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HYBRID RENEWABLE ENERGY SYSTEMS WITH OPTIMAL DESIGN OF GAS GENERATOR AND GRID SYSTEM INTEGRATED WITH PHOTOVOLTAICS FOR INDUSTRIAL AREAS OF BANGLADESH: A CASE STUDY FROM NARAYANGANJ INDUSTRILAL AREA

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Abstract*- The demand for electricity is ever increasing due to rapid industrialization which leads to rapid depletion of Bangladesh's fossil fuel reserve. Now it is essential to find a suitable solution to satisfy the load demand of Bangladesh.. This research work is an in-depth scenario and analysis of the renewable hybrid energy system an industrial area of Bangladesh. This study has also included co-production of diesel generator, solar PV and grid system. This energy systems looks into the process of selecting the best components and its sizing with an appropriate operation strategy to provide cheap, efficient, reliable and cost effective alternative energy. This paper analyzes all the conditions and constraints of the renewable energy integrated grid connection system with compensation and proposes an optimal combination of energy components for compensating regular grid failure in an industrial area .The final optimization result from HOMER shows that the cost of energy (COE) is 0.1$/ kWh.*

Keywords: *Smart grid, Energy Systems, Renewable energy, Industrial sector.*

I. INTRODUCTION

For highly economic growth of a country, the Electricity access rate and utilization of electricity are the indicators where Bangladesh is a developing and over populated country it has about 160 million peoples. 50% peoples can access electricity which is not good for wealthy economy. Due to maximum demand, maximum generation about of 6500 MW in 2015 could not remove power crisis in the country [1]. At present power demand in Bangladesh is about 7500MW and generation is 6400-6700 MW [2]. Demand is estimated to exceed 10,000 MW by 2015 [2]. As there is far difference between generation and demand of electricity, people of Bangladesh is experiencing a significant amount of load shading at every day.

Again Bangladesh relies heavily on fossil fuels for its energy especially on gas resources. For energy generation, total 63.11% energy generated from natural gas used as fuel [2]. But the present proven reserve would be depleted by a decade. Around the world coal is still a main fuel for power generation. Bangladesh has Sufficient high quality coal resources. But the coal mining is at its initial stage [2].The exploration of gas and coal continues to remain uncertain. Without renewable energy resources all are not eco-friendly as like as oil, coal, gas etc. though the fossil fuels are not available in our country.

As alternative of diesel generator, there are various work is being done to study the possibility of using renewable energy with hybrid system [4-5]. The Hybrid power systems considerably reduce the need for storage of fuel, fuel consumption cost, and greenhouse gas emission as well [6-7]. Performance analysis of integrated hybrid energy systems has been carried out by several researchers [8-9] [19-20]. Optimization of sizing of solar-wind hybrid system has been investigated [11, 14].

Alternative way of energy generation in Bangladesh is the need of time even it needs a decade. Renewable energy is also considered as green or clean energy, because it does not produce toxins or pollutants that are harmful to the environment as much. Now a days, the renewable energy is the most popular energy sources for rural electrification of Bangladesh where could not reach electricity till today from the national grid. Renewable energy resources a s like solar, wind, hydro and tidal could be utilized in some areas of Bangladesh to establish green energy based power generation stations.

Renewable energy is also considered as green or clean energy. The industrial areas of Bangladesh has a huge potential of establishing solar combined diesel generator and grid connected power generation as considered for Narayanganj which is near of Dhaka city.

Narayanganj district is situated between $23^0$60' North latitude and $90^0$50' East longitudes and the area in the northern part of Dhaka has huge potential area establishing power generation. Narayanganj is a district of Dhaka division in Bangladesh. The annual average solar radiation is 4.430 kWh/m^2/d is suitable for setting up solar energy system [3]. There are many garments industry, textile, river port and processing zone in Narayanganj about 2000 factory which contribute the economic growth in Bangladesh. Government cannot fulfill their energy demand which is essential for whole day. So now its essential to meet the energy demand of industrial sector by set up new energy production plant. Bangladesh government and several non-government organizations have been working on setting up single renewable resource based energy system.

In order to decrease the gap of demand and supply, On grid with compensation or off grid of hybrid renewable energy system is the most efficient and reliable energy source than the energy source which based on single renewable energy such as Solar or wind energy source also that could be connected with gas generator where carbon emission will be low and can be meet the demand of electricity. The hybrid system will reduces the load demand on grid and save fuel as well as natural resources. It is also economical and eco-friendly which contribute in balancing of environment [17-18].

