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Renewable Power Hybrid Distributed Generation for Rural Area: Ethiopia Perspective

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Abstract: The energy generation involves both non-renewable and renewable energy sources. Among them renewable energy becoming more and more popular as it is a sustainable, and environmentally friendly source of energy Energy is one of the essential needs of human life. A good energy system adds value to the lives of people in a society. Moreover, it requires less maintenance than traditional generators. Like other developing countries energy is the most important factor in Ethiopia... Already the use of different types of renewable sources like solar energy, bio energy, wind energy, has come into focus of several government and non-government organization. In this paper we mainly focused on providing the need of energy of a typical rural village with a Renewable Power Hybrid Distributed (HDRP) system which includes solar energy and Biomass. A model of off-grid HDRP generation and distribution system is analysed in HOMER (Hybrid Optimization Model for Electric and Renewable) to find the optimal size and cost of different components of the system.

Keywords: Renewable Power Hybrid Distributed (HDRP), Distributed Generation, Rural Area, Renewable Energy Resources, Solar Energy, Photovoltaic, Biomass

1. Introduction

Ethiopia has enormous potentiality of renewable energy development. Since, power crisis has become a phenomenon in Ethiopia, so searching for new resource of energy is a burning question at present. For economic solvency, upgrading the standard of living and industrialization, Power is an essential need of developing countries like Ethiopia. But in this twentieth century, still we have to depend on hydro power, fossil fuel plants which are insufficient for fulfilling the increasing power demand now as well as in the future and also a major barrier for foreign investment. Moreover, a huge portion of the total population of our country still does not have the access to electricity. Only 10% of the rural households have electricity connection where 70% of the total population live in rural areas. There are some parts of Ethiopia (60%) which will not get the access of electricity connection from the national grid within the next 30 years which will be an alarming situation. Besides, degradation of the capacities of existing power plants with derated machineries continuously causing load shedding problems in consumer and industrial distribution system. So, it's high time, to utilize renewable energy resources for off-grid, power generation and enlighten even the remote areas of Ethiopia.

At present, 96% of the total electricity generation of ethiopia is from the hydro power plants 4% diesel power plant under public sector . In contrast, of the power demand of 2025mw the generation is only 2000Mw-3000Mw including quick rental plants. That's why; to increase the production of electricity, Government has imposed priority on renewable energy technology and aimed at target to produce 500MW of electricity from these resources by 2016 . Renewable energy is achieving immense popularity in developed and developing countries due to noiseless, pollution free and production of electricity without emitting poisonous gases. For the preservation of the Green environment from global warming and reducing the threats of the Greenhouse effect, renewable energy is the best alternative way for power generation. In ETHIOPIA, available renewable energy resources are solar energy, wind power, biomass, geothermal, and Micro hydro power plants. Among them, solar energy and biomass are two main resources for alternative power generation. Biofuels are an attractive source of energy as it reduces CO_2 emission and can be used instead of fossil fuels which is depleting at an alarming rate. Production of biodiesel from algae is less time consuming and cheaper than the petroleum diesel. Recycling industry wastes raises a total of 400t/d of material recovery. Moreover, 3,054t/d of wastes is expected to be collected in 2015 and cumulative disposal volume is estimated at about 5 million tonnes by the end of 2015. Production of Biogas from these huge amounts of waste materials can be used in gas turbine power stations to reduce pressure on reserving natural gases [1]. Solar energy is an inevitable alternative source of energy as ETHIOPIA has a geographical fitting condition for solar power that receives an average daily solar radiation of 4-6.5 kWh/m^2. As a result, photovoltaic system installation is becoming an integral part of renewable energy production in ethiopia both in rural and city areas.

There are several studies about deploying distributed renewable power generation system. For example, [4] highlights the benefits of distributed generation for developing countries and modelled a PV system and analysed the cost pertaining to that system for two different household scenario. In this paper, we highlighted the benefits of Renewable Power Hybrid Distributed (HDRP) generation which is a combination of two or more renewable energy sources. A RPHD system, including two renewable energy sources is also modelled to provide electricity to two typical villages of Ethiopia. In this work energy consumption scenario of two villages of Ethiopia are considered and an off grid HDRP system is modelled to provide the energy need of the two villages. The optimal sizes and costs of the components and the feasibility of the model is analyzed using The Hybrid Optimization Model for Electric Renewable (HOMER) software.

The rest of the paper is arranged as follows: In section II, A brief discussion about HDRP and its benefits are given. Section III includes the simulations and results. And finally section IV provides the conclusion of this paper.

