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Micro Study of Hybrid Power System for Rural Electrification- A Case Study

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Abstract

The prime challenge for improving ease of living of human being is increasing utilization of energy day by day but for sustainable development, the world has to look for hybrid renewable energy. Our research work presents a case study of the development of a productive approach of design, simulation and analysis of stand-alone hybrid renewable energy resources for a typical rural village in a remote area situated in Digha, West Bengal in India whose location is (21^0 37.6'N, 87^0 30.4'E). The aim of the study is to get a reliable independent system, optimized component size and Levelized Cost of Energy. The photovoltaic panel batteries, wind turbine inverter system, are used as primary source of power while the diesel generator is used as backup units. The optimal architecture means the size of the PV array size and number of battery string, inverter, and size of diesel Generator are optimized by HOMER. The data of Wind speed and solar radiation have been taken from NASA's meteorological department. A remote village Digha having an energy consumption of 1650 kWh/day with 385.51 kW peak power and a Deferrable load of 24.86 kWh/day with 4.62 kW peak load demand was appraised. The feasible solution for the distributed generation of electric power for a remote village with 1000 households with an average of five family members per household with school, hospital and other commercial uses like tube well, grinding mill machine etc. is obtained from the proposed hybrid system. The carbon emission is 96.75 % less is an additional upper hand of the proposed hybrid system. An innovative approach to determining rural electric load for the remote village which does not have electric access has been proposed.

Keywords: Renewable Energy, Hybrid Power, HOMER, SOLAR, Standalone Generation**.**

INTRODUCTION

The electrical energy consumption growth is increasing due to industrialization, urbanization, improving ease of living day by day. Reliable access to electricity is a basic precondition for improving people's lives in rural areas, for enhanced slandered of living, healthcare, education, and for growth within local economies as well as to meet millennium development goal in 2022. At present, more than 250 million people in India do not have access to electricity in their homes. Almost all of these people live in rural areas. The state of power in the country is best captured by looking at the per capita power consumption. On an average, in 2016-17, the per capita consumption in India was 1,070 kWh, less than the world average of 3,026 kWh, as per data from the International Energy Agency. It is also the lowest among BRICS nations. The Indian Government tried to connect this rural location by using national grid extension for the last two decades. However, still, the current electricity access to 79.12% overall population out of rural population is 67% only. In this scenario, the rural people who have very low load demand with dispersed settlement will not get electricity in the near future.

The dependency on the conventional resources will have to reduce to achieve sustainable development of human society. Fortunately, in India, there is a huge scope for utilizing renewable energy sources, e.g. solar energy, wind energy to provide a quality power supply to remote areas. The superabundant energy available in nature can be utilized and converted to electricity to supply the essential power to improve the living standards of the people without access to the electricity grid. The advantages of using renewable energy sources for generating power in remote areas are obvious such as it will never run out, Renewable energy facilities generally require less maintenance reduce the cost of operation and more importantly it produces less or no waste so has minimal impact on the environment. The disadvantage of standalone power systems using renewable energy is non-uniform availability, resulting in intermittent delivery of power and causing problems if supply continuity is required. This can be avoided by the use of standalone hybrid systems. A hybrid power system can be defined as a combination of different, but complementary energy generation system based on renewable energy or mixed (RES- with a backup of Diesel Gen-set). Hybrid systems utilize the best outcome of each energy resource and can provide "grid-quality" electricity, with a power range of one kilowatt to several hundred kilowatts. Proposed Hybrid power systems in this paper typically rely on renewable energy to generate 96.10% of the total power supply. The large share of renewable energy will minimize the cost of operation and in case of unavailability of renewable energy or high-power demand, Diesel generator can be used as a backup. The battery backup size is lower due to back up system and suffers less stress than in a 100% renewable power system, prolonging battery life significantly and reducing replacement costs.

METHODOLOGY

The simulated hybrid renewable energy system consists wind turbine, photovoltaic (PV) array with a power converter, battery and Diesel generator. The battery is added to the system as a backup unit and acts as a storage system. The system is designed by considering remote village called Digha which, is located around 183 km from Kolkata city in West Bengal state in the eastern region of India. The solar and wind resource data of the remote site was taken from online data of NASA Methodological department and National Renewable Energy Lab (NREL). The field survey has been conducted to get daily load profile and energy usage pattern of a similar socio-economic village for simulation. Since the village does not have Electricity access. The HOMER software is used to determine the optimal sizing and operational strategy for a hybrid renewable energy system based on three principal tasks which are simulations, optimization and sensitivity analysis. The following subsection discusses the three principal tasks of the HOMER software.

