

## **Distributed Generation – An Alternative**

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Users of alternative power sources range from a restaurant using a micro turbine generator to lower its monthly electric utility bill to an office complex installing a fuel cell to run its data center allowing a savings to extensive facility electrical distribution equipment and system modifications.

Distributed generation is no longer just for large manufacturing facilities and/or industrial plants. A convergence of trends is sparking interest in distributed generation (DG) also known as distributed power (DP). They include an increased demand for reliable and high quality electric power, shrinking reserve capacity, troubles with deregulation and restructuring of the electricity industry, an aging and under-built electric power transmission grid that is increasingly overloaded and widespread opposition to construction of new power plants.

Improvements in technology and a growing demand for environmental friendliness in power generation has seen an increase in use of DG products. Distributed power is modular electric generation or energy storage located at or near the point of use. It ensures continued electricity during system outages, maintaining electric reliability and can allow customers to save money by switching to distributed generation during high cost peak periods or take advantage of peak shaving incentives offered by utility companies.

DG also provides stand-alone, remote power generation where the electric utility connection point is not readily available. Homes, commercial buildings and manufacturing facilities can generate electricity with the use of small DG systems such as; micro turbines, solar cells, wind turbines, diesel generators and fuel cells. Each of these sources can either be connected to the electric utility for parallel operation or operate independently for stand-by operation.

DG systems typically range in size from less than a kilowatt (1 kw) to tens of megawatts. Because these distributed power systems are typically closer to the user, and possibly used only by the user, the chances of outages occurring are decreased.

If distributed power systems are connected for parallel operation with the electric utility, then users could buy and sell excess power back to the utility and could add to the utility companies grid capacity. The connection arrangement and selling of electricity will vary with each electric utility company.

DG faces several roadblocks such as regulatory processes, which will increase the cost of new distributed power projects. Current practices still reflect the previously regulated electricity industry dominated by utilities with rate structures that are not priced to reflect benefits that distributed generation can provide. One of the biggest roadblocks distributed power faces is how each state and utility company has different interconnection requirements. Simplifying these requirements would help minimize engineering and design costs, streamline the installation of distributed systems and increase safety with more reliable, standardized protective relaying systems.

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Interconnection with the electric utility grid continues to be a source of conflict and is not utility bias; it is the safety of personnel who have to clear faults and protecting the DG generator from feeding into a utility fault. A fault could cause the DG system to be tripped off line, requiring it to be resynchronized with the utility grid. When reconnected, the potential for uncoordinated back feeds to the system poses problems to line workers that may be working on dead lines that can become re-energized. Complex protective relaying and close coordination with the serving electric utility is required.

The following identifies the more popular forms of DG forms with a brief description of their technology:

### **Reciprocating Diesel or Natural Gas Engines**

Reciprocating engines, developed more than 100 years ago and were the first among DG technologies. These engines have gained widespread acceptance in almost every sector of the economy. They are used on many scales, with applications ranging from fractional horsepower units that power small tools to enormous 60 MW base load electric power plants. Smaller engines are primarily designed for transportation and can usually be converted to power generation with little modification. Larger engines are most frequently designed for power generation, mechanical drive, or marine propulsion.

Reciprocating engines are most commonly fueled by diesel or natural gas, with varying emission outputs. Almost all engines used for power generation are four-stroke and operate in four cycles (intake, compression, combustion, and exhaust). The process begins with fuel and air being mixed. In turbocharged applications, the air is compressed before mixing with fuel. The fuel/air mixture is introduced into the combustion cylinder and ignited with a spark. For diesel units, the air and fuel are introduced separately with fuel being injected after the air is compressed.

Reciprocating engines are currently available from many manufacturers in all size ranges. They are typically used for either continuous power or backup emergency power. Cogeneration configurations are available with heat recovery from the gaseous exhaust.

### **Microturbines**

Microturbines are an emerging class of small-scale distributed power generation in the 30-400 kW size range. The basic technology used in microturbines is derived from aircraft auxiliary power systems, diesel engine turbochargers, and automotive designs. Several commercial units are now available for purchase.

Microturbines consist of a compressor, combustor, turbine, and generator. The compressors and turbines are typically radial-flow designs, and resemble automotive engine turbochargers. Most designs are single-shaft and use a high-speed permanent magnet generator producing variable voltage, variable frequency alternating current (AC) power. Most microturbine units are designed for continuous-duty operation and heat can be recuperated to obtain higher efficiencies.

