A new energy alternative: Distributed Generation

Surbhi Bakshi
surbhi_pec@yahoo.com
Deptt. of Electrical Engg, PEC University of Technology, Chandigarh, India

Abstract: ***Distributed Generation is currently preferred for clean power generation in the form of renewable power generation systems. All the different parts of an electric power system, customers identify closely with the distribution subsystem due to its proximity and visibility on a daily basis. It has a significant impact on the distribution systems. DG plays a significant role in the electric power system of the near future. This paper presents an analysis of DG as a feasible solution. In addition, several compact distributed generation technologies are fast becoming economically viable. This paper also discusses technologies of DG, the technical and potential benefits of DG. Integration of DG into an existing utility can result in several benefits. This work also studies the goals and applications of DG.***

Index Terms: Distributed generation (DG), Distribution networks, benefit of distributed generation.

1. Introduction

More than fifty years, Electric power system development has been based on centralized large generating stations and with large generating units at a relatively small number of locations. In these stations, the voltage is stepped up to high voltage, extra high voltage, and ultra high voltage (HV, EHV and UHV) levels to be transmitted over long distances through interconnected transmission systems. The voltage from the HV transmission systems is then stepped down to radial medium voltage (MV) distribution systems and then to radial low voltage (LV) distribution systems, where the electric power is distributed to the loads [1]. Over the last few years, a number of influences have been combined to lead to the increased interest in the use of small-scale generation, connected to local distribution systems, which is commonly called 'Distributed Generation'. Environmentally friendly electricity supply, electricity market liberalization, constraints on the construction of new transmission lines, increasing demand on highly reliable electricity supply, and reduction of the usage of fossil fuel resources, are some of benefits that DG can offer [2-5].

DG can come from renewable or non renewable energy resources, using both modern and conventional technologies. DG technologies include internal combustion engines, small gas turbines, wind turbines, small combined cycle gas turbines, micro turbines, solar photovoltaic, fuel cells, biomass and small geothermal generating plants [6-8].

The structures of a traditional electric power system and a power system with distributed generation are shown in Figure 1. The presence of local generation in a distribution system will affect the distribution system. For example, the DG will alter the power flow in the distribution system, and the distribution system can no longer be considered as a system with unidirectional power flow. On the other hand, distribution systems have, for many years, been designed based on the assumption that the power flow is unidirectional [6], [9-11]. Hence, the presence of the DG, especially when the DG share is significant, will obviously impact the power distribution system operation and control.

