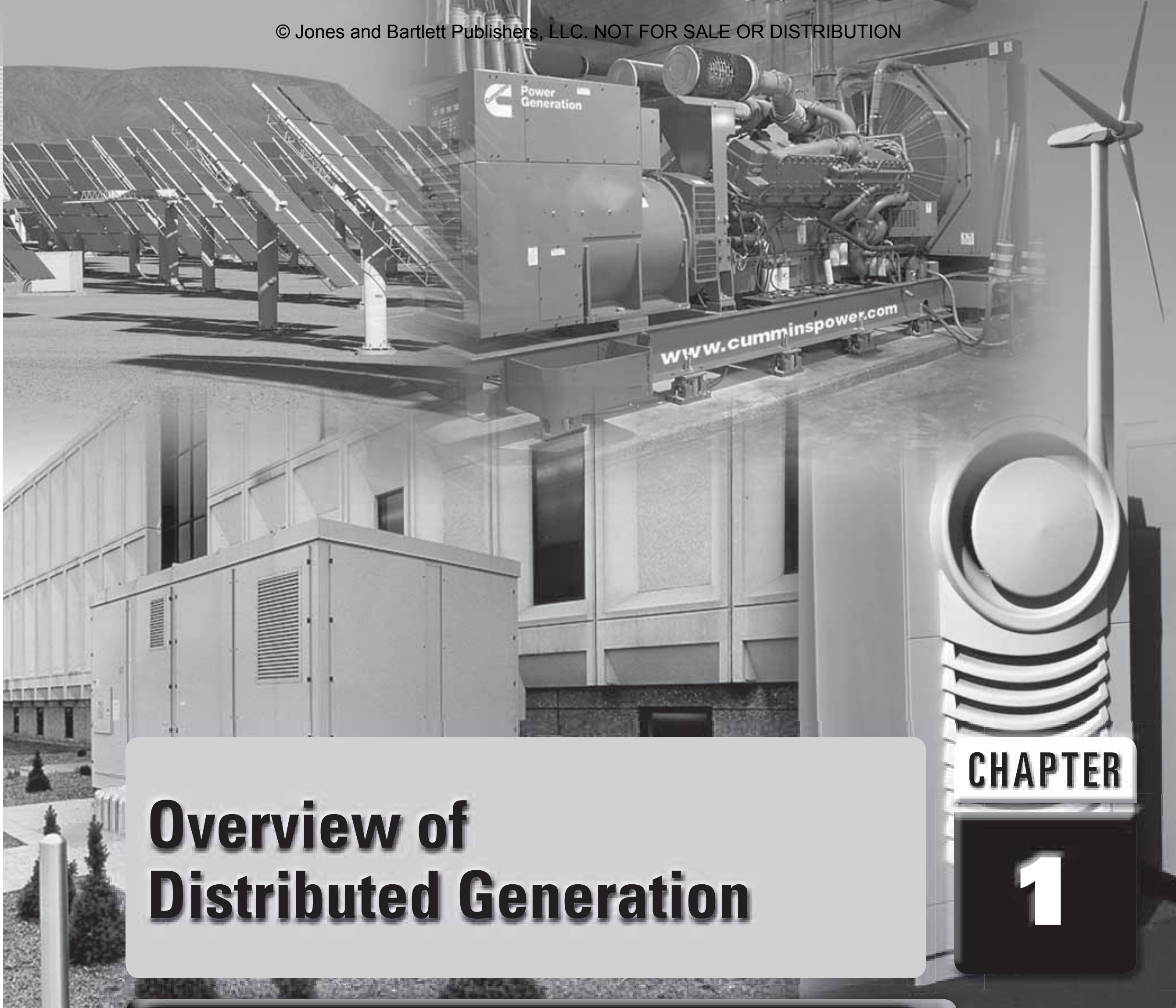

CHAPTER 1

Overview of Distributed Generation

OBJECTIVES

- Understand the benefits of distributed generation
- Describe the electric utilities' use and view of distributed generation
- Identify five types of distributed generation technology
- List the applications for passive and active generation
- Outline the goals of distributed generation
- Illustrate utility concerns with interconnected generation

Introduction

Distributed generation is the practice of locating small electrical power generation units close to the point of end use. Distributed generation has many benefits, including:

- Reducing electric utility bills
- Increasing the reliability of electric power
- Improving the payback of required generation systems
- Making power marketable to sell to utilities
- Generating environmentally friendly power

The practice of distributed generation is sometimes also referred to as "on-site generation," "customer-owned generation," or "distributed energy."

