Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2013
(ICMERE2013) 1-3 May 2014, Chittagong, Bangladesh

ICMERE2013-PI-199

FEASIBILITY STUDY OF THE RELIABLE POWER SUPPLY FOR THE COASTAL ISLAND THROUGH RENEWABLE ENERGY

Sampad Ghosh[1] and S. M. Mezbahul Amin[2]

[1, 2]Department of Electrical and Electronic Engineering (EEE), Chittagong University of Engineering and Technology (CUET), Chittagong-4349, Bangladesh

[1,*]sampad04cuet@yahoo.co.in, [2]mezbahulamin@gmail.com

Abstract*- Electrical energy is the most important thing for prosperous social life and economy. Coastal islands which are far from the main land face acute electrical energy problem. In the coastal areas which are not directly connected with the main land, it is quite impossible to extend high tension transmission lines. This problem can be solved by the help of proper use of renewable energy. This lacking of electrical energy is the main obstacle of the development of those islands. So, it is very essential to provide electricity for the betterment of coastal islands. In this study, we analyze the data of one island in Bangladesh named Sandwip. This island is far from the main land Chittagong. But, this island will play an important role after the Chittagong port extension. In this paper we tried to analyze the prospect of using renewable energy as a solution for the coastal islands. We have collected various data about different forms of renewable energy such as solar PV system, wind-diesel hybrid system, ocean wave energy, biogas and tidal energy and analyze these sources how far these can contribute to solve the energy problem and give clean energy to the remote island. Renewable energy sources are the best option for empowering a coastal island because it doesn't depleting energy sources and also environment friendly. A costal island can meet its energy requirements by using single techniques and also hybrid technology.*

Keywords: Renewable energy, Solar PV system, Wind-diesel hybrid system, Coastal Island Power

1. INTRODUCTION

In the recent ages Energy Crisis is now one of the world's most major problems. The standard of living and economic condition depend on the energy of per capita consumption. In Bangladesh the per capita energy consumption in 2012 stands at 160.9 kgOE (kilograms of oil equivalent), which is much below the world average (Bangladesh is standing 146 among 187 countries in 2011 IDH ranking) [1]. Bangladesh and most of the countries are now facing the energy problem. These countries are now trying to solve their energy problems through renewable energy. In Bangladesh there are many areas where electricity will not available in the next 30 years. The energy supply in the island areas is very tough. Most of them have no direct connection in the main land. In this case those islands can use renewable energy in various formats. The island Sandwip is situated in the Latitude 22°28′34″ N and Longitude 91°21′27″E, Elevation above sea level is 6 m and nearly 350,000 people live in the area of 762.42 km^2 (294.372 sq mi). In this paper we will give some idea about using renewable energy, which can be use in other islands. The energy format can be Solar PV system, wind turbine, biogas, ocean-wave energy and wind-diesel hybrid system by using CHP technology [2]. The island areas have the benefits of wind in almost seasons of a year. So, there is a chance of using combined energy production system in the island areas. This wind energy is naturally very hard to get in the areas far from the sea. The islands have these benefits.

2. PRESENT ENERGY SCENARIOS

The price of oil and gas is raising abundantly, this problem force to find alternative energy. Bangladesh heavily depends on the Gas. The 88.39% generation of electricity is depending on the indigenous natural gas. But the present reserve will be depleted in the upcoming 15-20 years. Bangladesh is also heavily depending on imported oil for running its quick rental power plant. The energy demand will be 11,974 MW for low economic growth of 6% and it will be 17,580 MW if the economic growth rate is 8% [3]. Bangladesh has the target to bring the whole country under electricity service by the year 2020. This is very hard to fulfill the criteria due to the high price and lacking of oil and gas. In this case it is very hard to give electrical energy in the coastal areas and it's almost same all over the world. So, the only option to overcome this problem is renewable energy. Bangladeshi policy maker's sets targets for developing renewable energy resources to meet five percent of the total power demand by 2015 and ten percent by 2020.

