International Journal of Electronic and Communication Research.
ISSN 2231-1246 Volume 11, Number 1 (2020), pp. 1-11

http://www.ripublication.com

# Feasibility Analysis of Renewable Energy Based Hybrid Power System for Rural Area of Bangladesh

**M.M. Atiqur Rahman[a], Md. Atiq Zaowad[b]**

*[a]Assistant professor, Dept. of Electrical & Electronic Engineering*
*Ahsanullah University of Science & Technology, Dhaka, Bangladesh.*

*[b] Dept. of Electrical & Electronic Engineering*
*Ahsanullah University of Science & Technology, Dhaka, Bangladesh.*

**Abstract**

Bangladesh is the 8th largest populated and according to the density of the population it is in 10th position. More than one third of the population is living without electricity. The demand of electricity is increasing tremendously. The main resources in Bangladesh for generation of electricity are fossil fuel, gas, coal. As an alternative, renewable energy based system are becoming popular in Bangladesh. Solar, Wind, Hydro are the main resources of Renewable Energy System. The objective of this study is to discuss the feasibility of renewable energy based hybrid system in the rural area in southern side of Bangladesh. The system is designed based on the resources available at the location. Using HOMER software, an energy system is developed with PV, Wind, Gas generator and battery backup system and simulated the power system with real weather data and nominal load profile. Sensitivity analysis has also been carried out on the best suitable system to prove the system sustainability in the future. PV-wind-battery-natural gas based system is a feasible solution for the location under consideration. The optimum system has the initial cost $189,870, operating cost of $5,719/year, net production cost $263,805 and COE of $0.143/kWh with very low greenhouse gas emission.

**Index Terms:** Hybrid, renewable energy, HOMER, wind power, photovoltaic.

## 1. INTRODUCTION

Bangladesh is a small country with a large number of population. Presently 70% of the total population has access to electricity. Among to the total population having electricity, 80.4% are from urban area and 18.7% from rural area [1]. The electricity demand of the country is very high and the demand is rapidly increasing day by day. In Bangladesh, electricity is the major source of power and most of the economic activities depend on electricity. The total installed electricity generation capacity (including captive power) of Bangladesh is 15,351 MW. The capital availability per annum is 321 kWh and only 68% of the population has the access to the electricity [2-3]. The main problems in electrical sectors of Bangladesh includes high system losses, delays in completion of new plants, erratic power supply, electricity theft, low plant efficiency, corruption in administration, blackouts, and shortages of funds for power plant maintenance. The country's generation plants are unable to meet the overall electricity demand of the country.

Bangladesh has small reserves of oil and coal but potentially very large reserve of natural gas resources that is why, most of the generation plant used natural gas as fuel. Some coal, diesel, furnace oil is also used in production of electric power. About 87% of our total electric power is produced by natural gas, 5.75 % by furnace oil, 4.29 % by coal, 3.19 % by diesel and 3.95 % is produced from hydroelectric plant.

The electricity distribution system in Bangladesh is controlled by the National Grid. The total electric power produced by the Power Plants is first supplied to the National Grid and then to the Whole country through the National Grid. The power distribution zone is divided into two zones East and West by the rivers Padma-Jamuna-Meghna. The East contains nearly all of the country's electric generating capacity, while the West, with almost no natural resources, must import power from the East. The interconnection between East and West was established in 1982 by a new 230 kV power transmission line. The major portion of the electricity of the country is consumed by the east zone and the west region of the Jamuna river consume only the 22 % of the electricity. The feasibility of hybrid system in the southern rural area of Bangladesh is considered here.

## Electrical Load Profile

The load profile is based on a rural area with 100 families. There is no electricity there. To create the load profile, the loads considered for each family are 5 CFL bulbs, 2 fans, 1 refrigerator, 1 television and 2 point of charging. The load calculation is shown in table 1, where the maximum power consumption as well as the average power consumption throughout the year is shown. To generate realistic load profile probabilistic method is used [7]. Moreover, seasonal impact on the load profile is also considered. Fig. 1 shows the hourly load profile in a year. Fig. 2 represents the daily load profile generated by HOMER. The load characteristics show that, there is a base load throughout the day, and the peak load is at noon and mainly in the evening. The peak load is 30kW, recorded during summer season. The scaled annual average load is 213 kWh/day.

