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A Feasibility Study of Electrification of a Base Transceiver System (BTS) using Renewable Energy Generators

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***Abstract*— The focus of this report is to design a renewable energy based generator to supply power to a remote mobile phone base station. This study has investigated different renewable based hybrid system using HOMER simulation software to provide continuous power to mobile phone base station. This paper presents an overview of hybrid system which includes solar PV, Wind turbine and Diesel generators. In addition, this study performed the economical analysis for different components of proposed hybrid systems. This report also states that the potentiality of renewable energy integration especially in the remote areas in Bangladesh.**

Index Terms* — *PV, STP, MPP, WP, KWh, Load Curve, HOMER, Cut off frequency, COE, Solar Radiance, Swept Area.

I. INTRODUCTION

The consumption of electrical energy is rising rapidly [1] over the last few decades where global energy demands have not yet been fully realized due to the lack of sophisticated technologies and sufficient energy resources so the world is facing severe energy crisis and it is expected to increase in the forthcoming years. Nowadays, the global power generation is majorly done using conventional energy sources though such energy reserve is very much limited and expected to end within few decades.

So, renewable energy resources [2-4] is increasingly being quested for as an alternative sources of energy generation because these are everlasting and eco- friendly and it has been drawn more and more attention in recent years to abridge the gap between energy demand and supply. Renewable energy sources such as wind turbines, photovoltaic (PV) generators, fuel cells, small hydro and wave generators, are being integrated into power systems at distribution level to a large extent.

Extension of grid electricity is not always economically feasible especially in some rural areas of Bangladesh because its economical condition where people's basic needs have not been met yet. In some isolated areas where supply of electricity from national grid is quite impossible but all socio economic developments and modern lifestyle depend solely on electricity. The main focus of this study is to provide electricity to mobile base station from renewable energy sources in the remote areas. A hybrid system based on renewable generator has been designed to provide electricity and schematic diagram is shown in Fig. 1. This report is divided into nine parts. Simulation of different hybrid system is done by HOMER (Hybrid Optimization of Multiple Energy Resources) software.

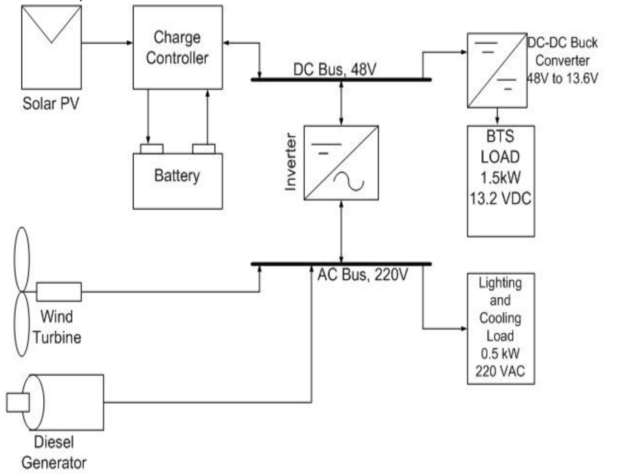

Fig. 1. Schematic diagram of hybrid system

II. SITE DESCRIPTION

In this report we have proposed a mobile base station at middle of St. Martin's island is to be electrified by renewable energy. St. Martin's island also called by "Narical Gingira" translated from Bangla, meaning 'Coconut Island' is located in the northeastern part of the Bay of Bengal.

The geographic location is roughly in between 20° 34² - 20° 39² N and 92° 18² - 92° 21' E, about 9 km south of the tip of the Cox's Bazar-Teknaf peninsula, and forming the southernmost part of Bangladesh. Fig. 2. illustrates the aerial view of St Martin's Island.

The island has huge potential of wind and solar energy. It is noticeable that land is flat and just only about 3m high from the sea level with approximately 6000 Inhabitants living on fishing. As national grid is far away it is not very cost effective, in some cases it is impossible to extend the grid to St Martin. Currently some electricity demand is being fulfilled by stand alone diesel generators [5] and PV solar panels.

