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Solar-Biomass-CAES Hybrid System: Proposal for Rural Commercial Electrification in Bangladesh

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ABSTRACT: Energy is one of the essential requirements to alleviate poverty and socioeconomic advancement. Most of the rural area is not under the national grid; therefore, electrification in rural area is the crying need of Bangladesh. Government of the People's Republic of Bangladesh has issued its vision to bring the entire country under electricity service by the year 2030. The reserve of fossil fuel is diminishing; also the price of fuel is increasing throughout the world. Environmental pollution is another important issue. Green energy is current demand for the existence of future world. For that reason, reducing carbon emission and meeting energy demands are the main topologies to plan energy systems. As Bangladesh is an agricultural based country, biomass resources are available here and there is also good prospect of solar energy. Now-a-days CAES (Compressed Air Energy Storage) is another potential resource in the world. In this paper, a solar-biomass-CAES hybrid system is proposed for electrification of rural area in Bangladesh.

KEYWORDS: Solar PV, Biomass, CAES, Hybrid System, Gasification, HOMER, Power Generation.

1 INTRODUCTION

Electricity is a very important factor in developing the economy and the standard of living of a country. It must be generated using the national resource of that country [2]. Bangladesh is suffering from energy crisis for long many years. The main source of energy generation of Bangladesh is natural gas. 81.4% of the total electricity generation from the installed capacity is accounted by this source of energy. The country lags behind than its expected production capacity. The way the energy consumption is increasing (10% annually), the reserved natural gas of Bangladesh will not last more than 15/ 20 years. [3]Though many power generation units have been added to the national grid to solve the power crisis issue, it is not enough. High demand and increasing need of power have created challenge for the power stations to meet the demand. In our country, a major portion of total population still does not have the access to electricity. More than 75% of total population lives in rural area in Bangladesh. Bangladesh has lack of grid Network and electric generation to satisfy the demand of 100% electrification (Uddin and Taplin, 2006). Only 31.2% of the total population is connected to grid capacity (about 80% of urban and 23% of rural households) with vast majority being deprived of a power supply (BBS, 2000, 2008). Only 10% of the rural households have electricity connection and there are some parts of Bangladesh which will not get the access of electricity connection from the national grid within next 30 years [1]. So, there is no possibility to do any commercial electrification in rural areas. To solve this energy crisis we can use different form of renewable energy to generate power. In this paper, we consider a commercial Resort which is located in a remote area of Gazipur district, Kaliakair upazilla for commercial electrification. The particular area that we desire to electrify is a remote area located at 23 degree latitude and 90 degree longitude. [5][6] In this paper we tried to develop an optimal system from the practical view point. This paper focuses on contribution of Renewable Energy Technologies (RETs) & Hybrid system using this Renewable Energies in the rural development.

In this paper we use simulation software named HOMER (Hybrid Optimization Model for Electric Renewable) for finding out the best possible outcome & combination for the system where cost minimization gets priority. At first we pick our desired resources (Solar cell, Bio-fuel& CAES) & complete the combination & load Calculation for entire population of a rural area corresponding to summer and winter season. Working module and raw data from embedded HOMER database are set in the application and our module is ready for analysis. [7] Here we also compare with Diesel Generator instead of CAES in this proposed hybrid system.

2 HOMER TECHNOLOGY

Homer micro power optimization software is a computer model that was developed by National renewable energy laboratory (NREL) in the U.S.A. One of the major applications of HOMER is the design of micro power systems for the efficient evaluation of various renewable energy power generation technologies. It compares a wide range of equipment with different constraints and sensitivities to optimize the system design. In the early phases of planning and decision making in rural electrification projects, HOMER can be of significant use for the designing of the system due to its flexibility. Its analysis is based on the technical properties and the Life cycle cost (LCC) of the system. The LCC is comprised of the initial capital cost, cost of installation and operation costs over the system's life span.

The user can input varying data and compare different designs based on their technical and economic factors. HOMER also considers the effects of uncertainty in its modeling. It allows modeling of grid-connected or off-grid systems, generating electricity and heat from various combinations of PV Modules, Wind turbines, biomass based power generation, micro-turbines, fuel cells, batteries, hydrogen storage, and generators with various fuel options.

Designing a micro power system with various design options and uncertainty issues to obtain optimal performance is a challenge. HOMER was designed to overcome these challenges and also the complexity of the RES (Renewable energy source) being intermittent, seasonal, non dispatch able and having uncertain of availability. Simulation, Optimization and Sensitivity analysis are the three major actions run by HOMER. In the simulation process, different micro power system configurations for every hour of the year are generated with their technical feasibility and LCC. In the optimization process, HOMER selects one system configuration out of all configurations generated in the simulation process that satisfies all technical constraints and has the lowest LCC.

In the sensitivity analysis, multiple optimizations are performed on the selected configurations by HOMER with a range of uncertain input parameters that are assumed to affect the model inputs with time. For the different variables known to the system designer that is, the mix of system components and their respective quantity and size - the optimization process allows to calculate the optimal value. There are, however, also unknown factors such as uncertainties or changes in the variables outside the designer's control (for example, rises in the fuel price or changes in brightness factor etc). The effects of these can be analyzed with the help of the sensitivity analysis. One of the results of HOMER's simulation is the Economical Distance Limit (EDL) in kilometers, where creating a renewable stand-alone/mini-grid system is cost-competitive with a grid extension. HOMER has advantages over the usual statistical models, since its high processing speed allows it to run and evaluate an hourly simulation of thousands of possible system configurations, whereas statistical models usually only compare the average monthly performance of the configurations. Simulations modeled by HOMER are thus more accurate [7].