Renewable Power Hybrid Distributed (RPHD)

Distributed Generation is an efficient system in the world of the power system. It is now being used all over the world for small scale power generation for household applications as an off-grid or grid connected system. This type of system are located near or at the point of use. Distributed generation technologies include small wind, small hydro, solar photovoltaic (PV), biomass, micro turbines, gas turbines, fuel cells etc. Renewable Power Hybrid Distributed (RPHD) system combines two or more renewable energy sources, that when integrated, overcome the limitations inherent in either. To achieve higher reliability, redundant energy sources are used in RPHD, which can simultaneously improve the quality and availability of the power. This type of system can be designed to maximize the use of renewable energy, resulting in a lower emission than the traditional fossil fuelled power sources. HDRP system can be designed to acquire desirable attribute at the lowest acceptable cost, which will be the key to market acceptance. This type of power system can be used for village power, remote (off-grid) power etc.

HDRP systems can be deployed largely to provide the electricity deprived villages of Ethiopia. Two main renewable energy sources in Ethiopia are solar energy and biomass energy. In villages, we can provide a biogas generator where we can use biodiesel as a fuel rather than fossil fuels. Production of biodiesel is available from algae, Jatropha, rapeseed, peanut, sun-flower and soya bean. Solar energy can be utilized through photovoltaic systems which is enough for a single home, school or a local market. In this paper, we modelled an off-grid HDRP system using this two renewable energy sources to provide the electricity needed for daily activities of two typical villages of Bangladesh.

3 Simulation and Results

3.1 Simulation Tool

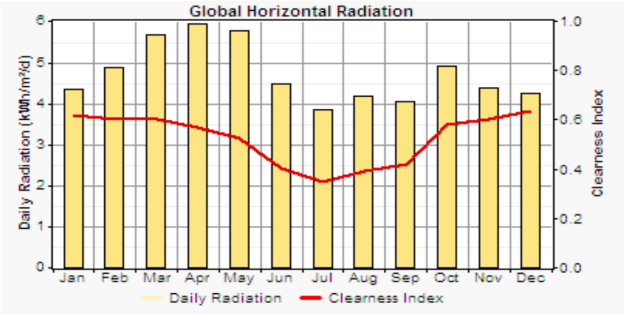
In this paper all the simulations are carried out on the Hybrid Optimization Model for Electric Renewable (HOMER) version 2.68. HOMER facilitates the task of evaluating design of both off-grid and grid connected power system for a variety of applications. If the model with inputs, component costs and, resource availability is provided, HOMER can generate results that provide a feasible configurations sorted by net present cost.

3.2 Load profile of the villages

I. IN THIS PAPER, WE HAVE ASSUMED TWO TYPICAL VILLAGES IN ETHIOPIA AND THE DAILY LOADS OF THE TWO VILLAGES ARE CONSIDERED FOR THE SIMULATION. IN THE FIRST VILLAGE THE ELECTRICAL APPLIANCES ARE DISTRIBUTED AMONG 900 HOUSES, 2 PRIMARY SCHOOLS, 1 HIGH SCHOOL, 1 POST OFFICE, 2 POULTRY FIRMS, A MARKET WITH 25 SHOPS AND 4 IRRIGATION PUMPS. THE SECOND VILLAGE INCLUDES 700 HOUSES, 2 PRIMARY SCHOOLS, 1 HIGH SCHOOL, 1 POST OFFICE, 1 POULTRY FIRM, 1 DAIRY FIRM, A MARKET WITH 200 SHOPS, 1 BUS STOPPAGE, 1 COMMUNITY CLINICS AND 3 IRRIGATION PUMPS. THE PRIMARY LOAD FOR VILLAGE 1 IS 2.1 MWH/D AND 394 KW PEAK AND FOR VILLAGE 2 THE PRIMARY LOAD IS 2.4 MWH/D AND 368 KW PEAK. THE LOADS ARE ASSUMED AS PREPARE YOUR PAPER BEFORE STYLING

3.3 Solar irradiance

The solar irradiance of Ethiopia is obtained by HOMER software via internet. The scaled annual average radiation of the site is obtained as 3.72kWh/m2 per day



3.4 Biomass

The scaled annual average biomass resources is presumed to be 20.6 tonnes/day, which includes carbon content of 5%, Gasification ratio 0.7 kg/kg and Lower Heating Value of biogas is taken as 5.5 MJ/Kg. Fig 2 shows the available biomass resources. The capital, replacement and O and M cost for 20kW biomass source is taken as $1700, $170 and $0.5/hr. And the considered sizes are 0kW, 50kW, 100kW, 120kW, 150kW, 200kW and 250kW.:

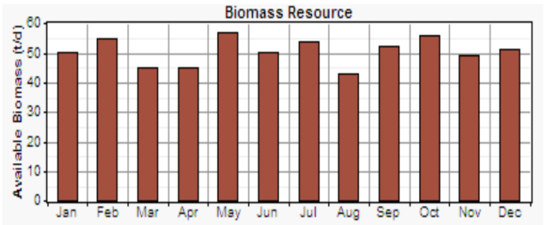


Figure 2. The available biomass resources

3.5 Size of the Photovoltaic

Size of photovoltaic is very crucial part of the modelled system. An under-sized PV system will not perform accurately to charge the battery and supply the load. The cost per Watt-peak of PV may vary from $1.5 to $2 [5]. In this paper the installation, replacement and maintenance (O and M) costs for 1kW-p solar power generator are taken as $2500, $2500 and $0 respectively [4]. The considered size of the PV panel in this simulation are 100kW-p, 200kW-p, 300kW-p, 400kW-p, 500kW-p and 600kW-p. Other properties are, lifetime 20 years, derating factor 80%, slope 23.5 degrees, and ground reflectance 20%. No tracking system is considered in the simulation

3.6 Battery

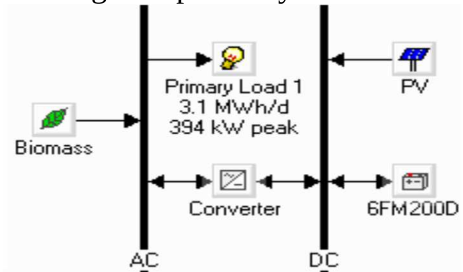
The vision 6FM200D battery is selected in HOMER. The properties of the battery are: Nominal voltage 12V, nominal capacity 200Ah (72.4kWh), lifetime throughput 917kWh, 20 batteries per string, minimum battery life is 4years and installation, replacement and O&M costs are $275, $275 and $20/year [4].

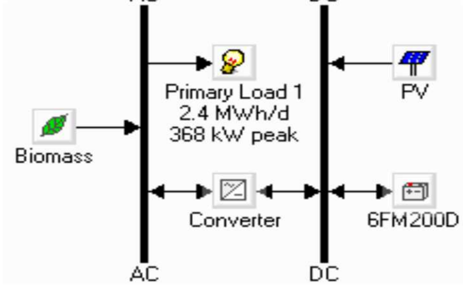
3.7 Inverter

For a 1 kW inverter the capital, replacement and O and M cost is considered as $250, $250 and $100/yr respectively [4]. In this is paper the sizes of inverters are considered as 50 kW, 100 kW, 150 kW, 200 kW, 250 kW and 300 kW. The lifetime of the inverter is taken as 15 years and efficiency is assumed 90%.

3.8 Modelling of the systems in HOMER

The systems are modelled in HOMER by selecting "do not model grid" option, which represents a typical stand-alone system. The model for village 1 and village 2 are shown in Fig 3 and Fig 4 respectively.





3.9 Simulation result

By simulating all the data HOMER generates an optimal result for the HDRP system for the two villages. It finds the best sizes of photovoltaic panel, biomass, inverter, and battery based on the lower Net Present Cost (NPC). Fig 5 and Fig 6 show the search area space in HOMER where the optimized sizes are highlighted with yellow mark. The optimal sizes for village 1 is founded as 500kW photovoltaic panel, 120kW Biomass plant, 3units of battery and 200kW inverter and for village 2 the optimized sizes are 200kW Photovoltaic panel, 100kW biomass plant, 1 unit of battery, and 100kW converter. The initial cost found by HOMER is $1,418,50 and $615,50 for village 1 and 2 respectively. The total operating costs are $70,53/yr and $43,44/yr respectively.

	PV Array (kW)	Bio (kW)	6FM200D (Strings)	Converter (kW)
1	100.000	50.00	1	50.00
2	200.000	100.00	2	100.00
3	300.000	120.00	3	150.00
4	400.000	150.00	4	200.00
5	500.000	200.00	5	250.00
6	600.000	250.00	6	300.00
7				
8				
9				
10				

<< Hide Winning Sizes   Overall winner   Category winner

	PV Array (kW)	Bio (kW)	6FM200D (Strings)	Converter (kW)
1	100	50	1	50
2	200	100	2	100
3	300	120	3	150
4	400	150	4	200
5	500	200	5	250
6	600	250	6	300

The total Net Present Costs (NPCs) are $2,320,15 and $1,179,85. And the Cost of Energy (COE) found for two villages are $0.197/kWh and $0.124/kWh respectively.

