Distributed Generation Overview

Distributed generation (also known as distributed resources, dispersed power, or distributed energy resources) is the use of small-scale power generation technologies (typically in the range of 3 to 10,000 kW) located near the load being served. This type of generation is connected to the distribution network rather than the high voltage transmission network and provides an alternative to or an enhancement of the traditional electric power system.

While centralized electric power plants will remain the major source of electric power supply, distributed generation can complement it by providing incremental capacity to the utility grid or to the specific load. Utilities can avoid or reduce the cost of upgrading transmission and distribution systems by installing distributed generation at or near the load. Distributed generation also has the potential to improve the reliability of the power supply, reduce the cost of electricity, and lower emissions of air pollutants through the use of renewable distributed energy generation and "green power" such as wind, photovoltaic, geothermal or hydroelectric power.

Several reasons exist for the high level of interest in distributed generation. Some of these include the desire for alternative renewable resources, the need for higher quality power for some commercial and industrial facilities, and the ability to use cogeneration. However, two of the most important reasons for interest in distributed generation are deregulation and the lowering cost of distributed technologies.

For the past 60 years, electricity production and supply has been performed by centralized, regulated electric utilities that have controlled power generation facilities as well as the transmission and distribution lines. Since the 1970s, federal and state public policy has encouraged the opening of the electric power system to entities other than the electric utilities. A significant change in the U.S. regulatory system began with the
Energy Policy Act (EPAct) of 1992, which required interstate transmission line owners to allow all electric generators access to their lines.

The deregulation has allowed more competition within power generation and has opened access to the transmission system by paying users. This competition in the wholesale electricity markets has increased the possibilities for sales of customer-owned distributed power. Furthermore, the newly competitive markets can feature prices that vary hourly and that are high during periods of peak demand, creating a situation where it would be most profitable to operate distributed generators.

The second drive for distribution engineering is the advances in electricity generation technologies that have reduced the costs of smaller-capacity systems (generally those under 2 MW). Typical costs of electricity from certain distributed generation systems are now within range of those from large-scale power plants (100 MW or more), which are typically used by vertically integrated utilities. The costs of some technologies are even below the average prices of electricity in some regions of the United States, such as New England as shown below in Figure 1.

Figure 1: Levelized Cost of Selected Distributed Generation Technologies (Goett)
With deregulation allowing customers to use distributed generation and technology advances making it comparable to grid power, many applications have been found for distributed generation. Among the many applications, the most common are customer-owned generators that produce both electricity and steam for on-site use (called cogeneration) and emergency backup generators. Together, those two sources account for more than 95 percent of the customer-owned generation capacity in the United States.

Cogeneration, also known as Combined Heat and Power (CHP), uses the exhaust heat from the electricity generation process as useful thermal output, typically steam, which significantly increases the overall efficiency of the system. This steam can be used as a heat source for both industrial and domestic purposes or can be used in steam turbines to generate additional electricity (combined cycle power). For the most part, the cogeneration plants that have been built to date are large facilities that sell the majority of their output to utilities.

Standby or emergency power applications are driven by the reliability of the grid and the cost of an outage to the customer. Although the distributed generation unit may only operate a few hours per year, it is used to power critical devices whose failure would result in property damage or threatened health and safety. Public safety codes may require some (e.g. hospitals and airports) to install and maintain emergency power units, while the high cost of outage drives others to implement these units. The choice of technologies for these emergency and standby applications is determined by installed cost, time required to start (black start response), fuel access and storage, and size and weight of the unit.

Continuous customer generation applications produce power on a nearly continuous basis, running at least 6,000 hours per year. Considerations for this application include the competing grid price, as well as the installed cost of the unit and fuel costs, maintenance costs, power quality, and the reliability of grid power. Furthermore, residences and small commercial establishments (such as ranches and dairy farms) that are located far from the transmission and distribution system may choose continuous generation. This eliminates both the cost of connecting to the grid and problems that result from being at the end of a long distribution line, such as power outages and lower quality power.
Distributed generation can also be used by commercial and industrial facilities that need higher quality power and reliability to operate effectively and to minimize costs. These customers include banks, semiconductor manufacturers, grocery stores, hospitals, and many other industrial and commercial market sites. Another application is peak shaving, where distributed generators are operated only during high demand utility charges, when the cost of operating the generator is less than the grid price. Also, some states allow customers to use net metering for their distributed generation. In this case, the excess generation is sold back to the grid at the same retail price as the customer buys power from the grid during other periods.

Although there are many benefits and applications for having distributed generation connected to the grid, it also carries risks for the distribution system. The system becomes more difficult to manage as customers add and draw electricity from the grid at will, resulting is lower power reliability and quality. If ratepayer-funded investments are necessary to maintain the quality, the retail price of electricity could rise. Also, having distributed generators connected to the grid can hinder the ability to detect and interrupt faults on the circuit. Furthermore, distributed generation can prove a safety risk if part of the distribution circuit is believed to be de-energized (to clear a fault or for maintenance), but a distributed generator is energizing the circuit (called islanding). While distributed generation benefits the system overall, the risks must be taken into account when adding distributed generation to the grid.

