Hydrogen Energy Storage Based Green Power Plant in Seashore of Bangladesh: Design and Optimal Cost Analysis

S.M. Baque Billah[1,*], Kazi Meharajul Kabir[1], Md. Onik Islam[1], Alok Nath[1], Md. Sultan Mahmud[2], Mohammad Nurul Absar [1]

[1]Department of Electrical and Electronic Engineering, University of Science & Technology Chittagong (USTC)
Chittagong, Bangladesh

[2]Department of Green Energy Technology, Pondicherry University
Puducherry, India

[*]baque.ustc06@gmail.com

***Abstract*— Adequate energy supply capability is the key factor for the development of any country. Despite of having enormous energy resources, Bangladesh is facing acute shortage of Electricity and needs to enhance the power generation capacity to support the rising demand. Power production and its related environmental issues are becoming a major concern to our country. Effective and efficient use of sustainable energy sources will be an environment friendly attempt towards reducing power crisis. In this paper we came up with an idea to establish a green (environment friendly) power plant at various seashores throughout the country, based on hydrogen energy storage. Proposed power plant will store solar and wind energy using hydrogen storage which is a green fuel to generate electricity during peak load demand. For design and optimization, we have chosen Patenga seashore where wind flow is reasonable as well as the solar radiation is optimal. The major objective of this proposed optimized design to be able to meet peak load demand using hydrogen energy with low THD (total harmonics distortion) and also reduce the GHG (Green Houses Gas) emission. Here, HOMER is used to examine the most cost effective configurations among a set of systems for electricity requirement of 8 MWh/day peak load demand in patenga.**

Keywords— Sustainable energy; hydrogen energy; peak load; cost effective; harmonics distortion; green house gas;

I. INTRODUCTION

Bangladesh is a developing country with 152 million people spread across a land of 147,570 sq km. A thriving economic expansion, rapid urbanization and increasing industrialization have increased the country's demand for electricity. Around 62% [1] of the total population (counting renewable energy) have access to electricity and 321 KWh [2] is per capita generation. Compared to other developing countries this power generation is very low. In Bangladesh the power supply is lacking and cannot meet the peak demand. About 75 percent population in rural area are beyond the range of grid electricity. At this time, the country is facing a critical electricity emergency due to growth of almost each and every sector. According to the BREB (Bangladesh Rural Electrification Board), scarcity of electricity is almost 15-20 percent of actual generation during present peak and off peak hours. To meet the growing electricity demand the use of fossil fuels need to be increased which in turn has negative environmental effects. The power sector alone contributes to 40% of total CO_2 emissions in Bangladesh [3]. In this case, to ensure energy security without raising environmental impacts, it is obligatory to develop and endorse unconventional energy sources. Due to the shortage of fossil fuels and limitations of using natural fuels, the government has already started to shift its focus on various renewable energy resources like wind, solar, tidal and the underlying technologies used to extract energy from these resources. A huge amount of sunlight during the day is a great blessing for Bangladesh as it contributes to a yearly average of about 500W/m^2/day [4] [5]. Wind flow is also reasonable in coastal areas and annual average solar radiation is similar throughout the coastal areas of Bangladesh. Patenga is one of the coastal areas with an average annual solar radiation of 4.63 KWh/m^2/day and monthly average wind speeds at a height of 30 meters is 2.74 m/s. So, based on solar and wind energy, it is feasible to implement a grid connected hybrid power system in this area which will solve energy crisis to some extent. The grid connected hybrid technology faces quite a few problems such as, energy storage for storing excess electricity and total harmonics distortions (THD) from inverter where THD should be 5% of rated inverter output [6].To overcome this situation, hydrogen economy is widely discussed by researchers be a solution to the world's future energy and play an important role as an energy carrier. In near future Hydrogen may be converted into useful forms of energy more efficiently than fossil fuels [7]. In addition, water electrolysis is a very promising technology for future production of renewable hydrogen [8]. Hydrogen production from water electrolysis can be performed using renewable energy and PEM electrolyzer become known as one of the most clean and talented alternatives to reduce fossil fuel dependency [9]. Electrolytic hydrogen (H_2) is appropriate for seasonal storage applications because of its inborn high mass energy density, leakage from the storage tank is insignificant and it is easy to install anywhere in contrast to battery storage which is commonly used in hybrid technology [10].