Distributed generation can operate in parallel with or independently of the electric utility grid. The **electric utility grid** (also known as the electric utility supply system or electric power production and distribution network) is a complex interconnection of four components: generation plants, substations, transmission systems, and distribution systems. Generation plants produce bulk electric energy through the conversion of another form of energy such as hydroelectric, nuclear, fossil fuel (e.g., coal, oil, or natural gas), wind, or solar power. Substations change voltage from one system to another. Transmission systems transport bulk electric power over long distances through high-voltage transmission lines. Finally, distribution systems deliver power at a lower voltage for final connections to end users. These distinct components are interconnected to meet the capacity and operational requirements of end users, considering factors such as economics, reliability, and power quality.

When distribution systems operate in parallel with the electric utility grid, they are considered **grid connected** because they rely on the electric utility grid to establish the system operating voltage and frequency. **Stand-alone** generation operates independently of the electric utility grid in supplying its loads. Generation that operates stand-alone cannot depend on the electric utility grid to establish the operating voltage and frequency. Stand-alone generation must be capable of independently establishing and regulating its operating voltage and frequency. Stand-alone operating is also known as **islanding**—when stand-alone generation supplies its load or a portion of the utility distribution system while disconnected from the electric utility grid.

Distributed generation is the ideal solution for many goals because smaller generation units are readily available, simple to install and operate, easy to relocate, modular, and cost effective. Space is always a concern, and whereas larger distributed generation installations may require a building or powerhouse, many systems and components can fit in an area the size of an average parking space for a car.

A power plant can be assembled from smaller units to meet the power requirement of virtually any load. Smaller units of generation are simple to install and operate. Most manufacturers provide standard protection and control packages suitable for distributed generation applications without external equipment. Using the manufacturers' standard products shortens the time from concept to power generation.

Electric utility companies have been in the business of distributed generation for years, leasing large, trailer-mounted diesel generators for operation at select substations during times of peak loading, such as during the summer air-conditioning season. Utility companies also use self-contained diesel engine-generators in distributed generation applications connected to various points in their distribution systems. Self-contained systems allow the utility operators to control and load these generators remotely, maximizing economic benefits.

Electrical utility companies view distributed generation as a means of distribution system planning. Constructing any type of bulk power plant takes time, as does upgrading transmission and distribution resources. Frequently, it is cost effective for a utility company to identify and convince customers who already have generation capabilities—such as hospitals and manufacturing plants—that entering into an interruptible utility contract or an energy buy-back agreement would be beneficial.

Electrical energy consumers that are required to have standby or emergency generators by applicable codes or regulations are afforded the opportunity to recoup the capital costs of installing required generation. For a relatively low number of operating hours per year, customers can enjoy year-round savings on their electrical utility bill.

Distributed Generation Technologies

Five generation technologies have emerged as leaders in the distributed generation market: solar photovoltaic power, wind power, fuel cells, microturbines, and engine-generators. These five technologies have limitations in their application and operation that make them more or less suitable to meet the various goals of installing distributed generation. Several factors affect the choice of generator technology for a given application:

- Fuel availability and type
- Available space and required clearances for equipment
- Environmental conditions
- Frequency and type of maintenance required

Although the electrical grid in the United States operates at an alternating current (ac) frequency of 60 cycles per second, or 60 Hz, some generation technologies can produce direct-current power (e.g., solar arrays and fuel cells) or ac power of some other frequency than 60 Hz (e.g., low-speed wind turbines and microturbines). The power from these technologies must be converted into an ac waveform that is compatible with the 60-Hz frequency of the electrical grid.

