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Performance Analysis and Feasibility Study of Solar-Wind-Diesel Hybrid Power System in Rural Areas of Bangladesh

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Abstract— Continuous usage conventional resources to meet the growing demand of electricity have resulted in increased energy crisis and the pollutants created from the burning of the conventional resources cause respiratory illnesses and death in humans and destroy fragile ecosystems. These are some prominent reasons that make renewable energy extremely important for the future of our society as they are more reliable, effective, sustainable and pollution-free power supply source. The first initiative that is needed to design a hybrid power generation system (HPGS) is the feasibility study. The goal of this paper is to evaluate the performance and study the feasibility of a solar-wind-diesel hybrid energy system through computer simulation studies to achieve an efficient and cost competitive system. The feasibility study mainly focuses on the technical and economic analysis of the components of the hybrid power generation system. Considering the Net Present Cost (NPC), Cost of Energy (COE) and Renewable fraction (RF), the prospects of solar and wind energy was evaluated with the help of the Hybrid Optimization Model for Electric Renewable (HOMER). From the study, it can be interpreted that the solar-wind-diesel system consumes less fuel than the diesel generator which is run by only diesel. As a result, the total net present cost of solar-wind-diesel system is less than the diesel generator. The study found a wind-pv-diesel hybrid power system with 65% renewable energy penetration (41% wind and 24% solar PV) to be the feasible system with the cost of energy of 0.822US$/kWh. The hybrid system will reduce CO2 emission by 60% in the local atmosphere compared to electricity draw from the national grid.

Keywords— Hybrid Renewable Energy System, PV, Wind, Feasibility study, Performance analysis, HOMER.

1. INTRODUCTION

Energy is essential to our society not only to ensure our quality of life but also for our economy. The demand of electrical energy has developed largely across the whole world; in every country, in every society we live. This demand has been stimulated by the relative ease with which electricity can be generated, distributed, and utilized, and by the great variety of its applications. Now, the controversial question is whether the consumption of electricity should be allowed to grow in an uncontrolled manner where the demand is increasing day by day. In that situation, the world's electricity generation capacity surely has to keep pace with the increasing demand of electric energy. Presently, almost all the electricity generation takes place at a central power station where coal, gas, fossil fuels and nuclear materials are used as the primary fuel source. But if we keep depending on these conventional sources for energy generation or further development, then definitely we have to face problems in the future as they are finite sources. In the geographically suitable areas, Hydro-power generation is inadequate. In additional, the reserves of coal may be plentiful at present, but they are being used continuously and if this continues, the day is not far away when there will be insufficient amounts of coal and these resources are not even renewable. The possible hazards of nuclear power have been much publicized, particularly those concerning the storage and military use of nuclear waste material [1]. It is high time to think about the alternatives, and renewable energy can be the best alternative of these fossil fuels. Renewable energy is the cleanest and infinite sources of energy, which is more sustainable and has a much lower environmental impact that the conventional sources of energy [2].

Bangladesh is a small developing country endowed with plentiful natural resources. Currently, electricity produced from both renewable energy and energy sources is being used by 70% of total populations [3]. The installed electricity generation capacity in

Bangladesh is about 11532 MW in June, 2015 [4]. Bangladesh is one of those countries which have lower per capita energy consumption (321 kWh) in the world [5]. The major and most available energy source in Bangladesh is natural gas, which is greatly used in most of the power generation unit. About 62.26% % (6809 MW) energy comes from natural gas, followed by HFO (21.04 %, 2301 MW), HSD (8.2 %, 897 MW), hydro (2.1 %, 230 MW) and Coal (1.83 %, 200 MW) [6]. But the country lags behind than its expected production capacity and meets the demand of its population because of the limitation of resources, weak policies, inefficient power plants and high system losses [7]. Adequate power generation capacity is the main enforcement of social and economic development of a country. But it's a matter of sorrow that most of the rural households in Bangladesh are divested from steady electricity supply as the national grid is incapacitated to meet the energy demand of vast populations. So, increasing the power generation is the only accession for the overall development of the country. And this can only be done by fuel diversification. At present, more than 1% share is added by the renewable energy to the total power generation of Bangladesh. According to the anticipation of the Renewable Energy Policy, Bangladesh has to achieve 5% of total energy production by 2015 and 10% by 2020 from renewable energy for overall development [8]. And to achieve this target local energy resources such as Micro, Hydro, Wind, PV etc. through the stand alone hybrid system can be ensconced in the remote areas of Bangladesh. Renewable energies which are plenty in our country like solar, wind can be installed as a self-contained energy system. A diesel generator can be used as a backup of a solar-wind-diesel hybrid system due to unavailability of sunlight during the night and wind speed fluctuation during day time so that the supply of electricity remains uninterrupted.

