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Optimization and Techno-Economic Analysis of PV-Wind Power Systems for Rural Location in India.

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Abstract. One downside to Green Energy is that it cannot be estimated. Therefore, determining the optimum planning and perfect working strategies for the resources to be included in the hybrid system is very important. HOMER software has been used in this research paper to solve the case study of the hybrid renewable energy system. Due to its extensive analytical capabilities and advanced prediction capabilities based on the sensitivity of variables, HOMER is one of the most used software for optimal planning purposes. A case study for the sizing of a renewable energy-based hybrid system is solved in this article, using the Hybrid Optimization of Multiple Energy Resources (HOMER) software. Photovoltaic panels (PV panels), wind turbines (WT), batteries, converters, electric charge and grid are used in case study. The results of the simulation are presented in graphical form and tabulated for better system visualization. The design of a system to supply 6.8 KWh/d whereas the peak is 1.04 KW electric loads has been performed using HOMER software. In order to allow the user to choose the most suitable option, a comparative analysis has made, showing the pros and cons of cases. Optimum construction conditions help to lower operating costs.

1 Introduction to HOMER software

Homer is free software created by the United States of America (USA) and the National Renewable Energy Laboratory (NREL). Using this software alternatives are planned and tested technologically and cost-effectively for off-grid and on-grid energy systems for centralized, stand-alone and distributed system generation. This enables the user to consider the accessibility of energy sources and other factors in a wide range of technology choices. HOMER was first developed under the Department of Energy Production (DOE) in 1993 to comprehend the trade-off between different energy production configurations [1]. NREL supplied free service to an increasing community of system designers who were interested in renewable energy after a few years of original design. HOMER has since remained free software, which has become a modelling tool for conventional and renewable energy technologies [2].

1.1 Principal Tasks of HOMER

1.1.1 Simulation

The simulation method is implemented in two respects. First, it tests the System's viability. This method is followed for two reasons. First, it is testing the viability of the system. If a system can properly compensate for electrical loads and take into account any other limitations imposed by the user, that would be considered feasible. Second, the cost estimate on the life of the system reflects the overall cost and overall Net Present Cost (NPC) of optimizing the hybrid renewable energy system installed and operated by HOMER PRO throughout its lifetime [3].

1.1.2 Optimization

The factors that make up the optimization system determine the combination of factors and the size or amount of the optimal value of such variables. In Homer, at the lowest total net present expense, the ideal or optimum device configuration meets the user-specified boundaries [9].

1.1.3 Sensitivity

Analysis of sensitivity enables estimation of the impact of uncertainty or conditions over which the planner has no influence over average wind speed or solar radiation [2]

2 HOMER Model

The planned hybrid energy systems include renewable sources such as PV, wind and biogas. Part of the battery is charged using a PV and wind system, but the generator is used in case of an emergency. The source bus was replaced by an AC, using a power converter. This integrated system is designed for off-grid electrification and on-grid electrification. A homer is assigned software for operational measurement. This software is used with various sensitive components for cost optimization. Various topics like load, global solar irradiation, wind speed etc. have been considered. HOMER's model organization is addressed in Fig.1.

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2.1 Load Profile

Cited place for this analysis is Sarthak Niwas, A/p:Kashti, Tal: Shrigonda Dist: Ahmednagar . The latitude and longitude of location is $18^{0}32.8^{'}N$, and $74^{0}34.9^{'}E$ respectively. The load profile is acquired dependent on the basic requirements of appliances such as light,fan, refrigerator, TV and cooking. Depending on the climate, load varies with seasonal and monthly consumption. Total consumption is 6.8 kWh / d while peak consumption is 1.04 kW. Figure 2 depicts the load profile

