1.7 SOLAR POWER

Solar power makes use of the abundant energy of sunlight, and it has the potential to meet a significant portion of the future energy demands in an environmentally clean and cost-effective way. Solar energy can be converted directly into electricity by photovoltaic (PV), using the semiconductor materials in solar panels. A more economical method is using concentrating solar power (CSP) technologies. CSP technologies use mirrors to reflect and concentrate sunlight onto receivers that heat a working fluid to high temperatures. The resulting heat energy is used to power a steam turbine, driving a generator. Solar concentrators come in three main designs: parabolic troughs, parabolic dishes, and central receivers. Tracking techniques are required in these systems to ensure that the maximum amount of sunlight enters the concentrating system. In all of these systems, a working fluid is heated by the concentrated sunlight and is then used for power generation or energy storage.

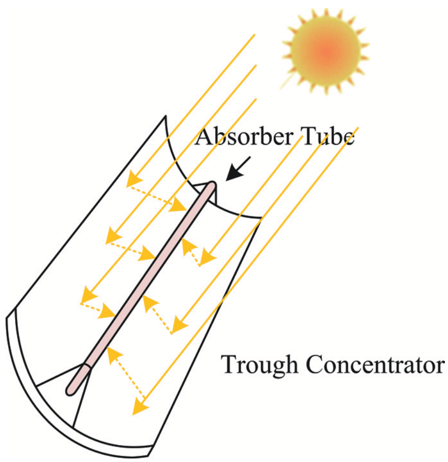

FIGURE 1.8
Schematic of a parabolic trough concentrator.

1.7.1 PARABOLIC TROUGHS

A parabolic trough system consists of many long parallel rows of curved mirrors that concentrate light onto a receiver pipe positioned along the reflector's focal line, as shown in Figure 1.8. The troughs follow the trajectory of the sun by rotating along their axis to ensure that the maximum amount of sunlight enters the concentrating system. The concentrated solar radiation heats up a fluid circulating in the pipes, typically synthetic oil or molten salt, to temperatures of up to750°F. The hot oil is pumped to heat exchangers to generate steam, which is used to drive a conventional steam turbine generator. A schematic diagram of a solar power plant using parabolic trough concentrators is shown in Figure 1.9.

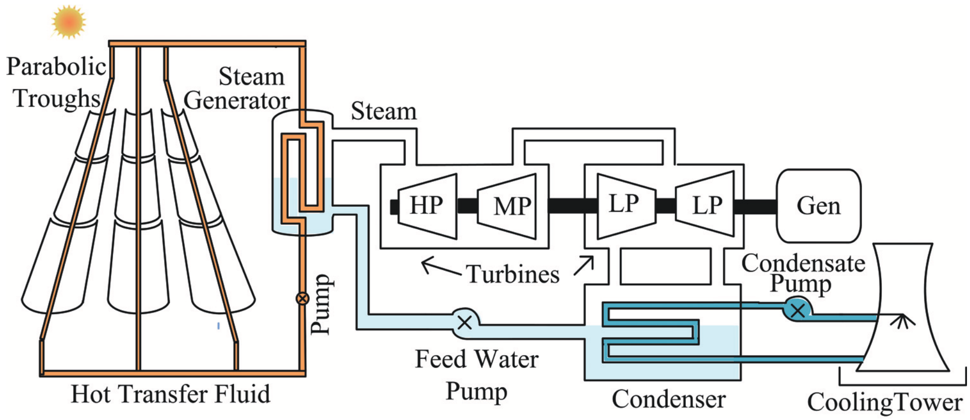

FIGURE 1.9
Schematic diagram of a solar power plant with parabolic trough concentrators.

Solar power is intermittent and is not available overnight; therefore, some solar power plants are designed to operate as hybrid solar/fossil plants. As hybrids, they have the capability to generate electricity during periods of low solar radiation. The new parabolic trough plants use molten salt for the heat transfer medium, which is cheaper and safer than oil. Also, because salts are an effective storage medium, the spare solar power is used in the form of heated molten salt in storage tanks, for use during periods when solar power is not available. This makes the CSP technology truly dispatchable.

