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Types of solar thermal power plants

A solar thermal electricity generating system also known as solar thermal power plant is an emerging renewable energy technology, where we generate the thermal energy by concentrating and converting the direct solar radiation at medium/high temperature (300ºC – 800ºC). The resulting thermal energy is then used in a thermodynamic cycle to produce electricity, by running a heat engine, which turns a generator to make electricity. Solar thermal power is currently paving the way for the most cost-effective solar technology on a large scale and is heading to establish a cleaner, pollution free and secured future. Photovoltaic (PV) and solar thermal technologies are two main ways of generating energy from the sun, which is considered the inexhaustible source of energy. PV converts sunlight directly into electricity whereas in solar thermal technology, heat from the sun's rays is concentrated to heat a fluid, whose steam powers a generator that produces electricity. It is similar to the way fossil fuel-burning power plants work except that the steam is produced by the collected heat rather than from the combustion of fossil fuels. In order to generate electricity, five major varieties of solar thermal technologies used are:

* *Parabolic trough solar electric generating system (SEGS).*
* *Central receiver power plant.*
* *Solar chimney power plant.*
* *Dish sterling system.*
* *Solar pond power plant.*

Most parts of India, Asia experiences a clear sunny weather for about 250 to 300 days a year, because of its location in the equatorial sun belt of the earth, receiving fairly large amount of radiation as compared to many parts of the world especially Japan, Europe and the US where development and deployment of solar technologies is maximum. Whether accompanied with this benefit or not, usually we have to concentrate the solar radiation in order to compensate for the attenuation of solar radiation in its way to earth's surface, which results in from 63,2 GW/m^2 at the Sun to 1 kW/m^2 at Earth's surface. The higher the concentration is, the higher the temperatures we can achieve when converting solar radiation into thermal energy.

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Introduction

A solar thermal electricity generating system also known as solar thermal power plant is an emerging renewable energy technology, where we generate the thermal energy by concentrating and converting the direct solar radiation at medium/high temperature (300ºC – 800ºC). All solar thermal systems capture the energy of the sun by absorbing light as heat. Solar thermal power systems focus sunlight, usually with mirrors, to heat a fluid to high temperatures and drive an engine. With their high efficiency and the lowest power production costs of all solar technologies, the technologically mature parabolic trough power plants in particular have outstanding prospects for the future.

The uninhabited deserts of North Africa alone could generate many times the European power requirements. It will also contribute directly to the CO_2 reduction strategy. According to a Greenpeace study, the use of CSP (concentrated solar power) can prevent 154 million tonnes of CO_2 emissions worldwide by 2020. This approach stands in contrast to photovoltaic solar power systems, in which light interacts with special materials directly to separate charges and generate electricity. Photovoltaic power enjoys many advantages, such as unattended operation and small-scale feasibility, but remains significantly more expensive as a source of large-scale power than solar thermal technologies. The modern era of large-scale solar power generation was born in California's Mojave Desert in the 1980s, when Luz Industries built a total of 354 MW of solar electric generating system, or SEGS, power plants. The SEGS plants use long parabolic mirrors with pipes at the focus point, where circulating oil is heated to 700ºF (350ºC). The oil is pumped through heat exchangers which boil water to make high-pressure steam, which drives turbine generators to make electric power.

The ability to store energy as heat makes solar thermal electric power particularly valuable, because energy can be stored when the sun is shining and released for electricity generation when the power is needed most. Often peak electricity demand extends well into the evening on hot summer days; solar thermal electric power is uniquely able to deliver zero-carbon electric power to meet these demands. Solar plants can be built to be dispatchable, gathering energy during daylight hours and releasing it during times of peak demand. Solar technologies have the potential to be major contributors to the global energy supply. The ability to dispatch power allows large-scale central solar technologies to provide 50% or more of the energy needs in sunny regions around the world. Solar thermal power plant technology is particularly efficient at high solar irradiation.