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3. PRESENT POWER SUPPLY CONDITION IN THE ISLAND SANDWIP

Bangladesh Atomic Energy Commission (BAEC) first carried out a Solar Photovoltaic Pilot project at Sandwip Island in 1988. At that time a solar-powered beacon light was installed on top of a watch tower, solar-powered refrigerators in a veterinary hospital and solar light and microphone in a local mosque was set upped. But all this setup was destroyed by the cyclone of 1991. Country's first solar mini grid is now fully operational in the island Sandwip. It started its operation on September 29, 2010. This solar mini grid has the capacity of 100kW and it's the first in this region. This solar park is directly connected to the inverter system, which allows consumers to use 220 Volt AC power in a day time from a three phase mini grid system [4]. 60 percent of the total 100 kW can be directly fed into the three phase line through grid tied inverters during daytime, remaining 40 percent of the energy will be stored in high quality battery bank for the night. Total project cost is BDT 55.37 million and it is financed through a mix of debt, equity and grant from KfW. PGEL is a consortium of four NGOs namely Bangladesh Rural Integrated Development Grub-Street Economy (BRIDGE), Integrated Development Foundation (IDF), Upokolio Bidyut and Mohila Unnoyon Samity (UBOMOUS) and Rural Energy and Development Initiative (REDI). A 25 kW solar mini grid will generate electricity for 4.5 hours and produce 113kWh which can reduce the demand of 82 GWh (GigaWatt) of electricity per year from the national grid. A study examines that the feasibility of PV grid system for 500 kW plant is cost competitive with grid connected diesel generation plant which lies between 15-18 BDT per unit [5]. Government of Bangladesh is planning to setup a 500 MW solar plant with the financial help of Asian Development Bank (ADB).

4. SOLUTION THROUGH RENEWABLE ENERGY

In the perspective of coastal island Sandwip; we can solve the energy problem through biogas, biodiesel, solar PV system, tidal power, hybrid wind-diesel turbine which are described below.

4.1 Biogas

Many countries all over the world are now paying a great attention to the biogas technology for its environment friendly behavior; it can also be the supplement of the decreasing reserve of fossil fuel [6]. Fossil Fuel is the main natural resource or raw material for generating electrical energy and at presently people is fully dependent on electrical energy. Biogas can be a good alternative in place of natural Gas. Biogas is produced from the natural waste materials. Waste materials from day to day life usage, animal waste, crop waste, can be a good source of producing biogas. This can help to meet the electricity demand through biogas. In the island areas natural waste is more available then urban areas. This waste has good compostable and fermentation property, which can be use for both electricity generation and cooking purposes. Small farms and houses can produce biogas through their daily wastage. Waste to Electricity production is a great chance for the coastal island areas, whose are not directly connected to the main grid.

4.2 Biodiesel

Fossil fuels are depleting day by day and cause a global warming issue. These fossil fuels are heavily emitting Carbon-di-Oxide; biodiesel can be a great alternative for the fossil fuel. Biodiesel is produced by Transesterification of oils with short chain alcohols. Biodiesel can be made from Algae, Coconut, Rapeseed, Sunflower and some other sources. Now a day's researchers give their attention to produce biodiesel from algae because of their availability in the nature, high Triacylglycerides and their high productivity rate. Production of algae is easy, cheaper and less time consuming than the fossil fuels. Production of algae is not needed a critical setup as fossil fuels. These help us to reduce dependency on the fossil fuels. Productions averages of biodiesel from various crops are as follows.

Table 1: Production averages for common oil crops

Plant	lb. oil/acre	Gallons of Biodiesel/acre
Algae	6757	700
Coconut	2070	285
Jatropha	1460	201
Rapeseed	915	126
Peanut	715	112
Sunflower	720	99
Soybean	415	62

From the table we got that Algae is best for producing biodiesel [7]. This biodiesel can be directly use in generator. In the coastal area the production of Algae is easy due to its weather condition. So, biodiesel can be use an alternative energy form in coastal areas.