Homer: Simulation

HOMER simulates the operation of the system based on the components chosen by the designer. In this process, HOMER will perform the energy balance calculation based on the system configuration consisting several numbers and sizes of the component. In this case study, PV array system, wind turbine, diesel generator with battery and converter are the components chosen for the analysis. HOMER simulates the system based on the estimation of installing cost, replacement cost, operation and maintenance cost, fuel and interest rate.

Homer: Optimization

The optimization process is based on the technical characteristics of the system and life cycle cost (LCC) of the system. HOMER display a list of configurations sorted based on the Total Net Present Cost (TNPC). It can be used to compare different types of system configuration from the lowest to the highest TNPC. However, the system configuration based TNPC is also affected by sensitivity variable.

Homer: Sensitivity Analysis

The HOMER software will repeat the optimization process for each sensitivity variables for the hybrid renewable energy system. The sensitivity variables here taken are such as fuel price and the electrical load, however, the global solar, wind speed etc. can be considered. After this TNPC of various configurations of hybrid renewable energy will be sorted from lowest to highest. Out of these, the lowest TNPC will be considered as the optimal solution.

SYSTEM CONFIGURATION

The hybrid renewable energy system includes PV system, WT system, battery units, diesel generator, power converter and electrical loads. Hybrid power generation systems can be classified into three kinds according to bus bar forms, including pure AC bus bar system, pure DC bus bar system and hybrid AC-DC bus bar system. In this study, AC-DC configuration is considered due to its advantage compared to other configurations.

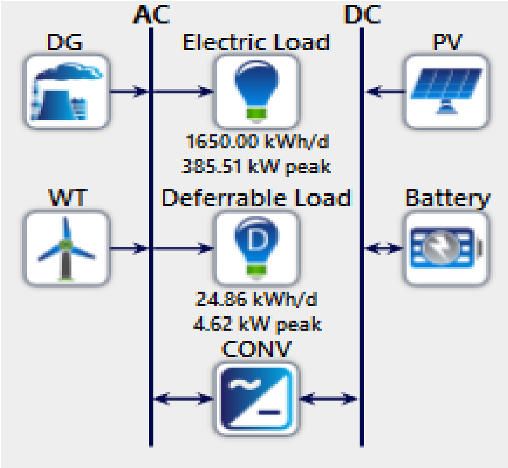

Figure 1. Hybrid configuration of system

In this scheme the renewable energy source and the diesel generator supply a portion of the load demand directly, resulting in higher overall system efficiency. The diesel generator and the inverter can operate in standalone or parallel mode. This combination when the load is low either the diesel generator or the battery can supply the load. Here diesel generator will be forced off between 10.00 AM to 3.00 PM because of more power availability from PV array source. However, during peak load, both sources are operated in parallel mode. Due to this parallel operation, the initial capacity of diesel generator and inverter can be reduced. In this scheme, a controller is required to control the operation and meet the power supply without interruption.

Electrical Load Information

The load profile for the hybrid system was taken from the result of a survey of an electrified village with the same socio-economic status of the selected case study village. The daily load and hourly load was calculated by using spreadsheet program EXCEL. HOMER software needs hourly load as input for simulation. The case study village is consisting of residential houses considering three class such as higher, medium and lower society, the public institution (three schools and two health center), small commercial center (shop and one grinding mill) and water pumps for potable drinking water. The lifetime estimated for this project is 25 years in the simulation while the real interest rate is fixed at 5.88% and the inflation rate is 2% which is common in many developing countries like India.

As seen from the survey of some rural villages in West Bengal the electrical load demand is dominated by lighting and fan load. In this study, 1000 rural houses with average family size of five, public and commercial centers are considered. Here we are considering two type of load one is the main electrical load which is of rating 1650kWh/day with peak load is 385.51 kW and another is deferrable load 24.86 kWh/day with peak load is 4.62 kW. The main load having total electrical appliance power consumption and deferrable load consist water pump load which is used for irrigation purpose. The deferrable load is defined as an electrical load that requires a certain amount of energy within a given time period, but the exact timing is not important; it can wait until power is available. These loads are normally classified as deferrable when they are associated with storage. Here we assume around six water pumps are assumed to deliver the water need for agriculture and drinking water. Two pumps used for school, health clinic and a milling machine two for the house and remaining two for agriculture purpose use. Some people of lower classes having manual hand pump which does not consume electricity. The selected type of water pump has a capacity of 1243W power rating, with a pumping capacity 50 litre/minute. The required amount of water needed per person is ~117 litres/day, for cattle ~20 litres /day, for school, health centre, shopping centre and milling house~2000 litre/day. The above assumption is based on average consumption of water per person and per cattle in India i.e. the average consumption is 117 litre/person/day and 20liter/cattle/day in the rural area. Since in the village, we assumed 1000 households with the average of five members per family and approx. 250 family having one cattle per households, the total consumption of water per day is around 600m3/day. Six water pumps with the capacity of 50 litres/min can provide more than 180m3/day if it runs for 10 hours per day. Many are having manual hand pump which does not consume power and meet the requirement of rest of water. The peak deferrable load is taken for the water pump which is used for irrigation purpose and having the rating of 1.243kW which is the rated power of the pump. It would take 12 hours for the pumps at full power to fill the tank. So, the storage capacity is 12-hour times 2*1.243kW (two pumps used for irrigation) which is 29.83kWh. It would take for the pumps 10 hours at full power to meet the daily requirement of water for the village. So, the average deferrable load is 10 hours per day times 2.486kW, which is 24.86kWh/day with peak deferrable load is 4.62 kW. In order to analyze uncertainty in the future, load sensitivity analysis has been done by the random variability of day to day 10% and time step is 20% increment of the load. The monthly load demand of this village is shown in Fig. no 2 It is observed that the annual peak load of 385.51 kW has occurred in the month of July.

