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DISTRIBUTED GENERATION SYSTEM: A REVIEW AND ITS IMPACT ON INDIA

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Abstract: *As the world is moving towards a dramatic change in the mode of power generation, transmission and distribution, Distributed Generation system is going to play an important role in mitigating the very ongoing concerns about climate change, rising demand for economical power and reliable and sustainable electric power for all. Distributed Generation systems are small power generating units near end users, which provide a way to harvest renewable energy for clean power, even the unexploited ones. Grid connected DG systems serve as the backup in the case of brown outs or black outs and also minimize the central utilities' peak load. In this paper, we have discussed in brief about the Distributed generation system and its impact on Indian power generation system.*

Key words: Distributed Generation system, Benefits, Grid integration, Impact on Indian power generation system, Indian govt. schemes and projects

1. Introduction

By the start of 21st century, the demand of reliable and economical electrical energy has shown an exponential increment, which is leading to the evolution of electrical energy generation, transmission and distribution. Traditionally, central generation plants have been the sole part of the electrical systems, fulfilling the demands of the consumers, located either close to the resources or far from the populated load centers [1]. As the demand of electrical energy is increasing, the central generation plants seem to need an extra hand in providing economical and reliable electrical energy to each and every consumer. In addition, considering the environmental issues, the continuous peak loads on conventional central power plants also play a major role in polluting the environment [2], [3].

To overcome these problems, the idea of distributed generation systems came into existence. Distributed generation (DG) can be defined as the small scale (typically 1kw-50mw) generating units connected to the distribution grid installed close to the load or on customer sites [4], [5]. According to International Energy Agency (IEA), five major factors that have gained the interest of the concept of many small scale energy sources connected to the grid are developments in distributed generation technologies, constraints on the construction of new transmission lines, increased customer demand for highly reliable electricity, the electricity market liberalization and concerns about climate change [6], [9].

Further, in this paper, we will discuss the distributed generation sources, benefits, integration of DG system into the grid (issues and probable solution) and impact on Indian power distribution systems.

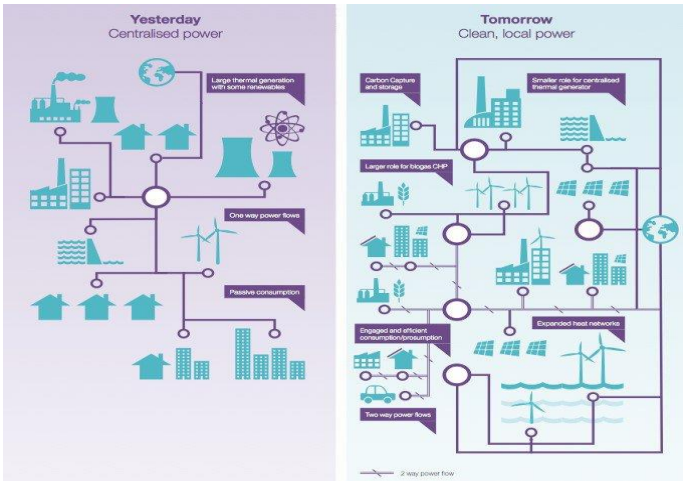

Fig.1. Central and distributed generation [7]

1.1. Distributed Resource source:-

DG should not be exclusively confused with renewable energy generation. Considering environmental issues in today's scenario and the limited availability of the fossil fuels, renewable energy sources(such as solar, wind, biomass, fuel cells etc) are very much encouraged over non-renewable energy sources (like diesel, coal, etc) for exploitation in distributed generation system. The goal of distributed generation system is to minimize the adverse effect of energy production on the environment and introduction of renewable energy sources to the distribution network.

Table 1: DG system resources [8]

Fuel source	Energy conversion	Interconnection
Sun light	Solar Panel	DC-AC Inverter
Wind and hydro	Turbine	Induction Generator
Biomass	Sterling Engine	Induction Generator
Hydrogen	Fuel Cell	DC-AC Inverter
Natural Gas	Turbine	Synchronous generator
Diesel	Reciprocating Engine	Synchronous generator

1.2. Benefits of DG system:-

DG system offers potential benefits to electric system planning and operations. On a local basis there are opportunities for electric utilities to use DG to reduce peak loads, to provide ancillary services such as reactive power and voltage support and to improve power quality. Using DG to meet these local system needs can add up to improvements in overall electric system reliability [9]. Utility deregulation and rural electrification are also the reasons for the high level of interest in Distributed Generation. Other important benefits associated with distributed generation are:

- **Flexibility:-** In today's liberalized market, due to the small sizes and the short construction lead times compared to most types of larger central power plants, flexibility could allow the participants (entities other than electric utilities, such as homeowners, businesses, farmers, manufacturers, non-profits and government entities) to respond to changing traditional method of power generation. It facilitates market interactions, providing customers access to products and services with choice, based on price and environmental concerns. Important aspects of the above mentioned flexibility of distributed generation technologies are operation, size and expandability [10].