In Bangladesh, renewable energy has a prosperous future. The simple generation structure and availability make the Hybrid renewable energy systems (HRES) more captivating and popular in the power generation sector in Bangladesh HRES combines renewable energy sources like solar, wind, and others to deliver useful energy. A combined system of various renewable energy sources can be a good example of the energy system in case of balance, reliability and stability. The balanced system can provide substantial outputs from sources with a minimized dependency of the output upon seasonal changes and by this way utilization of the different renewable sources of energy can be optimized [9]. A dramatic decrease in the cost and investment of energy storage can be done if multiple energy storage devices with complementary performance characteristics are used [10] together, but the main problem with these types of system is to maintain the continuity and reliability. The storage systems are costly and usually they are large in size. So, cost-effective size of the storage system is required and to reduce these requirements Hybrid Power system can be used [11].

The purpose of the paper is to evaluate the performance and feasibility of PV-wind-diesel hybrid system in rural areas of Bangladesh through computer simulation using the Hybrid Optimization Model for Electric Renewable (HOMER) software. Besides, the study estimates the amount of CO_2 emission and helps in reducing CO_2 emission to atmosphere.

The following is the arrangements of this paper. Section 2 illustrates a brief description of solar and wind energy resources at different locations in Bangladesh. Section 3 presents information about hybrid systems. The system descriptions including the electric load demand profile of the selected location and details about simulation software HOMER are presented in section 4. Section 5 delineates the results and discussions and at the end section 6 concludes.

2. RENEWABLE ENERGY RESOURCES IN BANGLADESH

The electricity that is gained from the conversion of sunlight is known as Solar Power; the conversion can be done by either directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). By using the photovoltaic effect electric current can be transmuted from light in the Photovoltaic [12]. Bangladesh is a small country of 147,500 km2 area with nearly 162 million populations. It is situated between 20.34° and 26.38° north latitude and 88.01° and 92.41° east longitude, which is very much convenient for the production of solar energy. And for the wind energy we can mention the 724 km long coastline and a number of small islands namely Saint Martin, Kutubdia, Swandip and Hatia in the Bay of Bengal of Bangladesh.

2.1. Solar Energy Resources

Solar Energy can be a great source of electricity by which power crisis can be overcome. On a horizon plane the average annual power density of solar radiation is 100-300 W/m^2. To initiate an average power output of 100 MW, which is about 10% of a large coal or nuclear power plant, a solar PV efficiency of 10% and an area of 3-10 km2 are required [13]. For the limitlessness and pollution free quality energy conversion technologies can be installed near consumers. It will also reduce the total production cost. An unused land or rooftops can be used for the installation of solar energy technologies. About 4670 km2 household roof area is available in Bangladesh [14] which are 3.2% of total land area of the country. In Dhaka city, there are 7.86% of rooftop areas that can be used for solar PV electricity generation [15].

The total the potential of grid-connected solar PV in Bangladesh is about 50,174 MW. This number is obtained by calculating the annual mean value of solar radiation (200 W/m2) and a 10% efficiency of the solar PV system [16]. Table 1 shows the average daily solar radiation at different locations in Bangladesh.

Table 1. Monthly global solar radiation at different cities of Bangladesh (in kWh/m^2/day) [17]

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barishal	Jessor
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.96	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97
Average	4.73	5.00	4.54	4.85	4.71	4.85

From table 1, we can see that about 4.64 kWh/m^2 solar radiations per day is being received in Bangladesh and it is a very good number for generating electricity. If we account an average standard 50 WP solar panel per household, then the total capacity stands to 200 MW (200 MWp) [18].

2.2. Wind Energy Resources

Wind power is the kinetic energy of wind, which is generated from air using wind turbines to make electrical power, windmills for mechanical power, wind pumps for water pumping or drainage, or sails to propel ships [19]. Bangladesh has 724 km long coast line and a number of small islands namely Saint Martin, Kutubdia, Swandip and Hatia in the Bay of Bengal of Bangladesh. After passing a long distance over the water surface the strong south-westerly monsoon wind which has come from Indian Ocean enters Asia over the coastal area of Bangladesh. With a monthly average speed 3 m/s to 6 m/s these winds flow all over Bangladesh from March to September [20]. This wind is more boosted when it enters the V- shaped coastal region of the country. In consonance with preliminary studies, (from meteorological department, BCAS, LGED, and BUET) during the monsoon and around one to two months before and after the monsoon (7 months, March to September), there is available winds in Bangladesh. The wind remains either too high or either too low during October to February in Bangladesh. The peak wind speed occurs during the months of June and July [21].