The monthly load variation graph consists average load consumption of 12-month having peak load in July month in India. Generally, there is significant seasonal load variation in the urban area due to change of equipment used in the home such as heating and cooling devices which consumes the significant amount of Energy. However, the seasonal load variation in the proposed rural village is insignificant since the electrical equipment used in the village assumed to be same throughout the year.

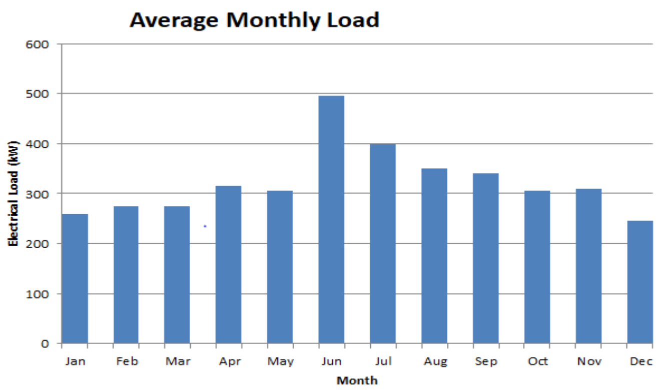

Figure 2. Monthly load variations

Table 1. Load profile of the Village

Type	No of House	Appliance Type	Ratting(W)	No of Appliance	Hours of Operation	Watt*Hour	kWh/day
Residential Load							
High class House	200	CFL	15	800	8	96000	96
		Fan	75	400	10	300000	300
		Television	250	250	4	250000	250
						Total kWh/day /high class house	**646**
Middle class House	500	CFL	15	1500	6	135000	135
		Fan	75	350	8	210000	210
		Television	250	250	4	250000	250
						Total kWh/day /middle class house	**595**
Lower class House	300	CFL	15	300	6	27000	27
		Fan	75	150	6	67500	67.5
						Total kWh/day /low class house	**94.5**
Public and Commercial Load							
School	3	CFL	15	30	6	2700	2.7
		Tap Recorder	75	6	3	1350	1.35
		Television	250	3	2	1500	1.5
		Computer	700	9	5	31500	31.5
		Refrigerator	200	3	12	7200	7.2
		Others	250	3	6	4500	4.5
						Total kWh/day	**48.75**
Health center	2	CFL	15	45	12	8100	8.1
		Tap Recorder	75	4	4	1200	1.2
		Television	250	2	14	7000	7
		Lab Equipment	1000	4	10	40000	40
		Refrigerator	200	4	16	12800	12.8
		Others	250	2	8	4000	4
						Total kWh/day	**73.1**
Commercial Load		CFL	20	60	6	7200	7.2
		Street Light	50	20	10	10000	10
		Grinding Mill	12000	1	8	96000	96
		Water Pump	1243	6	10	74580	74.58
		Others	300	1	6	1800	1.8
						Total kWh/day	**189.58**
						Gross Electrical Load per day	**1646.93**

Photovoltaic (PV) Economic Information and Solar Resource

The size of a PV array system in the optimum system is 614 kW. While the total capital cost is $ 4,79,921.18 and the replacement cost is zero since the project lifespan is the same as PV array lifetime, which is 25 years. The fixed PV panels will have a rated power of 10 kW per unit with the output voltage of 24V D.C. the number of PV panels is even since the D.C. bus bar voltage is 48V D.C. The design accounts for the decrease in PV efficiency panels with the ambient temperature. The solar radiation data is taken from NASA meteorological department database. The lifetime for this PV array system is 25 years with a de-rating factor of 96% and ground reflectance is 20%. Fig. 3 shows the average monthly solar radiation data at Digha, West Bengal where maximum radiation occurs in the month May and the minimum radiation available in the month of August, which is the raining season in the Indian subcontinent. It is seen from the data that the site has tremendous solar resource potential. This is the reason behind 86.50% of electrical energy come from the Photovoltaic array while the rest diesel generator and a wind turbine in the optimum system.

