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Designing and Optimizing a Hybrid Renewable System Using Homer for Site Selected

Falguni Pande*, Harshal Thakre, Shubham Ladukar, Prof. Mrs. Deeksha Radke

Department of Electrical Engineering, KDK College of Engineering, Nagpur, Maharashtra, India

ABSTRACT

The present scenario describes that there are some untouched areas in Maharashtra, which are still unelectrified. This is mainly due to the unfeasible and uneconomical extension of grid. Thus opting for standalone hybrid renewable energy systems for rural electrification is the only solution. A hybrid system uses multiple energy sources for generating electricity with some kind of energy storage medium. However, the most important thing is that the system should be economically attractive. To achieve both of these features, each of the components in the hybrid system should be optimally sized. This requires a detailed analysis of different possible hybrid system configurations. The analysis of the hybrid system is done using the 'HOMER' software. Thus the objective of this paper is to investigate an optimum combination of different energy systems, which can supply electricity to a rural community in Maharashtra at an affordable price with an accepted level of reliability.

Keywords : Hybrid System, HOMER, Renewable energy sources, LCOE, Net Present Cost, Renewable Fraction, Capacity Shortage

I. INTRODUCTION

Generation of electricity is one of the most important factors for the development of any country. In India the electricity generation more or less is based on conventional system which consists of large scale thermal power plants that transmit and distribute the generated electricity by means of the grid. But it turns out to be more expensive to install a transmission and distribution system for a small community, isolated places, deserted areas, or islands. Thus the preferred technology over the grid extension would be a standalone hybrid renewable energy system that will provide an economical solution to this problem.[4] Utilization of these renewable energy resources such as solar, wind, small hydro and bio energy for rural electrification has become an attractive solution for those areas where the grid extension was unfeasible and uneconomical. But the main difficulty of using these renewable energy systems is that they cannot provide reliable electricity due to the intermittent nature of these resources[1]. Therefore micro grids based on hybrid systems have been identified as a better solution for rural electrification. But designing of a hybrid system is challenging ,due to the large number of design options. But add to that the most important thing is, the proposed system must be economically attractive, while providing a reliable supply of electricity for the consumers. Moreover, the combination of generation sources, components and their capacities selected for a hybrid system have a great influence on the system cost, its lifetime and the affordability of the service to the end users. Therefore sizing the components in the hybrid system in an optimized way is too very important .[3] Number of software has been developed by different institutions for analyzing the hybrid energy systems. For example RET Screen, PV-Design Pro, Hybrid2 etc. Among all these software HOMER is the widely used tool for hybrid system sizing. It performs complicated optimization task accurately by doing hourly simulations of the power flow between the load and the other components in the hybrid system over a one year period .The objective of this work is to examine the optimal configuration of a renewable hybrid energy system for electrification of a village named MIRKALM ,GADCHIROLI,MAHARSHTRA by using HOMER

Figure 1. Geographical location of Mirkal

II. METHODS AND MATERIAL

A. Research Methodology

The flowchart of methodology is shown in figure, which initiates with electric load estimation. After that, resources available at particular region of application are analysed for suitable hybrid energy system components. Various economic analysis or optimizations are applied to obtain the optimum hybrid energy system configuration. In this work, entire system is simulated on HOMER Pro 3.8.3 optimization tool and results are obtained. The main factor which will be optimized is the cost of production of electricity generation with maximum utilization of available resources.[2]