Solar Photovoltaic Power

A **solar photovoltaic system** generates electrical power from sunlight (**FIGURE 1-1**). Solar cells convert light energy to electricity. Solar photovoltaic power has no ongoing fuel costs; sunlight is a free source of fuel for solar arrays. However, because solar photovoltaic systems only generate power when the sun shines, their application is limited.

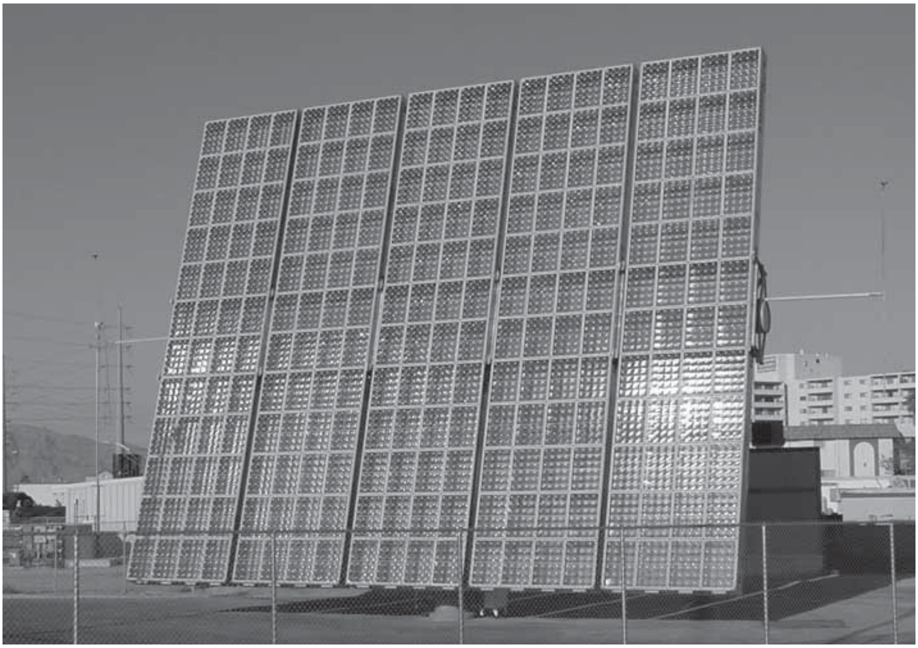

FIGURE 1-1 Solar array.

Wind Power

Wind power is electrical power generated from the wind (**FIGURE 1-2**). **Wind turbines** are generators powered by wind pushing against fan blades. Like solar photovoltaic power, wind power has no ongoing fuel costs but has limited applications (because wind is a free source of fuel for wind turbines and wind power systems only generate power when the wind blows).

FIGURE 1-2 Wind turbine.

Fuel Cells

Fuel cells are devices that use electrochemical principles to convert external supplies of hydrogen and oxygen into electricity, heat, and water with virtually no emissions (**FIGURE 1-3**). Fuel cells are essentially batteries that have a fuel supply instead of storing energy. Fuel cells have no moving parts and are exceptionally quiet. Fuel cells operate on a variety of fuels, are modular, and can be paralleled to meet virtually any power requirement. Fuel cells

