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Design, analysis and optimal sizing of standalone PV/diesel/battery hybrid energy system using HOMER

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Design, analysis and optimal sizing of standalone PV/diesel/battery hybrid energy system using HOMER

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Abstract: Now that the world's most important problems are the lack of fossil fuel reserves, we need to find a solution to preserve non-renewable resources and replace them with other renewable resources such as solar power. The next focus is on the rising level of undesired gases, such as carbon dioxide, etc. There is a need to regulate the impact of such greenhouse gases. This paper mainly intentional to situate optimal scheduling and to meet the power demand profile by the utilization of available solar energy resources. Considering the above data we have put forth an attempt to scrutinize the leverage of distributed Generation considering solar energy, alone can vary, when associated together they give a dependable wellspring of vitality as a DG is utilized as reinforcement unit for the crisis.So consolidating a solar powered energy source with a diesel generator provides reliable generation, utilizing independent sunlight based renewable power system for a chose area in Vellore region, Tamil Nadu, India.The principle goal of this paper is to decide the optimal sizing dependent on different designs, moreover reduce the cost parameters such as, total net preset Cost (TNPC), system cost of Energy (COE), unmet electric load, CO_2 emissions by utilizing HOMER Software. It is found that the PV/Diesel/converter combination provides optimal results which providing vitality with 0% unmet load at the minimum electricity cost, which is diminished from\$ 0.672 to \$0.319/Kwh.

Keywords: Solar energy, Backup system, HOMER, Cost of energy, Pollutant Emission

1. Introduction

Due to rising communities, and because of fast industrialization a sustainable power source with better proficiency is emphatically rely on socio economic advancement for any countries. As developing nations like India has relies upon fossil derivative to satisfy daily energy need, which confronting an intense vitality emergency which influences the lives of the individuals as well as a significant hindrance in the turn of events and progress of the nation. Despite the unpredictability of solar or wind power, complete hybrid power plants are now operating in many parts of the world [1]. The single sources of activity of these creating units are not skilful in imperatives of cost, productivity and dependability. Combining these diverse renewable resources is an effective alternative to building a hybrid energy system. By joining these divergent renewable sources with fossil derivatives to frame a composite imperativeness system is a viable substitute choice [2].

A new research has found that solar battery storage devices are more affordable to meet social load requirements than diesel and wind power batteries [3]. A detailed analysis in the middle of solar PV-Diesel generator and solar PV-fuel cell hybrid systems, as utilized for a 5kW operation, is given in [4] which is more effectiveness in producing the optimum outcomes on the basis of cost-effectiveness.

In [5] execution of the stand-alone hybrid solar photovoltaic /diesel engine with an electric generator/battery system has been marked by conscious design for an inaccessible society in

Bangladesh. The effect of energy storage has been assessed regarding the cost of vitality and the net present expense of the framework. Most appropriate sizing of the hybrid power system has been inspected by HOMER programming.Author [6] suggested techno-economic feasibility investigation for electric power siring through hybrid system which includes biomass, wind and solar photovoltaic. They pointed out that the designed hybrid structure is less expensive contrasted with typical production of electricity.