2.1 SOLAR-BIOMASS-CAES HYBRID SYSTEM

In this analysis, we have designed the hybrid renewable system with biogas generator and CAES generator. Here, solar photovoltaic panel is used as renewable resource and biogas is produced from biomass sources. CAES is considered a hybrid generation/storage system because of the use of natural gas as fuel in the process. However, the natural gas input is much lower than with a conventional gas turbine. The hybrid system consists of electric loads, solar resources, Biomass resources, CAES resources and components such as PV, generator, Battery, and converter. Figure-1 shows the Hybrid energy renewable system.

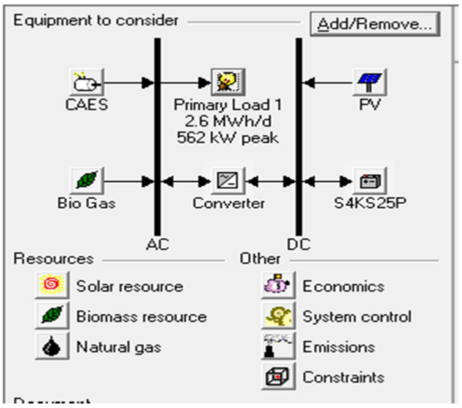

Fig. 1. Hybrid modeling configuration using HOMER

3 HYBRID SYSTEM METHODOLOGY

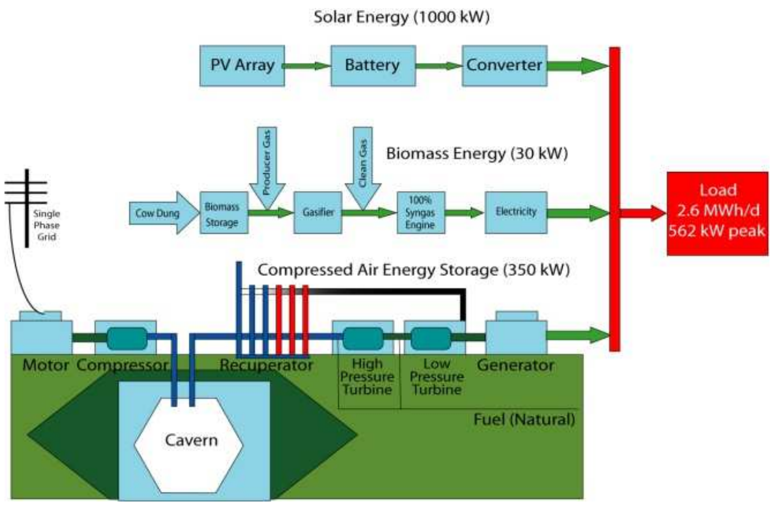

Fig. 2. Hybrid System 3D modeling

- In this research, 1000 kW solar photovoltaic is used with biogas and CAES generation for the establishment of a hybrid system. The sun shines on the solar panels generating DC electricity, with the help of Surrette 4KS25P storage batteries we store this DC electricity. Converter converts the dc power to ac power. As, most of the home appliances are operated in ac, dc generation from the PV array is converted to ac following through a controller. In this, proposed system, 1000 kW converters are considered for optimum solution.
- Here we used 30kW Biomass Energy for electricity Generation. Power generation by using cow dung consist of several process steps, which are shown in figure 2. First, cow dung is stored in biogas digester and produced gas in gasification process in cleaned and supplied it to syngas engine to produce electricity.
- CAES stores energy by using off-peak electricity to power a motor, which drives a compressor that compresses air into an underground reservoir. Energy is recaptured by expanding the compressed air through a high pressure air turbine (not a gas turbine), then mixing the exhaust from the high pressure turbine with natural gas, and finally firing the mixture in a low pressure natural gas turbine. Waste heat from the exit of the low pressure turbine is passed through a heat exchanger as the air comes out of the reservoir to preheat the compressed air and improve efficiency. The high pressure air turbine reduces technical risk by dropping the pressure of the air before mixing it with fuel, and without it the pressure in the cavern would have to be reduced to allow the low pressure gas turbine to operate reliably. In this research CAES we used only in peak hour its April to October.

In this research, we also used Solar-Biomass-diesel generator hybrid system instead of Solar-Biomass- CAES system for comparing the results by using Homer.