This work a design of On-Grid and off grid for Efficient Hybrid Renewable Energy System is presented and compare them for best option. At first, the hybrid energy system that has been established all over the world is reviewed. Then, methodology of analysis of this work is described in details. The data of energy resource collected from various reliable sources are presented here. The energy resource data analysis procedure is discussed. Then the designed hybrid energy systems are provided. After that selection process of the efficient components which are used in the hybrid system are described. Detailed economic analysis of the proposed system is also carried out to validate the design and presented here. On-Grid and off grid systems for Efficient Hybrid Renewable Energy System based on photovoltaic energy, natural gas and grid connection are also done here. This study shows renewable hybrid system is the most cost effective. Analysis of hybrid energy system for Bangladesh like this work has not reported yet. From this work, the proposed hybrid system shows tremendous prospect in Bangladesh.

In this work, the Efficient Hybrid Renewable Energy System is proposed for an industrial area of Bangladesh. Also this system design can be applied to other industrial areas of Bangladesh. First of all, Energy resources are analysed to find out the most suitable energy resources for planning a hybrid energy system. Then using the best suitable energy resources a hybrid energy system is designed. For the optimal planning of sizing of different components of the system the simulation software HOMER (Hybrid Optimization Model for Electric Renewables) is employed. The simulation software HOMER performs the energy balance calculations for each system configuration that can be considered. The system cost calculations are done studied which account costs such as capital, replacement, operation and maintenance, fuel and interest also. This economic analysis of system is carried out to determine the feasibility of the proposed system.

II. ENERGY RESOURCES

In this energy system design, the selection of energy sources such as solar energy is determined by giving priority to renewable sources. The renewable energy sometime it called infinitive energy which come from nature. The solar energy be converted electricity from visible to near infrared light by photovoltaic cell. It has potential to provide unlimited supply of electricity for our huge and large industries. Moreover the use of such green energy is increasing worldwide because it does not produce any kind of pollution such as carbon di oxide, carbon monoxide [15-16]. This energy system process will be good for the location of our study because of electrification, the amount of solar energy present is enough for electrification. Natural Gas and oil are major fuel used in Bangladesh to produce electricity but at present the price of gas and oil fuel is rising dramatically. The gas transmission line is also connected to the study location. The gas can be used as a fuel and Diesel is used as the fuel for power generation from fossil fuel.

A. Solar Energy Resources in Narayanganj industrial area

The sun rays means the UV-VIS light energy that reach the earth being converted to energy through different processes and ultimately the photon energy can be converted to electricity. Photovoltaic systems use solar cells or panels to convert sunlight directly into electricity where it depends on solar irradiance, measure of incoming solar radiation, of Bangladesh is very good for the purpose of electricity generation. The monthly averaged global radiation data for that region has been taken from NASA (National Aeronautics and Space Administration) 4.443 kWh/m^2/d and clearness index is a measure of the clearness of the atmosphere has an average value of 0.673 for Naranyanganj industrial areas. Table 1 shows the clearness index and daily radiation for Tongi. Figure 1 shows the monthly averaged values of clearness index and daily radiation.

B. Design of Hybrid Energy System

This hybrid combination power system for Narayanganj is designed where Issuzu Gas generator and grid system by natural gas has been combined with solar power generation. Issuzu Gas generator and grid connection has been chosen for its operating feasibility, uninterrupted power connection, low cost and easy installation where we also designed the system without grid connection. The system will run by on grid and off grid management to meet full load demand in the industry. Only standalone,

the gas generator and PV cannot fulfill the total load demand in industrial sector. So the solar-generator-on grid management power model is the most cost effective system.

Table 1: Solar irradiation and Clearness Index in Tongi

Month	Clearness Index	Daily Radiation(kWh/m^2/da
January	0.665	4.610
February	0.617	4.950
March	0.580	5.430
April	0.566	5.910
May	0.477	5.250
June	0.335	3.740
July	0.339	3.750
August	0.390	4.140
September	0.398	3.860
October	0.498	4.180
November	0.627	4.490
December	0.673	4.430
Annual Average	0.673	4.430

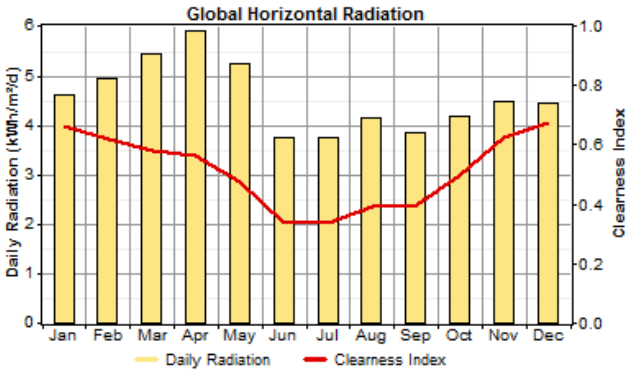

Fig.1: Monthly averaged daily radiation and clearness.

