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Analysing Techno-Economics on Hybrid Power System to an Educational Institute

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ABSTRACT:The insufficient capacity of the Indian grid has required the use of distributed energy resources for on-site generation. The emergent potential of renewable based electricity generation systems, diversity of storage and various loads are interconnected through the microgrid structure. Alternate energy sources such as biogas may offer a more economic and environmentally-friendly approach to meeting energy demand when compared to fossil –based onsite generation such as the use of gasoline or diesel generators. Hybrid energy systems may also be more beneficial economically and technically. In this paper, micropower modelling and optimization software was used, to determine the optimal configuration of a biogas-based power system for a facility of an institute. A feasible, optimal hybrid configuration for the system was determined, considering biogas, diesel generator and grid under certain constraints. Simulation results presented that the biogas/grid /diesel generator configuration is the most suitable techno-economic configuration for our design. An analysis was also carried out for various factors such as tariff rates, capital cost of solar-PV and biomass. In this paper, the renewable hybrid power generation which is suitable to an institution situated in the state of Andhra Pradesh, India has been discussed. All the details regarding the load of the institute have been collected and the amount of power to be generated by solar PV-bio hybrid system has been calculated accordingly. A feasible, optimal hybrid configuration for the system was determined, considering biogas generation, diesel generation under certain constraints. Simulation results showed that the biogas, diesel generator and grid configuration is the most suitable techno-economic configuration for our design.

KEYWORDS:Rural electrification, Biomass plant, Solar PV plant, Economic considerations, Carbon credits, load details.

I. INTRODUCTION

The failure of India's electric grid to meet the energy demand of the populace has made the integration of alternative energy sources imperative. Onsite generation or microgeneration using gasoline or diesel powered generators is not uncommon among residences and industries as solutions are sought to mitigate the rather erratic and often unavailable power supply. The use of these generators come at huge financial cost, however as the exigency to meet energy demand may result in poor analysis of decisions in terms of cost-benefit. Renewable energy systems have also been used for meeting energy demand especially in areas completely inaccessible to grid (oladi). For instance, more residences and facilities in the country are increasingly taking advantage of the huge solar energy potential in the country by installing PV systems. Small and micro hydro-electric power systems have also been implemented especially for rural electrification. Electric energy from biogas is another alternative source given the availability of biomass resources in the country and this can help meet energy demands. Biogas generators have been used extensively for electrification as in [2] and [3]. However, as with all alternative energy systems, there is a need for a robust viability analysis to minimize risk of system failure and maximize benefit. As an illustration, utilizing hybrid energy systems may help overcome challenges of supply limitations or intermittency faced by a single energy source that is renewable. There is usually need for cost optimization in the design of these systems as some trade-offs may be needed, The need to model and optimize Hybrid energy systems (HES) has resulted in the proliferation of work in that area. A lot of recent work has centred on the use of hybrid/renewable energy design and analysis software such as Hybrid2, HOMER and RET Screen [4]. We also consider the hybridized configurations for our biogas-based system in order to determine

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the most suitable cost-effective system model for meeting energy demand in the facility. The provision of reliable electricity supply systems is among the primary needs for the socio-economic development of a country. Energy has to be conserved in an most efficient manner as it is vital for the progress of a nation. The use of Renewable Energy technology has been steadily increasing so as to meet demand. Most importantly, energy should be produced in the most environment friendly manner by using all varieties of fuels and it should also be efficiently conserved. However, there are some drawbacks associated with renewable energy systems such as poor reliability and lean nature. Biomass is the biological material from living, or recently living organisms. As an energy source, biomass can either be used directly, or converted into other energy products such as biofuel. Biomass (fuelwood, crop residues and cattle dung) accounts for about 40% of India's primary energy use [5]. This world of deteriorating amount of non-renewable resources, the relevance of a biomass gasifier is immense [2]. Power generation from biomass has become a complement to conventional sources of energy due to its contribution to the reduction of greenhouse effect [6]. Biomass ranks fourth as an energy source and, in developing countries. Gasification converts biomass in to a combustible gas mixture of carbon monoxide, hydrogen and methane [6]. It must be noted that gasification is cheaper as well as having considerable efficiency. Hybrid plants will become an increasingly attractive option as the cost of solar thermal falls and feedstock, fossil fuel and land prices continue to rise [7].

