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SOLAR THERMAL - A VERSATILE TECHNOLOGY

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Abstract : Solar energy is classified as Solar Photo Voltaic and Solar Thermal Energy. While Solar photo voltaic (PV) has the primary function of generation of electricity, solar thermal has wide application in water heating, cooking, water purification, desalination and generation of electricity by creating high temperature directly through parabolic mirrors which becomes heat source for production of superheated steam required for running a turbine generator. An overview has been made in this paper to discuss mainly on three emerging technologies of solar thermal in the areas of solar water heater, concentrated solar power, and solar desalination, briefly highlighting the technical features of the same. Also a comparative statement of salient features of solar thermal and solar PV power has been included in the paper.

Keywords : Solar energy, solar thermal, solar water heater, solar power, solar desalination.

1. Introduction

Solar energy is one of the fastest growing technologies in the world, and perhaps, it can be put in at par with the growth of information technology. Basically, solar energy is harnessed by two principal technologies, such as Photo Voltaic Technology and Solar Thermal Technology. Photo Voltaic Technology is primarily applied for generation of electricity when sun ray is directly intercepted by solar panel made out of photovoltaic cells which are connected in series to get adequate amount of voltage and the electric power is generated as per requirement without any mechanical device. In Solar Thermal Technology, sun ray converted to heat energy directly, creates steam for running turbo generator, or, applied for water heating, desalination, heating ventilation, cooking, etc. [1,2].

Generation of solar thermal power, commonly known as concentrated solar power which is basically the technology of producing electricity from the energy derived from sun rays directly, is developing fast globally, and already large capacity concentrated solar power stations are operating successfully. There are also immense possibilities in countries like India having vast arid zone. As the information goes, in the year 1866, first parabolic mirror was used for creating a high temperature up to 400°C by concentrating sun ray and creating super heated steam to run the first solar steam engine. Later on, a solar thermal power station with a capacity of 1MW was built in Italy with improvised technology in the year 1968. The plant had a solar receiver and at the centre of the field, solar collector producing superheated steam at 100 bar with a temperature of 500°C operated steam turbine for generation of power. Currently the largest solar thermal power of 500 MW capacity is under commissioning with the most developed solar thermal technology in the Mojave Desert USA [2-6]. The European solar energy experts think that if a solar thermal power plant is built in the Sahara desert with the facility of high voltage

transmission cables, it may be possible to meet the power demand of whole of Europe. So, it can be envisaged the immense potentiality of solar thermal power. Although India is in infant stage in this field, various projects in solar thermal power plants are progressing fast, and the first solar thermal power plant of 50 MW capacity is being installed in Rajasthan, having very high solar irradiance of approximately 6 kW per sq.m.

2. Solar Thermal Technology

As mentioned earlier, solar thermal technology (STT) is getting developed globally in areas such as air-cooling, heating ventilation, cooking, etc. Following three areas where fast developments are taking place are discussed in detail [1-4].

(i) Solar Water Heater
(ii) Concentrated Solar Power
(iii) Solar Desalination

2.1 Solar Water Heater

Solar water heaters are basically composed of a solar collector fitted with metal or glass tubes and a storage tank with proper insulation for retention of thermal energy [1-3]. The tank is connected with the collectors with inlet and outlet pipes for necessary circulation of the fluid. The solar water heaters are broadly categorized in the following two systems :

Passive System : In this system (Fig.1A), hot water/ fluid is produced directly by the heat of the sun in the flat plate type collector through convection of heat. The cold water source tank is essentially placed above the collector at an adequate height (normally 5 to 10 feet). The heated water is stored in the system storage tank which is also essentially placed above the collector, and hot water is collected at the storage tank by thermo siphon system. Hence, there is no need for installation of a pump for circulation of fluid in this system.

Active System : In this system, a small pump run by electricity produced by photo voltaic panel incorporated in the system circulates the heat transfer fluid. Usually this system (Fig.1B) is applied where the storage tank is mounted on the ground below the level of the collectors.

Evacuated Tube Collector : The evacuated tube collector (ETC), belonging to a passive system, uses a glass tube placed inside another tube coaxially with their ends fused. A vacuum is created between the two glass tubes by evacuating air. Outer surface of the inner tube acts as a collector area and receives the heat of the sun directly heating the fluid flowing through the inner tube. The vacuum created between the tubes acts as a strong insulation and minimizes heat loss due to convection. And the glass tubes by virtue of its cylindrical shape, can track the sun throughout the day in more efficient way than the flat plate collector. The temperature of 60-120°C is achieved by the ETC, and it is much faster than the flat plate collectors achieving 60-80°C in a slower pace. Furthermore, there is hardly any deposition of scale in the ETC, whereas scale deposition and cleaning of the same in case of metal tubes in the flat bed collector requires regular maintenance. The above mentioned superior features of the ETC including high thermal efficiency are making this system more popular [1-3].