The author reviewed the economic feasibility of the earliest hybrid system with a solar photovoltaic and coal fired power stations in the Inner Mongolia locale of China. They utilized their conclusion to make proposals for the improvement of this plan kind of hybrid innovation [7].Authors [8] discusses the difficulties in improving the utilization of secluded Small solar photovoltaic in distant zones. In consideration of the intrinsic complexity of the generation of solar power and the load criteria, the author has developed a method for estimating the existence of the different PV technologies. The aim of this proposed work is the simulation and optimization of hybrid solar power generation / diesel engine / power storage for residential load power supply. Systems implementations were shown in Figure 1.
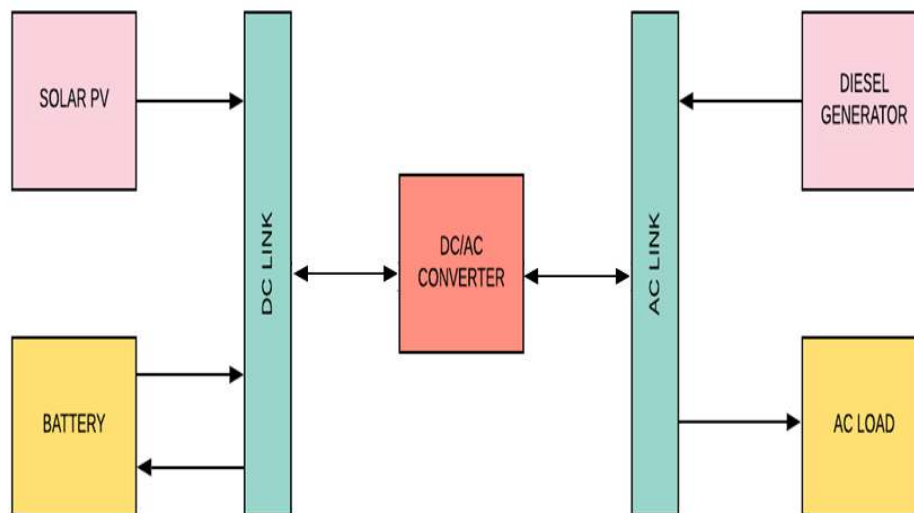

Figure 1.Schematic diagram comprises of solar PV, diesel generator and Battery system

2. Hybrid Optimization Model for Electric Renewables (HOMER) software program

Homer Technology was established by the American National Renewable Energy Laboratory in 1993 [9]. It is a system model that can be used to access combinations of different components of a grid connected system and the performance requirements of an off-grid system. HOMER executes the following three basic functions, begins with simulation then performs optimization and finally a sensitive examination of the energy systems being planned. Throughout the simulation process, the HOMER simulations has been carried out for each hour of the year and assess its technological viability along with the relevant terms of the life cycle cost, such as acquisition, repair, service and maintenance.

In the optimization procedure, HOMER models numerous setups to determine the most suitable option that meets the requirements of technical feasibility in terms of lowest life cycle cost. Insensitive analysis, HOMER plays out multiple optimizations with considerations of various data parameters to decide the impact of vulnerability and inconsistency on the model info [10], [17].

3. Zone of analysis and description of load

The chosen region is the district of Vellore, Tamil Nadu, nation of India, and the position of this research region on the chart at latitudes 12°,55.0'N and longitude 79°,7.9'E, where the usability of the renewable vitality supply were immense in this analysis area, insofar as 'solar, biomass and biogas,' were each of these are used in stand-alone format.

Standard measurement of normal energy usage is 11.26 KWh/day; average system load is 0.47 Kilowatt, peak demand output is 2.09 KW, because the position selected has so little requirement. Load data is estimated and averaged over 24 hours to create an energy demand profile as seen in Figure. 2(a) and Figure. 2(b) displays the annual load profile info.
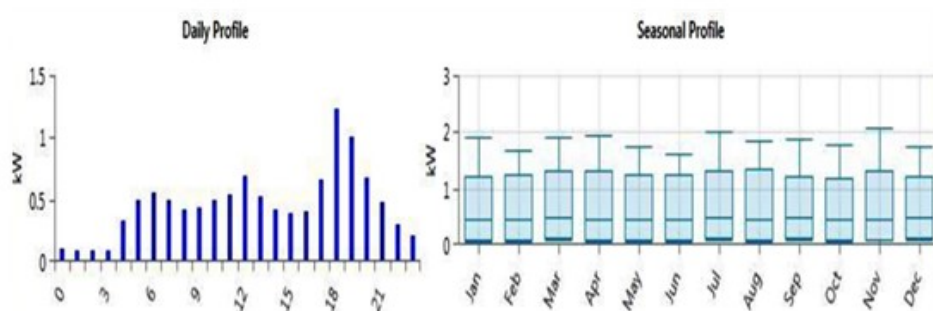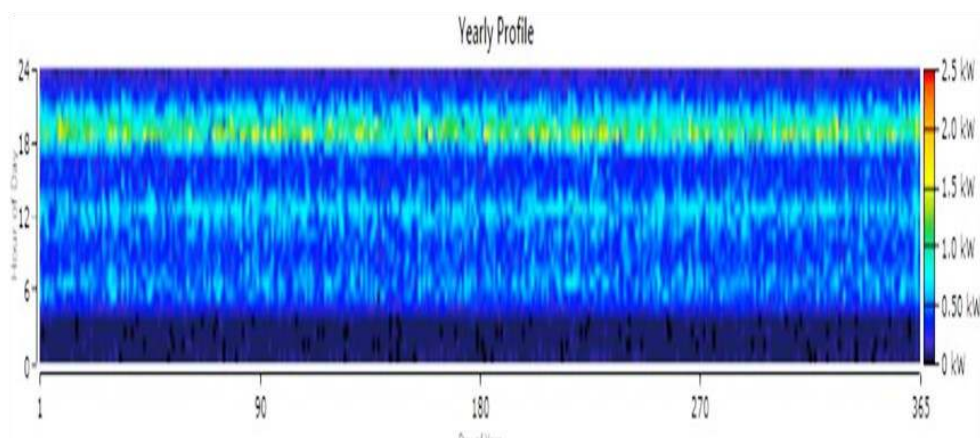