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. Aerial view of St. Martin's Island

Fig. 2. Aerial view of St Martin's Island

III. ALTERNATIVE ENERGY RESOURCE

Annual solar insolation over St Martin is 4.84 kwh/m^2/day though there is no specific ground data of St Martin according to NASA satellite. Table I reveals the monthly Global Horizontal Insolation (GHI) data which is sampled for 10 km spatial resolution for St Martin. Table includes three type of measurement such as from NASA (for 10 years period), estimated values from Teknaf sunshine data (also data have been taken for 10 years period) and German Aerospace Center (DLR)(used three years data 2000,2002,2003). It has found that April is the highest solar insulation getting month throughout the year.

TABLE I
GHI VALUES FOR ST MARTIN'S ISLAND

Month	NASA	Estimated (from sunshine)	DLR
Jan	4.84	4.00	4.63
Feb	5.46	4.44	5.04
Mar	6.41	5.37	5.62
Apr	6.48	5.87	6.47
May	5.96	5.43	4.94
June	3.60	4.10	3.39
Jul	3.62	3.87	3.31
Aug	3.69	3.95	3.78
Sept	4.34	4.09	3.96
Oct	4.72	4.21	4.28
Nov	4.42	3.72	4.54
Dec	4.54	3.75	4.16
Annual	4.84	4.40	4.50

Table II shows the information about the wind resource of St Martin's island. It is clearly noticeable that wind speed varies from time to time. Data has been taken from NASA and Scientific and Industrial Research (BCSIR) [6]. BCSIR has taken data from for the period of three years (1999 – 2001) at a height of around 30 meters above the ground level whereas NASA has taken data for 30 meters above the ground level for the same location.

TABLE II
WIND SPEED AT ST MARTIN ISLAND

Month	NASA (10m)	Measured (30m)
Jan	3.27	5.03
Feb	3.39	4.70
Mar	3.57	4.24
Apr	3.67	3.79
May	3.89	5.07
June	6.27	6.17
Jul	6.35	5.56
Aug	5.64	5.78
Sept	4.05	4.47
Oct	3.27	4.11
Nov	3.24	3.53
Dec	3.10	4.11
Annual	4.14	4.71

Fig. 3. Discloses the variation of solar irradiation and includes cleanliness index from the latitude information of St Martin. The bar graph is extracted from HOMER (Hybrid Optimization of Multiple Energy Resource) with the input data is collected from BCSIR have been used along with the information of height = 30m, elevation = 3m, surface roughness = 0.01m. HOMER synthesized these monthly average data based on the other parameters such as Weibull factor "k" = 1.8, Autocorrelation factor (randomness in wind speed) = 0.90, Diurnal pattern strength (wind speed variation over a day) = 0.25, Hour of peak wind speed = 22 to generate hourly data for a year.

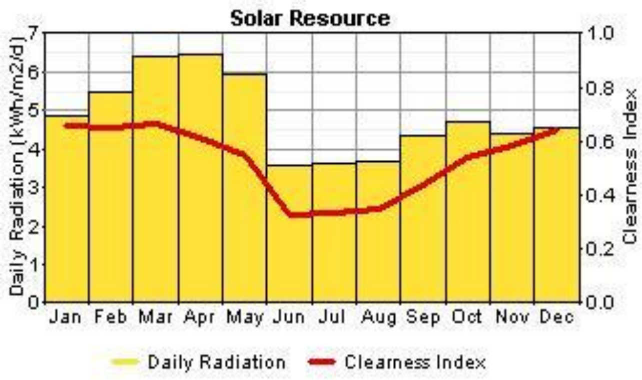

Fig. 3. Solar Radiance at St Martin Island [6].

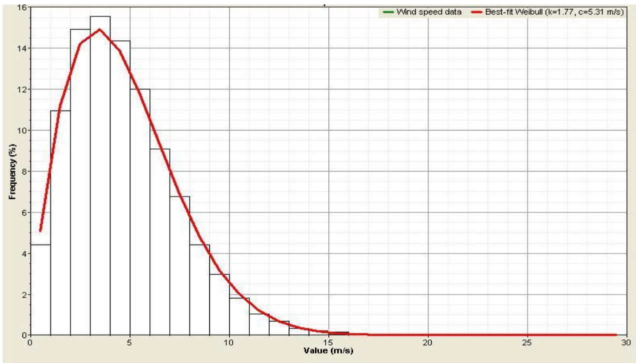

Fig. 4. Wind speed probability density function [6].

