OPTIMUM DESIGN OF HYBRID RENEWABLE ENERGY SYSTEM FOR THE LECTRIFICATION OF PUDUCHERRY REGION'S BUILDING

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Abstract: The recent sharp increase in the price of oil, natural gas, uranium, coal underline the importance for countries to focus on the development of alternate energy resources. Energy security is very important for developing countries. The galloping energy demand cannot be met by conventional energy (coal, oil, natural gas, etc.,) alone. In order to get parity between energy demand and energy supply, renewable sources of energy have to be tapped. Renewable energy resources will play a key role in meeting energy needs and also device a strategy that serves to drive the maximum energy of an improved performance with enhanced reliability. The energy demand is fulfilled by installing hybrid renewable electric power generation based on renewable energy resources availability in particular geographical area. This paper proposes the detailed procedures for designing and developing hybrid electric power generation system consisting of photovoltaic modules, wind turbine for electrification to the school of electrical engineering building, Pondicherry engineering college, Puducherry, India. The proposed system performance optimization and economic analysis can be predetermined with operating constrains of demand fulfillment and net present value of project investments for peak load management using optimization algorithm.

Keywords:PV power,wind power, Hybrid Renewable Energy System(HRES), Hybrid Optimization Model for Electric Renewables, On-grid electricity generation.

I.INTRODUCTION

In this 21st century electricity becomes one of the essential needs for mankind. As conventional energy resources are getting exploited generation of electricity from these sources will not be sufficient for meeting the future demands. Hence an alternate source is needed for replacing conventional energy resources. The solution is renewable energy resources. Renewable energy sources are naturally available and inexhaustible i.e., energy generated from solar, wind, biomass, hydro power, geothermal and ocean resources are considered as a technological option for generating clean energy [1]. The energy generated from solar and wind is much less than the production by fossil fuels. However, electricity generation by utilizing PV cells and wind turbine increased rapidly in recent years. This paper mainly deals with yield electric power generation from Natural resources such as solar together with wind energy and propose the design procedures setup to avoid the challenges with optimum hybrid electric renewable model design, such as uncertainty of resource availability, invariable financial investments with hybrid system cost, achieving the distributing generation benefits, optimum performance of the hybrid system and sensitivity analysis of the system [1-4].This hybrid solar-wind power generating system is suitable for residential as well as commercial buildings, industries and also to domestic areas.

The utility electricity sector in India had an installed capacity of 298 GW as of 31 March 2016. Renewable Power plants constitutes 28% of total installed capacity and Non-Renewable Power Plants constitutes the remaining 72%[5]. The gross electricity generated by utilities is 1,106 TWh (1,106,000 GWh), besides 166 TWh by captive power plants during the 2014–15 financial year. The gross electricity generation includes auxiliary power consumption of power generation plants. India became the world's third largest producer of electricity in the year 2013 with 4.8% global share in electricity generation [6]. However, India is still facing severe power cuts and in many regions of India are still lag in electrical power connection.

In spite of the total installed electric power generation capacity of India about 298 GW (as on 31st March 2016).our country is still struggling to meet out the increasing power demand. The government of India came up with many reforming rules and procedures to crack these issues. Through the Electricity act 2003, it improves the efficiency of usage of electricity power in the entire power utilization sectors. Due to Electric power supply and demand mismatch, financial constraints the consumers facing problems with tariffs upward [6]. These problems can be overcome by implementation of Hybrid electric power generation in the area of electric power distribution sides.

II.HYBRID SYSTEM

The process of construction of electrical system using variable renewable energy resources for electrification is called Hybrid Renewable Energy System. Irregular power supplies, nonlinearity behavior of energy resources are the most important reasons to implement a hybrid electric energy supply system. This proposed hybrid electric model consist of yield electric power generation from Sun irradiation and wind dynamic properties with backup battery arrangement.at any time instant the developed power demand can be fulfill by solar-wind power and battery backup connection. The best hybrid electric model sizing can be found in terms of the financial investments and operating performance of the hybrid setup .the suitable implementation area of our proposed system models are remote places of grid power utility ,such as rural area of country ,hill stations islands, communication towers, etc.. The main environment challenge of clean and distributing energy production can be achieved by our proposed hybrid electric energy model. Now, India has become fifth position in the world installed capacity of both solar and wind power plant. Due to seasonal variations, combination of wind and solar energy system is utilized [4],[9].

