Energy Management for Electrification in Village for Varying Loads

KEYWORDS: HRES, renewable sources of energy, electrification of village, biogas, and solar water pumps.

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ABSTRACT *Renewable sources of energy are environment-friendly and are still being not being used. There is a fundamental attractiveness about harnessing natural forces for energy production. For complete electrification of rural India, planning was done to integrate the abundantly available renewable resources. After assessing the village load, available sources and economic aspects in village Nangal, it was found that Hybrid renewable energy system is an excellent solution for complete electrification of rural areas .This paper aims to devise a plan for a village with a feasible solution to meet all the energy requirements of the village under study using non conventional source of energy and reliable electricity supply.*

I. INTRODUCTION

India has a vast supply of renewable energy resources. Solar resources, animal wastes and crop residues are some of the major renewable sources available in rural areas that can be harnessed in an efficient way to meet the energy demand. These natural resources can be used to produce energy to enhance the living standards of the villagers, provide clean energy and reducing the burden on conventional grid. The using the crop residues to generate electricity not only mitigates problem of electricity but also resists the practice of burning crop residue openly in the field. Some of the renewable resources are biomass, solar energy, wind, geothermal energy, waves, ocean currents, temperature differences in oceans. By converting these natural renewable resources either into electricity or other forms of energy, different type of energy demands can be accomplished. But some of these major renewable sources available in rural areas that can be harnessed in an efficient way to meet the energy demand are solar resources, animal wastes and crop residues. Such newer and non-conventional sources of energy are environment-friendly and clean, unlike the conventional sources and much newer nuclear source of energy. So, using such renewable sources of energy and replacing the conventional sources of energy will provide a healthier environment to the flora and fauna on this living planet. The main objective of this dissertation is to devise a plan for a village with a self-sustainable solution to meet energy requirements of the village under study by using the renewable sources of energy and reliable electricity supply.

Biomass is an organic material which has stored solar energy from sunlight through a process called photosynthesis [1]. It includes all the vegetation (land and water based), waste biomass (MSW), sewage, agriculture residues, animal wastes and few industrial wastes.

It may be classified as woody and non woody biomass. Woody includes all the woods. MSW, agricultural residues and waste from cattle and poultry are biodegradable in nature and are collectively constitute non woody biomass. The major biomass sources which are mainly available in this village are agro residue and animal waste. Agricultural residues can be categorised as crop residues and agro industrial residues. Crop residues include the materials from the main crop left behind in the field. This can be of different forms, densities and sizes. On the other hand the agro industrial residue comprises the by-products of post harvest processing of crops. Such processing includes cleaning, threshing, sieving and crushing [2].

The amount of agricultural residues produced varies from crop to crop. The other factors like soil types, seasons and irrigation conditions determine the amount of agriculture residues produced. These are directly related to corresponding crop production and ratio between the main crop product and a residue varies from crop to crop [3, 4]. Hence for a given amount of crop production, amount of agriculture residue can be estimated using to residue ratio. In the village all the biomass was collected for estimating the biomass generation capacity of a village as a whole. The cultivable area and the biomass yield of residue available from crop were obtained by averaging the yield of previous years. Besides primary data collection, simultaneously the consumption of biomass through direct interaction with the villagers was collected and the residue generation estimation is made by using residue production ratio. Residue production ratio (RPR) can be estimated by direct measurements in the fields. Air dried residue- product ratio for some crops was also available and can be used [5]. This paper aims to devise a plan for a village with a self-sustainable solution to meet energy requirements of the village under study by using the renewable sources of energy and reliable electricity supply.

II. PROPOSED WORK

To make a village self sustainable for its energy needs the current use of existing resources in the village should be assessed and analyzed. In order to get the effective data related to biomass availability an analysis is done in a village “Nangal” of district Barnala in Punjab, India (Table 1). From the survey it is found that village has enormous biomass and solar energy available which could be used in an efficient way..Hybrid (biomass + solar) renewable energy system (HRES) is proposed for meeting the electricity demand based on a renewable resources available [6].