This paper proposes a novel power system at patenga seashore based on hydrogen economy. In this proposed system, power plant consists of 3MW alternator which will be run by hydrogen gas. Hydrogen will be produced from sea water electrolysation using solar and wind energy and further stored in a tank. As alternator produces pure sin wave so power grid will experience low THD. As hydrogen is a green fuel so there is no (CO_2) carbon emission from the proposed system.

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II. System Methodology

We want to establish a green energy plant and thus we have used two renewable energy (solar and wind energy). When solar radiation falls on the PV panel and wind rotates the turbine both will produce DC power. The power obtained from both sources will then feed to PEM electrolyzer throughout a converter. Using this DC power PEM electrolyzer will produce Hydrogen (H_2) from sea water which will be eventually stored in a tank .We use a hydrogen fuel generator to generate AC power from hydrogen (H_2). All of the calculations, analysis, simulations are done by HOMER Pro. Software. Fig. 1 shows the block diagram of the proposed system.

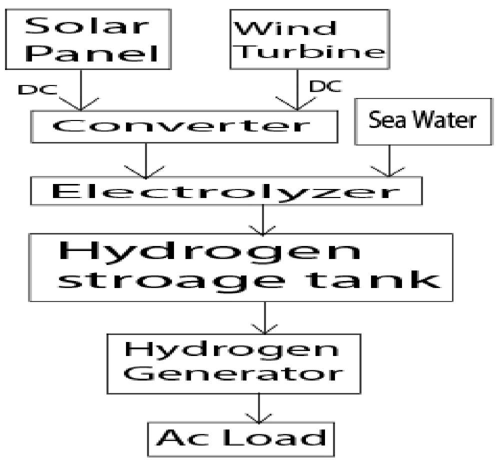


Fig. 1: Block diagram of the proposed system

III. Proposed Plant Model

Propose model consists of two renewable primary sources (solar, wind), tank, load, converter, Hydrogen generator and sea water which is used by electrolyzer. Table 1 shows the proposed plant location. Table 2 shows proposed plant specification. Fig. 2 shows plant model by Homer

TABLE I
PROPOSED PLANT LOCATION

Location	**Golden Beach Road, Patenga, Chittagong, Bangladesh**
Latitude	22 degrees 15 minutes North
Longitude	91 degrees 48 minutes East

TABLE III
PROPOSED PLANT SPECIFICATION

PV	Generic flat plate PV	2.5	MW
Wind Turbine	Norvento nED	7	MW
Generator	3MW Genset	3	MW
Electrolyzer	PEM Electrolyzer	5	MW
Storage Tank	Hydrogen Storage tank	10000	Kg
Converter	Converter	5	MW

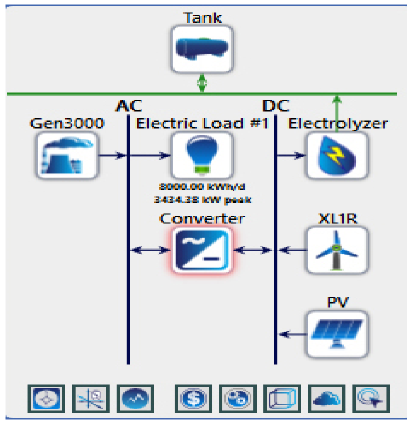


Fig. 2: Plant Model by Homer

IV. Resource Data Analysis

We have collected all the data of annual solar radiation and wind speed form Bangladesh Meteorological Department airport patenga branch and The National Aeronautics and Space Administration (NASA). Table III shows the Global Horizontal Irradiation (GHI) value for Patenga, Chittagong. Table IV shows the Wind speed data for Patenga, Chittagong.

TABLE III
GLOBAL HORIZONTAL IRRADIATION (GHI) VALUE FOR PATENGA, CHITTAGONG

Month	**Clearness Index**	**NASA Daily Radiation KWh/m²/day [11]**	**Weather Office Daily Radiation KWh/m²/day [12,13]**
January	0.335	4.597	4.240
February	0.379	5.126	6.350
March	0.490	5.634	7.800
April	0.540	5.760	8.110
May	0.577	5.786	7.750
June	0.613	4.335	5.040
July	0.598	4.048	5.590
August	0.571	4.224	4.320
September	0.528	4.083	4.670
October	0.453	4.725	4.180
November	0.360	4.409	6.910
December	0.324	4.391	5.250
Annual Average	0.543	4.63	5.85

