Design and Analysis of SPV-Diesel Hybrid System for Rural Electrification in Odisha

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Abstract: Energy is a crucial input in the economic, social and industrial development of the country. Areas such as hilly regions, forest, tribal and islands which are in remote due to their varied geographic and demographic locations, generally have low load potential, low load factor and inaccessibility to national grid thereby making them unable to connect to the grid due to the involvement of heavy capital investment and therefore are also not expected to have power in the long run. In order to energize such areas the renewable energy sources have been found to be most reliable, economic, eco-friendly and quickly installable as compared to conventional energy sources. Fossil fuels have powered the tremendous industrial and economic development of the developed countries. The oil crisis of 1973 served the warning that fossil fuels were neither inexhaustible nor any cheaper. Renewable energy sources like Solar, Wind, Biomass, SHP, Tidal etc. are the main sources of renewable/green power which can be used to electrify such areas in most appropriate and economic way. Out of these sources, SPV is considered reliable, pollution free and convenient power generation system. In this paper, the study has been carried out to design a SPV-Diesel hybrid system for providing sustained power to a typical remote area in our country. On the basis of energy resources data & load pattern of the area, it was found that the system design will consist of 70 % of SPV & 30% of DG generation with peak power of 160 kW. Accordingly, the system has been designed & unit cost of energy is calculated including cost of energy of all SPV & all DG power. It was also found that the DG-set is not suitable to electrify the selected remote area in comparison to SPV stand-alone system even if the unit cost of energy of former is very less.

Keywords: *SPV-Diesel; Hybrid; Non-Conventional Energy; Eco-friendly; Green Energy*

1. A Case Study

In India, about 55% households have access to electricity. Most of those who have access do not get uninterrupted reliable supply. Orissa state is situated on the Northeast in the geographical map of India. Bhubaneswar is its capital. Its geographical area is 1, 55,707 sq. km. and population is 36,706,920, with literacy rate of 63.61%, about 87% of Orissa's population live in villages. Its total number of villages is 50,887, out of which 37,307 villages are electrified while 13,580 villages are unelectrified. The selected area of the state is more than 20 kms far away from grid supply, to which the grid supply is not economical and also T & D losses are maximum. Its climate is tropical, which is influenced by the Southwest monsoon and is characterized by high temperature from March to May and high rainfall from June to September. The state also receives a small quantity of rain from the retreating monsoon in the months of October-November when occasional cyclonic storms are experienced. The annual average rainfall is 1482 mm, out of which 76% is received from June to September. The maximum temperature in May is about 40□ - 450 C. The low temperature in coastal district is usually between 120-140C.

The district of Kendrapara in Odisha, India is situated at the northeast coastal region of Orissa (Bay of Bengal) and is surrounded by Bhadrak, Jajpur, Cuttack and Jagatsinghpur districts. Its geographical area is about 2,548.0 sq. km, and one Sub-division, is sub-divided in like Tehasils-7, Blocks-9, Towns-2, Gram Panchayats-205, Villages-1, 532, Population-13, 01,856. The literacy rate is 77.33% followed by forest 248.05 km2, Rainfall-1463.6mm (average). The main occupations of peoples are agriculture and fishing.

The block selected as study area is Rajnagar consists of 18-gram panchayats, 307 villages, Population of 1, 02,520, 273 villages are electrified and 34 villages unelectrified and is situated near river Brahmani. The main occupation of the peoples is agriculture and fishing.

The villages of the study area belonging to Rangani Panchayat are located on eastern part of Kendrapara district on south side of river "Brah mani" and western side of Bay of Bengal. The distance of the village from Block and District headquarter is 51 and 91 kms respectively.