**Table 1:** Considered load calculation to prepare the load profile

| Appliance | No. of Units | Power Consumption by each unit (W) | Power Consumption per hour (Wh) | Maximum Power Consumption (kWh/day) | Working time /day (hour) | Average Power Consumption (kWh/day) |
|---|---|---|---|---|---|---|
| **Refrigerator** | 100 | 80 | 8,000 | 192 | 24 | 192 |
| **TV 19' color** | 100 | 70 | 7,000 | 168 | 5.527 | 38 |
| **Celling Fan** | 200 | 50 | 10,000 | 240 | 10.5 | 105 |
| **CFL Bulb** | 300 | 23 | 6,900 | 165.6 | 6.84 | 47.2 |
| **CFL Bulb** | 200 | 15 | 3,000 | 72 | 2 | 6 |
| **Charging Point** | 200 | 3 | 600 | 14.4 | 3 | 1.8 |

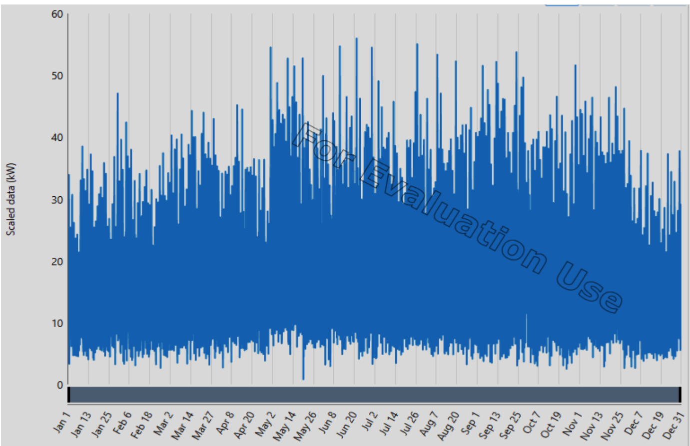


**Fig. 1:** Hourly Load Profile

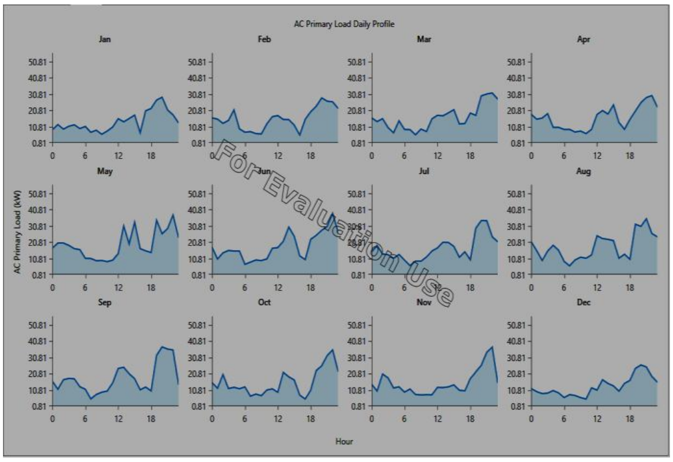


**Fig. 2:** Daily Load Profile

## II. PROPOSED HYBRID SYSTEM

A hybrid system comprised of various sources such as solar, wind, fuel cell and geothermal energy, etc. to provide sustainability in electrical power generation and to increase the performance of all over system [8,10]. In the location, solar radiation and wind power are the only renewable resources. That is why a model is designed based on Wind turbine, photovoltaic array, natural gas generator (availability of gas is more than other fuels in Bangladesh), storage device (battery) and converter. As the price of diesel is very high; gas is used to generate energy when no renewable resource is available. The Hybrid renewable power system shown in fig. 3.