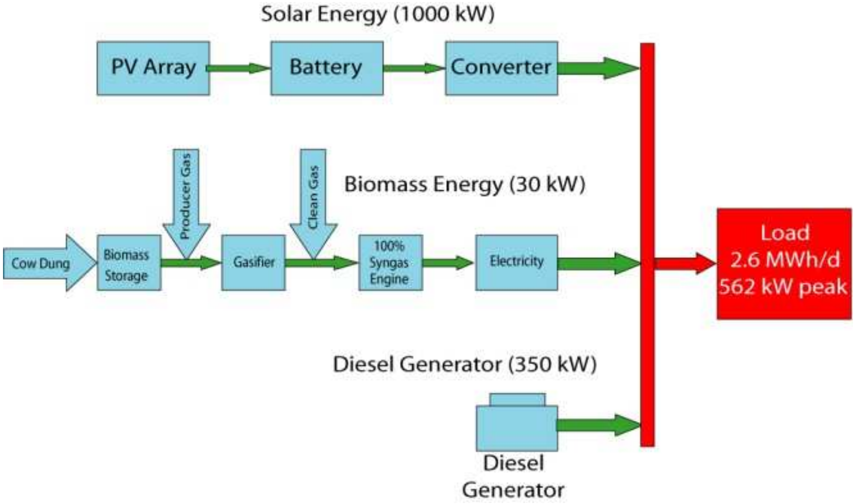

Fig. 3. Hybrid System with Diesel Generator

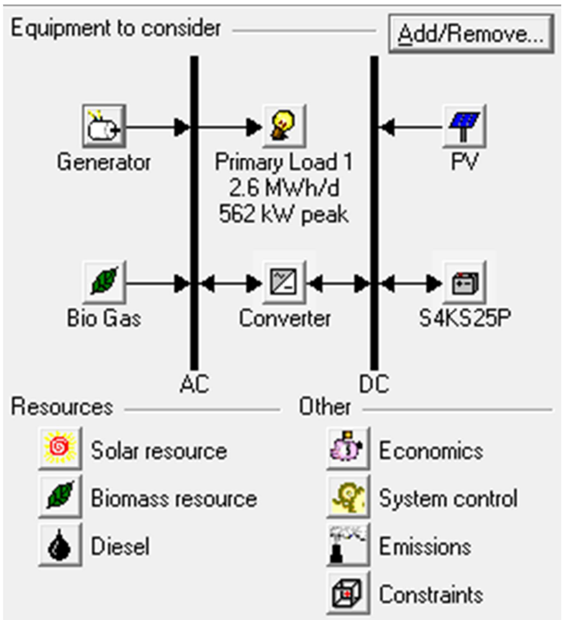

Fig. 4. Hybrid System with Diesel Generator using HOMER

3.1 SOLAR RESOURCES

Bangladesh has good prospects of solar photovoltaic generation. The average isolation in Bangladesh is 4.64kWh/m2/day. In this analysis, monthly average global radiation data has been taken from NASA (National Aeronautics and Space Administration) to estimate the generation of solar system. Solar data at Gazipur (Latitude: 23, Longitude: 90) in Bangladesh is presented graphically by using HOMER software in Figure 5. Homer use the solar resources input to calculate the PV array power. And, the synthesized data is obtained by putting the longitudinal and latitudinal value in HOMER software.

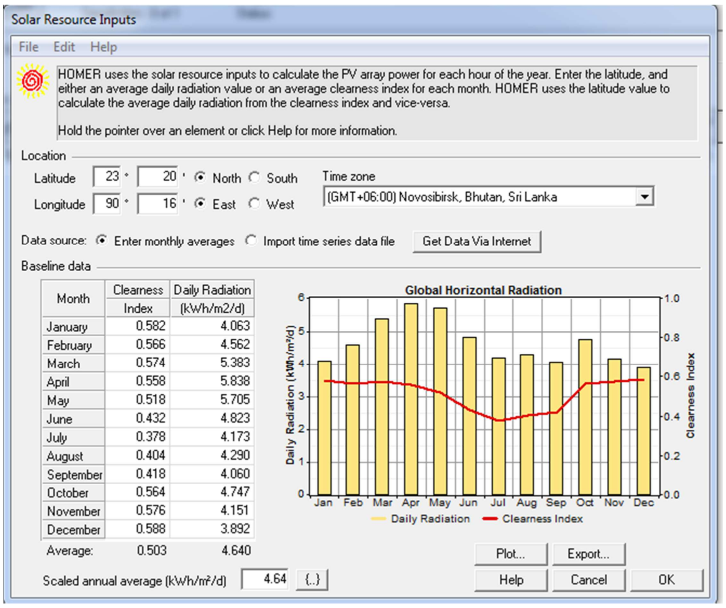

Fig. 5. Solar Resource Inputs at HOMER

3.2 BIOMASS RESOURCES

Biomass is the oldest source of energy known to humans. The term biomass encompasses a large variety of materials, including wood from various resources, agricultural residues, and animal and human waste. Bangladesh is an agree-based country and main sources of biomass are agricultural residues. And in villages, mainly in Barisal, cow is still utilized for plowing land and farming. So, animal dung is available in resourceful amount.

Biomass contains stored energy. That's because plants absorb energy from the sun through the process of photosynthesis. When biomass is burned, this stored energy is released as heat.

Many different kinds of biomass, such as wood chips, corn, and some types of garbage, are used to produce electricity. Some types of biomass can be converted into liquid fuels called bio fuels that can power cars, trucks, and tractors. Leftover food products like vegetable oils and animal fats can create biodiesel, while corn, sugarcane, and other plants can be fermented to produce ethanol.

More than 25000 bio gas plants are already set up in Bangladesh and they are mainly family sized and used only for cooking purposes. But, we need to focus to use this biomass energy for rural electrification. And that will be helpful for our economic advancement.

Theoretically, biogas can be converted directly into electricity using a fuel cell. In most cases, biogas is used as fuel for combustion engines, which convert it to mechanical energy, powering an electric generator to produce electricity.

Appropriate electric generators are available in virtually all countries and in all sizes. The technology is well known and maintenance is simple. In most cases, even universally available 3- phase electric motors can be converted into generators.

Gas turbines are occasionally used as biogas engines, especially in the US. They are very small and can meet strict exhaust emissions requirements. Small biogas turbines with power outputs are available on the market, but are rarely used for small-scale applications in developing countries as they are expensive. Furthermore, due to their spinning at very high speeds and the high operating temperatures, the design and manufacturing of gas turbines is challenging and maintenance requires specific skills.