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Fire wood and LPG cylinders are currently used for cooking. The use of firewood is not environment friendly, unhealthy as well as not efficient, therefore a biogas plant with a fixed cost is best suited as animal waste is used for the producing a biogas which serves as cooking gas and it is environment healthy.

A solar photovoltaic irrigation pump is chiefly proposed for village water supply and irrigation purpose as an alternative with the diesel pump which is currently used.[7] It is an excellent mean to meet the energy crises in peak irrigation seasons. It can also be used to cultivate lands and for meeting the village water supply needs [8].

Solar streets lights are suitable for village street lighting as Street lighting in the village are very few and most of the time not working so the battery powered solar street light with a very less maintenance is a very good option

III. LITERATURE SURVEY

Table 1. Village Information

Name of Village	Nangal
District, State	Barnala, Punjab
Location	30°24′52.31″N latitude and 75°36′27.77″E longitude
Number of house hold	450
Population	3500
Main occupation	Farming.
Total area	1754 hectare
Main crops	Paddy/Wheat
Cultivable area	1650 hectare

Table 2. Residue Production

Crop	RESIDUE	RPR
Rice paddy	Straw	0.45-2.9
	Husk	0.22-0.5
Wheat	Straw	0.7-1.8

Air dry weight of residue produced per tonne of crop produced

Residue production (tonnes/year) = Grain production (tonnes/year) × RPR (residue production ratio)

A. Domestic Load :- The load of village at domestic level differs in different seasons. In other words seasonal variation leads to change in the energy requirements of the village in domestic sector. To cope up with this problem, this study divides a year into two seasons: April to October comprises summer season and winter season spans from November to march. The assumed demand for this village per hours is taken as an input to HOMER software. It has average value of 510 kWh/day and having a peak value of 71kW.

Table 3. Domestic Load Data of A Village In Summer Season

Appliance	Power(W)	No. in use	Avg. operating hours(summer)	Energy (kWh/day)
CFL	20	1350	8	216
FT	40	900	4	144
COOLER	120	450	12	1080
FAN	50	1800	12	1296
TELEVISION	100	450	10	450

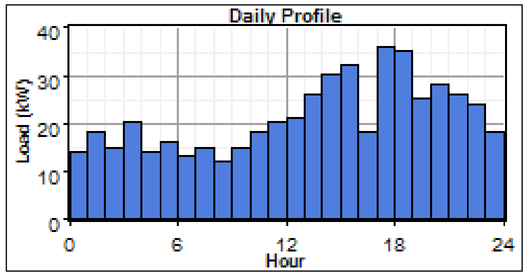

Fig. 1 Daily domestic load profile of a village in Summer Season

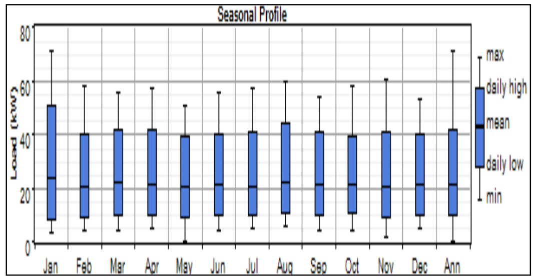

Fig. 2 Yearly seasonal domestic profile

B. Commercial Load: - It comprises the shops, school, dispensary, village panchayat offices etc. The load demand is approximately 43 kWh/day and 9 kW peak. The various appliances that are assumed to be used in commercial and their average operating hours with details of energy used by each of them are shown in Table 4.