4.3 Solar Energy

Solar energy can be the best solution for meeting the energy needs; it's a good form of clean and cheap energy. The most suitable area for getting the solar energy is between the two broad band's encircling the earth are between 15" and 35" latitude north and south. The island Sandwip is situated in this area [8]. Normally the radiation of solar energy in Bangladesh varies between the ranges of 1575 kwh/m² to 1840 kwh/m²; in most of the cases the radiation is 50%-100% higher than Europe. If we assume that the radiation of solar energy is 1900 kWh/ m², the total annual radiation in Bangladesh can be 1010×10^{18} J. If there is a chance of utilization of this energy, only 0.07% of this energy is enough for meeting the need of the whole country. In the present condition the availability of this energy is 208 watt/m², but only 0.15 watt/m² is utilized [8]. Figure 1 and 2 shows the lowest and the highest intensity of direct radiation in W/m² and the available sunlight hour throughout the whole year respectively [9].

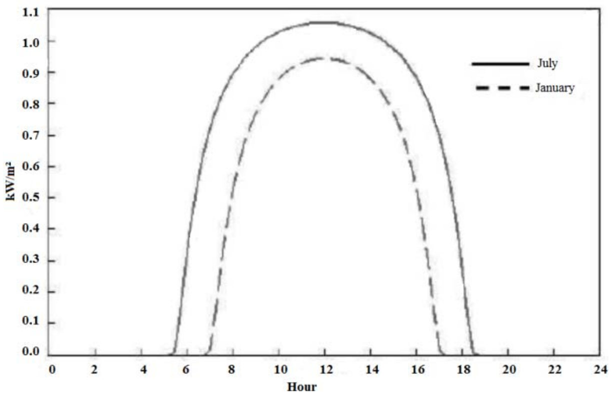

Fig.1: Lowest and highest intensity of radiation in W/m²

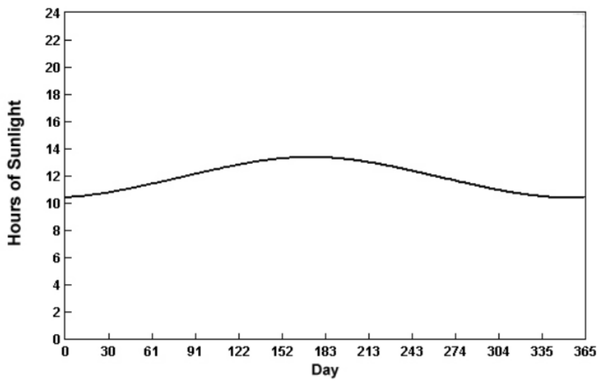

Fig.2: Available sunlight hour throughout the year

The average solar radiation is 4 to 6.5kwh/m² in a day. The minimum amount of solar radiation is in the month of December-January and the maximum is in the month of March-April. A salt gradient or non-convective solar pond can also be used for storing solar energy. In ordinary pond the heat is released to the atmosphere through convection and evaporation. In the non-convective solar pond this heat loss is reduced and the thermal energy is stored.

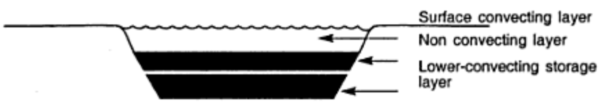

Fig.3: Salt-gradient solar pond

The solar pond has normally three layers. In the first layer convection takes place due to wind evaporation. In the second layer salt gradient is used and make it non-convective this layer is 1m thick and in the final layer is convective layer which is act as thermal storage. A saturated pond is some time used for maintaining solubility of salt in water.

