OPTIMIZATION AND COMPARATIVE ANALYSIS OF NON-RENEWABLE AND RENEWABLE SYSTEM

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ABSTRACT
A Hybrid Renewable Energy System for rural electrification is a better solution to reduce environmental pollution. Renewable energy systems offer power supply to those areas where grid electricity is not feasible or cost of grid extension is relatively large. The main objective of this paper is to compare a non-renewable system with a renewable energy system for remotely located site in Tirunelveli, Tamilnadu .The current system is operated using a diesel generator and batteries and the proposed system integrates a hybrid combination of wind and solar energy system into existing diesel generator and battery system to serve the same load. This paper also performs cost optimization of the proposed system and the optimal cost analysis of HRES is done using Hybrid Optimization Model for Electric Renewable (HOMER). The HOMER is a energy modelling software for designing and analyzing hybrid power systems, which contain a combination of conventional generators, wind turbines, solar photovoltaic's, hydropower, batteries, fuel cells, hydropower, biomass and other inputs. It is currently used all over the world by tens of thousands of people. The results show that the proposed hybrid renewable energy system is more cost effective than the non-renewable system. The proposed system significantly reduces the running time of diesel generator and this helps to reduce the emission level.

KEYWORDS: *Hybrid Renewable Energy System, Non Renewable Energy System, Feasibility Study, Photovoltaic, Wind Turbine Generator.*

I. INTRODUCTION

Rapid depletion of fossil fuel resources on the world wide basis has necessitated an urgent search for alternative energy sources to cater to present day's demand. Another key reason to reduce our reliance on fossil fuel is the growing evidence of the global warming phenomena. It is imperative to find energy sources to cover the continuously increasing demand of energy while minimize the negative environmental impacts [1].

Hybrid Renewable Energy System (HRES) is composed of one or more renewable sources combined with conventional energy source, that works in stand alone or grid connected mode [2]. The most popular alternative sources are wind and photovoltaic. Research indicates that hybrid Wind/PV/battery system is a reliable source of electricity [3-5]. Since these sources are intermittent in nature therefore, in most cases diesel generator and batteries are integrated for power storage respectively [6].

The objective of this work is to optimize and compare a non-renewable energy system (existing system) with a hybrid renewable energy system (proposed system) for a site in Tirunelveli. The current system uses diesel generator and batteries for power generation and the proposed system adds hybrid wind and solar system into the current system. HOMER is used to obtain the most feasible configuration [7].

The paper is divided into four subsections. Section II describes the input variables like solar irradiation, wind speed and load data. In section III the simulation of current system and proposed system using HOMER as well as cost summary of the system components is explained. In section IV comparison between current system and proposed system is explained and discussed. Section V gives some of the future trends of hybrid renewable energy system.

II. SYSTEM DESCRIPTION

The design of HRES is based upon the certain important sensitivity variables to optimize the cost and size effectively. Hence, before designing the system, certain parameters like solar irradiation, wind speed and load profile must be evaluated. It is presented in the following sections.

2.1. Solar Radiation

The latitude and longitude of Tirunelveli are 8°.73´N and 77°.7´E respectively. The hourly solar radiation is collected for year from NASA website [8]. The average solar radiation is 4.91kWh/m^2/d. Clearness index and average solar irradiation for a year are shown in Table I, while Figure 1 shows the solar irradiation in a year produced by HOMER.