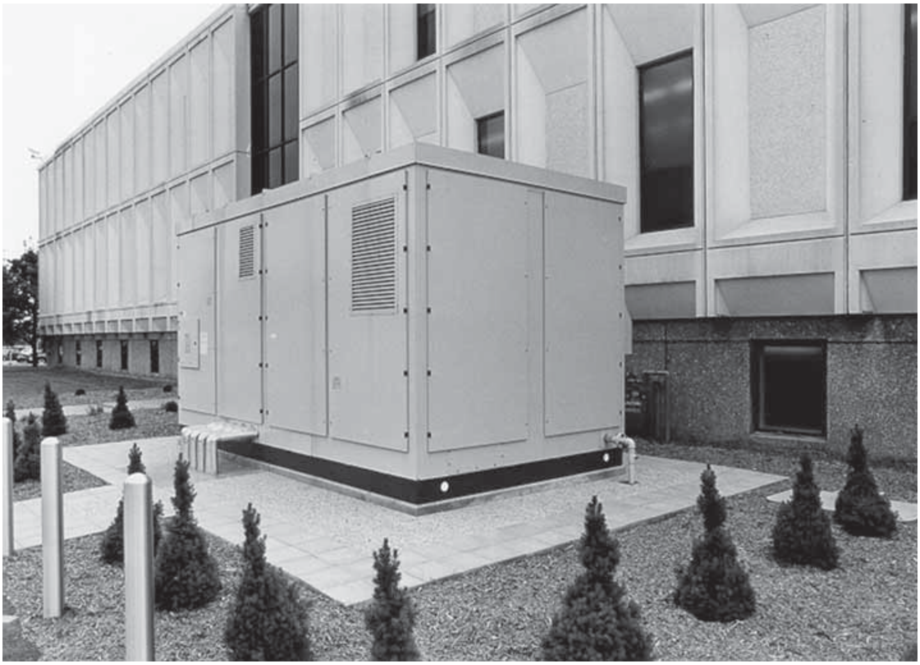

FIGURE 1-3 Fuel cell.

can have extremely high operating temperatures and are particularly suited to combined heat and power installations. Combined heat and power applications use both thermal and electrical energy from the distributed generation technology at the site.

FIGURE 1-4 Microturbine.

Microturbines

Microturbines are small, single-staged combustion turbines that consist of a compressor, combustion chamber, turbine, generator, recuperator, and power controller (**FIGURE 1-4**). Microturbines operate on a variety of fuels, are modular, and can be paralleled to meet any power requirement. Like fuel cells, they also have high operating temperatures and are particularly suited to combined heat and power applications.

Engine-Generators

Engine-generators are generators driven by an internal combustion engine (**FIGURE 1-5**). Engine-generators are powered by a variety of gaseous and liquid fuels and are available in most nominal phase and voltage configurations, including single and 3 phase and low and medium voltage, with power ratings upwards of 2000 kW. Engine-generators are modular and can be paralleled to meet any power requirement. They can be physically located most anywhere.

Passive Versus Active Generation

Distributed generation can also be divided into passive and active generation technologies. **Passive generation** is generation technology that has no control over the fuel input or the power output of the system, such as solar photovoltaic power and wind power. Solar photovoltaic power only generates power when the sun shines, and wind power only generates power when the wind blows. Passive generation cannot be **dispatched**, that is, the output level of passive generation cannot be increased in response to increase in load.

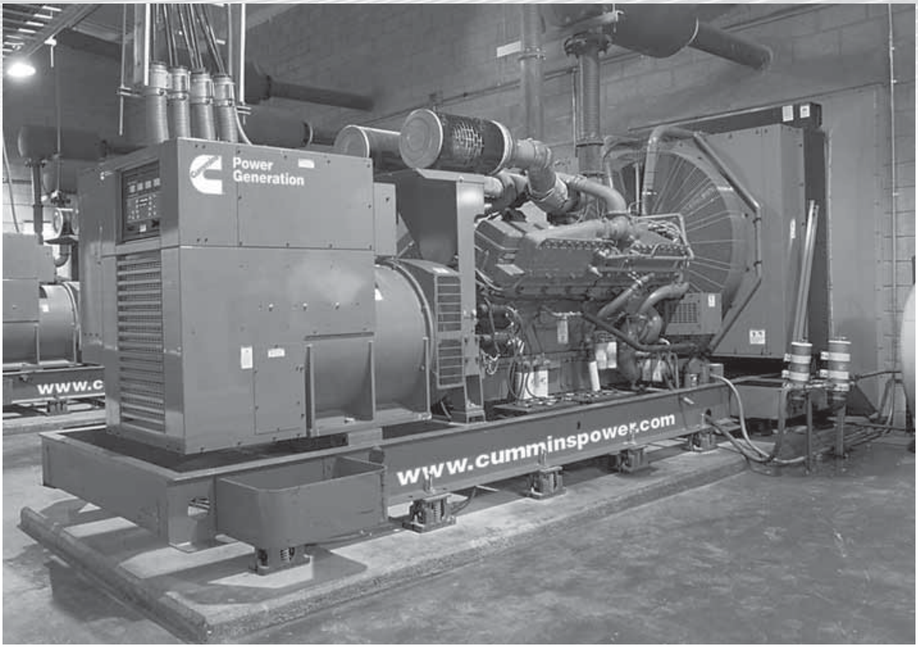

FIGURE 1-5 Engine-generator.

