Rural Off Grid Electrification Using Hybrid Mini grid and its Socio Economic Impact : A Case Study of District Pilibhit

Apoorva Saxena and Subhash Chandra

***Abstract*— Despite the best efforts of the governments of various countries to promote rural electrification, it is not enough to keep in pace with rapid urban and industrial growth. In remote areas, off grid technologies combined with sustained financial management can lead to environment friendly access to electricity by rural population. This paper explores the socio-economic impact of rural electrification, various technical approaches for rural electrification with focus on Hybrid mini-grid & financial model for sustained low cost operation of hybrid mini-grid involving skilled village population.**

***Index Terms*—Rural electrification, Hybrid mini-grid architecture, scope analysis, community based implementation model.**

I. INTRODUCTION

Modern energy services are crucial to human well being and play an important role in the economic and social development of the country. Significant efforts have been made globally to provide electricity to both urban & rural population. In this regard, global electrification rate went from 49 % in 1970 to 80.5 % in 2011 with around 5.2 billion people having access to electricity [1].Despite this, over 1.3 billion people worldwide are still without access to electricity. An estimated 80 % of these people live in rural areas with majority of them having scant chances of accessing electricity in near future. More than 95 % of these people reside either in Sub-Saharan Africa or developing Asia [1].

In developing Asia, it is projected that number of people without access to electricity will come down by 45% from 675 million people in 2009 to 375 million in 2030[1] through government sponsored schemes of grid extension.. But still rural population will make majority of people which will not be having access to electricity. One more point to consider is regarding Quality of the service. Grid extension increases the demand but if it is not accompanied with corresponding increase in generation(which is most likely case in majority of Asian countries), adding new customers only aggravates the problem of electricity outages and will ultimately lead to lesser number of hours for which electricity will be available.

An Action-Aid study [2] takes our attention to an interesting fact regarding rural electrification in India. According to the report, the installed capacity of coal-fired power plants in India increased from 74429 MW in 2002 to 96,794 MW in 2009.Along with this increase in 22365 MW in coal based energy, 10,000 MW of hydro power capacity was also added between 2002 and 2009.During the same time period number of un-electrified villages came down marginally from 52 % in 2002 to 45 % in 2009 which counts to the electrification of 20,000 villages. Further, out of these 20,000 villages electrified, 2000 villages were electrified through de-centralized renewable energy system. So renewable energy contributed around 2% of those reductions in un-electrified villages. On the other side, despite addition of over 33,000 MW of coal fired power plants & large hydropower, they contributed only 5 % in the rural electrification. So inference that can be taken out from this is that the addition of electricity generation for conventional power plants has not addressed the issue of electricity access to the poor rural population.

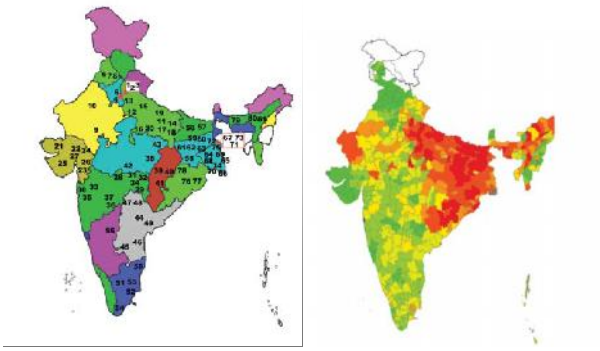

Fig.1.Location of coal based plants & rural electrification scenario [2]

The maps shown above clearly indicate that the area which has highest concentration of thermal power plants has dismal 1-10 % of rural electrification rate (shown in red). This clearly justifies our inference above & underlines the need to look something beyond just extending the national grid to rural areas.

Looking into this scenario, major technological challenge is how to deliver sustainable electricity services to these rural populations. Given the relatively small loads, topographical

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constraints-isolated "Hybrid Mini grid" can attain a greater penetration, far beyond those which can be achieved in large scale grids in the near future. This point will be elaborated further in this paper.

The goal of this paper is to explore the positive impacts of rural electrification and how it can lead to social upliftment & gender equality among poor communities at village level, contribute to the knowledge base of hybrid mini grids and analyze the scope of implementing hybrid mini-grids in district Pilibhit taking into consideration available local resources. This paper is organized as follows: Section II describes implications of rural electrification, Section III details the various technical approaches to bring electricity to rural areas with special focus on hybrid mini grids, Section IV discusses the scenario regarding installation of Hybrid Mini grids in district Pilibhit & Section V discusses the effective business model that could be adopted for sustainable operation of Hybrid mini grid.

II. IMPLICATIONS OF RURAL ELECTRIFICATION

Access to electricity leads to some direct benefits like higher productivity of agriculture products [3] and some indirect benefits like improved knowledge of weather conditions and crop prices due to access to televisions and radios.

Electrification will be necessary in achieving any of the goals laid down by the Government of India in 12th five year plan. It can help to reduce child mortality rate through refrigeration of vaccines which will be available at village panchayat levels. It can help to achieve universal primary education by improving evening study conditions.

