CHAPTER 3
DISTRIBUTIVE POWER GENERATION: ESSENTIAL ASPECTS

3.1 Preamble
This chapter deals with the various factors associated with the different concepts of the power system, issues of the power system, distributed power system, problems in the distributed power system, and power management in the distributed system, fault tolerance and cost factor in the distributed system.

3.2 Existing System
The technological advancement in the various domains has forced to think of different methods to fulfill the demands of power. These demands usually need to be fulfilled by traditional power systems (composes generation, transmission, and distribution) [98]. The output factor of this power system mainly depends on the type and size of the generation unit. The generation units are capable of generating the power ranges from 102Mega-Watt to several Giga-watts [99]. The generation unit and load units are located at a longer distance and are mainly linked with each other by the transmission line and distribution feeders.
The prime feature of the power system is to offer reliable as well as economical electricity to the end users [100]. The power generation influences present power systems from renewable energy resources like solar, wind, etc. The critical issues that electrical utilities are facing are low power quality, reliability and high construction, operation and maintenance cost. The prior objective of the present power system is to provide sufficient power to the end users [101].

3.3 Limitations of Existing System
The power industries are in transition with the aim of developing new power distribution system to fulfill the futuristic demands of power [102, 103]. In that sense many of the following points are to be considered:

- The interest towards the Distributed Power Generation (DPG) based on renewable resources will be continued due to environmental factors.
- Better use of electric power at customer end achieving significant response for the demand has become the primary concern.
• Due to increased regulatory action at customer end, it is leading to the power quality issues and the same way the climatically variations are expected to bring higher failures.

• The economic factor is also one of the major concerns because the utilization of the existing system has become very high. The conventional distribution system development with passive wires may lead to low utilization rate.

• It is found that most of the components of the traditional system of power are at the end of their lifetime which requires replacement in a safe and controlled manner.

• The power industries have limited themselves with regulations to achieve profit in business. This indicates the rationalization of power management under short-term and long-term perspective.

• Nowadays disturbances are increasing in both probability and consequences. The failure rates in the system are increased due to climatically variation and power system complexity leads to increased likelihood. These sequences are growing due to the higher dependency on electrical energy. The distribution system faces the following issues while enhancing the functionalities:

• Conventional power generation, distribution and loads been considered independent processes. With the increased interest towards the distributed power system, it is introducing the changes in the traditional methods.

• A reason for increased attention towards the existing resources at a power distribution system is a complexity of interconnection process.

• As per the power management perspective, the increasing amount of distributed power generation is considered with reluctance as it leads to complexity in the transmission unit to the distribution unit.

• Mainly, the complexity takes place due to existing methods of distribution unit management and also the features of various resources components themselves which are not built to achieve simple interconnection.

• Thus far customers and loads will have passive networks. Also by introducing the flexible and interactive customer connection, it can bring controllable operation, load control and cost minimization can be achieved.
3.4 Distributed Power Generation

Generally, a distributed system of DPG can be used for small and micro-generators to supply for houses, factories and where the low voltage of power is required. The power demands of the customers are directly fed by the active distribution system to meet customer’s power demands [104]. The storage system is used to store the generated excess power. Substantial power systems and renewable systems are connected to higher voltage transmission lines subjected to back up the power solution and dispute the quality of power [105]. The storage systems are mainly utilized to accommodate the generated output power. DPG mainly effects relay protection system, network voltage and the planning of the distribution grid [97]. The Figure 3.1 illustrates the DPG model.

The interest towards the non-conventional model of DPG system is increasing due to its cost-effectiveness in offering system capacity to meet the demands of power. These DPG systems are having the capability of operating over gas fuels and offers efficient, reliable, flexible and clean onsite power alternatives. This kind of advancement in DPG system can be obtained by incorporating the energy provider companies and independent power supplier companies to fulfil consumer demands. Both these options need better time and cost investment to enhance the capacity [106].