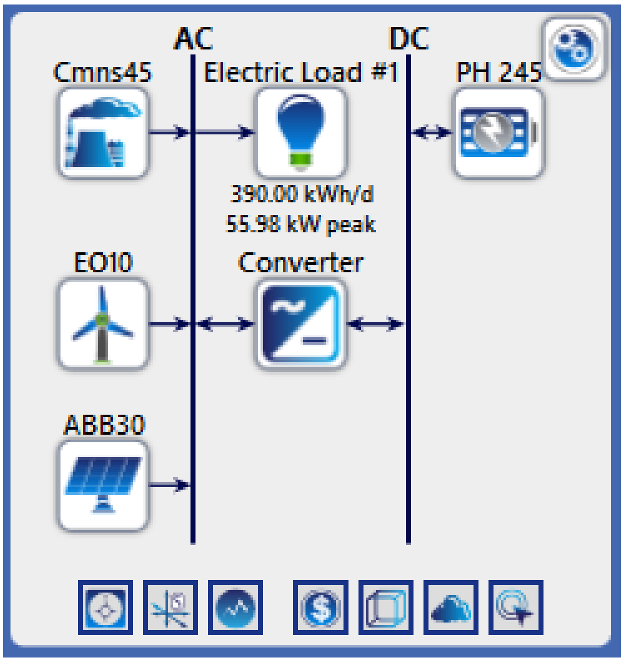


**Fig. 3:** Proposed Hybrid System

The system modelling includes defining the decision variables and size range of the components. The pricing and manufacturer of each component is described earlier. To obtain optimum system, the following parameters need to be defined:

- Size range of PV, battery, converter and diesel generator
- Number of wind turbine
- Electricity shortage is considered 10% maximum. And operating reserve is 10% of hourly load.
- Annual real interest rate is considered 2%. It is calculated from nominal interest rate and inflation rate.
- Project lifetime is 25 years due to maximum component expires within that time.

## III. WIND AND SOLAR ENERGY POTENTIAL OF THE LOCATION AN INPUT DATA

As a coastal area, the location experiences high wind speed. The wind speed during the monsoon is highest and lowest in winter. According to the survey done by A.A. Bhuiyan et al., the wind speed varies from 2.8 m/s to 5.9 m/s. The average wind speed is 4.1 m/s at the height of 30m. A 1kW wind turbine can produce 3170 kWh energy every year from this wind potential [4]. Thus by deploying higher number of turbines or by selecting higher capacity of turbines more power can be produced. Fig. 4 represents the variation of wind speed throughout whole year, where the tower height is considered as 30m. The wind speed is ideal for implementing wind turbine for power generation. According to Bangladesh metrological department and NASA website, the solar radiation range is 4 kW/m$^2$/d to 5.9 kW/m$^2$/d at the selected place [5]. Considering the solar radiation data from HOMER Software, the maximum radiation occurs in March, April and May shown in Fig. 5. The annual average radiation is 4.28 kWh/m$^2$/day with 0.471 of average clearness index. Where Bangladesh receives an average daily solar radiation of 4–6.5 kWh/m [6]. Load calculation is shown in table 2.