II. HOMER

HOMER is micro-power modelling and optimization software which was developed by the National Renewable Energy Laboratory (NREL), U.S. [8]. It instructs several factors such as availability of resources, configurations of the systems and cost, in order to provide optimized solutions which can help guide its users to realize full-bodied designs of energy system as well as make system decisions. Its numerous functionalities consist of; system simulation of energy generation for all the hours of the year by calculating energy balance; optimization i.e. defining optimal system structures based on cost and technical constraints; emission analysis; and sensitivity analysis i.e. determining how the results are affected by dynamic/varying inputs e.g. fuel costs and interest rates[8]. As previously mentioned, HOMER has also been extensively used among scholars and designers of energy systems. In [9], cost-benefit analysis of a PV/Wind/Diesel Hybrid system was done using HOMER. [2] Also uses HOMER for the cost simulation of a standalone, solar and biomass energy system. Having established the suitability of HOMER for the modelling and analysis of energy systems, particularly hybrid configurations, we may then proceed to model our system using HOMER. It should be noted that the HOMER Legacy (version 2.68) was used for the modelling and simulation presented herein.

III. SYTSEM MODELLING

In order to model and analyse the biogas generator configurations for the facility, an energy audit for determining the load profile was carried out in the institute. The average energy consumption per day (kWh/day) is 5200 kWh/day. We considered the following equipment for electricity generation for the proposed system in HOMER; diesel generator, biogas generator, Grid.

A. Diesel Generator

Considering the peak load of 480kW, Diesel generator of 380kW, 500kW is used. Life time of about 15 000 hours for a generator and operation and maintenance (O & M) cost value of \$2.47 per hour were assumed. The price of diesel was set at 0.9 \$/litre. The capital and replacement cost curve for each diesel generator scenario are as shown in Fig 1.

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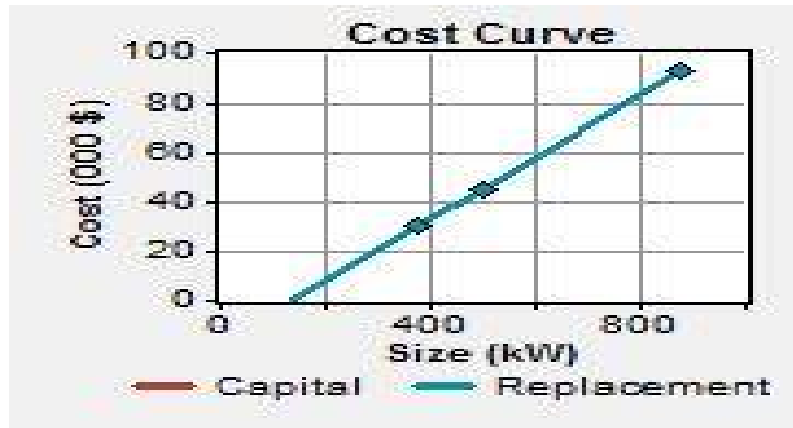


Fig. 1. Diesel Generator Cost Curve

B. Biogas generator/power plant

The biomass resource considered was food waste given the large number of waste at the institute and the average available biomass in tonnes per day is 5 tonnes. Biogas plants are a closed container in which anaerobic fermentation of cellulose containing organic material takes place so as to produce biogas and slurry. There are three basic designs of biogas plant popular in the world. These are the floating-drum type, fixed-dome type and bag digester. The biogas generator cost curve is shown in Fig 2.

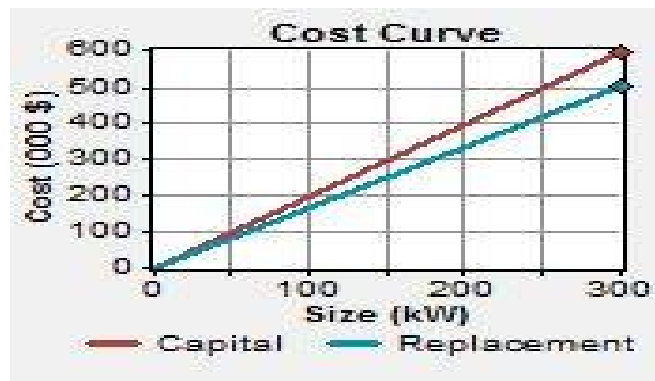


Fig 2 Biogas Generator Cost Curve

C. Converter

In HOMER, the converter equipment is used to model both inverters and rectifiers. As the battery is a DC component, a converter is needed between the AC and DC bus. Converter capital cost was estimated to be \$28046 per kW and replacement cost is same as the capital cost for a 750kW converter. Here, no sensitivity variables are considered.

