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An Overview of Distributed Generation

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Abstract: *The Power Generated in Karnataka(INDIA) is 7445.91MW and Demand is 8500MWwhich causes the problem of Load shedding, many states face this problem and are forced to buy the power from other states which leads to the extra economical burden, this is where the Distributed Generation (DG) plays a role to cut down the costs of the power purchased. This paper discusses the various aspects of DG Opportunities, conversion system, technology interconnections and environmental performance. Also some of the challenges DG system is confronting, an overview of connection between DG system and Microgrid, the feature aspects of DG and benefits of DG system are also brought out.*

Keywords: *Distributed Generation (DG), Microgrid (MGR), Economic benefits and challenges, distributed generation technologies, environmental performance.*

I. Introduction

Distributed Generation (DG) not an entirely new concept considering the manner in which the early unit operating to produce and deliver the electricity. National grids were formed by large interconnected system that made power system more economic and reliable. DG is a back-up electric power generating unit that is used in many facilities. Most of these back-up units are used primarily by customers to provide emergency power during times when grid-connected power is unavailable and they are installed within the consumer premises where the electric demand is needed. The installation of the back-up units close to the demand centre avoids the cost of transmitting the power and any associated transmission losses. Back-up generating units are currently defined as distributed generation to differentiate from the traditional centralized power generation model. With the lack of significant increase in building new generating capacity or even in expanding existing ones to meet the needs of today's mega cities' demand, the whole electrical power industry is facing serious challenges and is looking for a solution. These issue decentralization of power system and liberalization of the electricity sector, along with dramatically growing demand for electricity in many countries has made DG an attractive option.

The following are the general definition for DG

- IEEE defines DG as: "A facility smaller then central plants/national grids, which is usually 10 MW or less, so that an interconnection can be allowed to any near point in the Grid, as Distributed resources"[1] .
- US Department of energy (DOE) defines DG as: "Distributed power is modular electric generation or storage located near the point of views. Distributed system include biomass-based generation, combustion turbines, thermal solar power and Photo Voltaic (PV) system, fuel cells, wind turbines, micro turbines, engines/generator sets storage and control technology. DG can either be grid connected or independent of the grid. Those connected to the grids are typically interfaced at the distribution system."[2].
- General definition of DG is: "A generating plant connected directly to the grid at distribution level voltage or customer side of the meter" [3].

The general DG technologies are such as solar power and PV, fuel cells, reciprocating engines. Wind technology has been excluded, since it usually appears as wind farms and acts as centralized power plant. The above definition does not specify any criteria or classification of DG capacity. Under different generating schemes diverse rating, behavior, regulation, purpose are being consider as DG in the power industry. Hence the capacity specifications are not universally defined.

1.1 DG Energy Conversion Systems

A typical DG energy conversion system has two main energy converting stages. The first stage is the prime fuel converting block in which the prime fuel internal energy is converted into mechanical energy, as in the case of internal combustion engines. The second stage converts the mechanical energy into electrical power using an electromechanical energy conversion device such asynchronous alternator or induction generator, which produces AC power. Another way of obtaining electrical energy is through a chemical or photosynthesis conversion process. Fuel cells and PV solar energy converter are good examples of this category and produce

DC power. The interfacing unit is essential to convert the produced DC source into harmonized constant voltage and frequency AC power source.

DC to AC power electronic converter system is incorporated as interfacing unit. One important requirement for the inverter is to produce good quality AC power with supply frequency fluctuation limited to 1.2 Hz and with less than 5% THD of its voltage waveform at the coupling point in accordance with IEEE 519 standard [4].Islanding is a condition occurring when a generator or an inverter and a portion of the grid system separates from the remainder of the large distribution system and continues to operate in an energized state. Islanding may pose a safety threat or cause equipment problems; therefore, it cannot be permitted without full coordination and planning between the parties [5–7].An additional requirement of the inverter is to have the capability of preventing the DG from islanding (anti-islanding capability) on the hosting grid.

