Optimising Simulated Model of HRES with HOMER Software for Mirkal M

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Abstract

Energy security and sustainable development are prime issues these days in developing countries like India. Off grid hybrid renewable energy-based power systems for rural electrification have become an attractive solution for areas where grid electricity is not feasible. Hybrid energy system uses several energy technologies, and the selection of proper technologies with optimal sizing of the selected components has become very important. The objective is to investigate the optimum configuration of a hybrid system that can supply electricity to a rural community in India. A rural village Mirkal M in Gadchiroli district of Maharashtra, India comprising approximately 41 households with resultant average daily electricity demand of 123.38 KWh/d and peak of 16.28 KW has been studied. This region receives abundant solar radiation with an average of 5.58KWh/m2 /day. In addition annual average wind speed of this region is 4.20m/s, at above the ground. The total net present cost of configuration has been calculated for a year in HOMER software of the system lifetime to examine the lowest cost option. The combination of solar PV system, diesel generator, converter and a battery bank has been found to be the optimal hybrid system. This system can supply electricity at an approximate levelized cost of 0.4104$/KWh.

Keywords- *Renewable energy, hybrid power system, photovoltaic, wind turbine, diesel generator, optimization, HOMERPRO software*

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1. INTRODUCTION

The role of electricity generation is one of the most important factors for the development of any country. In India the electricity generation more or less based on conventional system. But conventional system failed to provide reliable electricity in rural areas because the grid extinction is difficult and not economical due to energy crisis and increasing in fuel rates [1].Hence, With the rapid development of photovoltaic (PV), wind turbine and battery technologies, hybrid energy system has received increasing attention as an alternative to conventional system, with diesel generation only as emergency backup. But the design of such system is a very difficult task as the integration and control between renewable energy sources, energy storage and loads are very complicated. Hence optimal planning of such a system is very essential before its construction[2]

The wind is a more dynamic source than solar, it also provides energy during periods oflittle or no sunshine, the battery storage allows for the displacement of the energy by storing at a favourable time and then using the excess energy when necessary. This complementary feature is favourable to system reliability[4]

By targeting the rural energy planning of a developing country, this paper presents the simulation and optimization of hybrid PV-wind renewable energy system.

2. RESEARCH METHOD

The presented hybrid renewable energy system consists of wind turbine and solar photovoltaic panels with diesel generator as backup, battery for storage and converter. Before designing the system, available renewable energy resources and load profile should be evaluated and they are summarized below.

2.1 Location of the Project

The site selected for hybrid renewable energy system is located in, Mirkal M village, near Aheri in Gadchiroli district of Maharashtra, India. It is situated 24Km away from sub-district headquarter Aheri and 138Km away from district headquarter Gadchiroli. The total geographical area of village is 765.78 hectares. The village has a total population of 236 peoples. There are about 41 houses in Mircal M village. The village has one common well, which is the only source of drinking water. Agriculture is the main source of earning. Literacy rate is very low as compare to Maharashtra and the selected site is completely off-grid.

Fig.1. Map of study area

2.2 Data Collection

Methodology used for data collection is divided into two parts: Primary and secondary sources. Primary source mainly consist of interviews and questionnaires survey with the villagers for collecting load data. Secondary sources consist of NASA for collecting solar radiation and wind speed data along with research papers.

2.3 Load Profile

The proposed site is completely unelectrified. With the aim of providing basic need like 2 CFL, 1FAN for each house and 30 T.V, 15 (1 HP) motor for pumping water and irrigation purpose. In the present study the electrical load profile is considered according to the seasonal variation i.e. during summer, winter and rainy season. The average estimation of load profile consumption is 123.38KWh/day and peak requirement of load is about 16.28 KW as shown in fig.3

