lines, and individual distribution lines. At the consumer end, an AC is reached in three phases. The 3 phase AC is connected to the AC line.

The blades of the turbine take in wind (kinetic energy-containing moving air). During the wind, the rotors capture some of the kinetic energy, and that power is used to turn the central driveshaft. Even though the outer edges of the rotor blades move quickly, the central axle (drive shaft) to which they're connected rotates quite slowly. Typically, the blades of big turbines are swivelled back and forth, rotating under the precise control of electric motors or hydraulic rams. The pitch control of smaller turbines is typically mechanical. Many turbines, however, have fixed rotors. It converts the low-speed rotation of the drive shaft (e.g., 16 revolutions per minute, rpm) into high-speed rotation (e.g., 1600 rpm), which drives the generator efficiently. It converts the kinetic energy of the spinning driveshaft into electrical energy via a generator immediately behind the gearbox. An average 2MW turbine generator is capable of producing 2 million watts of power at approximately 700 volts at maximum capacity. The nacelle is equipped with an anemometer at a height of 20.48 m above sea level and wind vanes to measure wind speed and direction. Using these measurements, a yaw motor can be mounted between the nacelle and tower and spin the top parts of the turbine (the rotors and nacelle) so that they face directly into the oncoming wind and capture the maximum amount of energy. Wind can cause the rotors to spin (for safety reasons) if there is too much wind or turbulent conditions. Routine maintenance includes the application of brakes. A cable runs through the inside of the turbine tower carrying the electric current produced by the generator. With a step-up transformer, the wind turbine converts the electricity to about 50 times higher voltage so that it can be transmitted efficiently to the power grid (or to nearby buildings or communities. Since the output is AC, it can be fed directly to the AC load.

Loads

This project takes into account two types of loads. Loads from institutions and electric vehicles. Solar and wind energy can meet the demands of the Institutional Load. Since the Solar Panels produce DC while the Institutional Load is AC, an inverter is used to bring the two together. EV Charger Stations consume the remaining power from the solar panels. However, this DC output fluctuates with time and is not sufficient to charge a 60volt electric vehicle battery. MATLAB is used to design a boost converter that boosts the solar panel's output to 60V DC. A PID controller then receives this output. Controlling temperature, flow, pressure, and speed with a PID controller is an important step in industrial applications. The most accurate and stable controllers are PID (proportional integral derivative) controllers. These controllers use a feedback mechanism to control the process variables. Using PID controllers, the DC output is consistently stable and steady. Input for the charging station is then given to this electric vehicle.

C. COMPONENT OVERVIEW

In this section, all the components along with their technical data have been explained.

Microgrid Components	Microgrid Components		
	Grid power price	8.50 Rs/kWh	
	Grid sellback price	3.50 Rs/kWh	
	Manufacturer	Fronius Symo	
	Panel type	Flat Plate	
	Rated capacity	4.4	kW
PV	Efficiency	74	%
	Capital cost	2,65,000.00	Rs
	Replacement cost	2,30,400.00	Rs
	O&M cost	10,000.00	Rs
	Lifetime	25	years
	Manufacturer	AWS HC	
	Turbine type	AC	
	Rated capacity	650	W
Wind Turbine	Efficiency	56	%
	Capital cost	56,126.00	Rs
	Replacement cost	46,126.00	Rs
		4,520.00	Rs
	Lifetime	20	years
	Manufacturer	Sonnen Batterie	
	Battery type	Li-Ion	
	Nominal capacity	4	No
	Capital cost	12,500	Rs
	Replacement cost	12,500	Rs
Battery	O&M cost	200	Rs
	Initial state of charge	10	%
	Minimum state of charge	60	%
	Lifetime	10	years
	Manufacturer	CAT BDI-SI	
	Capital cost	70,000	Rs
	Replacement cost	60,000	Rs
Converter	O&M cost	10,000	Rs
	Lifetime	20	years
	Efficiency	95.80	%
	Relative capacity	100	%
	Efficiency	95.80	%

Table-1:Component data

4. PROJECT MODELLING

A. LOAD ASSESSMENT

The pre-HOMER analysis involves a detailed assessment of Institutional load and available resources in the selected area. This is carried out outside HOMER and data is fed into the software. We have considered the following case when the annual load demand is 3348 kWh/yr, with the peak load is 0.84 kW. The Institutional Load consists of surveillance cameras, lights, fans, practical labs, computers, and other machinery.

There are two important categories of system load:

- College Load - The load demand is approximately 5.36 kWh/day and 0.84 kW peak
- EV Load - It is approximately 2.70 kWh/day and 0.81 kW peak. The EV Load is a battery with the specifications mentioned in.