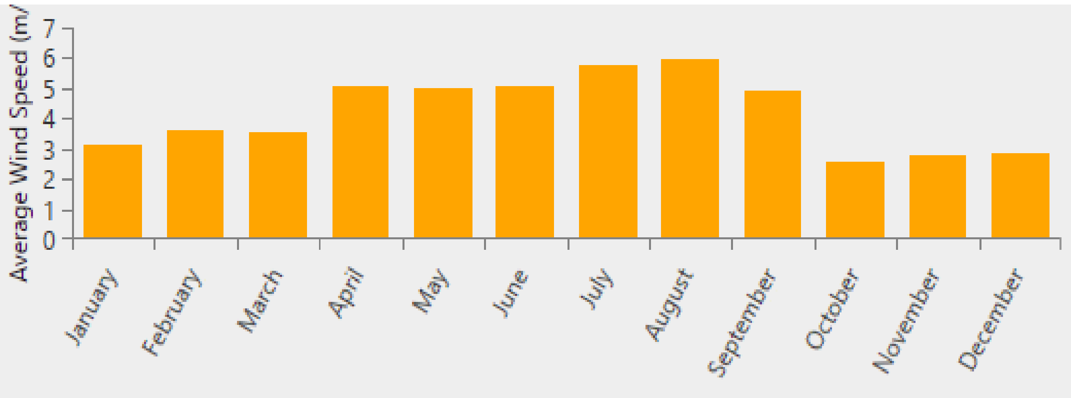


**Fig. 4:** Monthly Average Wind Speed

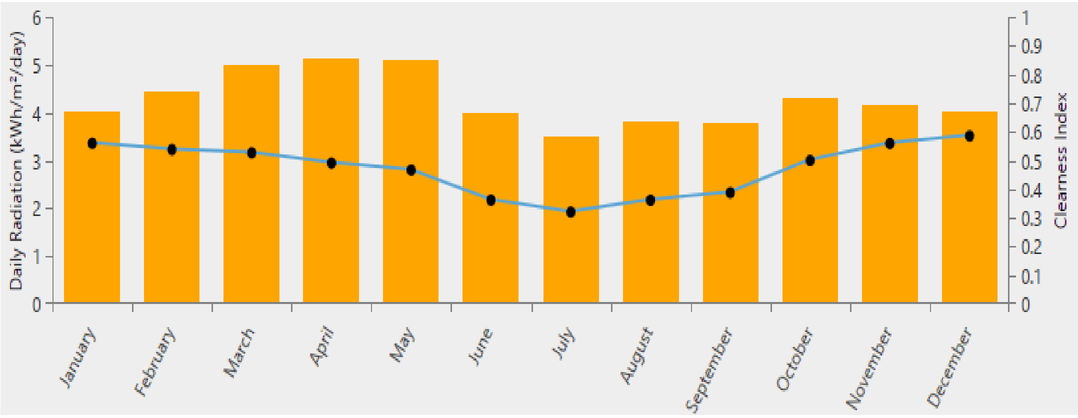


**Fig. 5:** Monthly Average Solar Radiation

**Table 2:** Considered load calculation to prepare the load profile

| Appliance | No. of Units | Power Consumption by each unit (W) | Power Consumption per hour (Wh) | Maximum Power Consumption (kWh/day) | Working time /day (hour) | Average Power Consumption (kWh/day) |
|---|---|---|---|---|---|---|
| **Refrigerator** | 100 | 80 | 8,000 | 192 | 24 | 192 |
| **TV 19' color** | 100 | 70 | 7,000 | 168 | 5.527 | 38 |
| **Celling Fan** | 200 | 50 | 10,000 | 240 | 10.5 | 105 |
| **CFL Bulb** | 300 | 23 | 6,900 | 165.6 | 6.84 | 47.2 |
| **CFL Bulb** | 200 | 15 | 3,000 | 72 | 2 | 6 |
| **Charging Point** | 200 | 3 | 600 | 14.4 | 3 | 1.8 |

**Wind Turbine Data**

Model: Eocycle E010

Rated capacity: 10 kW

Considered quantity: 8

Capital: $10,000/piece

Replacement: $9,000/piece

Operation and Maintenance Cost: $100/year

Total Capital cost: $80,000

**PV Generatoe Data**

Model: ABB Pro33

The size of photovoltaic array is 33 kW.