Application of end-use energy technologies like food preservation and processing, electric appliances for grinding , local craft production would encourage home based women micro enterprises which can contribute significantly to house hold incomes[4].Electrification can thus enhance social welfare through augmented incomes.

In rural Asia 1.9 billion men and women relies on wood, charcoal and dung as a major source of energy especially for cooking purposes.These methods of energy production are highly inefficient and poses significant health risk. As per World Health Organization (WHO) projections, the number of people who die prematurely each year could be over 1.5 million by 2030, which will be around 35 % more compared to death caused by malaria & HIV/AIDS combined together[4].

To promote the fuel transition in rural Asia from unhealthy fuel-wood and traditional bio-mass to electric based / improved bio-gas technology key factor would be to increase the income level of women working as a labor that would ultimately lead to economic worth in the use of women as a labor. This could act as a strong incentive to economies on women's unpaid labor time in fuel collection and other household activities, encouraging use of clean, efficient sources of energy. So rural electrification can be a major driving force in attaining good health for children & women & can also lead to gender equality in rural India by empowering rural women.

III. TECHNICAL APPROACHES FOR RURAL ELECTRIFICATION

There are three basic technical approaches to bring electricity in rural areas [5]:

(a) Extension of national grid
(b) Isolated off-grid using renewable energy
(c) Hybrid mini grid

First option deals with simply extending the national grid to remote locations. But this approach of rural electrification is a challenging task because it involves delivery of a service to the people that are remote, dispersed and with low electricity consumption. This means that on one side the customer base is generally poor and less able to pay the full cost of the service and on the other side extending the transmission line to these remote, tough terrains include high expansion cost [4] .Combining both of these factors, it is imperative that to expect extension of grid to the un-served rural population in near future is a distant reality.

The second option depends mainly on the dispersion of the household and type of load required. In these stand alone systems, power generation is installed close to the load and hence transmission and distribution costs are minimized. However the total cost of energy tends to be higher due to lack of subsidies.

The third option deals with a distribution network spread in a localized area covering one or two villages and using at least two different non renewable technologies (PV panels, small hydro plants, biogas plants, wind turbines etc) for power generation with a diesel driven generator acting as a back-up. The combination of renewable energy sources with diesel driven generator has proven to be the least – cost solution as the advantage and benefits of every energy resource complement each other, with solar PV collectors complementing wind power during the month with less wind or picking up when hydro-generation drops during the dry season.

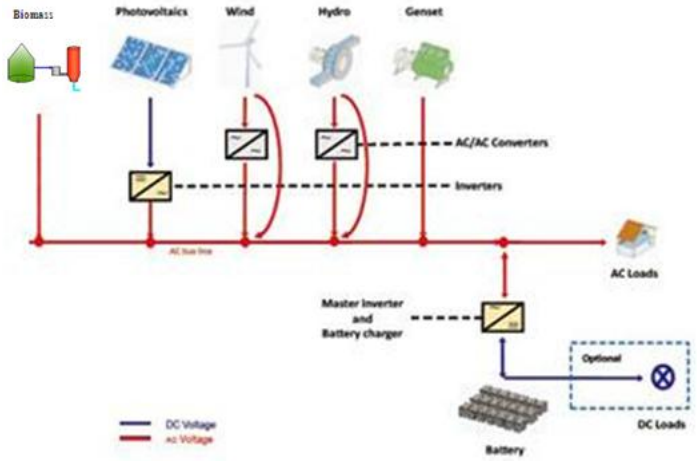

Fig.2. AC bus bar coupled Hybrid mini-grid [6]

A Hybrid mini grid is composed of three subsystems: generation, distribution and demand [7].The structure of each sub-system depends on the availability of resources & user characteristics.

A. Generation

This sub-system comprises of renewable based generation, storage devices, converters and energy management system of Hybrid mini-grid.

B. Distribution

This subsystem is responsible for distribution of energy to the end user via mini grid. For the case discussed in this paper, we propose the use of single phase alternating current system. This decision will have direct impact on the cost of the project and appliances that can be used.

C. Demand

This subsystem includes all the end user side equipments such as meters , wiring and equipments which will run on power generated by hybrid power plant.

IV. IMPLEMENTAION SCOPE ANALYSIS FOR PILIBHIT

A. Adjusting to local resources available

Renewable energies are highly location specific in nature. So any specific hybrid energy technology should be selected according to the availability of different renewable sources in a particular region.

Animal husbandry is very popular in this district due to the availability of 78639 hectares of large dense forest[9] and accessibility of fodder in the nearby forest. The number of livestock present in the district is given in table below [9]

Cattle	**Numbers**
Cows	154633
Buffaloes	264822
Goats	99735
Pigs	11091
Poultry	95805

So it can be concluded that due to large number of cows and buffaloes, there is a sufficient availability of cow dung in the region which can act as a raw material for biomass plant

B. Calculation for digester sizing

The energy available from a biogas digester is given by [10]

$$E = \eta H_b V_b \quad (1)$$

where η is combustion efficiency of boiler

H_b is the heat of combustion per unit volume of biogas

V_b Volume of the bio-gas

Also, $V_b = cm_0$ (2)

where c is biogas yield per unit dry mass of whole input

m_0 is the mass of dry input.