External combustion engines such as Stirling motors have the advantage of being tolerant of fuel composition and quality. They are, however, relatively expensive and characterized by low efficiency. Their use is therefore limited to a number of very specific applications. In most commercially run biogas power plants today, internal combustion motors have become the standard technology either as gas or diesel motors.

ENERGY GENERATION BY USING COW DUNG

Several types of gasifier e.g. fixed bed updraft and downdraft gasifier, fluidized bed gasifier and bubbling bed gasifier are available in the existing market with different sets of pros and cons. However, the downdraft gasifier is a comparatively cheap and gasification in this type of gasifier can produce a product gas with very low tar current [14].

All the collected cow dung is fed into an anaerobic digester. The digester is built to hold 21 days of farm waste. Bacteria convert the waste into various products, one of which is methane gas. Gas produced by the bacteria builds up the pressure in the concrete vessel, and a pipe delivers the biogas to a modified natural gas engine.

The biogas fuels the engine, which in turn spins an electric generator to create electricity. Waste heat from the engine is used to keep the digester warm and offsets fuel purchase on the farm.

One cow's waste can produce enough electricity to light two 100-watt light bulbs for 24 hours a day. The energy is fed onto the electrical system for distribution to customers. Cow dung gas is 55-65% methane, 30-35% carbon dioxide, with some hydrogen, nitrogen and other traces. Its heating value is around 600 B.T.U. per cubic foot. Cow dung slurry is composed of 1.8-2.4% nitrogen (N_2), 1.0-1.2% phosphorus (P_2O_5), 0.6-0.8% potassium (K_2O) and 50-75% organic humus.

About one cubic foot of gas may be generated from one pound of cow manure at around 28°C.

This is enough gas to cook a day’s meals for 4-6 people in Bangladesh. About 1.7 cubic meters of biogas equals one liter of gasoline. The manure produced by one cow in one year can be converted to methane, which is the equivalent of over 200 liters of gasoline.

Gas engines require about 0.5 m^3 of methane per horsepower per hour. Some care must be taken with the lubrication of engines using solely biogas due to the “dry” nature of the fuel and some residual hydrogen sulphide; otherwise these are a simple conversion of a gasoline engine.

Power generation by using cow dung consist of several process steps, which are shown in figure 6. First, cow dung is stored in biogas digester and produced gas in gasification process in cleaned and supplied it to syngas engine to produce electricity.

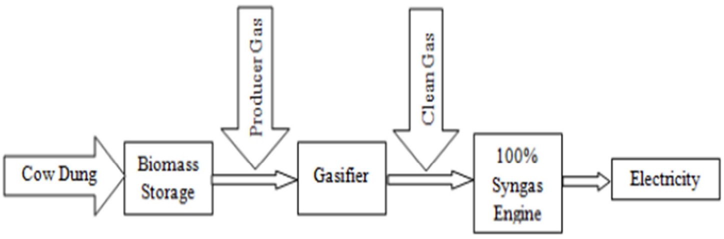

Fig. 6. Electricity Generation by cow dung gasification

3.3 COMPRESSED AIR ENERGY STORAGE

Compressed Air Energy Storage is a mature energy storage technology that has existed for nearly 30 years. There are currently two CAES plants operating in the world; one in Huntorf, Germany, which open in 1978, and the other in McIntosh, Alabama, which opened in 1991. These facilities are both used for peak shaving and load following, but could be used for wind integration as well. The Huntorf facility is a 290 MW facility, but only has the reservoir capacity to generate for 2-3 hours per cycle. The McIntosh facility can is a 110 MW facility with a reservoir capacity of 19 million cubic feet, which allows it to generate for 26 hours per charge [4]. Additional facilities are under development. A large CAES facility (2700 MW) is planned in Norton, Ohio [4], but economics have stalled this project for several years. The Iowa Stored Energy Park is developing a CAES plant, with plans to integrate it with a wind energy project as well [4].

CAES stores energy by using off-peak electricity to power a motor, which drives a compressor that compresses air into an underground reservoir. Energy is recaptured by expanding the compressed air through a high pressure air turbine (not a gas turbine), then mixing the exhaust from the high pressure turbine with natural gas, and finally firing the mixture in a low pressure natural gas turbine. Waste heat from the exit of the low pressure turbine is passed through a heat exchanger as the air comes out of the reservoir to preheat the compressed air and improve efficiency. The high pressure air turbine reduces technical risk by dropping the pressure of the air before mixing it with fuel, and without it the pressure in the cavern would have to be reduced to allow the low pressure gas turbine to operate reliably [4].

CAES is considered a hybrid generation/storage system because of the use of natural gas as fuel in the process. However, the natural gas input is much lower than with a conventional gas turbine. CAES requires approximately 0.7-0.8 kWh off-peak electricity and 4100-4500 Btu (1.2-1.3 kWh) natural gas to produce one kWh of dispatchable electricity [4]. This compares with a heat rate of roughly 11,000 Btu/kWh for conventional natural gas turbines. A generic diagram of how CAES works is shown in figure 7.

