International Journal of Innovative Studies in Sciences and Engineering Technology (IJISSET)

ISSN 2455-4863 (Online) www.ijisset.org *Volume: 3 Issue: 5 | May 2017*

Optimal Unit Sizing and Cost Estimation of Hybrid Renewable Energy Sources in Microgid Environment Using Homer Software

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Abstract: *A growing interest in renewable energy resources has been observed for several years, due to their pollution-free nature, availability all over the world .These facts make these energy resources attractive for many applications. Hybrid Renewable Energy source, which is the combination of various Renewable Energy Sources have great potential to provide higher quality and more reliable power to consumers. Hybrid Renewable Energy Sources are mainly recognized for remote area power applications and are cost effective where extension of grid supply is expensive. Over recent years, researchers have developed many works based on various constraints of Hybrid Renewable Energy Sources along with variable load conditions. Suitable Renewable Energy Sources are constructed in particular areas depending on their geographical scenario and sizing of their units are carried out with minimization of tariff rate reasonably. This work aims to formulate an optimization model for unit sizing and minimization of total net present rate of energy for Hybrid Renewable Energy Sources consisting of PV, Wind, and Biomass .A typical case study consisting of load data collected from different regions is used as the test system. The performance analysis of the results obtained has been analyzed in detail.*

Keywords: *Hybrid Energy system, Optimisation, Renewable energy, Homer Pro software*

1. INTRODUCTION

The combination of RES, such as PV arrays or wind turbines, with engine-driven generators and battery storage, is widely recognized as a viable alternative to conventional remote area power supplies (RAPS). These systems are generally classified as hybrid energy

Systems (HES). They are used increasingly for electrification in remote areas where the cost of grid extension is prohibitive and the price for fuel increases drastically with the remoteness of the location. For many applications, the combination of renewable and conventional energy sources compares favorably with fossil fuel-based RAPS systems, both in regard to their cost and technical performance. Because these systems employ two or more different sources of energy, they enjoy a very high degree of reliability as compared to single-source systems such as a stand-alone diesel generator or a stand-alone PV or wind system. Applications of hybrid energy systems range from small power supplies for remote households, providing electricity for lighting and other essential electrical appliances, to village electrification for remote communities has been reported. Hybrid energy systems generate AC electricity by combining RES such as PV array with an inverter, which can operate alternately or in parallel with a conventional engine driven generator.

Researchers and scientists continuously find the optimum performance of the renewable energy systems with the best possible way of unit sizing approaches (Zhou et al. 2010)[1]. Methodologies for the optimal design of the hybrid solar–photovoltaic (PV) and wind energy systems are discussed in Gomaa, Aboul Seoud, and Kheiralla (1995)[2], Chedid and Rahman (1997)[3], Borowy and Salameh (1997)[4], Deshmukh and Deshmukh (2008)[5], Shaahid et al. (2010)[6], Gupta, Saini, and Sharma (2011)[7] and Belmili et al. (2014)[8]. The optimisation is aimed to minimize the cost function based on demand and potential constraints. Wies et al. (2005)[9] presented a MATLAB/Simulink simulation approach for the unit sizing of the solar–PV and diesel-electric generator. Unit sizing approaches of the solar PV/ wind/ diesel/ battery/FC for stand-alone applications are vastly reported.

2. HOMER PRO SOFTWARE

HOMER is an efficient software tool widely preferred to optimize the hybrid energy system. HOMER simulates the hybrid energy system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares the electric and thermal demand in the hour to the energy that the system can

ISSN 2455-4863 (Online) www.ijisset.org Volume: 3 Issue: 5 | May 2017

supply in that hour, and calculates the flows of energy to and from each component of the system. For systems that include batteries or fuel-powered generators, HOMER also decides for each hour how to operate the generators and whether to charge or discharge the batteries.

HOMER performs these energy balance calculations for each system configuration that anybody wants to consider. It then determines whether a configuration is feasible, i.e., whether it can meet the electric demand under the conditions that have been specified, and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest.

3. SYSTEM DESCRIPTION

Hybrid renewable energy system of an Educational Institution of Latitude of 9°35' North and Longitude of 77°57' East with Time zone of (GMT+05.30)India is considered for Homer Simulation. Its location is shown in Fig. 1.

Figure 1: *Location of Microgrid System*

In the present work, two microgrid systems are considered with two different generator systems namely

I. Diesel Fed Generator System

II. Biogas Fed Generator System

However both the systems have same load profile, solar radiation, battery storage system and converter

3.1. Solar Radiation

The hourly solar radiation is obtained for year from NASA website [8]. The average solar radiation is 5.53kWh/m2/d. Clearness index and average solar irradiation for a year are shown in Table 1, while Fig. 2 shows the solar irradiation in a year produced by HOMER.

