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A new multi-hybrid power system for grid connected area (Solar-Compressed Air Energy Storage-Grid power)

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ABSTRACT: Renewable energy based hybrid energy system have been considered as an efficient mechanism to generate electrical power. The basic idea of hybridizing the energy sources is that the base load is to be supplied by principal energy source and the peak load supplied by other irregular sources. The Bangladesh Government decided to provide electricity throughout the country by 2021. According to government policy the BREB (Bangladesh Rural Electrification Board) is work for ensuring electricity in the rural area of Bangladesh. But in some rural forest area like kaliakair upazilla in gazipur district it is very difficult to provide electrification all the time during the month of April to September because of heavy rainfall and storm. The purpose of this study is to suggest the optimal hybrid energy system for generation of electricity from a combination of energy sources to fulfill the energy demands of the Kaliakair Upazilla in Gazipur District of Bangladesh. The design of hybrid energy system based on PV system, CAES and grid are considered in this study. The study area is the vannara, Kaliakair Upazilla in Gazipur District of Bangladesh.. The study is based on simulation and optimization of renewable energy system using Hybrid Optimization Model for Electric Renewable (HOMER). The hybrid model has been designed to provide optimized system configuration based on hybrid energy component costs, technical specifications and energy demand. The proposed hybrid energy system is environmental friendly which mitigates the CO2 emission and other greenhouse gas emissions.

KEYWORDS: Solar PV, CAES, Hybrid System, HOMER, AirSim, Diesel Generation.

1 INTRODUCTION

For developing country electricity is most important factor so that the economy and standard of living of a country can increase. It must be generated using the national resource of country. Bangladesh is suffering from energy crisis for long many years. The main source of energy of Bangladesh is natural gas. 81.4% electricity generation is done by this source of energy. The country lags behinds 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 more than 75% of total population lives in rural area in Bangladesh and many green industry are situated in this rural area. Bangladesh government already take the initiative for connecting all house and industry to the national grid by 2021. But Bangladesh has lack of electric generation to satisfy the demand of 100% electrification and also very difficult to provide electrification in rural areas at the time of rainy season because of heavy rainfall and storm. So, there is no possibility to do 100% commercial electrification in rural area. To solve this energy crisis we can use different form of renewable energy to generate power beside the grid.

In this paper, we consider a project site of REB named Vannara which lies in Kaliakair Upazilla of Gazipur district and located in between 24°00' and 24°15' north latitudes and in between 90°09' and 90°22' east longitudes. It one of the commercial rural grid connected areas of Bangladesh and lots of industry situated here. It is surrounded by forest areas and most of people living here are dependent upon industrial work and agriculture for their livelihood. Most of the Grid lines are lies in the forest side so that it is difficult for REB to provide electricity at the time of rainy season because of heavy rainfall and stormed. In this paper we tried to develop an optimal system from practical view point. We tried to focuses on contribution of Renewable Energy Technologies (RETs) and Hybrid system using this Renewable Energies in the rural development beside Grid connection.

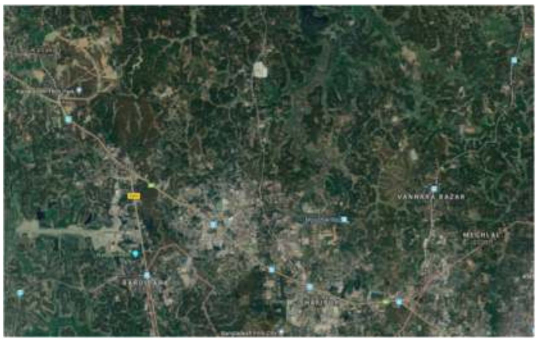


Fig. 1. Vannara, Kaliakair Upazilla, Gazipur -a top view from google earth

In this paper we use simulation software named HOMER (Hybrid Optimization Model for Electric Renewable) and Air Sim 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, CAES, Grid Connection) & complete the combination and load calculation for entire rural area corresponding to summer/rainy season 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 Grid connection in this proposed hybrid system.

2 LOAD ESTIMATION

Many garments industry, School, colleges, Tourism Industry like resort, picnic spot and many more offices are situated in Vannara, kaliakair upazilla, Gazipur . From BREB (Bangladesh Rural Electrification Board) we find the load information of this area in different time period. In Vannara BREB using two 11kv feeder (Feeder no. :3,5) for providing electrification in this area and feeder no. 3 length is 238.872 kilo meter, feeder no .5 length is 282.253. In different time period the load demand is different. So, The average load table are given below :

Table 1. Average Daily Load (Nov-March)

Name of the S/S & Capacity (MVA)	Day Peak Demand (MW)	Evening Peak Demand
Vannara (20MVA)	5.72	7.39

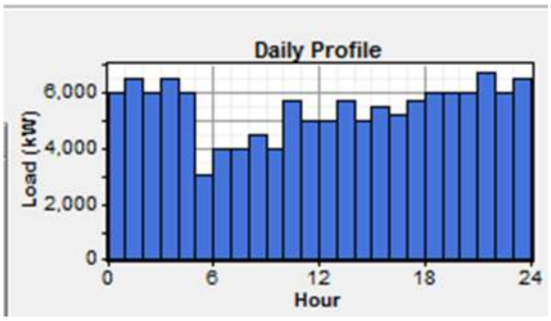


Fig. 2. Daily Load Profile (Nov-March)