TABLE IV
WIND SPEED DATA FOR PATENGA, CHITTAGONG

Month	**Wind speed from NASA[11]**	**Weather Office Average wind speed(m/s) (30 feet)[12,13]**
January	2.480	2.220
February	2.730	2.220
March	2.900	2.500
April	3.070	2.500
May	3.040	3.050
June	3.420	2.780
July	3.250	3.050
August	2.930	2.780
September	2.440	2.500
October	2.040	1.390
November	2.240	1.940
December	2.330	1.670
Annual Average (m/s)	2.74	2.38

V. Simulation & Results

The simulation of our model was carried out using the HOMER pro software.

A. Component specification for simulation

Solar cell	2500KW
Lifetime	20 yr
Derating factor	80%
Tracking system	No Tracking
Slope	23.000 deg
Azimuth	0.000 deg
Ground reflectance	20.0%

Fig, 3 shows the solar GHI resource

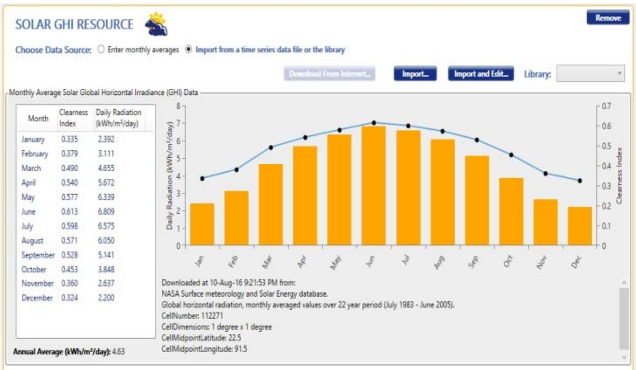


Fig. 3 Solar GHI Resource

Wind Turbine: 14
Rated capacity : 500 KW
Rotor Diameter : 22m
Hub Height ; 30 m
Life time : 20 year
Figure 4. shows the wind speed

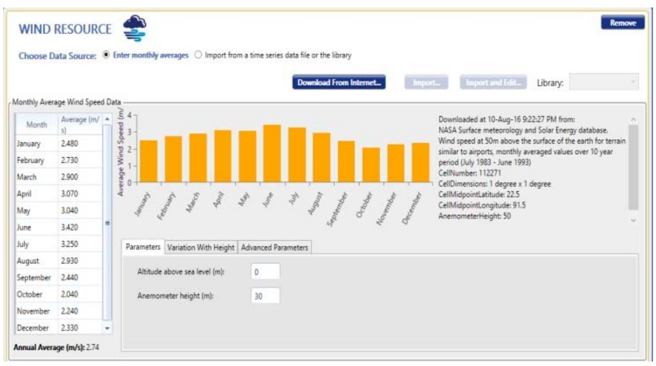


Fig. 4 Wind Speed

Converter capacity :5000KW
Hydrogen Storage tank : 10000Kg
Electrolyzer : PEM Electrolyzer
Capacity : 5000KW
Life Time : 20 yr
Efficiency: 85%

Generator : 3000KW
Fuel : Hydrogen
Efficiency : 80%
Fig. 5 shows the generator efficiency curve

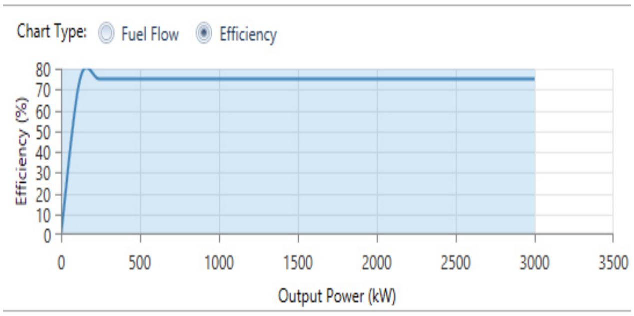


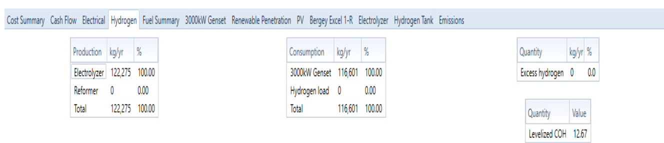
Fig. 5 Generator efficiency curve

Our main target was to fulfill the peak load demand in patenga Chittagong. The daily demand is 8MW and the duration of Peak demand is from 6pm to 10pm and total demand in a year is 2920000KWh/yr. Fig. 6 Shows electrical peak load demand in patenga.