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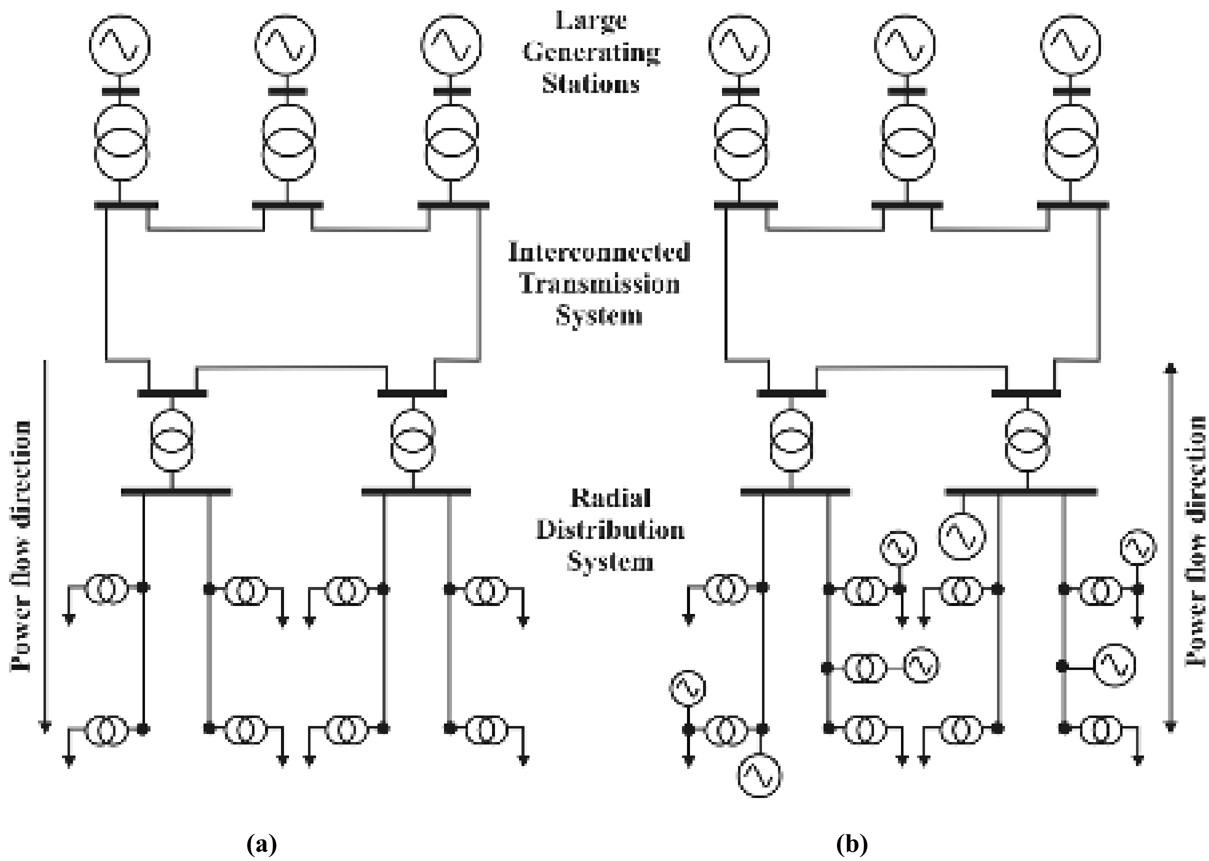

Figure 1. a)Traditional electric power system and b)electric power system with distributed generations

Normally, the term Distributed Generation refers to any electric power production technology that is integrated within distribution systems, close to the point of use. Distributed generators are connected to the medium or low voltage grid. They are not centrally planned and they are typically smaller. Central power is composed of large capital-intensive plants and a transmission and distribution (T&D) grid to disperse electricity. Distributed generation complements central power by (i) providing in many cases a relatively low capital cost response to incremental increases in power demand, (ii) avoiding T&D capacity upgrades by locating power where it is most needed, and (iii) having the flexibility to put power back into the grid at user sites.
DG is a faster, less expensive option to the construction of large, central power plants and high-voltage transmission lines. They offer consumers the potential for lower cost, higher service reliability, high power quality, increased energy efficiency, and energy independence.

2. DG Technologies

Distributed generation (DG) technologies can meet the needs of a wide range of users, with applications in the residential, commercial, and industrial sectors. In addition, DG units can help meet the changing demands of end users for premium, reliable or green power. Distributed generation technologies can provide energy solutions to

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some customers that are more cost-effective, more environmentally friendly, or provide higher power quality or reliability than conventional solutions. Some of the DG technologies offer high efficiency, resulting in low fuel costs, but emit a fair amount of pollutants (CO and NO_2); others are environmentally clean but are not currently cost-effective. The main DG Technologies are:

- Combined heat and power (CHP, or cogeneration) systems: CHP are systems that produce both electrical and thermal energy and use the heat or steam for industrial processes, heating or cooling. Systems can run on fossil fuel, biomass or waste heat and can be designed to use more than one fuel. Among the technologies are internal combustion engines, combustion ands team-cycle turbines, micro turbines, fuel cells, Stirling engines and gasification digesters.
- Systems that use renewable energy resources: To generate electricity without making use of any waste heat, such as solar electric systems, wind turbines, small hydroelectric generators, and turbines or internal combustion engines using landfill gas.