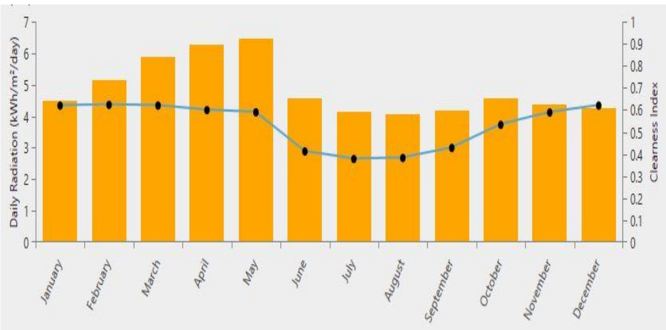

Figure 3. monthly average solar radiation

Significant information about solar Flat PV cell such that temperature coefficient is -0.4100, operating temperature is 45^0 C, efficiency at standard condition is 17.30% is taken from the solar manufacturer of SOLARMAX. The tracking system is horizontal axis daily adjustment taken here. The MPPT is also taken to increase the output efficiency of PV plate and battery as well. MPPT stands for Maximum Power Point Tracker. It is a circuit (typically a DC to DC converter) employed in the majority of modern photovoltaic inverters. Its function is to maximize the energy available from the connected solar module arrays at any time during its operation. The minimum output of PV plate is 0 and maximum output is 500 kW. The hours of operation of PV is 4392 in the year and levelized cost is 0.0482 $/kWh. Total energy production from PV is 10,42,276 kWh/year.

Wind Turbine

The wind turbine is considered to generate wind power as the project location is the nearby Bay of Bengal so wind speed is available in ample amount. The monthly wind speed data have been taken from NASA metrological department

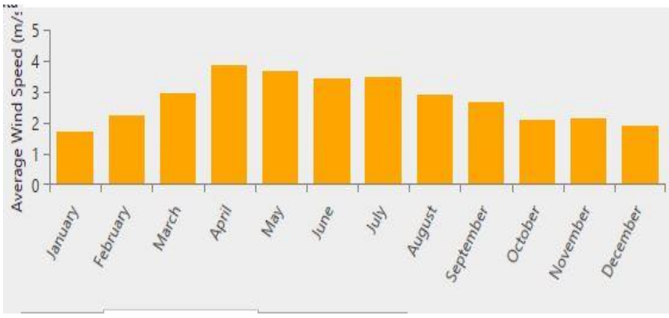

Figure 4 Monthly average wind speed variation

The rated capacity of WT is 500 kW. The capital cost of WT is $1,60,000 and replacement cost is zero as the life of WT is same as project life. The HOMER optimizes the wind turbine operational cost $646.38 and fuel cost is zero. The maximum output from the WT is 202 kW, hours of operation is 5574 hours and levelized cost is 0.0897 $/kWh. The technical information given by manufacturer data sheet is given as rotor diameter is 33.2m, rated wind speed is 9.5 m/s, cut-in-wind speed is 3 m/s, cut-off-wind speed is 25 m/s and hub speed is 40m.

Diesel Generator

The diesel power plant of 360 kW is used in the optimal configuration. The diesel price with two discrete values of 0.92$/L and 0.95$/L is used for the sensitivity variables. At present, the diesel price is about 0.92$/L in India. The lower heating value is 43.20 MJ/kg, the density of the fuel is 820kg/m3 and carbon content is 88% and Sulphur content is 0.40%. The emission rate of different pollutant per litre of fuel of the generator are such as CO 12.56 g/L, particulate 0.718 g/L, unburned HC 0.72 g/L, NOX 14.36 g/L. are given in manufacturer sheet. The diesel generator forced to off from 10:00 to 15:00 because of the advantage of more availability from PV array (for rest of time HOMER will optimize) for the optimum system to supply required load and to avoid frequent startup of the generator which reduces its life.

Battery

The type of battery that used for the system is 55.8 kWh model with the rating of 720 V, 77.6 Ah, with lifetime throughput 42,89,095 kWh. The cost for one battery is $9,500 with the replacement cost of $7,500. Total of 29 batteries of 55.8 kWh capacities is used in the optimal system. The initial state of charging of all the batteries is 100%. The capital cost of batteries is $2,75,500 and replacement cost is $81,388.97 because of life of the battery is 17.2 years only.

Power Converter

A power electronic converter is used to maintain the flow of energy between ac and dc component. The optimal size of power converter used in this system is of 268 kW. The capital cost, replacement costs and maintenance for this equipment for a power converter is $32,168.90, $18,946.15 and $3,465.53 respectively. The lifetime for one unit of the converter is 10 years with the efficiency of 97.60%.