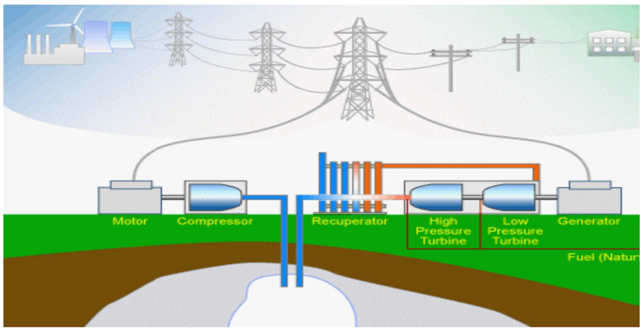

Fig. 7. Generic diagram of CAES operation

4 Electric Load

A Resort has been chosen for the case study which is situated at Kaliakair Upazilla Gazipur District, Bangladesh. The Resort has 100 rooms, one Restaurant, 3 motor pumps, 2 water treatment pumps and 400 hundred road lamp. Below the total loads are given separately:

Table 1. 100 Rooms Load

S.N.	Items	Load (KW)	Quantity	Total load (KW)
1	A/C	3	100	300
2	Light	0.015	500	7.5
3	Fan	0.1	100	10
4	Geyser	2	100	200
5	Socket	1.1	100	110
6	TV	0.07	100	7
7	Intercom	0.07	100	7
			Total	**641**

Table 2. Restaurant's Load

S.N.	Items	Load (KW)	Quantity	Total load (KW)
1	A/C	3	10	30
2	Light	0.015	100	1.5
3	Refrigerator	1.2	5	6
4	Geyser	2	1	2
5	Socket	1.1	5	5.5
6	Micro oven	1	2	2
7	Intercom	0.07	1	0.07
			Total	**47.07**

Table 3. Motor's Load

S.N.	Items	Load (HP)	Quantity	Total load (HP)
1	Motor Pump	7	3	21
2	Water Treatment pump	10	2	20
			Total	**41**

Table 4. Road Lamp's Load

S.N.	Items	Load (KW)	Quantity	Total load (KW)
1	Lamp	0.005	400	2

Total Load of the Resort

= (641+47.07+41*746+2) KW

= 720.656 KW

Here Fig-8 presents the daily load from April to October and Fig-9 contains the daily load profile from November to March. Fig-10 contains the monthly load profile of the Resort. From the monthly load profile we find that the peak load of Resort is 562 KW and average load is 110 KW.

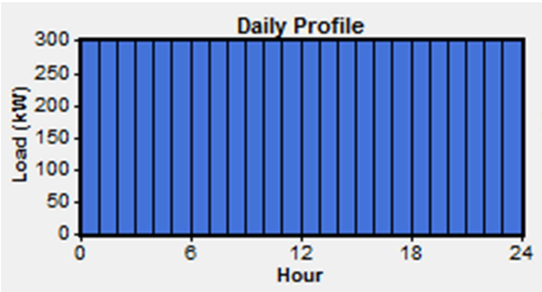

Fig. 8. Load Profile of a day (April-October)

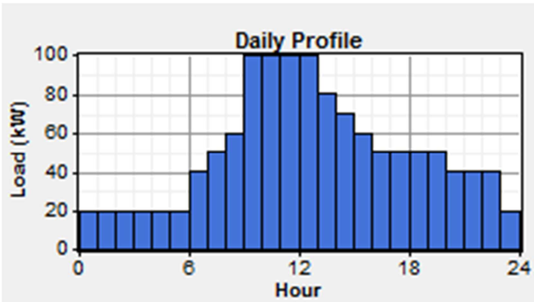

Fig. 9. Load Profile of a day (November-March)

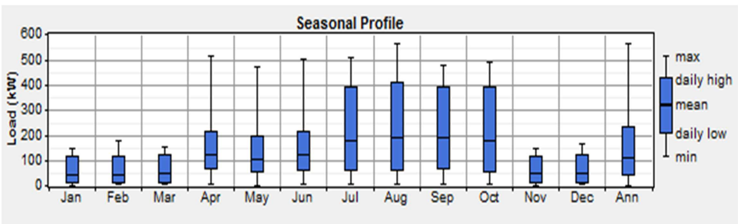

Fig. 10. Monthly Load Profile

5 System Components

In this analysis, the major components are PV panels, Biogas disaster, bio fuel generators, CAES generator, batteries and Converter. For economic analysis, the number of units to be used, capital cost, replacement and O&M costs and operating hours to be defined in HOMER in order to simulate the system.

5.1 SOLAR PHOTOVOLTAIC

Sun rays are available with prosperity in Gazipur, Bangladesh. Lots of solar home system has been installed. But, there is no set up yet established for off grid networking. In this research, solar photovoltaic is used with biogas and CAES generation for the establishment of a hybrid system. Solar system cost consists of cost with cables and charge controllers. It's known to me by analyzing present market; cost of PV panel with set up cost Tk. 96,000 for 1 kW generation. Various costs are represented in Table 5 and cost is considered in BDT. Life time has been taken 20 years and 1000 kW PV modules are considered.

Table 5. PV cost assumption and technical parameters

Parameter	Unit	Value
Capital Cost	BDT/W	96
Replacement Cost	BDT/W	96
Operating & Maintenance Cost	BDT/W	104
Lifetime	Years	20
Derating factor	Percent	80
Slope	Degree	25.33
Tracking System	No Tracking System	0.05

5.2 BIOMASS GENERATOR:

In this research, one set of 30 kW biomass generators are considered to find out the most cost effective system. The main reason of using to fulfill the energy demand in peak hour both for winter and summer season and also meet the terms of backup requirements. As biomass resource is available in prosperity, fuel cost is considered zero. The main cost is considered for biogas generation procedure and biogas power generator. . To produce 1KW electricity from biomass,

$1200 is required including plant cost and generator cost, i.e. about BDT 28800000 is required in this purpose [15]. Digester lifetime is considered for 8 years and fuel curve slope and intercept are taken as 0.05 and 0.33 respectively [16]. Different costs and parameters are given in Table 6.