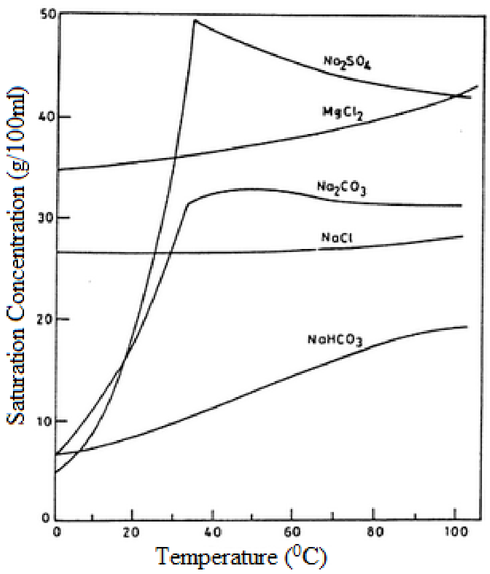

Fig.4: Solubility of salts in water

It was estimated that 100m-diameter solar pond which has 1m deep storage layer can be drive a Ranking cycle cooling unit to meet the air-conditioning needs of 50 homes [10]. This solar pond process can be useful in some cases where adequate solar energy is not available at all the time.

4.4 Tidal Energy

Tidal energy is produced when turbine of electrical generators are placed on the surface of the ocean. The coastal island has the benefits of using tidal energy. The island Sandwip has full benefits of using tidal wave energy. The island Sandwip is a mudflat created from the Ganges delta. There are two types of head for generating tidal energy. They are- (i) Low head tidal movements (2~5 m head) and (ii) Medium head tidal movements (> 5 m head). The island Sandwip has lass then 5m tide accessibility. The tidal plant needs barrage and sluice gates for generation; this island has a flood control barrage around the entire island and contains 28 sluice gates. This tidal plant needs three elements. They are under-shot paddle wheel, existing electronic controllers for regulating power output and variable speed electricity generation equipment.

Table 2: Tidal levels in Sandwip

STATION	LAT	MLWS	MLWN	ML	MH-WN	MH-WS	HAT
Sandwip	-0.58	0.24	1.63	3.24	4.85	6.25	7.07

There are some limitations of tidal energy such as it changes some natural condition including the change of salinity in the water, the initial setup cost is very high and there is a very small chance of getting reliable place for setup. But there are many good points for tidal plants, such as the operation of the plant is intermittent with load factor 22-35% and the setup and equipment has a very long life time. The sea level is increasing day by day, so the tidal behavior is changing rapidly. If the coastal islands can use this changes condition, it will be a great option of getting energy.

4.5 Ocean Wave Energy

Ocean wave energy is directly generated from the waves of the ocean. The worldwide potential of wave energy is estimated to be around 2 TW. A large amount of energy can be found by setting turbines at strategic locations under strong current. Coastal islands may have a very good chance of using this technology rapidly. According to reference, the Oscillating Water Column method is technically feasible and becoming economically attractive. This type of wave energy harnessing device is being commissioned by several countries such as the United Kingdom (500 kW), Ireland (3.5 MW), Norway (100 kW), India (150 kW), etc. Bangladesh has potential for harnessing wave power from the Bay of Bengal.

4.6 Wind Energy

The coastal islands have a huge chance of using Wind energy by using wind turbine. In Bangladesh the wind is coming from the Indian Ocean from March to September with an average speed of 3m/s to 6m/s. The peak wind speed is found during the months of June and July and from late October to February the wind speed is low [11]. The wind speed is increased when it enters in the V-shaped coastal region of the country. An average wind speed in m/s and available power in the different island Teknaf, Kutubdia, Sandwip, Kuakata, Mongla are given in Table 3 and Table 4 respectively.