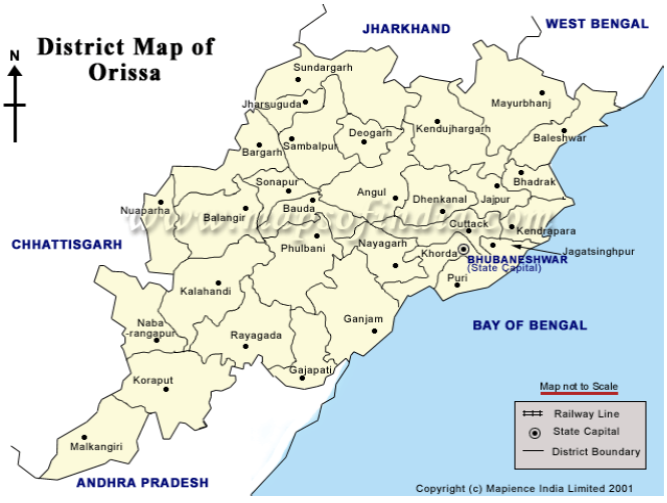


Fig 1. Study Area Location in the Geographical map of Orissa [1]

2. Estimation of Load Pattern

Table-1 shows the total average load 690 kWh per day for 6 hrs per day uses. The appliances like lights, fans, TV, and pumps are therefore arranged in hours of consumption of the families on of 24 hours per day. The standard rating of devices has been used for computing load pattern. The maximum consumption in the families is between 18-20 hrs of the day. In this situation, all the appliances can be operated based upon the maximum load at the power station. This is one of the most critical parameter for operating the power plant very smoothly without any power failure. The detailed hourly load patterns are shown in Table 1.

Table 1. Daily hourly load/ consumption

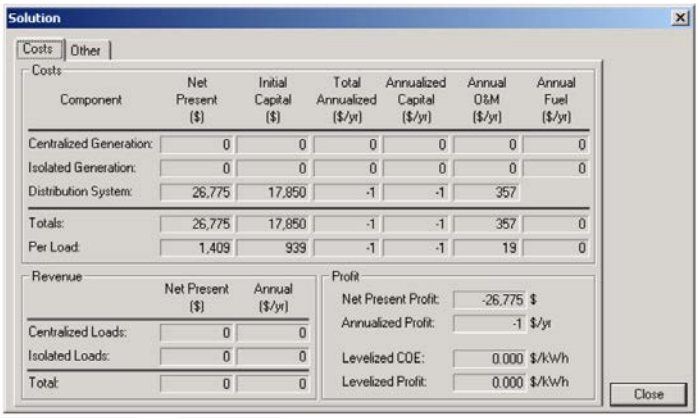
Time of the day (hr)	Ratings				Number of Appliances to be operated				Total load in (kW)	Total load in (kWh)
1.1.1.1.1 Range	DL+SL	F	TV	PUMP	DL+SL	F	TV	PUMP		
1 hr	9+11	40	18	375	2374+118	1187	1187	03		
0-1	11	40			118	1187	0	0	48.77	48.77
1-2	11	40			118	1187	0	0	48.77	48.77
2-3	11				118	0	0	0	1.30	1.30
3-4	11				118	0	0	0	1.30	1.30
4-5	11				118	0	0	0	1.30	1.30
5-6	11				118	0	0	0	1.30	1.30
6-7			18		0	0	1187	0	21.36	21.36
7-8			18		0	0	1187	0	21.36	21.36
8-9		40			0	1187	0	0	47.48	47.48
9-10		40			0	1187	0	0	47.48	47.48
10-11				375	0	0	0	03	1.125	1.125
11-12				375	0	0	0	03	1.125	1.125
12-13		40			0	1187	0	0	47.48	47.48
13-14		40			0	1187	0	0	47.48	47.48
14-15				375	0	0	0	03	1.125	1.125
15-16				375	0	0	0	03	1.125	1.125
16-17		40			0	1187	0	0	47.48	47.48
17-18		40				1187	0	0	47.48	47.48
18-19	9	40	18		2482	1187	1187	0	91.18	91.18
19-20	9	40	18		2482	1187	1187	0	91.18	91.18
20-21	9+11				2592	0	0	0	23.56	23.56
21-22	9+11				2592	0	0	0	23.56	23.56
22-23	9+11				2592	0	0	0	23.56	23.56
23-24	11				118	0	0	0	1.30	1.30
									TOTAL	689,218 = 690kWh

Fig. 2 indicates that, the peak demand of 92 kW is in between 18-19 and 19-20 hours of the day. This indicates that during 18-20 hrs. i.e, evening time has maximum peak load on the plant. This will be the basis for further designing the proposed SPV-Diesel hybrid power plant for meeting the energy demand of the study area in an effective manner.