In this paper considering a hybrid renewable system involves solar panels (P_{PV}) ,wind turbine generators(P_{WG}) ,batteries storage(P_{BTT}) with Grid connectivity (P_G) .In this proposal the renewable apparatuses are combined and complement each other ,in order to meeting performance objectives of generation system and to access the most economic power generation.

The PV sizing variable comprises of size of a PV panel and the number of strings in a PV array. The necessary number of PV panels to be connected in series is derived by the number of panels needed to match the bus operating voltage. When matching the current requirements of the system, several PV strings which are connected in series, need to be installed in parallel. The number of parallel PV strings is a design variable that needs optimization. The Solar PV panels power output must include the impact of geographic location, such as solar radiation and temperature, etc. The output power (Ppv) of photovoltaic panels at any time (t) can be calculated as[5]:

$$Ppv(t)=Efpv*NpvP*NpvS*Vpv*Ipv \quad (1)$$

Solar energy conversion efficiency of PV panel [Ppv(t)], NpvP is the number of PV panels in parallel in PVarreay, NpvS is number of PV panels in series, Vpv is the operating Voltage of PV panels, and Ipv is operating current of PV panels.

The electric energy outputs of the wind turbine are calculated on the basis of indigenous weather conditions and install height of wind generators. The wind velocity at the selected site can be calculated by the following expression in terms of hub height and reference height

$$v(t) = vr(t).\left(\frac{h}{hr}\right) \text{^R} \qquad (2)$$

Wind turbine power output expression can be derived as follow

$$P_{WG}(t) = Ef_W * Efg * 0.5 * Ra * Cp * A * Vr^3 \qquad (3)$$

Here is the wind turbine power output at time base $P_{WG}(t)$, efficiency of wind turbine is Ef_W, efficiency of generator Efg, the density of air Ra, the power coefficient of wind turbine is Cp , with the wind turbine swept area A.The batteries are used to store the excess energy generated by hybrid system and supply energy during the low generation period. The power input to the battery bank is calculated as

$$PBtt = P\ total\ (t) - P\ load(t) \qquad (4)$$

The main objective optimum discretion of the hybrid renewable power generation to the building created in terms of optimum performance and economic considerations as[5];

$$MIN\ Ct\ (Ppv, P_{WG}, P_{Btt}) = MIN(Cpv, C_{WG}, C_{Btt}) \qquad (5)$$

The objective of optimum design is to minimize cost function , Cpv is Cost of solar panal arrangements include investment ,replacement and operational and maintenance cost,C_{WG} is Cost of Wind power arrangements include investment ,replacement and operational and maintenance cost and C_{Btt} is Cost of Wind power arrangements include investment ,replacement and operational and maintenance cost.The total cost of seeing power supply consistency is: Cc=CCO(Compensation Coefficient)*EENS (Expected Energy Not Served). The hybrid setup follow the below operation constrains for feasibility solution for best optimum performance.

$$Ppv(t) + P_{WG}(t) + P_{Btt}(t) + P_G(t) \geq (1-R)P_d(t) \qquad (6)$$

Ppv, $P_{WG}(t)$, $P_{Btt}(t)$,$P_G(t)$,$P_d(t)$ are Solar power, Wind power, Battery power ,total load demand power , R is the ratio of the maximum permissible unmet power with respect to the total load demand at each time instant.

2.1 Basics of HOMER

The HOMER model is highly flexible and can model both off-grid and grid connected to micro-grid power systems serving electric and thermal loads. It can simultaneously model both AC and DC in the design system with any combination of PV modules, wind turbines, small hydro, biomass power, reciprocating engine generators, micro turbines, fuel cells, batteries, and hydrogen storage [10]. Input to the HOMER model includes: load, resources of the particular area, specifications of renewable energy generators used. The HOMER model performs three principal tasks *(shown in Fig.2.1)*: 1) simulation, 2) optimization, and 3) sensitivity analysis [4] and their functional relationship are graphically represented below.

