A Case Study for Optimum Sizing and Selection of Components in HRERs based Power Sysetm

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ABSTRACT

The demand of electricity in rural India is increased two fold in the last decade and this demand has been met by the electricity grid extension so far. But the cost of extension of grid is very high and also depends upon land location, distance to be covered and more importantly size of the load. The recent researches show that adding the renewable energy resources to the system at the load centre makes the system less costly and environment friendly. The different configurations are compared and the selection of optimum configuration is based on the least value of cost of energy (COE) and net present cost (NPC) along with the highest value of renewable fraction (RF) and lowest harmful emissions (CO2) using HOMER (Hybrid Optimization Model for Electric Renewables) software is presented. A village location, Kotali Charkan (32° 37' 0" North, 74° 50' 0" East) in Jammu and Kashmir state of India is chosen for the system under the study, the hydro, solar and wind resources are available almost throughout the year on the selected village location.

Keywords: *HOMER, RERs, optimum sizing, Hybrid system*

I. INTRODUCTION

In recent decades, rapid population growth and technological development have resulted in to more consumption of energy, especially in electricity sector. Moreover, there are many parts of the world particularly in rural areas in developing countries which have limited or no access to electricity. It is also reported that rural electrification is very important for development of the rural areas so as to obtain economic growth, poverty elimination, employment generation and improvement of living standard of the villages. According to the Census held in 2011 in India, 0.83 billion out of 1.21 billion resides in rural areas and out of which around 44% population does not have the access of grid [1]. In order to overcome these problems, electricity generation has to be increased. In India, a large part of the electricity is produced by fossil fuel resources [2]. As on June 30, 2017 India has total installed capacity of 329.23 GW and coal and diesel based power plants has 66.7% share [2]. To electrify the rural areas and to reduce the dependency on conventional energy resources, Government of India has started various programmes like as Remote Village Electrification Programme (RVEP), Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY), etc. [1]. Government has also revised the target of solar power projects from 20 GW to 100 GW by 2021-22 under Jawaharlal Nehru National Solar Mission (JNNSM) as of rapid rise in power production from solar power plants [1].

The electrification of rural area by grid extension in India costs about 8000$/km to 10000$/km and it can cost more in difficult terrains. Even if the grid is extended and source of power is secured, there are huge transmission and distribution (T&D) losses occurs. So electrification of rural areas by conventional grid extension method is not a viable option. This problem can be solved by distributed generation where T&D losses can be minimized and also the RF can be increased. In the past decade, many researchers studied about the more reliable renewable energy sources (RES) based system in combination of

other energy systems to form a single system i.e. hybrid renewable energy systems (HRES) [3]. The COE decreases and reliability of the system increases if the different combinations of RESs are used together, as they support each other in cost-effective way. For example in rainy season the solar energy is not available but hydro energy is available to support and as many energy sources are available, so the source with least COE can be chosen.
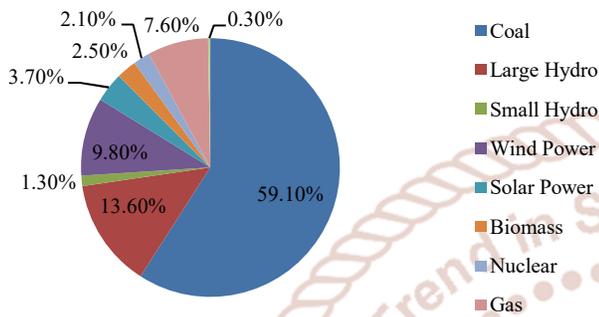

Fig1. Installed capacity by source in India as on 30 June 2017 [2].

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Malik has conducted a study to assess the potential of renewable energies in Brunei Darussalam. From the study, the author identified the availability of renewable energies that could be utilized [4]. A review is provided by Bhattacharyya [5] for off-grid PV systems in regarding to the rural electrification of developing countries in South Asia, South East Asia, Latin America and Africa. Sathans and Om Krishan [6] provided a comparison of COE and NPC of a grid integrated hybrid system of a small village when RERs are added to the system using HOMER simulation tool. The results show the significant drop in COE and power outage hours. Fantidis et al. [7] studied the potential of solar radiation and solar power plants at 46 location of Greece and found that solar power plants could avoid on an average 20.19 tons of

greenhouse gases emission. Chade et. al [8] conducted a case study of islanded location and compared the COE of different configurations applying HOMER software and hydrogen energy storage system with wind turbine found to be a feasible solution.

