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Review Article

REVIEW ON COMPARISON OF DIFFERENTSOLAR TECHNIQUES AND THERMAL STORAGE SYSTEM

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ABSTRACT

In developing world, the energy requirement is very high, to execute the demands for future need of energy, the renewable sources are to be needed. As usage of fossil fuel is increased day by day and it pollutes the environment. There is an alternate energy source is required it should be protect the environment from the pollutants and also to produce cost-effective. Solar is the best energy source which accomplishes energy requirements with the eco-friendly nature. The parabolic trough collector (PTC) using phase change materials (PCMs) absorbs the solar energy and delivers constant heat to the cooking vessel which have been attempted by experimental model analysis. This review is confined to the enhancement of a PTC is utilized as the source of heat and TES (Thermal storage system) and PCMs for intermediate energy storage. The review covers different solar techniques and TES and tracking system.

INTRODUCTION

In present era, the power generated commonly by fossil fuels, which emits huge amount of carbon dioxide which are major pollutants of the environment. As there is a great demand for green energy, the solar power is one of the fastest growing forces in the market. Earth's energy is the main source of the sun. All air, hydro and biomass energy have their appearance from sunlight. The total output of solar energy is 3.8×10^{20} MW which is equal to $63MW/m^2$ of the sun surfaces, in all the directions. Just a small fraction 1.7×10^{14} KW of total energy falls to the earth's surface (Kreith, *et al*., 1978) which means all the solar energy received from the sun in 30 min is equal to one year of global energy needs. (Panwara, *et al*., 2011) suggested that solar energy is eco-friendly energy source will not affect climate conditions, human health but unlike fossil fuel and other energy sources, which releases green air gases such as CO_2, CH_4, N_2O, CFCS, and Helens, raising Earth's surface temperature (Panwara, *et al*., 2011). There are many applications for solar power, i.e., electricity generation, photochemical, solar cooking purpose, melting and freezing room's etc. Solar thermal technology for low temperature is used in heating and household use and high temperature solar applications are principally for electric power generation. Now-a-days there are many important prospects are there for solar technology development.

HISTORY OF SOLAR ENERGY

Eighteen hundred years ago, the Greek scientist and Archimedes were attacked the Roman naval by using the hundreds of shiny polished shields which absorbs solar energy and reflecting at the same instant (Anderson, 1977). In 1878 August Monset invented a generator to convert low-power sunlight into a generator and run steam apparatus but this terminology was ignored by the French government due to its higher expense (Meinel and Meinel, 1976). The Monsanto solar collectors are significantly predictable by creating a precise cone reflective shape; with silver-metal plates are 5.4 m

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in diameter and 18.6 m^2. The moving part weighed 1400 kg (Meinel and Meinel, 1976; Krider and Krith, 1977). As the follower of Monochot, Abel Pifre has successfully made fabricated solar engines. Pifre's solar collections were parabolic reflectors made of small mirrors. In 1901, A. G. Eneas discovered a large umbrella of 1788 glasses, which received solar radiation and were concentrated at a focal point on a boiling water to produce a steam, which in turn the steam engine and centrifugal pump (Kreith, *et al.*,1978; Meinel and Meinel, 1976). In 1913, Schumann used long parabolic cylinders to focus on sunlight in a long sucking pipe, 62 meters long and cylinder bank's total area of 1200 m^2 developed the solar power machine of 37-45 KW capacity which runs continuously for a period of 5 hours (SERI, 1987). It was shut down in 1915 due to cheap fuel prices and the beginning of First World War.