Table 3: Average wind speed in m/s in different island and coastal areas (Bangladesh 2003)

Locations	Month						
	Mar	Apr	May	Jun	Jul	Aug	Sep
Teknaf	2.85	2.56	2.39	4.71	2.83	4.14	3.11
Kutubdia	3.78	12.02	2.37	4.71	5.73	4.78	2.92
Sandwip	6.23	8.34	2.28	3.93	5.44	4.44	5.18
Kuakata	3.07	5.26	3.10	3.69	4.28	3.37	2.03
Mongla	3.07	2.41	2.94	4.23	4.34	4.44	2.92

Table 4: Theoretical available power in different island and coastal areas (Bangladesh 2003)

Locations	Months	Avg. speed (m/s)	Theoretical available power (W/m^2)
Teknaf	March to Sept.	3.23	20.17
Kutubdia		5.19	83.74
Sandwip		5.12	80.53
Kuakata		3.54	26.68
Mongla		3.48	25.26

From the table, the maximum speed of the wind is in Kutubdia but this is unstable. In Sandwip the speed of the wind is stable. So, it is important to analyze wind data before setup a plant.

4.7 Wind-Diesel Hybrid Power System

Most of the islands don't get enough wind energy around the year. In this state a hybrid Wind-Diesel system can be a good alternative. The use of only diesel generator is not cost effective, which was previously used in Sandwip. The wind data of Sandwip is shown below, from that the average wind speed is 6.15 m/s at Sandwip which is sufficient to generate electricity commercially.

Table 5: Wind speed at 45m height

Month	Wind speed (m/s)
January	4.83
February	3.79
March	8.59
April	11.5
May	3.14
June	5.42
July	7.50
August	6.12
September	7.14
October	5.71
November	5.20
December	4.87

The Diesel generator has many benefits including low fuel consumption, good load support, operating feasibility, Low cost, quick start and small size.

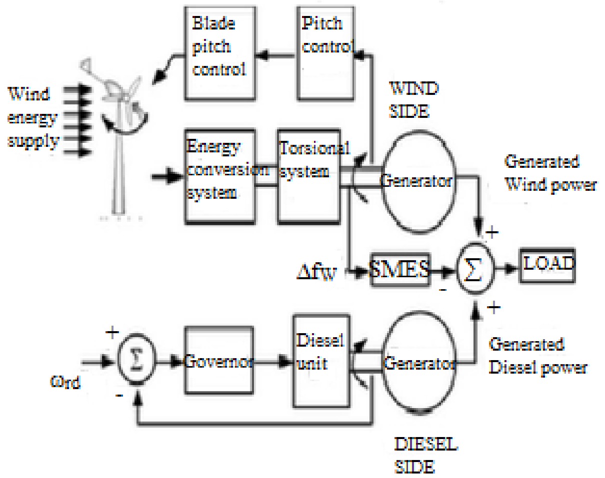

Fig.5: Wind-Diesel hybrid power system

A Wind-Diesel hybrid power system is more economical then only Solar PV setup. The Initial investment cost ($/kwhr), Transmission and distribution cost ($/kwhr) more cheaper then solar PV system [12].

Table 6: Cost comparison of wind and solar PV system

Energy system	Fuel cost ($/kwhr)	Initial investment cost ($/kwhr)	Transmission and distribution cost ($/kwhr)	Total cost ($/kwhr)
Wind	0	0.08	0.023	0.103
Solar PV	0	1.05	0.020	1.070

The table clearly indicates that using Wind-Diesel Hybrid Power System is more preferable than using Solar PV system in the coastal island Sandwip.