Additionally, DPG is accompanied with main power by a) providing low investment cost response to increased power demand, b) avoiding Transmission and Distribution (T&D) capacity upgrades through locating the power whenever required., and (c) having power flexibility at a grid and user area. The technological advancement in the research domain improves the economic, operational and environmental performance [104,105].
3.4.1 Current Trend

Due to reduced investment in T&D and minimized losses in T&D, the distributed power generation (DPG) is attracting most of the market specialists, policymakers. The significant improvement in the current power technologies has reduced the cost of the small-scale power systems. The micro-turbine is one of the powerful techniques in DPG which exhibits the capacity of 102 KW, and it has smaller size like an automobile engine. The large-scale power systems generate the power of > 102 MW and these are used in a vertically integrated system (exhibits a higher cost). This factor of cost variation has affected the power maintenance problem leading to necessary technological development to reduce the cost of T & D in the large-scale power system. Most of the business persons are focusing on the futuristic perspective of distributed power generation that includes cost saving and supplying reliable power to the industries as well as homes.

The DPG plays a significant role as it contains demand management techniques and offers low-cost electricity [105,106, 107, 108].
3.5 Applications of Distributed Power Generation

The applications of DPG can be found at consumer end to fulfill their electricity requirements. Various application areas of DPG are found in today’s world as a) few consumers utilize DPG to bring down power demand generated by electrical equipment b) Some consumers use DPG as the primary source to eliminate the environmental emission. The electric utilities also use the DPG to increase their distribution systems. Also, some other applications exist for DPG and are detailed with respect to electric utility and users [109, 110, and 111].

3.5.1 Interrupted Power

In order to accomplish this application, DPG will be operated for 6K hours in one year that facilitates generation of some or all the power on a continuity basis. The DPG characteristic in this application includes:

- Higher power efficiency
- Least maintenance cost
- Fewer emissions

Nowadays, the distributed power generation is mainly used in continuous power supply for the industries like plastic, food, metal manufacturing and chemical production. In commercial aspects, the DPG is used for industrial sectors like grocery stores and hospitals.

3.5.2 Hybrid (Power and Heat)

This application is meant for both cooling, cogeneration, heating, where DPG is operated uninterruptedly to facilitate the generation of power. The heat energy generated by DPG can be used in water heating, steam formation, thermal requirements or space heating. The thermal energy can be utilized in special cooling components. The characteristics associated with this application are given as:

- Higher efficiency
- Least maintenance cost
- Less emission.

These hybrid (heat and power) characteristics are the same as that of continuous power, and hence the applications are helpful for high thermal demands and are not
useful in un-interrupted power applications. As per this, the hybrid system is useful in both the commercial as well as industrial applications.

3.5.3 Peaking Power

In this application, the DPG is operated over 3K hours/year to minimize the power cost. The units are produced in this peaking time to reduce the power demand or avoid buying of electricity during higher price. The DPG includes following characteristics for this applications:

- Low installation cost
- Speedy start
- Least and Fixed maintenance cost

This application is presented by most of the power companies with an intention to minimize the buying cost at high price duration. Mainly, the applications of this kind of DPG can be observed in commercial areas where load profile matches with industrial sectors. The main application of this can be seen in educational institutes, lodging, etc.

3.5.4 Green Power

DPG units are facilitated to operate to minimize the environmental emissions from generating its power supply. This DPG includes the following characteristics in green power applications:

- Higher efficiency
- Least maintenance cost
- Less radiation.

This can also be utilized in different power companies to fulfill the customer demand with a particular client who wants to buy low emission based power.