The study done by the Bangladesh Center of the Advance Studies (BCAS) project in collaboration with the Local Government Engineering Department (LGED) and the UK's Energy Technology Support Unit (ETSU) showed that the average annual wind speed measured in the seven coastal stations ranged from 2.94 m/s to 4.52 m/s which is shown in Table 2.

Table 2. Monthly average wind speeds at 25 meter height at seven coastal stations measured by WEST [22].

Year	Month	Monthly average wind sp	eed (m/s) at	he monitoring	tations stated			Kuakata
		Patnga	sp		Noakhali	Char Fasion		
	June	8.75						
	July	5.87	5.42	5.77				
	August	5.32	5.33	4.9	4.7	5.2	5.7	
2009	September	3.36	3.69	3.46	2.94	3.34	3.77	3.58
	October	3.2	3.74	3.3	2.83	3.7	2.18	3.98
	November	2.61	2.93	2.29	1.91		1.98	3.23
	December	2.97	1.78	1.44	1.35	3.09	3.35	3.38
	January	3.25	2.33	1.99	1.31	2.8	3.18	3.67
	February	3.13	1.99	1.9	1.9	2.69	3.37	3.29
	March	2.88	2.42	2.26	2.38	3.54	4.84	3.53
	April	4.96	1.84	1.65	2.25	3.29	4.93	3.1
2010	May	5.83	3.97	3.09	3.99	4.81	6.28	4.89
	June	5.67	4.64	3.26	5	5.76	7.31	5.9
	July	5.13	4.8	4.33	4.92	5.22	7.34	6.17
	August		4.31	4.03	3.85	5.17		5.34
	September		2.96	1.83	2.77	3.08		3.97
Annual Average		3.95	3.34	2.94	2.96	4.07	4.52	4.21

3. Hybrid System

The main obstacle of the renewable energy such as solar and wind energy is these changes randomly and for that reason these are less reliable. Again, if we think of a stand-alone energy production system with PV modules or wind turbine, it will cost a lot in case of technical solution. For this solution, a large surface is compulsory. In winter, the solar potential remains low and in that case, the consumers can be supplied with energy through a large storage capacity. From the above discussion, we can see a lot of disadvantages if a stand-alone energy production system is used. But if a combined system of solar and wind resources is used so that they can complement each other by means of daily and seasonal variations [23]. As the Hybrid systems involve several generation methods, it provides a high level of energy security. Usually, the Hybrid systems incorporate a storage system (battery & fuel cell) or small fossil-fueled generator to ensure maximum supply reliability & security. Due to the regional conditions, the system costs might slightly reduce [24].

Wind turbines & Solar panels are the noteworthy renewable energy devices that are frequently used in hybrid power systems. In villages, various hybrid power systems can be found which differ in size. There is the small size of hybrid power systems which covers small household systems (100 Wh/day) and again, there is the largest size of hybrid power systems which covers a whole area (10 MWh/day). Micro grids and Mini grids are the two types of village scale hybrid power system. Wind, PV, Batteries and conventional generator are the essentials of Micro-Grid (100 kWh/day) power system and the generator is for providing DC power. Same components but larger in size is used for the Mini-Grid power systems (700 kWh/day). The various combinations of the hybrid system are PV-Wind, PV-Fuel cell, PV-Wind–Fuel cell, PV-Wind-Battery etc. Hybrid system provides certain advantages such as lower energy cost, high reliability, low maintenance, flexibility, longer equipment life and utility grade potential, which are unavailable in a single resource energy system [25]. Figure 1 shows the general block diagram of a hybrid power system:

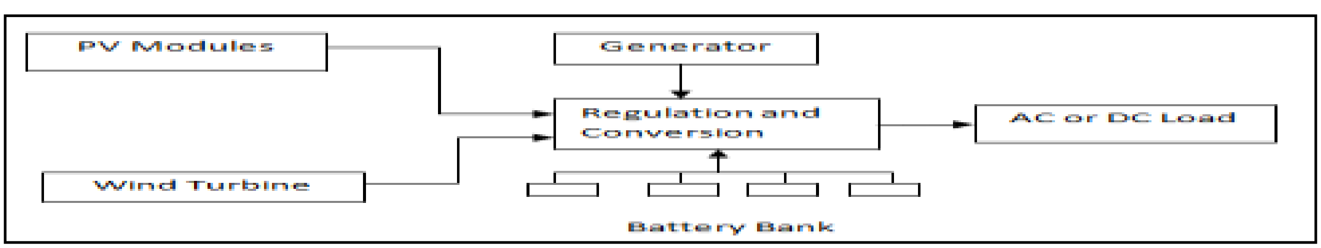


Fig. 1. General block diagram of a Hybrid Power System

4. System Design and Simulation

A solar-wind-diesel hybrid system is one of the projects that are focused for the feasibility study in Bangladesh. Hybrid Optimization Model for Electrical Renewable (HOMER) software has been used for the Hybrid Energy System design and simulation. The design and simulation procedure is described below:

4.1. System Description

A solar-wind-diesel hybrid system is used to provide power supply in remote areas, which are far from the public power grid or rural areas in Bangladesh. The system consists of a PV Panel, wind turbine, diesel generator, battery and converter. The system comprises two buses; AC and DC bus. The DC power produced from PV arrays and the fuel cell is converted into AC power, and then fed to the AC bus. The AC power generated from the wind turbines is directly fed to the AC Bus. Excess power goes to the battery bank and is utilized by the fuel cell in case of unavailability of power from wind or PV sources. Figure 2 shows the design of the system:

Fig. 2. Configuration of the proposed hybrid system

4.2. System Sizing

The equipments that we used in our simulator are wind turbine (10kW), PV array (20kW), battery (360 Ah) and DC/AC converter (20kW). A diesel back-up system (15 kW) is considered for reliable supply of electricity. The HOMER software is used to determine the best optimal sizing and pre-feasibility study of the system. The HOMER determines the optimal system based on input assumptions. The detailed descriptions of the loads and key assumptions about the price of different components of the hybrid system are given below.

4.2.1 AC Load Data

The seasonal load profile of the hypothetical community situated in the rural or remote areas in Bangladesh is presented in figure 3. The energy consumption by a hypothetical community on the proposed site is 219.92 kWh/day with 25.64 kW peak demand and the load factor is 0.36.

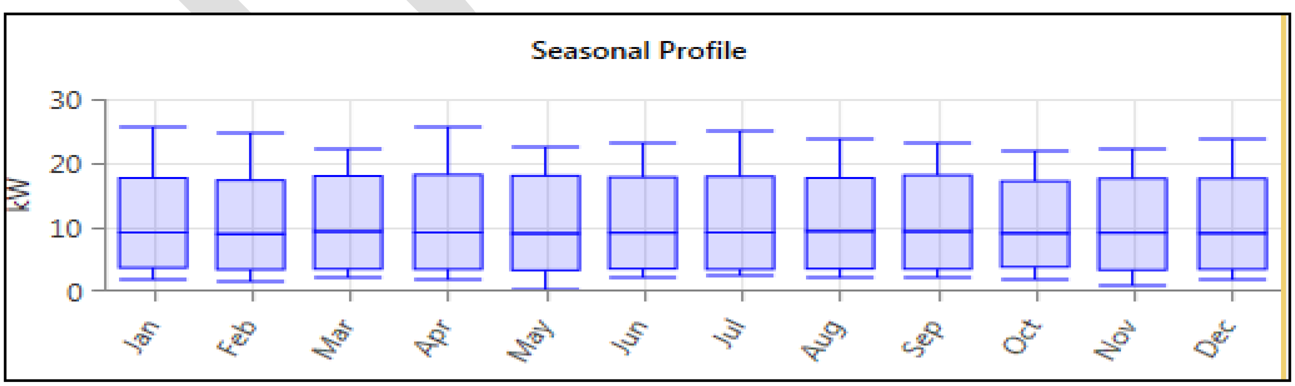


Fig. 3. Seasonal load profile

4.2.2. Wind Turbine

Norvento nED 100 wind turbine has been used in this system. The rated capacity of the turbine is 10kW and it provides AC power. The Cost of one unit is considered to be capital cost and is estimated as $5000. The replacement cost is estimated at $4000 and annual operation and maintenance cost is estimated at $50 and the lifetime of the turbine is taken to be 15 years. The power curve of the wind turbine is shown in fig. 4.