The speed probability distribution function and averaged hourly wind speed variation for 1 year for St Martin's island is shown in Fig. 4. and Fig. 5, respectively.

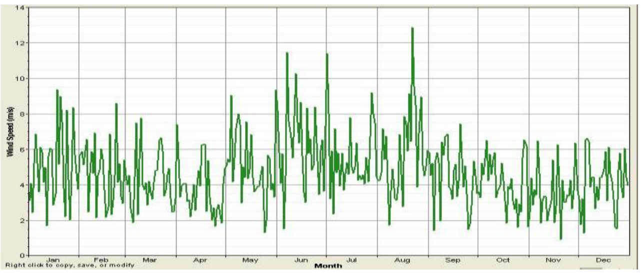

Fig. 5. Daily wind speed for St Martin [6].

IV. ELECTRICAL LOAD DESCRIPTION

The base station transmitter equipment requires 1.5 kW electrical powers to be supplied for without interruption operation, at 13.2 V. d.c. in addition with this we need to consider for cooling since it is warmest region in Bangladesh. An air cooler ratings 300W has been considered for maintain the inside temperature of 5 – 30 °C of the base station. Moreover 200W needs to be included in total load for security lightings as an additional ac loads.

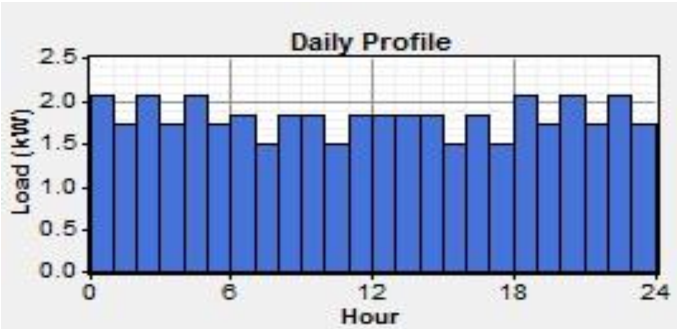

Fig. 6. Daily load curve in summer of this site

The additional load duration is varied with the season. For instance, air cooler load is always higher in summer season than in winter. The total energy consumption per day is 41kWh/day and 2.1kW peak load has been estimated. The daily load curve in summer and winter season has shown in Fig. 6 and Fig. 7, respectively. Maximum demand of summer is much higher than winter maximum demand.

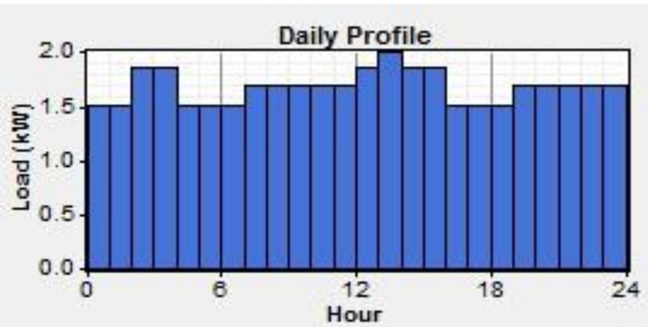

Fig. 7. Daily load curve in winter of this site

V. FEASIBLE HYBRID SYSTEM

A. PV Sizing

At first stage of hybrid system design PV sizing is determined. As the total load requirement has already been determined we can easily calculate the size of the PV module for our design. But the size of the module depends on which kind of module we are going to use. As an example we are considering ENF Solar225 module of 225Wp to be an ideal module. The specifications of various types of ENF solar module has given below:

Max Power = 225W (STP)
Max Voltage = 29.4V (at MPP)
Max Current = 7.66A (at MPP)
Nominal output voltage of this panel is 24V.
Total PV panels energy needed = 41000Wh/day.
Total Wp of PV panel capacity needed = 41000/ 4.55hours = 9011Wp
Number of PV panels needed = 9011/ 225 = 40 modules
So this system should be powered by 40 modules of 225Wp.