Table 2. Average Daily Load (April-October)

Name of the S/S & Capacity (MVA)	Day Peak Demand (MW)	Evening Peak Demand
Vannara (20MVA)	6.32	8.06

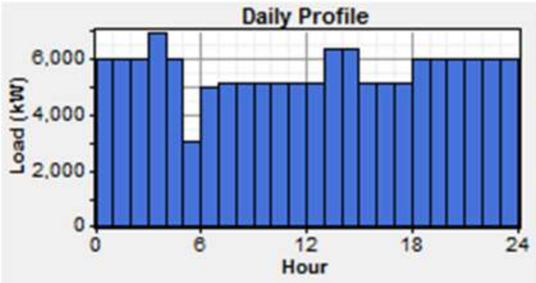


Fig. 3. Daily Load Profile (April-October)

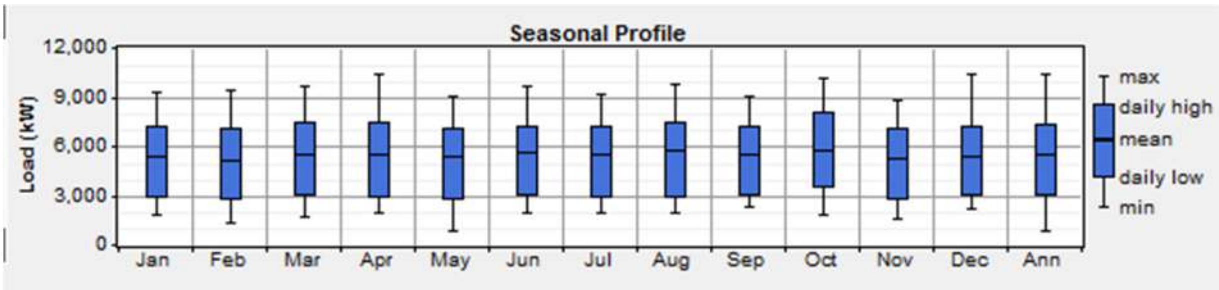


Fig. 4. Monthly Load Profile

Here Fig. 02 indicates the daily loads from November to March and Fig. 03 indicates the daily load profile from April to October. Fig. 04 contains the monthly load profile of the vannara area of Kaliakair Upazilla. From the monthly load profile we find that the peak load of this area is 10MW and average load is 5.485MW.

3 COMPONENT OF HYBRID SYSTEM

According to our project location we have designed our hybrid system with the combination of PV panels, CAES Generator, batteries, Converter and Grid. Here we also used Diesel Generator instead of Grid for compares the cost. We used here AirSim Simulation system for measuring energy consumption that we used for air compressor in CAES. For the economic analysis we used here number of units, capital cost, replacement and O&M costs and operating hours to be defined in HOMER in order to simulate the system. Hence the components of our system are :

1. PV panels,
2. CAES Generator
3. Batteries
4. Converter
5. Diesel Generator
6. Grid

3.1 SOLAR PHOTOVOLTAIC

In Gazipur, Bangladesh Sun rays are available with prosperity. Bangladesh has good prospects of solar photovoltaic generation. Per day the average isolation in Bangladesh is 4.64kWh/m2/day. In this paper, the monthly average global radiation data has been taken from NASA (National Aeronautics and Space Administration) to estimate the generation of solar system. By using HOMER software in Fig. 05 Solar data at Vannara, Kaliakair, Gazipur (Latitude: 24.20, Longitude: 90.16) in Bangladesh is presented graphically. To calculate the PV array power HOMER use the solar resources as a input. By putting the longitudinal and latitudinal value in HOMER software the synthesized data is obtained.

