Solar photovoltaic cell

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Abstract— **Concentrating solar power (CSP) is a power generation technology that uses mirrors or lenses to concentrate the sun's rays and, in most of today's CSP systems, to heat a fluid and produce steam. The steam drives a turbine and generates power in the same way as conventional power plants. Other concepts are being explored and not all future CSP plants will necessarily use a steam cycle.**

1 Introduction

Solar cells are typically combined into modules that hold about 40 cells; a number of these modules are mounted in PV arrays that can measure up to several meters on a side. These flat-plate PV arrays can be mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun, allowing them to capture the most sunlight over the course of a day. Several connected PV arrays can provide enough power for a household; for large electric utility or industrial applications, hundreds of arrays can be interconnected to form a single, large PV system.

Thin film solar cells use layers of semiconductor materials only a few micrometers thick. Thin film technology has made it possible for solar cells to now double as rooftop shingles, roof tiles, building facades, or the glazing for skylights or atria. The solar cell version of items such as shingles offer the same protection and durability as ordinary asphalt shingles.

Solar cell

Some solar cells are designed to operate with concentrated sunlight. These cells are built into concentrating collectors that use a lens to focus the sunlight onto the cells. This approach has both advantages and disadvantages compared with flat-plate PV arrays. The main idea is to use very little of the expensive semiconducting PV material while collecting as much sunlight as possible. But because the lenses must be pointed at the sun, the use of concentrating collectors is limited to the sunniest parts of the country. Some concentrating collectors are designed to be mounted on simple tracking devices, but most require sophisticated tracking devices, which further limit their use to electric utilities, industries, and large buildings.

2. Concentrating Solar Power Technologies

Concentrated Solar Power

The innovative aspect of CSP is that it captures and concentrates the sun's energy to provide the heat required to generate electricity, rather than using fossil fuels or nuclear reactions. Another attribute of CSP plants is that they can be equipped with a heat storage system in order to generate electricity even when the sky is cloudy or after sunset. This significantly increases the CSP capacity factor5 compared with solar photovoltaics and, more importantly, enables the production of dispatchable electricity, which can facilitate both grid integration and economic competitiveness.

CSP technologies therefore benefit from advances in solar concentrator and thermal storage technologies, while other components of the CSP plants are based on rather mature technologies and cannot expect to see rapid cost reductions. CSP technologies are not currently widely deployed.
A total of 354 MW6 of capacity was installed between 1985 and 1991 in California and has been operating commercially since then. After a hiatus in interest between 1990 and 2000, interest in CSP has been growing over the past ten years. A number of new plants have been brought on line since 2006 (Muller- Steinhagen, 2011) as a result of declining investment costs and LCOE, as well as new support policies. Spain is now the largest producer of CSP electricity and there are several very large CSP plants planned or under construction in the United States and North Africa. CSP plants can be broken down into two groups, based on whether the solar collectors concentrate the sun rays along a focal line or on a single focal point (with much higher concentration factors). Line-focusing systems include parabolic trough and linear Fresnel plants and have single-axis tracking systems. Point-focusing systems include solar dish systems and solar tower plants and include two-axis tracking systems to concentrate the power of the sun.

2.1 Parabolic trough Collector technology

The parabolic trough collectors (PTC) consist of solar collectors (mirrors), heat receivers and support structures. The parabolic-shaped mirrors are constructed by forming a sheet of reflective material into a parabolic shape that concentrates incoming sunlight onto a central receiver tube at the focal line of the collector. The arrays of mirrors can be 100 metres (m) long or more, with the curved aperture of 5 m to 6 m.

A single-axis tracking mechanism is used to orient both solar collectors and heat receivers toward the sun (A.T. Kearney and ESTELA, 2010). PTC are usually aligned North-South and track the sun as it moves from East to West to maximise the collection of energy. The receiver comprises the absorber tube (usually metal) inside an evacuated glass envelope. The absorber tube is generally a coated stainless steel tube, with a spectrally selective coating that absorbs the solar (short wave) irradiation well, but emits very little infrared (long wave) radiation. This helps to reduce heat loss. Evacuated glass tubes are used because they help to reduce heat losses.

2.2 Linear Fresnel Collector technology

Linear Fresnel collectors (LFCs) are similar to parabolic trough collectors, but use a series of long flat, or slightly curved, mirrors placed at different angles to concentrate the sunlight on either side of a fixed receiver (located several metres above the primary mirror field). Each line of mirrors is equipped with a single-axis tracking system and is optimised individually to ensure that sunlight is always concentrated on the fixed receiver. The receiver consists of a long, selectively-coated absorber tube. Unlike parabolic trough collectors, the focal line of Fresnel collectors is distorted by astigmatism. This requires a mirror above the tube (a secondary reflector) to refocus the rays missing the tube, or several parallel tubes forming a multi-tube receiver that is wide enough to capture most of the focussed sunlight without a secondary reflector.