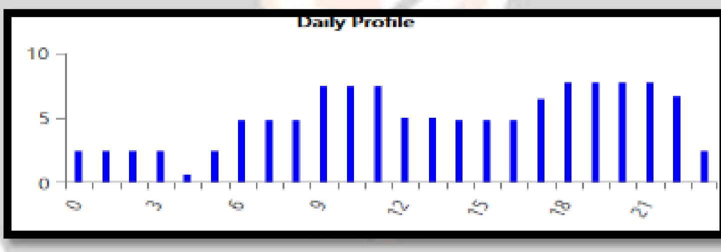

Fig.2. Daily average load for a complete year

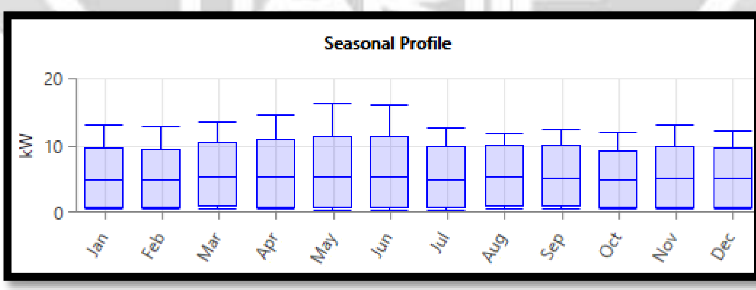

Fig.3.sasonal average load for complete year

2.4. Solar Radiation Data

Soar data input for the proposed site (longitude $80^0$11.6'E, latitude 19^0 21.4'N) is collected from NASA. Fig.4 represents the annual average daily radiation for this site is 5.58 KWh/m^2/d. According to solar radiation data photovoltaic output power existing all over the twelve month is shown in fig.4, solar power is higher in summer season comparatively to winter season. Here solar insolation and clearance index in table.1.

Table.1.Monthly solar radiation

Month	**Clearness Index**	**Daily Radiation (kW/m2/d)**
January	0.545	5.480
February	0.562	5.840
March	0.553	5.810
April	0.559	5.700
May	0.558	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	0.557	5.58

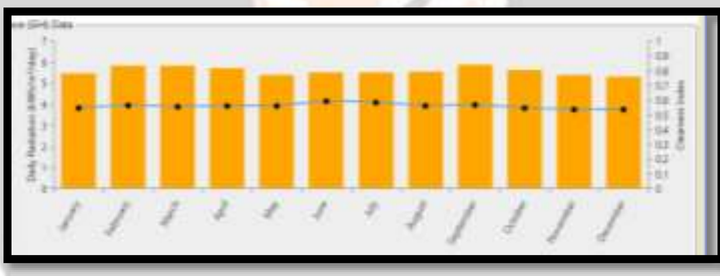

Fig.4.Solar Resource data

2. 5 Wind Resource Input

The second resource for hybrid renewable energy system is the wind. Wind energy is the energy created due to heating of the earth's surface and rotation of earth. Uneven heating of different parts of the earth causes difference in the air pressure, which causes air to flow from high-pressure region to low pressure region. The average monthly wind speed data are collected from NASA and it is found that annual average wind speed is 4.20m/s shown in fig.5.

TABLE.2.MONTHLY WIND SPEED

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	4.590
Average	4.20

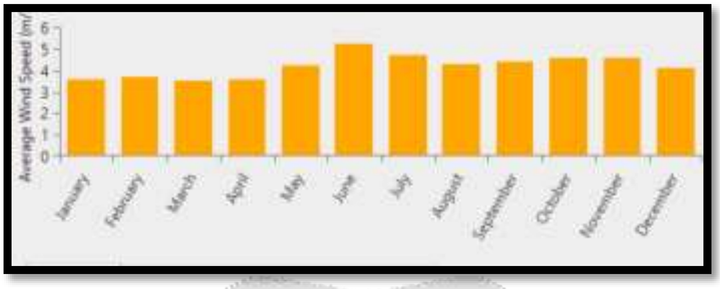

FIG.5. WIND RESOURCE DATA

3. COMPONENTS OF THE PROPOSED HYBRID SYSTEM:

Considering our project site we have designed our hybrid system with power source of Wind Energy, Solar energy and diesel. Solar energy is the most abundant green energy source here when necessary wind speed for power generation will only be available for 2-3 months. So a diesel generator is
taken for continuous supply of power. Hence the components of our systems are:

1. Wind Turbine
2. Solar Photovoltaic system
3. Diesel Generator
4. Storage device
5. Convertor

TABLE.3. SHOWS TECHNICAL DATA OF COMPONENTS

PV (1KW solar panel, total 20KW)	
Installation cost	$746.20
Replacement cost	$746.20
O &M cost	$0.15
Life Time	25 years
Wind Turbine	
Installation cost	$859.00
Replacement cost	$859.00
O &M cost	$1.80
Life Time	20 Years
10KW Diesel Generator	
Installation cost	$2985.00