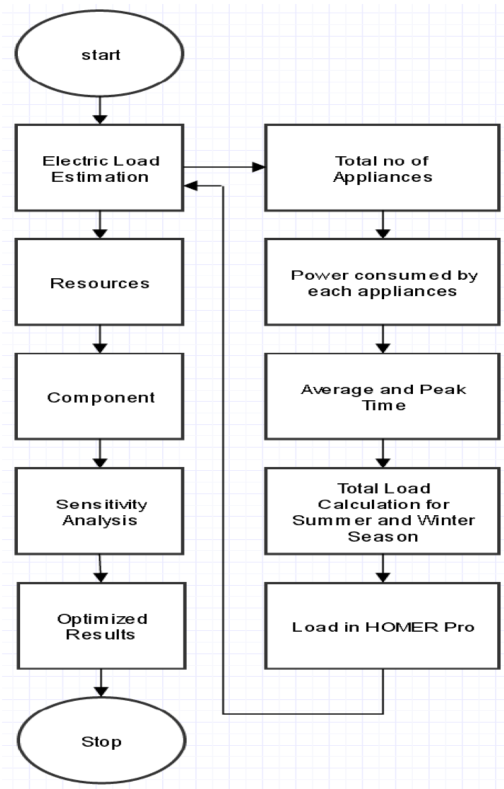


Figure 2. Step Wise Research Methodology

The hybrid renewable energy system consists of solar photovoltaic panels, wind turbine with batteries, converter and a DG set as shown in fig.2. But before designing the system, study of the location , correct component selection, available energy resources, and load profile should be evaluated and as they are summarized below.

B. Location of Study Area

The site selected for designing a micro power system is MIRKAL is which located near Aheri Tehsil , Gadchiroli district in ,Maharshtra,India having longitude 190 21.4’ N and Longitude of 800 11.6’ E.

C. Summary of Site Selected

Mirkal M Village, is 127 km away from gadchiroli and 24 km away from Aheri. The total geographical area of Mirkal M village is 8 km2 .The village is home to 236 people, among them 93 (39%) are male and 143 (61%) are female. 3% of the whole population are from general caste, 1% are from schedule caste and 96% are schedule tribes. Child (aged under 6 years) population of Mirkal M village is 20%, among them 30% are boys and 70% are girls. There are 41 households in the village and an average 6 persons live in every family. The village has water and drinking water facilities in the form of water –wells and hand pump..The village has no access to grid electricity, thus this offers an opportunity for off grid electrification of the village.

D. Load Estimation

In a remote village ,the demand for electricity is not high as compared to urban areas. The electricity is demanded for domestic use (for appliances such as compact fluorescent lamps (CFL), ceiling fans or table fans) and community load would consist of street lights and motor to head over water from the community well and the agricultural load would involve water pumping load. Therefore the load estimation has been done by keeping these conditions under consideration.

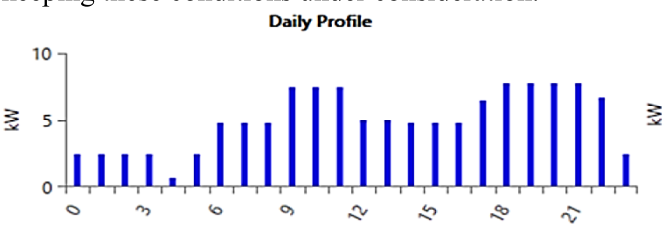


Figure 3. Daily Load Profile

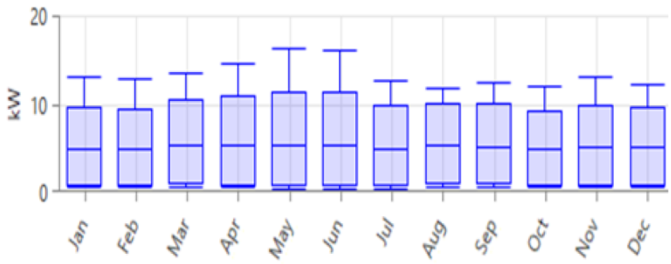


Figure 4. Seasonal Load Profile

E. Solar Radiation Data

The table below shows the solar radiation data of Mirkal-M, gadchiroli Indian here the solar energy resources data are taken from NASA. Figure shows the average daily solar radiation on the left vertical axis and the clearness index value on right vertical axis of the figure. The annual average solar radiation is 5.58kwh/m2/day and average clearness index is 0.554.[6]