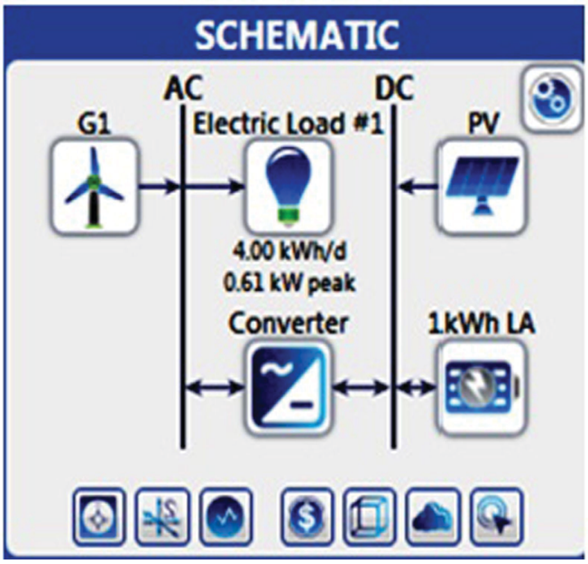

Fig. 1. Hybrid Energy System [16]

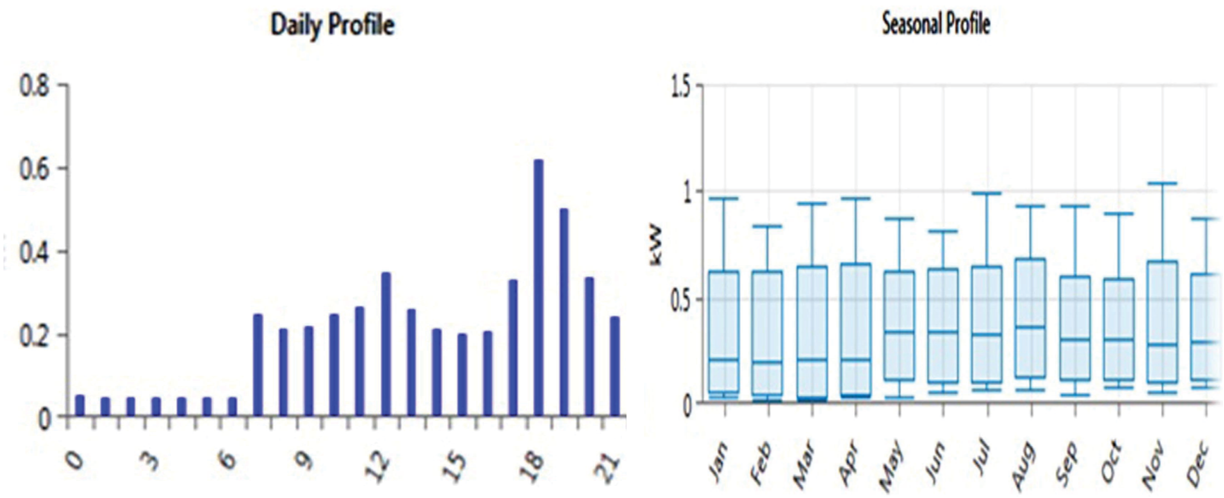

Fig. 2. Daily and seasonal profile [16]

2.2 Solar Resource Data

The solar resource has used for a rural site at a location of latitude and longitude is $18^{0}32.8^{'}N$, and $74^{0}34.9^{'}E$ respectively as shown in Figure 3. The solar radiation information was obtained from the website of NASA Surface Meteorology and Solar Energy. For this region, the average annual solar radiation is $5.33 Kwh/m^{2}/day$. Figure 4 shows a one-year solar resource profile. Maximum daily radiation occurs in a month of May which is $6.55\ Kwh/m^{2}/day$ and minimum daily radiation occurs in a month of July is $4.036\ Kwh/m^{2}/day$.