Considered Size: 20 kW

Output current: AC

Lifetime: 25 years

Derating factor: 96%

Tracking system: No tracking

Capital: $3,000/kW

Replacement: $3,000/kW

Total Capital cost: $60,000

**Natural Gas Generator**

Size: 45 kW

Capital: $22,000

Replacement: $20,000

Operation and Maintenance: $0.20/hour

**Storage Device**

Battery type: Generic Pumped Hydro 245 kWh

Nominal voltage: 240 V

Considered quantity: 1

Lifetime throughput: 197,923.49 kWh

Batteries per string: 1(240 V bus)

Dispatch Strategy: Load Following (LF)

Capital per piece: $22,000

Replacement per piece: $500

Operation and Maintenance: $2,000/year

**Converter**

Considered Size: 19.6 kW

Inverter inputs,

Lifetime (years): 15

Efficiency: 95%

Rectifier inputs,

Capacity related to inverter: 100%

Efficiency: 90%

Capital: $300/KW

Replacement: $300/KW

Operation and Maintenance: $0/year

## IV. RESULTS AND DISCUSSION

### Optimization Result and COE Calculation

The input data of each component and variables defined for controlling and optimizing the system and enable HOMER to come up with the most economical and efficient system. The optimization is performed considering flexibility in source selection. The optimal configurations are found after performing several simulations considering 4.28 kWh/m$^2$/day of solar radiation with 0.471 of clearness index, 4.18 m/s of annual scaled average wind speed and 0.88 $/L of diesel price.

The hybrid system is implemented considering PV, wind turbine, battery, converter and generator. Number of results are carried out with different cost. Among these results most appropriate result is chosen where Cost of Energy is $0.143 per kW/h. The renewable fraction is 84%, which is 84% of total electricity production. The net production Cost is $263,805, where operating cost is $5,719 per year and initial cost is $189,870 shown in table 3. In this case the NPC increases by $31. But the amount of fuel consumption decreases by a significant amount. As well as the amount of electricity production using fuel and its cost also decrease.

**Table 3:** Optimization Result (COE Calculation)

| Architecture | | | | | | Cost | | | | System |
|---|---|---|---|---|---|---|---|---|---|---|
| ABB30 (kW) | EO10 | Cmns45 (kW) | PH 245 | Converter (kW) | Dispatch | COE ($) | NPC ($) | Operating cost ($) | Initial capital ($) | Ren Frac (%) |
| 20.0 | 8 | 45.0 | 1 | 19.1 | LF | $0.143 | $263,677 | $5,720 | $189,726 | 84 |
| 20.0 | 8 | 45.0 | 1 | 19.3 | LF | $0.143 | $263,774 | $5,722 | $189,800 | 84 |
| 20.0 | 8 | 45.0 | 1 | 19.6 | LF | $0.143 | $263,805 | $5,719 | $189,870 | 84 |
| 20.0 | 8 | 45.0 | 1 | 18.7 | LF | $0.143 | $263,809 | $5,740 | $189,603 | 84 |
| 20.0 | 8 | 45.0 | 1 | 18.7 | LF | $0.143 | $263,813 | $5,740 | $189,607 | 84 |
| 20.0 | 8 | 45.0 | 1 | 19.6 | LF | $0.143 | $263,819 | $5,721 | $189,865 | 84 |

## Electrical Production

The yearly electricity production and consumption information can be observed in Table 4. It shows that wind turbine generates the major portion of the total electricity, followed by PV system and gas generator. The purpose of gas generator and battery system is to support the excess load. Thus the production of diesel generator is low. The AC Primary load is 142,347 kWh/yr. Most of this amount is generated by PV or wind due to their environment dependence, which can be reduced by load shifting. 83.07 % of total electricity production comes from only wind turbine and PV system provides 10.84% of total production. When gas generator produces only 6.86% of total electricity production. The monthly average electricity production is shown in fig. 6.

**Table 4:** Electrical Production

| Component | Rated Capacity kW | Mean Output kW | Capacity Factor % | Total Production kWh/yr | Percentage of total Production |
|---|---|---|---|---|---|
| **Wind Turbine** | 80 | 33.56 | 41.95 | 293,963 | 83.07 |
| **PV** | 20 | 4.23 | 21.16 | 37,078 | 10.84 |
| **Gas Gen.** | 45 | 14.9 | 5.80 | 28,845 | 6.86 |
| **Total** | | | | 359,286 | 100 |