During last 50 years, the solar technologies used for two major receiver systems. The first one is central receiver systems use two-axis mirrors tracking to focus on the energy of sunlight on a tower-mounted receiver (SERI, 1987) and the second one is Receiver distributed technique includes parabolic dishes, Major lenses, parabolic thoughts, and special bowls. In both systems obtained temperature range from 100°C to 1500°C (Krider and Krith, 1977). In 1960, many industries launched the solar water heater (SWH) is thermosyphon type and its consists of two-flat plate. The part of absorption includes 3 to 4 m^2 and 150 to 180 lit/m^2, and a cold-water storage tank. The SWH connected to the heater or thermal transmitter with sub-power sinking with the help of continuously producing hot water. In solar panels, hot water storage tank is located inside a plant room and it is covered by a pump, different thermostats (Kalogirou, 1997). In 2002, PV cells were made of different semiconductors, such as Si and compound of cadmium, Cuprous Sulphide and GAAS. These technologies are relatively inexpensive to compare to amorphous silicon modules (Lysen, 2003). PV module is applicable for remote electricity, lamps and charging battery in the fire and space. PV applications can either be stand alone or connected to the grid. A single system is independent from the power grid, which is usually stored on batteries. The grid PV system is connected to the local electricity network. Earlier, in the grid connections obtained less than 10% efficiency. Nowadays, it is increased about 15% but, have not been commercialized still now. The great French chemist Lavoisier (1862) mounted on complex supporting structures for used large aluminium coated plate and silver glass mirror, to concentrator solar energy on the filling of distillation flasks have been described by Mouchot (Malik, 1985). The produced steam from the boiler is passed through a water-cooled condenser, which is accumulated in distilled water. The regeneration of importance in the solar atmosphere occurred after the First World War at that time several new techniques has been developed such as roof type, tilted wick, inclined tray and inflate solar system [10]. Another application of solar energy is solar drying which is primarily used by the agricultural industry for minimize moisture to extend the period of storage (Norton, 1992).

SOLAR TECHNOLOGIES

There are various types of solar energy techniques exist but are widely classified into Non – concentrated PV solar panels and concentrated solar power.

Non–concentrated photovoltaic solar panels

Solar techniques differ from the concepts and its advantages. Non-concentrated photovoltaic solar panels devices are:

- Solar Thermo electricity device.
- Dye Sensitized solar cell,
- Concentrated Photovoltaic cell,
- Photovoltaic solar panels.

Solar thermo electricity device (STE)

- STE device, the parabolic disc concentration (PDC) was used to capture the thermal energy based on the thermoelectric effect.
- The PDC collects the sun light, it creates a difference of temperature causes charging the entity to move from hot side to cool side through the thermoelectric materials and generates voltage involving the two ends efficiently (Blundell, 2009). The equations used for measuring temperature difference across the materials induced the magnitude of the thermoelectric voltage is

$$Z = (\sigma S^2/K)$$

Where σ is the Electric conductivity, S is the See back coefficient and k is the thermal conductivity of materials.

The ultimate working capacity of thermal energy materials η is:

$$\left[\frac{T_H - Tc}{T_H}\right]\left[\frac{\sqrt{(1+ZT)} - 1}{\sqrt{(1+ZT)} + (T_C/T_H)}\right]$$

Where T_H, T_C refers to the temperature on the hot side and the cold side.

According Hungnan Fan et al tested of a single thermo electric generator conducts a maximum

power of 4.9 W for a temperature difference of 110 K, there were able to obtain a conversion efficiency of 2.9% (Fan hongnan, *et al*., 2011).

Advantages

- It is easy to use in roof tops.
- It can withstand cruel environment.
- Extremely reliable in operations.
- The thermoelectric device is simple and stable.
- At Low-capacity heat energy and its produces voltages.

Disadvantages

- The thermoelectric Products performance is very low, the latest record is 1.3-2.0% approximately.
- This method is not possible to collect wide radiation and depend only on direct radiation only.
- High temperatures require it to work efficiently, which guide the higher concentration rate of the collector and more accurate tracking systems. However, higher concentration collectors increase the cost of capital expenditure and maintenance.
- Thermoelectric materials, such as Bismuth telluride, are poisonous and expensive.
- The cooling system is required to increase the efficiency by decreasing cool side temperatures.

By discussion, Solar thermoelectricity is the new model but not affordable at market level. If it is combined with hybrid system, it will be able to achieve overall higher efficiency.

Dye sensitized solar cell (DSSC)

The DSSC Cell is a semiconductor-based photographic sensitivity between anode and electrolyte, a photovoltaic chemical system (Fan hongnan, *et al*., 2011). This cell is called Gratzel cell, invented by Michael Gratzel and Brian O Regan at the Ecolo polytechnic Fedorale de Lausanne in 1991 (Fan-Tai Kong, et al., 2007; Michael, 2001). Sunlight enters the tip of the open lid, striking the surface of TiO_2's death. This creates an excitation of TiO_2, thus taking an electron to the process of electron diffusion, this electron accelerates and reaches the anode at the top. The dye molecule, after losing an electron is liable to decompose. Hence it acquires an electron from the electrolyte. This occurs almost instantaneously, preventing there work of the earlier electron from dye. The counter electrode absorbs the free electron and let it into the electrolyte via external circuit establishing current flow. In TiO_2 is a very small conduction and optical losses occurs in the front electrode. In TiO_2 are the smallest losses due to Optical losses in front of the electrode. Therefore, the overall efficiency is 90% and overall pack power production efficiency is about 10.9% tested in January 2011 (Green, *et al*., 2011).