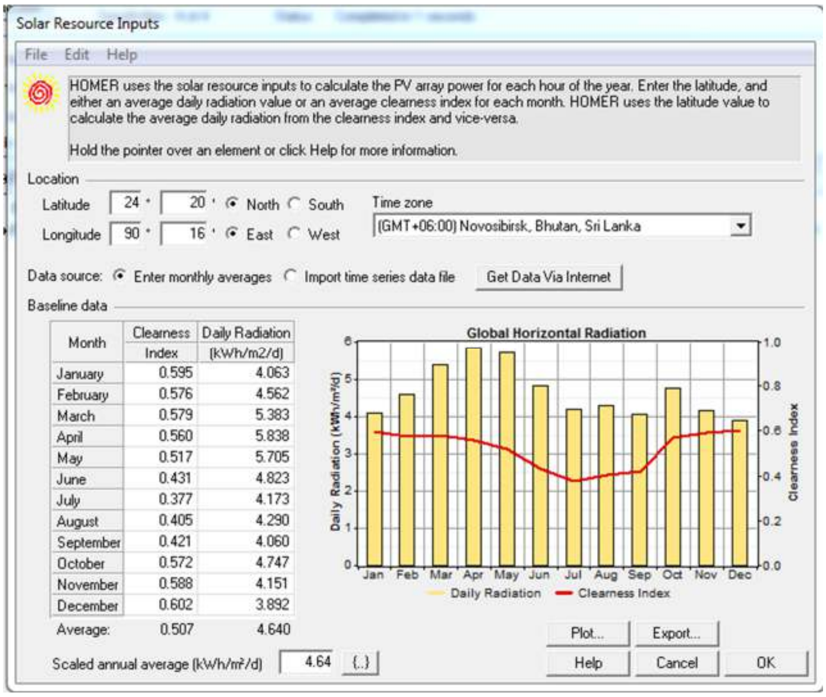


Fig. 5. Solar Resource Inputs at HOMER software

In this research, solar photovoltaic is used with CAES generation and Grid for the establishment of a hybrid system. Solar system cost consists of cost with cables and charge controllers. At present market; for 1 kW generation the cost of PV panel with set up cost is Tk. 96,000. Various costs are represented in Table 3 and cost is considered in BDT. Life time has been taken 20 years and 5000 kW PV modules are considered.

Table 3. PV cost assumption and technical parameters

Parameter	Unit	Value
Cost of Capital	BDT/kW	1,09,200
Cost of Replacement	BDT/kW	1,09,200
Cost of Operating & Maintenance	BDT/W	10,920
Lifetime	Years	20
Derating factor	Percent	80
Slope	Degree	24.33
Tracking System	No Tracking System	0.05

3.2 BATTERY

For storing the solar photovoltaic output Batteries are used. In rural area like our proposed are, where most of the power is used when the electricity are not available on the grid . So, main target of our system is to store energy at day time and discharge the stored energy when there is no electricity specially at 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 [7]. The specifications and different costs of batteries are shown in Table 04.

Table 4. Battery cost assumption

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

3.3 CONVERTER

Converter working for converts the dc power to ac power. As, most of the home appliances and industrial equipments are operated in ac, through a controller dc generation from the PV array is converted to ac. For optimum solution in this proposed system, 5000 kW converters are considered. The details of converter cost assumption and different parameters are given in Table 5.

Table 5. Converter cost assumption and technical parameters

Parameter	Unit	Value
Life time	Years	20
Efficiency	Percent	90
Rectifier Capacity	Percent	100
Rectifier Efficiency	Percent	85
Capital Cost	BDT/KW	1600
Replacement Cost	BDT/KW	1600

3.4 CAES GENERATOR

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 dispatch able electricity [16,17]. 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 06.

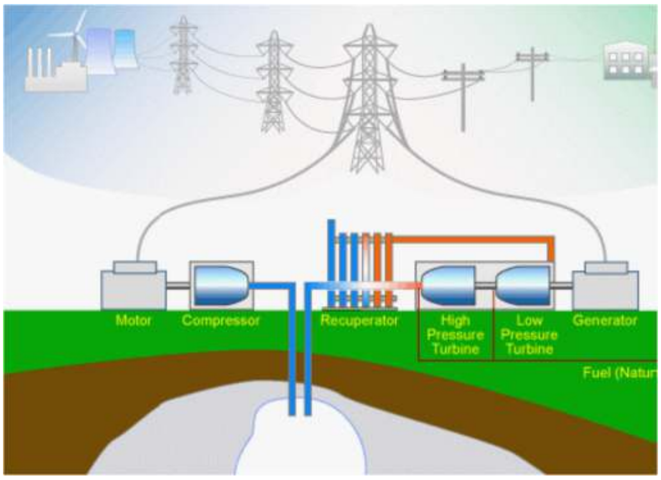


Fig. 6. Generic diagram of CAES operation

In this research, one set of 1000 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/rainy season and also meet the terms of backup requirements. As CAES resource is available in prosperity, fuel cost is considered 32.76 BDT/m^3. Here we use AirSim software to measure energy consumption for the compressor to compress air as a fuel for CAES. We can use electricity for running the compressor from grid and also from PV system. The main cost is considered for CAES cavern establishment and gas generator. To produce 1KW electricity from CAES,$666 is required including plant cost and generator cost, i.e. about BDT 56000 is required in this purpose [8].

Table 6. 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	32.76

Fig. 7. Scheduling of CAES generator at peak hours

We used here 1764-hp rotary-screw single air compressors to provide compressed air for the plant. The activation pressures on the compressor were 110 psig and 100 psig. To estimate the expected savings, we simulates the performance of the compressor and calibrated it to the measured current draw using AirSim. The AirSim input screen is shown in figure 08 [18].

