RURAL ELECTRIFICATION USING DECENTRALISED DISTRIBUTION GENERATION TECHNOLOGIES

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Abstract

This study determines the optimal renewable energy systems to be implemented for electrification in the 5 sample tribal hamlets viz, Manemulle, Anemala, Malada, Balle, Majjanakuppe.The tribal hamlets selected for the study are located midst Nagarhole National Forest, H D Kote taluk, Mysore District. The simulation software HOMER which is a computer model developed by NREL (National Renewable Energy Laboratory) is used in the study for comparative analysis. This analysis quantifies the probability of adoption of Distribution Generation power systems which involves system design, technical, financial, environmental and social parameters. Based on these paramaters an optimal decentralized distribution generation technology (DDGT) is selected for electrification of each of the selected hamlets, which forms a representative for a majority of the rural areas in the country which are without electricity.

Keywords: rural electrification, DDGT, renewable energy, HOMER

Introduction

Rural electrification forms an intergral part in the development of country. It improves the socio-economic conditions of the rural people by promoting livelihood security. Electricity acts as an input for productive activities like agriculture and small scale industries and inturn improves the quality of life of the people.(Nouni et al, 2008)

At present, there are 1.6 billion people in the world who do not have access to electricity and about 1.3 billion, live in rural areas, mostly in Asia and Africa (Priddle,2002).According to Census 2001,about 70% of India’s population lives in rural areas and they do not have access to electricity. The main reason for this is that grid extension is expensive in rural areas due to high transmission and distribution costs. The people are poor and unable to pay for the electric services(Johansson et al.,2004).A report from the international energy agency states that ”In India, the electricity network is technically within reach of 90% of the population, but only 43% are actually connected because people cannot afford the cost of connection(Priddle,2002).

Currently, about 2.4 billion people in developing countries depend on traditional biomass which is more prevalent in rural areas because of easy availability (Aeck et al.,2005).Ranjan Banerjee highlights in energy Policy that overall” biomass (fuel wood, crop residues and cattle dung) accounts for about 40% of India’s primary energy use,” with the largest being consumed in rural areas(Banerjee,2006).

The economic development of a country is dependent upon sustainable use of natural resources. Poverty and the accompanying ignorance of natural resource degradation present major obstacles to sustainable development. The absence of clean household energy exposes rural population, particularly women and children, to high risks associated with poor indoor air quality, due to traditional cooking practices, lighting applications and critically hampers their prospects of escaping from poverty. Indoor air pollution is one of the leading causes of infant deaths after water borne and sanitation related diseases.

The most viable and efficient option for electrification of rural areas is the decentralized use of renewable resources (Banerjee, 2006; Bhattacharyya, 2006; Nouni et al., 2008). Small-scale power generation technologies which are used to provide an alternative to or an enhancement of the traditional electric power system are called as DDGT. Distributed generation is an electric power source connected directly to the distribution network or on the customer site of the meter (Thomas Ackermann et al.,2000)

In the rural areas where conventional energy supply is not economically possible Decentralised energy sources can be utilized. The load requirement for a rural household is minimum and includes home lighting, street lighting, pumping water for agriculture and drinking purposes. Nouni et al(2008) found that the average electrical load is 0.675kW for household in rural areas. In the present study the average load is about 0.0630kW.

In order to determine the optimal renewable energy system for the electrification of the 5 sample hamlets a software developed by National Renewable Energy Laboratory(NREL) named HOMER is used. HOMER, the micro power optimization model, simplify the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications. HOMER can model hybrid systems as well as standalone systems. For a each particular case the inputs include load data, renewable store data, system component qualifications and costs and various information of optimization like number of components.

Further,” sensitivity analysis” can also be performed by varying the values of parameters to determine their impact on the COE for the system under study.

Objectives

Data collection about the energy sources and energy needs of the villagers

Development of the Optimal DDGT

Evaluation of the parameters for economic viability

Development of analysing model for sizing and rating of the decentralised distribution generation technology

Materials and Methodology

PV panels: Sanyo solar panels(SANYO)

Inverter: Inverter(Schneider Pvt India Ltd)

Battery:

Manufacturers

1.Rolls/Surrette 2.Trojan Battery Company

Generator: used as a base system as well as used with hybrid technologies to cover up the peak load.