3. Results & Discussion

Based upon the optimization, the breakdown of the costs and revenues associated with the optimal solution of all the systems have been evaluated for the study area by us-ing VIPOR and the results are shown in Table-2 which indicates that the T & D costs ex-ceed the revenues obtained.

Fig 3. Cost output results of all centralized power distribution system



VIPOR displays a breakdown of the costs and revenues associated with the op-timal solution. The above figure shows the distribution cost details i.e. Net Present cost of Rs. 12.04 lacs, Initial capital cost is Rs. 8.03 lacs, and annual O & M cost Rs. 0.16 lacs of all centralized T & D system. The net profit is Rs. 12.04 lacs. As VIPOR searches for the optimal system, it remembers not only the overall opti-mum, but also the optimum at each different value of grid load (the total load on the centralized grid). In other output, the total centralized load points are 19 and isolated load points are zero. It also shows the total length of M V line (red line) of 6077 m and number of bus bar as 19, which is equal to total number of load points

Sr. No.	Components	Only SPV system (Rs. In lacs)	Only Diesel System (Rs. In lacs)	SPV-Diesel Hybrid (Rs. In lacs)(By HOMER)
1	SPV	Rs. 502.00 lacs	--	29.11
2	Diesel	--	Rs. 32.30 lacs	22.22
3	Battery & Charge regulator	Rs. 354.00	--	20.25
4	Inverter	Rs. 15.00 lacs	--	4.25
5	T & D	Rs. 21.00 lacs	Rs. 21.00	1.1.1.2 Rs. 21.00
Total Cost		Rs. 892.00 lacs	Rs. 53.30 lacs	96.83
Unit energy Cost (Rs./kWh)		Rs. 20.00	Rs. 18.25	Rs. 38.84

Table 2: Components Cost Comparison of all Systems

4. Conclusion.

In this paper, the SPV-diesel hybrid system based power generation, the unit energy cost of only SPV stand-alone power generation system and DG set is calculated, its values are Rs. 20.00 (including T & D) for SPV and Rs. 11.00 for generator set. But due to some constraints like higher unit cost, pollution problem and not reliable throughout the year, both the isolated system are not preferred in the selected study area. Hence

the SPV-diesel hybrid system is selected for power generation in this area. Since manually it is a tedious work to mix different type of optimization results, hence the computer software like HOMER (version 2.09) for power generation and VIPOR (version 0.9.22) for T & D systems is ap-plied to this hybrid system to optimize on least cost basis. By applying this optimization procedure, finally the unit energy cost is Rs. 30.00 and including T & D cost, its value is Rs. 38.84 per kWh. The study area is selected at eastern costal region of Orissa due to its topography and non-availability of regular grid supply. Based upon survey and demographic data, the existing energy consumption pat-tern, energy resources and its potential and load pattern are made for the study area. The unit energy cost of SPV stand-alone and DG set power generation sys-tem is calculated. Based upon the study, following conclusions can be drawn: (i) SPV-Diesel Hybrid system is more reliable and economical in comparison to all SPV stand-alone system; (ii) The optimization system may be able to supply con-tinous reliable power depending upon the load pattern and hence will help to im-prove the living standard of the people of the area; (iii) In the design of such a hy-brid system, the lower size inverter and battery may reduce the installation cost of the system; (iv)The continuous supply of power through SPV-Diesel will improve the living standard and enthused to do extra work during night; (v) The unit gen-eration cost of hybrid system is less compared to SPV stand-alone and DG set generation system; (vi) It will create relatively less air and noise pollution and hence provide cleaner atmosphere.

5. References

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