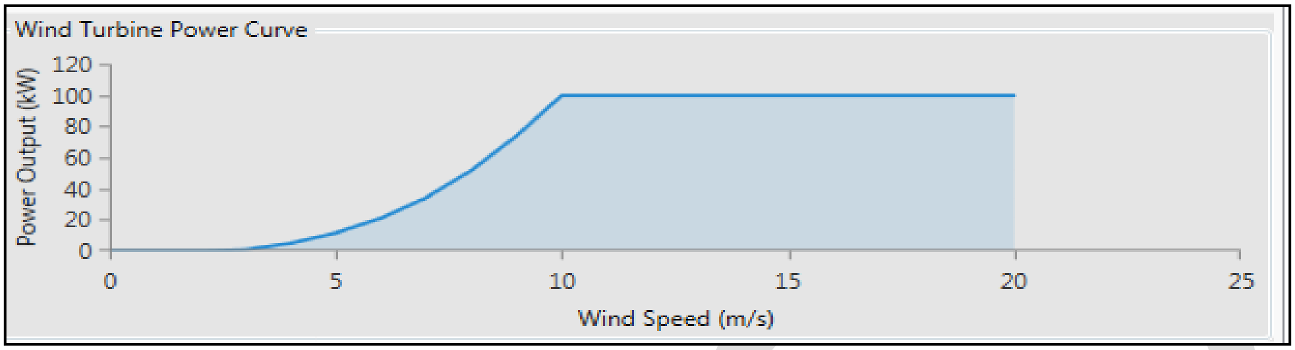


Fig. 4. Wind turbine power curve

4.2.3. Photovoltaic Array

The sun rays are absorbed by the solar panels and in turns solar panels convert them into electricity. A 20kW solar energy system's installation, replacement costs and operation-maintenance cost are taken approximate as $5000 and $2500 and $3 respectively. The expected lifetime of a solar panel is 20 years.

4.2.4. Diesel Generator

The 15 kW diesel generator capital cost, replacement cost, operation-maintenance cost are $8000, $6000, $0.7 respectively. Diesel generator's lifetime is defined in operating hour and that is 15000 hours. Diesel price at the site is $0.6 per liter.

4.2.5. Battery

Trojan L16P type batteries have been used in this system whose nominal voltage, nominal capacity and lifetime throughout are 6V, 360Ah and 2.16kWh respectively. The one battery initial capital cost, replacement cost, and maintenance and operation cost are about $225, $200 and $1 respectively.

4.2.6. Power Converter

The flow of energy between the AC and the DC bus is maintained by a converter and its capacity is 20kW. The initial capital cost and replacement cost and operation-maintenance cost is $400, $250 and 1 respectively. The converter is assumed to be replaced after 20 years.

4.3. Simulation Procedure

The simulation of the hybrid power system is carried out in HOMER software. The Hybrid Optimization Model for Electric Renewable (HOMER) is a software tool that simulates and optimizes an electric power system which is the combination of conventional generators, cogeneration, wind turbines, solar photovoltaic, hydropower, batteries, fuel cells, hydropower, biomass and other inputs [26]. It performs detailed chronological simulations at an hourly level. That detail is necessary to realistically model intermittent renewable power sources, such as wind and solar. Using site-specific information about loads, resources, technology costs and performance, HOMER simulates all possible permutations of the system and then ranks the results, clearly showing the optimal, least-cost configuration. In addition, its sensitivity analyses demonstrate the results of changes to and uncertainty in the input parameters [27].

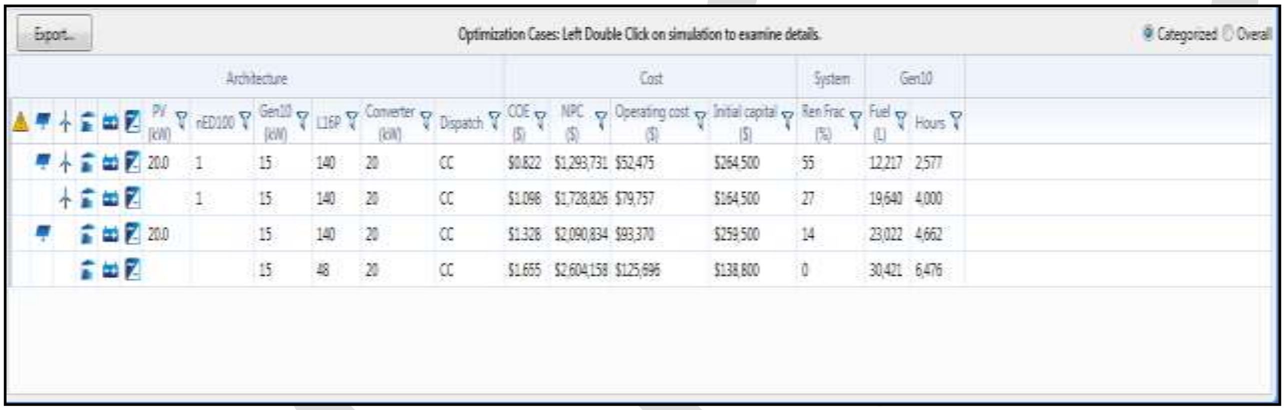
HOMER provides an important overview that compares the operating expenses of the system and feasibility of different configurations so that the designers or users can be aware of the potential impact of the uncertain factors. This overview is also very much helpful when more specialized software is used to model technical performance as the users know the uncertain factors. Its sensitivity analysis allows the users to understand how a hybrid renewable system works [28].