Replacement cost	$2985.00
O &M cost	$0.030
Life Time	15000 hours

Battery	
Installation cost	$15.01
O &M cost	$0.15
Replacement cost	$13.51
Life Time	10 years
Converter	
Installation cost	15.01
Replacement cost	13.51
O & M Cost	0.15
Life Time	15 years

4. HOMER SIMULATED MODEL OF HYBRID ENERGY SYSTEM

The proposed hybrid renewable energy system shown in fig.6, it consists of Photo voltaic solar panels, diesel Generator, battery, and a converter. In this system the wind turbines and PV will be the primary power source and a diesel generator will be used as a backup and batteries for short-term storage system.

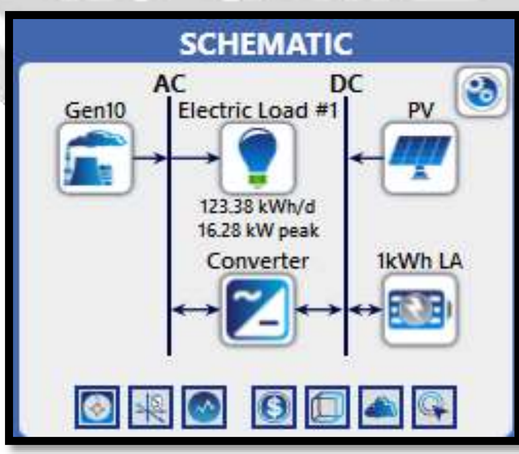

FIG.6 HOMER SIMULATED MODEL OF PV-WIND SYSTEM

5. RESULTS

5.1 Optimization results of hybrid system

For the off-grid electrification of a village Mirkal M various combinations of hybrid system have been obtained with solar PV array, wind generator, battery, converters from the HOMER software. All possible combinations are listed in ascending order of their Total Net Present Cost. The first row in the Figure7 shows the best possible combination, which include PV array, wind generator, batteries, and converter.

The optimum system has PV array with capacity 20KWand 15KW diesel generator along with 1KWh LA battery. It requires a converter with the capacity of 12.8KW.The total net present cost of this system is $238,913.10.This hybrid system can supply electricity at a levelized cost of $0.4104/KWh

Architecture						Cost				System
PV (kW)	G1	Gen10 (kW)	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)
20.0		15.0	1	12.6	LF	$0.417	$243,017	$17,210	$19,605	23
20.0	1	15.0	1	12.8	LF	$0.418	$243,629	$17,263	$20,467	23
20.0		15.0		12.6	CC	$0.423	$246,097	$17,521	$19,390	22
20.0	1	15.0		12.8	CC	$0.424	$246,792	$17,508	$20,452	22
		15.0	1	0.510	LF	$0.523	$304,399	$23,190	$4,500	0.0
	1	15.0	1	0.510	LF	$0.524	$304,830	$23,165	$5,159	0.0
		15.0			CC	$0.524	$305,189	$23,261	$4,478	0.0
	1	15.0			CC	$0.525	$305,653	$23,231	$5,337	0.0

1kWh LA		Converter	
Autonomy (hr)	Annual Throughput (kWh)	Rectifier Mean Output (kW)	Inverter Mean Output (kW)
0.12	320	0.03	2
0.12	320	0.03	2
		0	2
		0	2
0.12	268	0.03	0.03
0.12	270	0.03	0.03

Gen10					PV		G1		
Hours	Production (kWh)	Fuel (L)	O&M Cost ($)	Fuel Cost ($)	Capital Cost ($)	Production (kWh)	Capital Cost ($)	Production (kWh)	O&M Cost ($)
7,061	34,642	14,992	318	14,992	14,924	31,722			
7,054	34,562	14,964	317	14,964	14,924	31,722	859	186	2
7,139	35,207	15,209	321	15,209	14,924	31,722			
7,135	35,137	15,186	321	15,186	14,924	31,722	859	186	2
8,759	49,001	20,321	394	20,321					
8,758	48,850	20,277	394	20,277			859	186	2
8,760	49,232	20,388	394	20,388					
8,760	49,087	20,346	394	20,346			859	186	2

Fig.7.Optimization results of hybrid system

5.2 Simulation Results Of The Hybrid System

A. Simulation Results for Solar Photovoltaic System:

The solar PV system participating in the hybrid system delivers 20KW of power to the load when operating in a hybrid system. The simulation results obtained for Solar PV is given below in Table 4.