COST DETAILS OF ALL THE COMPONENT

The capital cost, replacement cost, O&M cost, fuel cost, salvage cost and total cost is shown below.

Table 2 .Cost details of the entire component

Component	Capital ($)	Replacement (%)	O & M ($)	Fuel ($)	Salvage ($)	Total ($)
DG 360	$ 30,000	$0.0	$ 2,34,231	$ 96,586	$ 858	$ 3,61,675
Battery	$ 2,75,500	$ 81,388	$ 3,749	$0.0	$ -28,462	$ 3,32,175
Converter	$ 32,169	$ 18,946	$ 3,465	$0.0	$ -2,569	$ 52,011
PV MPPT	$108,322	$0.0	$21,543	$0.0	$0.0	$129,865
PV Solar	$ 4,79,921	$0.0	$ 39,720	$0.0	$0.0	$ 5,19,641
WT 900	$ 1,60,000	$0.0	$ 646	$0.0	$0.0	$ 1,60,646
System	$10,85,912	$ 1,00,334	$ 3,03,354	$ 96,586	$ -30,173	$ 15,56,013

OPERATION PRINCIPLE OF STANDALONE HYBRID SYSTEM

The operation principle of the proposed hybrid system is based on optimization of a simulated component of the hybrid power system. PV arrays and wind turbine which are the primary load suppliers will charge the battery bank when there is an excess power remaining after meeting the load demand. The converter is used here to convert from DC to AC because PV output is in DC which need to be converted in AC power. If PV module and wind turbines are not sufficient to provide the demand then the battery will provide power through discharge itself. The control strategy determines the energy flows from the various sources like diesel generator and different types of renewable generators, towards the user loads, and pump load, including the charging and discharging of the energy storage systems, on a time scale of minutes to hours, in such a way as to optimize system performance in terms of operating cost.

There are two type of dispatch strategy on which HOMER work, one is cycling charging and another one is load following which is optimal depends on many factors, including the sizes of the generators and different component, the price of fuel, the O&M cost of the generators, the amount of renewable power in the system. Under the load following strategy, whenever a generator is needed it produces only enough power to meet the demand. Under load following strategy whenever generator has to operate it operate only enough to supply power demand with reduced capacity while under cyclic charging strategy whenever the generator has to operate, it operates at full capacity with surplus power going to charge the battery bank.

RESULT AND DISCUSSION

Optimization of Hybrid Renewable Energy System without Considering Sensitivity Variables

The proposed hybrid renewable energy system for the village consists of the primary load of 1650 kWh/day, with the peak load of 385.51 kW and a deferrable load of 24.86 kWh/day with peak load 4.62 kW. The HOMER software identifies the best possible economical configuration for the hybrid renewable energy system. For an example, the optimal sizing and operational strategy for a hybrid renewable energy system may sometime consider all of the equipment or without considering one part of the equipment. Thus, the combination of the equipment is depending on the optimization procedure and sensitivity variables. Here four types of combination are found optimum after calculation by the HOMER. These are PV, WT, DG with the storage system, PV and DG with the storage system, PV and WT with battery and the last one is only PV with battery. Out of four first combination is most optimum and having lowest NPC and COE value. All the four combinations are given in the following table no 3 and it can be seen that top of the list has minimum $1.56M of NPC value.

HOMER performs the optimization process in order to determine the best solution in terms of component size and Total Net present cost of hybrid renewable energy system based on several combinations of equipment. Hence, multiple possible combinations of equipment could be obtained for the hybrid renewable energy system due to different size of PV array system, number of wind turbines, size of generator, number of batteries and size of dc-ac converter.

The combination of system components is sorted from least TNPC to highest TNPC. The optimization results of hybrid renewable energy system are obtained for every selection of the sensitive case i.e. fuel price 0.92 $/L primary load 1650 kWh/Day, real interest of 5.88%. The list of TNPC of different configuration without considering sensitivity variable like electrical load or fuel cost. The best (least) TNPC obtained here is $1.56M and cost of energy(COE) is $0.197/kWh with total renewable fraction is 96.10%. However, sensitivity variables are also taken for future uncertainty in calculation of TNPC. The price of fuel and variation in electrical load are taken as sensitive variable here.

