Renewable Generated Electricity for Enhancement of Sustainable Livelihoods in Rural India

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Abstract: **India is developing country and electricity demand is increase rapidly. Many of Indian villages about 19000 are not electrified since independence. Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) is a government of India scheme to provide continuous power supply to off-grid rural area of India. This paper, we propose the best Hybrid Energy System (HES) for off-grid electrification of rural area where conventional grid power supply is not possible. Electricity need for an off-grid remote area supply from a mixture of biodiesel generator and Nonconventional energy resources to satisfy in a reliable manner. Here we are using HOMER software is used for whole analysis. The simulation results indicate that the proposed HES would be a feasible solution for distributed generation of electric power for remote locations and the total CO2 emission is reduced comes from gird-extension.**

Keywords: DDUGJY, HES, HOMER, Emission.

1. INTRODUCTION

Energy demand increase due to industrialization and urbanization rapidly. In all over the world, about one hundred thirty million people in the world live without access to electricity in [1]. The challenge of providing cost-effective and reliable electricity services remains the major global challenge. This problem isn't only facing by India but also by the world. Grid extension still remains the preferred mode of rural electrification. The grid extension of the central electricity grid to urban and rural area electrification can either be financially feasible or practical impossible [2]. Off-grid electrification options can be helpful in such remote area.

The government of India founded the Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) for rural electrification where the electrification not possible with grid extension. Under the DDUGJY used the separate feeder for rural domestic and agriculture uses [3]. The focused of government of India to strengthening sub-transmission and distribution infrastructure with metering of all level of remote areas.

The objective of this research effort is to find out the mixture of nonconventional energy resources from the available resources in a given remote area location to reduced grid extension. The Hybrid Energy System (HES) is a combination of nonconventional energy system sources in the remote area, where the utility of grid extension is either financially unfeasible or practical impossible and where the cost of fuel change with respect to a diversity of remote location [4].

In recent time, the combination of flat PV array, a wind turbine is become more popular and being widely used in all over world alternative of fossil fuel.

113 villages yet to be electrified out of 43,264 census villages, 43,151 villages (99.7%) have been electrified in Rajasthan, India [5]. All remaining off-grid village are electrified under DDUGJY. In our research work, we choose remote area narayanpura village of district Jhalawar, Rajasthan for electrification and used HOMER software. HOMER software is the widely used for system optimization. For optimization result first, we identify the available resources at the remote location, model electricity generation based on various mixtures of nonconventional energy sources and biodiesel generator. Secondly, we used HOMER software and obtain the best optimization result of the hybrid power system.

For example, Bhattacharya and Hafez investigated the optimal model of the RES based micro grid system for a hypothetical rural area. Where the base load demand is 600 kW and daily energy demand is 5000 kWh/day. The hybrid system is combination of flat PV, wind turbine, hydro and diesel generator resources for electricity generation [6] and AHM Yatim et al. analyzed the case of a hypothetical residential area with peak demand 80kW in Malaysia and used HOMER software to optimization of a hybrid system [7].

By using HOMER software, in this paper, we are trying to address the following issues.

- How economical would it be if electricity supply by the hybrid system?
- If renewable energy system used for villages, what will be the gain in an economy?

Another advantage, the total CO2 emission is reduced by using nonconventional energy sources..

2. METHODOLOGY

2.1 HOMER Software

HOMER is "A tool for modeling and evaluating micro power technology or hybrid power system, which contain conventional generator, Flat PV, batteries, fuel cells, biomass and other input". It is developed by NREL for designing and simulation of hybrid power systems but correlatives it by engaging HOMER analyses [8]. The framework of HOMER software is shown in fig.1.

Fig.1 Framework of analysis using HOMER

The HOMER optimization study is based on the technical characteristics of the system and the life-cycle cost (LCC) of the system. The LCC includes the initial capital cost, the cost of installation and operation over the system's lifespan. HOMER does simulations to meet the given electric demand using alternative technology and resource availability. Based on the simulation, the best-adapted arrangement is selected.

We have considered the mixture of the biodiesel generator flat PV array, wind turbine, converter systems and batteries for back-up. In the hybrid system, the bio-diesel generator and the wind turbine is AC-coupled on AC side of the system and the solar PV cell array and the batteries are connected to its DC side of the system.

2.2. System Modeling

In our research, we choose off-grid Narayanpura village is located in Jhalrapatan Tehsil of Jhalawar district in Rajasthan, India. It is situated 23km away from sub-district headquarter Jhalrapatan and 15km away from district headquarter Jhalawar [9]. First, we pick out the best hybrid system from available renewable sources and Second, remote area electrified by the hybrid system. According to the NASA Surface meteorology and Solar Energy, the RET Screen Data [10]for Narayanpura show in below table 1.