Table 1. Solar radiation at the site

Month	Clearness Index	Daily Radiation (kW/m2/d)
January	0.545	5.480
February	0.562	5.840
March	0.553	5.810
April	0.530	5.700
May	0.550	5.390
June	0.591	5.500
July	0.582	5.490
August	0.560	5.550
September	0.566	5.850
October	0.544	5.640
November	0.535	5.400
December	0.535	5.300
Average	0.554	5.58

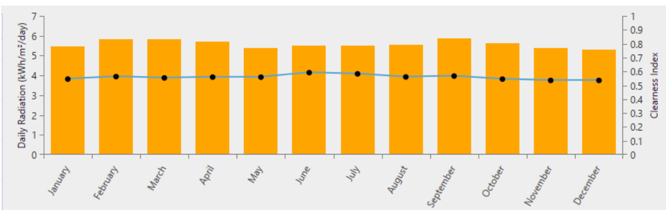


Figure 5 : Monthly Averaged Insolation Incident on A Horizontal Surface and Clear Ness Index

F. Wind Speed Data

Wind resource data can obtain from nasa surface metrology and solar energy database.The annual averag wind speed from database is 4.20m/s. Monthly average wind speed ranges from 3.490 m/s to 5.210m/sec with highest in month of june and lowest in the month of march the average monthly profile of daily wind speed data for selected site is shown in fig below.[9]

Month	Wind Speed m/s
January	3.590
February	3.680
March	3.490
April	3.560
May	4.220
June	5.210
July	4.690
August	4.300
September	4.400
October	4.560
November	4.570
December	4.090
average	4.20

Table 2. Wind speed at the site

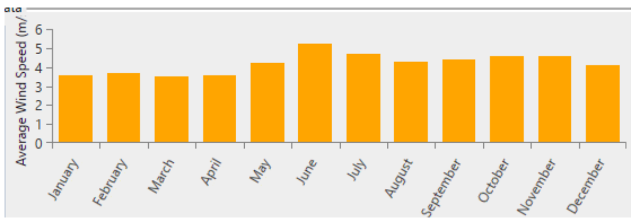


Figure 6. monthly averaged wind speed profile

1) HOMER Pro 3.8.3 Simulated Model Of Hybrid Energy And System

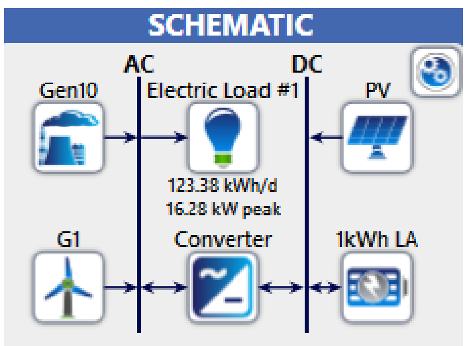


Figure 7. Simulated Model

Here the schematic diagram of the hybrid renewable energy system is shown above which represents the peak load demand of 16.28 kW and total energy Consumption of 123.38 kwh/day and load factor of 0.32.The schematic model represents different components connected to the AC and DC bus with a converter in the middle.

2) Simulation of the Components:

In order to estimate the cost of a hybrid power system, availability of renewable energy over a period of one year and details of each component are required. The available renewable resources are already discussed for the selected site. The details of each component include capital cost, replacement cost, operation and maintenance cost, diesel cost and some other constraints that will be introduced in the following discussion. HOMER Pro 3.8.3 simulates the system with different combinations of the available sources. The output includes the capital cost, net present cost, energy per kWh cost, component size and other electrical characteristics. Available power sources are expected to be, PV, wind turbine, diesel generator, and battery storage. There is no grid connection to the system. HOMER pro 3.8.3 simulates the different combinations of these power sources and provides the optimal combination.[8] The characteristics of each source and component are explained in the following sections.