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D. Economics

The economic factors for HOMER are the annual real interest rate (%), project lifetime, system fixed capital cost, system fixed O&M cost per year, and capacity shortage penalty. The annual real interest rate calculated to be 8% was based on the literature.

IV. SIMULATION RESULTS

In this section, we present the result of the techno-economic analyses using HOMER Legacy 2.68 version. The simulation and analysis produced four different feasible power system configurations having permuted biogas, diesel and battery energy supplies. These configurations in order of lowest to highest Net Present Cost (NPC) are:

1. Biogas + Grid
2. Biogas + Diesel + Grid
3. Diesel + Grid

Among all the configurations, the following 2nd configuration gives the best results. Fig 3 gives the best optimized result.

Configuration	DG (kW)	BGAS (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kWh)	Ren. Frac.	diesel (L)	Biomass (t)	DG (hrs)	BGAS (hrs)
1				700	\$ 0	259,654	\$ 2,771,748	0.138	0.00				
2		300		700	\$ 594,260	251,056	\$ 3,274,232	0.163	0.01		35		75
3	380			700	\$ 33,266	304,768	\$ 3,286,591	0.163	0.00	64,554		1,096	
4	500			700	\$ 48,224	319,215	\$ 3,455,770	0.172	0.00	84,940		1,096	
5	380	300		700	\$ 624,175	296,170	\$ 3,785,724	0.188	0.01	64,554	35	1,096	75
6	500	300		700	\$ 639,133	310,623	\$ 3,954,960	0.196	0.01	84,940	35	1,096	75
7	880			700	\$ 95,591	364,962	\$ 3,991,477	0.198	0.00	149,494		1,096	
8	880	300		700	\$ 686,500	356,370	\$ 4,490,667	0.223	0.01	149,494	35	1,096	75

Fig 3: Optimised result of the 3rd configuration

From fig 3 it can be understood that 5th result the optimised result. Here we analysed some so many parameters to optimize the result. The monthly average production of the optimised result is shows in fig 4.

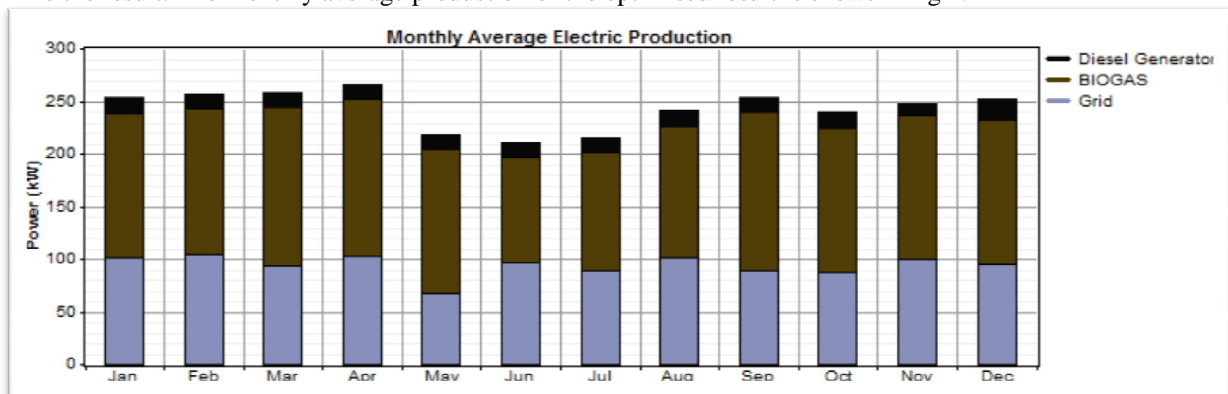


Fig 4 Monthly average electric productions

From fig 4 it can be understood that in September grid generate more electricity production than the other months. The details of the electrical production and consumption are shown in Table 1.

