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ORIGINAL ARTICLE

Concentrated solar thermal power technology

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Abstract

This review work consists of detailed description on various types of research in the field of solar thermal systems and various methods to improve the performance of the collector systems. Concentrated solar thermal systems are the highly advanced and large scale technology, which is used to generate the thermal energy and converted it in to electric energy through the application of power producing device coupled with the collector systems, therefore from the research point of view improvement in the working performance of the solar thermal system is highly important to achieve the better efficient device.

1. Introduction

Solar energy is a renewable and green resource of energy. Solar energy has several advantages over other alternative or renewable energy sources. All the primary or conventional energy resources are continuously depleting the environment of earth and are giving harmful effect to human health. Among all alternative sources of energies solar energy has great potential and India receives great amount of solar energy as compare to many other developed countries throughout the year.

Energy from the sun can be collected and utilized in many different ways, most of which may be grouped into three basic principle categories:

Direct thermal applications involving collection of sun light by solar energy thermal heat exchangers for heating and cooling of buildings, heated water distillation, providing industrial and agricultural process heat.

Solar thermal electric applications in which energy from sun is transformed into electricity via solar thermal electric photovoltaic, wind and ocean thermal conversion systems

Fuels from biomass involving the production of fuels such as wood, methane alcohol, hydrogen, bio –Diesel or other energy intensive products from organic waste materials.

All of these technologies exist and have been well demonstrated, however until recent years' development efforts have been limited in scope due to primarily to the relatively higher cost of utilizing solar energy and the abundance of cheap alternative fuel sources mainly oil, coal and gas.

The recent rapid escalation in the costs of the fossil fuels the rising awareness regarding environmental pollution issues and the finite size of fossil resources have changed the scenario. The alternative energy sources have been developed to supplement and eventually replace fossil resources.

Solar energy can play a major role and it can be used for a variety of applications which can be divided into the direct and indirect methods and range from small systems for individuals to the massive systems orbiting the earth such as for [1]

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- Heating water for domestic, industrial and agricultural processes
- Drying agricultural and industrial products
- Cooking of food and space heating and cooling
- Desalination of water and mechanical power production
- Refrigeration and preservation of food materials
- Electricity production

At present most research and development programs in the developing countries are oriented towards the application of solar energy for [1]:

Water heating, Solar distillation of sea and brackish water, Solar crop drying, Solar pumping (solar and wind energy), Biogas production, Production from the fuel from biomass, Small hydro power development, Green house technology, Solar cooking technology.

Research is also being carried out on the application of solar energy for [1-2]

Space heating and cooling using active and passive heating and cooling of buildings, solar Refrigeration and air conditioning, solar electricity production

However, this type of research is more common in the developed countries where extensive work is carried out in the following areas: Large scale energy plantations (biomass) and bio-conversion systems, Pyrolytic conversion of wastes, Development of large wind mill schemes, Harnessing tidal and wave power, Solar refrigeration and air conditioning, Ocean thermal power production, Photo-voltaic electricity generation

Solar thermal electricity generation, space heating and cooling (Passive and active systems).

2. Solar Thermal collectors [2]

A solar thermal collector collects heat by absorbing sunlight. The term "solar collector" commonly refers to a device for solar hot water heating, but may refer to large power generating installations such as solar parabolic troughs and solar towers or non-water heating devices such as solar air heaters.

Solar thermal collectors are either non-concentrating or concentrating. In non-concentrating collectors, the aperture area (i.e., the area that receives the solar radiation) is roughly the same as the absorber area (i.e., the area absorbing the radiation). A common example of such a system is a metal plate that is painted a dark color to maximize the absorption of sunlight. The energy is then collected by cooling the plate with a working fluid, often water or glycol running in pipes attached to the plate. Flat-plate and evacuated-tube solar collectors are mainly used to collect heat for space heating, domestic hot water, or cooling with an absorption chiller. In contrast to solar hot water panels, they use a circulating fluid to displace heat to a separated reservoir. The first solar thermal collector designed for building roofs was patented by William H. Goettl and called the "Solar heat collector and radiator for building roof". Evacuated flat-plate solar collectors are a more recent innovation and can be used for Solar Heat for Industrial Cooling (SHIC) and Solar Air Conditioning (SAC), where temperature in excess of 100 °C (212 °F) are required.