Its overall features can be classified into three steps [29]:

- Simulation – Estimate the cost and determine the feasibility of a system design over the 8760 hours in a year
- Optimization – Simulate each system configuration and display list of systems sorted by net present cost (NPC)
- Sensitivity Analysis – Perform an optimization for each sensitivity variable.

5. RESULT AND DISCUSSION

HOMER is mainly responsible for the elimination of all infeasible systems and thus it presents the results in ascending order of net present cost (NPC). Different hybrid options were analyzed to get an optimized hybrid system. Optimization analysis of the HOMER shows that the most least lowest cost and the optimal combination of energy system components is the combination of the 15 kW diesel generator, 20 kW solar PV array, 10 KW wind turbine, 140 L16P Battery and a 20 KW converter. Figure 5 shows the simulation result of HOMER.


Export...
Optimization Cases: Left Double Click on simulation to examine details.
Categorized Overall

PV (kW)	nED100	Gen10 (kW)	L16P	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Fuel (L)	Hours
20.0	1	15	140	20	CC	$0.822	$1,293,731	$52,475	$264,500	55	12,217	2,577
	1	15	140	20	CC	$1.098	$1,728,826	$79,757	$164,500	27	19,640	4,000
20.0		15	140	20	CC	$1.328	$2,090,834	$93,370	$259,500	14	23,022	4,662
		15	48	20	CC	$1.655	$2,604,158	$125,696	$138,800	0	30,421	6,476

Fig. 5. Simulation Result from HOMER

The electricity production, economic costs and environmental characteristics of each system has been provisioned from the simulation result of HOMER.

5.1. Energy Yield Analysis

Calculating wind power = 41% and solar power = 24% in total 65%; the energy requirement of the village was met by the renewable energy by the proposed wind-pv-diesel hybrid system incorporated with the existing diesel only power system.) In Figure 6 the energy contribution by wind, solar pv system and the existing generator is manifested. As seen from this fig. 6, 35% of the energy is supplied by the diesel generator and the remaining 65% by the wind and solar pv system. In terms of excess energy, which is 11.5% or 12,193 kWh/yr is most favorable for the proposed 65% wind and solar pv hybrid power penetration system.

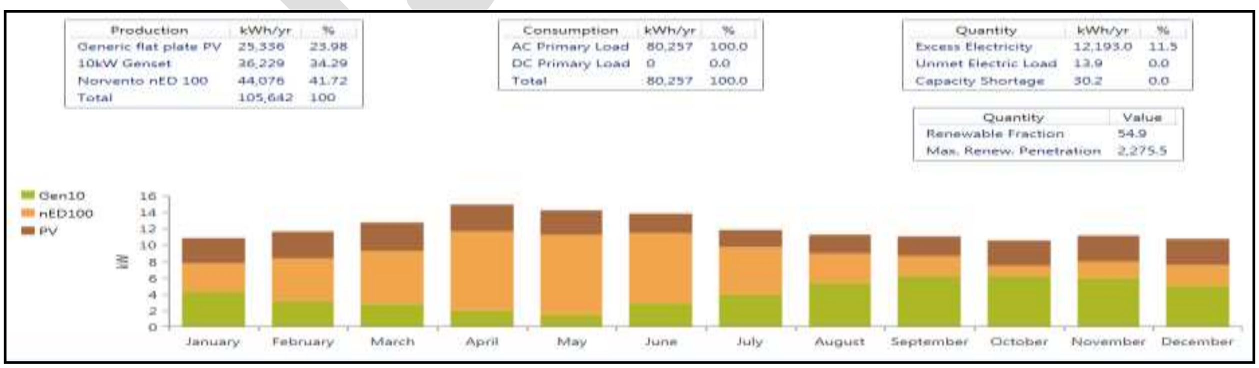


Fig. 6. Annual energy production from the optimized hybrid system

From the above graph, it is esteemed that power contribution of pv systems to the hybrid power system remains almost same with slight variation in peak and base value in the month of November and December. In figure 6, it is seen that wind power varied between a maximum in April and a minimum in October. And the power generated by the generator is maximum in September and minimum in May.