Computer systems manage the mirror positions, tracking the motion of the sun throughout the day to maintain the focus point on the absorber. At night and during stormy weather, the reflector units invert, exposing steel to the sky for maximal resistance to weather events such as ice, hail and high winds. Solar power plants use a simple Rankine cycle system for power generation from the steam collected by the solar field. Pipes in the absorber carry water which boils and can reach over 545 degrees F (285^{o}C) at about 70 times atmospheric pressure. This high pressure steam drives a steam turbine generator, then is recondensed to water and used over and over.

Types of solar thermal power plants

Parabolic trough solar electric generating system

Although many solar technologies have been demonstrated, parabolic trough solar thermal electric power plant technology proves to be one of the major renewable energy success stories of the last two decades. Among all the solar energy systems, parabolic troughs are one of the lowest cost solar electric power options available today and have significant potential for further cost reduction.

For example, nine parabolic trough plants, totaling over 350 MWe of electric generation, have been in daily operation in the California Mojave Desert for up to 18 years. These plants provide enough solar electricity to meet the residential needs of a city with 2,50,000 people. They have demonstrated excellent availabilities and have reliably delivered power to help California to meet its peak electric loads, especially during the California energy crisis of 2000-2001 (near 100% availability during solar hours). Although parabolic trough technology is the least cost solar power option, it is still more than twice as expensive as power from conventional fossil fuelled power plants at today’s fossil energy prices in the United States.

Central reciever power plant

It is also known as a power tower. It is a solar power facility that uses a field of two-axis tracking mirrors known as heliostats (devices that track the movement of the sun). Each heliostat is individually positioned by a computer control system to reflect the sun’s rays to a tower mounted thermal receiver. The effect of many heliostats reflecting to a common point creates the combined energy of many suns, which produces high temperature thermal energy. In the receiver, molten nitrate salts absorb the heat energy. The hot salt is then used to boil water to steam, which is sent to a conventional steam turbine-generator to produce electricity.

Solar chimney power plant

Basically solar chimney power plant is the combination of solar and wind energy, in which solar energy is used to heat the air and making air less dense, moves up with particular velocity and rotates the wind turbine. Ambient air is drawn into the glass collector. This is warmed by solar energy and rises up the chimney. The current of rising warm air drives a turbine and the turbine is set at the base of chimney and drives the electrical generator. The solar chimney power plant (SCPP) is part of the solar thermal group of indirect solar conversion technologies i.e. involving more than one transformation to reach a usable form. More specifically, a natural phenomenon concerning the utilization of the thermal solar energy involves the earth surface heating and consequently the adjacent air heating by the sun light. This warm air expands causing an upward buoyancy force promoting the flow of air that composes the earth atmosphere.

The amount of energy available due to the upward buoyancy force associated with the planet revolution is so vast that can generate catastrophic tropical cyclones with disastrous consequences. Thus, the SCPP is a device developed with the purpose to take advantage of such buoyancy streams converting them into electricity. For that, a greenhouse – the collector – is used to improve the air heating process, a tall tube – the chimney – promotes the connection between the warm air nearby the surface and the fresh air present in higher atmosphere layers and a system to convert the kinetic energy into electricity.

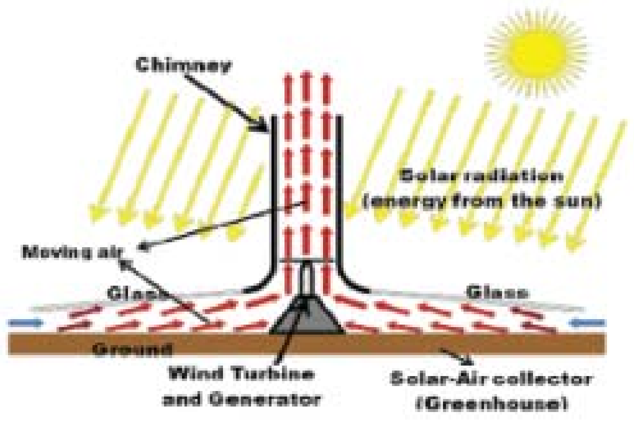

Fig.1. Solar chimney power plant

Dish stirling system

The dish or stirling system generates power by using parabolically arranged mirrors to reflect sunlight onto a small focal receiver, thereby heating a gas chamber connected to a piston and drive shaft. The drive shaft powers a generator which produces electricity to be distributed to a grid. A dish/ stirling system includes two components: the solar dish, which is simply a parabolic mirror or set of mirrors, and a stirling engine, a closed-cycle engine that operates silently using any heat source. Efficiency for the stirling engine approaches maximum theoretical efficiency for any engine, known technically as Carnot cycle efficiency.

