David Landa

Advances in Solar Power Generation

Abstract

In this paper I will be covering some of the main solar power technologies that are in use, along with some of the upcoming advancements that are now being developed. I cover the three generations of solar photovoltaic technologies, along with their limitations. I also cover the four main types of concentrating solar technologies, as well as going into the various methods of storing that energy so that it can be used at night.

Introduction

Global energy and electricity consumption are increasing rapidly due to the growth in population, industrialization, and urbanization. Compared to global population growth, energy consumption is growing much faster, and within the next 20 years, studies predict that total consumption will double. (1) Energy consumption of both conventional and renewable sources will play an important role in future sustainable development. At present, at least 80% of the global energy supply comes from fossil fuels, which are considered a depleting energy source and responsible for emitting greenhouse gasses. (2) Acknowledging that, there is an urgent need for the development and implementation of renewable energy technologies. In this paper, I cover some of the main solar power technologies that are in use today, along with some of the advancements that are in development.

There are two types of solar power generation covered in this report. Solar photovoltaic (PV), (3) and Concentrated solar power (CSP). (4) First is solar photovoltaic (PV). Capturing solar energy through PV panels in order to produce electricity is considered one of the most promising markets in the field of renewable energy. In order to keep that pace, new developments have been rising relating to material use, energy consumption for manufacturing, design, production and increased efficiency of the cells. The conversion of solar radiation into electricity occurs due to the photovoltaic effect, which was first observed by Becquerel in 1839. (5) This effect occurs in semiconductor materials, the most common of which is silicon.

The large-scale integration of solar energy into the electric grid has presented some major technical challenges. Solar energy, as an intermittent power source, requires either energy storage or a fuel-based backup power system. (6) Solar PV cells by themselves have a variable power output, which leads to grid reliability issues. An answer to this is to use concentrated solar power (CSP) systems. (4) CSP technology offers a renewable energy source that can incorporate a large amount of energy storage. CSP systems involve heating a working fluid using concentrated sunlight. (4) This heated fluid can then be used with conventional power generation equipment (i.e., turbines) to produce electricity. Because CSP's are capable of bulk electricity generations and off-peak power storage, many nations are investing heavily in that technology.

Solar photovoltaic (PV) cells

There is a wide variety of PV cell technologies in the marketplace today, using different types of materials, and an even larger number will be available in the future. PV cell technologies are categorized in the three generations, depending on the raw material used and the level of commercial maturity.

-First-generation PV systems use the technology of crystalline silicon, both in its simple and multi-crystalline forms. (1)

-Second-generation PV systems are based on thin-film photovoltaic technologies. (1)

-Third-generation PV systems include organic PV technologies that are still in development or have not been widely marketed. (1)

Silicon Cells

Silicon is the most popular material in commercial solar cell modules, accounting for about 90% of the PV cell market. (1) This success is due to several beneficial traits of silicon, mainly that it is abundant, being the second most abundant element on Earth. It is also generally stable and non-toxic.

Thin-film Cells

Thin-film solar cells require much less material from the semiconductor in order to absorb the same amount of sunlight, up to 99% less than Silicon crystalline solar cells. (The use of this technology has increased in recent years due to its high flexibility, easy installment, and service life of over 25 years. (3) Although thin-film systems generally cost less to be produced that silicon systems, they have substantially lower efficiency rates.(3) On average, thin-film cells convert from 5 to 13% of solar energy into electricity, compared to the 11-20% for crystalline silicon cells.(3) However, since thin-films are relatively new, they may offer greater opportunities for technological improvement in the future.

Organic PV cells

Organic PV cells offer the long-term potential of achieving the goal of a PV technology that is economically viable for large-scale power generation since organic semiconductors are a less expensive alternative to the inorganic semiconductors such as silicon.(3) Organic PV cells also have characteristics that make them very attractive, such as the potential to be flexible, semitransparent, easy integration in different devices, and a significant cost reduction. (3) Presently, however, organic PV cells have limited durability and are not yet capable of converting sunlight with the same efficiency as silicon cells.