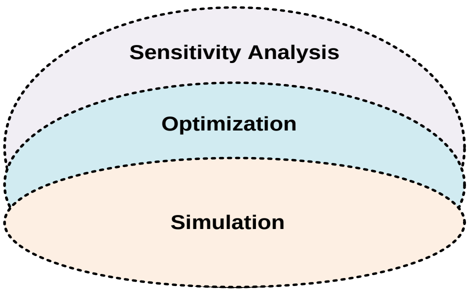

Figure 2.1. Basic homer diagram

2.2 Load profile calculations

A Design and simulation of the hybrid electric model which giving effective renewable power generation through PV array and wind turbines along with battery backup support for peak load management, the perfect value of load profiles are must .

The developed load demand was observed in all the hours of the annual days based on equipment rating with quantity of operating hours. This load profile calculation mainly giving the key range of average demand per day and peak load per day [4]. The determination of load demand for the considered building serves as the basic input for simulation. The load details are as follows:

The school of electrical engineering academic related rooms in Pondicherry engineering college are consider as utility load profile.

CLASS ROOMS:

a)5 B. Tech Classrooms - 9 Tube lights and Ceiling fans per classroom.
b)1 M. Tech Classrooms - 6 Tube lights and Ceiling fans.
Total Tube lights = 45 + 6 = 51
Total Ceiling fans = 45 + 6 = 51

GROUND FLOOR:

a)Office room - 1 Tube light and ceiling fan.
b)12 Staff room - 1 Tube light and Ceiling fan per room.
Total Tube lights = 12 + 1 = 13
Total Ceiling fans = 12 + 1 = 13

FIRST FLOOR:

a)10 Staff room - 1 Tube light and Ceiling fan per room.
b)1 Departmental library - 1 Tube light and ceiling fan.
c)1 M. Tech Room - 1 Tube light and ceiling fan.
Total Tube lights = 10 + 1 + 1 = 12
Total Ceiling fans = 10 + 1 + 1 = 12

CORRIDOR:

a)First floor – 15 Tube lights.
b)Second floor – 13 Tube lights
Total Tube lights = 28

Using the above details, the watt hours per day can be calculated using the formula:

Watt hours/per day = Quantity*Run watts*Working hours/day [4].

The overall demand calculated for the particular building is about 68 KWhr/day with the peak load of 4.5 to 8.1 KW/day. The details of load in monthly wise shown in *Fig.2.2* The load profile is calculation for different seasons and is fed as input for all the months of the year. The hourly load profile of each load needs to be entered into primary load according to the setup defined in the schematic model. The load profile depends on multiple parameters which include configuration, temperature, transferred power, locations, etc. Therefore, it is important to outline an accurate power profile to dimension correctly the renewable components for the system. The load forecasting can be calculated in different durations as short, medium and long terms of period in time series analysis[10] .That load forecasting data was used for finding optimum sizing of hybrid model components.

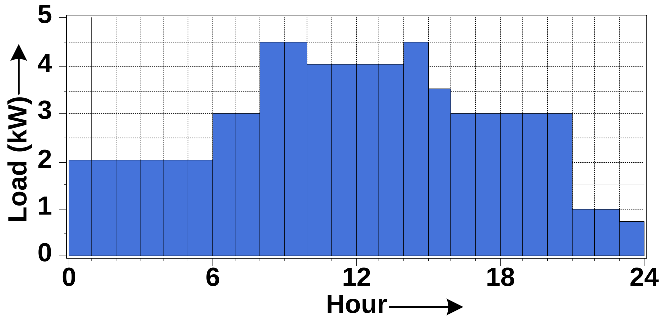

Figure 2.2 Load profile graph

III.RESOURCES ANALYSIS

The Solar and wind energy resources are used for hybrid system. Analyzing the resources of the particular geographical area is necessary for the successful construction of the HRES.