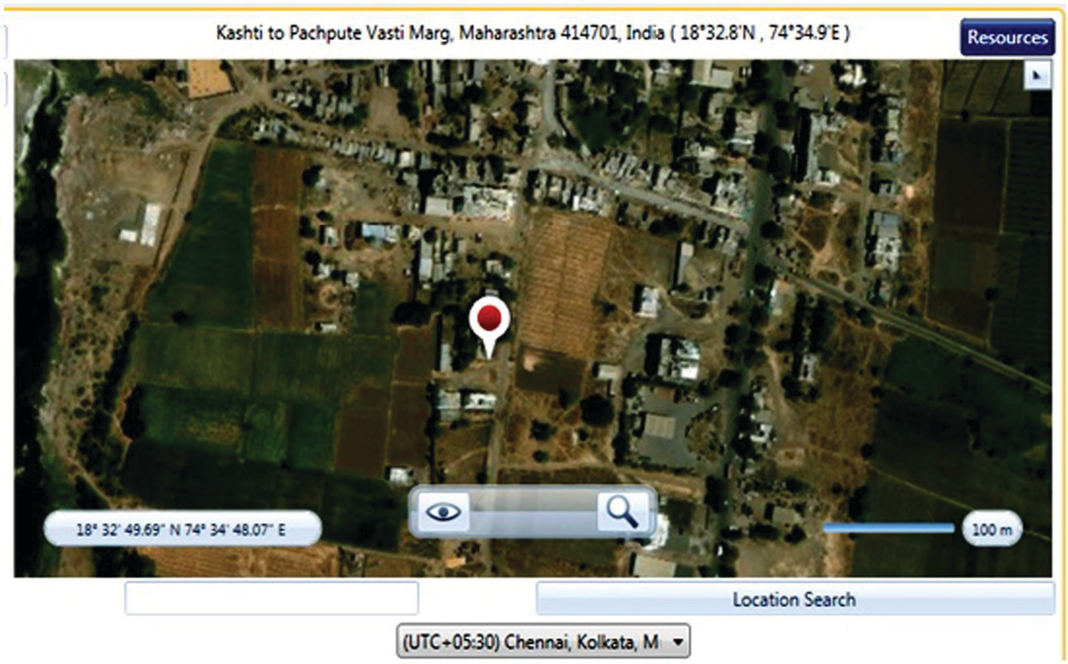

Fig. 3. location selected for case study [16]

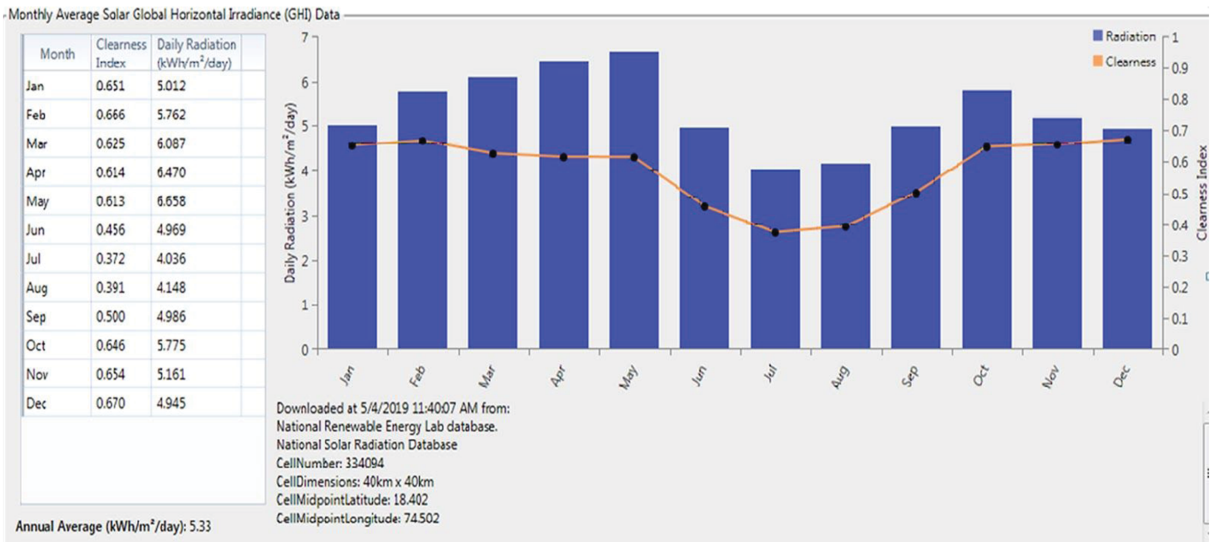

Fig. 4. Annual average solar radiation [16].