The village Kotali Charkan in Jammu & Kashmir state of India is selected for achieving this objective. The paper is organized as follows: Section I presents the introduction of the study. Section II presents system modelling and section III provides the results. The paper is concluded in section IV

II. System Modelling

HOMER software developed by NREL (National Renewable Energy Laboratory, USA) is used for finding the optimum configuration and assessing the techno-economic viability of HRES based system. Fig. 2 shows the schematic of the methodology used for this study. The location for study is identified and detailed assessment of the load profile and available RERs are explained further in this section.

The data collected is fed into the HOMER simulation tool and optimum configuration is found. HOMER compares the different RER based configurations and different constraints and sensitivity analysis are done for optimize the system design.

A small village Kotali Charkan in Jammu district in Jammu and Kashmir State of India is considered for this study. The details about the village demographic particulars are given in Table I. The village is situated near river Chenab within the distance of 1.5 kilometers. The water flow is continuous throughout of the years in the river. The selected village is mostly of flat terrain and receives average solar irradiance of 5.15kWh/m²/day. The average wind speed in the village is 4.3 m/sec. The drinking water facilities in the village are in the form of tube well and hand pumps. The village has total 1325 hectare of agricultural land and tube-wells are used for irrigation purpose.

III. USER LOAD ASSESSMENT

A. Primary load-I: This includes the load of the domestic appliances. The total primary load calculated for summers is 1151.87 kWh/day. The domestic load of the village in the winter season is 435.435 kWh/day. The calculated average annual consumption per household is 2.1 kWh/day. Peak

load for the summer is 197.29 kW and average load is 48 kW which gives the load factor of 0.24. As the winter load is less than half of the summer load so there is no need for calculating the peak load for the winters.

B. Primary load-II: This load includes the load of shops in the village, street lights, temples, primary health centre and schools. Average load calculated under the primary load-II comes out to be 95.35 kWh/day in summer and in the winter season it is 78.15 kWh/day. The peak demand is 13.5 kW and average demand is 3.978 kW giving a load factor of 0.29.

TABLE1: DETAILS ABOUT THE VILLAGE KOTALI CHARKAN

Particulars	Details	
Village Name	Kotali Charkan	
District	Jammu	
State	Jammu and Kashmir	
Country	India	
Latitude	32.37°	
Longitude	74.50°	
Elevation	555 m	
Nearby River	01	
Area of the village	325 Hectare	
Total House	332	
Total Population	1592	
	M 859	F 733
Educational facilities (No. of schools)	03	
Medical facilities (No. of primary health centres)	01	

The total consumption of the village is 1247.2 kWh/day in the summers and in the winters it is 513.585 kWh/day.

A. Resources assessment

Solar, wind, bio-gas, microhydro resources and grid are used in the simulation under this study. The resources are carefully chosen by taking into account the geographical conditions of the selected location. In the next part of this section, these sources are described in detail. The electricity from the grid is purchased at the rate $0.1/kWh with sell back price at $0.05/kWh.
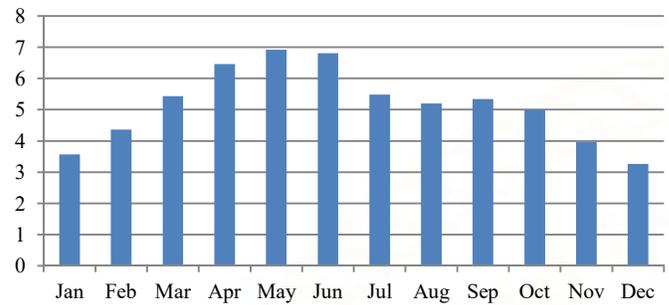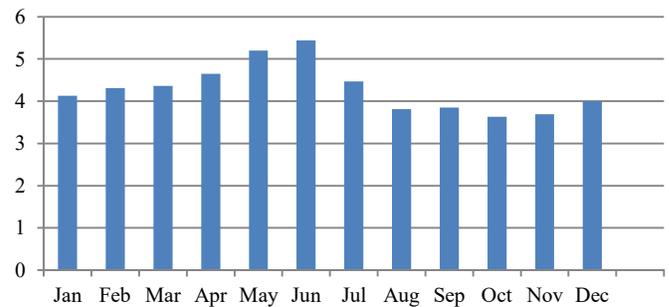

Fig. 2. Solar radiation at the selected location.

Fig. 3. Wind Speed at the selcted loaction.

1) Hydro Power

As mentioned previously, the study area is surrounded by the Chenab River. The river has length of 960 km and has maximum water discharge of 15733 cusec. Augmentation canal is the branch of Western Yamuna canal. It has maximum water discharge of 28273 cusec.

The village is well connected with the grid, but there is 8-10 hours of power outage per day. So in the simulation we have considered the 9 hours power outage per day and assuming 10 failures in a year, each failure has 2 hours of repairing time.