In the conversion types discussed above, the output produced must meet the hosting grid voltage and frequency standards. A coupling transformer is needed to interface the DG generator with the grid to match the distribution voltage level at the point of connection. Only when it is safe and exact paralleling conditions (synchronization) exists, the DG is interconnected with the grid after obtaining the permission and full coordination from the grid operator.

Another configuration normally adopted for supplying power to sensitive electrical load demand is to use DG armed with a UPS unit. The UPS system normally incorporates an energy storage medium such as batteries to enable power supply continuity as well as improve power quality and reduce the influence of voltage surges, spikes and swells which could cause loss of production. The DG/UPS can be configured in various schemes to meet consumer demand and positively be part of the ancillary support to a hosting grid. In all the systems described above, the DG output could ultimately be interconnected with the grid. The interconnection takes place at the PCC at the grid side. Once the interconnection is established the hosting utility assumes responsibility of DG operation and contribution and treats it as part of its generation system.

1.2 DG Opportunities

Energy investors and utility operators are attracted to the DG role and associated industry for the following foreseen opportunities. DG can be fuelled by locally available renewable and alternative mix of fuel sources to meet today's energy demand. Renewable sources are wind and solar, while alternative fuels are those produced from waste products or biomass and can be in gas, liquid or solid form. Greater independency from importing petroleum fuel can be achieved by incorporating DG that is powered by various fuel sources.

- DG can support future increase in power demand without investment in the expansion of existing distribution network as it can be installed very close to the new load center.
- Installing DG within the industrial/commercial premises avoids negotiating land use and the need for rights-of-way for electric transmission and distribution, thereby minimizing further capital investment.
- DG can be used in reducing intermittent and peak supply burdens on utilities grid by injecting power as and when required.
- DG will have the capability to support the existing energy supply when needed and in a short time (black start) without incurring capital cost.
- DG penetration in the energy market will create overall competitive pricing of energy. The current generation rate ($/KWh) of DG is now competitive with the centralized generation system as efficient fuel energy conversion units, such as fuel cells and micro turbines are continuously improved and diversified.
- DG could contribute to decreasing the vulnerability of the electric distribution system to external threats and hidden undetected faults that may cause wide scale blackout by feeding power to the sensitive infrastructure.
- DG have a flexible feature in the capability to be configured to operate in a stand-by mode, isolated mode, or sharing the load through integration with the existing nearby electric grid. For the general public, using DG that is fuelled by various prime alternative fuel sources will be welcomed in order to reduce fossil fuel consumption.[4-7]

1.3 DG Classifications

DGs are classified according to their rated generation capacity, location, and size and by ownership. DGs are also classified by their functionality in supporting the hosting grid, according to their interconnectivity, power electronics interface or by the prime fuel source used.

DG equipment owned and operated by the power utilities are strategically located along the distribution grid to support the power demand at specific locations for a specific time. The unit size is chosen to meet the required forecasted secondary grid support. Its rated capacity can span from a few watts to hundreds of kilowatts. Small rated units are normally designed to support residential and small industrial consumers and are likely located in urban surroundings. Large capacity DG units designed for large industrial consumers are located in industrial zones. Their units are energized by various primary fuel sources such as fossil polluting and diminishing and non-fossil clean and renewable.

II. Interconnection With Utility Grid

Many of DG units are fuelled by fossil and non-fossil fuel sources. When a cluster of large and capable generating units exist in a confined locality, they pose high potential for creating a distributed resources domain. It is quite possible to create a confined distribution network defined as a Micro Grid (MGR) generating and distribution system [13]. The purpose here is to combine all available energy sources and associated DG units in one domain to meet the demand of the well-defined energy consumer.

MGR infrastructure is based on distributed resources and DG units. Three available distinctive grid architectures are AC, DC and DC/AC distribution MGR.