3.1 Solar Resources

Solar resources are imported directly by HOMER from the NASA Surface Meteorology and Solar Energy database by entering the GPS co-ordinates. Selected site of Pondicherry engineering college , Puducherry located in between The latitude of 12.5' N and the longitude 79.59' E. Based on geography this coordinates of site location, the past 10 year historical solar irradiation and clearness index value are consider to forecast the future solar irradiation's time series of the year can be calculated. The annual solar radiation of this area is 5.37kWh/m^2/d. For this area the monthly solar irradiation seems to be constant than the wind speed [8].The monthly wise solar irradiation and clearness index clearly shown in *Fig.3*.1

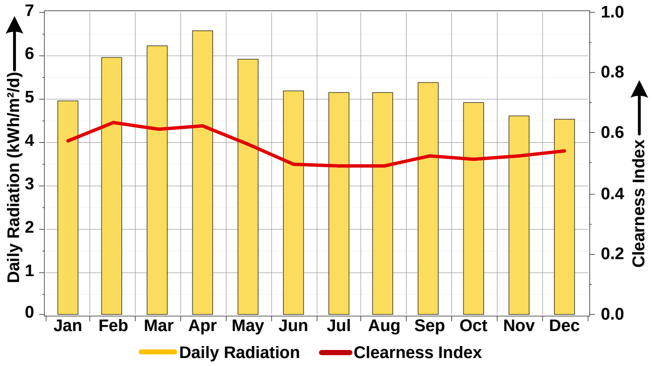

Figure 3.1. Solar resource profile

3.2Wind Resources

The wind resources potentials are predetermined from NASA Surface meteorology and solar energy data base. Here the Consideration of wind speed and direction measured 5 meters above the surface of the earth .the database provides the monthly wind speed means for that month over a 10 year period .the average of monthly wind speed was evaluated as the numerical average of 3 hour values of the given month. Observed wind speed in the selected site between 2.5m/s and 5m/s average per month [11]. Monthly wise wind potential availability in selected site shown in *Fig.3*.2

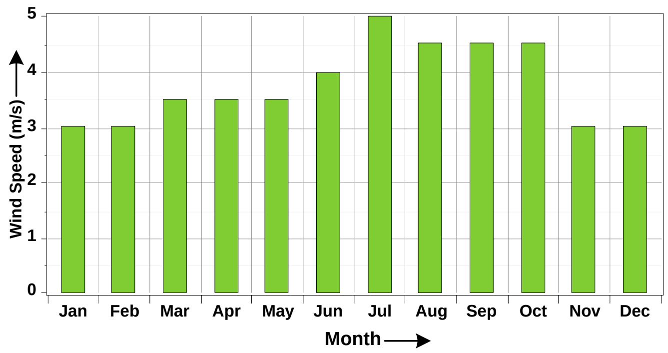

Figure 3.2 Wind resource profile

The annual wind speed average may perhaps be a good sign of the fittingness of the installation of a wind turbine in a given location and generally values above 5m/s with few months below 4 m/s are considered adequate for satisfactory results. The load calculations are done, the resources for this particular geographical area are analyzed and their characteristics are plotted in the form of graph using the software tool. These data are used for further simulation process [12].

IV. SIMULATION AND RESULTS

The HOMER model performs multiple simulations for a single optimization process, and multiple optimizations for the sensitivity analysis process. The HOMER model simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year and performs optimization and simulation analysis in time steps of upto one minute resolution.