Table 6. Cost and parameter of Biogas generator

Parameter	Unit	Value
Capital Cost	BDT/KW	96000
Replacement Cost	BDT/KW	67200
Operating & Maintenance Cost	BDT/KW	0
Lifetime	Hours	35000
Load factor	Percent	15

5.3 BATTERY

Batteries are used to store the solar photovoltaic output. In rural area like our proposed are, where most of the power is used after day time. So, main target of our system is to store energy at day time and discharge the stored energy after evening. So, batteries are used following through charge controller. Also, a dump load is used for the purpose of removing excess charge and preventing system damage. In this system, the Surrette 4KS25P storage batteries are utilized [17]. The specifications and different costs of batteries are shown in Table 7.

Table 7. Battery cost assumption and technical parameters

Parameter	Unit	Value
Nominal Voltage	Volt	4
Nominal Capacity	Ah(kwh)	1900(7.6)
Maximum Charge Current	A	67.5
Round-trip efficiency	Percent	80
Minimum State of Charge	Percent	40
Capital Cost	BDT/kwh	12000
Replacement Cost	BDT/kwh	8000
Operation &Maintenance Cost	BDT/kwh/yr	50

5.4 CONVERTER

Converter converts the dc power to ac power. As, most of the home appliances are operated in ac, dc generation from the PV array is converted to ac following through a controller. In this, proposed system, 1000 kW converters are considered for optimum solution. The details of converter cost assumption and different parameters are given in Table 8.

Table 8. Converter cost assumption and technical parameters

Parameter	Unit	Value
Capital Cost	BDT/KW	1600
Replacement Cost	BDT/KW	1200
Life time	Years	20
Efficiency	Percent	90
Rectifier Capacity	Percent	95
Rectifier Efficiency	Percent	85

5.5 CAES GENERATOR

In this research, one set of 350 kW CAES generators are considered to find out the most cost effective system. The main reason using CAES to fulfill the energy demand in peak hour at summer season and also meet the terms of backup requirements. As CAES resource is available in prosperity, fuel cost is considered 19.2 BDT/m^3. The main cost is considered for CAES cavern establishment and gas generator. To produce 1KW electricity from CAES,$245000 is required including plant cost and generator cost, i.e. about BDT 19600000 is required in this purpose [4].

Table 9. CAES cost assumption and technical parameters

Parameter	Unit	Value
Capital Cost	BDT/KW	56000
Replacement Cost	BDT/KW	56000
Life time	Hours	1500
Natural Gas Cost	BDT/m^3	19.2

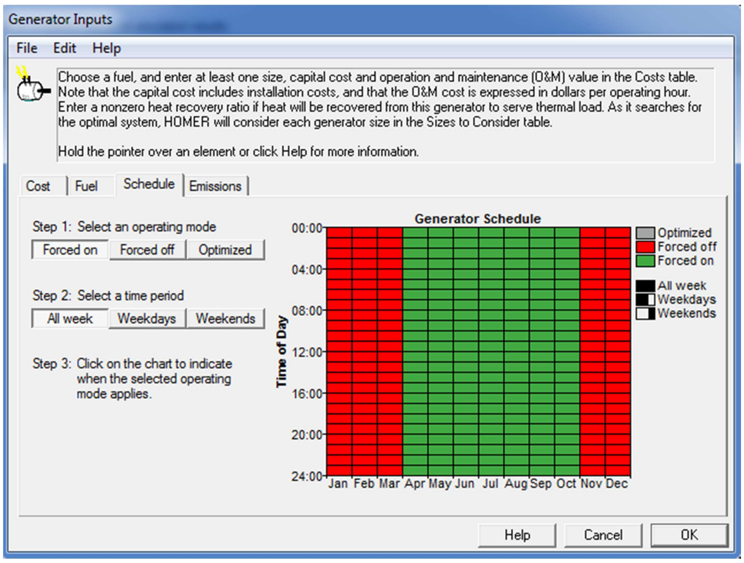

Fig. 11. Scheduling of CAES generator at peak hours

5.6 Diesel Generator

In this research, one set of 350 kW Diesel generator are considered for comparing with CAES generator to find out the most cost effective system. The diesel generator will use in peak hours and also meet the terms of backup requirements. Different costs and parameters are given in Table 10 .

Table 10. Cost and parameter of Diesel generator

Parameter	Unit	Value
Capital Cost	BDT/KW	15200
Replacement Cost	BDT/KW	15200
Operating & Maintenance Cost	BDT/KW	8.2
Lifetime	Hours	15000
Fuel Cost	BDT/L	64

6 Results & Discussion

The amount of the storage of the conventional energy sources is decreasing day by day. To support these conventional sources, renewable energy sources are being incorporated to ensure continuous power supply and a green sustainable world. In this study, an attempt has been taken to model a renewable energy generation system hybridized without the power grid connection which will be cost effective and optimized.

It is the main target to get the hybrid energy generation model which costs the least per kWh or costs least NPC. After thousands of simulations, HOMER shows the hybrid configurations with respect to net present cost and cost/kWh.