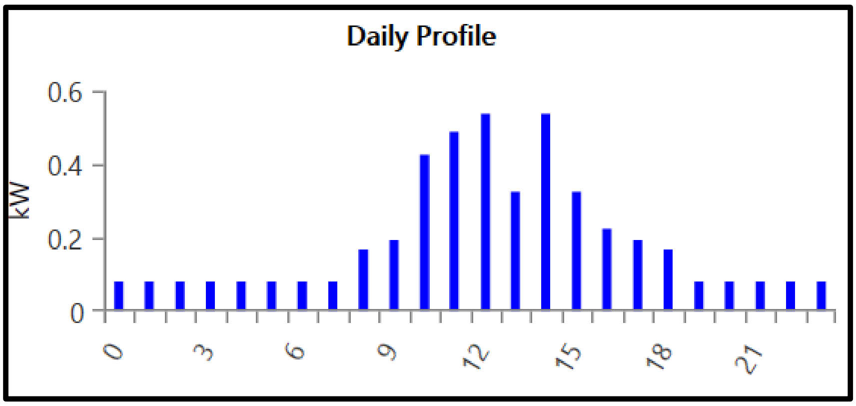

Fig-1: Load profile of College Load

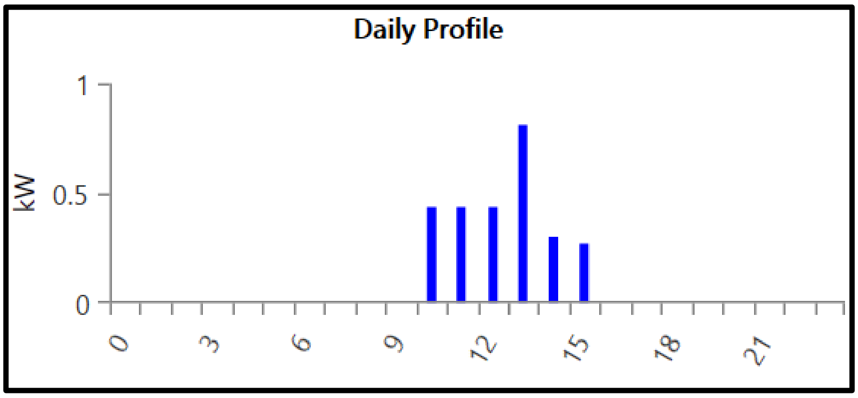

Fig-2: Load profile of Electric Load

B. RESOURCE ASSESSMENT

SOLAR

In this simulation, we have taken into account solar and wind resources. The resource assessment is presented below. The solar resource used for this location was taken from NASA Surface Meteorology and Global Solar Atlas website. The annual average solar radiation was scaled to be 5.09 kWh/m2 /Day and the average clearness index was found to be 0.548. In view of the location of this project, PV cells are a viable alternative because solar radiation is plentiful throughout the year.

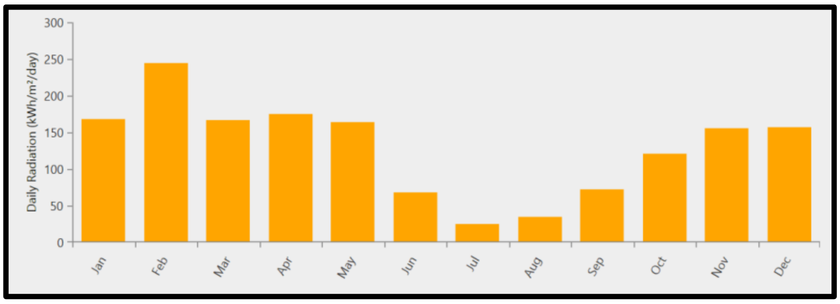

Fig-3:Solar Energy Profile at the selected site

WIND

The monthly average wind resource data from an average of ten years was taken into account from the NASA resource website based on the longitude and latitude of the selected location. The annual average wind speed for the location is 6.39 m/sec with the anemometer height at 20.48 meters. The wind speed probability and average monthly speed throughout the year are also observed. It shows that there are 7 hours of peak wind speed. The wind speed variation over a day is 0.01 and the randomness in wind speed (autocorrelation factor) is 0.85.