These non-concentrating collectors harvest both diffuse and direct light and can make use of steam instead of water as fluid

Concentrating collectors have a much larger aperture than the absorber area. The aperture is typically in the form of a mirror that is focused on the absorber, which in most cases are the pipes carrying the working fluid.

Due to the movement of the sun during the day, concentrating collectors often require some form of solar tracking system, and are sometimes referred to "active" collectors for this reason.

Non-concentrating collectors are typically used in residential and commercial buildings for space heating, while concentrating collectors in concentrated solar power plants, generate electricity by heating a heat-transfer fluid to drive a turbine connected to an electrical generator.

Flat-plate collectors are the most common solar thermal technology in Europe. They consist of an (1) enclosure containing (2) a dark colored absorber plate with fluid circulation passageways, and (3) a transparent cover to allow transmission of solar energy into the enclosure. The sides and back of the enclosure are typically insulated to reduce heat loss to the ambient. A heat transfer fluid is circulated through the absorber's fluid passageways to remove heat from the solar collector. The circulation fluid in tropical and sub-tropical climates is typically water. In climates where freezing is likely, a heat transfer fluid similar to an automotive antifreeze solution may be used instead of water, or in a mixture with water. If a heat transfer fluid is used, a heat exchanger is typically employed to transfer heat from the solar collector fluid to a hot water storage tank. The most common absorber design consists of copper tubing joined to a high conductivity metal sheet (copper or aluminum). A dark coating is applied to the sun-facing side of the absorber assembly to increase it absorption of solar energy. A common absorber coating is black enamel paint [2]. In higher performance solar collector designs, the transparent cover is tempered soda-lime glass having reduced iron oxide content same as for photovoltaic solar panels. The glass may also have a stippling pattern and one or two anti-reflective coatings to further enhance transparency. The absorber coating is typically a selective coating, where selective stands for having the special optical property to combine high absorption in the visible part of the electromagnetic spectrum coupled to low emittance in the infrared one. This creates a selective surface, which reduces black body energy emission from the absorber and improves performance. Piping can be laser or ultrasound welded to the absorber sheet to reduce damage to the selective coating, which is typically applied prior to joining to large coils in a roll-to-roll process. Absorber piping configurations include:

- Sharp: traditional design with bottom pipe risers and top collection pipe, used in low pressure thermosiphon and pumped systems;
- Serpentine: one continuous s-shaped pipe that maximises temperature but not total energy yield in

variable flow systems, used in compact solar domestic hot water only systems (no space heating role);
- Flooded: consisting of two sheets of metal molded to produce a wide circulation zone that improves heat transfer.
- Boundary layer: consisting of several layers of transparent and opaque sheets that enable absorption in a boundary layer. Because the energy is absorbed in the boundary layer, heat conversion may be more efficient than for collectors where absorbed heat is conducted through a material before being accumulated in the circulating liquid

A flat plate collector making use of a honeycomb structure to reduce heat loss also at the glass side too has also been made available commercially. Most flat plate collectors have a life expectancy of over 25 years [2].

Evacuated tube collectors are the most common solar thermal technology in China and in the World. They make use of a glass tube to surround the absorber with high vacuum and effectively resist atmospheric pressure. The vacuum that surrounds the absorber greatly reduces convection and conduction heat loss, therefore achieving greater energy conversion efficiency. The absorber can be either metallic as in the case of flat plate collectors or being a second concentric glass tube ("Sydney Tube"). Heat transfer fluid can flow in and out each tube or being in contact with a heat pipe reaching inside the tube. For the latter, heat pipes transfer heat to the fluid in a heat exchanger called a "manifold" placed transverse in respect to the tubes. The manifold is wrapped in insulation (glass wool) and covered by a protective metal or plastic case also used for fixing to supports [2]. Glass-metal evacuated tubes are made with flat or curved metal absorber sheets same as those of flat plates. These sheets are joined to pipes or heat pipes to make "fins" and placed inside a single borosilicate glass tube. An anti-reflective coating can be deposited on the inner and outer surfaces of such tube to improve transparency. Both selective and anti-reflective coating (inner tube surface) will not degrade until the vacuum is lost. A high vacuum tight glass-metal seal is however required at one or both sides of each evacuated tube. This seal is cycled between ambient and fluid temperature each day of collector operation and might lead to failures in time [2].