Table 3. Optimization result without considering sensitivity variable

Combination of System					Architecture							Cost				
PV	WT	DG	Battery	Converter	PV (kW)	MPPT (kW)	WT (Kw)	DG (kW)	Battery (Units)	Conv (kW)	Dispatch	COE ($)	NPC ($)	Operating Cost($)	Initial Capital	Ren Frac (%)
PV	WT	DG	Battery	Converter	614	500	1	360	29	268	LF	$0.197	$1.56M	$36,294	$1.09M	96.1
PV		DG	Battery	Converter	777	500	1	360	35	313	LF	$0.205	$1.62M	$38,876	$1.12M	95.8
PV	WT		Battery	Converter	588	500			80	408	LF	$0.206	$1.63M	$7,250	$1.54M	100
PV			Battery	Converter	1453	500			48	356	LF	$0.244	$1.92M	$14,120	$1.74M	100

Hybrid Renewable Energy System Considering Sensitivity Variables

There is two type of sensitivity variable are considered one is the Primary load which is 1650 kWh/day and 1815 kWh/day and another one is Diesel fuel price 0.92 $/L and 0.95 $/L.

The best configuration of hybrid renewable energy system consisting of the diesel generator, PV array system, wind turbine, battery storage and power converter with the total net present cost of $1.56M and cost of energy $0.197/kWh is obtained. As it can be seen the system comprising of the diesel generator, PV array wind turbine with battery storage and power converter yields to the most economical cost with the minimum TNPC of Energy. The wind speed profile of this particular village is low and the output from a wind turbine is comparatively less. The energy obtained from different components of the hybrid renewable energy system is shown in Fig.no.5 The PV array produced 10,42,276 kWh/year that is 86.50 % of the total energy served. The remaining 11.50% of total energy is served by the wind turbine, which is 1,38,470 kWh/year and diesel generator used as a backup and produce 1.96 % which 23,600 kWh/year. The optimization result considers every sensitive variable gives different TNPC value of hybrid renewable energy system. It is worth mentioning that the sensitivity variables comprise of primary load and fuel price Table 4 shows that the TNPC of PV, WT, Generator and battery hybrid system become economically feasible when the primary load is varied from 1650kWh/day to 1815kWh /day and annual real interest rate 5.88%. The system is also economical even if the diesel fuel price increase from the current 0.92$/L to 0.95$/L, which is actually expecting due to the variation of crude oil price.

As it is observed from simulation PV/WT/Gen/battery system is still optimum for the wide variation of load and diesel fuel price. Therefore, the optimum system for the case study village is PV/gen/battery system with the converter with minimum COE of $0.197/kWh.

Table 4 Optimization result with sensitivity variable

Sensitivity		Combination of System					Architecture							Cost				
Disel Fuel Price ($/L)	Electrical Load kWh/day	PV	WT	DG	Battery	Converter	PV (kW)	MPPT (kW)	WT (Kw)	DG (kW)	Battery (Units)	Conv (kW)	Dispatch	COE ($)	NPC ($)	Operating Cost($)	Initial Capital	Ren Frac (%)
$0.92	1650	PV	WT	DG	Battery	Converter	614	500	1	360	29	268	LF	$0.197	$1.56M	$36,294	$1.09M	96.10
$0.92	1815	PV	WT	DG	Battery	Converter	732	500	1	360	31	405	LF	$0.197	$1.71M	$38,140	$1.21M	96.60
$0.95	1650	PV	WT	DG	Battery	Converter	614	500	1	360	29	268	LF	$0.197	$1.56M	$36,538	$1.09M	96.10
$0.95	1815	PV	WT	DG	Battery	Converter	732	500	1	360	31	405	LF	$0.197	$1.71M	$38,378	$1.21M	96.60