Fig. 6 Electrical peak load demand curve

B. Optimization results

Fig. 7 shows the monthly hydrogen production by the system using HOMER. Also, Fig. 8 shows the electrolyzer output



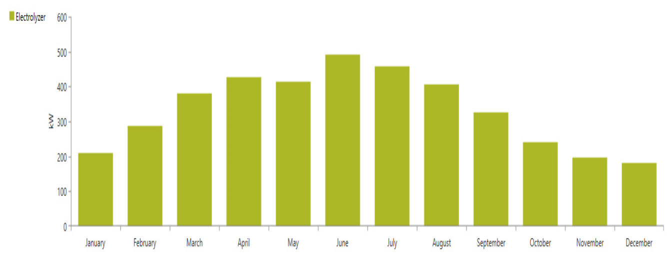


Fig. 7 Hydrogen production curve

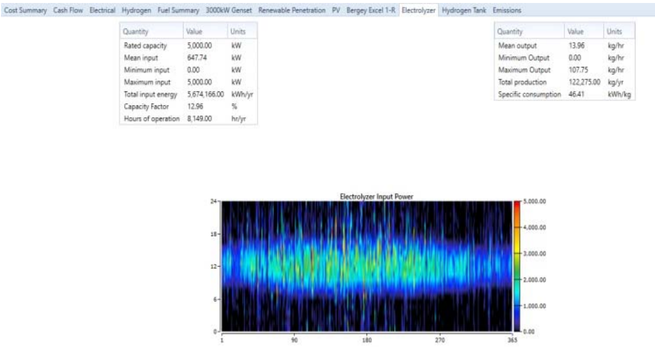


Fig. 8 Electrolyzer output curve

Generator: 3000kW Genset

Quantity	Value	Units
Hours of operation	1457	hrs/yr
Number of starts	365	starts/yr
Operational life	34	Yr
Fixed generation cost	0.43	$/hr
Marginal generation cost	0.00	$/kWh
Electrical production	2910906	kWh/yr
Mean electrical output	1998	kW
Min. electrical output	485	kW
Max. electrical output	3000	kW
Fuel consumption	116436	L/yr
Specific fuel consumption	0.04	L/kWh
Fuel energy input	3881214	kWh/yr
Mean electrical efficiency	75	%

Fig. 9 shows the fuel consumption for fulfillment of target production. Fig. 10 and Fig.11 Shows hydrogen generator production output and generator electricity production curve respectively.