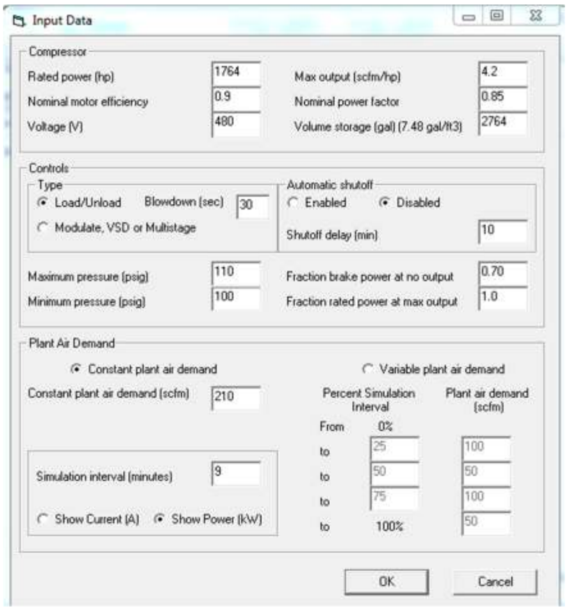


Fig. 8. AirSim input screen

In figure 09 shown the simulated current draw and system air pressure for the baseline condition. The compressor draws about 1500.5 A when loaded, 1000A when unloaded, and runs in auto-shut off mode for a few minutes during the middle of the period. The average simulated power draw of the interval is 1059.3 kW, which is the sme as the average measured current draw. Here we used 2764 gal cavern for compressed air as a fuel for CAES. [19]

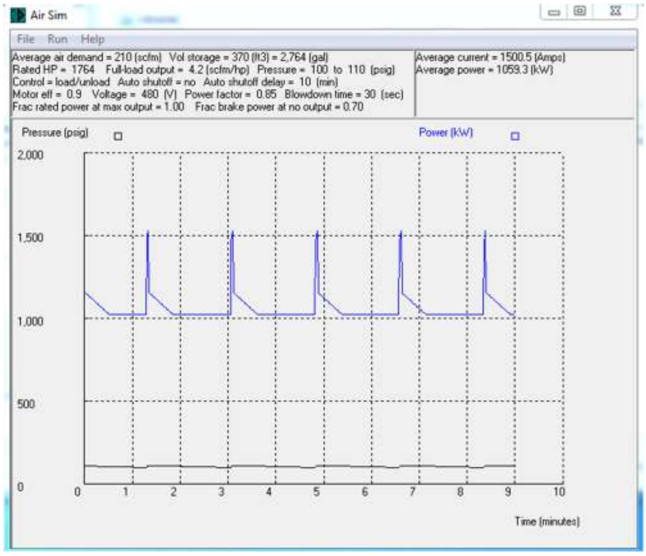


Fig. 9. AirSim output

3.5 Diesel Generator

In this research, We used here 7000 kW Diesel generator instead of grid for comparing 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 07.

Table 7. Cost and parameter of Diesel generator

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

4 Complete Model of Hybrid System

In this paper, we designed the hybrid system consisting of Solar PV, CAES and Grid.. Here, solar photovoltaic panel is used as renewable resource. 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, Air resources, CAES resources and components such as PV, generator, Battery, and converter including grid connection. Figure-10 shows the Hybrid energy renewable system with grid-connected industrial area.