$$No.of\ panel\ in\ series = \frac{System\ Voltage}{Nominal\ Panel\ Voltage} = \frac{48}{24} = 2\ modules$$

$$No.of\ panel\ in\ parallel = \frac{Total\ no.\ of\ modules}{No.of\ modules\ in\ series} = \frac{40}{2} = 20\ strings$$

B. Wind Turbine Sizing

For given load demand and according to the site wind speed limit, there may be Solar PV and Diesel based system will be optimized and cost effective model. If we consider setting up the wind turbine with Solar PV for supplying the continuous power, a supervisory controller needs to set up to control the supply based on percentages of load demand. Since the half percentages annual average load demand 21000kWh per day which is almost 2.3kW. If we choose 0.4 is the betz limit and air density12.2 kgm-3. Since the wind speed in given area is 4.71m/s, the swift area of the turbine is

$$A = \frac{2P_{real}}{\rho C_P V^3} = 95m^3 \qquad (1)$$

The radius of the turbine blade is

$$R = \sqrt{\frac{A}{\pi}} = 33.43m \qquad (2)$$

C. Battery Sizing

As we know that battery backup is very much crucial part of hybrid design and any BTS design as well. Special attentions have given while calculating battery sizing. Usually battery back is assumed for few hours of the day because sufficient sunlight other times of the day. So we should consider the battery backup from afternoon to the next morning so that the consumer will be benefited around 15-16 hours. We know that general equation of determining battery capacity for a PV system by following equation:

$$Battery\ Capacity = \frac{Total(\frac{Wh}{day})\text{at night}*\text{Derating Factor}*\text{Day of Autonomy}}{\text{Battery Efficiency}*DOD*\text{Nominal Battery Voltage}} \qquad (3)$$

$$= \frac{41000 * 1.2 * 2}{0.9 * 0.6 * 2} = 30371\ \text{Ah}$$

If we consider battery from Trojan Battery Company with Model: Trojan L16P, 6V and 360 Ah.

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Total number of battery required $= \frac{30371}{360} = 84$

Number of battery per string $= \frac{System\ Voltage}{Battery\ Voltage} = \frac{48}{6}$
$= 8$

Number of battery string $= \frac{84}{8} = 11$

D. Inverter Sizing

As total ac load demand by the site is known about 500W, it would be facilitated the process for calculating the inverter sizes. If we choose the inverter with 90% efficiency and 48V operating voltage then,

Minimum power ratings of the inverter $= \frac{500}{0.9} = 555.55W$

E. Charge Controller Sizing

Since the voltage is coming from solar array is 48V and the battery bank is always maintaining 48V bus with the load demand is 2.1kW or 2100W, so a charge controller with efficiency 85%, power rating 2.5kW, input and output voltage 48V and current rating is almost 50A is chosen.

F. DC-DC Converter Sizing

The base station transmitter is operated with 1.5kW power demand with voltage level 13.2V dc. But our solar PV system is maintaining voltage 48V. So output of PV voltage needs to be reduced to 13.2V dc to operate the base transceiver system. A buck dc-dc converter from Power Stream Company [http://www.powerstream.com/dcdc-48V.htm] with efficiency 85% is chosen with power rating converter 1.8kW, input voltage 48V, output voltage 13.6V and current rating is near 110A.

VI. SIMULATION AND COST ANALYSIS USING HOMER

Simulation diagram of HOMER total load supplied by PV and a generator is shown in Fig. 8. Since mobile base station very important load a back diesel generator is taken as back up.

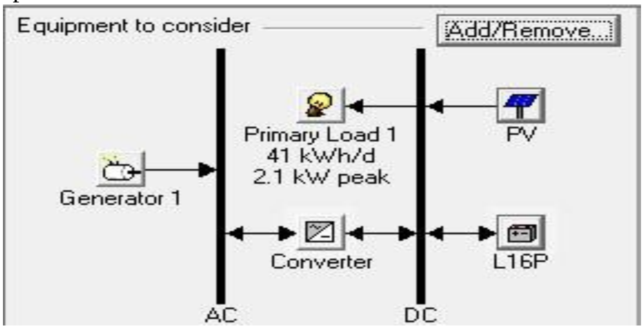

Fig. 8. Load supplied by PV and a disel generator

Another means of supplied load shows in Fig.9. load is supplied by PV, a diesel generator and a wind turbine.