  Wind turbine systems - In recent years, wind turbine generation has developed rapidly as a competitive and effective source of distributed generation. Wind turbines (WT) use wind energy to generate electricity and have various ratings from a few kW to a few MW [12]. To produce electric power, WT can be operated at variable or constant speeds and is coupled to induction generators. Nowadays, induction generators are widely used in WT and a variable speed generator is the preferred option in newer WT installations Wind turbines are currently available from many manufacturers and range in size from less than 5 to over 1,000 kW. They provide a relatively inexpensive compared to other renewable) way to produce electricity. Wind turbines are being used primarily in remote locations not connected to the grid and by energy companies to provide green power.
- Reciprocating engine generators and small combustion turbines that run on diesel or natural gas: The engines range in size from less than 5 to over 5,000 kW, and use either diesel, natural gas, or waste gas as their fuel source typically used for backup power or for power in remote locations. Many of these technologies can be more energy-efficient and cleaner than central-station power plants. Their smaller size can better match gradual increases in utility loads. Distributed generation also can reduce demand during peak hours, when power costs are highest and the grid is most congested. If located in constrained areas, distributed generation can reduce the need for distribution and transmission system upgrades. Adding small generators to the grid also can increase reliability. Customers can install generation to cap their electricity costs, sell power, participate in demand response programs, provide backup power for critical loads.
- Microturbines: Microturbines are currently only available from a few manufacturers. Their models range from 30 to 200 kW. Micro turbines promise low emission levels, but the 2 units are currently relatively expensive. Obtaining reasonable costs and demonstrating reliability will be major hurdles for manufacturers. Micro turbines are just entering the marketplace, and most installations are for the purpose of testing the technology.
- Fuel cells - Fuel cells are electrochemical devices that convert fuel (hydrogen) and air directly to electric power and provide thermal energy through electrochemical processes Although the first fuel cell was developed more than one hundred fifty years ago, this technology remains in the development stage. Currently, fuel cells are commercially available from only one manufacturer, with several others developing units in the 5 to 1000+ kW size range. Fuel cells does not burn hydrogen and there are no moving parts during operations .The emission levels are quite low, but cost and demonstrated reliability remain major problems for the market penetration of this technology.. Unlike other distributed generation, FC efficiency is higher than 60 per cent, which is considered to be double that of conventional power generations [13].The fuel used is generally natural gas or hydrogen.
- Photovoltaic - The Photovoltaic module is an unregulated DC power source that uses semiconductor cells. It generates direct voltage and current from sunlight that falls on the cells. In order to interface the array to the

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power systems, it has to be conditioned first and a DC/AC inverter has to be used [14]. PV systems have no moving parts, and thus require less maintenance and generate electricity without producing CO_2. Commonly known as solar panels, photovoltaic (PV) panels are widely available for both commercial and domestic use. Panels range from less than 5 kW and units can be combined to form a system of any size. However, they can be quite costly. Photovoltaic are currently being used primarily in remote locations without grid connections and also to generate green power.

3. Benefits of DG

Most of the benefits of employing DG in existing distribution networks have both economic and technical implications and they are interrelated [9, 12].

Potential Benefits are:

- Has a lower capital cost because of the small size of the DG (although the investment cost per kVA of a DG can be much higher than that of a large power plant).
- May reduce the need for large infrastructure construction or upgrades because the
- DG can be constructed at the load location.
- If the DG provides power for local use, it may reduce pressure on distribution and transmission lines.
- With some technologies, produces zero or near-zero pollutant emissions over its useful life (not taking into consideration pollutant emissions over the entire product lifecycle i.e. pollution produced during the manufacturing, or after decommissioning of the DG system).
- With some technologies such as solar or wind, it is a form of renewable energy.
- Can increase power reliability as back-up or stand-by power to customers.
- Offers customers a choice in meeting their energy needs.

Technical benefits are:

- Reduced line losses
- Voltage profile improvement
- Reduced emissions of pollutants
- Increased overall energy efficiency
- Enhanced system reliability and security
- Improved power quality
- Relieved T&D congestion

Economic benefits are:

- Deferred investments for upgrades of facilities
- Reduced O&M costs of some DG technologies
- Enhanced productivity
- Reduced health care costs due to improved environment
- Reduced fuel costs due to increased overall efficiency
- Reduced reserve requirements and the associated costs
- Lower operating costs due to peak shaving
- Increased security for critical loads

4. Goals of DG

DG can be selected, sized to meet the respective goals such as reducing utility bills, improving electrical system reliability, improving selling power, improving payback of emergency or legally required standby systems and generating environment friendly power.

