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MINI GRID DEVELOPMENT FOR RURAL ELECTRIFICATION IN REMOTE INDIA

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ABSTRACT

In many cases grid extension is often highly costly and unlikely to happen – even in the medium- to long-term. In these scenarios, mini-grids (MG) could provide an ideal intermediary solution, especially for small towns or large villages where enough electricity can be generated to power household use, as well as local businesses. MGs provide centralized electricity generation at local level using the village's distribution network. When used in conjunction with renewable or hybrid systems, they can increase access to electricity, without undermining environmental factors. The mini grids are advantageous in remote areas to provide sustainable, reliable electricity and cost effective electricity. The paper covers the Indian energy scenario, renewable energy penetration in rural India, brief literature review, mini-grids (concept of MG, technologies deployment in MG, types of MG, merits and demerits). The paper also deals with the potential applications of MG in rural electrification and Indian initiatives of MG development in India.

Keywords: MG; Rural Electrification; Renewable Energy etc.

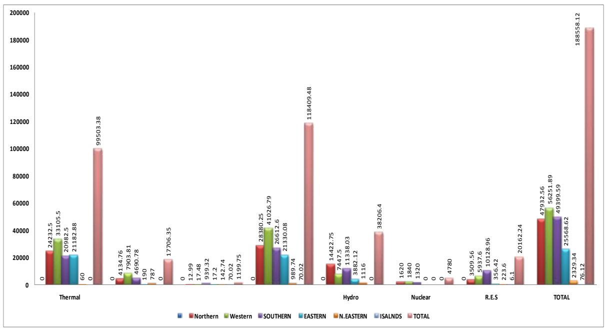
1. INTRODUCTION

It is now well recognized that electric power is a key driver of economic growth and prosperity. But access to electric power remains a distant dream for majority of the poor living in developing countries. Per capita electricity consumption in developing countries is far lower than the developed world. In developing country like India, where about 68% of population is living in villages, the per capita consumption is very less compared to developed country like USA. Ministry of Power has set the goal of providing "Power for all by 2012" and therefore, there is need to develop the technologies for effective utilization of available renewable energy resources for electrification of remote rural areas [1]. Even in villages that are 'electrified' (connected to a grid or a centralized distribution system), supplies are erratic and of extremely poor quality. Access also is limited. In many 'electrified' villages, all village residents do not have access to electricity. Thus the village electrification needed a system that they can feed locally available energy resources rather than the central gird [2].

The paper covers the Indian energy scenario, renewable energy penetration in rural India, brief literature review, mini-grids (concept of MG, technologies deployment in MG, types of MG, merits and demerits). The paper also deals with the potential applications of MG in rural electrification and Indian initiatives of MG development in India.

2. INDIAN ENERGY SCENARIO

India is world's 6th largest energy consumer accounting for 3.4% of global energy consumption. Due to rapid growth of Indian economy, the demand for energy has grown at an average rate of 3.6% per annum over the past 30 years [3]. According to the ministry of new and renewable energy (MNRE), today the share of renewable based capacity is 10.9% (excluding large hydro) of the total installed capacity of 170 GW in the country, up from 2% at the start of the 10th plan period (2002-2007), [4-5]. In context to this, Fig. 1 depicts the sector-wise installed capacity (MW) as on 31.07.12 [4-8].



Captive Generation Capacity in Industries having demand of 1 MW or above, Grid interactive (as on 31-03-2010) =31516.87 MW

Fig.1 Sector-wise installed capacity (MW) as on 31.07.12 [1-4]

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The Fig. 1 indicates that RES has been making significant participation in the overall mix of energy generation.

3. RENEWABLE EENRGY (RE) PENETERATION IN RURAL IN INDIA

MNRE has been run many supporting programmes for the use of RE beside that there are numerous rural and remotely located villages yet not electrified. Currently, only seven states have achieved 100% village electrification, and five of these states are smaller ones. The remote village electrification (RVE) programme of the ministry aims at providing basic lighting/electricity facilities through RESs in those un-electrified remote census/hamlets villages, where grid connectivity is either not feasible or not cost effective. In the line above the potential of various RESs in India is shown in Table 1 as on 31.03.12, [4-5]; however this potential distributed non-uniformly across the country.