Fuel: Diesel

Wind Turbines

To obtain the input data for HOMER a field survey was conducted in the 5 sample hamlets. The Hamlets are located in the midst of Nagarhole forest near H D Kote taluk which lies 55kms away from Mysore district. H D Kote was purposively selected for the study because of good concentration of forest cover and distribution of tribal population in the taluk and which have no access to electricity. The tribal population of H.D. Kote consists of six different sects and among which Jenukurubas form the major sect accounting for about 60 per cent of the total tribal population.

The Jenu Kurubas are a Scheduled Tribe of Karnataka inhabiting mainly in Hunsur, Heggadadevana Kote, and Periyapatna taluks of Mysore dist, Gundlupet taluk of Chamarajanagara dist and Virajpet, Somavarpet and Madikere taluks of Madikere district.

The Jenu Kurubas are mainly distributed in Nellikuppe which is in the midst of forest and is about 20 kms from Hunsur. In this area they are scattered in Anemala hamlet, Manemule, Malada hamlet, Ballehamlet, Golur hadi ,near Antharasanthe. Majjanakuppe hamlet lies 25kms away from H D Kote. The Jenu Kurubas settlements are scattered over a number of hamlets and these hamlets are situated in the interior forest and tiny hilly side.

Data from the research literature was also taken. Estimates of costs was taken from the manufacturers and distributors of renewable energy systems.

Off-grid Technologies Selected for the study

1.Solar Photovoltaic systems

These work on the principle of the photoelectric phenomenon-direct conversion of light to electricity. The solar radiation confrontation upon a silicon-based semiconductor photovoltaic cell produces direct electric current. Photovoltaic cells are integrated into modules with a volatage of 6-12V,the interconnected modules form solar systems with an output voltage of 230V and more.(Allwyn et al.,)

PV cell: A photovoltaic panel consists of several connected 0.6V dc PV cells, which are made up of semiconductor material, generally mono- or multi-crystalline silicon. The thin layes of silicon is sandwiched between two metallic electrodes and the cells are usually encapsulated behind glass to make them weatherproof. Multiple PV panels can be then connected to form an array. The average lifetime of a PV system is 20 years. A solar cell made up of multi-crystalline silicon, which accounts for most of the PV panels currently in use and production, converts sunlight to electricity at about 13.5% efficiency.(Allwyn et al.,)

Balance of system(BOS)

BOS is constituted by the mechanism added to the modules to complete a PV-system

1.Mounting structure: photovoltaic arrays have to be mounted on a stable and durable structure that can support the array and withstand wind, rain and any other adverse conditions.

2.Inverter: it converts DC voltage and current into AC sine wave power

3.Battery:in which the solar generated electric energy may be stored.

4.Regulator: it controls the amount of voltage to maintain a battery bank at its optimal level, maintaining efficiency and battery life. A supervisor prevents overcharging of the battery bank resulting in reduced battery life

5.MPPT(maximum power point tracker): it maintains the voltage of an array to a value that maximizes the output.

The purchasing costs of a PV system encompasses the cost of the PV module, the mounting structure, the regulator and the MPPT.

Cost of PV system

Module Cost: The cost per peak watt of the PV system basically depends on the perpeak watt cost of the PV module and the BOS. The cost of the PV is dependent on the cost of the materials making up the module. The cost of PV modules at present is $1-$2 per peak watt.

BOS cost: They account for approximately 40-60 percent of the total capital cost

Operating and Maintenance (O&M) costs: O&M costs for PV modules and systems are generally low because of absence of moving parts in electricity generating components. O&M reportedly varies from 1-4percent of the capital cost.(Kandpal et al.,)

Energy output

HOMER assumes the output of the PV array is linearly related to the solar radiation incident on the PV array. So if the radiation is 0.70kW/m2,the array will produce 75% of its rated output.

