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Distributing Electrical Energy Efficiently and Economically in Rural India: The Micro-Grid Option

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Abstract — *This paper deals with distributing electrical energy in rural India with efficiently and economically. This paper also demonstrated the basic policy, perspective planning, Power quality issues related to distributed generation source integrated to utility grids and also the concept of Micro-Grid option.*

Keywords- *Distributed generation system (DGS), Grid integration, Micro-Grid, Power quality.*

I. INTRODUCTION

The distributed generation system is generally considered as an alternative to bulk power transport. The basic idea is that the presence of electricity generation inside the distribution systems leads to a reduction of the local electricity needs, which consequently leads to a reduced need for power transmission capacity and thus a deferral of investments in transmission lines.

DG is not a new phenomenon. Prior to the advent of alternating current and large-scale steam turbines - during the initial phase of the electric power industry in the early 20th century - all energy requirements, including heating, cooling, lighting, and motive power, were supplied at or near their point of use. Technical advances, economies of scale in power production and delivery, the expanding role of electricity in American life, and its concomitant regulation as a public utility, all gradually converged to enable the network of gigawatt-scale thermal power plants located far from urban centers that we know today, with high-voltage transmission and lower voltage distribution lines carrying electricity to virtually every business, facility, and home in the country. Today, advances in new materials and designs for photovoltaic panels, micro-turbines, reciprocating engines, thermally-activated devices, fuel cells, digital controls, and remote monitoring equipment, among other components and technologies, have expanded the range of opportunities and applications for "modern" DG, and have made it possible to tailor energy systems that meet the specific needs of consumers. These technical advances, combined with changing consumer needs, and the restructuring of wholesale and retail markets for electric power, have opened even more opportunities for consumers to use DG to meet their own energy needs, as well as for electric utilities to explore possibilities to meet electric system needs with distributed generation. With countries such as China and India quickly entering developed status, determining new and more sustainable methods of electrification becomes important before inefficient and unsustainable networks are implemented. This report focuses on electrifying communities where connecting to an electrical grid is difficult, of which there are three acknowledged methods: actual extension of the existing transmission and distribution network; individual purchase and installation of photovoltaic (PV) systems to generate personal electricity; and the implementation of a micro-grid.

Micro-grids offer a promising solution to total electrification. They are very flexible to the use of renewable energy sources and will also cater to small load factors, two key characteristics for sustainable electrification of remote communities. Several cases of successful micro-grid implementation can be found in both developed and developing nations. Learning from these past case studies this report will analyze and propose a method of sustainable micro-grid implementation for rural communities in Bihar, India where only 20% [1] of rural villages have been electrified.

II. DISTRIBUTED GENERATION SYSTEM

Distributed generation, or DG, includes the application of small generators, typically ranging in capacity from 5kW to 10MW, at or near to the end-user to provide the electric power needed. As applied in this paper, DG includes the complete power generation and distribution system for small villages. This includes generation, energy storage, on-site management (i.e., dispatch, control, communications), and all ancillary devices and services.

The bulk of the DG equipment today is reciprocating engines that can run on various fuels but most often are run on diesel fuel. Although relatively inexpensive and readily available from multiple suppliers, these small reciprocating engine generators are generally considered degrading to the environment (high greenhouse gas emissions and noise levels), and they have high maintenance requirements. The expectations are that emerging technologies will play a significant future role in DG especially with regard to village electrification. Micro turbines, fuel cells, solar, and wind-powered generation are all now in the early commercial or field-prototype stage. These technologies were originally developed for defense and non-polluting transportation applications. The stationary power market appears to be the first large-scale commercial opportunity for these devices.

III. CENTRAL V/S DISTRIBUTED GENERATION

When energy is generated and distributed using small scale technologies closer to its end users, it is termed as Distributed Generation. These generations are based on the technologies, mainly renewable, including but not limited to, wind turbines, photovoltaic cells, geothermal energy and micro hydro power plants. Onsite power generation has many benefits over the centralized power generation systems, as it eliminates the costs associated with the transmission and distribution of power over long distances. These small scale technologies can yield power from 1KW to as much as 100MW.