Table 1 Power from Renewable as on 31.03.12 [4-5]

S.No.	Sources/Systems	Estimated Potential (MW)	Cumulative Achievement as on 30.06.2011 (MW)
A	**Grid Interactive Renewable Power**		
1	Wind Power	45195	17352.66
2	Biomass Power	16881	1150.10
3	Bagasse Cogeneration	5000	1985.23
4	Small Hydro Power	15000	3395.31
5	Waste to energy (urban and industrial)	2700	89.68
6	SPV Power	-----	941.28
	Subtotal (A)		**24914.26**
B	**Captive/Off-grid/Distributed Renewable Power**		
7	Biomass/Cogeneration (Non-Bagasse)		382.50
8	Biomass gasifier (rural and industrial)		150.21
9	Waste to energy (urban and industrial)		101.75
10	Aero-generators/ hybrid systems		1.64
11	SPV systems (>1 kW)		85.21
12	Watermills/ micro hydel		1877 (more than 1397 numbers)
	Subtotal (B)		**721.31**
	Total (A+B)		**25635.57**
C	**Remote Village Electrification (*Villages/hamlets*)**		**9160**
D	**Other RESs**		
13	Family type biogas plants (in lacs)		45.09
14	Solar water heating systems-collector area (million sq. m)		5.46

The Table indicates that highest potential of wind energy has been exploited followed by SHP and cogeneration while the captive generation potential is highest from Bagasse cogeneration followed by biomass gasifier systems.

The RVE programme of the ministry aims at providing basic lighting/electricity facilities through RESs in those un-electrified remote census/hamlets villages, where grid connectivity is either not feasible or not cost effective. The RVE programme is being implemented by the MNRE to provide, RVE which are not going to be covered under Rajeev Gandhi Vidyut Garamin Yojana (RGGVY) for grid electrification. The programme is being implemented in complementary mode to RGGVY. It is also worthwhile to mention that the National Rural Electrification Policy, 2006 clarified that provision of RE based systems in un-electrified villages and hamlets should not jeopardize the rights of such villagers to grid connectivity. As well as the Integrated Rural Energy Programme (IREP) introduced during the 10th plan period, such as RVE project, Village Energy Security (VES) test projects and Biogas Power Generation, continue to be implemented during the 11th Plan (2007-12) under the RGGVY [1,3,5-8,].

3.1 Challenges and Barriers in RVE

The Ministry of Power, MNRE has taken considerable interest in accelerating the RE development policies across the country in the remote and rural sector. Indian rural energy scenario is characterized by inadequate, poor and unreliable supply of energy services. In spite a huge potential available of RE in the state, remote and rural villages electrification programme facing several barriers, may be elaborate as:

i. Users in rural areas need to be adequately mobilized for payment of user’s charges–NGOs & Local bodies could be involved [9-10].
ii. Unawareness of remote village’s peoples about RE programmes [11].
iii. Capacity building-promotion & development of Energy Servicing Companies (ESCOs) for local programme implementation required [9-12].
iv. Inherent intermittent nature of RE sources leading to relatively lower capacity utilization factors [13].
v. Instances of inadequate load–need to couple rural-industrial load.
vi. Lack of O&M services providers–Need to develop sustainable revenue/business models.
vii. Feasibility for CDM mechanism–Assistance for project preparation to be provided 14].
viii. High capital costs when compared to conventional power systems–requires incentives and financial arrangement [15].

There are three ways to electrify remote rural areas:

i. National Electricity Grid: requires extensive network of power generation, transmission and distribution.
ii. Off-grid Electricity: Through power sources like diesel or renewable energy systems supplying an individual or clusters of households in a given area.

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iii. Mini-grid Electricity: Through decentralised power stations connected to small isolated power line network supplying several households and larger buildings as well as machinery, [8].

Out of the three, the rural electrification through mini/micro grid is of immediate concern and is the subject of this paper.

4. LITERATURE REVIEW

The PV-Wind-Diesel hybrid mini-grid system with a three phase AC coupled modular expandable component has been described and implemented by Suwannakum et al. [9]. The economic analysis has shown the specific cost of energy from PV-Diesel hybrid mini-grid system as 9.75 Baht/kWh, while the specific cost of energy of PV-Wind-Diesel hybrid mini-grid system as 12.43 Baht/kWh. A design scenario has been developed by Setiawan et al. [10] to provide reliable supply of power and water to meet the demands for remote areas and emergency relief conditions. A simulation has also been performed to get optimum configuration of a hybrid power system using HOMER software.

Mini-grid technology is being pursued in several OECD (Organisation for Economic Co-operation and Development) countries with the hope that it will be viable within 5-10 years but reliability of power delivery, integration of renewable energy sources at high penetration, diversification of energy supply, rural electrification still being debated [11].