With the help of these data, volume of fluid in the digester (V_f) can be calculated. Hence volume of the digester is given by

$V_d = V_f$ (flow rate) . t (retention time in digester) (3)

Taking total wet manure per animal per day/ Kg as 35 of which 4.5 Kg. is the total solid content [10], the total electrical energy output and digester volume will be calculated while designing the hybrid mini-grid

C. Resources for Hydro-energy

In terms of water resources, this area has 17 rivers including major rivers like Sharda & Gomti [11] and has a total canal length of 938 Km [11] .

Name of the channel	Length (in Km)
Sharda Canal	12.64
Hardoi Branch	36.80
Kheri Branch	31.20
Sharda Sagar feeder	3.9
Outlet channel	3.23
Subsidiary Hardoi Branch	21.55

Looking into this scenario, there could be a major possibility of having micro hydro power plants in this region.

The assessment of both biomass energy & hydro-energy clearly indicates that a hybrid mini grid with biomass and micro-hydro as energy sources will be ideally suited for designing a self sustained, cost effective hybrid power distribution network in this region.

V. PROPOSED BUSINESS MODEL

A. Community based Model

Hybrid mini grids are usually located in remote isolated areas and hence does not attract private-sector /utility interest due to obvious commercial reasons. So we propose a Community based mini grid model in which community becomes the owner and operator of the system and provide maintenance, tariff collection and management services. In a community based organization, the owners/managers are also the consumers and hence they have strong interest in the quality of the service and on the other side generate O & M jobs for local poor people in the community.

However, there are some challenges facing this socio-business structure [5]. First of all, local communities lack the technical skills to design, install & maintain the system and business skills to formulate & calculate tariff structure. So this community based model requires substantial technical assistance with regard to system installation, operation & maintenance of Hybrid mini grid which can only be implemented through participation from Central/State government.

Second challenge facing this community based model is to measure and limit the consumption of each user to avoid potential conflicts within the community. Hence the committee which will be in-charge of the system management has to be constituted keeping in view the social structure of the area and with due consent of local leadership. Therefore, it is clear that if a community-based organization is to be successful, it requires time, nurturing, and capacity building. Sometimes, it may be more efficient to involve a private or public entity that will take on the technical aspects and

therefore limit the community organization's role to monitoring.

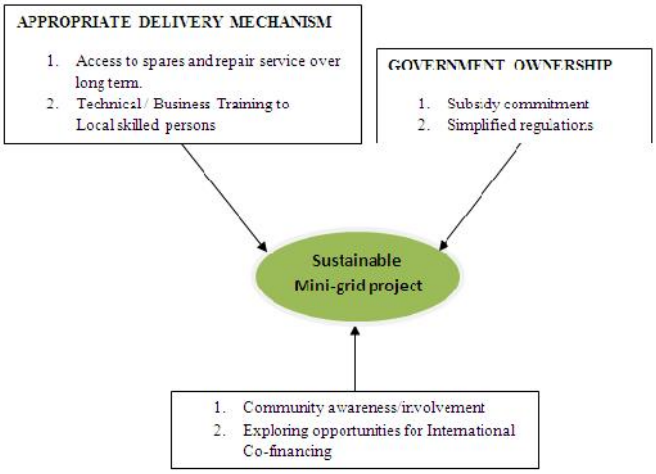

Fig.3. Proposed Business Model

VI. CONCLUSION

Hybrid mini grids can help to increase the rural electrification rate along with reliable power supply as compared to off- grid single source stand alone system. This is due to the fact that availability of power is ensured even when one of the generation sources faces intermittence. Biogas digesters and biomass gasifiers are particularly promising from the economic perspective, given their high capacity factors and availability in size ranges matched to mini grid loads. Mini grid system are also becoming economically viable option as the cost of renewable energy shows downward trend and fuel prices increases . Despite these opportunities, penetration of hybrid mini grid in most of the countries remains low. Some of the reasons behind this could be use of poor quality or untested technologies, insufficient funding or lack of subsidies.

Poor assessment of local conditions often compounded by lack of local data is also the major cause of failure in many of the cases. Development of schemes without attention to developing supplementary programmes dealing with issues such as access to markets, SME development and working with local financing institutions, has contributed to a lack of demand and an inability to sustain the schemes.

So for long term viability of the system it is imperative to include local leaders in decision making process and encourage local rural population in the operation & maintenance of hybrid mini-grid. This community based model of rural electrification could have myriad of positive impacts on the socio-economic conditions of the rural community and can ultimately lead to gender equality among the rural communities. However, serious training programs should be developed to compensate for the lack of skills among local peoples with participation from Central/State Government.

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