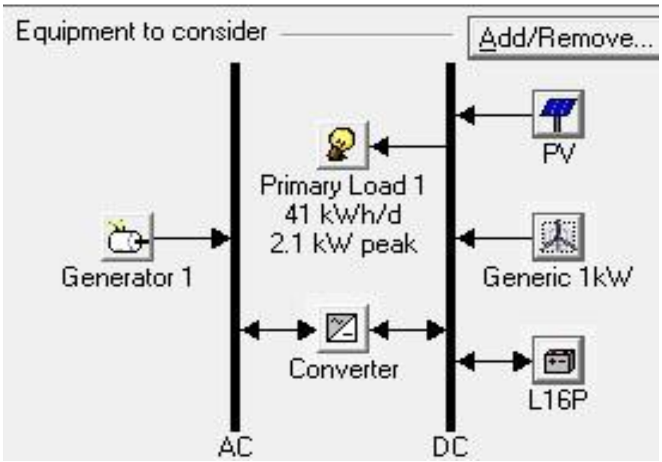

Fig. 9. Load supplied by PV, wind turbine and a disel generator

A. Solar PV Panel

The cost of PV module including installation has been considered as 250 BDT/W for this site. Life time of the PV modules has counted as 25 years. Ratings of PV modules are ranging from 25 kW to 45 kW are considered. Table III gives the economical data according to the parameters have been considered for the simulation solar PV.

TABLE III
SOLAR PV PANEL SPECIFICATION

Parameter	Unit	Value
Capital Cost	GBP/W	0.45
Replacement Cost	GBP/W	0.40
Operation and Maintenance Cost	GBP/W	0.002
Lifetime	Year	20
Deration Factor	Parcent	90
Tracking System	NoTracking System	

B. Wind Turbine

Generic 3 KW wind turbine has been assumed for our hybrid system with starting wind speed 4.31m/s in this case study. Cut off wind speed is also taken as 15 m/s. Table IV gives the information about technical parameters and cost of it.

TABLE IV
SPECIFICATION OF WIND TURBINE

Parameter	**Unit**	**Value**
Rated Power	kW	3
Cut in wind speed	m/s	4
Rated wind speed	m/s	13
Cut off wind speed	m/s	15
Capital cost	GBP/W	0.5
Replacement cost	GBP/W	0.33
O&M cost	GBP/W/yr	0.0013
Operational Life time	year	15

Fig. 10. illustrates the characteristics curve of power vs wind speed of this mentioned wind turbine.

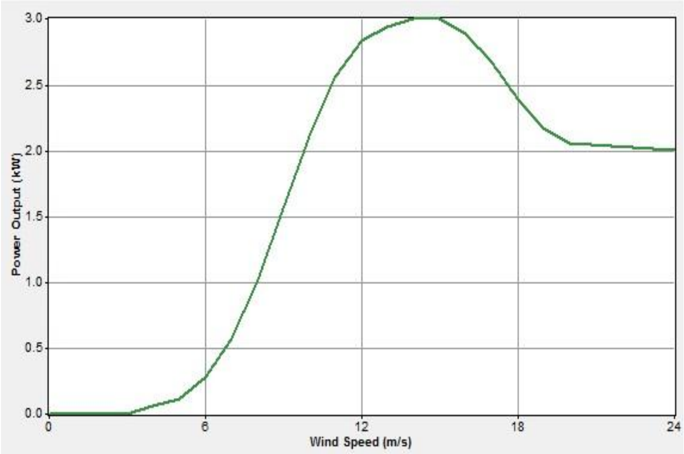

Fig. 10. Power vs wind speed curve of wind turbine

C. Diesel Generator

The fuel used is calculated by a linear curve characterized by a slope and intercept at no load in HOMER. For a capacity range of 15 kW, the slope and the intercept are 0.33 l/h/kW and 0.05 l/h/kW, respectively [5]. Table V gives technical and economic parameters for a diesel generator of 15 kW.