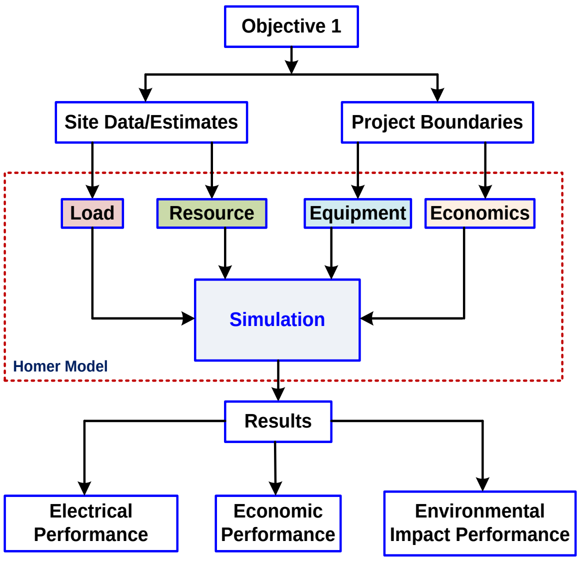

Figure 4.1 Overall process of HOMER

This fine resolution greatly increases the robustness of the model as it allows the energy designer to evaluate the performance ability of the HOMER model close to a real world scenario [7-12]. In the optimization process, multiple simulations are performed and the results are presented for in three broad performance categories: 1) electrical, 2) economic, and 3) environmental impact. Finally, in the sensitivity analysis or 'what-if' analysis, multiple optimizations are performed to analyze the sensitivity of output results for changes in the input variables. The developers of the HOMER model have provided a detailed description of the HOMER model in "Integration of Alternative Sources of Energy" and "Computer Modeling of Renewable Power Systems". Details on how different electricity system designs were simulated in the HOMER model are also provided in *Fig. 4.1*. The outline of the steps involved in the simulation process can be represented graphically as follows:[10]

The overall component configuration of the designed system and its model in HOMER is presented in Fig. *4.2*. The Program set-up includes all the simulation and possible arrangements that were tested for solar PVs and wind turbines, for several sensitivity value ranges of generation capacity, financing costs, wind speed and solar irradiation

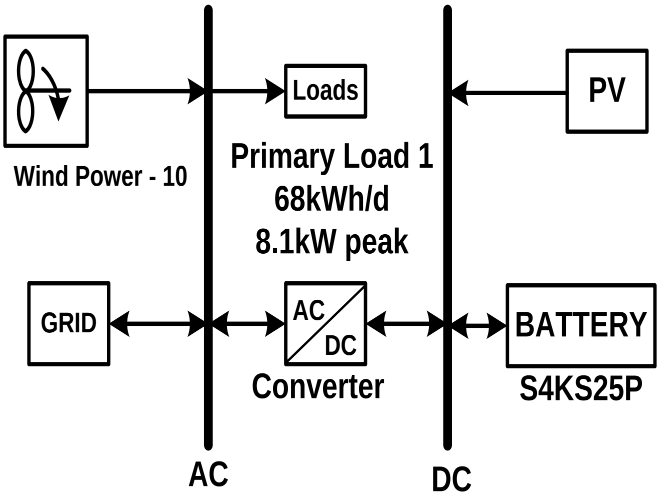

Figure 4.2 Proposed Hybrid model structure

4.1 Optimized result

The categorized optimization results list, gives the best suitable configuration of hybrid system priority based on all the category wise *(shown in table.4.2),* such as sizing of solar PV and wind turbine, operation constraints regarding load following or cycle charging, least to higher net present value of the project, life time of the project and its cash flow. From the categorized result select the most recommended configuration of hybrid power system for selected geographical area was finalized .Then it financial and performance optimization analysis done in the parameters of net present cost and cost of electricity[12], The above mentioned hybrid system was categorized mainly into six optimum cases based on constrains and objective fulfillment . The detailed sub analysis are done and verified for first category of setup.

4.2Sensitivity result

In optimum analysis HOMER algorithm discovers the system formation that is finest under a certain set of input constraints. The system sensitivity can be understood with help of change in system behavior with different possible inputs with possible range. Here each case of possible inputs consider as sensitivity variables. Due to this sensitivity variables nature uncertainty of resources can be balanced with performance levels which one meet out our optimum issues in maximum. Based on this criteria consent the following result was observer from proposed optimum hybrid configuration [19-20].In the proposing selected model, PV panel size consider as sensitivity variable. Chooser search space for PV panel size is 1 or 2 each panel rating 1KW.

4.3Electrical performance

The electrical performance provides information on production and consumption of electricity and gives detailed analysis of percent of excess electricity, unmet electric load, and capacity shortage across various temporal scales. In the economic modeling, the HOMER model performs lifecycle cost analysis that incorporates all capital and operating costs that occur within the life span of the system [11-12].