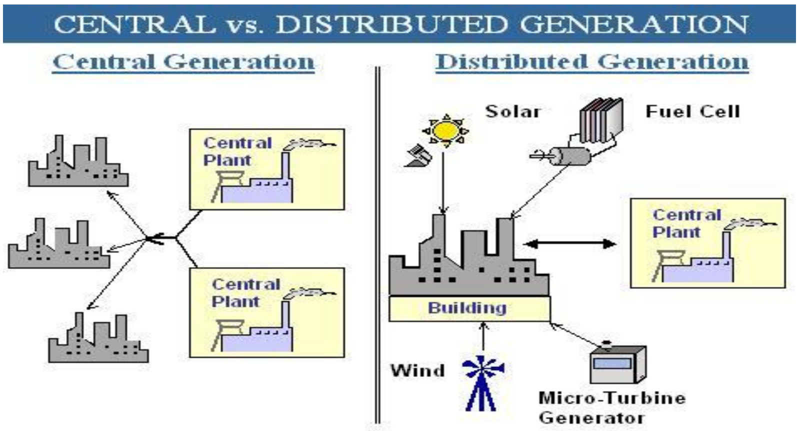

Fig. 1. Centralized vs. Distributed Generation

Distributed generation can take place at two scales. At a local level, site specific energy sources are used to generate electricity, constituting a Micro-Grid which is a cluster of generations serving a limited number of consumers. It can be either connected to the grid at a single point or can be totally independent of it. At the second level, the same technologies are used at much smaller scale and are installed by an individual energy consumer. Such a system is called Distributed Generation. These sources can be individually connected to grid, so that they can supply power to the grid when required – creating a presume, i.e., a producer and a consumer of electricity.

IV. BENEFITS OF DISTRIBUTED GENERATION

Decentralized generations are small and offer numerous benefits in comparison to the conventional centralized systems. Few of its benefits are discussed as follows:

No high peak load shortages - Distributed generation systems can reduce the peak demand and offer an effective solution to the problem of high peak load shortages.

Reduced high transmission and distribution losses - It can greatly reduce the losses during transmission and distribution of power from central location and hence improve the reliability of the grid network. In India, the current losses amount to about 35% of the total available energy.

- *Linking remote and inaccessible areas* - Distributed generation can play a major role in providing power to remote and inaccessible areas. For a country like India, it offers a solution towards rural electrification.
- *Faster response to new power demands* – The micro-grid systems are small scaled and often require lower gestation periods, it enables faster and easy capacity additions when required.

Improved supply reliability and power management - With independence from utility grid systems, istributed generation systems offer easy maintenance of power, voltage and frequency. It also offers the possibility of combining energy storage and management systems, with reduced congestion.

V. ROLE OF DISTRIBUTED GENERATION IN MICRO-GRID

Decentralized Generations are natural extensions of smart grids. Their ability for on-site decentralized power generation helps in reducing peak loads and hence better system management of the central grid. In future, both smart micro grids and smart decentralized generations will be able to sell their generation back to the utilities from whom they buy the power thus providing additional revenue stream. This will help utilities to reduce the need for massive investments in building new high-voltage transmission lines to carry renewable power from far-off plants to towns and cities. Locally based solar, wind, biomass generators, fuel cells and other decentralized generation systems are much more convenient sources of power, thereby cutting down on the line losses associated with long-range transmission.

A key feature of a micro-grid is its ability to separate and isolate itself from the utility seamlessly during a utility grid disturbance with little or no disruption to the loads within the micro-grid. The micro-grid can automatically resynchronize itself when the utility grid returns to normal functioning, and reconnects itself to the grid, in an equally seamless fashion. Additionally, it reduces carbon emission and thus supports sustainable livelihood.

VI. DISTRIBUTED GENERATION IN INDIA

In India, many renewable energy technologies are being employed in a number of decentralized generation projects. The figure below illustrates the technology options for decentralized power generation.