2.3 Solar tower technology

Solar tower technologies use a ground-based field of mirrors to focus direct solar irradiation onto a receiver mounted high on a central tower where the light is captured and converted into heat. The heat drives a thermo-dynamic cycle, in most cases a water-steam cycle, to generate electric power. The solar field consists of a large number of computer-controlled mirrors, called heliostats, that track the sun individually in two axes. These mirrors reflect the sunlight onto the central receiver where a fluid is heated up. Solar towers can achieve higher temperatures than parabolic trough and linear Fresnel systems, because more sunlight can be concentrated on a single receiver and the heat losses at that point can be minimized. Current solar towers use water/steam, air or molten salt to transport the heat to the heat-exchanger/steamturbine system. Depending on the receiver design and the working fluid, the upper working temperatures can range from 250°C to perhaps as high 1 000°C for future plants, although temperatures of around 600°C will be the norm with current molten salt designs. The typical size of today's solar tower plants ranges from 10 MW to 50 MW (Emerging Energy Research, 2010). The solar field size required increases with annual electricity generation desired, which leads to a greater distance between the receiver and the outer mirrors of the solar field. This results in increasing optical losses due to atmospheric absorption, unavoidable angular mirror deviation due to imperfections in the mirrors and slight errors in mirror tracking. Solar towers can use synthetic oils or molten salt as the heat transfer fluid and the storage medium for the thermal energy storage. Synthetic oils limit the operating temperature to around 390°C, limiting the efficiency of the steam cycle. Molten salt raises the potential operating temperature to between 550 and 650°C, enough to allow higher efficiency supercritical steam cycles although the higher investment costs for these steam turbines may be a constraint. An alternative is direct steam generation (DSG), which eliminates the need and cost of heat transfer fluids, but this is at an early stage of development and storage concepts for use with DSG still need to be demonstrated and perfected. Solar towers have a number of potential advantages, which mean that they could soon become the preferred CSP technology.

The main advantages of linear Fresnel CSP systems compared to parabolic trough systems are that LFCs can use cheaper flat glass mirrors, which are a standard mass-produced Commodity LFCs require less steel and concrete, as the metal support structure is lighter. This also makes the assembly process easier

Solar Tower

2.4 Stirling DISH technology

The Stirling dish system consists of a parabolic dishshaped concentrator (like a satellite dish) that reflects direct solar irradiation onto a receiver at the focal point of the dish. The receiver may be a Stirling engine (dish/ engine systems) or a micro-turbine. Stirling dish systems require the sun to be tracked in two axes, but the high energy concentration onto a single point can yield very high temperatures. Stirling dish systems are yet to be deployed at any scale. Most research is currently focussed on using a Stirling engine in combination with a generator unit, located at the focal point of the dish, to transform the thermal power to electricity. There are currently two types of Stirling engines: Kinematic and free piston. Kinematic engines work with hydrogen as a working fluid and have higher efficiencies than free piston engines. Free piston engines work with helium and do not produce friction during operation, which enables a reduction in required maintenance.

The main advantages of Stirling dish CSP technologies are that:
The location of the generator - typically, in the receiver of each dish - helps reduce heat losses and means that the individual dish-generating capacity is small, extremely modular (typical sizes range from 5 to 50 kW) and are suitable for distributed generation.

Stirling dish technologies are capable of achieving the highest efficiency of all types of CSP systems.

Stirling dishes use dry cooling and do not need large cooling systems or cooling towers, allowing CSP to provide electricity in water-constrained regions.

Stirling dish

Stirling dishes, given their small foot print and the fact they are self-contained, can be placed on slopes or uneven terrain, unlike PTC, LFC and solar towers. These advantages mean that Stirling dish technologies could meet an economically valuable niche in many regions, even though the levelised cost of electricity is likely to be higher than other CSP technologies. Apart from costs, another challenge is that dish systems cannot easily use storage. Stirling dish systems are still at the demonstration stage and the cost of mass-produced systems remains unclear. With their high degree of scalability and small size, stirling dish systems will be an alternative to solar photovoltaics in arid regions.

3 Photovoltaic power generation

Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material. Materials presently used for photo voltaics include mono crystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulfide. Due to the growing demand for renewable energy sources, the manufacturing of solar cells and photovoltaic arrays has advanced considerably in recent years.[1][2][3]
Cells require protection from the environment and are usually packaged tightly behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules, or solar panels. A single module is enough to power an emergency telephone, but for a house or a power plant the modules must be arranged in multiples as arrays.
A significant market has emerged in off-grid locations for solar-power-charged storage-battery based solutions. These often provide the only electricity from gas torch to fully self-sufficient electrical power. Threat modeling is a security engineering activity that documents the key assets found in an application or system and purposely exposes risks to those assets in a thorough and disciplined manner. The goal of a threat model is to shine a light upon hidden security risks that may not be obvious or anticipated by the design team. This information can then be used to develop a risk management strategy and provide a roadmap for future security engineering activities.

4. Solar Photovoltaic Cell/Module Manufacturing Activities

Photovoltaic devices use semiconducting materials to convert sunlight directly into electricity. Solar radiation, which is nearly constant outside the Earth's atmosphere, varies with changing atmospheric conditions (clouds and dust) and the changing position of the Earth relative to the sun. Nevertheless, almost all U.S. regions have useful solar resources that can be accessed.

Solar resource

5 Applications

1. Power stations
2. Buildings
3. Standalone Devices
4. Rural electrification

6.References

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