2.1 AC Architecture

Every DG unit generates high quality AC power. The various DG units are connected together to form a local AC distribution network. The modular structure of connecting DG is as shown in Fig.1. Number of DG units can be added to meet the local demand continuously supplied through the constructed MGR. This configuration requires ancillary support, particularly VAR requirements. Precise coordination between the DG units is essential for the continuity of the power flow into the grid. Depending on the availability of the source, DG can be connected or disconnected from the utility grid and also power exchange with existing utility is possible.

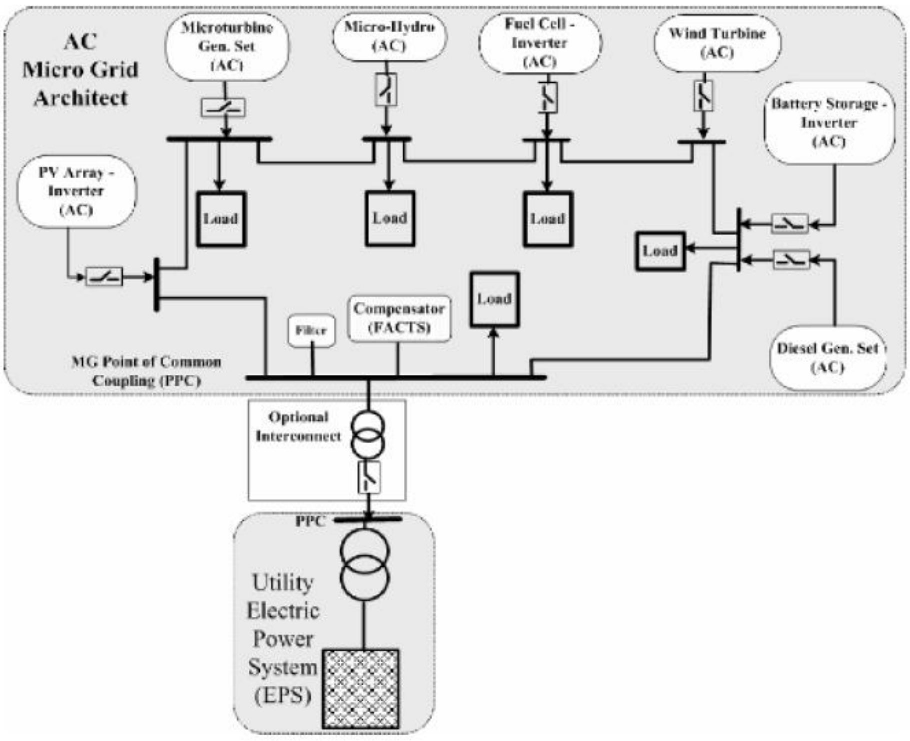

Fig 1 MGR architectures AC based architecture

Example

A PV system with 2-MW with low-voltage DC is not economical due to high power losses. The DC converters are used to step up the DC voltage of PV system to higher voltages to reduce the power losses. However, today, it is more economical to step up AC voltage to higher voltages using transformers for injection to utility system. Figure 2 shows such an arrangement. In addition, to provide regulating capability for the PV station, a number of PV arrays and wind power energy are processed in DC and the energy is stored in a flow battery or battery–flywheel system. The DC power of storage system is used for regulating the load voltage and load frequency control. The size of the storage system is specified by the regulating requirements of the PV station when it has to operate as an island. The PV station voltage is stepped up with the transformer T2 for parallel operation of the PV station as part of the utility system.