Table 3. Simulation Of The Components

SOLAR PHOTOVOLTAIC	
Installations cost	$746.20
Replacement cost	$746.20
O&M cost	$0.15
Life time	25 year
Wind turbine	
Installation cost	$859.00
Replacement cost	$859.00
O&M cost	1 $1.80
Life Time	20 year
10KW Diesel Generator	
Installation cost	$2985.00
R Replacement cost	$2985.00
O&M Cost	$ $0.030
Life Time	15000 hours
Battery	
Installation cost	$ $15.01
Replacement cost	$13.51
O&M Cost	$0.15
Life Time	1 10 years
Converter	
Installation cost	

G. Cost Summaries

HOMER PRO 3.8.3 simulates all the possible combinations that are given in search space of each configuration and component. Thus choosing the best feasible configuration and components with minimum net present cost is an optimization problem

III. RESULTS AND DISCUSSION

A. Summarized Results

HOMER Pro 3.8.3 simulates all the possible combinations that are given in the search space of each configuration and components. HOMER Pro 3.8.3 calculates the total net present cost of all feasible systems and display them in the optimization results by ranking them in ascending order of the total net present cost .thus the system having the lowest total net present value is the optimized hybrid configuration. From the results below it can be analyzed that ,the most optimized configuration consists of PV-DIESEL GEN SET-CONVERTER-BATTERY system. It requires a SOLAR PV of 20 KW , a diesel generator of 15 KW, 1 string of (1 kKwh lead acid)batteries and a converter of 12.6 KW.

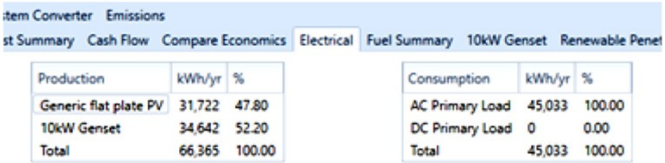
Architecture						Cost			
PV (kW)	G1	Gen10 (kW)	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)
20.0		15.0	1	12.6	LF	$0.417	$243,017	$17,2[illegible]	$19,605
20.0	1	15.0	1	12.8	LF	$0.418	$243,629	$17,263	$20,467
20.0		15.0		12.6	CC	$0.423	$246,097	$17,521	$19,590
20.0	1	15.0		12.8	CC	$0.424	$246,792	$17,508	$20,452
		15.0	1	0.510	LF	$0.523	$304,399	$23,198	$4,500
	1	15.0	1	0.510	LF	$0.524	$304,830	$23,165	$5,359
		15.0			CC	$0.524	$305,189	$23,261	$4,478
	1	15.0			CC	$0.525	$305,653	$23,231	$5,337

Figure 8. Optimization results of the designed system

The total net present cost of the system turned out to be $243,017.This hybrid system can supply electricity at a levelized cost of $0.417/kwh .HOMER PRO 3.8.3 simulation results the dispatch strategy of the generator as "load flowing".

B. Simulation Result

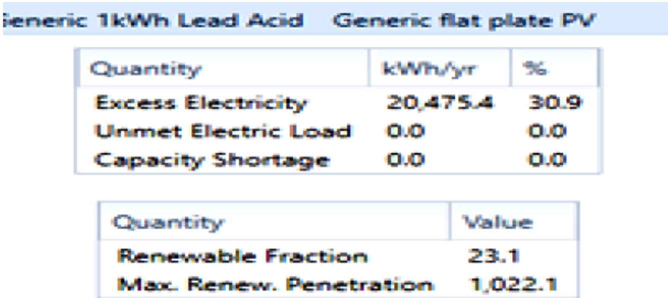
The simulation result eliminates all the infeasible combination and ranks the feasible systems according to increasing net present cost .in this system the total production of electrical energy is fulfilled by PV array ,DG set, Battery bank and converter .Around 47.80% is covered by PV array and 52.20% is covered by DG set.


stem Converter Emissions
st Summary Cash Flow Compare Economics Electrical Fuel Summary 10kW Genset Renewable Penet

Production	kWh/yr	%
Generic flat plate PV	31,722	47.80
10kW Genset	34,642	52.20
Total	66,365	100.00