6.1 Analysis of the model where energy is supplied by CAES, PV, Biogas

The optimal system performance analysis has been carried out by using HOMER software. The optimized result is calculated for specific solar irradiation 4.64 kWh/m^2/d. The hybrid system encompass of 1000 kW PV array, One 30 kW Biogas generator, one 350 kW CAES gas generator and 200 storage batteries with 1000 kW converter is economically more feasible with a total net present cost (NPC) $ 5,518,358 and minimum cost of energy (COE) of tk 35.92/kW ($ 0.449). Optimized result is represented in figure 12. (1$ = BDT 80tk)

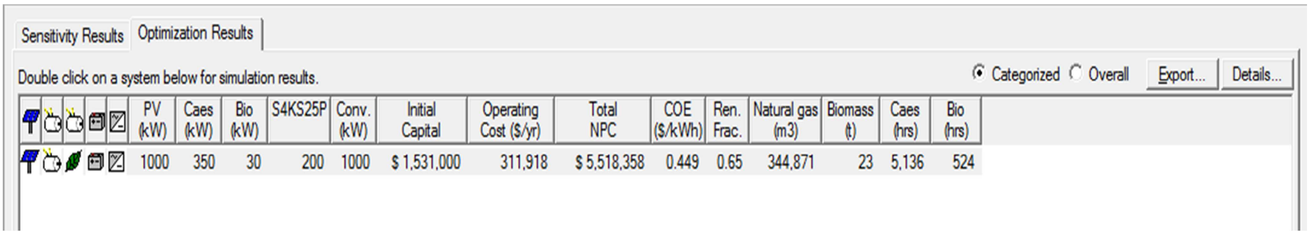

Fig. 12.   Optimization result from HOMER

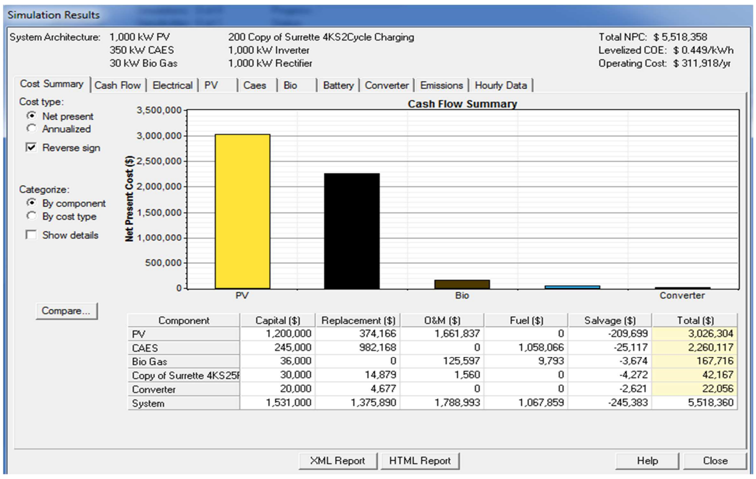

Fig. 13.   Cost Summary from HOMER

From the figure 13 we find the cost summary of our proposed hybrid system. Here, we find that the capital cost of this project is $ 1,531,000, Replacement cost $ 1,375,890, operation and maintenance cost $ 1,788,993, fuel cost $ 1,067,859.

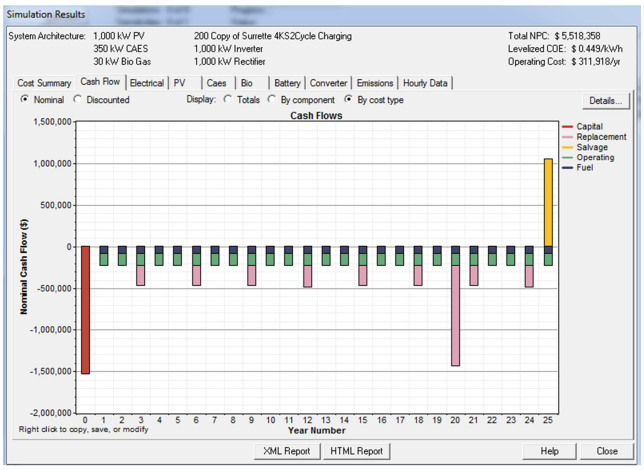

Fig. 14.   Cash flow summery of hybrid system at HOMER

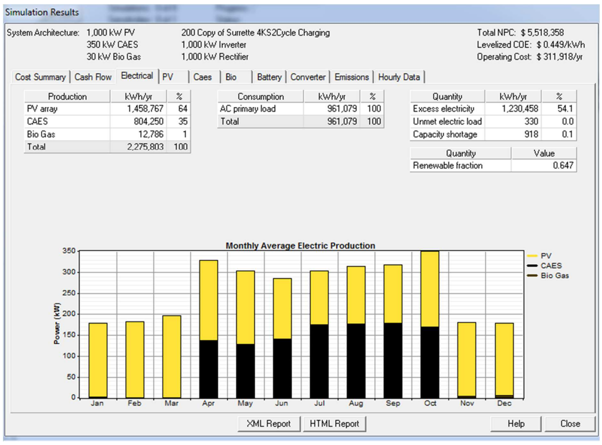

Fig. 15. Electrical Summary from HOMER

From the electrical summary we find that 64% electricity of this commercial resort project is comes from PV array, 35% from CAES and 1% from Bio gas. From the summary we can say that this proposed hybrid system can fulfill our demand that the resort need for commercial uses.

Here, after fulfilling all the demand in this project we have excess electricity which will we used for operating the compressor motor of CAES.