One of the largest parabolic trough power plants is the Solar Energy Generating Stations (SEGS) in California's Mojave Desert. It consists of nine solar power plants that have a combined capacity of 354 MW. Over the past 20 years these plants have delivered power with a high degree of reliability, and they continue to operate well in the Mojave Desert. A new solar project based on advanced parabolic trough technology and thermal storage using molten salts is being built by Abengoa Solar, Inc., a Spanish firm under contract with Arizona Public Service (APS). This plant, called *Solana* (which means "a sunny place" in Spanish) Generating Station, has a capacity of 280 MW and is scheduled to go on-line in 2010. It is claimed that the plant will have the capacity to supply clean power to 70,000 homes and will eliminate around 400,000 tons of carbon dioxide. On May 22, 2009, APS and Starwood Energy Group Global announced plans for a 290 MW concentrating solar plant to be built in the Harquahala Valley, Arizona. The project will use the same parabolic trough technology with molten salt storage. The plant, scheduled for completion in 2013, will have the capacity to supply clean power to 73,000 homes. The largest solar thermal parabolic trough technology project proposed in the United States is the 553 megawatt Mojave Solar Park in the Mojave Desert, to be built by the Israeli company Solel for Pacific Gas and Electric in order to meet California's renewable energy laws, which require 20 percent of the power provided to be from renewable sources. Construction is scheduled to begin in 2009 and is due for completion in 2011.

1.7.2 PARABOLIC DISH CONCENTRATORS (DISH STIRLING)

A parabolic dish concentrator consists of a parabolic dish-shaped mirror that reflects solar radiation onto a receiver located at the focal point of the dish.The dish structure is designed to track the sun on two axes, allowing the capture of solar energy at its highest density. A schematic of a parabolic dish concentrator is shown in Figure 1.10.

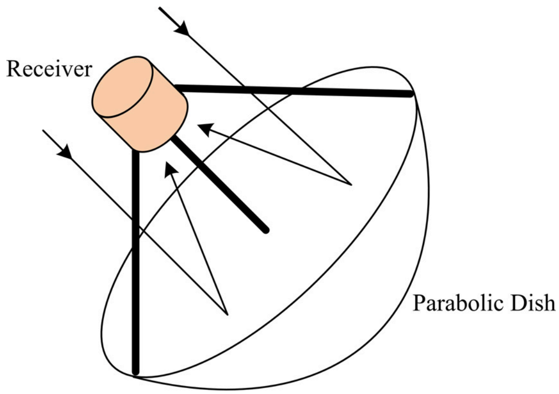

FIGURE 1.10
Schematic of a parabolic dish concentrator.

The solar dish concentration ratio is much higher than the solar trough, typically over 2,000, with a working fluid temperature to over 1300°F. The thermal receiver consists of a bank of tubes filled with a cooling fluid, usually hydrogen or helium, which is the heat transfer medium and also the working fluid for an engine. The thermal receiver absorbs the solar energy and converts it to heat that is delivered to a Stirling engine, which is attached to the receiver. The engine is coupled to an electric generator to generate electricity. Similar to the parabolic trough, a concentrator can be made up of multiple mirrors that approximate a parabolic dish to reflect the solar energy at a central focal point.

One of the first commercial-scale Dish Stirling systems will be built near Phoenix, Arizona by Tessera Solar International. The 1.5 MW plant consists of sixty 25 kW units known as the *SunCatcher*, as shown in Figure 1.11.

The SunCatcher dish is formed into a parabolic shape using multiple arrays of curved glass mirrors. Each unit is designed to track the sun continuously and to reflect the solar energy onto a Power Conversion Unit (PCU) positioned at the focal point of the dish. The focused solar thermal energy heats up the hydrogen gas in tubes in the PCU, and the gas goes through a heat exchanger to run a four-cylinder Stirling engine. The engine then drives a generator to produce electricity. The main

FIGURE 1.11
Dish Stirling systems – SunCatchers by Tessera Solar, ”Courtesy of Sandia National Laboratories.”

advantage of the solar dish technology is that the Stirling system requires no water for heating or cooling. The project will serve as a precursor to the deployment of much larger commercial projects to be developed by Tessera Solar and Stirling Energy Systems, including a 27 MW solar project for CPS Energy in West Texas and a 500 MW solar project for Southern California Edison.

1.7.3 SOLAR TOWER

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Example 1.2

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1.7.4 PHOTOVOLTAIC ELECTRIC POWER PLANTS

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