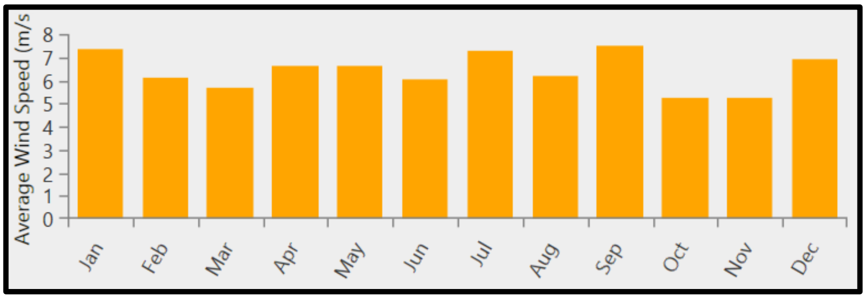

Fig-4: Wind Energy Profile at the selected site

C. SOFTWARE OVERVIEW

HOMER

HOMER is a software application developed by the National Renewable Energy Laboratory in the United States. The purpose of this software application is to study and evaluate technically and financially the options for off-grid and on-grid power systems for remote, stand-alone, and distributed generation applications. In this project, we have used this software to find the least cost of electricity (COE) through the inbuilt functions and circuit development.

1. *TOTAL ANNUALIZED COST*

Type: *Output Variable*
Units: *$/year*
Symbol: $C_{am,tot}$

The total annualized cost is the annualized value of the total net present cost. HOMER calculates the total annualized cost using the following equation:

$$C_{ann,tot} = \mathrm{CRF}(i, R_{proj}) \cdot C_{NPC,tot}$$

where,

$C_{NPC,tot}$ = Total Net Present Cost ($)
i = Annual Real Discount Rate (%)
R_{proj} = Project Lifetime (yr)
CRF() = Function returning Capital Recovery Factor

HOMER uses the total annualized cost to calculate the Levelized cost of energy.

2. *TOTAL ELECTRICAL LOAD SERVED*

Type: *Output Variable*
Units: *kWh/yr*

Symbol: E_{served}

The total electrical load served is the total amount of energy that went towards serving the primary and deferrable loads during the year, plus the amount of energy sold to the grid. HOMER calculates the total electrical load served using the following equation:

$$E_{served} = E_{served,ACprim} + E_{served,DCprim} + E_{served,def} + E_{grid,sales}$$

where,

$E_{served,primAC}$ = AC Primary Load served (kWh/yr)
$E_{served,primDC}$ = DC Primary Load served (kWh/yr)
$E_{served,def}$ = Deferrable Load served (kWh/yr)
$E_{grid,sales}$ = Energy sold to Grid (kWh/yr)

3. *NET PRESENT COST*

The cost term 'NPC' is defined by the HOMER program as the following, 'The net present cost (or life-cycle cost) of a component is the present value of all the costs of installing and operating the component over the project lifetime, minus the present value of all the revenues that it earns over the project lifetime.' HOMER calculates the net present cost of each component in the system and the system as a whole.

4. *LEVELIZED COST OF ELECTRICITY*

COE is defined by the HOMER program as the following, 'To calculate the COE, HOMER divides the annualized cost of producing electricity (the total annualized cost minus the cost of serving the thermal load) by the total electric load served.' COE is calculated by

$$COE = \frac{C_{ann,tot} - C_{boiler}H_{served}}{E_{served}}$$

where,

$C_{ann,tot}$ = Total Annualized Cost of System ($/yr)
C_{boiler} = Boiler Marginal Cost ($/kWh)
H_{served} = Total Thermal Load served (kWh/yr)
E_{served} = Total Electrical Load served (kWh/yr)

5. *OPERATING COST (Rs)*

Operating cost is defined by the HOMER program as the following, 'The operating cost is the annualized value of all costs and revenues other than initial capital costs.' Operating cost is calculated using

$$C_{operating} = C_{ann,tot} - C_{ann,cap}$$

where,

$C_{operating}$ = Total Annualized Cost of System ($/yr)
$C_{ann,cap}$ = Total Annualized Capital Cost ($/yr)

6. *INITIAL CAPITAL COST (Rs)*

Initial capital cost is defined by the HOMER program as the following, 'The initial capital cost of a component is the total installed cost of that component at the beginning of the project.

7. *RENEWABLE FRACTION*

Renewable fraction is defined by the HOMER program as the following, 'The renewable fraction is the fraction of the energy delivered to the load that originated from renewable power sources.' Renewable fraction is calculated

$$□_{□□□} = 1 - \frac{□_{□□□□□□□} - □_{□□□□□□□}}{□_{□□□□□□□} + □_{□□□□□□□}}$$

where,

E_{nonren} = Non-Renewable Electrical Production (kWh/yr)
$E_{grid,sales}$ = Energy sold to Grid (kWh/yr)
H_{nonren} = Non-Renewable Thermal Production (kWh/yr)
E_{served} = Total Electrical Load served (kWh/yr)
H_{served} = Total Thermal Load served (kWh/yr)

MATLAB R2020a

MATLAB is a high-performance language and software for technical computing. We have used this software to design the function block for our EV Charging Station. Along with this, we have also used the inbuilt feature of ‘Simulink’ to create and design a systematic circuit diagram for our whole project.