- **Reliability: -** Reliability is the most important feature of electric power distribution system. It can be seen as the degree of assurance in providing customers with continuous service of satisfactory quality power supply. It is the probability of non-failure of the system over time. Installation of DG system is one of the many ways to improve reliability of the power distribution since they can be served as backup generation when a utility supply interruption occurs, therefore economic loss as a result of the power outage can be reduced. However, amount of reliability improvement depends on location and size of the DGs to be installed and on the various reliability indices measures. There are many indices for measuring reliability. The three most common are referred to as SAIFI, SAIDI, and CAIDI, defined in IEEE Standard 1366 (Appendix A) [11]

- **Environmental benefits:-**Environmental issues are probably the major driving force for the demand of distribution generation in the electrical power system. Since the renewable energy sources are by nature small-scale and dispersed over the grid, installing DGs provides the opportunity to exploit the cleaner energy within proximity. DGs with Renewable resources are not only capable of producing environmental friendly electrical energy, but also it helps in minimizing the emissions generated by conventional central power plants. The avoided emissions are in a first approximation similar to the amount of energy saving. [3]

- **Cost Efficient:-**The concept of onsite production could result in cost savings in transmission and distribution of about 30% of electrical energy costs. The smaller the customer size, the larger the share of transmission and distribution costs in the electricity bill. Thus, it is seen

as one of the biggest potential drivers for the distributed generation demand. Furthermore, locating the generation close to the loads could also contribute to reduced grid losses. The IEA estimates the grid losses reduction potential for 6.8% in the OECD countries leading to cost savings of about 10–15%. [12]

1.3. Grid Integration:

To include DG systems in the main network of power system distribution, DG systems are integrated with the same grid as the central grid. Grid integration of DG system not only promises more reliable functioning of power system, but also the inclusion of renewable energy resources in the main framework. While they can have positive impacts on the distribution network, they can also have negative impacts at high penetrations if appropriate measures are not implemented. This is due to the occurrence of various technical and economic issues in the grid integration. Those problems arise in the areas of power quality, voltage stability, harmonics, reliability, protection, control and islanding [13]. Each distributed generation resource has its own integration issues [14]. Successful integration of distributed and renewable generation (DG) into distribution networks relies heavily on effective planning and operation strategies. This can be achieved by introducing smart grid and micro grid (with storage devices) in the existing or new distribution networks.

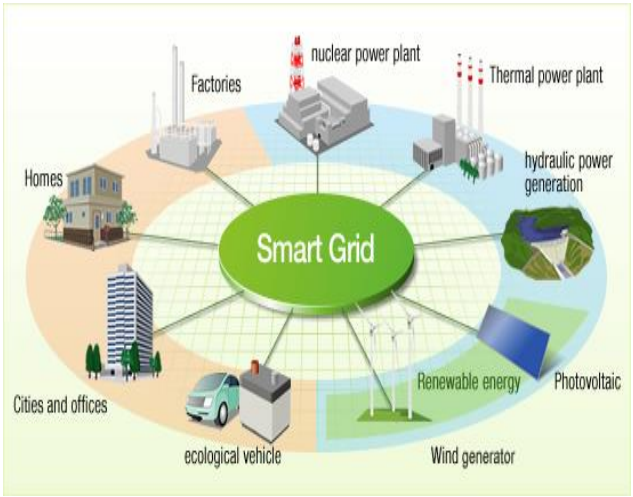

Fig.2. Smart Grid [15]