Advantages

- It's cheap and cost-effective, easy and technically attractive.
- It can be used as a replacement for technologies in 'low density' applications like roof top solar collection.
- In the silicon, the high energy electron can be re-attached to its own hole and to generate the low current.
- It works effectively in low level light conditions for cloudy skies and diffuses sunlight.
- An DSSC is typically constructed as a thin layer on the front conductive layer, allowing heat to be easily removed, so it operates at lower internal temperature.

Disadvantages

- The DSSC power efficiency is still low compared to the tradition semiconductor solar cells.
- Dyes will degrade ultraviolet radiation that exposes the limits of controls and stability.
- Dyes will degrade ultraviolet radiation that will expose limits of controls and stability of the cells. Therefore, an extra layer is required, which increases the cost and reduces performance.
- To carefully seal the electrolyte resolution because of it contains volatile organic solvents.
- A DSSC technology can only withstand low temperature because if the liquid electrolyte temperature increases, it will direct to serious problem in the ceiling panels.

For large scale employment may not be attractive the DSSC technology because of the higher- efficiency cells are more feasible, although more expensive but DSSC has more advantages compared with semiconductor solar cells.

Concentrated photovoltaic cell (CPC)

The CPC consists of optics such as lenses to concrete the largest amount of solar light to the lower part of the photoelectric materials to generate electricity and to generate electrons from photon in the Fatigue or semi-neutral zones. The electrons go from the

valence to the conduction band, the Electron and holes, which are accelerated by the hinge port that leads to movement current (Kurtz, 2009).

Advantages

- Despite the lost energy during the concentration process, The CPC has greater efficiency in all kinds of solar systems.
- CPC system is less expensive compared to DSSC and solar dish cell
- Disadvantages
- The Large concentration of concentrated systems could not extract widespread radiation
- Even small cloud can reduce production to zero. Use of TES is very difficult.
- For the same efficiency, the expenditure is more than 100% of a silicon cell.

CPC are better suited for solar farms rather than roof top usage. In a microscopic or co-production technology, combine with the CPC and thermal power and generates electricity and heat in the same constituency. The hybrid system may be connected to a concentrated solar panel to create high efficiency

Photovoltaic solar panels (PVSP)

There are many solar cells in the sun panels. In each solar cell contains photovoltaic materials. The solar cell is absorbed solar radiation is transmitted into photovoltaic materials, due to photoelectric effect to generating electrical power. Most commonly used photovoltaic materials are mono crystalline silicon, Polycrystalline silicon, amorphous silicon, CdTe and CIGS. Types of PVSP are:

Crystalline silicon: Most of the PV modules are based on wafer based crystalline-silicon. The single crystalline-silicon module has higher converting the capacity is 14 to 20 percent. In future research development, the capacity is expected to increase by 23 percent in 2020.

Thin films*:* Thin Films are manufactured by photo centric materials in a thin layer (micrometer) range, supported by glass, stainless steel or plastic. These films producing 50 MW limits, is estimated to increased effect in 2020 in the market share.

II-VI semiconductor thin films*:* This film is made up of cadmium telluride (CdTe) and copper-gallium-diseleine (CIGS) materials. The fabrication process and efficiency of these films is very high while compare to other films. However, these products are poisonous and less than silicon. It is difficult to predict any calculations that these film technologies reach higher market share in the long term. Despite the reliable predictability of photovoltaic industry, this technology must try to solve them. Solar energy is more expensive than other energy production, no electricity is produced at night and cloudy conditions. Therefore, the storage or filler power system is needed.

Concentrated collector (CC) solar system: The CC Solar System is the incoming solar radiation absorbing devices that transmit heat to fluid substances like air, water, oil. The heated circulating fluid is carried over the hot water or space containing equipment or to a TES tank and it can be used in light and rainy days. Basically, this is classified as two types of solar collectors.