Figure 2(a). Shows the demand profile hourly and monthly

(b)

Figure 2(b). Shows load profile annually

3.1. Solar potential

The better understanding of solar radiation and the clearness index is important for a chosen location to simulate and design of a solar system at HOMER.Average solar information was acquired from NASA via HOMER software, the solar based information comprising of the clearness index and solar radiation ranges from 0.476 to 0.664 and 4.694 kWh/m^2/day to 6.923 kWh/m^2/day respectively as indicated in Figure 3. and Table 1.December month has the lowest solar radiation of 4.694 kWh/m^2/day and the maximum solar irradiation point of 6.923 kWh /m^2 /day in the month of April.Be that as it may, a month with base sun oriented radiation esteem is adequate to utilize sun based energy for power generation.

The sun-dependent PV device converts irradiance dependent on sunshine into sun-powered vitality to satisfy electric demand. It functions simply when the sun is shining, and the abundance vitality generated by the solar photovoltaic is utilized to recharging the backup batteries, which can be used to fulfill the required load particularly at night when no sun-oriented vitality is present. The solar photovoltaic type utilized for this examination is a generic flat plate with its cost of capital, replacement cost and operational and maintenance cost given in Table 2.
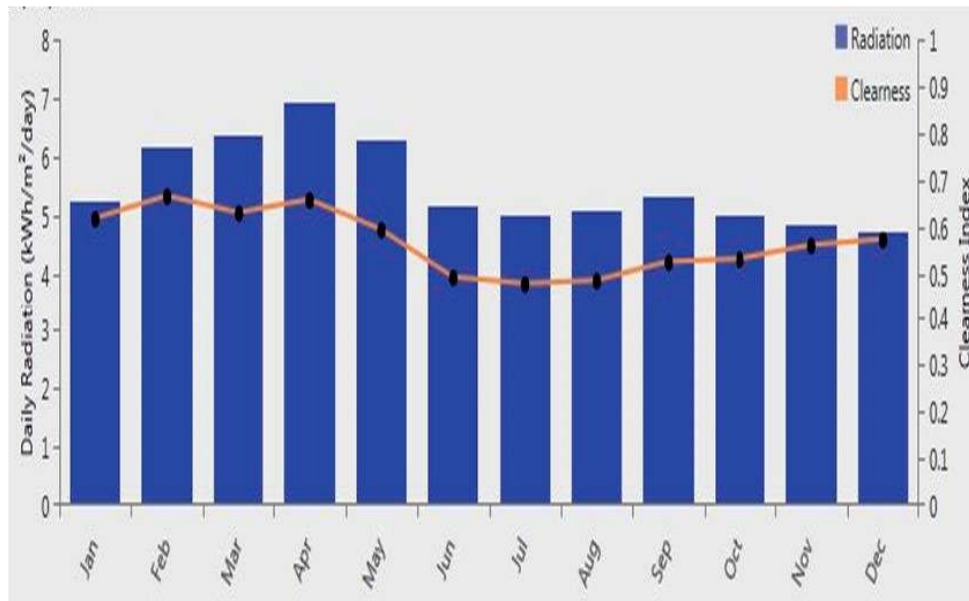