1. FUNCTION PROGRAM FOR EV BATTERY

The EV battery SOC and charging period need to be set using MATLAB code and command window.

CODE:

```
function ChargeOn = fcn(SOC)
if SOC < 40
   ChargeOn = 1
elseif SOC > 80
   ChargeOn = 0
else
   ChargeOn = 1
end
```

The parameters used for the boost converter block have values calculated before several designs of the block diagram. Using the below-given formula we have attained all the values of the boost converter.

2. CALCULATION FOR BOOST CONVERTER

Step1: Calculation of Output Current
Output Current = $(V_{mp} \times I_{mp}) / V_o$
where,

V_{mp} = *Voltage at maximum power (V)*
I_{mp} = *Current at maximum power (Amps)*
V_o = *Output Voltage (V)*

Step 2: Calculation of Duty Cycle
$V_o / V_m = 1 / (1-D)$
where,

D = *Duty Cycle*

Step 03: Calculation of Inductor
Inductor, $L = (V_{mp} \times D) / (f \times □i_L)$
where,

f = *Switching Frequency (Hertz)*
$□i_L$ = *Inductor Ripple Current (Amps)*

Step 04: Calculation of Capacitor
Capacitor, $C = (I_o \times D) / (f \times □V_o)$
where,

I_o = *Output Current*

ΔV_o = *Capacitor Ripple Voltage (V)*

D. ECONOMIC MODELLING

Homer's simulation attempts to minimize the total net present cost (NPC). Therefore, economics plays a crucial role in determining the optimal configuration and operating the system. To compare the economics of the different configurations, the life-cycle cost (LCC) is used, and the total NPC is considered the economic figure of merit. All economic calculations are in constant INR.

ECONOMIC INPUTS

The project's lifetime is considered to be 25 years with an annual discount rate of 6%. The system fixed capital cost is considered to be 1,50,000 Rs for the whole project and the system fixed O&M cost is estimated to be 17,500 Rs/year for the project lifetime. Capital costs for the system include various civil constructions, logistics, labour wages, required licenses, administration and government approvals, among other costs.

GRID

The grid was used by HOMER in this study as a standard benchmark so that it can be compared with the technical and cost parameters of the hybrid off-grid RETs system. Thus, the cost of grid extension is taken into account in the analysis of whether a grid extension is viable or an on-grid system would be more appropriate. The capital cost of grid extension per kilometre for the selected location is estimated at 2,50,000 Rs/km. Based on interpolation, the annual O&M cost per kilometre is considered to be 50,000 rupees/year/km and the grid power price is assumed to be 8.50 rupees/kWh.

ANALYSIS

HOMER performs the simulation for a number of prospective design configurations. Each design is compared to the constraints of the system and the designs are compared to find the most suitable one at the least cost. A range of exogenous variables is taken into account in the optimization and sensitivity analysis of all components and resources as well as technical and cost parameters. An assessment of the competitiveness of the best grid-connected hybrid RE system for institutional electrification is made using a conventional grid system, based on the COE for both options and based on this the economic distance limit (EDL) is determined.

5. SOLUTION METHODOLOGY

A. HOMER

SYSTEM SIMULATION REPORT

Location: Kopar Khairane, Sector 4, Vikas Nagar, Sector 4, Kopar Khairane, Navi Mumbai, Maharashtra 400709, India (19°6.3'N, 73°0.4'E)

Total Net Present Cost: ₹ 41,64,296.00

Levelized Cost of Energy (₹/kWh): ₹ 3.67

COST SUMMARY

This section includes capital, operating, replacement, salvage and total cost of all the various components used in the hybrid system.