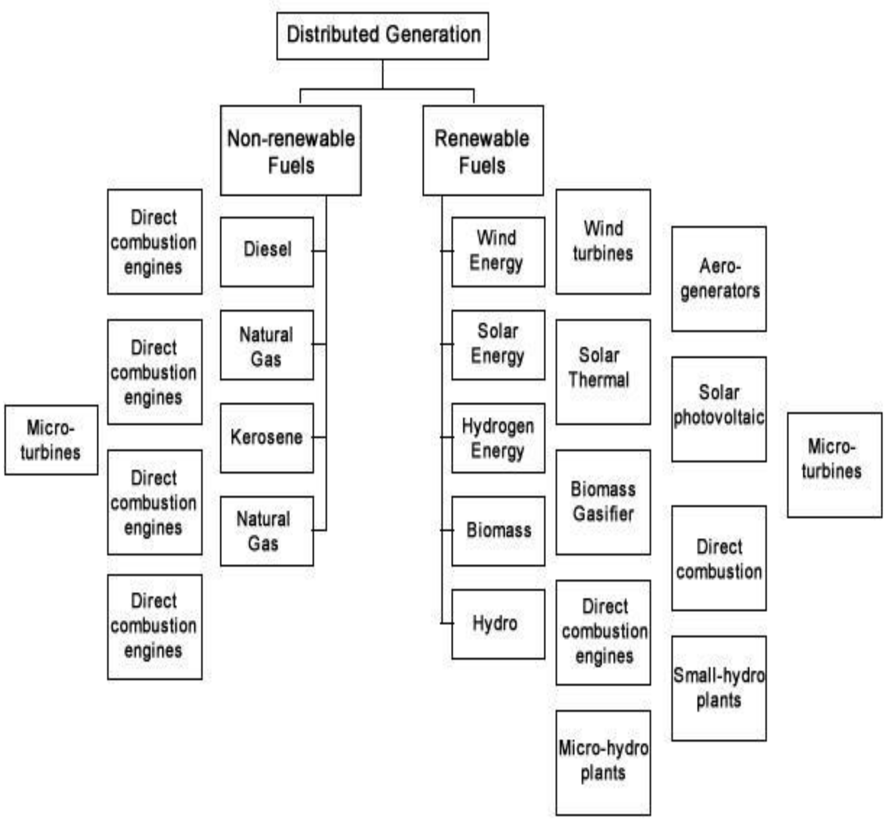

Fig. 2. Technology options for Decentralized Generation

In typical Indian rural areas, smart micro-grids can provide clean, reliable, affordable, and scalable electrical power. For Indian economy rising fuel costs, under investment in old infrastructure and climate change are some of the biggest challenges being faced by the energy industry today. A Micro-Smart Grid can deliver benefit by use of renewable energy sources, while improving the reliability, security, and useful life of electrical infrastructure.

VII. DISTRIBUTED GENERATION IN INDIA

In india, the energy supply is based on the nonrenewable energy sources as well as renewable energy sources. But the coal is the main energy source because 81% of total thermal generation. The Installed generating capacity in India is 207006.04 MW (CEA, August 2012). There is poor electrification status in India because Over 289 million people without access to electricity (~ 74 million households) Over 31,000 villages are yet to be electrified, poor even in electrified villages, Over 80% of rural India dependent on traditional fuels for cooking. India is endowed with good renewable energy resources like solar, wind, and biomass. Even at village level, use of locally available resources is preferable than using fuels/electricity transported from the far-flung areas. Renewable energy is more appropriate as the resources are diffused and decentralized.

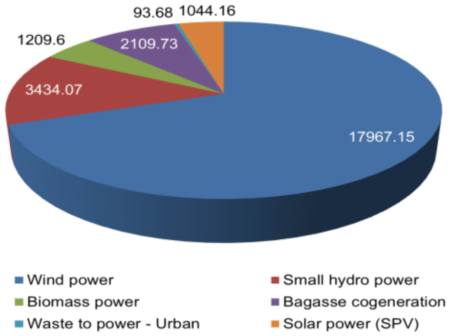

Fig.3. Grid connected RETs in India

VIII. POWER QUALITY ISSUES RELATED TO DGS

Some of the power quality issues might arise when distributed generators are interconnected to the utility distribution system. They are harmonics, voltage variation and voltage flicker, sustained interruptions, voltage sag and voltage regulation. Some of issues related to distributed generation system are discussed here.

Voltage Regulation: Over-voltages due to reverse power flow: If the downstream DG output exceeds the downstream feeder load, there is an increase in feeder voltage with increasing distance. If the substation end voltage is held to near the maximum allowable value, voltages downstream on the feeder can exceed the acceptable range.

Harmonics: DG technologies photovoltaic (PV) and wind generator depend on some form of power electronic device in conjunction with the distributed network interface. These devices inject currents which are not perfectly sinusoidal resulting harmonic distortion. If these harmonics are not properly filtered cause operational problems to load connected on the same distribution system But now new inverter designs are based on IGBTs use pulse width modulation (PWM) technique are capable of generating clean output that satisfy IEEE standards for harmonics [1,2].

Voltage Variation and Voltage Flicker: A wind turbine, a PV panel or a DG unit can result in large and sudden changes in the current injected into the network which results in variation in voltage. In case of wind and solar energy systems, the output fluctuates as the wind and sun intensity change If the wind stop blowing for one wind turbine, it will stop blowing for all wind turbines in the local area. The intermittent nature of DG units can results in variations in the network. Such intermittent power sources can be equipped with battery that stores energy at peak production and injects it into the network when needed. Though the high quality storage systems are expensive but with future advancements it can be cost effective option.

