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Feasibility assessment of Anchor-Business-Community model for off-grid rural electrification in India

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ABSTRACT

The concept of "micro-grids" as self-sustained power systems is driven largely by business models, which have to be developed by considering the perspectives of all the stakeholders. This study tests the feasibility of the Anchor-Business-Community model of off-grid electrification in a cluster of two Hamlets in Uttar Pradesh, from the perspective of a Renewable Energy Service Company. Telecom towers, Flour Mills and rural communities have been considered as the Anchor, Business and community customers respectively. Primary surveys have been carried out to assess socio-economic characteristics, renewable energy resource availability and energy demand. Cost savings has been assumed to be the primary incentive for the customers to switch to clean energy. Cash flow analysis has been done to estimate the level of profitability of the project with and without the current level of subsidy. Solar Photovoltaic systems, Biomass gasification systems and Solar-Biomass hybrid systems have been modelled using HOMER. The model for Solar PV system with subsidy was found to be the most robust out of all three models in the scenario analysis. Solar-Biomass hybrid systems and Biomass Standalone systems are found to have the potential to offer a healthy level of returns under the best case and most likely scenarios.

1. Introduction

Energy access is closely linked to sustainable development and is therefore a top priority for emerging economies like India [1]. However, a significant proportion of the Indian population is still devoid of electricity. As on 31-01-2014, a total of 39730 villages in India are yet to be electrified according to the new definition of electrification which came into effect in 2004–05 [2]. Hamlets on the outskirts of villages are not included in these statistics as electrification plans have been traditionally made and implemented for census villages only [3]. Dedicated government schemes like Rajiv Gandhi Grameen Vidyutikaran Yojana have resulted in substantial improvements in the percentage of village electrification, but the level of household electrification still remains low [3]. Even in the villages which are electrified by the grid, the per capita electricity consumption is 95 kWh per year as compared to 700 kW h per capita per year in urban India [4]. This underscores the relatively lower level of reliability in rural areas as well as lop-sided growth in electrification.

Renewable energy based Decentralized Distributed Generation (D.D.G) holds a high potential for supplying power to villages which either do not have electricity access or have insufficient levels of reliability in the prevailing electricity supply. In the recent past, new entrants have emerged in the off-grid energy sector, but only a few of them have got beyond the pilot phase [5]. A careful observation reveals a preponderance of grant-based or subsidy-based models over for-profit models and a conspicuous absence of productive loads as the targeted beneficiaries in most of the projects.

Productive loads could not only increase the prospects of long term sustainability by ensuring a steady revenue stream but could also provide the "critical mass" of market packages for private sector bidders [6]. The significant opportunity for leverage presented by the high growth of tele-density in rural India [7] coupled with the need to include productive loads in the power generation equation in rural areas has led to the evolution of the Anchor-Business-Community model of off-grid electrification. The key value propositions of the A-B-C model are represented graphically in Fig. 1.

In the recent past, market intelligence reports [8] have indicated

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an opportunity for Renewable Energy Service companies (RESCOs hereinafter) to collectively serve the power needs of mobile towers, local businesses and communities working on the A-B-C (Anchor Business Community) model.

Notwithstanding the willingness of many telecom companies to pilot this model [9], there is a need to investigate the benefits to all the stakeholders in a holistic manner. This study attempts to capture the incentives of various stakeholders to shift to the A-B-C model and examine the viability without and with present level of subsidy support at different levels of incentive in the research area.

The organization of this paper is as follows: Firstly in Section 2.0, a review of the previous literature on the topic of distributed generation has been presented with an intent to capture their key findings and limitations. Section 3.0 illustrates the research methodology including the rationale for survey sampling and procedure followed in the collection of data. Data analysis has been done by preparing baseline cases and business cases in subsections 4.1 to 4.7 and the method for Tariff formulation is illustrated in Section 4.8. The financial analysis of the business cases has been done in Section 4.9 and the overall results of the analysis have been summarized in Section 5.

2. Literature review

Several studies in the area of rural electrification have attempted to model distributed generation systems for capacity planning either as mathematical models or by using software tools. Many of these studies have used HOMER as the analytical tool to carry out simulation and system optimization. A brief account of such work considered useful for this study has been presented in this section.