Table 4.1: Electricity production from proposed system

	Power Resources	KWh/Yr	in %
Total Power Production	PV array	3,194	12
	Wind turbine	12,159	45
	Grid purchases	11,383	43
Total		**26,736**	**100**
Total Power Consumption	AC primary load	24,857	94
	Grid sales	1,543	6
Total		**26,400**	**100**
other Analysis parameters	Excess electricity	0.00224	0
	Unmet electric load	0.0000621	0
	Capacity shortage	0	0
	Renewable fraction	0.574	

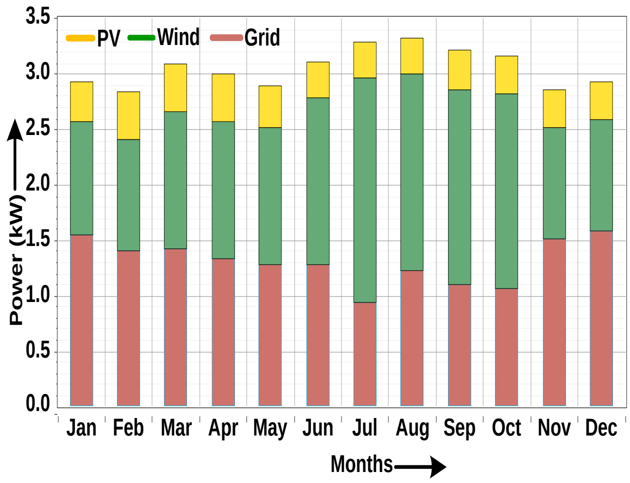

Figure 4.3 Electrical performance of the system

HOMER model performed simulation runs to determine the optimum wind-solar hybrid system configuration [9-10]. The graph shows, the major electricity production came from solar energy and some amount of power from wind and the rest is taken from grid.It is shown in *Fig.4.4 and Fig. 4.5.*

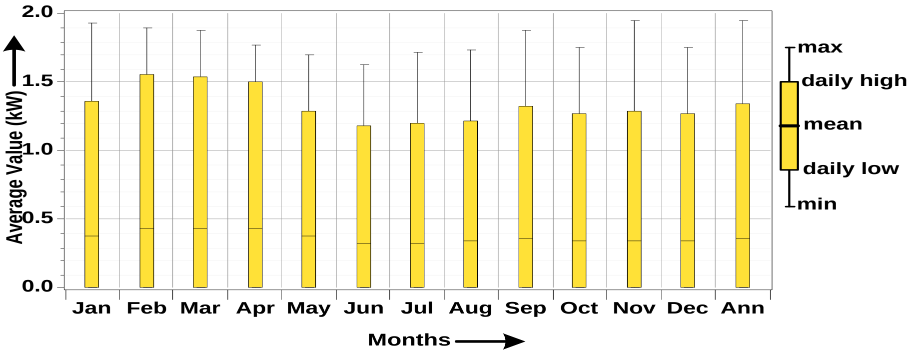

Figure 4.4 Solar power output

Table 4.2: categorized optimization results list

Optimization Configuration	PV Power (kW)	Wind Power (kW)	Battery	Converter (kW)	Grid (kW)	Initial capital (Rs)	Operating Cost (Rs/yr)	Total NPC (Rs)	COE (Rs/kWh)	Renewable fraction
	2	1	8	20	1000	320,030	82,551	1,375,314	4.328	0.57
	1	1	8	20	1000	270,030	90,797	1,430,726	4.503	0.52
		1	8	20	1000	220,030	99,265	1,488,973	4.686	0.47
	2		8	20	1000	220,030	163,724	2,312,966	7.279	0.13
	1		8	20	1000	170,030	172,400	2,373,881	7.471	0.06
			8	20	1000	120,030	181,164	2,435,920	7.666	0.00

4.4Economical performance

In the economic modeling, the HOMER model performs lifecycle cost analysis that incorporates all capital and operating costs that take place within the life duration of the system. The economic performance provides from net present cost of project, annualized cost summary and cash flow. Each bar in the graph symbolizes either a total investment or total equivalent of performance cost for a particular year [10].Economic values given in fig.4.6 and table 4.3