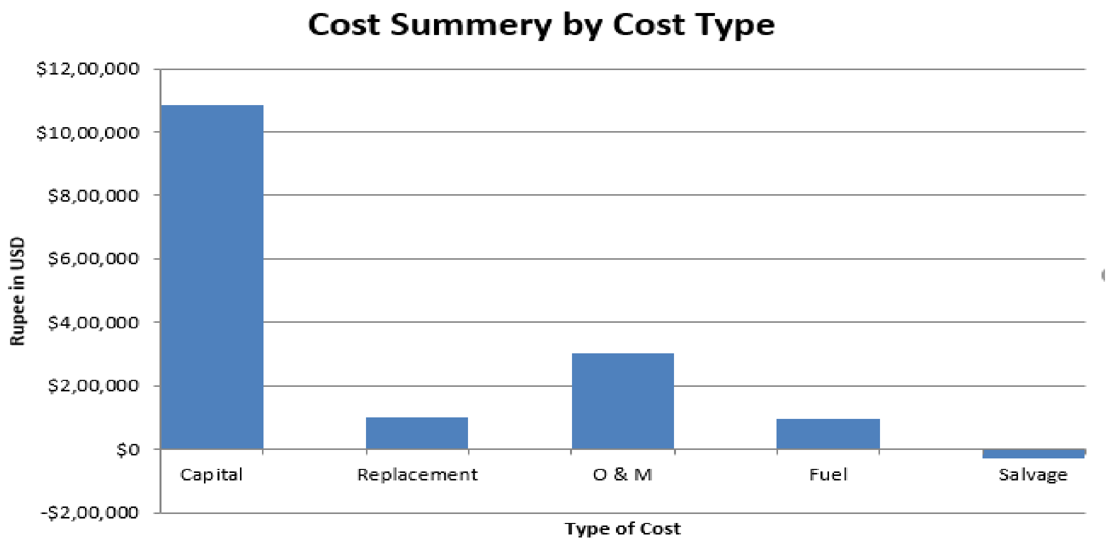

Figure 5. Cost Summery by cost type

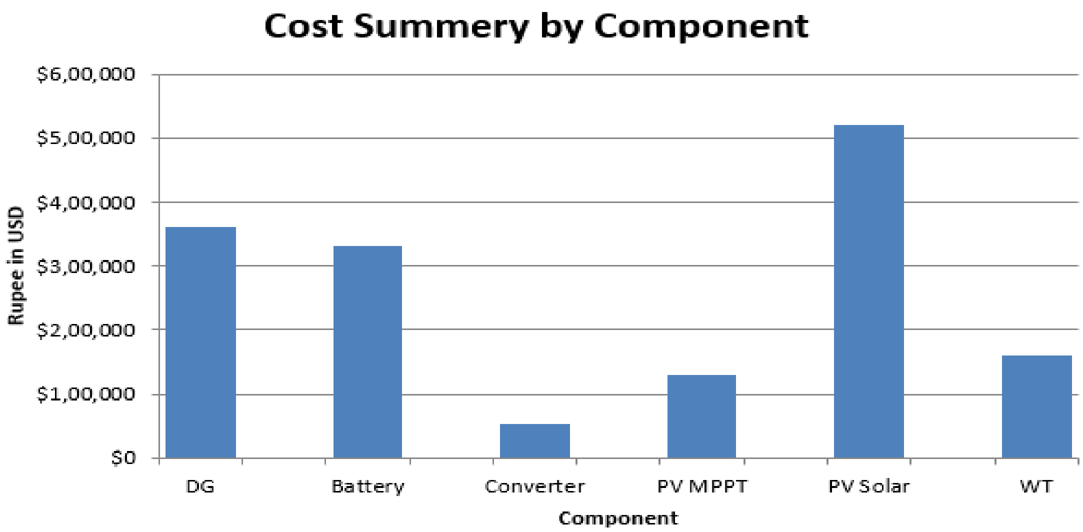

Figure 6. Cost Summery by component

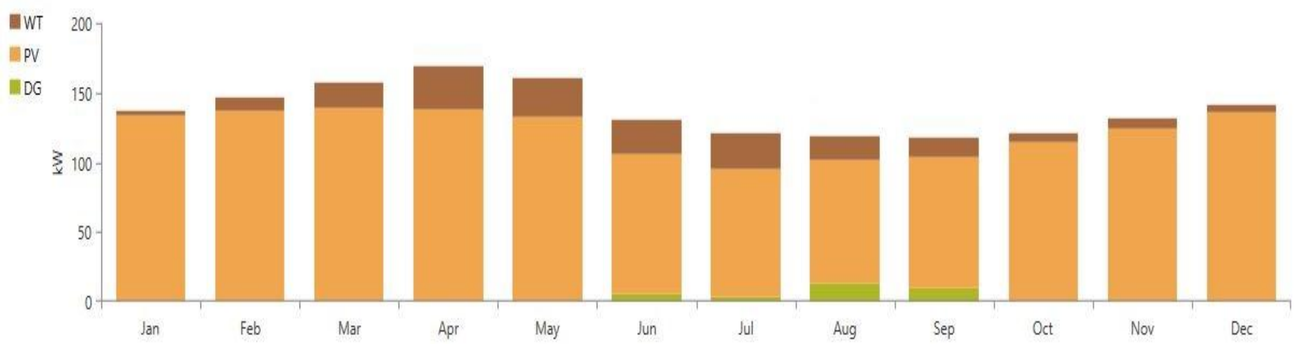

Figure 7. monthly average Electrical energy production of hybrid energy system

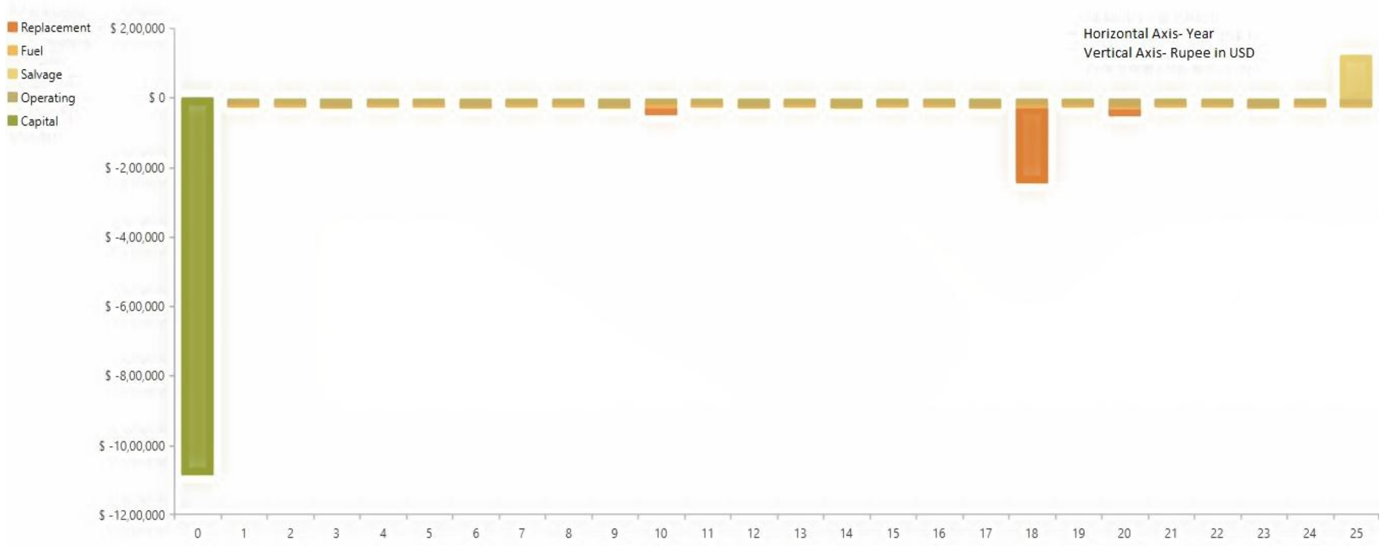

Figure 8 cash flow summery of 25 year by component

ENVIRONMENTAL ADVANTAGE

All energy sources have some impact on our environment but compare to conventional resources hybrid renewable energy sources have very less impact including air and water pollution, damage to public health, wildlife and habitat loss, water use, land use, and greenhouse gaseous emissions. Harnessing power from the wind is one of the cleanest and most sustainable ways to generate electricity as it produces no toxic pollution or global warming emissions. Similarly, the sun provides a tremendous resource for generating clean and sustainable electricity and it can be utilized by the better use of PV cell. The comparative data of greenhouse gaseous emission in both case i.e. conventional and hybrid renewable energy resources is given in table no.6 as it can be seen there is a huge reduction of greenhouse gas which encourages such type of hybrid renewable energy resources system.

Table 5. Reduction of greenhouse gaseous

Quantity	**Conventional (values in kg/year)**	**HRES System (values in kg/year)**	**% of reduction**
Carbon Dioxide	6,56,206	21,308	96.75
Carbon Monoxide	4136	102	97.53
Unburned Hydrocarbons	180	5.85	96.75
Particulate matter	25.1	5.83	76.77
Sulfur Dioxide	1607	52.1	96.75
Nitrogen Oxides	3886	117	96.98

CONCLUSIONS