3.5.5 Premium Power

The DPG is utilized at the global level to supply the electricity with higher quality, reliability than available from the grid. The increasing market value of premium power offers utilities with a perspective of providing the value-added quality of service to the clients. Most of the customers demand unbreakable power supply and hence the premium power can be categorized as emergency, standby and true power.
3.5.6 Transmission and Distribution Deferral

The use of DPG in better areas can postpone the purchase of a new transmission system and power equipment. A systematic cost analysis of various alternatives can lead to various issues relating to equipment deferrals need to observe properly. The characteristics associated with T&D are:

- Low installation cost
- Least and Fixed maintenance cost

3.5.7 Ancillary Service Power

This can be utilized by an electric utility to give subordinate associations (interconnected activities fundamental to influence the trading of power between the purchaser and the dealer) at the T&D level [111]. In business zones where the electric business has been de-controlled and associate associations unbundled, DPG applications offer explanations behind enthusiasm over start at eventually used advances. The aide associations merge cleansed age which can be set up to serve additional request) and non-turning or supplemental, spares which aren't associated with the system regardless whether it is fit for serving request inside a specific time that can be from the structure inside a predefined time. Other potential services go from responsive transmission supply and voltage control, which utilizes creating offices to keep up an appropriate line voltage transmission, to distribution level neighbourhood, which gives move down energy to end clients on account of a framework fault. The qualities that may impact the selection of DPG advancements for auxiliary administration applications will change as per the administration performed and a definitive state of the power service market [109-111].

3.6 Distributed Power Generation Technologies

The DPG includes the following technologies for present power industries [91-101].

3.6.1 Reciprocating Engines

This DPG advancement was made over a century back, and is still by and large utilized as a part of a broad bunch of usages. The engines stretch out in gauge from < 5 - 5,000 kW and use diesel, vaporous petroleum, or waste gas as their fuel source. Still, the progression wears down improving the viability, and on reducing
release, levels is going on. The reacting engines are for the most part used for fortification of basic power, stopping power, and in cogeneration applications.

3.6.2 Micro-Turbines
This is an emerging technique which is currently available from rare manufacturers. The other manufacturing industries were focusing on the models which provide the power of 30kW to 200kW. The micro turbine systems are promising for low emission levels while its units cost is more expensive. Thus, achieving low cost with better reliability in the system is the biggest issue for the manufacturers. The ideology of this system has just entered the business industry which needs proper testing phase.

3.6.3 Industrial Combustion Turbines
This is the biggest technology, whose capacity ranges from 1 MW to >5 MW. These technologies exhibit low cost, least emission levels but lags with low efficiency of electric rating. These exhibit low capital cost, emission levels, and also low electrical efficiency ratings. The development works on these issues are going on and even the ideology of this system has just entered the business industry which needs proper testing phase.

3.6.4 Photovoltaic
This is commonly considered as the solar panels or photovoltaic (PV) panels, and these can be used in both the commercial and domestic aspects. The panel range varies from less than 5 kW, and its units can be integrated for any size of systems. This system does not produce emissions and also needs very less maintenance but its cost is very high. Thus, manufacturing industries are focusing on designing low-cost components and eliminate the economic barriers of PV systems which can be used in remote areas as it does not need any grid connections.

3.6.5 Fuel Cells
These cells are exceedingly proficient and furthermore deliver low discharges. These cells work like a battery. It supplies power by consolidating hydrogen and oxygen electrochemically without burning. In any case, while the battery is a capacity gadget for the vitality that is in the end spent as well as must be energized; the energy
unit is for all time bolstered with fuel and an oxidant, so the electrical power age proceeds. The last item is unadulterated water; the electrochemical response produces power and warmth without a fire ("cool burning"). A solitary cell gives short of one volt, so a progression of energy units are regularly "stacked" one on another to build the power yield.

The fundamental energy component has two terminals isolated by an electrolyte. One of the cathodes (the anode) is provided with the fuel (for instance, hydrogen or petroleum gas). The second anode (the cathode) is provided with oxygen by basically drawing air in. The few energy units presently being utilized to give premium power. There are a few kinds of energy components. Proton trade layer power devices are presently days the most monetarily accessible compose. They have the most noteworthy vitality thickness per volume rate, and their costs are required to fall quickly since they are being adjusted by the car business for transportation utilize [107].