III. SIMULATION RESULTS

As mentioned above, the main aim of this study is to propose the optimal grid integrated hybrid power system which can provide uninterrupted power supply to the residents of the selected location as well as enhance the renewable energy sources contribution to the system. The proposed configuration of the system is simulated in HOMER software for economical and technical analysis. Implementation of the model using HOMER simulation tool is shown in Fig. 4.

Table II. Estimated load for the selected location.

| Sr. No.	Load	No. in Use	Power (Watts)	Summers (April-October)		Winters (November-March)	
				Hours/Day	Wh/Day	Hours/Day	Wh/Day
Domestic appliances load							
	CFLs	04	20	06	480	07	560
2.	CFLs	02	10	05	100	06	120
3.	Ceiling Fans	02	50	10	1000	00	00
4.	TVs	01	75	03	225	03	225
5.	Water pumps	01	500	01	500	0.5	250
6.	Refrigerators	(1×0.25) *	500	06	750	00	00
	Total				3055		1155
A.	No. of house	332			1151735		435435
Commercial purpose, temples and street light load							
1.	Shops	10	600	10	60000	08	48000
2.	Temples	02	500	06	6000	06	6000
3.	Street lights	30	50	10	15000	12	18000
C.	Total				81000		72000
Schools and primary health centre load							
1.	CFLs	40	20	02	1600	03	2400
2.	Ceiling Fans	30	50	06	9000	00	00
3.	Computers	03	250	05	3750	05	3750
C.	Total				14350		6150
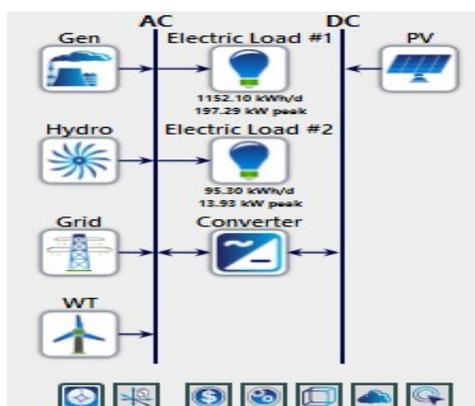
Fig. 4 Implimentation of model in HOMER software.

Simulation configurations

Five different configurations of the integrated hybrid system have been considered. The simulation time span is considered as one year on hourly basis. The simulation results for each configuration are discussed as under:

a) Configuration 1: Grid and Microhydro resource:
After the simulation for this configuration, the cost of energy (COE) was found to be $0.0759. Out of total supply 22% is supplied by grid and 78% from the microhydro source. The surplus energy i.e. 37000 kWh/year is sold back to the grid in the months of

August and September. Net present cost (NPC) is $483192.

b) Configuration 2: Grid, Microhydro and Wind resources:

Optimum sizes of the wind turbine and microhydro, as per the simulation, are found to be 30 kW and 92 kW respectively. The COE for this combination is $0.091/kWh which is higher than the previous combination mainly due to the initial cost of the wind turbine.

c) Configuration 3: Grid, Biogas, Wind and Microhydro:

For this configuration, the optimum sizes for the different components are: Biogas generator: 40 kW, Wind turbine 30 kW, microhydro 92 kW. The renewable energy penetration for the system is 72.3% and rest of the demand is met by the grid. The COE for the combination comes out to be $0.0724/kWh. In this combination also the surplus energy in the months of August and September (due to good water flow in the rainy season) is supplied back to the grid.

d) Configuration 4: Grid, PV, Wind and Microhydro:

The COE for this combination is $0.089/kWh. Renewable energy share is 34.5% and the optimum sizes for Photovoltaic, Wind turbine and microhydro turbine are 30kW, 40 kW and 92 kW respectively.

e) Configuration 5: Grid, PV, Wind, Microhydro and Biogas resources:

In this configuration of the system, all the renewable sources of energy are selected. The renewable energy share, as per the simulation, comes out to be 77.2%. As the renewable energy share is increased the COE is reduced down to $0.0698/kWh. There is 0% power outage and the COE is also minimum, so the main aim of this work is demonstrated. Fig. 5. shows power produced by each component in the configuration As the dependence on the grid is reduced in this configuration, 830015 kWh of energy is supplied back to the grid. This helps in the reduction of COE significantly.

Fig. 6 shows the waveforms of energy produced by RERs and total demand for a week in the month of August, where it is found that the RERS are serving most of the load.