(i) Non-concentrating or stationary collector

(ii) Concentrated collector

Non-Concentrating collectors have the same area of inter opting and absorbing solar radiation whereas CC solar system uses a glass or lens to concentric a large area of sunlight onto a small part area. The produced heat is stored into TES and is utilized for power generation or home heating and cooling system (TransWorld News, 2011).

Concentration techniques

Concentrated collectors have certain advantage over the convectional flat –plate type.

- For the same amount of working fluid, The CC system achieves high temperatures compared to a FPC system (Kalogirous, 2009).
- Since the receiver is small, the heat capacity is relatively high.
- The thermal efficiency is comparatively high because of receiver area is relative small.
- The reflective surface requires fewer materials and is structurally simpler than FPC.
- The collector area is relatively small, so it is easy to limit losses and upgrade to CC.
- The cost for a unit surcharge for the storage surface is less than FPC.

Tracking System (TS)

Tracking System is essential for the collectors to trail the sun, directing solar radiations to the small receiver system (Sorenson and Breez, 2009). It can be divided into i) Mechanical and Electrical system ii) Mechanical and electronic system.

The electronic system generally improved reliability and monitoring accuracy reveal. These may have sub-divided into motor as well as computer controlled system. The motor control system operates automatically through the sensors that detects the amount of sunlight. Using computer-controlled machines which operate dynamic response controls used to measure solar light to operate tracking system.

The design and fabricated automatic solar tracking system (STS) to build hardware and software unit, used to automatically operate the solar panel in the direction of the sun. As a result, automatic STS stored energy is 20% to 30% higher than the stock STS (Nikesh, *et al*., 2013). The research work is based on the advantages of STS over PV panel. The system is very useful for optimal tracking mechanism, easy to control the machine, the low energy required to operate. The results showed that the planned solution is useful for large scale PV structures (Tiberiu and Liviu, 2010).

Concentration collectors (CC) can be categories

CC can be categorized into:

- Parabolic Through Collectors (PTC).
- Linear Fresnel Collector (LER).
- Parabolic Dish Reflectors (PDR).
- Solar Towers (Heliostat Field Collector).

Parabolic Through Collectors (PTC)

PTC made by the reflective sheet of materials is Focuses on parabolic form as shown in (Fig. 1).

To reduced heat loss which is centred on a blank metal tube receptor covered by a glass pipe and use a single axis tracking to tilt the collector directly to the solar lanterns (Alternative Energy Tutorials, 2011). PTC can create 50°C to 400°C for solar thermal electricity generation or heat process applications (Kalogirous, 2004).

Linear Fresnel Collector (LFC)

The collector uses a linear glass, which focuses sun light on a standard receiver in a linear tower as shown in (Fig. 2). The LFC collector made of flat or elastic curve reflectors are cheaper compared to parabolic glass reflector. Linear Fresnel Collector field can be imaged as a broken –up parabolic through reflector but the only drawback is difficulty incorporating a TES (Siddiqui, 2012).

Parabolic dish Reflectors (PDR)

The PDR is a point-focus collector which focuses

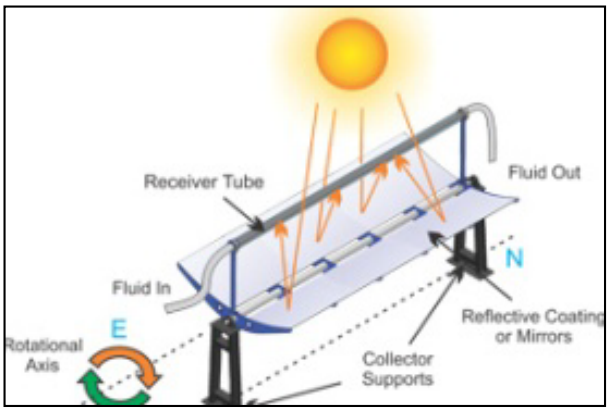

Fig. 1 Parabolic through collector.