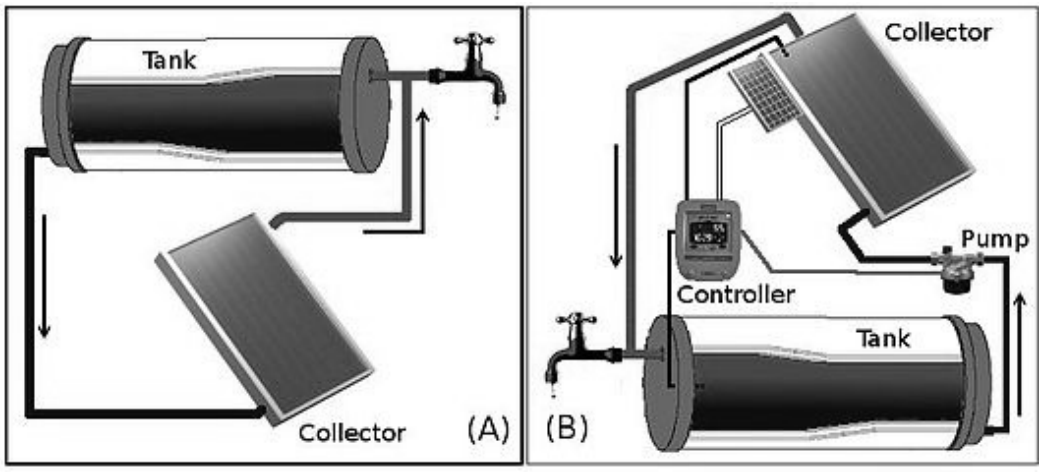

Fig.1 Solar water heater (A) Passive system (B) Active system

2.2 Concentrated Solar Power (CSP)

Concentrated Solar Power (CSP), commonly known as Solar Thermal Power, is a technology for creating strong beam of sun ray by focusing sun radiation through lenses/ mirrors. The strong beam of sun ray acts as a heat source which eventually heats a fluid in a receiver creating superheated steam essentially required to run a turbine for generation of power as done in a conventional fossil fuel power station [4,6,7]. For an effective operation of CSP, generally the minimum requirement of solar isolation is in the region of 5.5 kwh/sq.m/day, and in India, in some arid zones, the same is in the region of 6/8 kwh/sq.m/day that is ideally suitable for installation of CSP.

Generally four main arrangements are required to be created for generation of solar thermal power that are: a concentrator, a receiver, some form of storage and power conversion system. A concentrator is created by concentrating sun ray by using lenses or mirrors and by focusing a large area of sunlight into a small beam. The concentrated light becomes a heat source for the conventional power plant. The power is generated by heating the working fluid by the concentrated sunlight creating superheated steam. Thereafter the process is similar to conventional power plant. The difference is that CSP gets the input energy by concentration of solar radiation, whereas the conventional power plant gets its energy inputs through burning of fossil fuel [8,9].

There are many types of CSP systems available. These include a combination of nonrenewable and renewable energies, but following three are most commonly used technologies:

(i) Parabolic Trough
(ii) Solar Tower
(iii) Parabolic Dish

Parabolic Trough : In this system, sunlight is concentrated in a trough shaped mirror reflector, in which tubes are placed in the focal line of the trough and thermal fluid is circulated through it. As the tubes are situated in the focal line of the mirror reflector, the concentrated sun radiation heats the circulating fluid upto 400°C passing through heat exchangers producing superheated steam.

The super heated steam runs a steam turbine coupled with a generator producing

electricity in the same manner as in the case of a fossil fuel thermal power plant. The power generated is connected with grid in a hybrid manner.

Solar Tower : In this system, hundreds of flat type tracking mirrors, also commonly known as heliostas which receive the sun energy, are placed over a very large area in a barren field, and they focus the sun radiation on a tower situated in the centre of the heliostat field, as shown in Fig.2.

Fig.2 Solar tower with flat type tracking mirrors

The concentrated sun light created by the heliostats, is focused on a receiver situated on the top of the tower containing molten salt. The molten salt which is heated by the concentrated sun rays is able to achieve a temperature up to 500°C approximately flows into storage tank with high quality insulation maintaining about 95% thermal efficiency, and pumped into a heat exchanger for ultimately producing superheated steam to run a steam turbo generator for generation of electricity and connected with the grid. This system is considered as an effective energy storage system during non-sunny hours.