Patsalides et al. [12] have focused on the power quality of mini-grid system in terms of harmonics and established effective guidelines for the proper installation of grid connected photovoltaic systems in mini grids and distribution networks. The mini grid based on 10 kW gasifier systems has been found technically proven, efficient, and economically viable in Uganda, [13].

Yasuo et al. [14], have introduced key technologies for loosely coupled mini-grids. Robust generator control method is described mentioned for both when the grid is connected to large power system and when the grid is isolated from the main system. Further the operation system is introduced for co-generation systems. Neural network load prediction is also discussed. A AC mini-grid topology consisting of PV and gasoline hybrid generating capacity with integrated ultraviolet water purification and pumping system was powered by AC mini-grids equipped with multi-master operation is an exciting new advancement in off-grid PV technology, Brandt Dana, [15].

Chokmaviroj et al. [16], reviewed the climatic and solar radiation conditions at Pha Bong Projects (Thailand) and the performance of SPV system was assessed from a global perspective point of view. The system generated about 383,274 kWh during the first eight months and average electricity production was 1695.9kWh/day.

A load dispatch strategy was presented by Ortjohann et al, [17] for isolated mini-grids fed from decentralized energy sources under steady state conditions. It is a flexible and simple-to-implement strategy that accepts the conditions of the users easily.

5. MINI GRID

Mini-grids are small electrical distribution systems connecting multiple customers to multiple sources of generation and storage. Mini-grids are typically characterised by multipurpose electrical power service to communities with populations ranging upto 500 households with overall energy demand ranging upto several thousand kWh per day, [18]. Three different application domains of mini grids may be as follows:

i. *Village Micro-grids:* The village micro grids provide ac electricity to “off-grid” settlements offering step up from batteries, solar home systems and portable engine-generators.

ii. *Diesel mini-grids:* Diesel mini-grids are established as independent power grids using (primarily) diesel engines as the generation source. They supply the power to remote communities, industries, and for other local demand.

iii. *Urban mini-grids:* Urban mini-grids are the local distribution networks in developed areas that have a utility grid. The mini-grid can operate autonomously with local generating sources or interconnect to operate in parallel with the utility grid [11].

5.1 Mini Grid: Classification

The mini-grids can be classified on the basis of the types of coupling used [19-20]:

1. Mini-Grid with DC coupling:

As shown in Fig. 2 electrical energy from wind, diesel and hydro plant first converted to dc through AC/DC converter, then supplied to DC bus and electrical energy from solar system directly supplied to DC bus, which supplies electricity to DC loads directly and AC loads may be supplied through inverter. A battery is connected to DC bus which is charge and discharge according the conditions of load through charge controllers to avoid overcharging or discharging of battery.

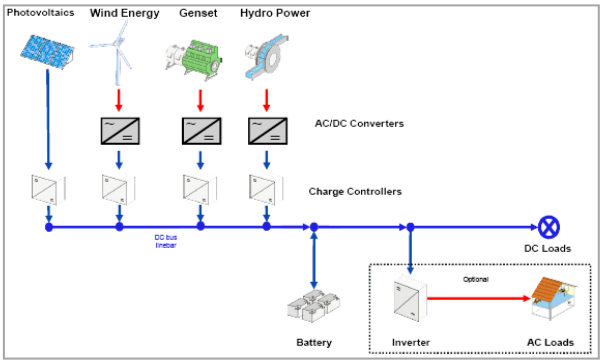

Fig. 2 Mini-grid with DC coupling [18-20]

2. Mini-Grid with AC coupling:

As shown in Fig.3 AC generating components are directly connected to the AC bus line or through a AC/AC converter to enable stable coupling of the components and DC generating components are connected to the AC bus line through inverter and a bidirectional master inverter controls the energy supply for the AC loads and the battery charging. DC loads can be supplied by the battery.