The efficiency of the PV panels reduce as their temperature increases. The power produced is anti-linear in the temperature range under which PV panels are exposed. A value is assigned by the manufacturers to this particular characteristic, and is expressed as a percent of the total power per oC. For example, if a panel has a temperature co-efficient of power that is -0.50%/oC, the panel produces 0.5% less power for every 1oC increase in temperature.(Paul Gilman)

PV panels get heated up when they absorb solar radiation. Their dark colour tends to warm the panels significantly and make them hot as 80oC when no wind is blowing. HOMER accounts for this reduction in efficiency by the input variable called the derating factor. HOMER applies this scaling factor to the PV array power output to account for reduced output in real-world operating conditions compared to the STC under which the PV panel was rated.(Paul Gilman)

To account for the loses due to soiling of the panels, wiring losses, shading, snow cover, aging, and so on a derating factor is entered and for this study a derating factor of 80% is assumed.

The energy formed by the PV array is evaluated using the formula:

$$\mathbf{EPV=D\times C\times I}$$

Where D is the derating factor,C is the total installed capacity of the PV array and I is the solar radiation.

2. WIND SYSTEM

Solar energy absorbed by the earth produces the upward motion and expansion of air, which creates areas of high and low pressure. The latter contain air currents (wind) whose direction is influenced by the earth’s rotation and the force of gravity. The kinetic energy in these currents is called wind energy.

Description of a WT

The basic workings include:

A rotar, consisting of blades with aerodynamic surfaces. While the wind blows over the blades, the

rotar turns, causing the generator or alternator in the turbine to rotate and produce electricity

A gearbox, which matches the rotar speed to that of the generator.

A brake to stop the machine for maintenance or when wind speed is excessive

A generator

A tailvane or yaw system, which aligns the turbine with the wind

An enclosure, or Nacelle, which protects the gearbox, with generator and other components of the turbine from the elements

Capital costs

The capital costs consists of the installation costs which includes land cost, access roads and civil construction and labor costs.

Operation and maintenance costs

A wind turbine requires periodic maintenance such as oiling and greasing and regular safety inspections. Bolts and electrical connections have to be checked annually; tightened if necessary.

For the study of the wind energy system with HOMER, a wind turbine having a low cut in wind speed was preferred considering the low wind speeds at the sites.

3.Solar-diesel hybrid4.Wind-diesel hybrid

4.Wind-diesel hybrid

5.Wind-Solar hybrid Results and discussions Characteristics of the sample hamlets

Table 1: Details of hamlets which were surveyed

	Name of the Hamlet	Total number of households	Distance from main road (kms)	Distance from the HT line (kms)	Distance from the LT line (kms)	No of cattle	Type of crops
1	Manemulle	27	0.33	0.33	0.5	Nil	Nil
2	Anemala	75	0.95	0.1	0.2	Nil	Nil
3	Malada	25	0.8	0.8	0.5	4	Nil
4	Balle hadi	96	0.1	0.1	0.1	200	Nil
5	Majjanaku ppe hadi	34	5	1.2	0.5	15	Jowar,ragi,corn, cotton

Table 2: Existing energy consumptions sources,quantity and prices paid for them

	Name of the Hamlet	Domestic lighting	Entertainment		Willingness to pay for monthly energy bill(in rupees)	Average Rs./month spent by household on kerosene
			TV	Radio		
1	Manemulle	Kerosene and wood	Nil	4	50-60	60
2	Anemala	Kerosene and wood	1	3	50	60-80
3	Malada hadi	Kerosene and wood	Nil	2	60-70	60
4	Balle hadi	Kerosene and wood	Nil	3	40	60
5	Majjanakuppe hadi	Kerosene and wood	Nil	3	100	50-80

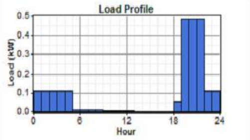
Table 3: Socio-economic details

	Name of the Hamlet	No of households	No of CFL and streetlights required	No of operational hours
1	Manemulle	27	1+5	6
2	Anemala	75	1+10	8
3	Malada hadi	25	1+4	6
4	Balle hadi	96	1+15	10
5	Majjanakuppe hadi	34	1+7	10

Load

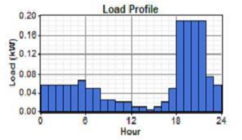
HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. Hourly load profiles are not available for the whole year, so HOMER is used to synthesize the load profiles by entering the values for a typical day.