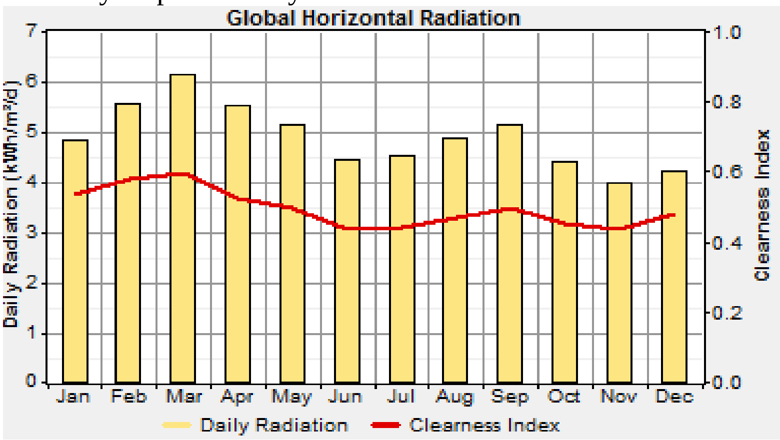

Figure.1. Monthly solar radiation

Table I Clearness Index and Average Daily Irradiation for a Year

Month	Clearness Index	Daily Radiation (kWh/m^2/d)
January	0.537	4.840
February	0.578	5.580
March	0.598	6.140
April	0.526	5.520
May	0.495	5.130
June	0.438	4.460
July	0.443	4.530
August	0.469	4.870
September	0.498	5.130
October	0.451	4.420
November	0.435	3.970
December	0.479	4.200
Average	0.495	4.895

2.2. Wind Speed Data

The second renewable source implemented in the system is wind. Wind data for this site is collected for year from NASA website. The average wind speed is 5.17m/s. The monthly average speed is shown in table II and figure 2 shows the wind speed in a year produced by HOMER.

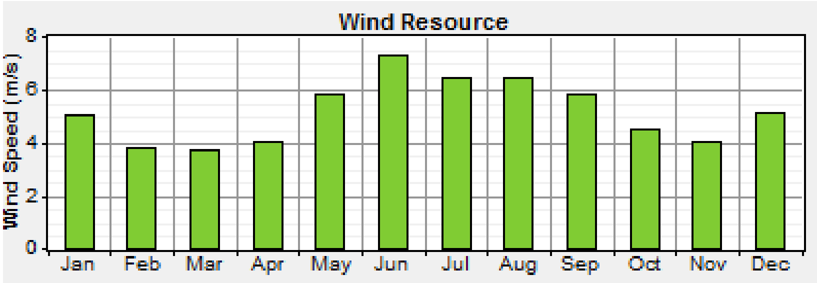

Figure .2. Monthly wind speed

Table II Wind Speed for a Year

Month	Wind Speed (m/s)
January	5.010
February	3.810
March	3.690
April	4.030
May	5.820
June	7.330
July	6.460
August	6.460
September	5.800
October	4.530
November	4.000
December	5.090
Average	5.18

2.3. Load Profile

Load is an important consideration in any power generating system. In this case study, we have considered a remote village in Tirunelveli, which lacks access to the utility grid. The measured annual consumption is considered as 97kWh/d in the present study. Figure 3 shows monthly average load profile. The peak load requirement decides the size of the system. Here peak load consumption is 9.7 KW.

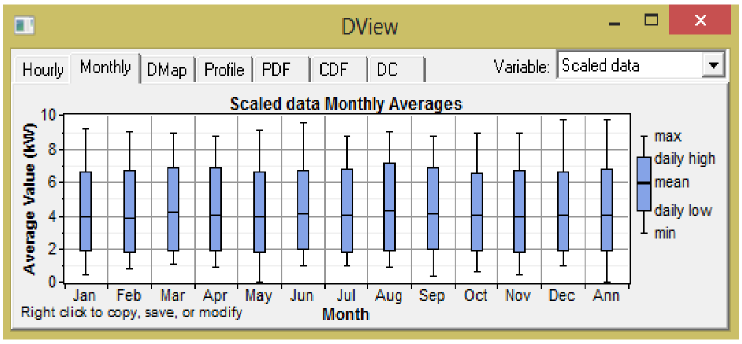

Figure. 3. Load profile for a village in Tirunelveli

III. System Optimization

The non-renewable energy system (existing system) and the hybrid renewable energy system (proposed system) are simulated in HOMER software.

3.1. Non-Renewable Energy System

The existing system model, which consists of a diesel generator and batteries to power the load, has been modelled using micro grid optimization software HOMER as shown in Figure 4.

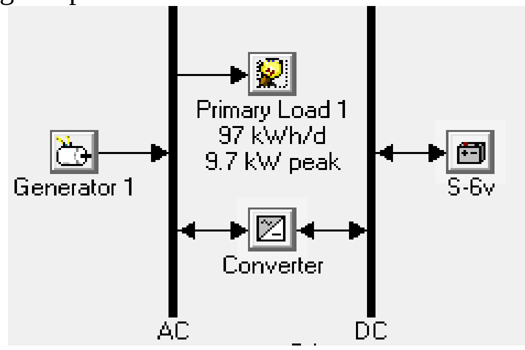

Figure .4. Existing power system at Tirunelveli

3.2. Renewable Energy System

The proposed hybrid renewable energy system, which consists of existing power system, wind turbine and photovoltaic, is shown in figure 5. The proposed system is going to reduce diesel fuel consumption and associated operation and maintenance cost. In this system PV and wind turbines will be the primary power source and diesel generator will be using as a backup for long term storage system and batteries for storage system.