3. Mini-Grid with DC/AC coupling:

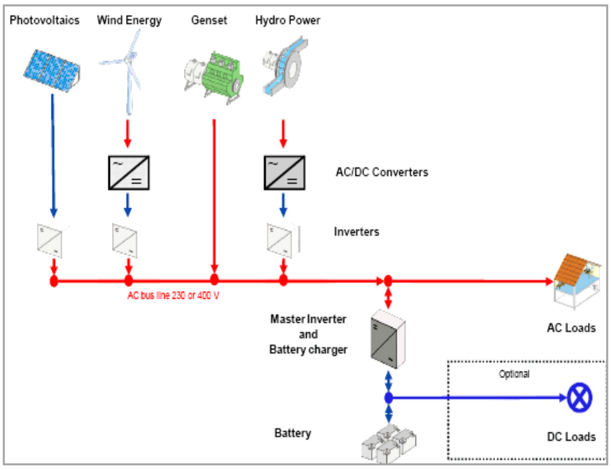

Fig. 3 Mini-grid with AC coupling [18]

As shown in Fig. 4 DC electricity generating components are connected to the AC bus line through a master inverter and AC generating components are directly connected to the AC bus line or through an AC/AC converter to enable stable coupling of the components. DC loads can be met by the battery [18].

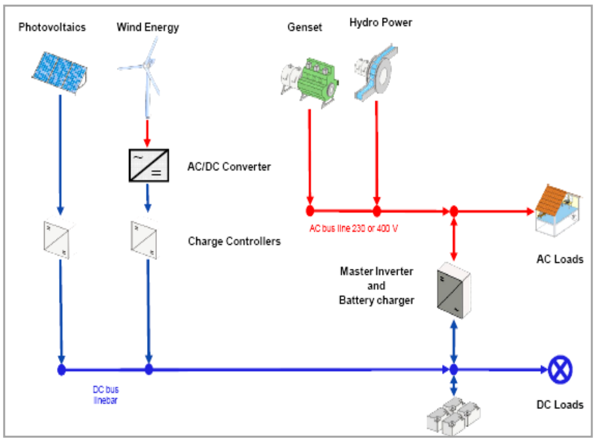

Fig. 4 Mini-grid with AC/DC coupling [18]

6 MINI GRID COST ANALYSIS OF DIFFERENT TECHNOLOGIES

In Fig. 5 comparison is made between various mini grid technologies available for rural remote village electrification in terms of capital cost forecast [11, 14, 19, & 21].

7 POTENTIAL APPLICATIONS OF MG IN RURAL & REMOTE VILLAGE ELECTRIFICATION

The remote villages have no access to the grid and have to depend on alternative power sources like solar, wind, biomass, biogas and small hydro available in a given area. Electricity from these sources known as the off- grid generation is not much reliable. The more reliable and sustainable supply to a village or a number of villages in a circle of a particular radius can be possible through the use of mini grid, which are the interconnection of small, modular generation sources to ac distribution systems. Mini-grids may be powered by a combination of PV, wind, micro-hydro, diesel based gen sets and other sources.

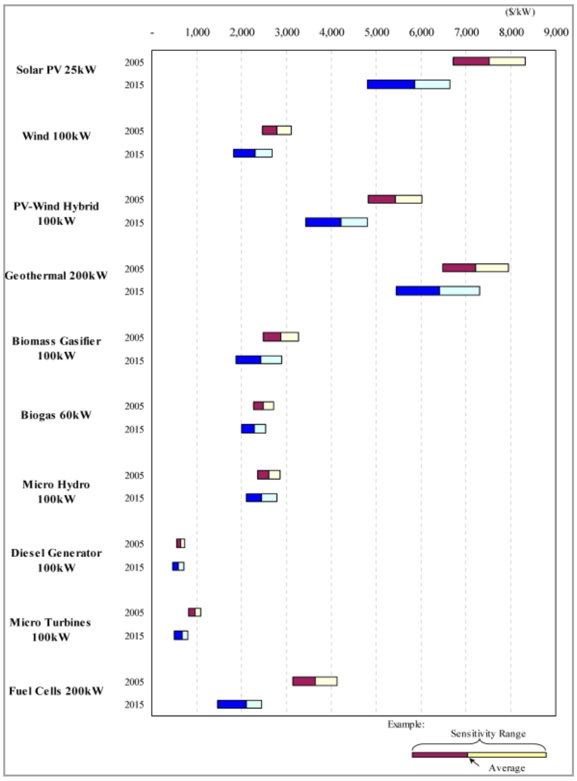

Fig. 5 Capital cost forecast of various Mini-grid systems

These mini grids may supply power to multiple users, and may be interconnected with (or be part of) the distribution grid of local electric utility [11]. The series and parallel configurations of typical mini-grid system are shown in Fig. 5 & 6 respectively.