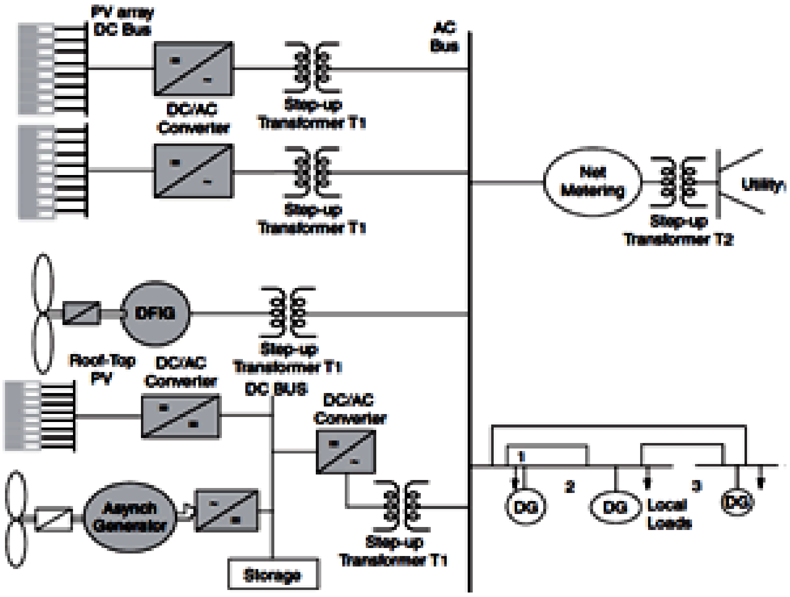

Fig. 2: The Architecture for design of a 2-MVA PV station.

2.3 DC architecture

In this architecture all the DG units are designed to generate DC power irrespective of the availability of prime fuel, creating DC distribution network. The Fig.3 shows created DC bus which can feed directly the individual consumer by standard DC voltage level. Such configuration has high reliability with high redundancy as it requires less sophistication to interconnect DC sources compared with AC sources. The main disadvantage is the risk of having circulating currents between the units. Each consumer may use the DC source or invert into AC source depending on the appliance used. Power exchange with existing utility is also possible by using a grid tie standard inverter unit.

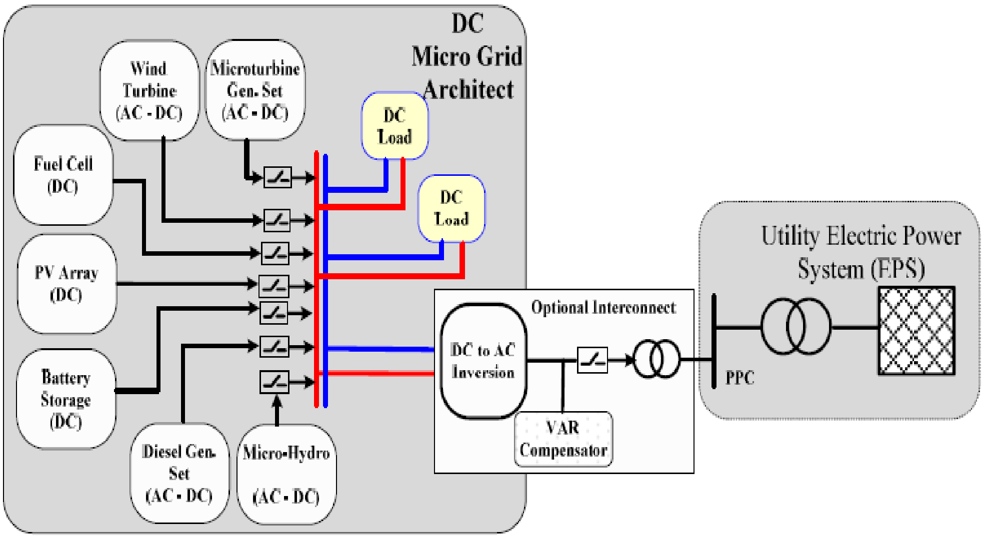

Fig3: MGR architectures DC based architecture

Example

The DG sources are connected to a uniform DC bus voltage including the storage system. This will facilitate plug-and-play capability by being able to store the DC power and use DC/AC converters to generate AC power. Today, commercially available storage devices such as flow batteries and battery–flywheel systems can deliver 700 kW for 5 sec to 2 MW for 5 min or 1 MW for up to 30 min, while 28-cell ultra-capacitors can provide up to 12.5 kW for a few seconds.