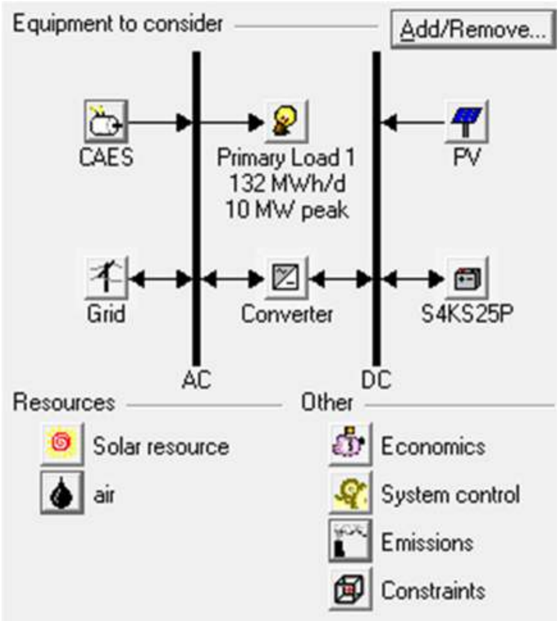


Fig. 10. Hybrid modeling configuration using HOMER

4.1 HYBRID SYSTEM METHODOLOGY

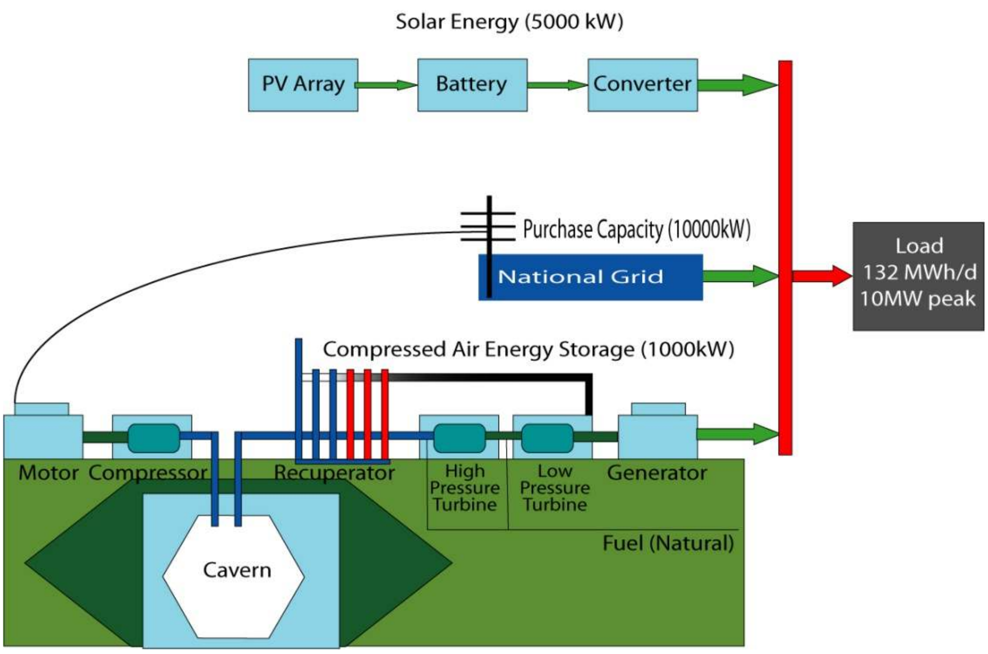


Fig. 11. Hybrid System 3D modeling

- Here we used grid connection which have the purchase capacity 10000kW. In Bangladesh most of the areas are grid connected now a days. But our production capacity cannot full fill the demand in peak time . The another problem is that most of feeder in rural areas are connected with the overhead line to the consumer and the feeder length is too long so that the voltage loss occurred . In Bangladesh most of the overhead line is lies on the forest and river side. So that it is not possible to provide electricity all the time in summer and rainy season because of heavy rain and storm though the power plant produced the electricity. On the other hand when the grid can full fill the demand of our proposed area than the extra production of electricity from PV system and CAES can contribute in national grid for full fill the demand in another area. This is our main aim for proposing this hybrid system.

- In this research, 5000 kW solar photovoltaic is used with CAES generation with grid connection for the establishment of a hybrid system. The sun shines on the solar panel 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, 5000 kW converters are considered for optimum solution.
- 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 when the BREB (Bangladesh Rural Electrification Board) cannot full fill the demand in rural area.

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

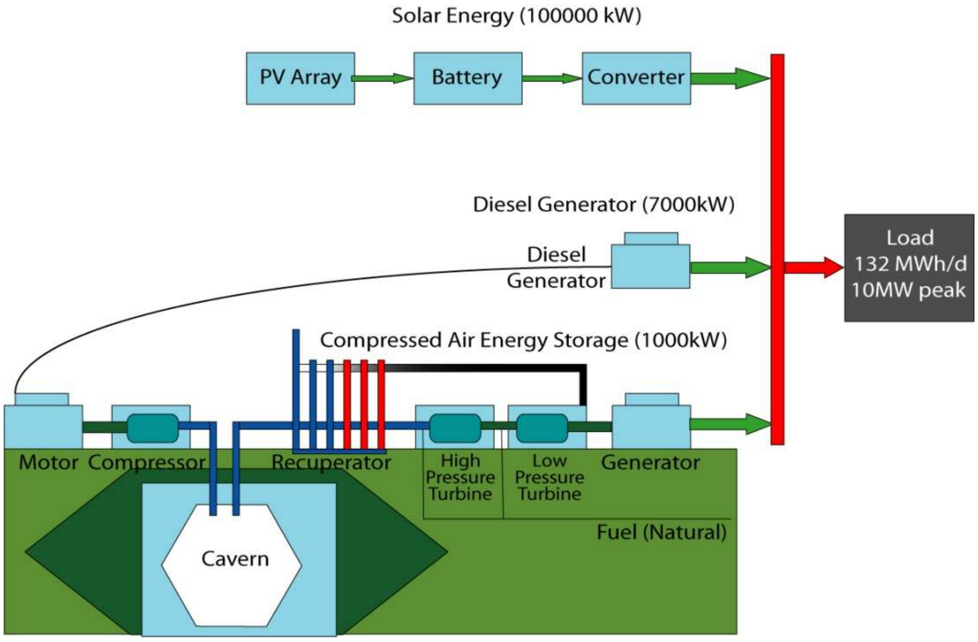


Fig. 12. Hybrid System with Diesel Generator

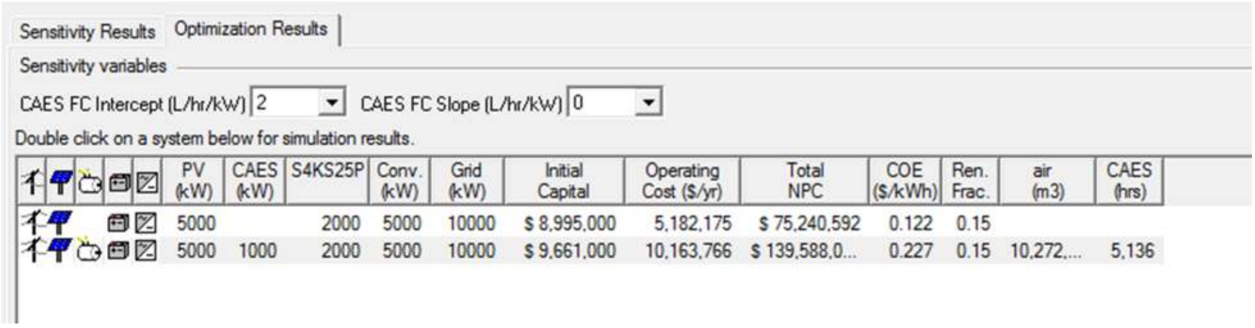
5 RESULTS & DISCUSSION

6 Day by day the conventional energy sources is decreasing. To support these conventional sources, renewable energy sources are only way to ensure continuous power supply and a green sustainable world for the people. In this study, an step has been taken to model a renewable energy generation system hybridized beside 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.