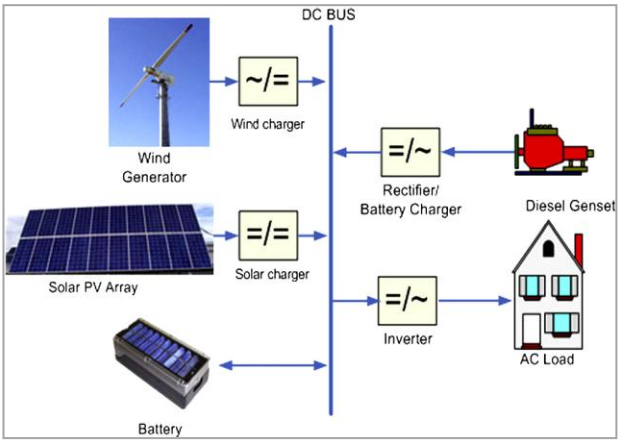

Fig. 6 Series Mini-grid system configuration

In a series hybrid system configuration (Fig.5), power generated by a diesel generator, wind generator and solar PV array are used to charge a battery bank. In a parallel hybrid system configuration (Fig. 6), the diesel generator and renewable energy generator supply a portion of the load demand directly. This system utilizes a bi-directional inverter which is operated in parallel with the diesel generator and can act as an inverter and rectifier/battery charger. The design principles of this system are relatively complicated but it is superior to the series configuration, [10].

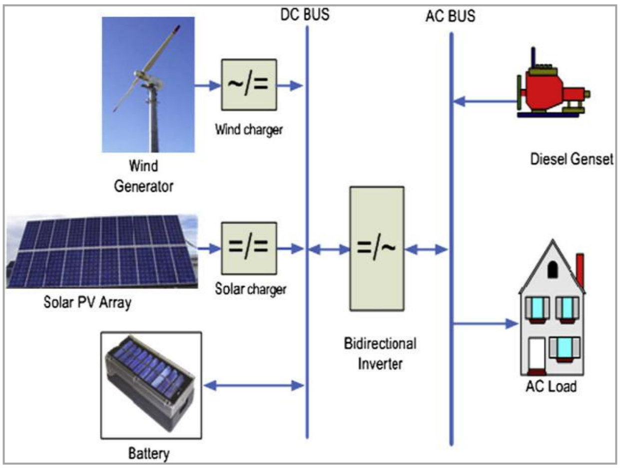

Fig. 7 Parallel Mini-grid system configuration

Mini-grids have the potential to bring cost-effective power to rural communities in remote areas of the world. Different tools are now available to design such distribution systems to reduce costs while ensuring the quality of supply, [20]. Since the mini grid combines renewable sources with diesel gen sets; it reduces the diesel consumption and provides clean energy. An improved reliability can be obtained by having multiple sources of generation connected to the users. Compared to stand-alone hybrid Systems/integrated renewable energy system, the obvious advantage of connecting more power plants via mini-grid helps to enhance the rated power of the system, [17].

In the remote village of Chalpadi in the State of Andhra Pradesh (India), oil extracted from the seeds of the Pongamiapinnatatree is being used as biofuel to operate a diesel engine that powers a community run village electrification mini-grid [20]. Sunderbans is area characterized by mangrove swamps and Islands interwoven by a network of small rivers, waterways, creeks and tracts is extremely difficult to extend high tension transmission lines to these areas. Village-level mini grids based on biomass gasifier, solar photovoltaic, wind-diesel hybrid and tidal power technologies are used for supplying electricity for domestic and commercial applications, [21].

7.1 Indian Initiatives in MG Development

Mini-grids are found to be a better option for supplying renewable energy based reliable power to remote rural communities. However, the challenge is to maximize the benefits of subsidy while ensuring that the consumer is happy to pay for the services. The MNRE provides a subsidy. Innovations in accessing local developmental and state funds for setting up the village level utility, and ensuring it's O&M from the sale of electricity, have brought clean electricity services within affordable limits to the rural consumer.

8. CONCLUSION

The mini grids are advantageous in remote areas to provide sustainable, reliable electricity and cost effective electricity. In many cases grid extension is often highly costly and unlikely to happen – even in the medium-to long-term. In these scenarios, mini-grids could provide an ideal intermediary solution, especially for small towns or large villages where enough electricity can be generated to power household use, as well as local businesses. When it is used in conjunction with renewable or hybrid systems, they can increase access to electricity, without undermining environmental factors. If the suitable subsidy of government program is used, there might be a chance number of MGs scheme should come up in near future for RVE.

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