The non-electrified rural population is currently difficult to make electrified through the extension of the grid in India since the connection cost is not economically feasible due to disseminate rural area and low load factor. Further, the increases in oil prices and the unbearable environmental impact of conventional energy source encourage to remove of such type of fuel Gen set based systems for the rural development agenda. Grid extension and off-grid hybrid solutions complement each other rather than compete. Off-grid hybrid standalone renewable energy is economically viable in Digha of grid extension in areas where there is low load factor, low population densities and difficult geographic terrain to be crossed. Apart from these advantages, any type of subsidy or incentive is not included in the result however in the majority of cases, the incentives from central and state governments and local utilities are necessary to make a hybrid system economically viable. So, this will be more economically viable if government permit any type of incentive to encourage rural development.

From simulation result, the combination of PV array, diesel generator, wind turbine, battery storage and converter bring to the optimal configuration of hybrid renewable energy system applicable to be used as an off-grid system for the selected village of 1000 household in the eastern region of India with the cost of energy $0.197/kWh. Since the solar resource potential of the site is high 86.5 % of the energy is produced from the solar array and 11.5 % from the wind turbine and 1.96% from the diesel generator. The energy storage system once and inverter should be replaced twice during the project period. However, the last time replacement of the battery occurred in the 16th year from 25 years of the total project lifetime salvage value of around $28,462 and from converter $2,569 left at the end of project period. As seen from the simulation result the designed system can provide 24-hour electricity for the village without interruption.

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