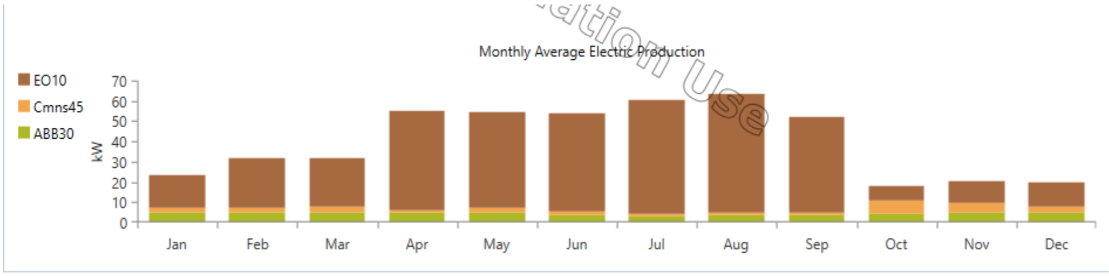


**Fig. 6:** Monthly Average Electricity Production

## Fuel Cost

Fig. 7, shows the overall fuel summary of the proposed hybrid system per year. The natural gas generator consumes fuel consumed fuel 13,715 m$^3$per year. The average fuel consumed per day is 37.6 m$^3$ and the average fuel consumption per hour is 1.57 m$^3$. The fuel consumption is higher from October to December when the renewable resources are comparatively less.

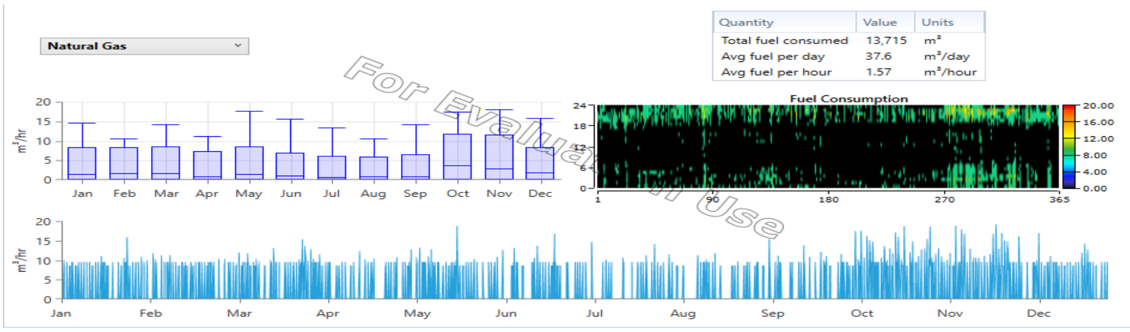


**Fig. 7:** Fuel (Natural Gas) Consumption

**Overall Cost Data**Table 5, shows the overall capital cost, replacement cost and the operation and maintenance cost of each component of the proposed Hybrid system. The fuel cost by each component are also shown. We can also see the total investment on each component including the salvage value from the table.

**Table 5:** Overall cost analysis of the Hybrid System

| Component | Capital cost ($) | Replacement Cost ($) | O&M ($) | Fuel Cost ($) | Salvage Value ($) | Total Cost ($) |
|---|---|---|---|---|---|---|
| **Wind Turbine** | 80,000 | 22,954.13 | 10,342 | 0.00 | 12,936.12 | 100,360.05 |
| **PV** | 60,000 | 0.00 | 2,585.48 | 0.00 | 0.00 | 62.585.48 |
| **Gas Generator** | 22,000 | 17,976.35 | 396,61 | 6,205.44 | 2,124.08 | 44,454.32 |
| **Battery** | 22,000 | 710,29 | 25,855.02 | 0.00 | 51.33 | 28,513.94 |
| **System Converter** | 5,869.92 | 2,490.45 | 0.00 | 0.00 | 468.73 | 7,891.64 |
| **System** | 189,869.92 | 44,131.22 | 39,179.15 | 6,205.44 | 15,580.26 | 263,805.47 |

**Economic Viability of Proposed Hybrid System Comparison with National Grid Connection**Cost of Transmission Line for different kV line in Bangladesh:

- 33 kV line/km => Tk 40,00,000 ($ 49,597)
- 11 kV line/km => Tk 25,00,000 ($ 30,998)
- 400 V line/km => Tk 18,00,000 ($ 22,319)
- 11 kV & 400 V line/km => Tk 35,00,000 ($ 43,397) (in same pole)

There is an existing overhead line of 132 kV in Patuakhali district. In Patuakhali there is an existing substation of 132/33 kV. This 33 kV line is extended up to Kalapara, Hazipur which is at a distance of 50 km from Patuakhali. In Kalapara, Hazipur there is a substation of 33/11 kV. This 11 kV line has been extended up to Kuakata which is at a distance of about 10km from Klalapara. But the project location is Chor Dhulashar which is about 20km away from Kalapara sub-station and no existing grid connection is available. Comparing the economic viability of this standalone Hybrid power system with respect to the national grid connection:

- Capital cost for extension of 33 kV line up to project location:

  $ (20 * 49,597) = $ 9,91,940

- Capital cost for extension of 11 kV line up to project location:

  (20 * 30,998) = $ 6,19,960

- Capital cost of our standalone Hybrid system:

  $ 1,89,870

The above analysis demonstrates that the proposed hybrid system is cost effective and viable than both 33 kV and 11 kV line extension.

## V. CONCLUSIONS

This paper represent the feasibility of a hybrid renewable energy based system in rural area of n Bangladesh, where grid electricity is not present. The optimized hybrid system consists of PV, wind turbine, gas generator and battery system. The results clarify the viability of the proposed system since the system has competitive energy costs in contrast with the other alternatives. Moreover, the system is a non-polluting and reliable energy source. The COE of the optimized system is $0.143 with 84% renewable energy fraction. Net present cost (NPC); operating cost; replacement cost and O&M for the optimized system are $2,63,805; $5,719; $44,132 and $39,180 respectively. The initial cost of the system is $1,89,870. The integration of large amount of renewable energy for electricity production also reduces huge amount of carbon emissions.

**REFERENCES**

[1]. Nandi, S.K. and H.R. Ghosh, “Prospect of wind–PV-battery hybrid power system as an alternative to grid extension in Bangladesh.” Energy, 2010. 35(7): pp. 3040-3047.

[2]. National Energy Policy, M.o. Power, Editor. 2014, Government of Bangladesh: Energy and Mineral Resources.

[3]. Arafat A. Bhuiyan & A.K.M. Sadrul Islam, “Application of Wind Resource Assessment tool: A case study in Kuakata, Bangladesh” International Journal of Renewable Energy Research July 2011, Vol.1, No.3. pp.83-90.

[4]. Bangladesh Meteorological Department. 2016 [online] http:// www.bmd.gov.bd/

[5]. NASA Surface Meteorology and Solar Energy. 2015; [online] https://eosweb.larc.nasa.gov/sse/

[6]. A.K.M. Sadrul Islam, M. Islam, and T. Rahman, “Effective renewable energy activities in Bangladesh.” Renewable Energy, 2006. 31(5): pp. 677-688.

[7]. Mohammed, O.H., et al. “Optimal design of a PV/fuel cell hybrid power system for the city of Brest in France.” In Green Energy, 2014 International Conference on. 2014. IEEE, pp. 119-123.

[8]. Atiqur Rahman, M.M., Ali T. Al Awami, A.H.M.A. Rahim, “Hydro-Pv-Wind-Diesel based stand-alone hybrid power system,” ICEEICT, 2014; pp 1-6.

[9]. Himadry Shekhar Das, “Feasibility analysis of standalone PV/wind/battery hybrid energy system for rural Bangladesh” International Journal of Renewable Energy Research, Vol. 6, No. 2, 2016, pp. 1-11.

[10]. Atiqur Rahman, M.M., Al Awami, A.T., "Decentralized wind-PV-diesel based hybrid power generation," International Conference in Electrical Engineering and Information Communication Technology (ICEEICT), vol., no., 21-23 May 2015, pp.1-5.