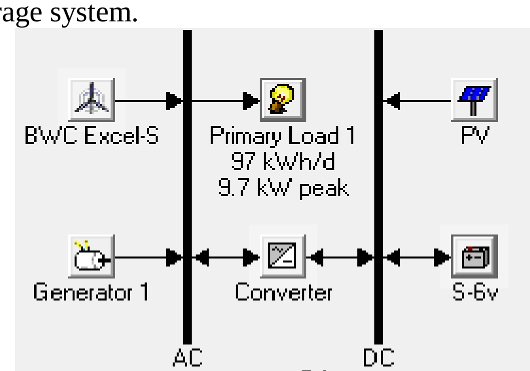

Figure .5. Proposed hybrid Power System for Tirunelveli

3.3. Homer Input Summary

Table III and IV give the summary of the costs, other technical details of the components and other required parameters which are given as inputs to the HOMER hybrid model.

TABLE III Cost summary of the system components

Component	Size	Capital Cost $	Replacement cost $	O & M Cost
PV system	10 kW	26700	20000	10$/year
Wind Turbine	10kW	20000	20000	500$/year
Battery	360 Ah	450	440	10$/year
Generator	10kW	5500	5475	0.5$/hr
	15kW	6600	6600	0.6$/hr
	21kW	7500	7500	0.7$/hr
	25kW	8000	8000	0.8$/hr
	30kW	8800	8800	0.9$/hr
Converter	30kW	23000	23000	10$/year

Table IV specifications of the components used

PV System	
Model	Canadian SolarCS6P-240P
Peak Power	240W
Derating Factor	80%
Slope	6.81°
Azimuth	0°
Ground reflectance	20%
Temperature coefficient	-0.43%/°C
Nominal operating temperature	45°C
Efficiency at standard test condition	14.92%
Lifetime	20 years
Wind Turbine	
Model	BWC Excel-S
Rated Power	10kW
Hub height	15m
Lifetime	20 years
Battery	
Nominal Voltage	6V
Nominal Capacity	360Ah
Lifetime throughput	1075kWh
Round trip efficiency	85%
Min. State of charge	30%
Float life	10 years
Maximum charge rate	1A/Ah
Maximum charge current	18A
Batteries per string	2(12 V DC bus)
Diesel Generator	
Lifetime	25000
Minimum load ratio	50%
Fuel	Diesel
Fuel cost	$1.19
Converter	
Lifetime	10 years
Efficiency	90%
Economics	
Annual interest rate	5%
Project lifetime	20 years

IV. RESULTS AND DISCUSSION

Both the systems are simulated in HOMER software. The software finds the optimal results in each case. Optimization result for non-renewable energy system is shown in Figure 6. As shown in the figure the total Net Present Cost (NPC) is $339,909. Diesel generator burns 14,872L of fuel per year and annual generator run time is 5291 hours. In twenty years, the diesel generator will burn 297,440L of fuel. The probability of fuel prices increase is also high. The total cost is calculated with constant price of fuel, which is $1.19 per litre. The total fuel cost during these 20 years will be 353,953.6$ and the total cost for the whole system will be $693,862.6. Figure 7 shows the monthly average electric production of the system which is totally produced by diesel generator.

Sensitivity Results | Optimization Results

Double click on a system below for simulation results. Categorized Overall Export... Details...