TABLE V
DIESEL GENERATOR SPECIFICATION

Parameter	Unit	Value
Capital Cost	GBP/W	0.22
Replacement Cost	GBP/W	0.2
Operation and Maintenance Cost	GBP/W	0.001
Operational Lifetime	Year	15000
Minimum load ratio	Parcent	30
Fuel curve intercept	l/h/KWrated	0.08
Fuel curve slope	l/h/KWoutput	0.25
Fuel Price	GBP	1.04

With rated output power of 15KW diesel generator the maximum efficiency just above 25 percent as shown in Fig. 10.

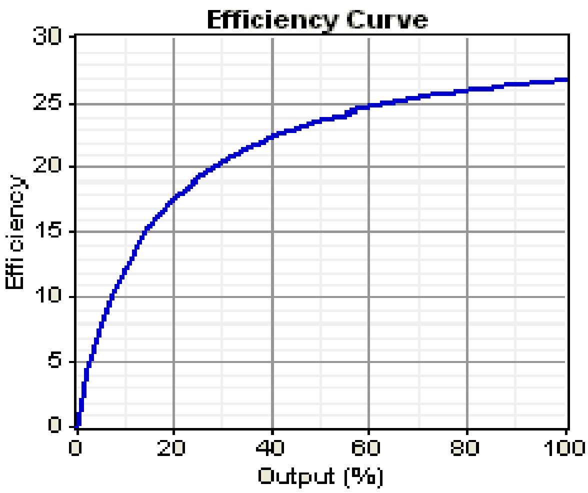

Fig. 11. Efficiency curve of a 15KW Diesel Generator.

D. Storage Device

The Trojan L16P storage batteries have been utilized in the hybrid system [6]. The technical and economic parameters are stated in Table VI

TABLE VI
SPECIFICATION OF BATTERY

Parameter	Unit	Value
Nominal Voltage	Volt	6
Nominal Capacity	Ah	390
Maximum Charge Current	A	18
Round trip Efficiency	%	85
Min State of Charge	%	30
Capital Cost	GBP/Kwh	23.15
Replacement Cost	GBP/Kwh	18.51
O&M Cost	GBP/Kwh/yr	2.31

E. Converter

For supplying electricity to air conditioner and security lights we have to consider a converter circuit since the output of PV and wind turbine is DC, converter is used to change it into AC power. Table VII shows the technical and economical parameters of the converters.

TABLE VII
CONVERTER SPECIFICATION

Parameter	Unit	Value
Capital Cost	GBP/Kw rated	200
Replacement Cost	GBP/Kw rated	150
Lifetime	Years	10
Efficiency	%	90
Rectifier efficiency	%	95
Rectifier Capacity	&	85

Cost summary of two optimized system (PV-Diesel and PV-Wind-Diesel) system are described by the Fig. 12-Fig. 14.