- "**Smart Grid** is a concept and vision that captures a range of advanced information, sensing, communications, control, and energy technologies. Taken together, these result in an electric power system that can intelligently integrate the actions of all connected users—from power generators to electricity consumers to those that both produce and consume electricity ("prosumers")—to efficiently deliver sustainable, economic, and secure electricity supplies" defined by [16]. The smart grid represents the full suite of various technologies, which can eliminate all the technical issues related to grid integration.
- **Micro grids**, localized grids that can be disconnected from the traditional grid to operate autonomously, provides a single point of common coupling with the traditional grid thus making it easier to integrate different energy source to the main grid and also making the distribution network less complex[17], [18].
- **Storage system** is an integral part of the smart grid /micro grids, due to the fact that availability of renewable energy resources varies with time, day of the week, season, and random factors such as the weather. It increases the effectiveness of the distributed generation system as end users want to be able to use the energy when they need it, not when technology or nature can provide it. Electrical energy is stored during times when production exceeds consumption in the storage unit, and returned to the grid when production falls below consumption. In addition, storage systems can be used to provide services such as peak shaving, load shifting, voltage and frequency regulation, demand side management and outage protection. Various types of storage including batteries, electric double-layer capacitors, Superconducting Magnetic Energy Storage (SMES), flywheels, compressed air and pumped hydro can be used to regulate power output [19].

2. Impact of DG systems on Indian power system:-

2.1. Need of DG system:

India, being the world's second largest populated country, is currently facing heavy energy demand. Regardless of its rapidly growing economy and massive

addition in generation, transmission and distribution capacity over six decades [20], demand has always left the increase in generation capacity behind [21]. The total installed capacity of India has reached 2, 88,664.97 MW (as on 29-2-2016) in which renewable plants constituted 28% of total installed capacity and non-renewable power plants constituted the remaining 72% [22]. The gross electricity generated by utilities is 1030.785 billion KWh, during the fiscal year 2014-2015, with a shortfall of requirement by 38.138 billion KWh (-3.6%). The peak load met was 141,180 MW with a shortfall of requirement by 7006 MW (-4.6%) against the 2.0 % deficit anticipated. The electrical energy demand for 2016-17 is expected to be at least 1392 TWh with a peak electrical demand of 218 GW [23] and it will keep rising more rapidly as the population rises and the quality of life for more Indians improves. However, economic growth and targeted policy intervention have lifted millions out of extreme poverty; energy consumption per capita is still only around one third of the global average and some 240 million people have no access to electricity or 20% of the population remains without electricity. Of the total without access, the large majority (some 220 million people) live in rural areas where extending access is a greater technical and economical challenge. In urban areas electrification rates are much higher, but the quality of service remains very uneven, especially in India's large peri-urban slum areas that are home to around 8.8 million households (national sample survey office, 2014)[24].

Rural electrification in India has long been regarded as a pre-requisite for socio-economic development. Grid connectivity is considered as the most common method of rural electrification of villages. In a large and diverse country like India, with its unique geography and village habitations, grid connectivity is neither feasible nor cost effective [25]. Moreover, India has one of the highest levels of electricity transmission and distribution losses in the world. India's T&D losses are almost 20% of the generation, more than twice the world's average [26].

DG system helps to avoid the impact of massive grid failure [27]. Therefore, off grid or mini grid solutions like decentralized distributed generation facilities stand as an ideal mode of supply of electricity in India. A DG system can employ a range of technological options (like small modular power generation technology combined with energy management and storage facility) from renewable to non-renewable sources and can operate either in a connected grid or an off grid mode.

2.2. DG system in India:-

India, having a diverse landscape and geographical condition, promises a resilient implementation and advancement of DG system as it has unexploited renewable energy sources in abundance, including a large land mass that receives among the highest solar radiation(equivalent to more than 5000 trillion KWh/year) in the world, a long coast line with high wind velocities that provide ample opportunities for both land based and offshore wind farms, significant annual production of biomass and numerous rivers and waterways that have potential for hydropower [28]. India has 45 GW of hydropower and 23 GW of wind power capacity, but has barely tapped its huge potential for renewable energy. India is, however, aiming high in this area with a target to reach 175 GW of installed capacity by 2022 (excluding large hydropower) which is steep increase from today's level of 37 GW [24]. Solar power is a key element of the government's expansion plan. This also seems to keep India's climate pledge of taking a cleaner path by using clean energy technology to deliver clean, reliable, sustainable and affordable energy system at the climate summit in Paris (COP21) [29].