Label (kW)	S-6v	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
10	32	30	$ 42,900	23,234	$ 339,909	0.754	0.00	14,872	5,291

Figure .6. Optimized result for the non-renewable energy system

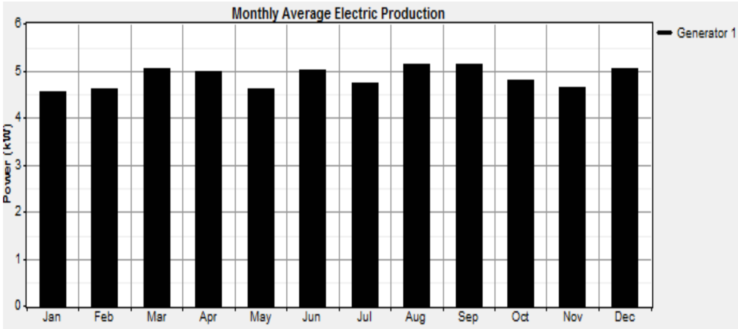

Figure .7. Monthly average electric production for non-renewable energy system

The hybrid renewable energy system was also simulated in HOMER software with four sensitivity variables. These variables are wind speed, solar irradiation, load, and diesel price. Figure 8 shows the optimized results for the proposed system. The total Net Present Cost (NPC) is $270,514. The system will consume only 3010 liters of diesel fuel per year and annual generator run time is expected to be 1034 hours. The lifetime of this system is 25 years, but 20 years life is used to make the comparison between two systems. In twenty years the diesel generator will burn 60200L of fuel and it will cost $71,638. The total cost of the system will be around $342,152 Figure 9 shows the monthly average electric production of the system. Photovoltaic production is 29% with 13,482kWh/yr. Diesel generator production is 18% with 8,731kWh/yr. Finally, wind turbine is expected to supply the rest of the load which is 53% with 25,068kWh/yr.

Sensitivity Results | Optimization Results

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PV (kW)	XLS	Label (kW)	S-6v	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
10	2	10	64	30	$ 149,000	9,751	$ 270,514	0.616	0.82	3,010	1,034
10		10	32	30	$ 94,600	19,781	$ 341,117	0.776	0.31	11,094	4,422

Figure 8. Optimized result for the renewable energy system

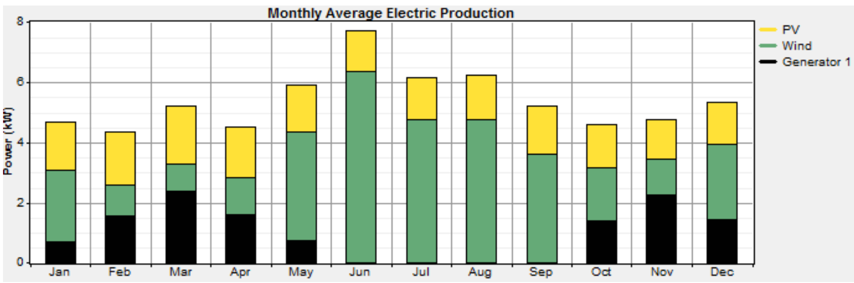

Figure 9. Monthly average electric production for renewable energy system

The difference cost between two systems is $351,710.6 which is a very significant number for a small system. Diesel generator run times are reduced and diesel generator in the proposed system will produce only 18% of the total power production. Moreover, the reduction of yearly diesel fuel consumption from 14,872L to 3010L has a large impact on the environment and it will reduce the net cost of the system. Also, the diesel generator will require less maintenance and operation cost and longer period of service before a replacement.

V. FUTURE TRENDS AND LIMITATIONS

The renewable technologies have come a long way in terms of research and development. However there are still certain obstacles in terms of their efficiency and optimal use. Following are the challenges faced by the designer.

- The renewable energy sources, such as solar PV and FCs, need innovative technology to harness more amount of useful power from them. The poor efficiency of solar is major obstruction in encouraging its use.
- The manufacturing cost of renewable energy sources needs a significant reduction because the high capital cost leads to an increased payback time.
- It should be ensured that there should be minimal amount of power loss in the power electronic devices.
- The storage technologies need to increase their life-cycle through inventive technologies.

These stand alone systems are less adaptable to load fluctuations. Large variation in load might even lead to entire system collapse.

VI. CONCLUSIONS

The paper compares two different systems for providing uninterruptible power for a remote site. One is the non-renewable energy system which consists of diesel generator and batteries and another is the proposed system which is a combination of existing system and hybrid wind and PV system. HOMER software is used for the comparison based on pre-feasibility study for each system. It is seen that the proposed system will save extra cost associated with transporting diesel and maintenance. Analysis indicates that renewable energy system will cost $351,710.6 less in its expected life than the existing diesel generator system. Therefore a hybrid renewable energy based system is recommended for Tirunelveli site.

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