Table 1: Location of Jhalawar, Rajasthan, India

Climate data (Unite)	**Value**
Latitude (°N)	24.597
Longitude (°E)	76.161
Elevation (m)	382
Heating design temperature (°C)	12.65
Cooling design temperature (°C)	37.43
Earth temperature amplitude (°C)	21.75

2.3. Load Assessment

In remote rural villages the demand for electricity is not high compared to urban regions demand. Electricity demand is separated into two sections

- Domestic demand (for apparatuses like fluorescent lamps, ceiling fans and table fans etc.)
- Agricultural demand (like water tapping).

Domestic Use

In this paper, the village's demand is precisely determined and number of household in this village is according to the census data of India in 2011. The demand has been calculated independently for two separate seasons prevailing in this remote location, specifically summer (April to October) and winter (November to March) considering the apparatuses holding and use pattern of households for a number of villages [11] shown in table 2.

Table 2: Estimated Electricity Domestic Demand for Off-Grid Remote Area

Domestic Purpose	Number in use	Power (W)	Demand in summer season		Demand in winter season	
			h/day	Wh/day	h/day	Wh/day
Low energy (LED)	3	5/9/14/20	6	120	7	140
Ceiling fan	1	50	15	750	0	0
Total				870		140
No. of houses	78			63,960		10,920
Shops	10	600	8	4800	7	4200
School	1			1360		1200
Community Centre	1	1000	8	8000	6	6000
Total		1670		78,120		22,320

*Number of houses according census data of India 2011

Agriculture Activities

The energy Ew in watt-hour/day (Wh/day) is equal to the multiplication of power P in watts and times the time period t in hours in per day:

$E_w = P(W) \times t(h/day)$

$= 1500\ W \times 6\ hours/day$

$= 9000\ Wh/day$

For seven unit of electric pump, the total Energy will be

$E_w = 7 \times 9000\ Wh/day$

$E_w = 63\ kWh/day$

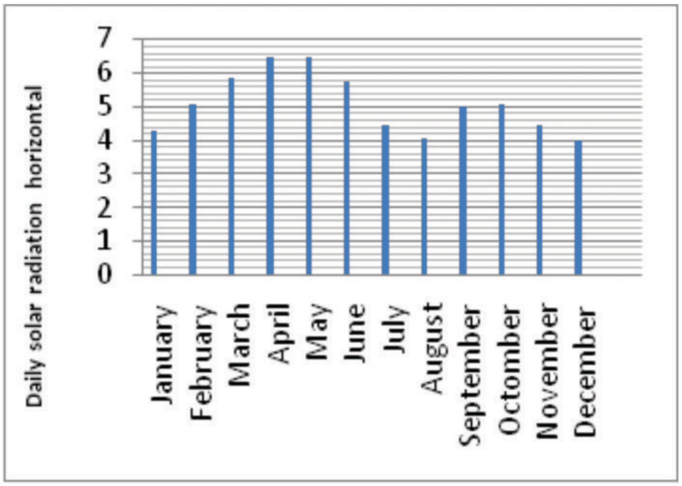

Fig.2 Daily Solar Radiation Horizontal Data

3. ECONOMICAL MODELING

CASE I: If the electrification of a rural area makes through the grid extension with where it is not possible because of the location of area rural area is so far from grid substation or it is situated at the critical location then the Cost Of Electricity (COE) is increased due to transmission cost and another cost also added to COE.

CASE II: Our objects to reduce the total net present cost both in determining the optimal system arrangement and in operating the system. We purposed hybrid system which is based on non-conventional energy sources. We have considered the mixture of the biodiesel generator flat PV array, wind turbine, converter systems and batteries for back-up. In the hybrid system, the bio-diesel generator and the wind turbine is AC-coupled on AC side of the system and the solar PV cell array and the batteries are connected to its DC side of the system shown in Fig.4 for a schematic system configuration diagram. We have considered Flat PV array, wind turbine and bio-diesel resources in this simulation of HES. The monthly Avg. temperature and wind resource data from an average of ten years were obtained from the NASA resource website based on the longitude and latitude of the area location [12].

According to NASA resource data, max. and mini. Solar radiation ranges are 3.80 kWh/m2/d in June, 1.80 kWh/m2/d in November, respectively shown in fig.2 and the maximum and the minimum wind speeds are 3.80 m/s in June, 1.80 m/s in November, respectively shown in fig.3.