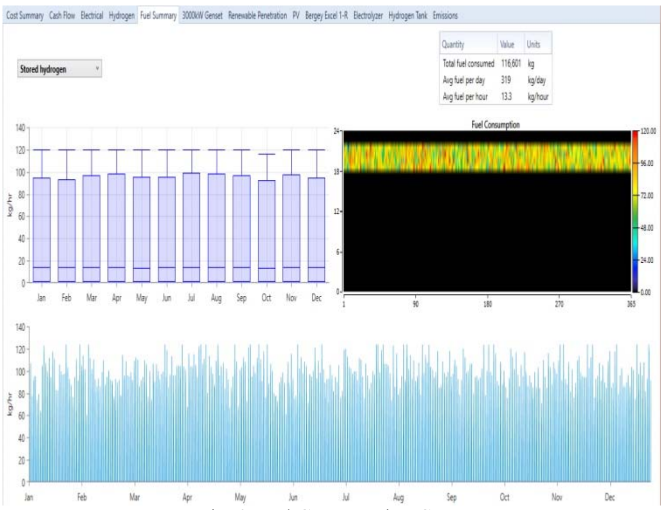


Fig. 9 Fuel Consumption Curve

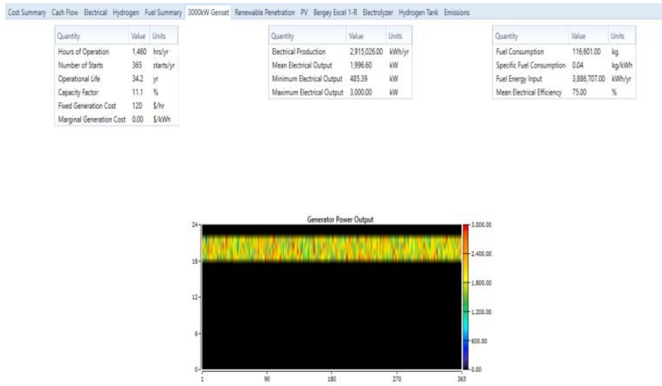


Fig. 10 Hydrogen Generator output Curve

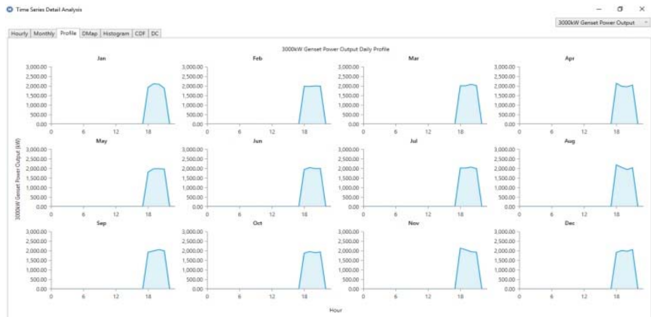


Fig. 11 Generator electricity production curve

The following result are obtained
Table V shows the overall system production output.

TABLE V
SYSTEM PRODUCTION

Component	Production (yr)
Hydrogen production	122,275 kg
Hydrogen generator	2,910,906KWh
Electrical AC load	2,917,683 KWh
Hydrogen consumption	116,601 kg

VI. COST ANALYSIS

1$ = 80TK
Table VI & VII. Shows the cost analysis of the system .From mentioned table it's very much clear that system net present cost is around 3,878,582$ and annual system cost is 283,415$.

TABLE VI
NET PRESENT COSTS

Component	Capital	O&M	Total
PV	937,500	13,685	951,185
Wind turbine	1,450,000	27,370	1,477,370
3000kW Genset	250,000	598	246,732
Converter	1,000	0	1,000
Electrolyzer	1,200,000	1,369	1,201,369
Hydrogen Tank	1,000	0	926
System	3,839,500	43,022	3,878,582

TABLE VII
ANNUALIZED COSTS

Component	Capital	O&M	Total
PV	68,505	1,000	69,505
Wind turbine	105,954	2,000	107,954
3000kW Genset	18,268	44	18,029
Converter	73	0	73
Electrolyzer	87,686	100	87,786
Hydrogen Tank	73	0	68
System	280,559	3,144	283,415

The overall cost summary are shown in fig. 12.

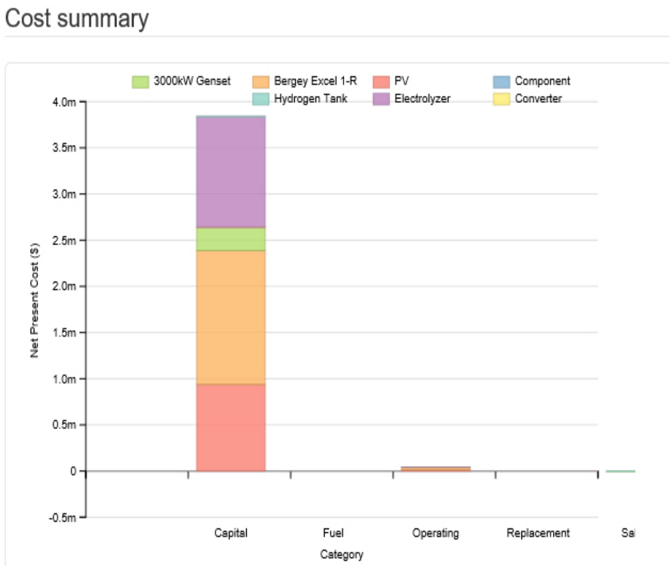


Fig. 12 overall cost summary

VII. CONCLUSIONS

Proposed system is suitable for sea based areas in Bangladesh and completely green energy model. For that system has not CO_2 emissions & pollution free. Basically proposed design is just for contributing in peak load demand but if the hydrogen storage is sufficient it can also contribute in base load demand. The initial cost of the system is very high but per unit cost of the system is 0.09$/KWh which is profitable than the conventional quick rental power plants of 0.23$/KWh cost per unit. As alternator gives pure sign wave so generated power has no THD. Finally the proposed system is reliable and efficiency is very high with negligible system loss.

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