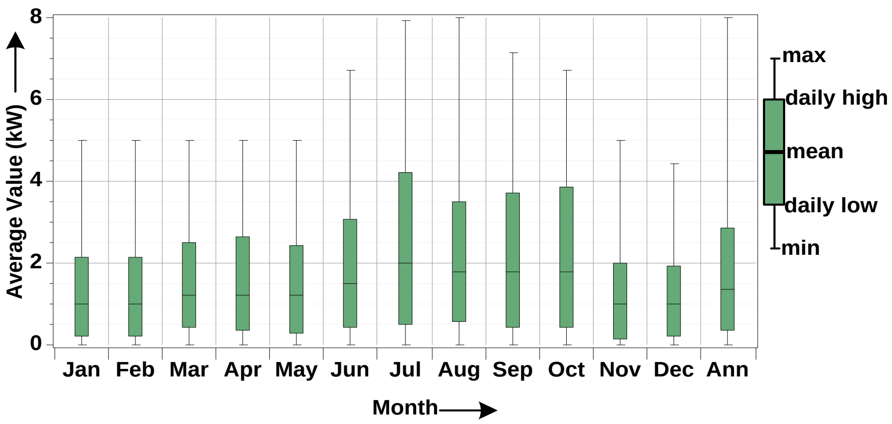

Figure 4.5 Wind power output

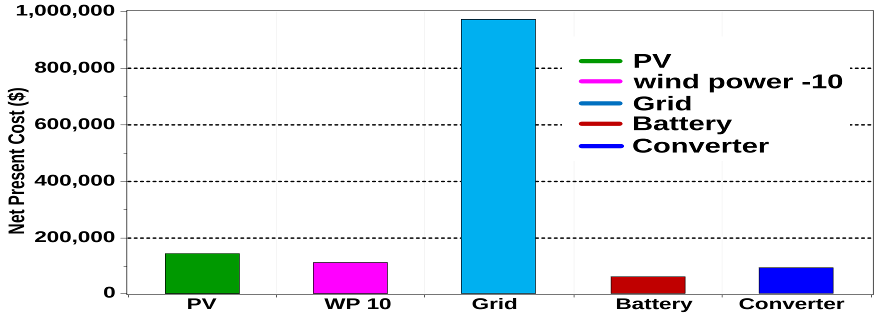

Figure 4.6 Cash flow summary

Table 4.3: Annualized cost of the proposed system

	Capital Cost (Rs/yr)	Replacement Cost (Rs/yr)	O &M Cost (Rs/yr)	Salvage (Rs/yr)	Total (Rs/yr)
PV	7,823	2,439	2,000	-1,367	10,895
Wind	7,823	163	500	-30	8,456
Grid	2	0	76,156	0	76,158
Battery	3,129	2,328	0	-668	4,789
Converter	6,258	653	500	-122	7,289
System	**25,035**	**5,583**	**79,156**	**-2,187**	**107,586**

4.5Environmental impact

In the environmental impact category, the HOMER model evaluates emissions of pollutants such as carbon dioxide, carbon monoxide, unburned hydrocarbon, particulate matter, sulphur dioxide, and nitrogen oxide. The emission of gases from the proposed hybrid system is very less [22], because the major part of the power is contributed by the renewable energy resources and hence the system has minimal effect on the environment

Pollutant	**Emissions (kg/yr)**
Carbon dioxide	6,219
Carbon monoxide	0
Unburned hydrocarbons	0
Particulate matter	0
Sulfur dioxide	27
Nitrogen oxides	13.2

Fig.4.8 Emission of gases

V.CONCLUSION

Initially the load demand calculations and resources analysis are done in an elaborate manner. With the available data sizing of the renewable energy generators are estimated. The effective operating technologies are selected for the efficient operation of the system. The estimated data, resources are fed into the software and making use of its tools the Hybrid renewable energy system is constructed and simulated using the renewable energy based optimization software namely HOMER. The optimized configuration and the cost analysis are done. The performance analysis is executed for the proposed system and an enhanced model for real time implementation of HRES is suggested to puducherry region’s building.

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