5.2. Economical analysis

In fig. 7, the total cost of the hybrid power systems is shown. Here, the wind turbine, pv panel, generator, batteries and a power converter are the components which costs are taken in account of during counting the total cost.

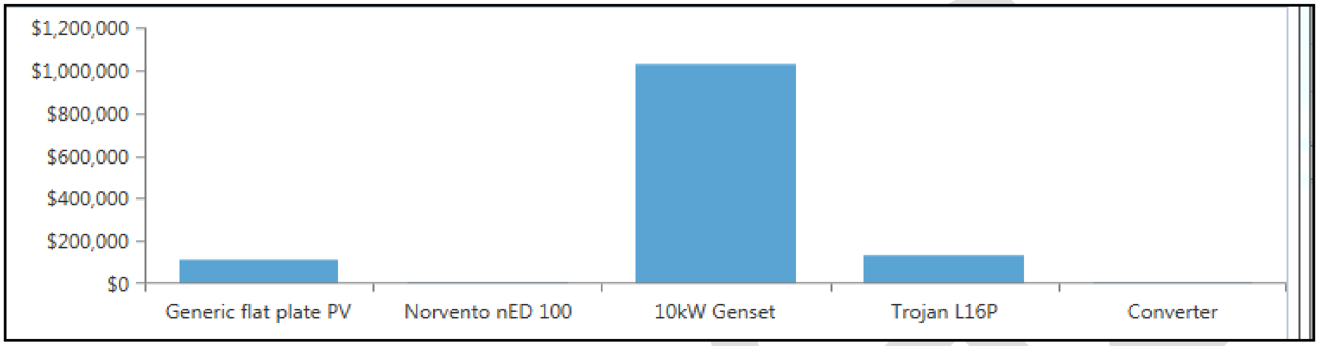


Fig. 7. Cash flow summary of various components of the hybrid power system

In fig. 8, the breakdown of capital, replacement, O & M, fuel and salvage costs of wind-pv-diesel power system are given. From the fig. 8, it can be clearly seen that for diesel generator the net present cost (NPC) is highest. The capital cost of the proposed hybrid power system was estimated as $2,64,500 with replacement, O & M, and fuel cost of $4,22,380, $5,36,011, and $1,43,768 respectively.

Component	Capital ($)	Replacement	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generic flat plate PV	$100,000.00	$33,908.00	$1,176.80	$0.00	($23,078.00)	$112,007.00
Norvento nED 100	$5,000.00	$2,989.20	$980.68	$0.00	($820.56)	$8,149.40
10kW Genset	$120,000.00	$273,556.00	$530,715.00	$143,768.00	($39,048.00)	$1,028,991.00
Trojan L16P	$31,500.00	$108,536.00	$2,745.90	$0.00	($7,673.70)	$135,108.00
Converter	$8,000.00	$3,390.80	$392.27	$0.00	($2,307.80)	$9,475.30
System	$264,500.00	$422,380.00	$536,011.00	$143,768.00	($72,929.00)	$1,293,730.00

Fig. 8. Summary of various costs related to the wind-pv-diesel hybrid power system

The comparison of an optimized hybrid system with PV-wind-Diesel generator-battery has been done with PV-diesel generator-battery, wind-diesel generator-battery and diesel generator-battery is given in table 3.

Table 3. The comparisons among the optimized hybrid options

Options	Initial Cost (USD)	Operating Cost (USD/Year)	Total NPC (USD)	COE (USD/KWh)
PV-Wind-Diesel Generator-Battery	264,500	52,475	1,293,731	0.822
Wind-Diesel Generator-Battery	164,500	79,757	1,728,826	1.098
PV-Diesel Generator-Battery	259,500	93,370	2,090,834	1.328
Diesel Generator-Battery	138,800	125,696	2,604,158	1.655

From the table 3, it can be perceived that the optimized PV-wind-diesel generator-battery system has the lowest NPC (1,293,731 USD) with a COE of 0.822 USD/kW. It is mentionable that the system reduces the NPC about 62% and 34% compared with PV-diesel generator-battery and wind-diesel generator-battery respectively. The source of revenue is only the selling of electricity.