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### **Combustion Gas (Miniturbines) Turbines**

Combustion turbines range in size from simple cycle units starting at about 1 MW to several hundred MW when configured as a combined cycle power plant. Units from 1-15 MW are generally referred to as industrial turbines (or sometimes as miniturbines), which differentiates them both from larger utility grade turbines and smaller microturbines. Miniturbines are currently available from numerous manufacturers. Historically, they were developed as aero derivatives, spawned from engines used for jet propulsion. Some, however, are designed specifically for stationary power generation or compression applications in the oil and gas industries. Multiple stages are typical and along with axial blading differentiate these turbines from the smaller microturbines described above.

Combustion turbines have relatively low installation costs, low emissions, and infrequent maintenance requirements. However, their low electric efficiency has limited turbines to primarily peaking unit and combined heat and power (CHP) applications. Cogeneration DG installations are particularly advantageous when a continuous supply of steam or hot water is desired.

### **Fuel Cells**

Although Sir William Grove developed the first fuel cell in 1839, it was not put to practical use until the 1960's when NASA installed this technology to generate electricity on Gemini and Apollo spacecraft. There are many types of fuel cells currently under development in the 5-1000+ kW size range, including phosphoric acid, proton exchange membrane, molten carbonate, solid oxide, alkaline, and direct methanol. A number of companies are close to commercializing proton exchange membrane fuel cells, with marketplace introductions expected soon.

Although the numerous types of fuel cells differ in their electrolytic material, they all use the same basic principle. A fuel cell consists of two electrodes separated by an electrolyte. Hydrogen fuel is fed into the anode of the fuel cell. Oxygen (or air) enters the fuel cell through the cathode. With the aid of a catalyst, the hydrogen atom splits into a proton (H<sup>+</sup>) and an electron. The proton passes through the electrolyte to the cathode and the electrons travel in an external circuit. As the electrons flow through an external circuit connected as a load they create a current. At the cathode, electrons combine with hydrogen and oxygen, producing water and heat. Fuel cells have very low levels of NO<sub>x</sub> and CO emissions because the power conversion is an electrochemical process. The part of a fuel cell that contains the electrodes and electrolytic material is called the "stack," and is a major contributor to the total cost of the total system. Stack replacement is very costly but becomes necessary when efficiency degrades as stack-operating hours accumulate.

Fuel cells require hydrogen for operation. However, it is generally impractical to use hydrogen directly as a fuel source; instead, it must be extracted from hydrogen-rich sources such as gasoline, propane, or natural gas. Cost effective, efficient fuel reformers that can convert various fuels to hydrogen are necessary to allow fuel cells increased flexibility and commercial feasibility.

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### **Photovoltaic (PV)**

Photovoltaic systems are commonly known as solar panels. Photovoltaic (PV) solar panels are made up of discrete cells connected together that convert light radiation into electricity. The PV cells produce direct-current (DC) electricity, which must then be inverted for use in an AC system. Current units have efficiencies of 24% in the lab and 10% in actual use, below the 30% maximum theoretical efficiency that can be attained by a PV cell.

Insolation is a term used to describe available solar energy that can be converted to electricity. The factors that affect insolation are the intensity of the light and the operating temperature of the PV cells. Light intensity is dependent on the local latitude and climate and generally increases, as the site gets closer to the equator.

Photovoltaic systems produce no emissions, are reliable, and require minimal maintenance to operate. They are currently available from a number of manufacturers for both residential and commercial applications, and manufacturers continue to reduce installed costs and increase efficiency. Applications for remote power are quite common.

### **Wind Turbines**

Windmills have been used for many years to harness wind energy for mechanical work like pumping water. Farms were the main user of windmills to produce electricity with electric generators. In the U.S. alone, eight million mechanical windmills have been installed.

Wind turbines, basically windmills dedicated to producing electricity, were considered the most economically viable choice within the renewable energy portfolio. Today, attention has remained focused on this technology as an environmentally sound and convenient alternative.

Wind turbines produce electricity without requiring additional investments in infrastructure such as new transmission lines, and are thus commonly employed for remote power applications. They are currently available from many manufacturers and improvements in installed cost and efficiency continue.