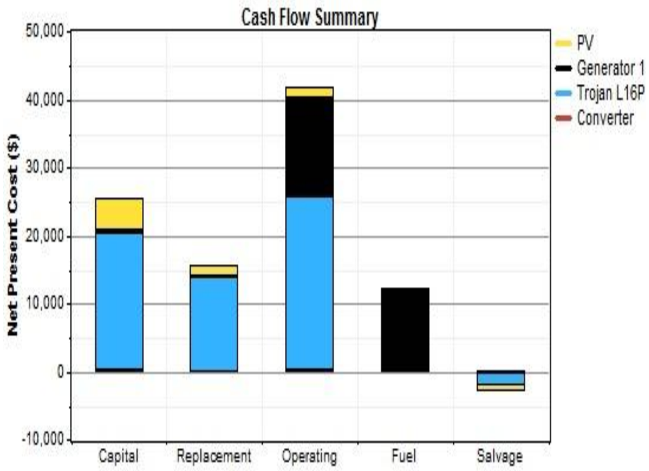

Fig. 12. Net cash flow for solar PV-diesel based system

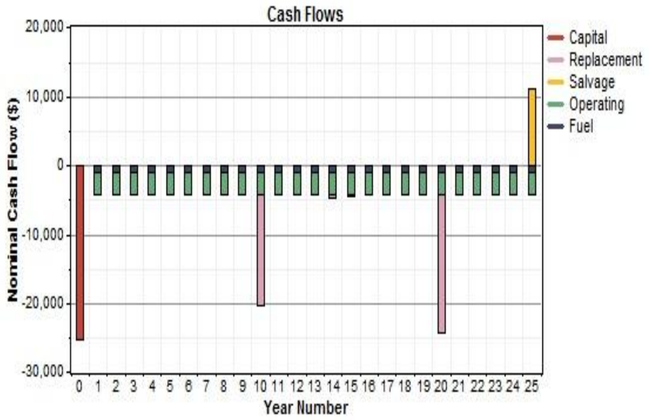

Fig. 13. Nominal cash flow for solar PV-diesel based system

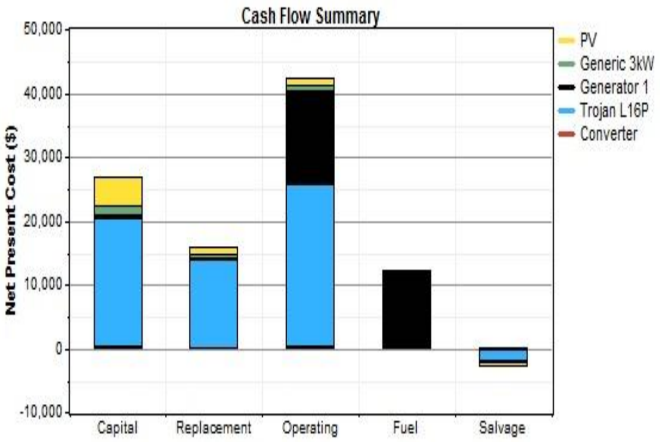

Fig. 14. Nominal cash flow for solar PV-wind-diesel based system

VII. Environmental Impact

Nowadays environmental impact is a great concern for electricity generating systems because modern society uses bulk amount of electricity.

TABLE VIII
Emissions From PV and Diesel System

Pollutant	Emissions (kg/yr)
Carbon dioxide	2.490
Carbon monoxide	6.150
Unburned hydocarbons	0.681
Particulate matter	0.463
Sulfur dioxide	5
Nitrogen oxides	54.8

Table VIII, Table IX compare differences between emission from PV-Diesel system and PV-Diesel-Wind system. There are no differences of emission level of both systems.

TABLE IX
Emissions From PV-Diesel And Wind System

Pollutant	Emissions (kg/yr)
Carbon dioxide	2.490
Carbon monoxide	6.150
Unburned hydocarbons	0.681
Particulate matter	0.463
Sulfur dioxide	5
Nitrogen oxides	54.8

VIII. COMPARISON AMONG DIFFERENT HYBRID SYSTEM

The table X compares the different economic parameters of various hybrid systems. PV-Diesel system is the most efficient among them though the renewable fraction is same for both PV-Diesel and PV-Diesel-Wind. With lowest initial cost GBP 25410 of PV-Diesel system cost of per unit generation is GBP0.

TABLE X
Comparison Among Hybrid Systems

Hybrid Systems	Initial Cost (GBP)	Operating cost (GBP/yr)	Total NPC (GBP)	COE (GBP/kWh)	Renewable Fraction
PV-Diesel	25,410	5,250	92,522	0.479	0.81
PV-Wind-Diesel	26,910	5,327	95,001	0.492	0.81
Wind-Diesel	22,340	15,344	218,389	1.113	0.00
PV-Wind-Battery	105,940	14,939	296,911	1.537	1.00

IX. CONCLUSION

Bangladesh relies heavily on fossil fuels for power generation where the energy policies and pilot projects for renewable energy are still being investigated. The future energy scenario will require a careful and effective change where smart grids and alternative power generation will play a vital role. Since Bangladesh has been privileged by geographic location, Photovoltaic's (PV) is the good solution for supplying power to remote infrastructure like mobile phone base station. In recapitulate, PV is the best renewable generators to supplying electrical power to this site.

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