Active generation is generation technology that has control over the fuel input and the power output of the system, such as fuel cells, microturbines, and engine-generators. Active generation can be dispatched, that is, the output level of active generation can be increased in response to increase in load.

Goals of Distributed Generation

Distributed generation can be selected, sized, and operated to meet one or more goals, such as reducing the electric utility bill, improving electrical system reliability, improving the payback of emergency or legally required standby systems, selling power, and generating environmentally friendly power.

Reducing the Electric Utility Bill

The fundamental goal of installing distributed generation is to reduce the electric utility bill. Distributed generation can reduce the electric utility bill by lowering energy usage and peak demand charges from the electric utility. Peak demand is defined as the maximum rate of consumer power consumption in a given period of time during the billing cycle. Distributed generation can reduce the peak demand as seen by the electric utility if distributed generation supplies a portion of the onsite load during the peak demand period during the billing cycle.

Improving System Reliability

The reliability of the electric power supply can be improved by installing distributed generation. Distributed generation 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. If the distributed generation is expected to operate as an island and supply the load during a utility outage, the source must be sized larger than the connected load and the generation technology must be capable of operating independently of the electric utility grid.

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 in hospitals and high-rise buildings. Emergency or legally required standby systems, which can be either fuel cells or certain types of engine-generators, can be connected to the electric utility grid and operated as distributed generation to recover installation costs for these required systems.

Selling Power

Distributed generation can be installed to fulfill the goal of selling power. In this case the output of the distributed generation sources must exceed the load at the site. It is important to select generation technologies that are cost effective when compared with the cost of utility power.

Generating Environmentally Friendly Power

Distributed generation can be installed to generate environmentally friendly power. Solar photovoltaic and wind power have no emissions. Fuel cells and microturbines (when operated on hydrogen created by electrolysis using solar photovoltaic or wind power) also have no emissions. Engine-generators that operate on gaseous fuels such as natural gas or propane have low emissions.

Electric Utility Companies and Distributed Generation

Electric utility companies have two primary concerns with distributed generation: safety of those who use or work on the electric utility grid and the reliability of power. To evaluate the safety and reliability of proposed distributed generation systems and equipment, electric utility companies use the distributed generation application process.

The application process is typically initiated by the completion and submission of an interconnection request to the electric utility company. A scoping meeting is held to review characteristics of the transmission providers' electric system, technical aspects of the proposed interconnection, existing studies, and the results of the application of technical screens, if applicable. Technical screens are used to streamline the distributed generation application process for systems and equipment that pose no adverse impact to system safety or reliability. Technical screens are applicable to relatively small systems and inverter-based systems. Such systems and equipment may be permitted to forgo further evaluation or studies before the signing of an interconnection agreement.

After this meeting, the electric utility conducts a feasibility study, which is a preliminary technical assessment of the proposed interconnection. If the results of this study are positive, then the company performs a more detailed assessment of the effect of the interconnection, known as a system impact study, which determines the possible effect on the transmission provider's electric system and affected systems. Occasionally, the feasibility study is incorporated into the system impact study. The final study, a facilities study, determines what modifications must be made to the electric utility company's distribution system, including the detailed costs and scheduled completion dates for these modifications. The owner of the distributed generation is typically responsible for the costs associated with the application process and studies and for the required modifications to the electric utility company's system. Upon successful completion of the distributed generation application process, the distributed generation operator and electric utility sign an interconnection agreement.

The **interconnection agreement** is the contract between the distributed generation operator and the electric utility company that outlines responsibilities of all parties for installation, operation, and maintenance. Typical interconnection agreements include contractual and technical requirements such as:

- Establishment of the distributed generation point of interconnection
- Limitations of power generation exportation

- Requirements for testing and maintaining records
- Right of access for equipment installation, removal, and inspection.
- Metering requirements

The interconnection agreement also outlines other nontechnical contractual requirements, such as invoices, payments, insurance, access, and other responsibilities, etc.