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Cost benefit and technical analysis of rural electrification alternatives in southern India using HOMER

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ABSTRACT

Demand for electricity in rural India has been met by extending the grid electricity distribution network. But the costs of extending lines to rural facilities are prohibitively expensive. Grid extension varies in cost on the distance to be covered, the land, utility and the size of the load. Considering these challenges, rural electrification will require considerable skill in the selection and implementation of technical and economic strategies for electrification. In rural places where the condition and quantity of grid power is expensive or insufficient, renewable energy alternatives may be the only option. So this paper estimates the domestic, industrial, agricultural, BTS load in a remote village called Kadayam, Tamilnadu, South India, identifies the optimal option for RE based electrification and compares it with conventional grid extension using HOMER software. The solution obtained from HOMER software shows that a hybrid combination of solar/wind/hydro/battery is a cost effective, sustainable, techno-economically and environmentally viable alternative to grid extension.

Contents

Abbreviations: HOMER, Hybrid Optimisation Model for Electric Renewables; BTS, Base transceiver station; RE, Renewable energy; LPG, Liquefied petroleum gas; DG, DG; LCC, Life cycle cost; kW h/day, kilowatt-Hour/Day; kW h, Kilowatt-Hour; NPC, Net present cost; COE, Cost of energy; CEQ, Carbon emission quantity; EDL, Economic distance limit

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1. Introduction

Rural or isolated regions lacking electricity supply are often characterised by well identified challenges [1]. Distance from national or regional electricity grids, difficult terrain such as rivers or jungles, harsh weather conditions etc., improper electricity supply in rural places [2–4]. The choice of specific power plant technology [5] or technology mix for rural electrification mainly depends on the targeted place, fields, number of houses, industries, education centres, health care centres, availability of natural resources etc. [6–9], grid extension, DG, LPG, disposable batteries, biomass technologies have been conventional means of electrification. Out of these, grid extension has been the predominant mode of electrification in rural India [10].

But today's level of energy services in southern parts of India fails to meet the needs of the rural area [11]. This lack of access to quality electricity services entrenches poverty, constraints the delivery of social services, limits the opportunities for poor [12]. So, the rural electrification is important to both the social and economic development of India [13]. Rural off-grid electrification can also provide an alternative solution. In electricity, the off-grid can be stand-alone hybrid renewable energy systems or mini grid [14–16]. Renewable energy systems can reduce environmental impacts and costs compared to the conventional grid extension or mini grid technologies [17–19].

Examples of such studies include Olatomiwa, Mekhilef, Huda and Ohunakin [20] who investigated the feasibility of different power generation configurations comprising solar, wind, DG in different locations using Homer within six geo political zones of Nigeria. They identified that the solar/wind/diesel/battery hybrid renewable system configuration is found as optimum architecture, fuel consumption and CO_2 reduction. However this study focuses on the basic need as such and does not include productive use of energy.

Chade, Miklis and Dvorak [21] conducted a case study of Grimsey Island. They have compared the cost of electricity from fuel cost of DG, applying HOMER Energy Micro grid Power Design software to perform energy balance simulations and to optimise the size of the system components. The result showed that a wind turbine with the hydrogen energy storage system is a feasible solution. This work was not part of any rural electrification programme.

Bhattacharyya [22,23] analysed the optimal design and planning of mini grid based system for a rural community of Bangaladesh where the base load is 24 kW. The study considers solar, wind, hydro- and diesel resources for electricity generation. It can be seen that most studies concentrate on electricity merely for domestic purposes and do not take into account the electricity demand for agriculture, irrigation, small scale business and communication towers. The load profiles are not considered in many cases. These issues are considered in the present study.

Some authors [24–30] studied the feasibility assessment of photovoltaic and wind energy through RET Screen modelling software. Other authors [31–38] carried the feasibility study of renewable energy sources with HOMER modelling software. From the literature [39–42], it is well known that RET Screen does not support [43,44] and is not appropriate for hybrid system consisting of more than one renewable energy technology (e.g. PV and wind energy) although it is dedicated to feasibility analysis.

In addition, analysis using Hybrid2 emphasised system design with little focus on the prefeasibility analysis of RES. HOMER gives more detailed information than the statistical models such as RETScreen and provides the optimisation and sensitivity analysis with limited input. Moreover, HOMER is widely used for most of the RES based systems. Thus, based on the literature reviews, HOMER software is taken for the purposes of this study to carry the feasibility assessment.

The main purpose of this paper is to meet the electricity demand in a reliable and sustainable manner and to find the optimal, techno-economical, cost effective hybrid renewable energy sources. To achieve this objective, a village called Kadayam, Tirunelveli district, Tamilnadu, India has been considered [45–47]. The load demand, available resources are identified for given village [48–50]. The electricity productions, cost comparison based on various combinations of RE systems are calculated using HOMER software. These results are compared with conventional grid extension related costs.

The organisation of this paper is as follows: Section 1 presents the introduction part of investigation; Section 2 presents schematic layout; Section 3 deals about HOMER analysis; Section 4 gives the results and conclusion.

2. Schematic layout of the work

Fig. 1 shows a schematic system configuration of the work. The un-electrified village in southern India is identified. Then a detailed assessment of the village load profile, site layout from the grid and the available resources in the selected village is obtained.

These collected data are fed in to the HOMER software. With the application of HOMER the RE system is designed. HOMER compares RE system to grid extension with different constraints and sensitivities to optimise the system design. The analysis is related to the technical properties of the system and the LCC of the system. The LCC comprises of the initial capital cost, cost of installation, maintenance cost and operation costs over the system's life span.

HOMER performs simulations to satisfy the given load demand. Based on the simulation results, the suitable configuration is selected. This work takes into account a combination of various systems namely wind turbines, solar systems, hydro-power plant, DG and battery.

3. System modelling

A small village Kadayam in Tirunelveli district in the Indian state of Tamilnadu is considered. The map details and details about the village are given in Fig. 2 and Table 1. The area around the village is partially hilly and flat plain.

The latitude and the longitude of the selected village are 8°49.3′ north and 77°22.5′ east. The average weather is 30 °C, 70% humidity. The village has water facilities in the form of water falls, water wells and hand pumps.