The following load curves were obtained



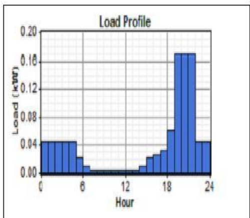
Manemulle Hamlet

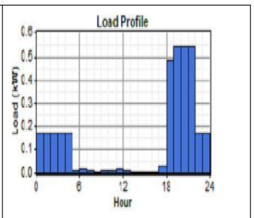
Peak load=339W Total load= 1.5kWh/day



Anemala Hamlet

Peak load=866W Total Load=2.3kWh/day



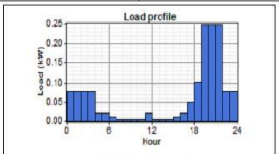


Malada Hamlet

Peak Load= 301W Total Load=1kWh/day

Balle haadi

Peak load=966W Total Load=3.4kWh/day



Majjanakuppe Hamlet

Peak load=440W Total load=1.5kWh/day

The demand curves show that the load characteristics of the 5 hamlets are almost similar. The over electricity demand increases with the same magnitude as the number of households. The peak demand in the evening is due to the lighting in each house and also the lighting of street lights. During night only the street lights remain on. The lights at night protect the villagers from the deterring animals from venturing too close to their home.

Generator being used as the Base system

1.Manemule

Base Case System for manemule		
System Characteristics		
Generator (1kW)	3,538	kWh/year
Efficiency	0.481	L/kWh
Diesel Usage	360	L/Year
GHG Emission	947	$kgCO_2/Year$
Fuel Price	46.21	INR/L
Fuel Costs	16,615	INR/Year
O&M	1,706	INR/Year
Replacement	9,072	INR/Year
Levelized COE	60230	INR/kWh

2.Anemala

Base Case System for Anemala		
System Characteristics		
Generator (1kW)	4,183	kWh/year
Efficiency	0.354	L/kWh
Diesel Usage	425	L/Year
GHG Emission	1,119	$kgCO_2/Year$
Fuel Price	46.21	INR/L
Fuel Costs	19,642	INR/Year
O&M	6,087	INR/Year
Replacement	8,687	INR/Year
Levelized COE	53576	INR/kWh

3.Malada

Base Case System for Malada		
System Characteristics		
Generator (1kW)	2,094	kWh/year
Efficiency	0.395	L/kWh
Diesel Usage	213	L/Year
GHG Emission	560	$kgCO_2/Year$
Fuel Price	46.21	INR/L
Fuel Costs	9,832	INR/Year
O&M	2,023	INR/Year
Replacement	6,128	INR/Year
Levelized COE	72975	INR/kWh

4.Balle Hamlet

Base Case System for Balle Hamlet		
System Characteristics		
Generator (1kW)	5,192	kWh/year
Efficiency	0.337	L/kWh
Diesel Usage	528	L/Year
GHG Emission	1,389	$kgCO_2$/Year
Fuel Price	46.21	INR/L

Fuel Costs	24,381	INR/Year
O&M	4,111	INR/Year
Replacement	8,421	INR/Year
Levelized COE	38645	INR/kWh

5.Majjanakuppe Hamlet

Base Case System for Majjanakuppe		
System Characteristics		
Generator (1kW)	2,634	kWh/year
Efficiency		L/kWh
Diesel Usage	268	L/Year
GHG Emission	705	Kg CO_2/Year
Fuel Price		INR/L
Fuel Costs	12,369	INR/Year
O&M	2,188	INR/Year
Replacement	5,926	INR/Year
Levelized COE	54968	INR/kWh

Conclusion

Using HOMER software different technologies like solar,wind,solar-diesel,wind-diesel,wind- solar based on their economic viability will be compared and the optimal technology will be

selected.

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