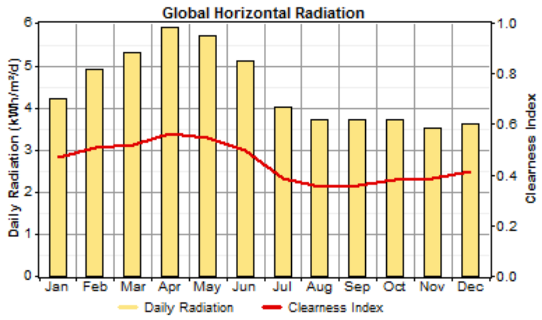


Figure 2: *Monthly solar radiation*

Table 1: *Clearness Index & Average Daily Irradiation for a Year*

Month	*Clearness Index*	*Daily radiation* kWh/m2/d
Jan	0.470	4.200
Feb	0.510	4.900
Mar	0.517	5.300
April	0.561	5.900
May	0.548	5.700
June	0.498	5.100
July	0.389	4.000
Aug	0.356	3.700
Sep	0.360	3.700
Oct	0.380	3.700
Nov	0.386	3.500
Dec	0.414	3.600

3.2 Load Profile

The load profile describes the electric demand that the system must serve at the particular location. The load can be classified as Primary load and Deferrable load and are shown in Fig.3 and Fig. 4 respectively

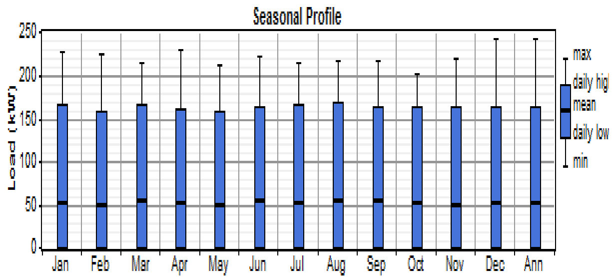


Figure 3: *Primary Load profile*

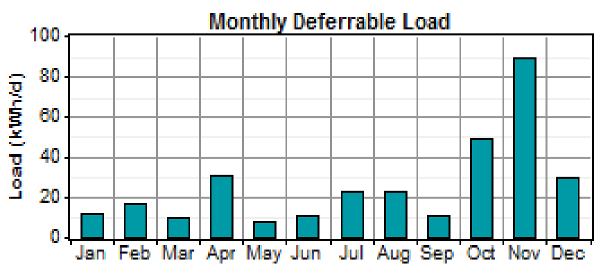


Figure 4: *Deferrable Load profile*

ISSN 2455-4863 (Online) www.ijisset.org Volume: 3 Issue: 5 | May 2017

3.3 Biomass details

The biomass collected from hostels and canteen for a typical educational institution has been estimated to account for 300kg/day. Yearly profile of biomass obtained is shown in Fig. 5.

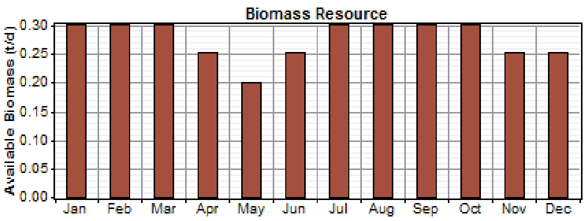


Figure 5: *Biomass source profile*

4. SYSTEM OPTIMIZATION

The Diesel fed generator system and Biogas fed Generator system are simulated using Homer software. As mentioned earlier since both systems have same components with same rating the cost of components remains the same in both the cases. It is shown in Table.2 as follows.

Table 2: *Cost of Sources available*

SYSTEM	CAPACITY	COST(Rs/yr.)	COST($/yr.)
GENERATOR 1	500kVA	34,58,420	57640
GENERATOR 2	250kVA	12,91,840	21530
GENERATOR 3	250kVA	12,78,024	21300
SOLAR 1	5kW	3,99,840	6664
SOLAR 2	25kW	16,00,000	26666
GRID(EB)	935kW	1,02,45,732	170762
DIESEL	540kW-70l	7,53,768	12562

4.1 Diesel Fed Generator System

The existing system of our institution consists of diesel fed generators, PV systems, batteries and loads. This has been modeled and simulated for cost optimization and sensitivity analysis using micro grid optimization software HOMER as shown in Figure 6.