Figure 3. Monthly average solar data for the selected location

Table 1. Meteorological reports collected from NASA shows average values.

S.no	Months	Clearness Index	Daily solar Radiation Kwh/m^2/day
1	January	0.616	5.232
2	February	0.664	6.166
3	March	0.628	6.348
4	April	0.656	6.923
5	May	0.592	6.271
6	June	0.491	5.153
7	July	0.476	5.005
8	August	0.483	5.072
9	September	0.532	5.325
10	October	0.529	4.998
11	November	0.558	4.815
12	December	0.571	4.694
13	Annual average	6.225	5.50

4. System components

The following components are considered to model a system which includes solar PV, rechargeable battery storage systems, and diesel generator for back-up. Figure 4. Defines the proposed configurations in which the demand for electrical load is AC load, the Solar system is has been integrated to a DC connection, the diesel engine source is connected to an AC connection, and the battery is linked with DC-link.
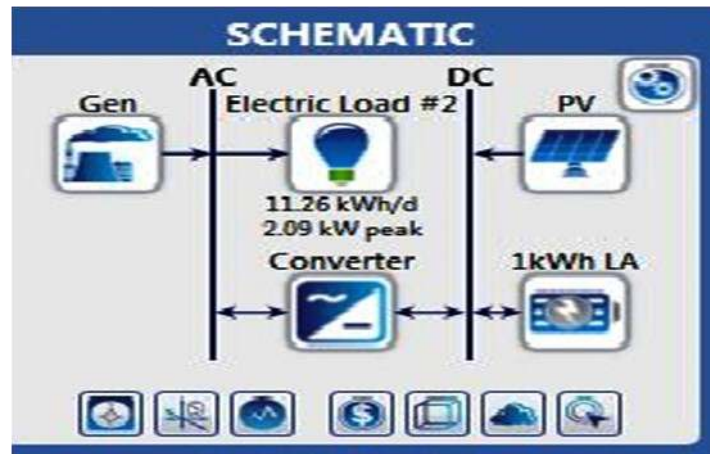

Figure 4. Design of a hybrid device in HOMER

4.1. Solar PV

The sun based PV system changes over the sunlight based irradiance into sun powered vitality to meet the electrical demand. It essentially works when the sun sparkles, and the abundance vitality produced by the PV is utilized to charge the backup batteries, which can be utilized to fulfill the desired load particularly during the night when there is no sun oriented vitality. The solar photovoltaic type utilized for this examination is a generic flat plate with its cost of capital, replacement cost and operational and maintenance cost given in Table 2.

4.2. Converter

In this analysis a generic converter is used with an efficiency of 95 % and 100 % rectifier relative capacity. The cost specifics of the converter, which include capital costs, costs of substitution, running and repair expenses and other basic criteria, are shown in Table 2. In this scenario, HOMER optimizer selects the converter size to match the needs.

4.3. Diesel generator

The diesel engine is integrated into hybrid systems to supplement for power needs where the availability of renewable resources is insufficient to reach the real load requirement. The cost of fuel is varying for each area owing to shipping costs. Generally, the fuel rate is greater in the regional areas, where extra freight expenses to be charge for the distribution of gasoline to certain towns. Diesel cost is varying from $0.7 to $1.0 depending on the venue. The Auto size Genset is the diesel generator which is chosen for this analysis. The specifics of the expenses are provided in Table 2.