Flicker is variation of luminous flux due to small cyclic variation of supply voltage and this effect is apparent at frequencies in the 5 to 20 Hz range. The magnitude and number of changes of voltages occurring per unit time are compared with GE flicker curve (IEEE standards 519 – 1992[7]) to make sure that they are below the visibility threshold levels. Appropriate mitigation is required [3] if these effects are above the threshold levels.

Voltage Sags : Voltage sags mostly occur in the network due to faults, utility based actions and sudden starts of large loads. During this period voltage decreases between 0.1 to 0.9 Pu for a period of 1 minute [4].

Ability of DG to alleviate sags depends on the type of generation technology and the interconnection location [5]. DG alleviates sags at its own load bus but impedance of interconnection transformer might prevent any relief to other loads on the same feeder.

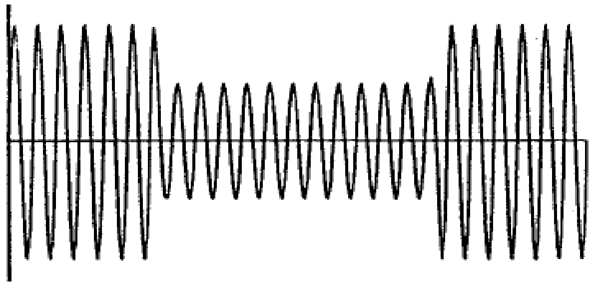

Fig.4. Voltage Sag

IX. MICRO GRID

A micro grid is a localized grouping of electricity generation, energy storage, and loads that normally operates connected to a traditional centralized grid This single point of common coupling with the can be disconnected. The micro grid can then function autonomously. Generation and loads in a micro grid are usually interconnected at low voltage. From the point of view of the grid operator, a connected micro grid can be controlled as if it was one entity. Micro grid generation resources can include fuel cells, wind, solar, or other energy sources. The multiple dispersed generation sources and ability to isolate the micro grid from a larger network would provide highly reliable electric power. Produced heat from generation sources such as micro turbines could be used for local process heating or space heating, allowing flexible tradeoff between the needs for heat and electric power. Small micro-grids covering 30–50 km radius-Small power stations of 5–10 MW to serve the micro-grids Generate power locally to reduce dependence on long distance transmission lines and cut transmission losses.

X. CURRENT MICRO GRID PROJECTS IN INDIA

The MoP has allocated US$44.3 million for smart grid pilot projects across the country. Indian government is going to finalize eight smart grid pilot projects worth US$ 9.69 million by March 2012.

1) One of the high profile partnerships brings together USAID, MOP, the Central Power Research Institute (CPRI) and Bangalore Electricity Supply Company (BESCOM) for a pilot project in Electronic City to cover around 17,500 domestic and business users with $100million fund.

2) The Smart Grid Task Force is currently coordinating eight pilot projects across the country's national electricity grid. For the next 18 months these projects will provide an indication of what the overall framework for a detailed national plan will be.

3) The Bureau of Energy Efficiency (BEE) is partnering with IBM on a project that would conduct a cost-benefit analysis on various smart grid initiatives and the deployment capabilities for smart grid technology by National Mission for Enhanced Energy Efficiency.

4) In India, managing peak load is critical as peak power plants will add an untenable margin to the cost of electricity in a developing nation. The Mangalore Electricity Supply Company (MESCOM) smart grid project [16] will seek to scale back demand rather than cut it off entirely, allowing customers to meet critical demand needs while giving critical sectors un-interrupted supply.

5) North Delhi Power Ltd, (NDPL) a consortium between the government and Tata Power, has partnered with GE for various smart grid solutions. The US Trade and Development Agency awarded NDPL a $686,447 grant for a smart grid project in North-West Delhi intended to reduce blackouts and increase reliability. NDPL is considered a smart grid technology leader in India rolling out smart metering infrastructure and automated meter reading.

6) IBM has joined hands with IIT Kharagpur (IITK) and IIT Madras (IITM) in 2010 to carry out research in Smart Grids to develop systems that will make power grids more efficient and resilient.

The fastest growing market segment is Communications and Wireless with a CAGR of 24.9%, the 2011 value of that sector is $144.5 million. Smart T&D will total $234.5 million in 2011. Smart meters currently constitute $286.6 million in 2011 and are projected to reach $445.5 million in 2015. In 2011, sensors were $136.5 million while software and hardware is estimated at $146.9 million.

XI. CONCLUSION

From this case study it is concluded that the India's Energy generation and consumption are on a high growth rate. The Climate change concerns due to emissions combined with resource and infrastructure constraints are dampeners. The micro-grid system proposed in this paper if properly developed and deployed will be a trend setter for such emerging economies to pursue 'green' and sustainable energy.

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