Table 2: Renewable Energy installed capacity of India (as of 29-02-2016): [30]

Grid connected power		Off grid/ Captive power		Potential (MW)
Technology	**Capacity (MW)**	**Technology**	**Capacity (MW)**	
Wind	25217.29	Aerogenerator/ hybrid systems	2.67	102788
Small hydel power projects	4194.40	Micro hydel/ water mills	17.21	20000
Bio-power (Biomass	4826.23	Biomass (non-bagasse	652.37	23000

& gasificati -on and bagasse cogenera tion)		cogenerat-ion)		
		Biomass gasifiers	178.72	
Solar	5547.21	SPV system (>1KW)	307.31	-
Waste to power	115.08	Waste to power	160.16	-
Total	39900.51	Total	1318.44	-

2.3. Indian govt. schemes and projects:

Recently, many renewable energy technologies and schemes are being employed in a number of projects approved by government of India. Some of them are [31]

1) Solar power:

- "Off-grid and Decentralized Solar Applications" scheme of the Jawaharlal Nehru National Solar Mission (JNNSM), namely 'Capital subsidy scheme for installation of solar thermal systems.
- Installation of 10,000 nos. of solar PV water pumping systems for irrigation purpose implemented through National Bank for Agriculture and Rural Development (NABARD) throughout the country.
- Grid Connected Solar Rooftop and small solar power plant Scheme.
- Scheme on development on solar cities.
- Scheme for providing basic lighting needs in 6000 Villages in 60 LWE (left wing extremism) districts in nine states through solar charging stations with LED lanterns.
- Development of grid connected Solar PV power plant on canal banks and canal tops.
- Akshaya Urja shops

2) Wind power:

- R&D projects under Small Wind Energy and Hybrid Systems (SWES).
- Programme on Small Wind Energy and Hybrid Systems (SWES) to develop technology and promote applications of water pumping windmills and aero-generators/ Wind-Solar hybrid systems.
- Under National Wind Resource Assessment Programme, Ministry through National Institute of Wind Energy, Chennai and State Nodal Agencies had installed and monitored 794 dedicated Wind Monitoring Stations (WMS) of height ranging from 20 m to 120 m throughout the country to extend it to new/ uncovered areas which are not explored in earlier projects to complete the Indian Wind resource mapping.

3) Biogas and Biomass power / Cogeneration.

- Scheme to support "Promotion of Grid Interactive Biomass Power and Bagasse Cogeneration in Sugar Mills, rice mills etc.
- Biogas based Distributed / Grid Power Generation Programme.
- Implementation of the National Biogas and Manure Management Programme (NBMMP) in all the States and UTs of the country, which provides for setting up of Family Type Biogas Plants mainly for rural and semi-urban/households.

4) Small hydro power (up to 25 MW):

- Scheme to support identification of new SHP sites.
- Scheme to support for setting up new SHP projects in the private/ co-operative / joint sector and in govt. sector.
- A number of mini/micro hydro projects have been set up in remote and isolated areas, mainly in Himalayan & Western Ghat region.

5) Others: [32]

- Several subsidy schemes for installation of localized DG system (solar, biogas, hybrid, small hydro power).
- National smart grid mission approved to bring efficiency in power supply network and facilitate reduction in power losses and outages.
- Integrated power development schemes in urban areas.
- Projects under hybrid cogeneration (solar-wind, solar-biogas and tri-generation).
- Deen Dayal Upadhyaya Gram Jyoti scheme for rural homes, micro industries and remote villages.

- Various research and development programmes and training programmes in the field of solar, wind, biogas and small hydro power.

3. New technologies in DG system around the world

Realizing the need of clean, efficient and sustainable power for future, many organizations and agencies are focusing on the advancement of the technologies used in grid connected and off grid power generation system relating to renewable source of energy. A significant number of research and development projects are persevering with the aim to achieve maximum efficiency, effectiveness and reliability. Some of them are:

1. Concentrated solar power(CSP).[33]
2. Hybrid co-generation (CSP and Biomass).[34]
3. PETE (photon enhanced thermionic emission) solar panels.[35]
4. ROV for Automated measurement of defects on the offshore wind turbines using a sensor ring to encourage industries towards offshore wind power harvesting.[36]
5. "INVELOX - A Sheerwind's technology" with multiple wind turbine generator systems.[37]

4. Conclusion

Recognizing, the fact that DG system can provide clean, reliable and affordable energy all at the same time, distributed generation moves to the forefront of the public and private sectors consciousness. They show a perfect blue print of today's and future's power generation and distribution system which could meet the demanding needs of the consumers economically and environmentally by minimizing the cost, complexity, interdependencies and inefficiencies associated with onsite power generation, transmission and distribution. Hence, the distributed generation systems are the new future of power generation system.

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