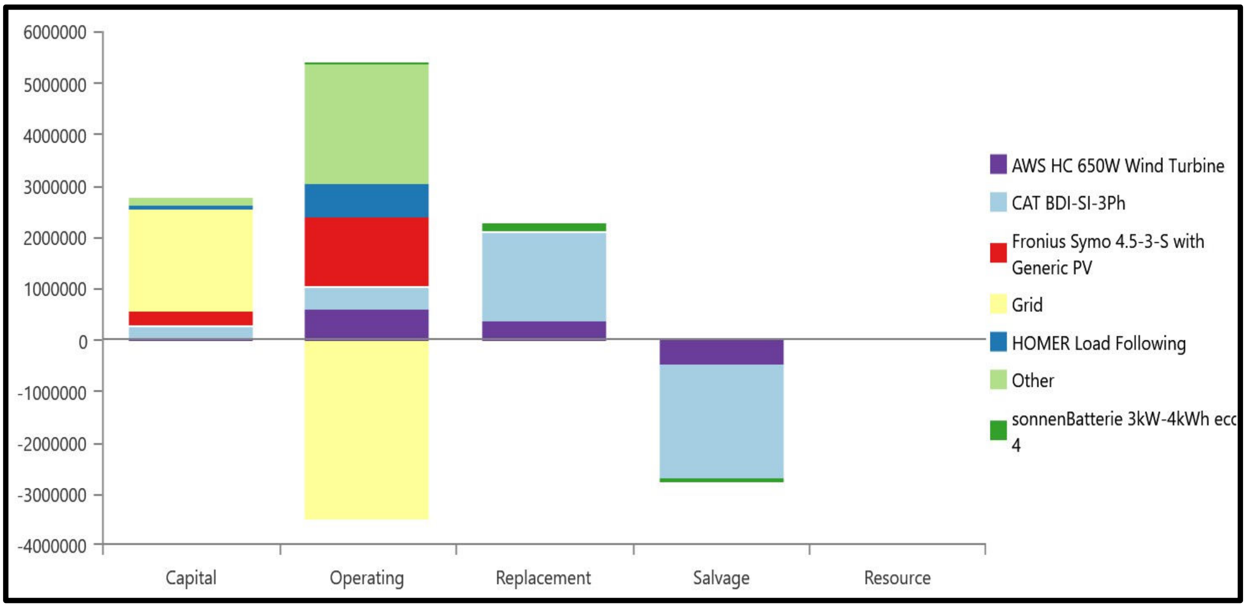

Fig-5:Graph of the component cost

Name	Capital	Operating	Replacement	Salvage	Total
AWS HC 650W Wind Turbine	₹ 56,126	₹ 6,04,550	₹ 3,93,975	₹ 5,05,139	₹ 5,49,513
CAT BDI-SI-3Ph	₹ 2,34,005	₹ 4,47,117	₹ 1.71M	₹ 2.20M	₹ 1,97,734
Fronius Symo 4.5-3-S with Generic PV	₹ 2,59,111	₹ 1.31M	₹ 0.00	₹ 0.00	₹ 1.57M
Grid	₹ 1.96M	₹ 3.45M	₹ 0.00	₹ 0.00	₹ 1.49M
HOMER Load Following	₹ 90,000	₹ 6,68,750	₹ 0.00	₹ 0.00	₹ 7,58,750
Other	₹ 1,50,000	₹ 2.34M	₹ 0.00	₹ 0.00	₹ 2.49M
SonnenBatterie 3kW-4kWh eco 4	₹ 12,500	₹ 26,750	₹ 1,43,298	₹ 0.00	₹ 91,287
System	₹ 2.76M	₹ 1.94M	₹ 1.94M	₹ 0.00	₹ 4.16M

TABLE-2: Component Costing

OVERALL ELECTRICAL SUMMARY

01. Excess and Unmet

Quantity	Value	Units
Excess Electricity	153	kWh/yr
Unmet Electric Load	0	kWh/yr
Capacity Shortage	1.21	kWh/yr

02. Production Summary

Component	Production (kWh/yr)	Percentage
Fronius Symo 4.5-3-S with Generic PV	7,537	84.7
AWS HC 650W Wind Turbine	986	11.1
Grid Purchases	379	4.26
Total	8,902	100

03. Consumption Summary

Component	Consumption (kWh/yr)	Percentage
AC Primary Load	1,958	23.1
DC Primary	986	11.6
Grid Sales	5,531	65.3
Total	8,474	100

COMPONENT ELECTRICAL SUMMARY

01. Fronius Symo 4.5-3-S with Generic PV Electrical Summary

Quantity	Value	Units
Maximum Output	4.40	kW
PV Penetration	256	%
Hours of Operation	4,398	hr/yr
Levelized Cost	1.55	₹/kWh

02. AWS HC 650W Wind Turbine Statistics

Quantity	Value	Units

Total Rated Capacity	0.650	kW
Mean Output	0.113	kW
Capacity Factor	17.3	%
Total Production	986	kWh/yr

03. SonnenBatterie 3kW-4kWh eco 4 Result Data

Quantity	**Value**	**Units**
Average Energy Cost	0	₹/kWh
Energy In	10.1	kWh/yr
Energy Out	5.01	kWh/yr
Storage Depletion	-4.00	kWh/yr
Losses	1.13	kWh/yr
Annual Throughout	5.41	kWh/yr