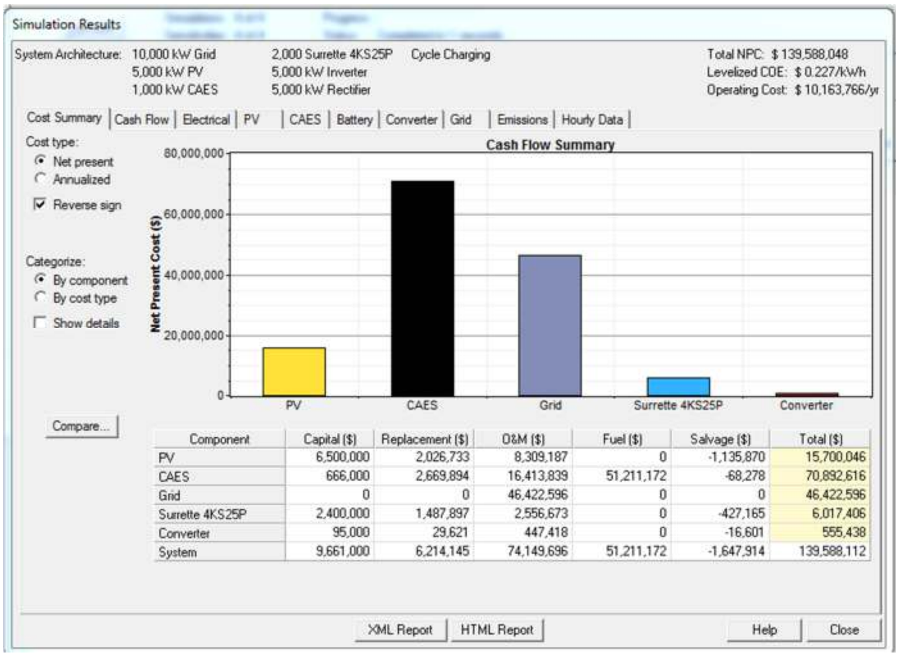
6.1 ANALYSIS OF THE MODEL WITH CAES, PV & GRID

Using HOMER software the optimal system performance has been analyzed. Here we find the optimized result for specific solar irradiation 4.64 kWh/m^2/d. The hybrid system consists of 5000 kW PV array, one 1000 kW CAES generator and 2000 storage batteries with 5000 kW converter is economically more feasible with a total net present cost (NPC) $ 139,588,112 and minimum cost of energy (COE) of tk 19.068/kW ($ 0.227). Optimized result is represented in figure 13. (1$ = BDT 84tk)



PV (kW)	CAES (kW)	S4KS25P	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	air (m3)	CAES (hrs)
5000		2000	5000	10000	$ 8,995,000	5,182,175	$ 75,240,592	0.122	0.15		
5000	1000	2000	5000	10000	$ 9,661,000	10,163,766	$ 139,588,0...	0.227	0.15	10,272,...	5,136

Fig. 13. Optimization result from HOMER



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	6,500,000	2,026,733	8,309,187	0	-1,135,870	15,700,046
CAES	666,000	2,669,894	16,413,839	51,211,172	-68,278	70,892,616
Grid	0	0	46,422,596	0	0	46,422,596
Surrette 4KS25P	2,400,000	1,487,897	2,556,673	0	-427,165	6,017,406
Converter	95,000	29,621	447,418	0	-16,601	555,438
System	9,661,000	6,214,145	74,149,696	51,211,172	-1,647,914	139,588,112

Fig. 14. Cost Summary from HOMER

From the figure 14 we find the cost summary of our proposed hybrid system. Here, we find that the capital cost of this project is $ 9,661,000, Replacement cost $ 6,214,154, operation and maintenance cost $ 74,149,969, fuel cost $ 51,211,172.

Fig. 15. Cash flow summery of hybrid system at HOMER

Fig. 16. Electrical Summary from HOMER

From the electrical summary we find that 74% electricity of this project is comes from Grid Purchases, 15% from PV array and 11% from CAES. From the summary we can say that this proposed hybrid system can fulfill our demand that the area Vannara, Kaliakair need for commercial uses smoothly without any disturbances throughout the year .

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

From the figure 17 we find the hourly data curves of Electrical load, CAES, PV array and Grid. From April to October the electrical demand is high but main problem is that at that time the BREB cannot provide electricity properly so that the industrial company cannot continue their production, as a result country and also company losing their profit. Because of that we use CAES in the time of April- October in this project for backup the PV array and Grid power.