TABLE.4 SIMULATION RESULTS FOR SOLAR PV SYSTEM

Quantity	Value	Units
Hours of operation	7061	hr/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
Electricity production	346E+04	kWh/yr
Mean electricity output	4.91	kW
Min electricity output	3.75	kW
Max electricity output	13.1	kW

B. Simulation Result for Diesel Generator System:

The Diesel generator system participating in hybrid system has nominal capacity of 3kW.The different simulation results obtained for Diesel Generator system while operating in hybrid manner with other system is given below in Table5.

TABLE.5 SIMULATION RESULT FOR DIESEL GENERATOR

Quantity	Value	Units
Rated capacity	20.00	Kw
Mean output	3.62	kW
Mean output	86.91	kWh/d
Capacity factor	18.11	%
Total production	31722.22	kWh/yr
Minimum output	0.00	kW
Maximum output	19.6	kW
PV penetration	70.4	%
Hours of operation	4343	hrs/yr
Level zed cost	0.0365	$/kWh

C. Simulation Results for Storage Device:

Battery was used as storage device for the hybrid system. The capacity of each battery was 83.4Ah. The simulation result for battery is given in Table 6.

TABLE.6 SIMULATION RESULTS FOR STORAGE DEVICE

Quantity	Value	Units
Nominal capacity	1.00	kWh
Usable nominal capacity	0.60	kWh
autonomy	0.12	Hr
Lifetime throughput	800.00	kWh
Battery wear cost	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 throughput	32005	kWh/yr

D. Electrical Results of the Hybrid System:

The production of electricity by individual scheme in hybrid system is given below in Table7.

TABLE.7 ELECTRICAL OUTPUT OF THE PV SYSTEM

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

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

It is seen from above table.7 that, PV array accounts for total of 47.80% of hybrid system production whereas Diesel Generator accounts for only 52.20% of total electrical energy produced by the hybrid system. Among renewable energy the

Electricity produced by 10KW Diesel Generator is more than any other scheme participating in the hybrid system thus is considered as the base load of the hybrid system. It is also conclude that the unmet electric load is 0.0kWh/yr and excess electricity could be used for future demand. Hence the hybrid system found to be economical viable.

6. PAYBACKS PERIOD ANALYSIS

Payback period means that the number of years required recovering the cost of the investment and cost benefit analysis of our system. Here we have to consider different rate of per kW hour as the fuel price as well as the electricity price is increased day by day.

a) Considering 1kWh = 0.1$

Total capital cost of the hybrid system = 19605$

Annual income = 4503.3$[As annual consumption of electricity = 45033kWh]

So, payback period in year =19605/4503.3 = 4.35≈ 4years, 3months

b) Considering 1kWh = 0.12$

Total cost of the hybrid system = 19605$

Annual income = 5403.96$ [As annual consumption of electricity = 45033kWh]

So, payback period in year =19605/5403.96 = 3.6 ≈ 3 years, 6 months.

c) Considering 1kWh = 0.15$

Total cost of the hybrid system = 19605$

Annual income = 6754.95$[As annual consumption of electricity = 45033kWh]

So, payback period in year = 19605/6754.95= 2.90≈ 3years

7. CONCLUSION

This paper has discussed the simulation, optimization, sizing, and operational strategy of hybrid renewable energy system, which refers to the minimum cost of Total Net Present Cost (TNPC). The result shows that the combination of PV system, diesel generator, battery storage and converter brings an optimal configuration of hybrid renewable energy system applicable to be used as a off-grid system. The conclusion was drawn from the results obtained from the analysis that there is a high potential of solar radiation in Mirkal M, which can be used for supporting the renewable energy especially in terms of solar energy compared to the wind energy. Such a hybrid system is recommended for electrification in remote locations.

8. REFERANCE

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