4.4. Battery

A generic lead-acid rechargeable battery with a nominal capacity of 1 kWh and 12 V nominal voltage is taken into consideration for this feature. It also has a roundtrip efficiency of 80%. For a minimum SOC of 40% and a maximum of 100%, the battery has a life of up to 10 years. The battery bank stores unused electrical power from the RES network and is be used to service the load when the RES fails to support the load.

Backup diesel generator provides the energy when the load is not serviced by the RES and in the state of battery capacity is completely discharged. The excess energy of the solar system is transferred

to the battery reserve, which can be used to assist the load when the renewable network falls. Diesel generator serves as a contingency supply that supply to the load when all renewable sources and the batteries struggle to reach the necessary load specifications. The expense information of the battery is reported in Table 2. And HOMER optimizer has choosing the required size of battery capacity.

Table 2. List of systems cost components used in hybrid systems

S.No	Component	Size (KW)	Capital cost ($)	Replacement cost ($)	O & M cost($/year)	Lifetime (Years)
1	Solar PV panel	1	700	700	10	25
2	Diesel generator	1	300	300	0.030/op.hour	15000 Hours
3	Battery	1	230	230	10	10
4	Converter	1	250	250	0	15

5. Economics

The viability of the designed hybrid system can be examined by distinguishing the financial parameters, for example, levelized cost of vitality, system net present cost, system capital expense, and salvage cost. HOMER simulation and renders the optimal outcome based on these economic parameters.

5.1. Net present cost (NPC)

The NPC is the crucial expense parameter in HOMER programming [11]. The NPC is defined by the calculation of all the expenses borne by the program over the life span of the system, less the value of the incomes earned during the venture's life expectancy. Net present cost comprising Initial capital cost, Replacement cost, expenses for operational and maintenance, fuel cost, etc. The NPC is mathematically expressed by equation (1) as [12].

$$\text{Net present cost} = \frac{\text{Cannual.Tot}}{\text{CRF(i,Lproject)}} \tag{1}$$

Where,

$C_{annual.Tot}$ is absolute annual cost

CRF is a capital recovery factor

i is the interest rate

$L_{project}$ is designed project life time

5.2. Levelized cost of energy (LCOE)

Levelized cost of energy is the amount of useful power generated by the system. As determined by HOMER the LCOE is the proportion of the complete yearly expense of power created to the total useful power generated by the system [13]. The LCOE equation is presented in Eq. (2) as [14].

$$\text{Levelized cost of energy (LCOE)} = \frac{\text{Cannual.Tot}}{(E_{primary.AC} + E_{primary.DC} + E_{gridsales})} \tag{2}$$

Where,

$C_{annual.Tot}$ is absolute annual cost

$E_{primaryAC}$ is Primary AC load served

$E_{primary\ DC}$ is Primary DC load served

$E_{grid\ sales}$ is absolute grid sales

5.3. Renewable fraction (RF)

Total renewable power produced by the sustainable power sources contrasted with the total power produced by the whole system is known as the renewable fraction [15]. For this investigation, the RF is required to be as high as conceivable to diminish the impact of greenhouse emissions which is ozone-depleting substance discharge by the traditional diesel generator even though it will have an impact on the NPC because of cost of the renewable power sources. It can be mathematically expressed as equation (3) [16-18].

$$\text{Renewable fraction (\%)} = 1 - \frac{\Sigma P diesel}{\Sigma \, P renewable} \qquad (3)$$

Where,

P_{diesel} - Output provided by the diesel generator

$P_{renewable}$ - Output from renewable sources

6. HOMER simulation results

HOMER simulates and gives optimization results, it is discovered that to satisfy the need profile 3.45 kW solar photovoltaic panel, 2.30 kW generators, 10 KWh lead- acid Battery and 1.01 kW converters are the ideal estimating for over a framework. In this framework, introductory expense is 5656 $ and working expense is 872.61 $/year, cost of power is 0.319 $, in the interim, there is a renewable fraction with the ideal setup is 75.1%. In addition, the total power generation of the hybrid system is provided as 6693 kWh/year; the total generation from PV array and the diesel generator is almost 84.7%, and 15.3%, respectively.