Table 4. Commercial Load Data of A Village In Summer Season

Appliance	Power(W)	No. in use	Avg. Operating hours (Summer)	Energy (kWh/day)
CFL	20	1350	8	216
FAN	40	900	4	144
REFRIGIRATOR	120	450	12	1080
WATER COOLER	50	1800	12	1296
TELEVISION	100	450	10	450
CFL	30	20	11	6.6

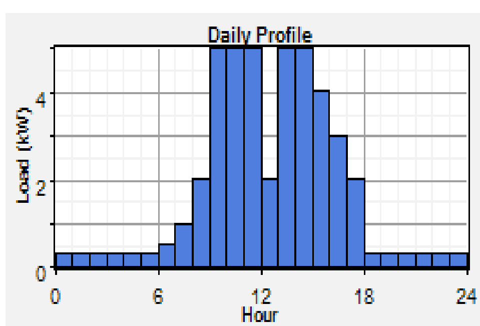

Fig. 3 Daily Commercial load profile of a village in Summer Season

IV. SYSTEM DESIGN TO MEET THE ELECTRICITY REQUIREMENTS AND SIMULATION RESULTS

Hybrid (biomass + solar) renewable energy system (HRES)

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was proposed for meeting the electricity demand based on a renewable resources available[6].The Hybrid Optimization Model for Electric Renewable (HOMER) software was used to determine the optimal sizing and operational strategy for a HRES. HOMER is an energy modelling tool for designing and analyzing hybrid power systems comprised of conventional generators, biomass, solar photovoltaic, wind turbines, hydropower, batteries, and other technologies [9]. The software creates a list of every possible system configuration based on the optimal sizing and related cost. Depending upon the available resources in village a model that is shown in Figure 3 is used for designing a hybrid renewable energy system which consists of a photovoltaic array, biomass generator, batteries and converter to meet the specified load.

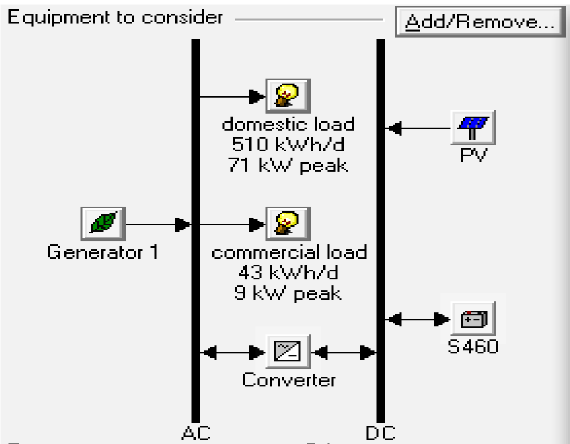
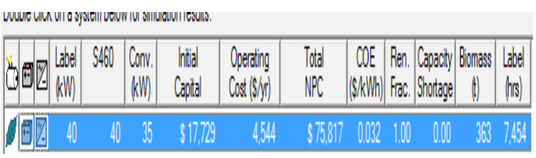


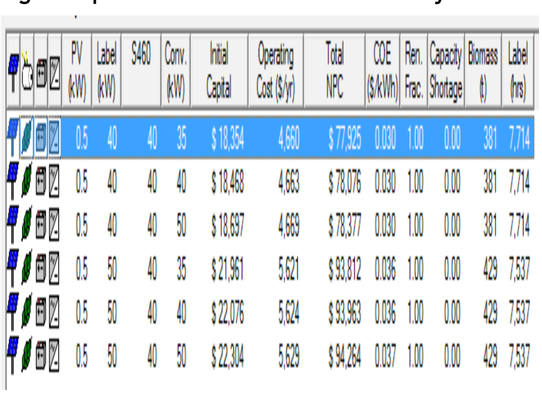
Fig. 4 Model of hybrid renewable energy system

The simulation of all the combination system configured in define search space is done with HOMER. The most feasible one will be displayed depending on net present cost (NPC). The system components are arranged from most to the least effective cost. The proposed hybrid renewable energy system for the village consists of domestic load which is 510 Kwh/d and annual peak load of 71 kW, commercial load which is 43 Kwh/d and annual peak load of 9 kW. The design comprises of PV system, Biomass generator, battery and a converter serving for an AC electrical load [10, 11].


Double click on a system below for simulation results.