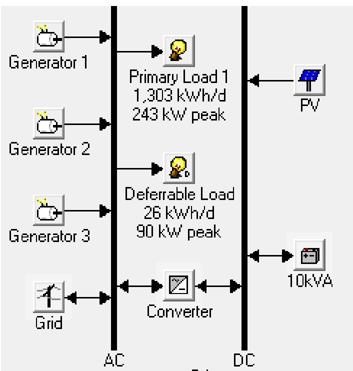


Figure 6: *Existing power system*

4.2. Biogas Fed Generator System

The proposed hybrid energy system, which consists of existing power system with biogas replaced for diesel generators and is shown in figure 7. The proposed system is going to reduce diesel fuel consumption and associated operation and maintenance cost. In this system, PV and grid will be the primary power source and biogas fed generator will be using as a backup for long term storage system and batteries for storage system.

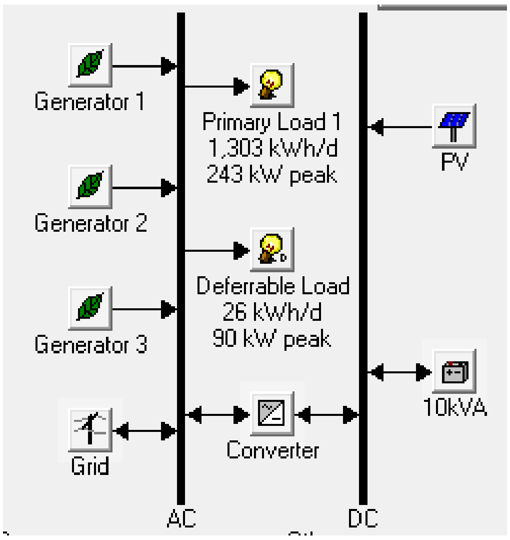
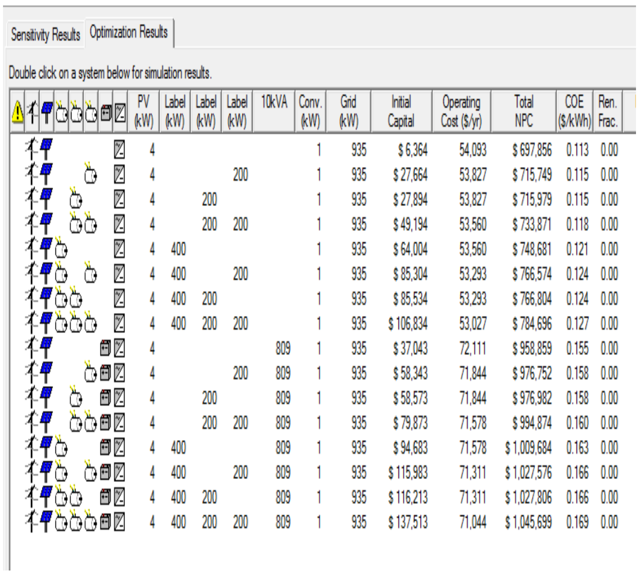


Figure 7: *Proposed power system*

5. RESULTS AND DISCUSSIONS

The cost optimization and unit sizing of hybrid renewable energy system for existing system along with annual electric power production are shown in figure.8 and 9 respectively.



PV (kW)	Label (kW)	Label (kW)	Label (kW)	10kVA	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
4					1	935	$ 6,364	54,093	$ 697,856	0.113	0.00
4			200		1	935	$ 27,664	53,827	$ 715,749	0.115	0.00
4		200			1	935	$ 27,894	53,827	$ 715,979	0.115	0.00
4		200	200		1	935	$ 49,194	53,560	$ 733,871	0.118	0.00
4	400				1	935	$ 64,004	53,560	$ 748,681	0.121	0.00
4	400		200		1	935	$ 85,304	53,293	$ 766,574	0.124	0.00
4	400	200			1	935	$ 85,534	53,293	$ 766,804	0.124	0.00
4	400	200	200		1	935	$ 106,834	53,027	$ 784,696	0.127	0.00
4				809	1	935	$ 37,043	72,111	$ 958,859	0.155	0.00
4			200	809	1	935	$ 58,343	71,844	$ 976,752	0.158	0.00
4		200		809	1	935	$ 58,573	71,844	$ 976,982	0.158	0.00
4		200	200	809	1	935	$ 79,873	71,578	$ 994,874	0.160	0.00
4	400			809	1	935	$ 94,683	71,578	$ 1,009,684	0.163	0.00
4	400		200	809	1	935	$ 115,983	71,311	$ 1,027,576	0.166	0.00
4	400	200		809	1	935	$ 116,213	71,311	$ 1,027,806	0.166	0.00
4	400	200	200	809	1	935	$ 137,513	71,044	$ 1,045,699	0.169	0.00