Besides, the amount of the fuel required to run generator is 385 litres per year and the generator runs for 1117 hours per year, while for the base case, the measure of diesel expended is 2457 litres for every year and its operating time is 8760 hours per year. This implies around 2000 litres of fuel and practically over 70% decrease in working time of diesel generator is achieved in optimal configuration.Optimization results of HOMER programming for the various configurations has shown in figure 5.

Figure 5. Optimization results from HOMER

Figure 6. Power generation of Hybrid energy systems

The Power delivered by the system is utilized to take care of AC essential burden. The normal utilization of the AC load is 4109 KWh/year. It very well may be seen that the average electricity generated by Solar PV system is 5668 KWh/year and diesel engine generator is 1025 KWh/ Year. The excess electricity available is 2066 KWh/year with zero percent unmet loads. Figure 6. Shows monthly average power produced throughout hybrid energy systems.It is noticed from Figure 7. shows that the proposed integrated green energy system saves expenses over the project life time with operating cost as $2707 for base case as diesel generator while it is for optimal lowest cost system as $872.61 and Figure 8. Shows Total Net present expenses for optimal configuration and is estimated to be $16936, while it is $35679 for the base case of diesel system. By concerning NPC, there is an extraordinary decrease in their expense by practically half in ideal crossover system.
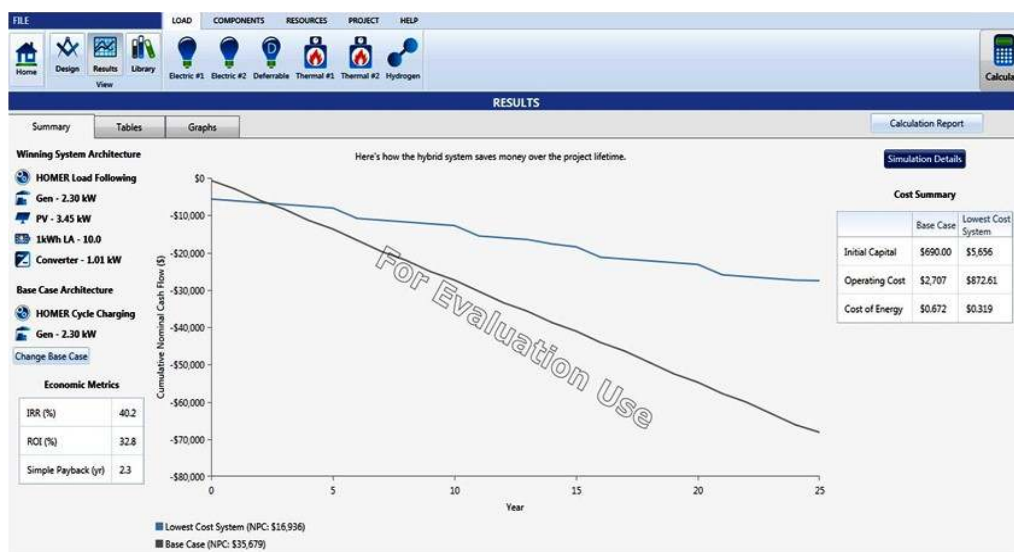

Figure 7 . Saves the money over the project lifetime

Figure 8. Net present cost flow summary of the base case and current system

7. Conclusion

In this paper, we have analyzed the results obtained from simulation and optimization of a hybrid system which consists of Solar photovoltaic, diesel engine generator, and battery for the generations of electrical power have been carried out using HOMER. The combination of a 3.45 kW PV, a 2.30 kW capacity diesel generator, 10 kW batteries and a 1.01 kW power converter with load following strategy is the best solution to this scenario analysis at NPC $ 16936, COE 0.319$ / kWh, and the cost of work $872.61 is more affordable than the base case structure with COE $ 0.672. So the solar photovoltaic-diesel-battery hybrid framework has prompted financially increasingly advantageous structure, by considering the load needs of these networks and the sustainable resources accessible in their individual locales.

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