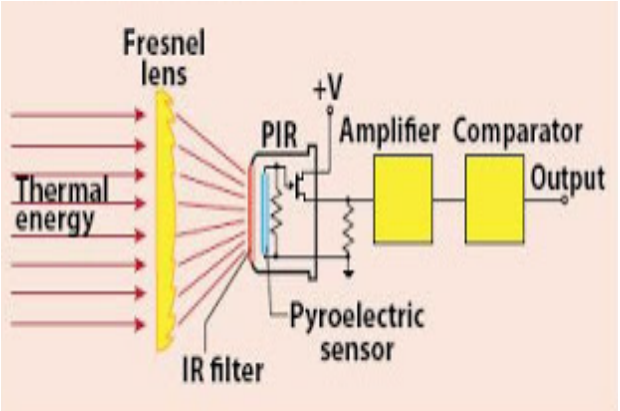

Fig. 2 Linear Fresnel collector.

concentrating solar light into a receiver as shown in (Fig. 3).

The dish construction is made up of a glass reflector to replicate the beam into the receiver. A circulating fluid passing through receiver which absorbs the radiant solar energy converting into thermal energy. The heat energy can be converted into electricity or can be utilized for home based heating and cooling applications (Alternative Energy Tutorials, 2011).

Advantages

- It always points at the sun and hence is the most resourceful collector system.
- The range of concentration ratio is 600-2000 and it is very efficient at thermal–energy absorption and power conversion.
- It functions as an individual device or as large system of dishes.
- The sterling heat engine used in the parabolic disc system.
- Increasing reliability and production mass techniques have been improved

Solar Tower (Heliostat Field Collector)

The effort of high radioactive energy inputs achieved by an arrangement of large number of mirror that reflect solar radiation into a receiver is called as Heliostat Field Collector. A systematic diagram is shown in (Fig. 4). The amount of heat absorbed by the receiver is converted to a circular fluid that can be stored and produce power (Review and comparison of Different Solar Technologies).

Advantages

- The solar energy is optically transferred to a single reservoir, thus minimizing thermal-energy transport requirement.
- The concentration ratio is in the range of 300-1500 and has a high collecting and conversion efficiency.
- It continuously and conveniently stores thermal energy.
- It produces more than 10 MV power and is economical for large scale power production.

Thermal storage system

TES is one of the most important roles in the efficient process of delivery systems, such as solar cooking systems, power systems, heat and cooling systems and industrial heat recovery system. The heat or energy is store and retrieve from the thermal storage system is classified into:

- Sensible heat storage
- Latent heat storage
- Thermo-chemical storage

Sensible heat storage

In this mechanism, Thermal energy materials are stored by raising the temperature. The rise and fall of the temperature of material occurs during the process of charging and discharging. The amount of thermal energy storage depends on the specific heat of the capacity of materials, the temperature change and the quantity of storage material.

Fig. 3 Parabolic dish reflector.

Fig. 4 Solar tower.

Latent heat storage (LHS)

The storage system thermal energy is based on heat absorbed or released. If there is no change in temperature during the process, then the stored materials undergo a phase change from solid to liquid or liquid to gas or vice-versa.

The research report focuses on various solar technologies of TES depending on their application. The technologies of TES used mostly for heat, chemical industries and hydride storage systems (Pawar, 2015). In modern technologies, the conversation of solar energy is stored in the LHS system. Justin Ning et al investigated salt hydrate PCMs as a LHS material. Salt Hydrate PCMs from the study have great storage efficiency, high thermal conductivity, low cost and high-power removal rate (Justin, *et al*., 2008). The investigation work based on building sector with insertion the PCMs into building element. The PCMs building element have high heat sensitivity, low change of heat and temperature fluctuations (Sarada, *et al*., 2013). From the investigation work is based on the use of nano particles for TES, this latest system is comparable to other storage settings, the lowest cost to store more energy (Lavinia Gabriela SOCACIU, 2012).

Thermo-chemical storage

In the thermo-chemical storage system, storage of the thermal energy is by certain physical chemical reaction. The stored energy is released by reverse of the chemical reaction. The storage system operates isothermal function during the process. This system has a greater promise for further use.

Selection of thermal storage medium

Some suggestions for selecting the storage system and its design are as follows.

- The temperature range required for storage.
- Heat capacity of storage unit such as Long term (or) Short –term storage unit.
- The heat losses from storage must be kept at least.
- Depending on the charging and discharge rate
- Cost savings storage materials.

CONCLUSION

The commonly used four types of solar technologies are solar disc technology, Dye Sensitized solar cell, Concentrated Photovoltaic cell and concentrated collector solar system. We have selected, studied and discussed their structure, performance, working principle, advantages and disadvantages. These solar technologies have their own advantages and drawbacks. Instead of saying that the review paper is very much support for understanding of different solar techniques and will serve as a reference for those who want to invest or work in the solar energy field.