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Table 1: Electrical simulation results

	Parameter	kWh/yr	%
Production	Diesel Generator	1,24,944	7
	BIOGAS	22,500	1
	Grid purchases	17,41,778	92
	Total	18,89,222	100
Consumption	AC primary load	18,86,683	100
	Grid sales	2,547	0
	Total	18,89,231	100

From Table 1 it shows that total production is 1889222 kWh/yr. and the total consumption is 1889231 kWh/yr. The details of diesel generator are shown in Table 2.

Table 2: Diesel Generator simulation results

Quantity	Value	Units
Hours of operation	1,096	hr/yr
Number of starts	1,034	starts/yr
Operational life	13.7	yr
Capacity factor	3.75	%
Fixed generation cost	30.2	\$/hr
Marginal generation cost	0.225	\$/kWh
Electrical production	1,24,944	kWh/yr
Mean electrical output	114	kW
Min. electrical output	114	kW
Max. electrical output	114	kW
Fuel consumption	64,554	L/yr
Specific fuel consumption	0.517	L/kWh
Fuel energy input	4,24,333	kWh/yr
Mean electrical efficiency	29.4	%

From Table 2 it can be understood that the total electrical production is 124944 kWh/yr and the fuel consumption is 64554 L/yr. The Biogas production is shown in the Table 3.

Table 3: Biogas simulation results

Quantity	Value	Units
Hours of operation	3,923	hr/yr
Number of starts	852	starts/yr
Operational life	3.82	yr
Capacity factor	44.8	%
Fixed generation cost	33.5	\$/hr
Marginal generation cost	0.125	\$/kWh
Electrical production	11,76,900	kWh/yr
Mean electrical output	300	kW
Min. electrical output	300	kW
Max. electrical output	300	kW
Bio. feedstock consumption	1,816	t/yr
Specific fuel consumption	1.08	kg/kWh
Fuel energy input	19,41,885	kWh/yr
Mean electrical efficiency	60.6	%

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From Table 3 it has been observed that the total electrical production of the biogas power plant is 1176900 kWh/yr. Bio feedstock consumption is 1816 tonn/yr. It is worth mentioning that the marginal generation cost is 0 kWh/yr. The details of the grid are shown in Table 4.

Table 4: Grid simulation results

Month	Energy purchased (kWh)	Energy sold (kWh)	Net Purchases (kWh)	Peak Demand (kW)	Energy Charge (\$)	Demand Charge (\$)
Jan	1,55,779	100	1,55,678	433	17,922	3,555
Feb	1,43,541	90	1,43,451	442	16,515	3,626
Mar	1,54,545	324	1,54,220	463	17,665	3,673
Apr	1,57,703	455	1,57,248	486	18,011	3,876
May	1,27,580	119	1,27,461	382	14,689	3,123
Jun	1,23,418	116	1,23,302	333	14,188	2,897
Jul	1,26,698	175	1,26,523	305	14,604	2,866
Aug	1,54,491	240	1,54,251	375	17,915	3,476
Sep	1,60,519	213	1,60,306	364	18,687	3,792
Oct	1,40,752	337	1,40,415	501	16,116	3,610
Nov	1,49,303	85	1,49,217	431	17,180	3,584
Dec	1,47,449	293	1,47,156	492	16,896	3,775
Annual	17,41,778	2,547	17,39,230	501	2,00,389	41,851

From Table 4 it can be understood that the total energy consumption in an year is 171778 kWh. Among all the months, the September month energy consumption was maximum comparing all the months. The total net purchases are 1739230 kWh/yr. The emissions of the optimized configuration are given in Table 5.

Table 5: Emissions simulation results

Pollutant	Emissions (kg/yr)
Carbon dioxide	11,97,387
Carbon monoxide	420
Unburned hydrocarbons	46.5
Particulate matter	31.6
Sulphur dioxide	4,978
Nitrogen oxides	6,077

From Table 5 it can be understood that the emissions are less when compared to the other.

V. CONCLUSION

In this paper, techno economic analysis has been done on three different systems to an educational institution and optimized one configuration among those and conducted all analysis on the optimized result for the optimized configuration. Here, we analysed the biogas system configuration along with grid and the diesel generator. So, the optimized configuration is diesel generator/biogas/grid.

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