C. System components

The cost of PV module including installation has been considered as $ 7278 however the life time of the modules has been taken as 25 years. The size is 6.9 kW of PV modules, Sun module SW 230 POLY V2.0 PALLET are considered. PV modules output is DC and is connected to DC bus. For all the system, Surrette 6CS25P battery with energy storage capacity of 6.94 kWhr, is used for design of the hybrid system. Issuzu gas generator are connected with the AC bus bar.

In figure 3 and **Figure 4** the systems is shown whereas the Converter is used to convert from AC to DC and DC to AC. To the systems the Inverter efficiency is taken 90% and the rectifier efficiency is considered 85%. Gas generators operate in parallel with the solar energy system to increase the maintenance flexibility, efficiency and distribute the electric load more optimally. Capital cost for per 200 KW of Gas generator is considered $5000 and there is no cost of grid connection on the system [10].

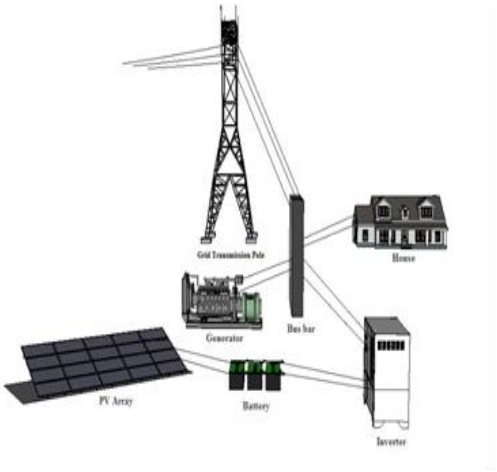

Fig.2: Single line diagram of hybrid energy system [permitted from Ref.21]

III. ECONOMICS AND CONSTRAINT

For industrial grid connected energy system that is designed in this work has assumed to have 25 years and the annual interest rate is considered 10%. The constraint that is applied is 50% of the load should be from the renewable energy.

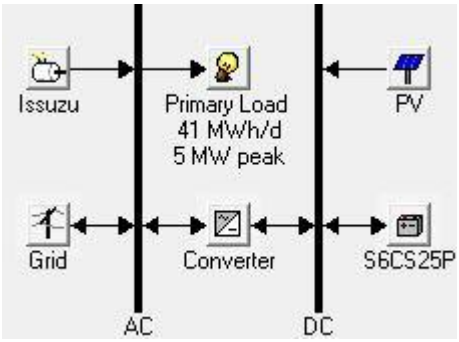

Fig. 3: On Grid energy system

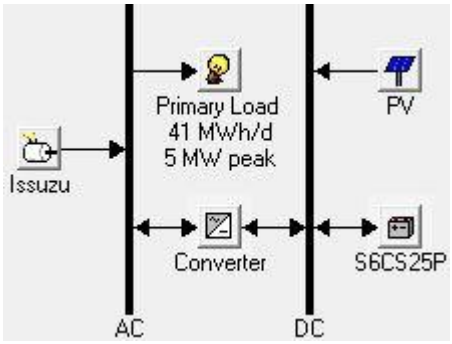

Fig.4: Off grid Energy system

A. Electrical Demand profile

In this study, after doing necessary survey of an industry power consumption is assumed about 41 MWh per day for analyzing the electrical demand for Narayanganj area where the base line load of 40.7 MWh/day is considered for simulation is taken. The randomness of the daily consumption is kept as 15%. And variability of hour to hour is considered as 20%. The daily electrical base line load shown in Figure 5 of the system.