Glass-glass evacuated tubes are made with two borosilicate glass tubes fused together at one or both ends (similar a vacuum bottle or dewar flask). The absorber fin is placed inside the inner tube at atmospheric pressure. Glass-glass tubes have a very reliable seal, but the two layers of glass reduce the amount of sunlight that reaches the absorber. The selective coating can be deposited on the inner borosilicate tube (high vacuum side) to avoid this, but heat has then to flow through the poorly conducting glass thickness of the inner tube in this case. Moreover, moisture may enter the non-evacuated area inside the inner tube and cause absorber corrosion in particular when made from dissimilar materials (galvanic corrosion).

A Barium flash getter pump is commonly evaporated inside the high vacuum gap in between tubes to keep the internal pressure stable through time.The high temperatures that can occur inside evacuated tubes may require special design to prevent overheating. Some evacuated tube collectors work as a thermal one-way valve due to their heat pipes. This gives them an inherent maximum operating temperature. that acts as a safety feature. Evacuated tubes collectors can also be provided with low concentrating reflectors at the back of the tubes realising a CPC collector.

2.1 Concentrated Solar Thermal collectors [2]

Concentrated solar thermal power is the most prominent and highly proven technology, which is used to generate electric power on large basis. Concentrating collectors are also known by focusing type collectors. Radiations coming from sun are falling on the collector and concentrating on the absorber area by reflected through mirrors. Continuous falling of radiations on receive per unit area can increase the temperature of receiver or absorber surface of collector. There are some losses which also accounts in the working mechanism of concentrating solar collectors and those losses are reflection losses from mirror and energy absorption losses on concentrating surface i.e. absorber copper tube. There are some advantages of concentrating collector over flat plate collector like achievement of higher temperature in receiver tube, which results in higher thermodynamic efficiency and further requirement of material in concentrating collectors are also less as compare to non-concentrating collector due to which cost reduction in fabrication of solar concentrating collector can be achieved. Solar concentrators can be classified in different ways or methods. Solar concentrators can have reflecting surface or refracting type surface and it completely depends upon the concentrating device used to concentrate the sun’s radiation on the absorber surface, reflecting surface are further classified into flat, spherical or parabolic type. Solar concentrators can be of imaging and non-imaging concentrators and further imaging type can be classified into line or point focusing solar concentrators. Concentrator’s classification also depends upon the amount of temperature requirement for various applications. High concentration ratio means achievement of high temperature. Efficient working of concentrating collector also depends upon adopted tracking mechanism [2]

Tracking can be done on intermittent and on continuous basis. Further tracking can be possible about one axis and two axes also. Flat plate collector along with mirror adjusted at edges has a capability to reflect and concentrated solar radiation on collector’s absorber plate. It has low concentration ratio approximately unity, can achieve higher temperature as compare to flat plate collector alone. Compound parabolic concentrating collector have curved parts of two parabolas, it is also a type of non-imaging collector. This type collector possesses moderate concentration ratio for e.g. 3 to 10. Apart from these advantage of compound parabolic collector having higher acceptance angle, which means that collector is adjusted on occasional basis. Another important type of collector known by cylindrical parabolic collector, sun rays are concentrated or image formation on the focal axis of the parabolic collector. Lenses are also used to concentrate sun light like Fresnel lens. Line concentrating collector like cylindrical, Fresnel lens having concentration ratio vary from 10 to 80 and range of temperature achieved between $150°C$ to $400°C.$ Point focussing collector like parabolic dish collector can achieve higher concentration ratio and temperature as compare to line focusing collector and point focusing collector can achieve concentration ratio from 100 to 1000 and temperature up to approximately $2000°C.$ For concentration of high amount of energy on a point, a new concept called as central receiver has been used on a large scale in the world. In this type of concentrating system, a large number of mirrors also known as heliostats are used to concentrate the sun light on the central receiver which is situated at the top of tower. The other potential application of solar energy is in providing comfortable thermal environment in the living space using passive concepts [2].

A longstanding argument exists between proponents of these two technologies. Some of this can be related to the structure of evacuated tube collectors which have a discontinuous absorbance area. An array of evacuated tubes collectors on a roof has space between the individual tubes and a vacuum gap between each tube and its absorber inside, covering only a fraction of the installation area on a roof. If evacuated tubes are compared with flat-plate collectors on the basis of area of roof occupied (gross area), a different conclusion might be reached than if the absorber or aperture areas were compared. The recent revision of the ISO 9806 standard states that the efficiency of solar thermal collectors should be measured in terms of gross area and this might favor flat plates in respect to evacuated tube collectors in direct comparison [2].