Concentrated Solar Power (CSP)

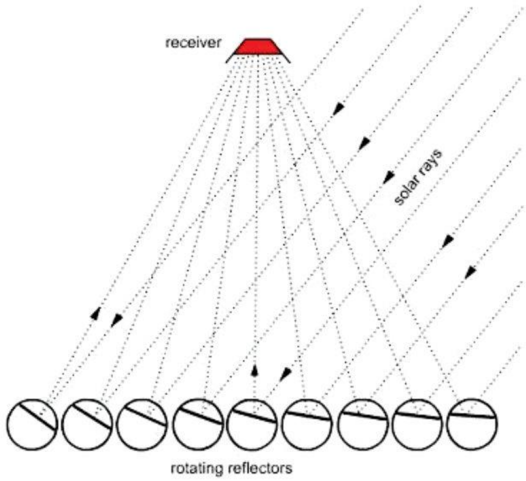
In CSP power plants, electrical energy is generated by concentrating solar radiation. (5) Many different kinds of CSP power plants are found: they are Parabolic trough collectors (PTC), solar power towers (SPT), compact linear Fresnel reflectors (CLFR) and the dish-engine. (4)

Parabolic trough

PTC systems use curved mirrors to focus the sun's energy onto a receiver tube that runs down the center of a trough. In the receiver tube, a high-temperature heat transfer fluid (i.e., synthetic oil or molten salts) absorb the suns energy and passes through a heat exchanger to heat water and produce steam. This steam drives a conventional steam turbine power system to generate electricity. (4)

Solar power tower

SPT systems use a central receiver system, which allows for higher operating temperatures and greater efficiency. Computer-controlled mirrors track the sun and focus on a receiver at the top of a high tower. This focused energy is used to heat transfer fluid to produce steam and run a central power generator. (4) Energy storage can be easily and efficiently incorporated into these projects, allowing for 24-hour power generation.



Compact linear Fresnel reflectors

A CLFR uses the principles of curved-mirror trough systems, but with long parallel rows of lower-cost flat mirrors. (4) These mirrors focus the suns energy onto elevated receivers, which consist of a system of tubes through which water flows. The concentrated sunlight boils the water, generating high-pressure steam for direct use in power generation and industrial applications. (4)

Dish-engines

With a dish-engine, mirrors are distributed over a parabolic dish surface to concentrate sunlight onto a receiver fixed at the focal point. (4) The system then uses a working fluid such as hydrogen in the receiver to drive an engine, and generate electricity.

As we talk about the types of CSP systems, we also have to examine the various methods of power storage they need in order to provide energy during the night. The main storage system that CSP use are liquid storage mediums. (6) The advantage of a liquid storage medium is that it can be circulated easily, transporting heat when required. Some of the storage liquids in use are water, molten salts, and mineral oil. (6)

Water is one of the best storage mediums for low-temperature applications. (6) Its advantages are high specific heat, non-toxicity, cheap cost, and easy availability. Water is best used for house space heating and hot water supply type applications.

Molten salts are currently the most used thermal energy storage materials in CSP plants. (6) They are cheap, and their energy density is high compared to other liquid storage mediums. Today the practice is to use salt composites that can act as a heat transfer fluid, but it is still considered safer to have antifreeze systems in place to deal with any freezing risk. One of the drawbacks of molten salts is that they are oxidizing agents and very corrosive, thus requiring more costly measures to prevent any damage. (6)

Mineral oil is used as a heat transfer fluid in CSP plants. (6) It can be used to store thermal energy in a highly insulated storage tank during the night, thus allowing for power generation during the off times. Mineral oil also has a lower vapor pressure than water and is capable of operation at high temperatures in liquid form. * Also, unlike molten salts, mineral oil does not freeze during the night in pipes, which removes the need for antifreeze systems. * However, mineral oil is costly compared to water and molten salts. A recent trend in CSP systems is to use indirect systems where mineral oils act as the heat transfer fluid, and molten salts mixtures act as a heat storage material. (6)

Conclusion

A problem with solar energy is that it is low-density, this forces conventional PV systems to occupy large areas in order to harness the needed amount of solar energy to be able to produce the wanted power output. In looking at the present PV technology, we find another drawback, in that its ability to absorb solar radiation is limited to visible light. This flaw causes PV cells to deliver relatively low electrical efficiencies since a large percentage of the incoming energy is rejected as heat. This heat increases the temperature of the PV cells and reduces their efficiency.

On the other hand, CSP collectors produce a more high-density form of energy output. However, the cost of the system and the need to involve several transformation stages increase the complexity and cost, which lowers the total efficiency of the system. With the continuing developments and increased efficiencies of solar power generation technologies, they are on track to become a major component of the energy policies of most industrialized nations. This trend will require that both private and public investments and implementation continue, however, as any slowdown will negatively affect the mass implementation of new solar power technology.

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