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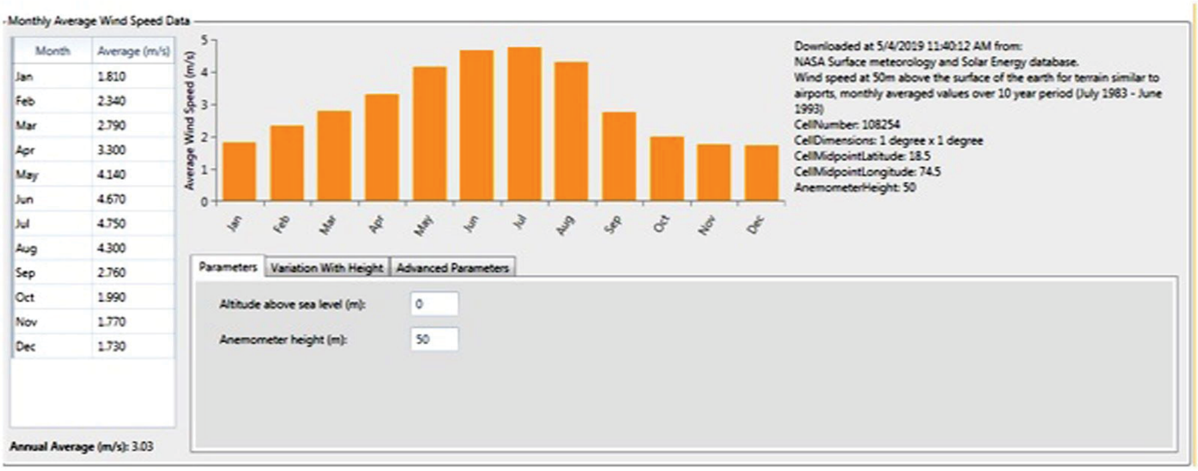

Fig. 5. Monthly average wind speed data [16].

2.3 Wind Resource data

Figure 5 shows the wind resource profile over a year period for a given region. This is acquired from the website of NASA surface metrology and solar energy. The anemometer is measured more than 50 meters above ground level and the wind represents an annual average speed of 3.03 m/s. Maximum wind speed occurs in a month of June is 4.67 m/s and minimum wind speed occurs in a month of December is 1.730 m/s.

3 Selection of Components

This project aims to reduce energy costs by using renewable energy systems such as photovoltaic panels / wind turbines. Optimization and COE are calculated using these two renewable power systems in HOMER software.

3.1. Sizes Considered for Optimization

Two renewable energy sources are used to generate electricity and to distribute charges. The sizes and prices of these renewable energy sources are set out in the table 1 and table 2. The information on wind turbines shows that five different size wind turbines were selected on the basis of load demand and size in the research area [7,11-14]. For each wind turbine rate, the factors that are useful in the mathematical modeling of the wind turbine are given in Table 1. Different parameters are considered such as rated output, rated wind speed, swept area, cut-in speed, Survival speed and cost per turbine etc.

Solar data is shown in Table 2. Four different size rating of PV panel are selected according to load demand. For the given study area, roof top area available for PV panel placement is 92 m^2. For each PV panel area is given in Table 2 and from this number of PV panel for each size to be calculated. Efficiency according to cost per PV panel is given in Table 2.

Table 1. Wind Turbine Data [10]

Rated output	5.1KW	4.2 KW	3.3 KW	1.8 KW	1.5 KW	650 W
Rated wind speed	11 m/s	11 m/s	10.5 m/s	10.5 m/s	10.5 m/s	10.5 m/s
Cut- in m/s, VC	2.7 m/s	2.7 m/s	2.7 m/s	2.7 m/s	2.7 m/s	2.7 m/s
Swept Area m2	21.4 m2	19 m2	16.4 m2	9.4 m2	9.2 m2	3.7 m2
Survival wind m/s	55m/s	55m/s	55m/s	55m/s	55m/s	55m/s
Cost per wind turbine	₹167500	₹134000	₹80400	₹67500	₹53600	₹40200