Solar pond power plant

Solar pond is a pool of salt water which acts as a large-scale solar thermal energy collector with integral heat storage for supplying thermal energy. A solar pond can be used for various applications, such as process heating, desalination, refrigeration, drying and solar power generation.

Fig.2. Dish stirling systes

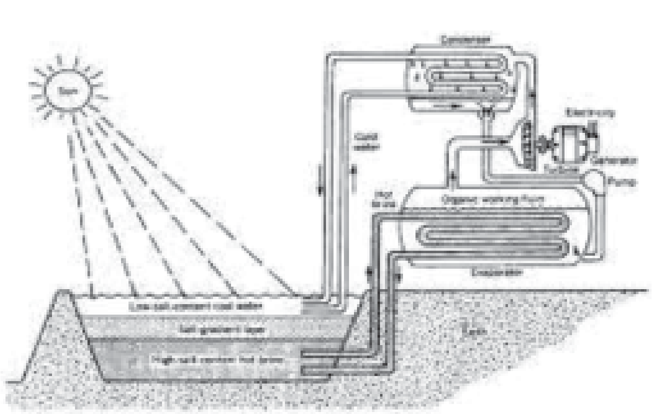

Fig.3 Solar pond power plant

Indian scenario

India is world's 6th largest energy consumer, accounting for 3.4% of global energy consumption. Due to India's economic rise, the demand for energy has grown at an average of 3.6% per annum over the past 30 years. In March 2009, the installed power generation capacity of India stood at 147,000 MW while the per capita power consumption stood at 612 kWh. The country's annual power production increased from about 190 billion kWh in 1986 to more than 680 billion kWh in 2006. The Indian government has set an ambitious target to add approximately 78,000 MW of installed generation capacity by this year. The total demand for electricity in India is expected to cross 950,000 MW by 2030. This indicates that India's future energy requirements are going to be very high and solar energy can be one of the efficient and eco-friendly ways to meet the same.

Solar thermal power generation can play a significant important role in meeting the demand supply gap for electricity. Three types of applications are possible:

1. Rural electrification using solar dish collector technology. Typically these dishes care of 10 to 25 kW capacity each and use striling engine for power generation. These can be developed for village level distributed generation by hybridizing them with biomass gasifier for hot air generation.
2. Integration of solar thermal power plants with existing industries such as paper, dairy or sugar industry, which has cogeneration units. Many industries have steam turbine sets for cogeneration. These can be coupled with solar thermal power plants. Typically these units are of 5 to 250 MW capacities and can be coupled with solar thermal power plants. This approach will reduce the capital investment on steam turbines and associated powerhouse infrastructure thus reducing the cost of generation of solar electricity.
3. Integration of solar thermal power generation unit with existing coal thermal power plants. The study shows that savings of up to 24% is possible during periods of high insolation for feed water heating to 241ºC.

Advantages

1. Solar thermal electric power collectors provide a practical, scalable solution to one of the greatest challenges of our times.
2. It can provide reliable, night and day electric power at market prices without carbon emissions.
3. It has availability that closely matches human energy requirements by hour and by season.
4. It uses less land than coal mining and transport
5. It is quick to implement.

6. It is available widely around the planet, not just in a few countries.
7. It has enormous primary energy resource which is inexhaustible over time.
8. A potential advantage of solar thermal systems is the ability to produce electricity when sunlight is weak or unavailable by storing solar heat in the form of molten salt.

Conclusion

Solar thermal power plants are a technically feasible option to supply a significant fraction of the world energy demand. Though current cost of electricity produced by solar thermal power plants is still high, there is a large potential for cost reduction in a medium to long term. A lot of money is currently invested to develop improvements and innovations that will achieve a significant cost reduction, thus making reduction of public subsidies possible. The MENA (Middle East and North Africa) region can play a significant role in the solar thermal power market, not only producing electricity for internal consumption, but also for exporting it.

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