3.6.6 Wind Turbine Systems

These are accessible from numerous manufacturers and range in estimate from under 5 to more than 1K kW. They give a generally reasonable (contrasted with other inexhaustible) approach to create power, however as they depend upon the variable and fairly eccentric breeze, are unsatisfactory for seamless power needs. Improvements endeavours hope to combine twist turbines with battery stockpiling frameworks that can give control in those circumstances when the turbine isn't turning. Wind turbines are being utilized basically in remote areas not associated with the framework and by vitality organizations to give green power.

3.7 Benefits Of DPG

There are various rounds of beneficial features for DPG that makes it preferred utilization for the commercial application of power. Majority of the beneficial features are associated with the tangible benefits to the consumers. The benefits of DPG with respect to customer and supplier perspective are discussed.
3.7.1 Customer Benefits

The properly installed DPG can improve energy supply reliability, increasingly critical for industrial as well as for business aspects. Following are the few benefits of DPG meant for customers; [111]

- The technologies of DPG present various opportunistic benefits for selecting better energy solution at required area of applications. These technologies can offer the stand-alone power application for different areas where the T&D infrastructures do not, or it may be expensive to install.
- The DPG likewise gives the proficient gain at the application region by lessening the line misfortunes and by using both the power and created warm amid the influence age process or by warming.
- The DPG provides flexible operation as it has small modular units which help in electricity saving through the self-generating process at high cost (peak power duration) and utilizing low-cost interruptible power rates.
- The DPG also makes a significant mark in providing the highly efficient promotion of renewable resources, low pollutant fossil energy technologies. The DPG provides power which can be delivered in the environmentally friendly way with least pollutant emissions.
- The DPG provides flexible, satisfactory supply of energy needs for the users.
- The DPG is small in size which offers superior performance with fuel flexibility towards the environment.

3.7.2 Supplier Benefits

The DPG has the limitation of constraints where the higher presentation and hazard variables can happen because of size, adaptability and quick establishment time managed by little, ecological neighbourly and separately built and fuel adaptable frameworks. Also, DPG gives the following beneficiary things to the supplier.

- With DPG, the unnecessary cost of investment can be limited by matching the capacity which increases with increment in the demand.
- The DPG avoids the major capital investment in T&D system upgraded by installing new power generation units near to the customer end.
- This also allows a low-cost system with the power industry.
- The market for remote areas for T&D systems.
3.7.3 National Benefits

The DPG technologies rely on the renewable resources which offers environmental friendly power generation and that yields beneficial factors for the national power sector in the world market.

3.8 Issues of DPG

The DPG system exhibits the following issues with different factors of power system [101-111].

3.8.1 DPG Electrical Interconnection

The interconnection with the framework is an entrapped technique that incorporates DPG application affirmation. The DPG movement is commonly suggested as a synchronized or parallel assignment. In this outline, the DPG is related with the framework for a comparable time that it's conveying power and for the circumstance that the load is met any excess demand, then it is transmitted to that. The parallel DPG action is the most convoluted curiously with a standalone DPG application. The versatile nature of DPG undertaking depends upon the level of participation within the present framework.

3.8.2 Technical Issues

The primary problems specialized for DPG association identify with dependability and nature of supply, assurance, metering, and working conventions for association and disengagement, islanding and receptive power administration. Voltage control, voltage glimmer, constant voltages and DC infusion is a basic nature of supply issues. Security issues emerge both for DPG gear and system hardware. The DPG assurance issues rely upon the kind of generator and the attributes of the system. System assurance issues rely upon the sort and area of the DPG establishment and system attributes. Consequently, insurance configuration requires great correspondence between DPG venture designer and system specialist organization amid the outlined procedure [107]. It might be hard to grow financially solid strategies to pay the redesigns in the utility foundation to ensure against those dangers. Specialists concur that the present changes to the dispersion framework from the parallel activity of little generators, speaking to just a modest division of a neighbourhood dissemination system's ability, are typically reasonable. In any case,
the combined impacts of many generators would be another issue. The utility system may require critical overhauls and extra defensive gadgets to oversee appropriate generators that could utilize a huge nearby dispersion system's ability.