Flat-plate collectors usually lose more heat to the environment than evacuated tubes because there is no insulation at the glass side. Evacuated tube collectors intrinsically have a lower absorber to gross area ratio (typically 60–80% less) than flat plates because tubes have to be spaced apart. Although several European companies manufacture evacuated tube collectors (mainly glass-metal type), the evacuated tube market is dominated by manufacturers in China, with some companies having a track records of 15–30 years or more. There is no unambiguous evidence that the two designs differ in long term reliability. However, evacuated tube technology (especially for newer variants with glass-metal seals and heat pipes) still need to demonstrate competitive lifetimes. The modularity of evacuated tubes can be advantageous in terms of extensibility and maintenance, for example if the vacuum in one heat pipe tube is lost it can be easily being replaced with minimal effort [2]. In most climates, flat plate collectors will generally be more cost-effective than evacuated tubes [13]. However, evacuated tube collectors are well-suited to cold ambient temperatures and work well in situations of low solar irradiance, providing heat more consistently throughout the year. Unglazed flat plate collectors are the preferred devices for heating swimming pool water. Unglazed collectors may be suitable in tropical or subtropical environments if domestic hot water needs to be heated by less than 20 °C (36 °F) over ambient temperature. Evacuated tube collectors have less aerodynamic drag, which may allow for a simpler installation on roofs in windy locations. The gaps between the tubes may allow for snow to fall through the collector, minimizing the loss of production in some snowy conditions, though the lack of radiated heat from the tubes can also prevent effective shedding of accumulated snow. Flat plate collectors might be easier to clean. Other properties, such as appearance and ease of installation are more subjective and difficult to compare [2].

Evacuated flat plate solar collectors provide all the advantages of both flat plate and evacuated tube collectors combined together. They surround a large area metal sheet absorber with high vacuum inside a flat envelope made of glass and metal. They offer the highest energy conversion efficiency of any non-concentrating solar thermal collector,[14] but require sophisticated technology for manufacturing. They should not be confused with flat plate collectors featuring low vacuum inside. The first collector making use of high vacuum insulation was developed at CERN while TVP SOLAR SA of Switzerland was the first company to commercialized

Solar Keymark certified collectors in 2012.Evacuated flat plate solar collectors require both a glass-metal seal to join the glass plate to the rest of the metal envelope and an internal structure to support such plate against atmospheric pressure. The absorber has to be segmented or provided with suitable holes to accommodate such structure. Joining of all parts has to be high vacuum tight and only materials with low vapour pressure can be used to prevent outgassing.

Glass-metal seal technology can be based either on metallized glass or vitrified metal and defines the type of collector. Different from evacuated tube collectors, they make use of non-evaporable getter (NEG) pumps to keep the internal pressure stable through time. This getter pump technology has the advantage of providing some regeneration in-situ by exposure to sunlight. Evacuated flat plate solar collectors have been studied for solar air condition and compared to compact solar concentrators. For providing a non-fluctuating temperature in a living room, a massive wall is usually introduced between the glazing and the room. Usually this massive wall, known as Trombe wall, is made of either concrete or consists of water drums stacked over one another. The introduction of such a massive wall, however, completely blocks the sun radiation hindering the utilization of natural light for normal illumination [2]

A new passive system employing a ‘Transwall’ which is a partially transparent thermal storage wall consisting of a plastic sheet placed inside a water storage tank. The system is placed adjacent to a window admitting solar energy. Part of the solar energy is absorbed within the trans wall and the remaining part is transmitted to the living space. In contrast to a conventional thermal storage wall most of the solar energy is absorbed at the center and not at the front facing the window and the room is heated both directly and indirectly and illuminated by the transmitted fraction of solar energy. This direct transmitted fraction of solar radiation can, however, be made small enough to avoid overheating and photo degradation of interior furnishing The concept of a Trombe wall with and without vents for providing comfortable environment is well known. It is, however, necessary to provide ventilation to let the fresh air flow for diluting the effects of moisture, dust and gases. The energy required for heating this ventilating air could be sizable and hence the idea of a 'Trombe wall' which has been provided with circular pipes for the flow of air. This idea of ventilated Trombe wall is more useful in dairies and farms, where animals are confined to remove the odor, moisture, dust and gases produced by the animals in the confinement. The building must be ventilated continuously with fresh air for diluting these unhealthy products. In hot climatic conditions, this hot air may be used for heating the gravel storage and if, sometimes, water is circulated, may be used for domestic purposes. This idea offers an application of solar passive systems like that of a storage wall provided with a network of circular pipes through which ambient air flows either through natural convection or forced convection mode [2].