Figure 8: *Optimized result for Existing System*

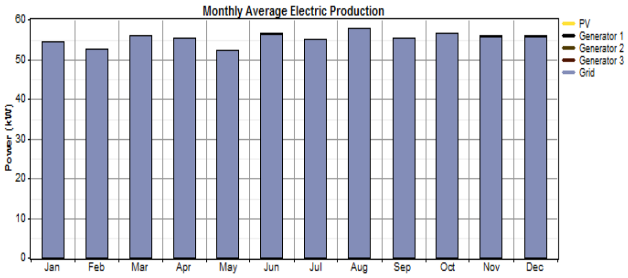
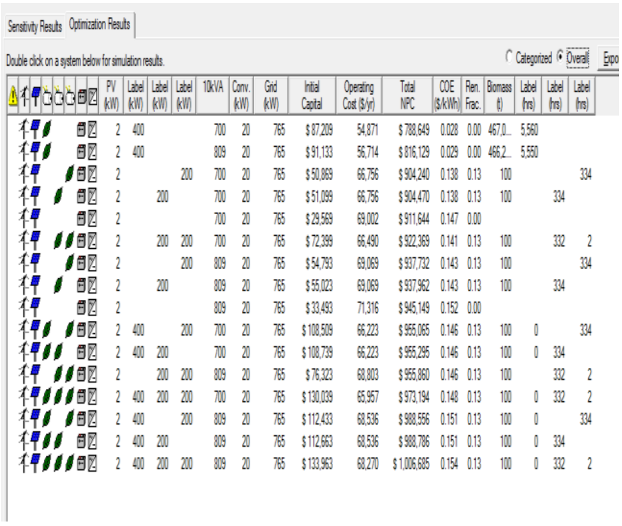


Figure 9: *Monthly average electric production for existing system*

It is well depicted that the cost of production of electricity is about $137513 with all system condition satisfied. And moreover there is larger dependence on grid.

The cost optimization and unit sizing of hybrid renewable energy system for proposed system along with annual electric power production are shown in figure.10 and 11 respectively.



Sensitivity Results Optimization Results

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

PV (kW)	Label (kW)	Label (kW)	Label (kW)	10kVA	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Biomass (t)	Label (hrs)	Label (hrs)	Label (hrs)
2	400			700	20	765	$ 87,209	54,871	$ 788,649	0.028	0.00	467,0...	5,560		
2	400			809	20	765	$ 91,133	56,714	$ 816,129	0.029	0.00	466,2...	5,550		
2			200	700	20	765	$ 50,869	66,756	$ 904,240	0.138	0.13	100			334
2		200		700	20	765	$ 51,099	66,756	$ 904,470	0.138	0.13	100		334	
2				700	20	765	$ 29,569	69,002	$ 911,644	0.147	0.00				
2		200	200	700	20	765	$ 72,399	66,490	$ 922,369	0.141	0.13	100		332	2
2			200	809	20	765	$ 54,793	69,069	$ 937,732	0.143	0.13	100			334
2		200		809	20	765	$ 55,023	69,069	$ 937,962	0.143	0.13	100		334	
2				809	20	765	$ 33,493	71,316	$ 945,149	0.152	0.00				
2	400		200	700	20	765	$ 108,509	66,223	$ 955,065	0.146	0.13	100	0		334
2	400	200		700	20	765	$ 108,739	66,223	$ 955,295	0.146	0.13	100	0	334	
2		200	200	809	20	765	$ 76,323	68,803	$ 955,860	0.146	0.13	100		332	2
2	400	200	200	700	20	765	$ 130,039	65,957	$ 973,194	0.148	0.13	100	0	332	2
2	400		200	809	20	765	$ 112,433	68,536	$ 988,556	0.151	0.13	100	0		334
2	400	200		809	20	765	$ 112,663	68,536	$ 988,786	0.151	0.13	100	0	334	
2	400	200	200	809	20	765	$ 133,963	68,270	$ 1,006,685	0.154	0.13	100	0	332	2

Figure 10: *Optimized result for Proposed System*

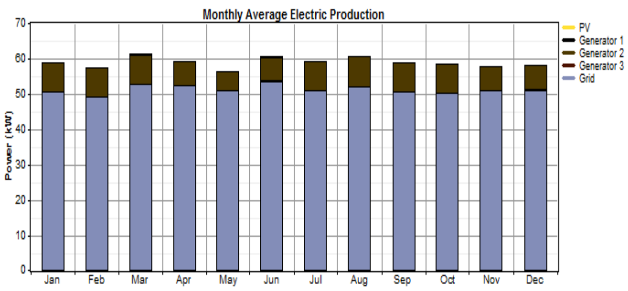


Figure 11: *Monthly average electric production for Proposed System*

It is well depicted that the cost of production of electricity is about $133963 with all system condition satisfied. However the electric production is supported by biogas fed generator system.

6. CONCLUSIONS

The paper compares two different systems for providing uninterruptible power for the institution considered. 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 with generator system replaced with biogas. 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.. Therefore a hybrid renewable energy based system is recommended for the location indicated.

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