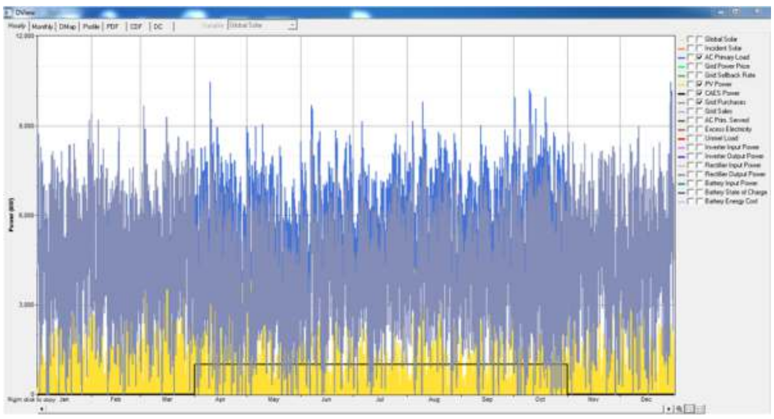
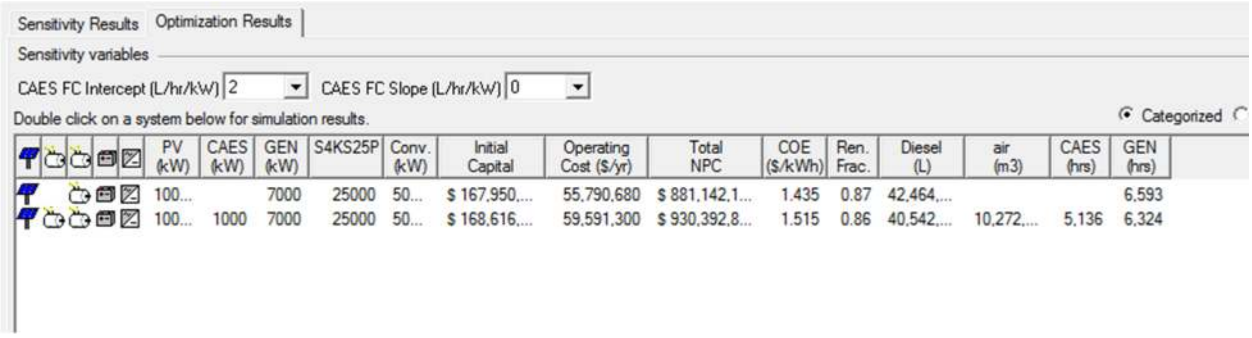


Fig. 17. Hourly Data from HOMER

6.2 Analysis of the model with Diesel Generator, PV & CAES

By using HOMER software here we find the optimized result. The optimized result is calculated for specific solar irradiation 4.64 kWh/m^2/d. The hybrid system encompass of 100000 kW PV array, one 7000 kW Diesel generator and 2000 storage batteries with 5000 kW Converter and 1000 kW CAES Generator. From the figure 18 we find that net present cost (NPC) $ 930,393,216 and minimum cost of energy (COE) of tk 127.26/kW ($ 1.515). Optimized result is represented in figure 18. (1$ = BDT 84tk)



Sensitivity Results | Optimization Results

Sensitivity variables

CAES FC Intercept (L/hr/kW) 2 CAES FC Slope (L/hr/kW) 0

Double click on a system below for simulation results. Categorized

PV (kW)	CAES (kW)	GEN (kW)	S4KS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	air (m3)	CAES (hrs)	GEN (hrs)
100...		7000	25000	50...	$ 167,950,...	55,790,680	$ 881,142,1...	1.435	0.87	42,464,...			6,593
100...	1000	7000	25000	50...	$ 168,616,...	59,591,300	$ 930,392,8...	1.515	0.86	40,542,...	10,272,...	5,136	6,324

Fig. 18. Optimization result from HOMER using Diesel generator

6.3 Discussion

Here we designed 2 types of model using hybrid system and we find the optimized result through HOMER software. From figure 13 for using PV array, CAES and grid power we find the net present cost (NPC) $ 139,588,112 and minimum cost of energy (COE) of tk 19.068/kW ($ 0.227). From figure 18 for using PV array, CAES and diesel generator we find the net present cost (NPC) $ 930,393,216 and minimum cost of energy (COE) of tk 127.26/kW ($ 1.515). Comparing between these two models we find that using power grid is more cost effective then using diesel generator. Already the BREB has power grid line connection in vannara, Kaliakair upazilla, Gazipur area for providing electricity to the house hold and also industry. So it is easy to implement PV array, CAES and power grid hybrid system for BREB (Bangladesh Rural electrification board) to ensure the electricity in all the time for consumer and also national grid can use extra power after using this area by this hybrid system. . If we compare with our present condition of REB then we will be able to find that PV array-CAES- Grid connected hybrid system can keep major contribution in rural commercial electrification. We are doing this project BREB in vannara, kaliakair upazilla of gazipur district. In this rural area REB is not giving required demand for this area . So, we think that PV array-CAES- Grid connected hybrid system will be the most helpful electrical generation system for the rural area in Bangladesh.