In a brief, it is noticed that though the diesel only system had the least initial capital cost, but the total net production cost for the whole project goes high at the end for this type of system. On the other hand, though the initial capital cost is high in the hybrid system topologies but the total net production cost for the whole project goes low at the end for this type of system.

5.3. Green house gas (GHG) emissions

This system emits 32,171 kg of CO_2, 79.41 kg of CO, 8.80 kg of UHC, 5.99 kg of Particulate Matter, 64.60 kg of SO_2, and 708.57 kg of NO**x** annually into the atmosphere as shown in table 4.

Table 4. Comparisons of simulation results of Pollutant Emissions

Pollutant (kg yr^{-1})	Emissions (kg yr^{-1})	
	Diesel Only System	Solar-Wind-Diesel System
Carbon Dioxide	80,109.00	32,171.00
Carbon Monoxide	197.74	79.41
Unburned Hydrocarbons	21.90	8.80
Particulate matter	14.91	5.99
Sulfur Dioxide	160.87	64.60
Nitrogen Oxides	1,764.40	708.57

In table 4, it is noticed that if renewable energy is used as a power generation system, then 60% decrease of pollutant can be rendered. The reduction in the quantity of different air pollutants for 65% renewable penetration compared to that diesel only are thus: 47,938 kg of CO_2, 118.33 kg of CO, 13.1 kg of UHC, 8.92 kg of PM, 96.27 kg of SO_2, and 1055.83 kg of NO**x** where the diesel only system generates 80,109 kg of CO_2, 197.74 kg of CO, 21.90 kg of UHC, 14.91 kg of PM, 160.87 kg of SO_2, and 1,764.40 kg tones of NO**x.**

5.4. Socio-economic Benefits

The study evaluates the performance of the hybrid system which is a combined system of 3 independent and globally tested and proven technologies (PV, wind and diesel). This combined hybrid system is designed in such a way so that by this system a good symmetry between environmental benefits and socio-economic development can be maintained in a convenient way. Deploying the hybrid system will not only provide electricity to the rural and remote areas of Bangladesh but also it will become a stimulant for the effective contribution in the social life. The benefits of this hybrid project are discussed below.

- The proposed PV-wind-diesel Hybrid power plant can be a secured and imperishable source of power generation and can be a better alternative in the rural and remote areas where there is an irregular supply of electricity.
- The implementation of the project will minimize the GHG Emission, resulting in a net reduction of the GHGs, thus bringing a local as well as a global carbon benefit.
- The successful implementation and operation of the hybrid system will lead to further future propagation and also scale-up of the system to larger capacities. This system can be the substitute of conventional grid where old diesel units are being used presently to produce unreliable and high emission.
- A number of households, who is currently meeting their lighting needs with kerosene, will switch over the electricity soon and this will definitely contribute to reduce fire-hazards.
- Being a small central rural power plant, the direct employment generation will be limited only to a few plant operators and maintenance personnel, including a Plant In-Charge. However, due to the enhancement of quality of life and facilitation of economic activities, the indirect employment generation will increase small rural incomes through handicrafts, weaving and other production activities.

6. CONCLUSION

Extensive and wide ranging change may occur in both the social and economic lives of people in rural and economic areas of Bangladesh by the adaptation of the hybrid system as there is an acute crisis of reliable supply of electricity. Various energy sources (wind, solar, and diesel generator) and storage systems (batteries) have been considered to evaluate the features of the hybrid system. NREL's optimization tool HOMER was used in identifying probable hybrid configurations and their feasibility. From this study, it is seen that a developing a stand-alone hybrid power system is more cost effective, reliable and suitable for rural applications than running stand-alone diesel generator. It is clearly perceived from the study that the optimized wind-PV-diesel hybrid system is more cost effective in terms of Net Present Cost (NPC) and the Cost of Energy (COE) compared to PV-diesel and wind-diesel system. Besides that, renewable energy offers a smart, affordable climate solution which will definitely make an impact in the future in both nationally and internationally. The annual emission of the system can be illustrated by the hybrid system which is environment benevolent in nature and another advantage of this system is it is very swift in power generation and response. It is also adapted for its effectiveness, reliability and durability. For effective and continuous power supply, the diesel generator will incorporate with the other technology to provide the required power in the absence of wind and sunlight. This proposed model of wind and solar hybrid system can be a role model of energy generation in the rural electrification. However, more experiments can be done to analysis the potential and effectiveness, advantages and disadvantages of the hybrid system so that it can bring a remarkable change in energy production of our country.

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