B. Homer Principle and Cost of integrated systems

HOMER analyzed the hybrid energy system according to the COE (cost of electricity) of the system. Other factors which influence the analysis are capital cost, operating cost, renewable energy factor, total NPC (Net present cost) and gas fuel consumption rate. Table 2&3 shows the net annualized capital cost, replacement cost, operation and maintenance cost and fuel cost of different system components to the system of on grid and off grid energy system of annualized. In the table 2 and table 3 shows the total net annualized cost of Off grid energy systems and On grid connected energy system respectively. Whereas the total system cost of grid connected hybrid energy systems is lower than off grid power system. For On grid the total annualized cost is about 1.5 million dollar where for off grid energy systems annualized cost is about 1.6 million dollar.

I. RESULTS AND ANALYSIS

In the table 4, shows that the comparison of cost by hour on grid and off grid system with excess electricity production. The COE is $0.1 per kilowatt hour for On grid energy system whereas the off grid energy system producing electricity at higher cost of $0.114 per kilowatt hour. In addition to the same way of power production, in the off grid system the total excess power producing about 7.86% and in grid connected energy system is about 0.62%. The purpose of energy production is for uninterrupted energy supply to the industrial areas at low cost and sell back the excess electricity to the grid with low prices

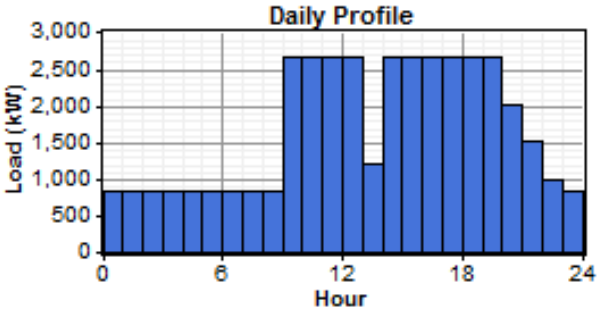

Fig.5: Electrical base line daily load profile.

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Table 2: Net annualized cost of Off grid energy systems

Component	Capital($)	Replacement($)	O&M($)	Fuel($)	Salvage($)	Total($)
PV	464,814	0	580	0	0	465,393
Issuzu	8,263	0	6,314	1,110,624	-26	1,125,175
Converter	88,134	0	2,000	0	0	90,134
Other	551	0	300	0	0	851
System	561,761	0	9,194	1,110,624	-26	1,681,553

Table 3: Net annualized cost of On grid energy systems

Component	Capital($)	Replacement($)	O&M($)	Fuel($)	Salvage($)	Total($)
PV	348,610	0	435	0	0	349,045
Issuzu	5,508	0	2,808	857,806	-147	865,975
Grid	0	0	258,379	0	0	258,379
Converter	20,932	0	2,000	0	0	22,932
Other	551	0	300	0	0	851
System	375,601	0	263,922	857,806	-147	1,497,183

Table 4: Net Electrical power production and levelized cost rate per kwh energy

	On Grid Energy System		COE of On grid system	Off Grid Energy System		COE of Off grid system
Production	kWh/yr	%		kWh/yr	%	
PV array	4,385,122	28		5,846,829	36	
Issuzu	8,353,419	54	$ 0.1 /Kwh	10,601,102	64	$ 0.114/Kwh
Grid purchases	2,696,657	17		0		
Total	15,435,196	100		16,447,930	100	

Table 5: Pollutant emission rate from proposed system

Pollutant	Emissions (kg/yr)
Carbon dioxide	5,355,385
Carbon monoxide	18,048
Unburned hydrocarbons	1,999
Particulate matter	1,361
Sulfur dioxide	14,145
Nitrogen oxides	161,041

A. Environmental Effects

The proposed On Grid hybrid system and Off Grid energy systems reduces gas emission by a significant amount due to reduced fuel consumption. However this reduction in gas emission is determined using HOMER software. The emission for this system has been decreased by 80 percent from the on grid based hybrid energy system. Table 5 shows the total emission of the system.

CONCLUSION

Today's Bangladesh is distressing from acute electricity problem. In the modern civilization electricity, the economic growth fully depends on continuous electricity which has become one of a basic need. Severe scarcity of power in Bangladesh has become a threat to its economic development. However, In the industrial areas where grid failure is very common , on load grid connected energy system consisting hybrid power electric sources like solar PV and gas generator can be a potential solution. Though the use of such renewable sources is already in process but standalone renewable energy system cannot supply entire load demand and also financially less viable. Therefore, On grid solar-grid-gas hybrid energy system can be cost effective solution for the industrial regions of Bangladesh. It also will reduce pressure on grid. Moreover this grid connected hybrid system reduces the emission of greenhouse gases with dramatically and help to trim down the environmental pollution.

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