B. MATLAB

Input: PV Solar Panel
Output: EV Battery Charging

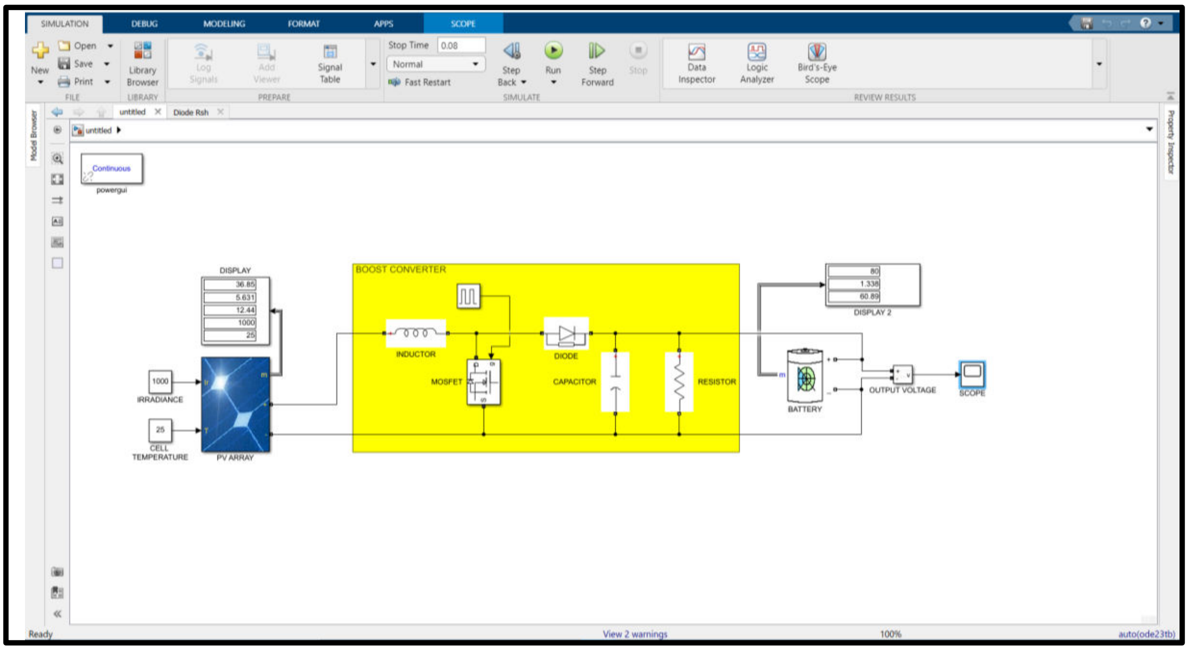

Fig-6: PV array connected to a boost converter, whose output is given to the EV battery.

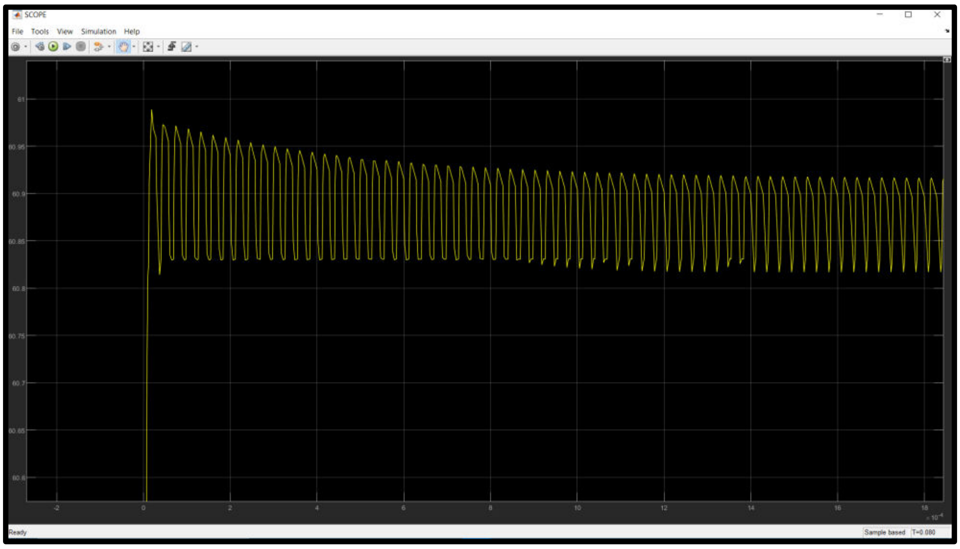

Fig-7: Output waveform on the EV Battery, too much ripple but the voltage requirement is fulfilled.