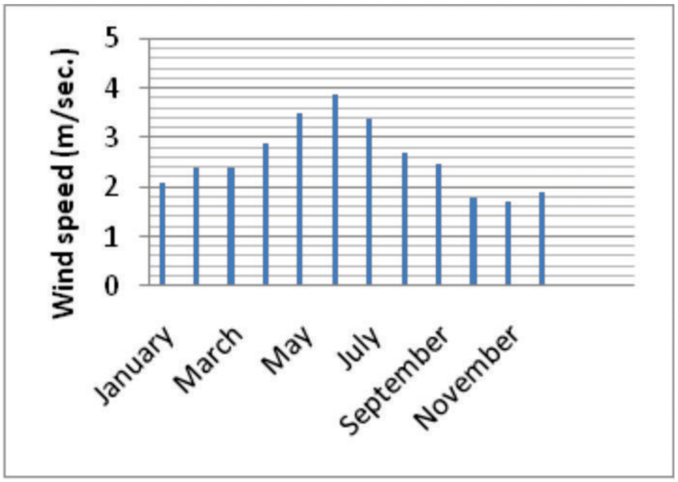

Fig.3 Wind Speed in M/Sec Data

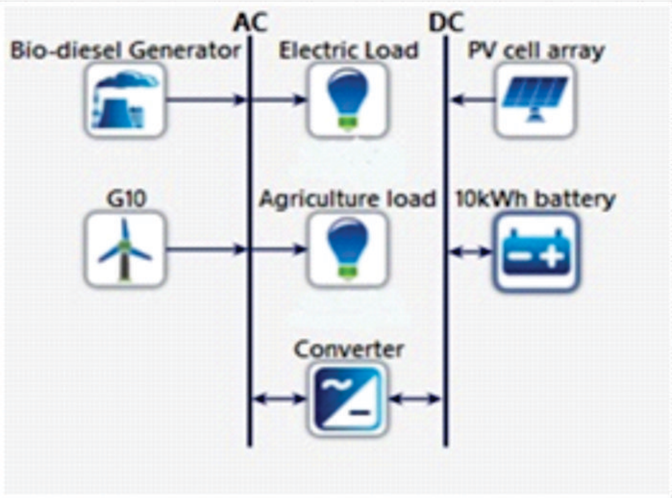

Fig.4 Schematic system configuration

The project's lifetime is estimated to be 25 years with an annual percentage rate of 10%. The capacity, lifetime, system fixed capital cost, replacement cost and the system fixed O&M cost is shown in table 3.

Table 2: Estimated Electricity Domestic Demand for Off-Grid Remote Area

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
Flat PV	143.98	00	0.035	00	00	144.01
Wind turbine	104.00	22.97	2.11	00	11.81	117.27
Hydro	29.25	00	3.16	00	00	32.41
Bio-diesel generator	73.12	187.78	13.14	33.53	0.88	306.70
10kWh battery lead acid	0.55	0.38	0.007	00	0.042	0.90
Converter	93.60	30.15	0.042	00	4.72	119.07
System	444.50	241.30	18.49	33.53	17.46	720.37

4. RESULTS AND DISCUSSION

This In this section, we show the results of our study. First, the Optimization results are given and secondly, the emission reduction is determined. The nonconventional energy sources are used and best simulations configuration by simulation process of the HES shown in table 4

Configuration: PV/Wind turbine/ Biodiesel/ converter/ battery

The average annually electricity generation by the hybrid system and total demands of the village is 85,004.00 kWh/y and 51,644.00kWh/y respectively, which are required to meet by the hybrid system. The excess electricity can be used to reduce demand on the bio-diesel generator as well as save fuel.

Table 4: Hybrid System Architecture for configuration

Configuration	NPC (Cost in Rs. Lakhs)	LCOE (Cost in Rs. Lakhs)	Operating cost	Bio-diesel generator production (kWh/yr)	Excess electricity (kWh/yr)	Unmet load (kWh/yr)	Max. renew penetration
PV/Wind turbine/ Biodiesel/ converter/ battery	720.37	141.05	18.49	29,527	30,823	3.3	915

The contribution of different non-conventional energy sources in the HES shows in below table 5.

Table 1: Location of Jhalawar, Rajasthan, India

Configuration		
Production	kWh/yr	Percentage
Flat PV	51,644	60.23
Bio-diesel generator	29,527	34.74
Wind turbine	4,277	5.03
Total	85,004	100.00

The HOMER software was used to evaluate the variation of Avg. AC primary load demand over the different month shown in fig.5. From January to December, the bio-diesel generator is used mixed with flat PV array and peak electricity demand in peak month is met by the wind turbine. Month's wise pattern, generation by different sources (in kW) by the wind turbine, flat PV array and bio-diesel generator shown in below fig.6.