Fig. 7 shows the cost summary of the grid integrated hybrid system under optimum configuration. The largest portion of the capital is used in the bio-gas system, mainly operating & maintenance cost. Wind turbine has high installation cost. The grid cost is very low as the surplus energy is supplied back to the grid in the rainy season and in the winters when demand is low. Although in the summers energy is purchased from the grid.
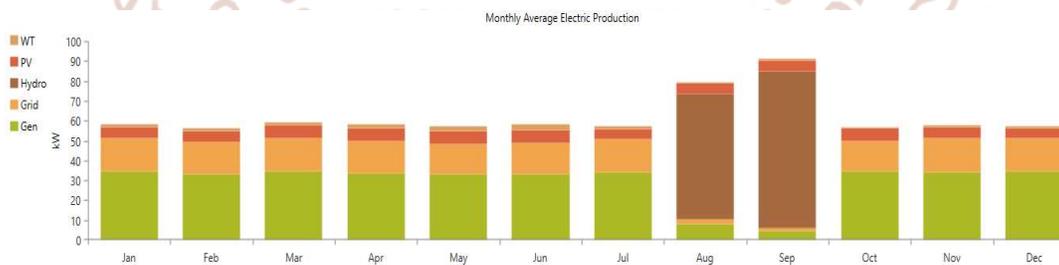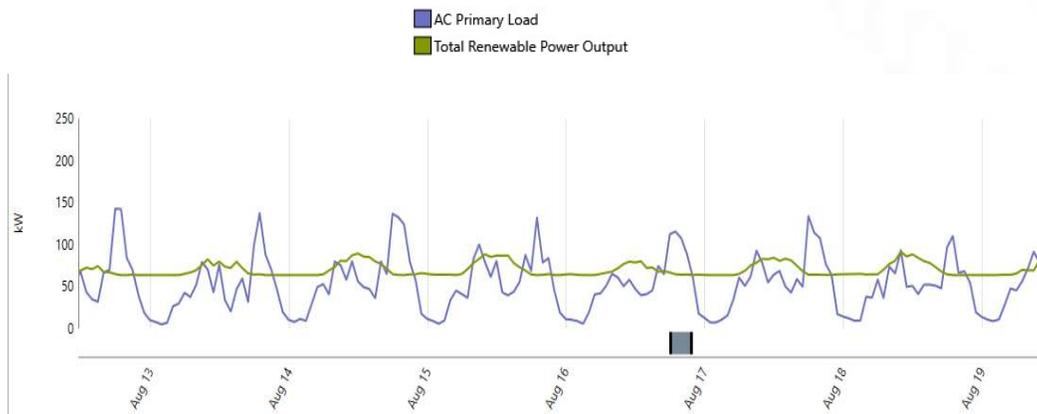

Fig. 1. Power generated by different resources.

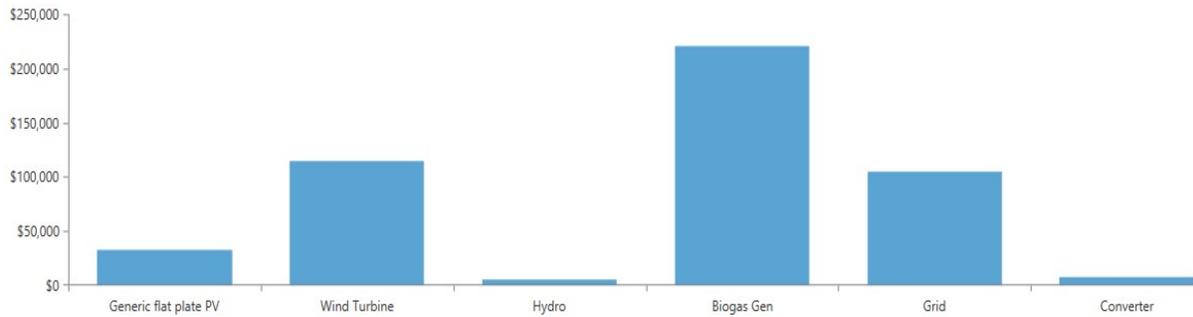Fig. 2. Plot of demand versus renewable energy resources output.

Fig. 3. Cost summary of the grid integrated hybrid system.

Conclusions

In this paper technical and economical analysis of grid integrated hybrid power system is carried out for the village Kotali Charkan in Jammu district of Jammu and Kashmir state, India. The data is collected from the selected location for load assessment and resources assessment. Five different configurations of RERs combination are simulated using HOMER software. From the results obtained from the different combinations, Grid-PV-Microhydro-Wind-Biogas combination is found to be most economical with COE $0.0698/kWh as compared to $0.1/kWh when purchased from the grid. The demand is met 100% at all the time during the year. Optimum configuration of the system consists of 30 kW PV system, 30 kW wind turbine, 92 kW microhydro turbine and 40 kW biogas generator.

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