- Reducing electric utility bill: The fundamental goal of DG is to reduce electric utility bill. DG can reduce electric utility bill by lowering energy usage and peak demand charges from electric utility. DG can reduce the peak demand as seen by utility if DG supplies a portion of onsite load during the peak demand during billing cycle.
- Improving electrical system reliability: The reliability of electric power supply can be improved by installing DG. DG can reinforce the electric utility grid during times of peak loading and if necessary, by islanding or disconnecting from the grid and operating independently during power outages.
- Improving selling power: DG can be installed to fulfill the goal of selling power. It is necessary that the output of DG sources must exceed the load at the site.
- Improving Payback of Emergency or legally Required Standby Systems: Some generation systems are installed as emergency or legally required standby systems where required by applicable codes such as hospitals, high rise buildings [15]. Emergency or standby systems which can be either fuel cells or certain type of engine generators can be connected to the electric utility grid and operated as DG to recover installation costs for these required systems.
- Generating environment friendly power: DG can be installed to generate environmentally friend power. Solar photovoltaic, wind power produce no emissions. Also the fuel cells and microturbines when operated on hydrogen created by electrolysis using solar photovoltaic or wind power produce no emissions.

5. Challenges associated with DG system are:

- There are no uniform national interconnection standards addressing safety, power quality and reliability for small distributed generation systems.
- The current process for interconnection is not standardized among provinces.
- Interconnection may involve communication with several different organizations
- The environmental regulations and permit process that have been developed for larger distributed generation projects make some DG projects uneconomical.
- Contractual barriers exist such as liability insurance requirements, fees and charges, and extensive paperwork [12,16].

6. Applications of DG:

Distributed generation (DG) is currently being used by some customers to provide some or all of their electricity needs. There are many different potential applications for DG technologies:

i. Continuous Power - In this application, the DG technology is operated at least 6,000 hours a year to allow a facility to generate some or all of its power on a relatively continuous basis. Important DG characteristics for continuous power include: ·

- High electric efficiency,
- Low variable maintenance costs, and
- Low emissions.

Currently, DG is being utilized most often in a continuous power capacity for industrial applications such as food manufacturing, plastics, rubber, metals and chemical production. Commercial sector usage, while a fraction of total industrial usage, includes sectors such as hospitals, etc.

ii. Combined Heat and Power : characteristics are similar to those of Continuous Power, and thus the two applications have almost identical customer profiles, though the high thermal demand necessary here is not a requisite for Continuous Power applications. As with Continuous Power, Combined Heat and Power is most commonly used by industry clients, with a small portion of overall installations in the commercial sector. Important DG characteristics for combined heat and power include:

- High useable thermal output (leading to high overall efficiency),
- Low variable maintenance costs, and
- Low emissions.

iii. Green Power - DG units can be operated by a facility to reduce environmental emissions from generating its power supply. Important DG characteristics for green power applications include:

- Low emissions,
- High efficiency, and
- Low variable maintenance costs.

Green power could also be used by energy companies to supply customers who want to purchase power generated with low emissions [17].

iv. Premium Power - DG is used to provide electricity service at a higher level of reliability and/or power quality than typically available from the grid. Important DG characteristics for premium power (emergency and standby) include:

- Quick startup,
- Low installed cost,
- Low fixed maintenance costs

7. Conclusion

Distributed generation is expected to become additional significant in the future generation system. DG is emerging as a new pattern to produce on-site highly reliable and good quality electrical power. Thus, the DG systems are presented as a suitable form to offer highly reliable electrical power supply. The concept is particularly interesting when different kinds of energy resources are available, such as photovoltaic panels, fuel cells or wind turbines. The DG of different kinds of energy systems allows for the integration of renewable and nonconventional energy resources. The benefits obtained by the introduction of DG should be weighed against the costs involved before deciding on the use of DG. As DG technologies improve and cost decrease, their use is expected to rise.

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