7 Conclusion

Because of growing population and industrialization Bangladesh is running in the crisis zone of power shortage. We all know for power generation we are mostly dependent on natural gas. But this natural gas is decreasing day by day. With this natural gas we can go hardly 15-20 years. The prime minister the government of republic of Bangladesh Sheikh Hasina declared that all the area will under the electricity by 2021. So to meet this challenges govt. has taken many steps for producing electricity and also import electricity from abroad. But if we implement this type of hybrid system beside grid power then we can full fill our demand and also we can export electricity to the neighboring country. So, solar -CAES hybrid system beside grid connection is essential for rural commercial electrification.

In this paper for commercial electrification of rural area, a village named vannara in a remote district of gazipur is chosen. The potentiality of solar, CAES beside Grid power is analyzed. Then, based on this potential, a feasibility study for a model combination has been conducted. Considering manufacturing cost and efficiency the optimized hybrid system developed. The unit price of electricity of the proposed model is around BDT 19.068/kW ($ 0.227)with a net present cost is around $ 139,588,112. Though the proposed system is designed considering a commercial electrification of a rural area named vannara situated in Kaliakair Upazilla in Gazipur District, but the system can be implemented for any community or industry and any place in Bangladesh. Though the net investment is high considering the life time of project but considering its reasonable unit price it hopes that the proposed hybrid model will be commercially viable and it can be a guideline for fulfill the demand of electrification of other rural areas in Bangladesh.

8 Future Work

We should work on efficiency of compressor, caravan size of CAES and also work on efficiency of PV system .

Acknowledgement

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REFERENCES

[1] Adnan Jamil, "Biogas and Cattle Organs: An Alternative Significant Source of Energy for Sustainable Development in Rural Bangladesh", Student Thesis, Institutional for livsvetenskaper, 2008.

[2] Khairul Anam, Husnain-Al-Bustam "Power Crisis & Its Solution through Renewable Energy in Bangladesh", Department of Electrical & Electronic Engineering, Islamic University of Technology.

[3] Hossain AK, Badr O. Prospects of renewable energy utilization for electricity generation in Bangladesh.

[4] Wind integrated compressed air energy storage in colorado by Richard David Moutoux, BS university of virginia, 1999, MS university of virginia, 2004.

[5] Islam MR, Islam MR, Beg MRA. Renewable energy resources and technologies practice in Bangladesh. Renewable & Sustainable Energy Reviews 2008;12: 299-343.

[6] SSE, "Surface meteorology and Solar Energy, A renewable energy resource web site, sponsored by NASA's Earth Science Enterprise Program. http://eosweb.larc.nasa.gov/sse. Cited 29 May 2009.

[7] Perspective Of Biodiesel & Solar Pv As A Combined Enewable Energy System For Rural Electrification Using Homer By Md. Sharafat Hossain, Ruhan Mahmud Shams, Mst. Rubinaaktar

[8] Optimization Of Integrated Renewable Energy System – Micro Grid (Ires-Mg) - By Preety Mathema

[9] R. Ramakumar, "Technical and socio-economic aspects of solar energy and rural development in rural area," Solar Energy, vol. 19, no. 6, pp. 643-647, 1977

[10] R. Ramakumar, "Renewable energy sources and developing countries," IEEE Transactions on Power Apparatus and Systems, vol.PAS-102, no.2, pp.502-510,Feb. 1983

[11] R. Ramakumar, "Energizing rural areas of developing countries using IRES," Proceedings of 31st Intersociety Energy Conversion Engineering Conference, vol.3, pp. 1536-1541, Aug. 1996

[12] "Renewables 2011 global status report," Renewable Energy Policy Network for the 21st Century, Paris, France, 2011

[13] M. S. Islam and T. Mondal, (2013) "Potentiality of Biomass Energy for Electricity Generation in Bangladesh." Asian Journal of Applied Science and Engineering, vol. 2, no. 2, pp.103

[14] J. Waewask, M. Mani, P. Buaphet and P. Panichayunon, (2007) "A Biomass Gas Engine System for Power Generation of OTOP Building in Southern Thailand," International Conference on Clean Electrical Power, ICCEP '07, pp. 415-422.

[15] M. R. Nouni, S. C. Mullick and T. C. Kandpal, (2007) "Biomass gasifier projects for decentralized power supply in India: A financial evaluation," Energy Policy, vol. 35, pp.1373

[16] K. Q. Nguyen, (2005) "Long term optimization of energy supply and demand in Vietnam with reference to the potential of renewable energy," Germany: University of Oldenburg.

[17] A. H. Mondal and M. Denich, (2010) "Hybrid system for decentralized power generation in Bangladesh," Energy for Sustainable Development;

[18] Kissock, K., 2003, AirSim, compressed air system simulation software.

[19] Compressed Air Challenge, 2002, "Fundamentals of Compressed Air Systems", U.S. Dept. of Energy, Office Industrial Technologies, www.oit.doe.gov/bestpractices/.

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