Table 2. PV cell Data [10]

Size	1 KW	2 KW	5 KW	10 KW
Area per panel	$9.2m^2$	$14.864\ m^2$	$27.87m^2$	$46.45m^2$
No. of PV panel	18	11	6	4
Efficiency	12%	16%	16 %	20%
Cost per panel	₹36000	₹72000	₹180000	₹360000

3.3 Converter

The converter is a system where the DC parts serve as AC loads or vice versa. It acts as a rectifier converting AC to DC, an inverter converting DC to AC, or both. The estimated capital cost of inverter is 3125 ₹/kW and replacement cost 3125 ₹/kW is calculated according to market survey. The normal life of the converter is considered 20 years.Battery and converter size costing shown in Table 3.

Table 3. Battery and converter size [10]

Component	Sizes	Cost
Converter	1kw	₹. 3125
Battery	1kwh	₹. 22600

4. HOMER Results

4.1 Flow chart of Homer optimization process.

The optimal system configuration can be determined by the components that need to be properly validated for each component of the system, and the strategies the system sends for use. The end goal is to identify a configuration that has low NPC [4]. Therefore, different system configurations and technical issues are simulated and create different combinations of system components. Finally, a list of those different configurations can be created and compared. The best viable pairs are separated, and the most viable pairs are considered, with the exception of the least viable pairs. The overall optimization process flow chart is shown in Figure 6.

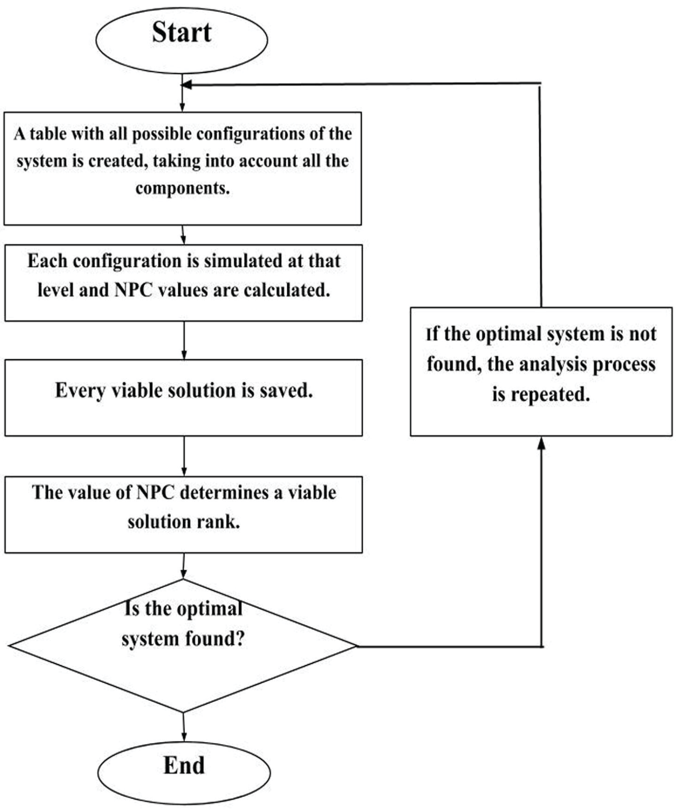

Fig. 6. Flow chart for optimization in Homer

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Table 4. HOMER Results without Grid Connection [161].

PV	Wind	Battery	Converter	PV(kW)	NPC(₹)	COE(₹)	Operating cost(₹/yr)	Initial Capital cost(₹)	PV energy production(kWh/yr)
✔		✔	✔	5.86	₹647,671	₹34.34	₹17,682	₹419,083	9,688
✔	✔	✔	✔	6.44	₹663,100	₹35.15	₹18,844	₹419,493	10,650

4.1 Without Grid Connection

In this study, using NREL's Homer software, the selection and sizing of components of a stand-alone energy system has been carried out. Homer is a hybrid system design software that facilitates the design for stand-alone applications of electric power systems [4]. HOMER assists in designing a systematic power system to deliver the desired load. The ordering system takes into account the cost of the life-cycle. It will provide a efficient user interface and comprehensive device description with correct sizing [5,6]. The software conducts automated sensitivity analyzes for the hybrid system's response to core parameters such as cost of services and components [8]. The simulation has been performed considering the project life of 20 years. The hybrid renewable energy system is built into HOMER. It considers the broad rigor of chronological simulation and optimization in the model. All resources, including all capital, replacement possibilities, and annual maintenance costs, have been added as input to obtain the optimal size combination of different resources from Table 1, Table 2 and Table 3.