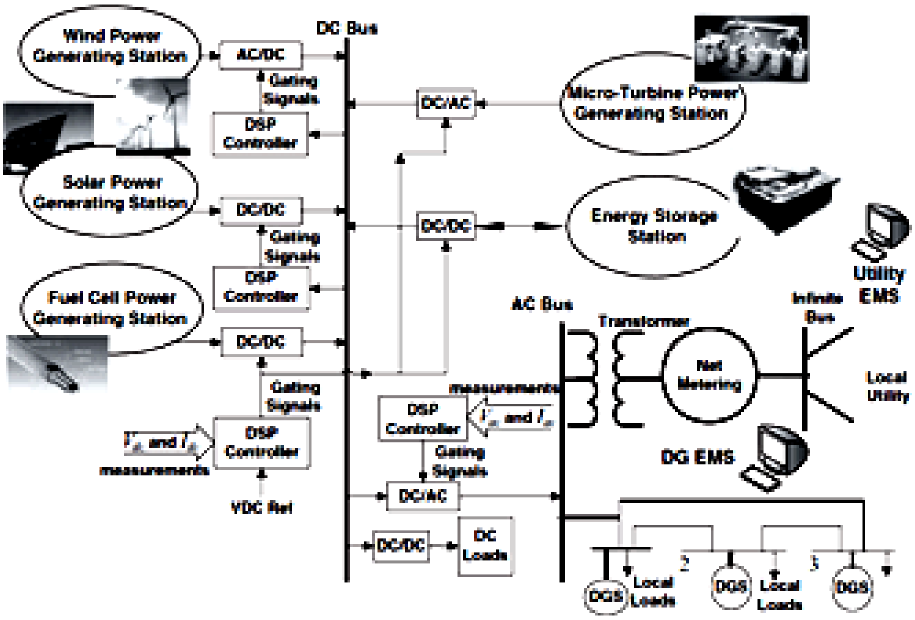

Fig. 4: The DC architecture of grid distributed generation systems.

2.3 DC/AC architecture

MGR could be structured around individual generating units that produce DC voltage sources connected to one DC bus. Collectively, units are networked to centralized AC interface system for the purpose of integration with the existing grid as depicted in Fig 5. A key weakness in this configuration is the total loss of AC power if the centralized inverter is down.

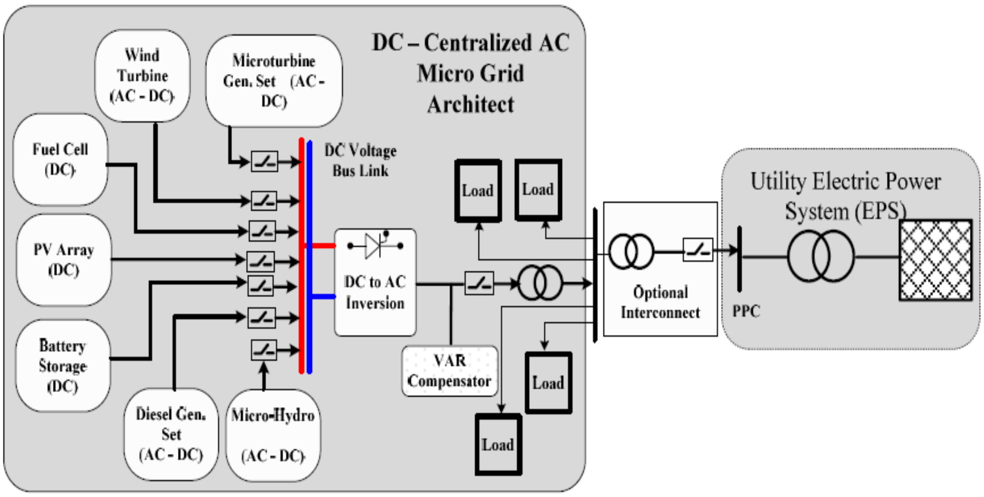

Fig 5: MGR architectures DC and centralized AC based architecture

In all possible architectures, different interconnection or energy management challenges need to be identified and addressed by the MGR operator and by the. Hosting network, such a variety of ways DG can be integrated with each other and with a hosting grid provides several opportunities. It provides support to the energy sector along with new and emerging technologies. It also opens new research areas and assists in creating employment opportunities in the sector.