Sen and Bhattacharya [10] identified the optimal hybrid technology combination for electricity generation in Palari village of Chhattisgarh and compared it with conventional grid extension. They found the hybrid technology to be a more cost-effective alternative to conventional grid extension. They went beyond the previous studies that used HOMER by adding Pre-HOMER and Post-HOMER analysis. In the Pre-HOMER analysis, the energy requirements of the village were estimated by multiplying the average hours of usage by the number of users. However, this approach may increase the margin for error in village sized projects and aggregating the individual demands through face-to-face surveys (as is done in this study) may be considered a better approach [11]. In the post-HOMER analysis, issues like business model, tariff selection and regulatory concerns were briefly discussed. The authors contended that system reliability was the main objective of their design for which they opted for Hybrid generation systems. Given that system reliability (in the form of maximum allowable Capacity Shortage) is an input for HOMER modelling and 100% reliability can be ensured even by a single generation system (say Solar PV) coupled with a battery bank, limited emphasis was given to the cost savings that resulted from modelling a hybrid as compared to a single generation system.

Hafez and Bhattacharya [12] used HOMER to design and analyse a renewable energy based micro-grid for a hypothetical rural community with base load 600 KW and peak load 1183 KW. Their study considered solar, wind, hydro and diesel technologies for the analysis and assumed 24 × 7 demand from the village. They conducted sensitivity analysis on variables such as unmet energy, diesel price and distance from the grid. Although they considered a rural area in their analysis, the load profile assumed by them may not represent the typical rural load profile which has a low load factor, periods of no/low loads and peak loads in morning and evening [13]. Further, the values of O&M costs considered by them for Solar, Wind and Micro-Hydro technologies are on the lower side resulting into lower cost of electricity generation. In order that the calculated load profile fits the typical rural load profile, a village-level survey may be regarded as a more appropriate elicitation technique [11] than hypothetical assumption because it visualizes the variation of load with time of the day in a very realistic manner, thereby providing a logically sound basis for applying load management measures. Hypothetical assumptions about hours of usage may run the risk of not being in tune with the usage patterns of the customer because of the bias of the modeller towards solutions with low costs. In addition, the willingness of the rural communities to get connected to renewable power is a very important variable for modelling a micro-grid, which cannot be accurately captured through assumptions.

Ma, Yang and Lu [14] carried out a detailed feasibility study and techno-economic evaluation of a standalone hybrid solar wind system with battery energy storage. They examined the effect of PV panel sizing, wind turbine sizing and battery bank capacity on the economic performance of the system. They also carried out a sensitivity analysis on the load consumption and renewable energy resource. This study brought forth the typical problem of timing mismatch between power demand and generation which resulted in high dumped energy. As a possible solution, it was suggested by the authors that a small percentage of capacity shortage or unmet peak load be allowed in the design phase itself which can result in significant reductions in the size of the components. However, this suggestion may not be very compelling for cases in which the energy customers have very high reliability requirement (i.e.-Telecom towers) [5]. Application of load management methods like peak shifting can enable the loads to be met with little to no capacity shortage by imposing a small degree of grid discipline.

In the present study novelty arises from the following points:

1. ***Examination of the incentives for the customers to switch to renewable energy***: Unless the perspectives and motives of all the customers are duly considered, there is a high degree of uncertainty associated with the revenue stream. Even a stated willingness to adopt clean energy by rural customers, needs to be backed by quantitative criteria, otherwise it stands the risk of being an over-optimistic evaluation. So, it has been assumed that the incentives to switch to clean power in the hamlet are primarily monetary in nature.
2. ***Consideration of Energy efficient appliances and Demand side management measures for generation of Load Profiles***: These measures can be useful to keep the prices on the lower side for the end-users in spite of inherent high cost of production of renewable energy.
3. ***Inclusion of project development costs in the calculation of Levelized cost of Energy***: Project development costs vary for different technologies and their inclusion is required when the developer also happens to be the operator (as in the RESCO model).
4. ***Value-based Pricing of clean power considering Willingness to Pay of rural* customers**: Cost based pricing of micro-grid power results in unreasonably high tariffs for the rural customer, much beyond their willingness to pay. The reverse approach of value based pricing would keep the interests of the community in mind for setting the price.
5. ***Analysis of the complete business model***: Most of the previous publications about the economics of micro-power generation have restricted themselves to capacity planning. In analysing the entire business model, the perspectives of various stakeholders can be given equal emphasis.

A summary of past studies relevant to this research and the key themes addressed by them is shown in Table 1.