The specific technologies implemented vary based on the application of the distributed generation. Most cogeneration plants are fueled by natural gas, although coal and biomass also power a significant portion. Most backup generators are internal combustion engines fueled by diesel oil or gasoline. Diesel-fired backup generators are commonly used in high-rise buildings for safety reasons (as required by local building codes), in hospitals, and in manufacturing facilities that depend on a highly reliable supply of power. Wind turbines and solar photovoltaic systems are renewable technologies that are currently used to generate electricity at homes and businesses. However, those technologies produce electricity intermittently and generally are not available to operate continuously.
Reciprocating engines are the most common and most technically mature of all distributed generation technologies. They are available from small sizes, such as 5 kW for residential back-up generation, to large generators, as much as 7 MW. Reciprocating engines use commonly available fuels such as gasoline, natural gas, and diesel fuel. Another prominent technology is conventional combustion turbine (CT) generators. They typically range in size from about 500 kW up to 25 MW for distributed generation, and as much as 250 MW for central power generation. They are fueled by natural gas, oil, or a combination of fuels. Modern single-cycle combustion turbine units typically have efficiencies in the range of 20 to 45% at full load and can be used for cogeneration.

The direction that distributed generation takes in the future depends on the emerging technologies and policies concerning the connection of generators to the grid and the pricing of electricity bought and sold by the customers. Rather than serving only as an emergency backup or providing cogeneration to large facilities, small generation systems could operate regularly. Customers could use distributed generation to meet most of their on-site requirements while relying on the grid as a source of additional power and as an outlet for excess power that they might generate (net metering). Utilities that distribute power to retail customers could use distributed generators to meet local peak loads (such as adding distributed generation at the substation) or to provide highly reliable electricity service to customers that required it.

Distributed generation may play a larger role, along with demand-management techniques and further innovations in wholesale and retail markets, in reducing the cost of electricity when traditional supply is tight or market demand is strong. For example, distributed generation may offer retail customers greater flexibility to alter their demand for electricity in response to hourly changes in prices (real-time pricing), thereby promoting the efficient operation and stability of energy markets as they become increasingly competitive. Some observers also expect distributed generation to aide in the commercial development of renewable energy and high-efficiency technologies.

Fuel cells and microturbines are frequently mentioned as such newly emerging high-efficiency technologies that are expected to contribute significantly to distributed generation in the future. Microturbines are small combustion turbines that are typically
installed as back-up power, though in some installations, these units can be used for peak shaving, net metering, or continuous generation. The turbine engines being coupled to high-speed generators in microturbine applications are from the same family of small jet engines that have been employed in the military and transportation industries for the past 50 years. These microturbine systems are considered to employ the most reliable power producing technologies in stand-alone and distributed systems.

Microturbines produce between 25 kW and 500 kW of power. Most microturbines are single-stage, radial flow devices with high rotating speeds of 90,000 to 120,000 revolutions per minute. However, a few manufacturers have developed alternative systems with multiple stages and/or lower rotation speeds. Microturbine generators can be divided in two general classes, recuperated and unrecuperated. Recuperated microturbines recover the heat from the exhaust gas to boost the temperature of combustion, which increases the efficiency, while unrecuperated microturbines have lower efficiencies, but also lower capital costs. While some early product introductions have featured unrecuperated designs, the bulk of developers' efforts are focused on the more efficient recuperated systems. Furthermore, excess recovered exhaust heat can also be used in a cogeneration configuration. Along with other emerging technologies, microturbines are expected to increase the use of distributed generation by providing an efficient and reliable power source.

Policymakers also have a large impact on the future of distributed generation. There are four main barriers that inhibit investment in distributed generation. The first is contractual and technical requirements for the installation of protective equipment and safety devices. While these requirements are necessary to protect the grid and ensure power quality, proponents of distributed generation argue that they are often duplicative, excessive, and time-consuming. The second barrier is the surcharges imposed by utilities on operators of distributed generators for standby service. Again, proponents contend that those surcharges often do not reflect the actual cost of the service and do not acknowledge the benefits distributed generation to the grid. The third barrier is pricing of electricity that is based on the utilities' average cost rather than their marginal cost (the cost of supplying an additional unit of electricity). Proponents argue that average-cost pricing does not give owners an incentive to operate their distributed generators during
periods when doing so will lower the overall cost of electricity. The fourth barrier is the environmental and permitting requirements of local governments, which, in the proponents' view, broadly restrict the installation and operation of electricity-generating equipment or impose burdensome approval processes on applicants.

These barriers that certain industry practices and governmental rules present to customers' potential investments in distributed generation could be lowered in two general ways. First, clarify and standardize the rules for connecting distributed generators to the grid. This approach could streamline the approval process and help to reduce uncertainty about the requirements and costs of compliance. Second, set the prices that operators of distributed generators pay and receive for electric power, connection to the grid, and transmission and distribution services at levels consistent with the actual costs to utilities to provide those services. This change could give customers incentives to install and operate distributed generators at a level that would help to ensure the lowest cost of electricity for all customers.

The many benefits of distributed generation are apparent through the many different applications that have been found for it. Critical and sensitive areas (e.g. hospitals and microchip manufactures) are aided by the use of distributed generation for back up or for premium power. Large industries are able to use the excess heat in a cogeneration process, while customers can reduce costs through peak shaving and net metering. However, the benefits of distributed generation are not without risks, as the system operators must try to maintain power quality and reliability with customers adding and drawing electricity from the grid. If policymakers are able to maintain the safety of the distribution system while reducing the barriers to investment, then distributed generation will see continued interest and advancement. While mostly used for cogeneration and backup, the future of distributed generation looks promising as emerging technologies such as fuel cells and microturbines offer efficient, reliable sources of power.
References