III. Economic Benefits And Challenges

The DG systems have an impact on electricity prices, improvement in power quality, combined heat and power generation. Additional advantages are utilizationof the waste as energy resources, fuel flexibility and micro grid benefits.

1. Impact on electricity prices

In the electricity markets the independent system operator (ISO) charges the customers with an uplift energy prices according to all services which are required to keep the system running in unrealizable manner. This uplift is the combination of transmission services, market administration, operating reserve, losses in secondary auxiliary and it approximately amounts to 20% of the energy market prices. This additional cost adds an extra tariff to the actual electricity market. Distribution companies and large consumers instead of buying electricity directly from the market may consider implementing DG system to meet the increasing load demand. This will reduce the cost and consumer can purchase less power from the gird.

2. Utilization of the waste as energy sources and fuel flexibility

DG technology use energy resources that are not economically or feasible to transport or convert. Some oil fields have low quality gas that is not economical to transport and is ignited when disposed. Gas turbine and micro turbine can utilize the bio-mass gas obtained from waste water treatment, landfills and farms. The most commercialized DG technologies uses oil or natural gas, most part of the research has been only towards fuel cells and gas turbine which uses natural gas because of which advantage of DG system due fuel flexibility is limited.

3. Combined heat and power (CHP)

This technology can increase the overall efficiency of the production to more the 90% by combining both heat and electricity usage efficiently. This technology is the better option, since the produced heat can be used onsite.CHP usually a small increase in cost which is proportionalto the total capital cost of the unit (less than 10% for industrial applications),hence economical also.

4. Microgrid

Microgrid is a new concept in which a cluster of loads and DG systems operate to improve the reliability and quality of the power system in a controlled manner. For customers Microgrid provides the need for power and heat in a reliable way. For the whole system, Microgrid are dispatch able cells which can respond to the signals from the system operator very fast. Information technology achievements along with new DG systems with intelligent control systems allow system operators and Microgrid operators to interact in an optimal manner [15].

5. Remote area electrification

The potential application of the DG is to provide electricity to the consumers who are located far from the grid and usually do not have enough demand to justify for expanding the grid. The only possible way to energize customer in remote communication site is though DG, mostly using PV system.

IV. Environmental Performance Of DG Systems

The main environmental concern of electricity production is its effect on the local and regional air quality by emission of NO and other greenhouse gases, in particular Carbon-did-oxide. This emission is largely associated with non-renewable power generating technologies such as coal-fired generation.

Diesel-fired ICE has the highest NO emission and in most regions the diesel engines cannot be operated for more than 150 hours (in USA). In regions with Coal fired generation, installation of low emission DG units such as gas turbines, micro turbines and fuel cells can reduce the emission of NO in the region.

Carbon-di-oxide emission from non-renewable DG technologies has to be considered as well. All non-renewable DG technologies without heat recovery have higher carbon-di-oxide emissions than combined-cycle plants. So coal plants with CHP system can reduce carbon-di-oxide emission. Commercially available DG systems still have a long way to go to be significantly helpful in emission reduction programs [12].

V. Conclusions

The potential applications for distribution generation (DG), decentralization of power system and the trend to use renewable energies in most developed countries suggests that DG may have a large share in power generation in the future. The DG opportunities, challenges and the economical benefits have been discussed, examples of the grid architecture has been included. Nevertheless, more research and development is required to overcome the barriers that DG systems are currently confronting. Higher efficiency, lower emissions and lower capital costs are the main goals DG systems need to accomplish. The electricity market regulatory authorities and government policy makers should consider the worth of DG systems and modify the structure, operation and pricing mechanisms of the open markets to help their viability and development.

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