Jan Fabian feldoff et al. [3] concluded that the Electricity Cost of a Direct Solar Generation plant could be higher than that of synthetic oil plant and both the power generation systems have a 100 MWe gross turbine and a 9 hours' storage capacity. And concluded that without the application of thermal storage system, the Direct Solar Generation plant could show lower Level Zed Electricity Cost. They analyzed both synthetic oil power plant with molten salt two tank storage system and Direct Solar Generation system uses phase change material. It has been seen that application of Thermal Energy Storage influence the cost of Direct Solar Generation plant up to very high level. Therefore, investment cost is higher about 10% and efficiency is about 8% better and finally they concluded that direct solar generation have higher levelized electricity costs are about 6%, which is due to the specific solar field costs and thermal storage costs.

Xiang-Qi Wang et al. [4] concluded with the change in geometry of flow, boundary conditions and by enhancing thermal conductivity of fluid, convective heat transfer can be increased and described that the Nano fluids also has capability to enhance heat transfer or thermal characteristics as compare to liquids, base or conventional fluids and superior in thermo physical properties as compare to mixture containing micro particles with base fluid. They also conclude that due to suspension of any type of Nano particles, surface area can be enhanced and results in increase in amount of thermal conductivity of working fluid. By using the method of steady state parallel plate for measurement, the thermal conductivity of Nano fluids. Suspension of Al_2O_3 and CuO Nano particles with average diameter of 28 and 23nm in base or conventional fluids (like H_2O and ethylene glycol ($C_2H_6O_2$)), they evaluate from experimental results that Nano fluids posses' higher amount of thermal conductivity than base fluids and also evaluate that thermal conductivity can be increased with decreasing of particle size and found that the thermal conductivity of suspended carbon Nano tubes can show higher thermal conductivity among all other Nano particles and CNT also have very high aspect ratio.

Soteris A. Kalogirou et al. [5] discussed about different type of solar thermal collectors like flat plate, compound parabolic solar thermal, cylindrical parabolic or parabolic trough (PTC), Fresnel lens reflector system (LFR), parabolic dish and heliostats for different applications like water and space heating and cooling also, industrial heat process and also in thermal power plants. Further they also analyze the effect of using conventional fuel sources on environment of earth, which is associated with the Problem (like pollution), they also analyze that Industrialization is also a big cause for degradation of environment. They gave the brief description on solar energy collectors and its different types. Solar collector is an instrument used to extract the sun's energy from incoming solar radiations, this energy convert directly into heat or thermal energy and further this heat or thermal energy transfer to fluid like water following through collector system. Basically two type of solar collector are available like Non concentrating and concentrating collector, apart from this solar collector are further classified according to motion like stationary collector, single axis collector and two axis collector.

T. Yousefi et al. [6] examined the effect of variation in pH of MWCNT-H_2O based Nano fluid on the flat plate collector's efficiency experimentally and they take volume concentration 0.2 wt. % MWCNT with the application of Triton X-100 and also with various pH values, 3.5, 6.5, and 9.5. and concluded from the ASHRAE standard that, the increasing or decreasing the pH values with respect to the pH , the efficiency of solar collector can be increased.

R. Saidur et al. [7] examined the effect of Nano fluid on the performance of direct solar collector by using Nano fluid as a working fluid. They investigate about extinction coefficient of Al-H_2O Nano fluid has been experimentally and found that the particle size has minute effect on the optical properties of Nano fluid. They observed the enhancement in optical and thermal properties due to the use of Nano fluid s as volumetric absorber in Direct Solar Generation system and finally concluded that the water behaves like a transparent for incoming visible light but it has a greater absorption capacity at longer wavelength and Aluminum nanoparticle showed high extinction coefficient at small wavelength. On the contrary a lower extinction coefficient possessed longer wavelength, therefore for this reason aluminum nanoparticle can be used to increase absorption ability of water at the visible and small wavelength of light.