REFERENCES

Alternative Energy Tutorials. 2011. Parabolic trough reflector.

Anderson, B. 1977. Solar energy: Fundamentals in building design. New York, McGrew-Hil.

Chiu, J.N.W., Viktoria, M. and Setter wall, F. A Review of thermal energy storage systems with salt hydrate phase change materials for comfort cooling. Department of Energy Technology. Brinellvagen. 68.

Green, M.A., Emery, K., Hishikawa, Y., Warta, W. and Dunlop, E.D. 2011. Solar Cell efficiency tables (Version 38). Prog. Photovolt: Res. Appl. 19 : 565-572.

Hongnan, F., Randeep, S. and Aliakbarm, A. 2011. Electric power Generation from Thermoelectric Cells Using a Solar Dish Concentrator. Journal of Electronic Materials. 40 : 1311-1320.

Kalogirou, S. 1997. Solar water heating in Cyprus, Current status of technology and problems. Renewable energy. 10 : 107-1012.

Kalogirou, S. 1997. Survey of solar desalination system and system selection. Energy. 22 : 69-81.

Kalogirous. 2009. Stories, solar energy engineering: Processes and systems.

Kalogirous, S.A. 2004. Stories, solar thermal collectors and applications. Science. 30 : 231-295.

Katherine, B. and Stephen, B. 2009. Concepts in Thermal Physics.

Kreith, F. and Kreider, J.F. 1978. Principles of solar emerging. New York. Mc Grew-Hill.

Krider, J.F. and Krith, F. 1977. Solar heating and cooling. New-York. McGrew –Hill.

Kong, F.T., Song-Yuan, D. and Kong-Jai, W. 2007. Review of recent progress in dye-sensitized solar cells. Advances in OptoElectronics.

Kurtz, S. 2009. Technical support. Opportunities and challenges for development of a mature concentrating photovoltaic power industry. NREL/TP-520-43208, Revised November.

Lavinia Gabriela SOCACIU. 2012. Thermal energy storage with phase change material. Leonardo Electronic Journal of Practices and Technologies. 20.

Lysen, E. 2003. Photovoltaics: An outlook for the 21st century. Renewable energy world. 6(I) : 43-53.

Malik, M.A.S., Tiwari, G.N., Kumar, A. and Sodha, M.S. 1985. Solar distillation. New-York:Prgamon Press.

Meinel, A.B. and Meinel, M.P. 1976. Applied solar energy: An introduction, Reading MA: Addition –Wesley.

Michael, G. 2001. Photo electrochemical Cells. Nature. 414 : 338-344.

Nikesh, D., Watane, R. and Dafde, A. 2013. Automatic solar tracking system. International Journal of Scientific & Engineering Research. 4(6) : 93.

Norton, B. 1992. Solar energy thermal technology. London Springer.

Panwara, N.L., Kaushikb, S.C. and Kotharia, S. 2011. Role of renewable energy sources in environmental protection: A review. Renewable and Sustainable Energy Reviews. 15 : 1513-1524.

Pawar, S.R., Mohite, V.R. and Vivekananda, N. Review of thermal energy storage systems and their applications. International Journal of Innovations in Engineering Research and Technology. 2(6).

Review and comparison of different solar technologies. Global energy Network Institute, www.geni.org.

Sarada, K., Jamie, T., Yogi, Goswami, D. and Muhammad, Rahman, M. 2013. Review thermal energy storage technologies and systems for concentrating solar power plants. Progress in Energy and Combustion Science. 39 : 285-319.

SERI. 1987. Power from the sun; Principles of high temperature solar thermal technology.

Siddiqui, H.A. 2012. Cheaper options of solar power. Technology times. http://www.technologytimes.

pk /2012/04/16/cheaper-options-for –solar-power-2.

Sorenson, B. and Breez, P. 2009. Renewable energy focus handbook. Academic Press.

Tiberiu, Tudorache. and Liviu, Kreindler. 2010. Design of a solar tracker system for PV power plants. Acta Polytechnica Hungarica. 7(1) : 23-39.

TransWorld News. 2011. Concentrated solar power system, Worldwide 2011 to 2017.