Parabolic Dish : This is a simple stand alone power generating system in which sun light is focused in a receiver which is situated at the focal point of the dish made of high powered mirror. Usually a transfer fluid or air or gas is placed inside a receiver which is situated at the focal point of the disc. The concentrated beam of sun ray heats up the transfer fluid/ gas, and runs a gas or micro turbine generator for producing power. This system has a high degree of thermal efficiency compared to trough and tower type solar thermal power and runs efficiently when installed with a Stirling engine.

2.3 Solar Desalination

The process of removal of salt and other minerals from water by using solar thermal energy is known as solar desalination. Solar thermal desalination unit harnesses sun energy for removal of salt and other minerals. In case of salt/ sea water desalination, the principal by-product of the desalination process is the table salt. The following two broadly categorized processes are used in solar desalination [4,7].

Direct Use of Solar Thermal Energy : In this system, a simple technology of evaporation and condensation of water is applied for separation of salt, minerals and other substances from water. Solar thermal energy produces water vapour by using parabolic or trough type collector which is condensed in a separate chamber by cooling off the vapour.

Indirect Use of Solar Thermal Energy : In this system, reverse osmosis process is applied where force is exerted for separation of minerals and other particles from the

water. Permeable membrane is installed along with circulation pump, pressure exchanger, etc. as shown in the schematic diagram in Fig.3. For running the circulating pump of this system in remote rural areas in India and other developing countries where grid electricity is not available, stand alone solar photo voltaic modules are used to generate electricity.

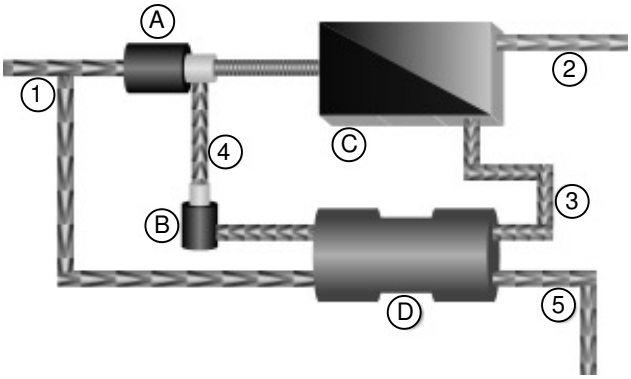

Fig.3 Schematics of a reverse osmosis system (desalination) using a pressure exchanger [1 : Sea water inflow, 2 : Fresh water flow (40%), 3 : Concentrate flow (60%), 4 : Sea water flow (60%), 5 : Concentrate (drain), A : Pump flow (40%), B : Circulation pump, C : Osmosis unit with membrane, D : Pressure exchanger]

3. Comparison between Concentrated and Solar PV Power

Although Concentrated Solar Power has many advantageous features over Solar PV Power, there are some negative features also when compared with PV Power, and these are detailed in Table I [9,10].

4. CONCLUSION

From this article, it may be evident that solar thermal technology, when applied as concentrated solar power is one of the most promising areas which can be an ideal substitute in the near future for fossil fuel

Table 1 Comparison between Concentrated and Solar PV Power

Concentrated solar power	Solar PV power
Requires high solar insolence directly in the region of 5.5 kwh/day.	Operates moderately under any sunny condition.
System unsuitable for roof top application, requires large area in acres for installation of parabolic/ trough reflectors for creation of high temperatures.	Roof top application is possible up to certain kwh output depending upon size of the roof top. PV panels can be installed in any terrain.
For generating power for more than 10 MW, large substations are required to be located nearby.	Stand alone (off grid) and grid connectivity arrangements can be done.
High installation cost and regular maintenance of parabolic/ trough reflector surface is required.	Installation cost is comparatively moderate with minimum maintenance of the PV panels. However, high cost of PV panels is affecting cost of power generation adversely.
Salt free water is essentially required for cooling of exhaust steam from the turbine.	Only limited quantity of water required.

power stations. Solar conversion efficiency is approximately 31%, and energy storage during non-sunny hours is possible through preservation of energy in molten salt.

If the cost aspect is considered, probably the solar water heating system is one of the most cost advantageous systems, and a house owner may recover the initial installation cost within six years approximately.

In case of solar desalination, the use of parabolic/ trough type collector has made the process quite simple. Due to simplicity of the process, and low investment and maintenance cost, this method of desalination is ideally suitable for small and medium scale application. However, some disadvantageous features of concentrated solar power are also there when compared with solar PV power, and these are mentioned in this paper.

Both the CSP and solar PV power systems are superior in their unique ways, depending upon the climatic and geographical conditions of the particular place where they would be installed.

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