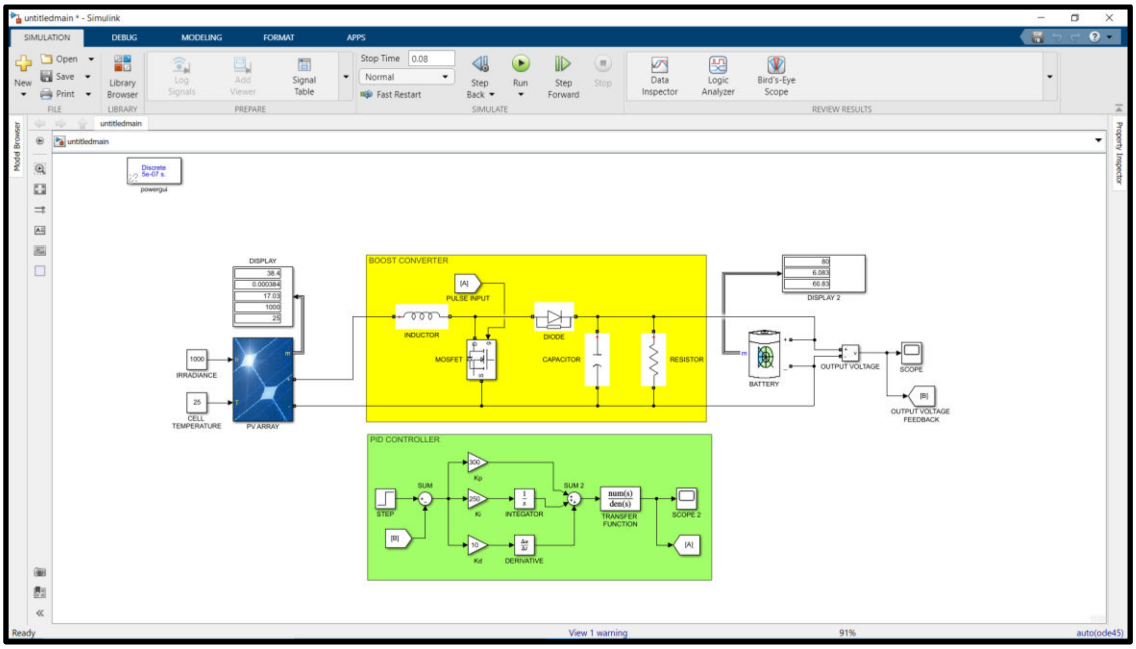

Fig 17: A PID Controller attached to the Boost Converter.

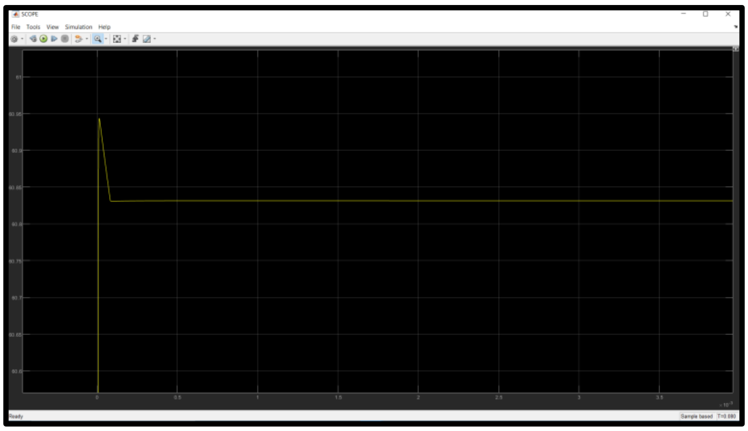

Fig 18: Damped voltage output waveform on the EV Battery.