Consumption	kWh/yr	%
AC Primary Load	45,033	100.00
DC Primary Load	0	0.00
Total	45,033	100.00

Figure 9..Simulation Results


ieneric 1kWh Lead Acid Generic flat plate PV

Quantity	kWh/yr	%
Excess Electricity	20,475.4	30.9
Unmet Electric Load	0.0	0.0
Capacity Shortage	0.0	0.0

Quantity	Value
Renewable Fraction	23.1
Max. Renew. Penetration	1,022.1

Figure 10. Simulation Result

C. Electrical Results of the Hybrid System:

It can be easily analyzed from table that PV array accounts for total of 47.80% of hybrid system production whereas Diesel Generator accounts for only 52.20% and battery accounts for 11% of total electrical energy produced and stored by the hybrid system. The consumption of electrical energy by AC primary load is 45,033 kwh/year which is 100% of the total electrical energy produced by the hybrid system as there is no running dc load on the system.

Production	kWhr/yr	%
PV array	31,722	47.80
Wind turbine	0	0
Generator	34,642	52.20
Total	66,365	100

Table.4. Electrical output of the system

D. Simulation and Optimal Sizing of Each Component

It can be seen from the above table ,that the maximum output from solar PV is 19.6 kW when the solar insolation is fully available and minimum output is 0 kW when the panel didn't get enough solar insolation to produce electricity .The total production of electricity from solar PV system is 31,722 kWh and total hour of operation is 4,343 hrs per year .The levelized cost only of this scheme is 0.0365 $/kWh

E. Simulation result for PV:

Quantity	Value	Units
Rated capacity	20	kW
Mean output	3.62	kW
Mean output	86.91	kW/d
Capacity factor	18.11	%
Total production	31,722.22	kWhr/yr
Minimum output	0.00	Kw
Maximum output	19.6	kW
PV penetration	70.4	%
Hours of operation	4,343	hr/yr
Levelized cost	0.0365	$/kWh

Table 5. simulation result of PV

QUANTITY	VALUE	UNITS
Hours of operation	7,061	Hrs/yr
Number of starts	487	Starts/yr
Operational life	2.12	Yr
Capacity factor	26.4	%
Fixed generation cost	1.02	$/hr
Marginal generation cost	0.286	$/kWh

Mean electricity output	4.91	kW
Minimum electricity output	3.75	kW
Maximum electricity output	13.1	kW

Table 6. Simulation Result of Diesel generator

The Diesel generator system participating in hybrid system has nominal capacity of 15kW with mean electrical output of 4.91 kW with electricity production is 3.46E+04 kWh and total hour of operation is 7,061 hrs per year. The marginal generation cost only of this scheme is 0.286 $/kWh. The different simulation results obtained for Diesel Generator system while operating in hybrid manner with other system is given above in Table 6.

F. Simulation of Storage Batteries

Battery was used as storage device for the hybrid system. The capacity of each battery was 83.4 Ah. The simulation result for battery is given in Table 8.

QUANTITY	VALUE	UNITS
Nominal capacity	1.0	KWh
Usable nominal capacity	0.60	kWh
Autonomy	0.12	Hr
Lifetime throughout	800	kWh
Battery wearcost	0.02	$/kWh
Energy IN	357.38	kWh/yr
Energy Out	286.27	kWh/yr
Storage depletion	0.40	kWh/yr
Losses	70.72	kWh/yr
Annual throughout	320.05	kWh/yr

Table 7. Simulation result of storage batteries

IV. CONCLUSION

The motive of designing a hybrid system for an un-electrified region at a levelized (least) cost of energy by using HOMER PRO 3.8.3 software is achieved in this paper. Thus HOMER proves out to be a kind of technology which is a step towards sustainable development.

Though the designed system have high installation cost but in long run it is highly profitable because it has a low operating and maintenance cost. It serves to enhance the economic development and living standards of the remote area. Hence this is a much needed step to avoid a situation of energy crisis in the near future .

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