	PV Array (kW)	Bio (kW)	6FM200D (Strings)	Converter (kW)
1	100.000	50.00	1	50.00
2	200.000	100.00	2	100.00
3	300.000	120.00	3	150.00
4	400.000	150.00	4	200.00
5	500.000	200.00	5	250.00
6	600.000	250.00	6	300.00
7				
8				
9				
10				

<< Hide Winning Sizes   Overall winner   Category winner

	PV Array (kW)	Bio (kW)	6FM200D (Strings)	Converter (kW)
1	100	50	1	50
2	200	100	2	100
3	300	120	3	150
4	400	150	4	200
5	500	200	5	250
6	600	250	6	300

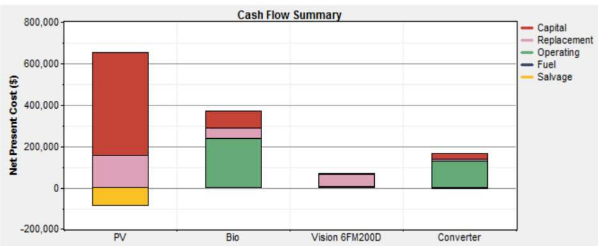
Fig 7 and Fig 8 show all the optimize results found by HOMER for village 1 and village 2 respectively. Table I and III show the net production from different sources for village 1 and 2. And Table II and IV show the total consumptions by the two villages. Fig 9 and 10 show the cash flow summery by components and by cost type respectively.

PV (kW)	Bio (kW)	6FM200D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)
500	120	60	200	$ 1,418,500	70,534	$ 2,320,159	0.197

PV (kW)	Bio (kW)	6FM200D	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)
200	100	20	100	$ 615,500	43,443	$ 1,170,851	0.124

From the cash flow summery for Fig 9 and 10, we can see the capital cost for PV is maximum. On the other hand, the operating cost of biomass is maximum. The fuel cost for the system is zero.

From Table I, The PV array selected for village 1 can produce 748,414kWh/yr which is 57% of the total production. And another 43% produced from the Biomass.



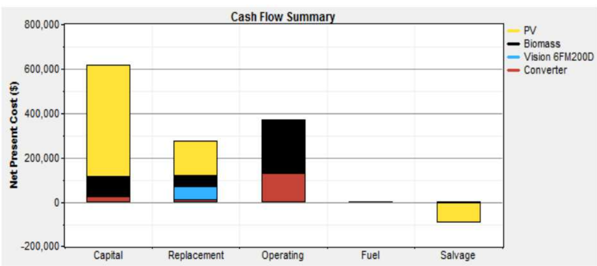


Table –I
Production from different sources for village 1

Production	Kwh/yr	%
Pv array	748,414	57
Biomass	572,152	43
Total	1,320,566	100

Table II
Energy Consumption of Village 1

Consumption	KWh/yr	%
AC primary load	919,478	100
Total	919,478	100

Table IV
Energy Consumption of Village 2

Consumption	KWh/yr	%
AC primary load	741,502	100
Total	741,502	100

Table II and Table IV show the total energy consumption for village 1 and village 2 respectively

3.10 Result Analysis

The current per unit cost of Electricity in Ethiopia varies from $0.01 to $0.08 for government owned power plants. For gas based power plant, per unit cost varies between $0.06 to $0.07 for the Quick Rental Power Plants (QRPPs) and $0.02 to $0.05 for the Independent Power Producers (IPPs). And in case of furnace oil fuelled power plant, per unit cost is about $0.2 for QRPPs and varies from $0.21 to 0.22 for IPPs [6]. For RPHD system, per unit costs are found $0.197 and $0.124, which is quite better than the furnace oil fuelled power plants. So, it is feasible to use this HDRP system. But there are many other issues involved while taking a decision between RPHD system and other power plants. There are many advantages and disadvantages RPHD system like, sustainability, lower emission, usage of renewable fuel, low operating cost, requirement of large area, cannot be used to generate power to satisfy major part of demand, large capital cost, low efficiency etc. So, it may not be possible to replace the furnace oil fuelled power plant by HDRP system. But HDRP system can assist the existing sources in a considerable manner by deploying it for the remote areas where the electricity is still out of reach.

4. Conclusions

In this paper, the feasibility of deploying HDRP system is experimented in HOMER by using it for providing the electricity need of two typical villages of Ethiopia. It is found that HDRP is feasible but, not for supplying major demand. But this system can considerably assist the existing system. Future studies may include, synchronizing the system with existing grid and finding the stability of the existing power system with large integration of HDRP systems.

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