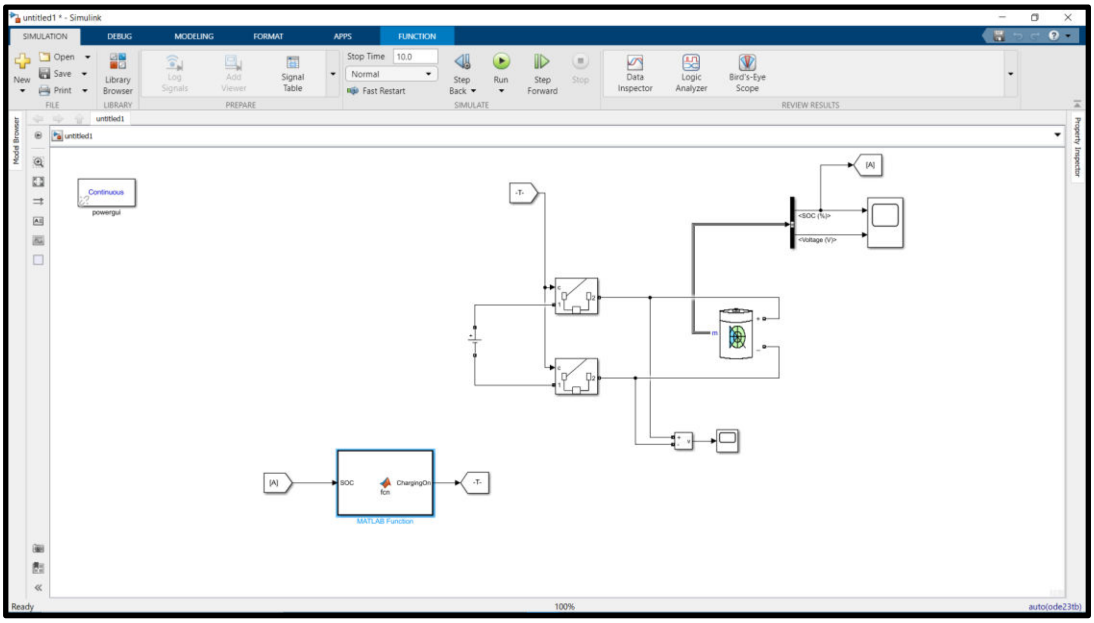

Fig 19: SOC and charging function circuit for the EV Charging Station

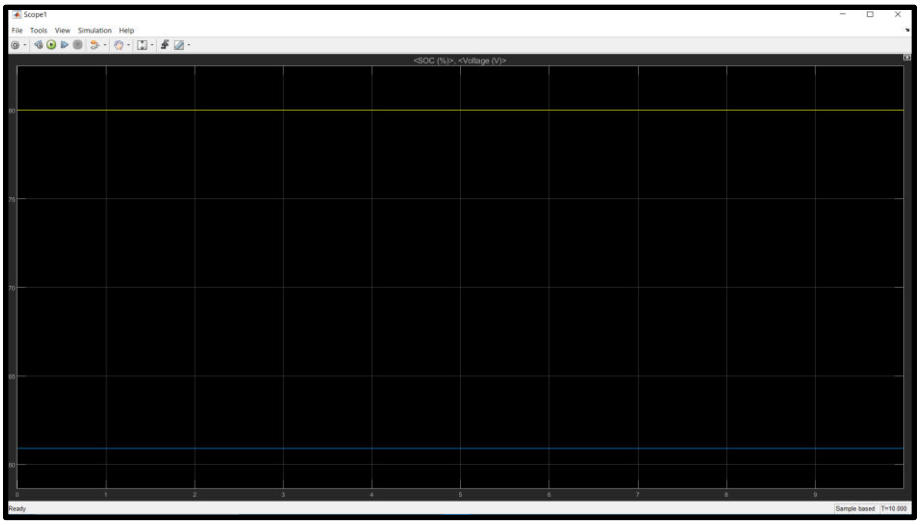

Fig 20: Output waveform for the SOC and output voltage of the EV Battery

6. CONCLUSION

This study defines a solar-wind hybrid energy system consisting of a PV panel, wind turbine, and energy storage unit to supply power to an educational institution. The goal is to reduce the total cost of electricity, add renewable energy sources, and have battery backup power for emergencies. To achieve maximum benefit, the size and operation of this additional system must be properly determined. Therefore, the proposed microgrid is designed, simulated, and optimized by using HOMER. By using the institute's real power consumption over one year, the simulation is set to run an optimization considering a lifetime of 25 years. Accordingly, a PV power source of 4.40 kW, a wind turbine of 1 kW, and an energy storage unit having a capacity of 4 kWh are found to be optimal for the selected load profile. A hybrid microgrid combining Grid-PV-Wind-Battery has been studied for its effects on PV module degradation, demand growth, and network outages, as well as an increase in diesel fuel prices. Added to the basic system, the effects of these variables result in the following increases: NET PRESENT COST is 41,64,327 Rs, COST OF ENERGY is 3.67 Rs/kWh, and OPERATING COST is 10,461 Rs. By supplying the PV system with energy for EV charging, solar energy can be more economically viable. It is concluded that the exposure of such a system affects its performance over its lifetime. However, the proposed system is feasible and fulfils the performance targets set at the beginning of the project.

Due to the seasonal nature of the independent energy systems, they are unable to provide a continuous supply of energy. Using a hybrid system of wind and solar will allow you to take advantage of the strengths of each system while overcoming the weaknesses of each, to achieve a balanced approach to energy production. Power costs should be minimized as much as possible. As a result of the longer payback time of renewable energy systems, few firms are interested in investing in them. Solar-wind hybrids, which bring a range of benefits with them, are gaining in popularity with major Indian wind companies including Gamesa, Inox Wind, and Suzlon. Compared to solar-wind power plants alone, solar-wind hybrid plants can deliver power even more cheaply.

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