Wind turbines are packaged systems that include the rotor, generator, turbine blades, and drive or coupling device. As wind blows through the blades, the air exerts aerodynamic forces that cause the blades to turn the rotor. As the rotor turns, its speed is altered to match the operating speed of the generator. Most systems have a gearbox and generator in a single unit behind the turbine blades. As with PV systems, the output of the generator is processed by an inverter that changes the electricity from DC to AC so that the electricity can be used.

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There are eight major customer DG applications:

### 1. Customer Generation

Allowing customers to continuously generate their own electricity, with or without grid backup. Continuous customer generation applications produce power on a nearly continuous basis, running at least 6,000 hours per year. When evaluating the usage of DG technologies in this capacity, customers consider competing grid price, as well as the installed cost of the unit and fuel costs. Maintenance costs, power quality, and reliability of grid power are other critical components. In non-attainment areas, emissions can provide a strong barrier to these applications.

### 2. Cogeneration

Permitting customers to generate power while serving their thermal and/or cooling loads. Cogeneration, also known as Combined Heat and Power (CHP), utilizes otherwise wasted exhaust heat as useful thermal output, typically steam. The steam may be used either for space heating or space cooling. Again, CHP applications are driven by grid price and installed cost, but emissions can provide a strong barrier to implementation, especially in non-attainment areas. As with continuous power applications, these units will run on a nearly continuous basis, typically at least 6,000 hours per year.

### 3. Peak Shaving

Generating a portion of electricity onsite to reduce the amount of electricity purchased during peak price periods.

Driven primarily by high utility demand charges, peak shaving applications (sometimes called peak clipping) are also affected by installed cost, perceived unit reliability, and fuel prices. These units operate much less frequently than do continuous power or CHP applications, often running as few as several hundred hours annually.

### 4. Selling Power

Licensing customers to sell excess generation back to the utility grid when their own demand is low, especially during peak pricing periods. Depending on what state they live in, some customers may be eligible for net metering. If eligible, net metering effectively allows a customer to sell its excess generation back to the grid at the same retail price as the customer buys power from the grid during other periods. With this financial incentive, the market for small commercial and residential DG installations, especially those based on renewable energy technologies, should increase.

### 5. Standby/Emergency Generation

Using standby or emergency power to backup grid based power. Applications providing standby or emergency power are typically driven by the reliability, perceived or real, of the grid and the cost to the customer of outage. Although the DG unit may only operate a few hours a year, it is used to power critical devices whose failure would result in property damage and/or threatened health and safety. Some customers like hospitals and airports may be required by code to install and maintain these units. For others, the high cost of outage drives the application. The choice of DG technologies for these emergency and standby applications is determined by installed cost, time required to start (i.e. black start response), fuel access/storage, and size/weight of the unit.

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### 6. Premium Power

Improving customer power quality and reliability. On-site generation can improve both power quality and power reliability, especially when backed up with grid-based power. This application requires a DG technology that can operate continuously. In an era of both increasing power outages and rising demand for premium power, many businesses may install DG units to protect against the risk and cost of power outages. These customers include banks, semiconductor manufacturers, grocery stores, hospitals and many other industrial and commercial market sites.

### 7. Green and Remote Power

Serving niche applications, such as "green" power or remote power. Many of the renewable technologies and fuel cells have very low emissions. With the addition of emission-reducing technologies, microturbines and miniturbines also emit low levels of regulated gases. Customers who are environmentally inclined may purchase these DG applications for this reason, even if they must pay a slight premium for green power compared with grid based power purchases.

Residences and small commercial establishments (such as ranches, dairy farms and flower growers) that are located well away from the transmission and distribution (T&D) system may opt to generate their power onsite. By doing so, they eliminate both the cost of connecting to the grid and any problems associated with their position at the end of a long T&D line. The elimination of these problems, which include power outages and lower quality power, can produce the compelling economics necessary to further the use of DG technologies in a remote power capacity.

### 8. Residential

Meeting continuous power, premium power, or cogeneration needs of the residential market. Individual households may choose to install DG for many of the same applications noted above, and may find DG especially practical if they are located far off the grid. However, residential installations must be relatively small, and given today's technology, the market most likely to develop is that for 4 to 7 kW fuel cells. These may be installed both in new construction and in retrofits of the existing housing stock.

Many factors can influence a decision to use DG for your facility. Choosing the type of DG technology or application should start with a feasibility study and requires the assistance from a professional engineer with experience in power distribution system design and protection experience. The study may indicate that DG is not right for your facility.

## BIOGRAPHY

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