Table 7: Comparative study of the use of renewable energy [13]

Evaluation	Solar thermal	PV	Wind	Tidal
Capital cost	Large	Large	Moderate	Enormous
Operating Cost	Moderate	Moderate	Small	Negligible
Efficiency	15%	5-10%	42%	25%
Renewable	Yes	Yes	Erratic	Yes
Storage	Not needed	Unclear	Essential	Unclear
Pollution	Non really	Waste-Heat	Visual	None
Levelized Cost	25cent/ kWhr	16cent/ KWhr	4.5 cent/ KWhr	Unknown
Environmental Impact	Moderate	Large	Small	Unknown
Large Scale	Too expensive	Expensive	Proven	Possible
Small Scale	No	Difficult	Definitely	Possible
Unit Capacity	1000 MW	Depends Acreage	Highly Variable	250MW

5. CONCLUSION

In the present century human civilization is completely depended on electrical power. The major sources of energy are now depleted heavily. In this state all the human civilization doesn't get the chance of using electricity. In many cases, coastal islands are far out from this facility. The energy crisis is severe in Bangladesh which is a threat to the economical development. In the coastal areas and the isolated islands where grid connection is not feasible, alternate electric sources like wind, solar PV or other sources can be the potential solutions. But the solar PV system is at least 4 to 5 times more expensive than wind power system. On the other hand only the wind power system cannot satisfy the whole demand of electricity. In this situation, a wind-diesel hybrid system can be a cost effective solution for the isolated islands.

6. REFERENCES

[1] http://en.wikipedia.org/wiki/List_of_countries_by_Human_Development_Index. (18/11/2012)

[2] Godswill Ofualagba, "The Modeling and Simulation of a Microturbine Generation System", *International Journal of Scientific & Engineering Research*, Volume 2, Issue 2, February-2012 ISSN 2229-5518.

[3] Final Report of Solar and Wind Energy Resource Assessment (SWERA) Bangladesh", Renewable Energy Research Centre (RERC), University of Dhaka, Bangladesh.

[4] http://www.bpdb.gov.bd. (29/11/2010)

[5] The New Nation, "Gas Crisis: 4 power plants likely to use liquid fuel from August", Sunday, July 12, 2009.

[6] J. Zhu and M. Chow, "A Review of Emerging Techniques on Generation Expansion Planning," *IEEE Trans. on power Systems*, vol. 12. pp. 1728, 1997.

[7] Nick Sazdanoff, *Modeling and Simulation of the Algae to Biodiesel Fuel Cycle*, Honors Undergraduate Thesis, College of Engineering, Ohio State University, 2006.

[8] Nasima Akter "Alternative Energy Situation In Bangladesh: A Country Review" *APPROTECH ASIA Philippine Social Development Center*, Philippines, July 1997.

[9] Kazy Fayeen Shariar, Enaiyat Ghani Ovy, Kazi Tabassum Aziz Hossainy, "Closed Environment Design of Solar Collector Trough using lenses and reflectors", *World Renewable Energy Congress*, Sweden, 2011.

[10] C.M. Leboenf, "Solar Ponds Applied to District Heating and Cooling", in *Proc. of the 1981 meeting of the American section of the Int. Solar energy society*, New York.

[11] S. Ahmed, *Investigation and Analysis of Wind Pumping System for Irrigation in Bangladesh*, M.Sc Engineering Thesis, BUET, Dhaka, February, 2002.

[12] Nahid-Al-Masood, Rifat Mirza, Jubaer Ahmed, Amina Hasan Abedin, S.R. Deeba, Faeza Hafiz,Mahmuda Begum and A. Hasib Chowdhury, "Design of a Cost Effective Off-Grid Wind-Diesel Hybrid Power System in an Island of Bangladesh" World Academy of Science, Engineering and Technology 60 2011

[13] HM Treasury and DETR press release (2000), "Protecting the Environment and Supporting Britain's Road Transport", UK Parliament, 7th March 2001.

7. NOMENCLATURE

Symbol	Meaning	Unit
LAT	Lowest Astronomical Tide	(m)
MLWS	Mean Low Water Spring	(m)
MLWN	Mean Low Water Neap	(m)
ML	Mean Level	(m)
MHWN	Mean High Water Neap	(m)
MHWS	Mean High Water Spring	(m)
HAT	Highest Astronomical Tide	(m)