### 3.8.3 Protection Issues

The security of the power framework is a specialized issue that is adequately vital to merit isolate dialog. The security plans to distinguish the fault condition (maybe because of a lightning strike or gear disappointment) and seclude the bladed area of the framework as quickly as could reasonably be expected while re-establishing normal activity to whatever is left of the frame. Coordinating the DPG with appropriation arranges presents a wellspring of vitality at a point where there might not have been a source previously. This may expand the "fault level" in the framework (that is, the fault current that may stream when the fault happens) and may convolute fault location and confinement. In a run of the urban mill system, DPG might be associated at voltage levels extending from 240V single stage to 132 kV (line-line). Associations at 132 kV are mind-boggling however surely knew, while associations at 240/415V and 11 kV can be more troublesome, for the most part on the off chance that they include net infusions into the system [112]. The objective of insurance plan within sight of DPG is to keep up the previous standard of consistent system quality, security, and quality, facilitate with existing system assurance and give sensible reinforcement.

The assurance masters suggest the utilization of devoted, utility quality insurance gadgets instead of depending on DPG control gear that is utilized as a part of the typical activity. Since each DPG establishment includes a remarkable blend of age and framework factors, security must be intended for each task and ought to be embraced as right off the bat in the venture plan as could be allowed [113].

### 3.8.4 Commercial and Planning Issues

The issues related to the costs and DPG benefits. In a couple of circumstances, DPG may have the ability to surrender mastermind increment costs, decrease compose adversities and improve impact structure security and nature of supply. In various conditions, DPG may drive additional power system working costs and require an enthusiasm for sort out assets. From one perspective, mastermind pro
communities and structure directors may feel that DPG advocates misrepresent the benefits of DPG, while of course; DPG protectors may feel that framework pro centres and system overseers overestimate the costs.

This refinement in points of view may be unavoidable given the inventive thought of DPG and its ability to significantly change the power business. In any case, the common thought of intensity industry action and wander in like manner contributes by darkening accountabilities and in this way clouding both the possibility of appropriate business responsibilities and assessments of whether those requirements have been met. All around, courses of action are being looked for after through general business sharpens and managerial traditions, notwithstanding the way that this technique is hampered by the basic thought of retail control exhibits in which the two buyers and DPG share. Before the introduction of DPG, spread orchestrate coordinators simply expected to consider the effect of supply from the central network generators.

DPG presents essentialness sources in movement frameworks where they had not existed beforehand, with a wide arrangement of advancement composes and properties. As the structure gives the fundamental conductor to the scattering of intensity, the coordinator's basic test is to have the ability to measure and guess the region and size of DPG related with the framework and to ensure that the discount objectives as set above are refined. DPG can bring both positive and negative characteristics from the perspective of scattering orchestrating:

- Positives can join the likelihood to yield utilization on sort out development, decrease organize hardships and improve comes about for the earth, voltage control and in addition openness and nature of supply.
- Negatives can join stresses over prosperity and protection, extended capital utilization, malignant effects on security and constancy of openness of supply, and more unfortunate outcomes for the area condition, voltage control and nature of supply.

DPG foundations must be reviewed on an individual commence, beside insignificant <10kW units, because of the assortment in DPG sizes and advancement composes,
and in light of the way that the impact on the framework can be zone specific. This results in long application getting ready circumstances and may secure essential costs. With improved learning and perception of the issues by all social occasions, the evaluation of impacts will push ahead. For little foundations, there is a prerequisite for the better systematization of conditions of affiliation. For more impressive foundations, there are basic issues to be kept an eye on which has a tendency to achieve extended application taking care of times and startling costs for the backer [104-114].

3.9 Summary

This chapter has expressed the essential aspects of the distributive power generation that is included with an explanation of the prior limitation in present power system model, generation of power from different resources, existing trend in the power research domain associated with DPG. The chapter also highlighted the applications of DPG, its technologies, benefits and finally the issues associated with DPG.