Label (kW)	S460	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Biomass (t)	Label (hrs)
40	40	35	$ 17,729	4,544	$ 75,817	0.032	1.00	0.00	363	7,454

Fig. 5 Optimization result without PV array



PV (kW)	Label (kW)	S460	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Biomass (t)	Label (hrs)
0.5	40	40	35	$ 18,354	4,660	$ 77,925	0.030	1.00	0.00	381	7,714
0.5	40	40	40	$ 18,468	4,663	$ 78,076	0.030	1.00	0.00	381	7,714
0.5	40	40	50	$ 18,697	4,669	$ 78,377	0.030	1.00	0.00	381	7,714
0.5	50	40	35	$ 21,961	5,621	$ 93,812	0.036	1.00	0.00	429	7,537
0.5	50	40	40	$ 22,076	5,624	$ 93,963	0.036	1.00	0.00	429	7,537
0.5	50	40	50	$ 22,304	5,629	$ 94,264	0.037	1.00	0.00	429	7,537

Fig.6 Optimization result with PV array

A. PLAN TO MEET COOKING GAS DEMAND

Biogas is an excellent renewable source of energy to meet the demand of cooking gas. Biogas production is chiefly a micro biological process in which carbohydrates of the organic matter is broken down in the absence of oxygen Production biogas technology is an effective utilization of local resources in rural India. Hence it is being promoted at large scales in the villages to effectively meet the energy requirements for cooking. It is economical, clean, convenient and environment friendly fuel. Using generators we can generate electricity from it. Other natural resources like oil, gas etc. are limited and will be exhausting in course of time but the renewable energy sources are not limited.[12] The sanitation in village could also be improved by linking sanitary toilets with biogas plants. Moreover the slurry which is by product is a fertilizer and can be returned to soil.

The installation of the biogas plant is dependent on the average population of the cattle and the quantity of the dung available. The size of a plant, cattle dung available and estimated cost is shown in Table 5

Table 5. Details of Biogas Plant Capacity With Its Cost

Quantity of cattle dung required daily	Number of cattle heads required	Estimated cost ($)
25 kg	2-3	121
50 kg	4-6	155
75 kg	7-9	181
100 kg	10-12	206
150 kg	14-16	226

In this survey it is seen that 3-4 cattle heads on an average are owned by each house hold. This results in 40 heads for every 4 houses, so, for 4 houses family type biogas plant is proposed. This will cost about Rs 13500. The gross cooking needs of the village can be met by 20 biogas plants costing about 10 lakh rupees.

V. ECONOMIC ANALYSIS OF HRES

The configuration modeled with the help of HOMER software that mostly matches the specification was 0.5 kW PV array, 40 kW biomass generator, 35 kW converter with 40 batteries The system architecture shown in table of Hybrid Renewable Energy System (HRES) system used and other details related to cost summary is in system report presented below in Table 6

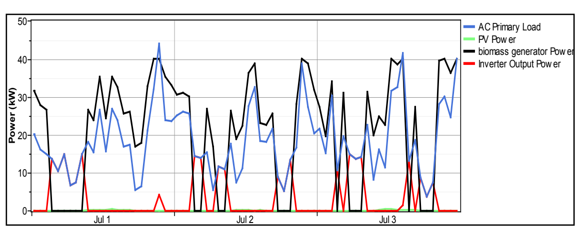


Table 6. System Report of HRES

Fig 6. Hourly electricity production from different sources and primary load simulated in HOMER

VI. CONCLUSION

Renewable sources of energy are environment-friendly and are still being not being used. There is a fundamental attractiveness about harnessing natural forces for energy production. For complete electrification of rural India, plan-

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ning was done to integrate the abundantly available renewable resources. The economics of the proposed plan indicates that though the initial installation costs of the projects using these sources of energy are high, still these are the most promising and clean sources of energy production.

VII. FUTURE SCOPE

This proposed plan shows the ability of renewable resources of energy to fulfil all the village needs. Efficient planning of villages and modelling hybrid energy system can lead to complete electrification of the villages. Successful commercialization of renewable technologies is needed for making it cost competitive without subsidies. Focus should be given for making technological improvements in biomass production and processing systems.

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