4.2 With Grid Connection

The hybrid renewable energy with grid system has been simulated in HOMER. For completion of system, battery was chosen per unit cost of ₹ 22,600. And the converter considered also has a power of 1 kW for this case. The Figure 7 and Table 5 shows HOMER developed a renewable energy grid hybrid model consisting of solar, wind as a renewable source, battery as a converter and grid power saver.

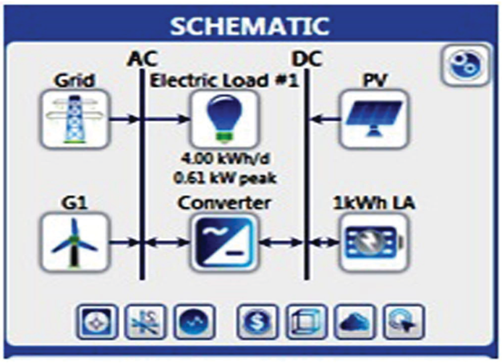

Fig. 7. Hybrid system with grid connection[16]

The result of the optimization in Table 5 shows that the combination takes into account both solar and wind, but among the values considered, the wind speed responsible here maximum power generation. This approaches the system's minimum NPC and lowest COE so it's acceptable. But if the wind speed is not above average, wind turbines should not be considered. The results of optimization without wind turbines are greater compared to wind turbines.

Table 5. HOMER Results with Grid Connection [16].

PV	Wind	Battery	Grid	Converter	NPC(₹)	COE(₹)	Operating cost(₹/yr)	Initial Capital cost(₹)
✔			✔	✔	-₹139,746	-₹1.35	-₹26,281	₹200,000
✔	✔		✔	✔	-₹112,028	-₹1.07	-₹26,071	₹225,000
✔		✔	✔	✔	-₹96,467	-₹0.930	-₹24,681	₹222,600
✔	✔	✔	✔	✔	-₹68,749	-₹0.659	-₹24,471	₹247,600
			✔		₹150,993	₹8.00	₹11,680	₹0.00
	✔		✔		₹177,257	₹9.39	₹11,778	₹25,000
		✔	✔	✔	₹194,478	₹10.30	₹13,285	₹22,739
	✔	✔	✔	✔	₹220,742	₹11.69	₹13,383	₹47,739

Cycle charging policy is a dispatch policy whereby the generator operates at full output power whenever it is required to operate to provide primary load. Surplus power goes towards lower-priority objectives such as reducing priority: servicing deferrable loads, charging battery bank. The plan behind sending a strategy is to send a generator running under load; it just produces enough energy to meet the primary load. Low-priority target, such as charging a battery bank for saving a deferrable load, are left to renewable energy sources.

5. Conclusion

Nature is rich in different sources, and abundant. But the capacity of the resources varies with the time and time of day. The lack of resources can be reduced by combining two or more resources by creating a hybrid energy system. For this purpose HOMER is capable of better optimisation. This paper represents the idea of creating a solar and wind hybrid energy storage system, taking into account the weather conditions latitude and longitudinal of that location ($18^0 32.8' N$, $74^0 34.9' E$). If the with-grid and without grid condition are compared with each other, it is observed that the capital cost in the with-grid condition is less than two lakhs. In terms of annual energy production with-grid condition produces 9688 KWh/year energy. But if sell excess energy through the grid, in with-grid cases you will make a profit. In the results of the simulation, it can be noted that the optimal solution can be achieved by incorporating PV panels, batteries and a converter into a hybrid grid connected system.

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