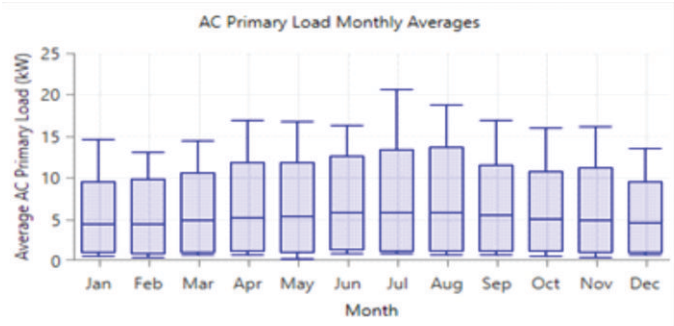

Fig.5 Avg. Ac Primary Load in Various Months

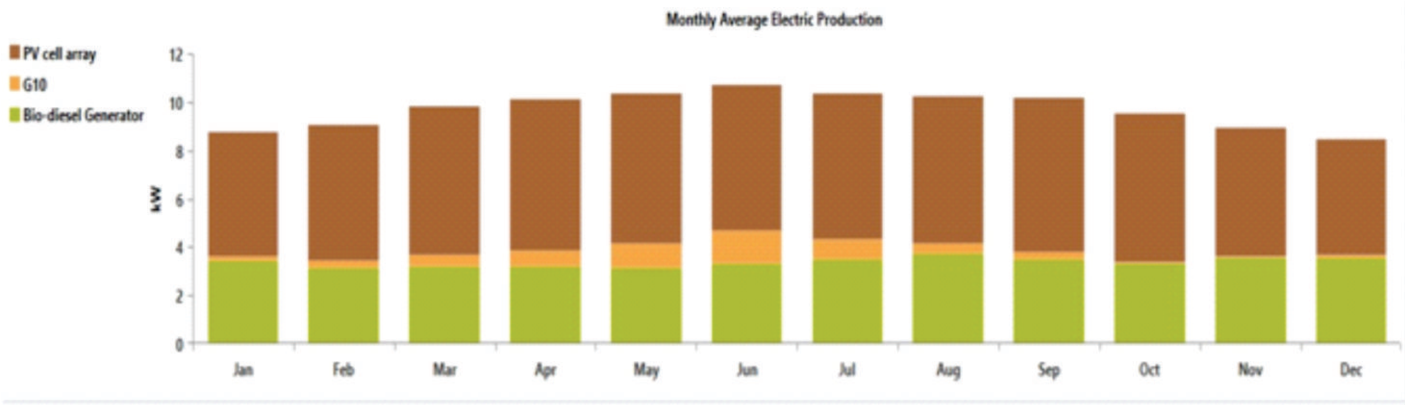

Fig.6 Monthly Avg. Electric Productions in Various Month

As per optimization result for configuration, the LCOE of the hybrid system is Rs. 141.05. So that, the Cost of Electricity (COE) for the configuration hybrid system Rs. 4.455/kWh.

The COE per unit for CASE I is based on the state government tariff for rural area base on the uses of consumption of units per months [13]. In CASE II, we calculate optimal COE of the HES by choosing best hybrid configuration based non-convention energy sources. The COE of all three cases shown in table 6

Table 6: COE for all different cases

CASE I		CASE II
For consumption up to first 50 units per month	Rs. 3.50/unit	The COE for optimal Hybrid system is Rs. 4.455/unit.
For consumption above 50 units and up to 150 units per month	Rs. 5.45/unit	

5. EMISSIONS

The optimal HES would save 201,165.00 kg/yr of CO2 per year show in below table 7. Emission of impure matters and NOX will be reduced due to dependence on non-conventional energy. In the hybrid system, we used two type of bio-fuel for a bio-diesel generator. Environmental Protection Agency of United States, two type B-20 (is mixture of 20% of bio-diesel and 80% oil-diesel) and B-100 (is 100% pure bio-diesel) bio-diesel [14].

Table 7: Emission Reduction

Quantity	Configuration-Value
Carbon dioxide (CO2)	133.37 kg/yr
Carbon monoxide (CO)	84.88 kg/yr
Unburned hydrocarbon	9.40 kg/yr
Unburned hydrocarbon	6.40 kg/yr
Sulfur dioxide	0.00 kg/yr
Nitrogen oxide	757.34 kg/yr

6. CONCLUSION

As a conclusion, our work is a feasible viable hybrid solution for off-grid electricity supply to villages resulted in a least-cost mixture of the wind turbine, flat PV array, bio-diesel generator and batteries. The electrification of off-grid remote villages with help of nonconventional energy sources than emission is reduced. Due to the decrease of CO2 emissions avoided petroleum fuel and decrease of deforestation.

The main lessons from this case research are:

- A mixture of technologies improves supply reliability and hence does better business sense.
- The cost of electricity supply of nonconventional energy sources based electricity may not always be a cost efficient option for rural electrification. If fixed cost of the HES and fuel cost of bio-diesel is raised.
- Economically viability is increased along with an increase in a number of off-grid villages.

On the Basis of the above analysis, we can say that HES becomes a technically possible and economically viable option in off-grid electrification in India than grid extension. Results, the DDUGJY scheme is more efficient and reliable if we electrified off-grid load with a mixture of non-convention energy than conventional grid extension and use of the only solar panel.

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