From the figure 16 we find the hourly data curves of Electrical load, CAES, Bio gas generator, PV array. Here, we find that CAES is using April to October when the electrical demand is high and all the year PV is using for fulfill the electrical demand according the production of electricity. Here, Bio gas generator is using for backup electrification, when CAES and PV array electrical production is not sufficient for the demand than the bio gas is using for electrical production.

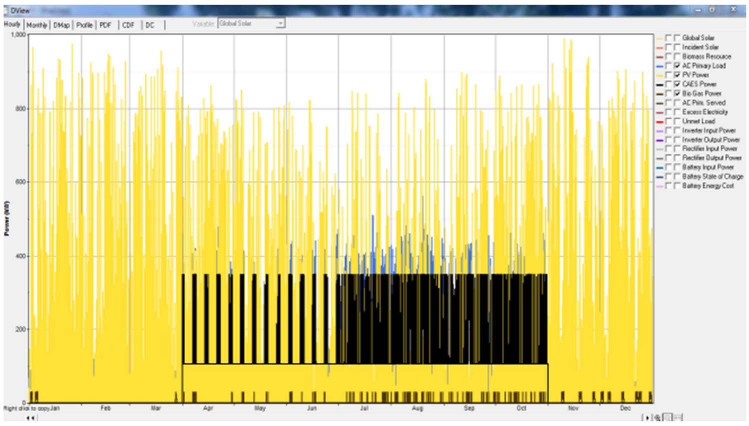

Fig. 16. Hourly Data from HOMER

6.2 Analysis of the model where energy is supplied by Diesel Generator, PV, Biogas Generator:

The optimal system performance analysis has been carried out by using HOMER software. The optimized result is calculated for specific solar irradiation 4.64 kWh/m^2/d. The hybrid system encompass of 1000 kW PV array, One 30 kW Biogas generator, one 350 kW Diesel generator and 200 storage batteries with 1000 kW. From the figure 17 we find that net present cost (NPC) $ 9,409,333 and minimum cost of energy (COE) of tk 61.28/kW ($ 0.766). Optimized result is represented in figure 16. (1$ = BDT 80tk)

Sensitivity Results | Optimization Results

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

	PV (kW)	Diese (kW)	Bio (kW)	S4KS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Biomass (t)	Diese (hrs)	Bio (hrs)
	1000	350	30	200	1000	$ 1,352,500	630,260	$ 9,409,333	0.766	0.65	344,871	23	5,136	524

Fig. 17. Optimization result from HOMER using Diesel generator

6.3 Discussion

We designed two types of hybrid system one is solar-biomass-CAES hybrid system and another one we use diesel generator instead of CAES. From these two types we find the optimized result using HOMER at figure12 and figure17. From the figure 12 for using solar-biomass-CAES hybrid system we find the total net present cost (NPC) $ 5,518,358 and minimum cost of energy (COE) of tk 35.92/kW ($ 0.449). From the figure 17 using the diesel generator instead of CAES we find total net present cost (NPC) $ 9,409,333 and minimum cost of energy (COE) of tk 61.28/kW ($ 0.766). Comparing between CAES and diesel generator we find that CAES is more cost effective then diesel generator. If we compare with our present condition of REB then we will be able to find that solar-biomass-CAES hybrid system can keep major contribution in rural commercial electrification. We are doing this project for a resort that is situated in Boali Union, kaliakair upazilla of gazipur district. In this rural area REB is not giving any commercial three phase connection for any resort industry or any other industry. So, we think that solar-biomass-CAES hybrid system will be the most helpful electrical generation system for the resort industry in all rural area in Bangladesh.

7 Conclusion

Bangladesh is running in the crisis zone of power shortage. Socio-economic development is stack into a point for the power crisis. Education is the backbone for the development of a nation. There is a great difference in education level in rural and urban areas in Bangladesh due to lack of electricity in rural area. In Bangladesh nearly 60% people in rural area have no access to the national grid and around 75% Bangladesh's 161 million citizens live in rural areas. Without electrification of rural area, it is impossible to connect the peoples of those areas to the main stream of development. So we need renewable hybrid system for rural commercial electricity. After meeting the demand of electricity of any rural commercial area they can give electricity to village house also. We all know for keeping the environment from pollution we need that kind of industry that has no negative effect on environment. Resort industry is a kind of industry that helps to keep environment from pollution. We all know without industrialization we cannot go ahead. Bangladesh is a beautiful country and it has beauties all the year. We should keep our country beauties by doing resort industry in rural areas. The prime minister the government of republic of Bangladesh Sheikh Hasina declared 2016 as a tourism year. So, solar-biomass-CAES hybrid system is essential for rural commercial electrification and also for resort industry.

In this paper for commercial electrification of rural area, a village named boali in a remote district of gazipur is chosen. The potentiality of solar, CAES and biomass is analyzed. Then, based on this potential, a feasibility study for a model combination of 100 rooms, 1 restaurant and needed electrical items of a resort has been conducted. The optimize hybrid system was developed considering manufacturing cost and efficiency. The unit price of electricity of the proposed model is around BDT 35.91/kW with a net present cost is around $ 5,518,358. Though the proposed system is designed considering a resort industry, the system can be implemented for any community or industry and any place in Bangladesh. For reasonable unit price, though the net investment is high considering the life time of project, it hopes that the proposed hybrid model will be commercially viable and will be a guideline for electrification of other rural areas in Bangladesh.

8 Future Work

In our proposed system we used CAES (Compressed air energy storage). We should work on CAES for developing the renewable electrification. We should work on efficiency of PV arrays and efficiency of converters also.

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