Alibakhsh Kasaeian et al. [8] described the ways to enhance the working performance of solar parabolic trough collector system. For the purpose of investigation or inspection they employed four different types of receivers like evacuated steel tube with painted black, bare copper tube with painted black, non-evacuated copper tube with glass envelop along with painted black and evacuated copper tube with painted black to examine and compare the optical and thermal efficiency of solar parabolic trough collector system. They take volume concentration of Nano particles is decided as 0.2% and 0.3% in oil base fluid for preparation of the working fluid for testing of these four different types of receiver and concluded that the efficiency of evacuated tube showed about11% higher than the bare tube efficiency due to convection losses and also conclude that time response is an important factor for evaluation of performance because it tells us that how much time needed by the system to stabilize it. It has been seen that evacuated copper tube showed greater time response due to minimum heat loss as compare to heat losses in evacuated steel tube with painted black due to radiations. They observed that the efficiency of solar trough collector system with volume concentration 0.2% and 0.3% can be enhanced 4-5% and 6-7% with the help of MWCNT and mineral oil based nano fluid as comparison to efficiency achieved from pure oil only and found that black coated copper tube possesses high absorptive and thermal conductivity.

Nor Azwadi Che Sidik et al. [9] carried out review study, on concentrated on methods to prepare the nano fluids along with challenges due to nano fluids and described all methods of preparation given by different investigators or researchers. Also concluded that the metallic and nonmetallic particles can be used to fabricate nano particles. They also describe the synthesis process for nano fluids along with characterization of nano fluids. They also included that some challenges come in the synthesis process. Further they found that nonmetallic particles like silicon dioxides, titanium dioxides, aluminum oxide, iron oxide, aluminum nitride and carbon nano tubes. Further metallic particles like gold, silver and copper can be used for fabrication of nano fluids. They also concluded that effect on properties like thermal conductivity of nano particles, Brownian motion of particles, thermo physical properties along with change in temperature are due to factors like poor dispersion or suspension of nano particles and lack of knowledge in understanding of mechanism that all are responsible. They also observed that increasing concentration of nano particles results in viscosity increases; this became also a challenge due to more requirement of pumping power to operate the system and noticed that the thermal conductivity of pure metallic particle based nano fluids will be higher as comparison to nano fluid containing oxide nano particles and also noticed that nano fluids possess less specific heat as comparison to base fluids. Further they observed that viscosity of nano fluids generally higher than the base fluids and it depends upon type of particles and also depends upon particle volume concentration. They also evaluate that homogeneous and stable dispersion of nano particles in conventional fluid are always a challenge for investigators. They conclude in his review study that preparation of nano fluids is followed by three common methods like sonication, PH control and surfactants. Cost comes on synthesis of nano particles and stability of nano particle in base fluid; both are the major factors that prevent the use of nano fluid on commercial basis.

Zhongyang Luo et al. [10] constructed a simulation model of solar collector using Nano fluid based on concept of Direct absorption collector by understanding the radiative transfer equations of particulate media and by combining both conduction and convection heat transfer and concluded from the results of simulation model that Nano fluid s improved the outlet temperature by 30–100 K and system efficiency by 2–25% than the base fluid flowing through the system. Also found that the photo thermal efficiency of graphite based Nano fluid with 0.01wt% flowing through a coating absorbing collector is measured 122.7% and concluded that the Nano fluid s with in small concentration have a good ability to absorb the solar radiation, and also has an ability to improve the outlet temperatures and efficiency of system.

John Philip et al. [11] described the developments and advances in the field of nano fluids applications and also they found their effect on the thermal characteristics of nano fluids. They described an approach to achieve better thermal conductivity of nano fluids or heat transfer fluid. Enhancement ink is due to weight fraction of nano particles in base fluid like in water and ethylene glycol/MWCNT based nano fluid showed an increase in 'k' with an increment in$'\varphi'$. Water based CNT describe a nonlinear behavior between k andφ. They also found that thermal conductivity also affected by size of nano particles like dispersion of Al_2O_3 nano particles in water with different diameter i.e. 20, 50 and 100nm determine an increment in thermal conductivity with the reduction in the size of nano particles. It has been seen that 'k' for Al_2O_3 in water and E.G. based nano fluid increases with the reduction of size of nano particles. Apart from this some kind of nano fluids showed different characteristics and behavior like SiC and water based nano fluid with different diameters of 16, 29, 66 and 99nm determine an increment in 'k' with an enhancement in size of particle. It has also been seen that in metallic dispersion like gold nano particle in water based nano fluids determine a decrement in 'k' with decrease in size of particle within the range of 2 to 40nm. Metal nano fluids like Cu with particle diameter 80nm dispersed in water and E.G also show an incremental change in 'k' with an enhancement in temperature. Ag in water based nano fluid show an incremental change in 'k' approximately 3.2% at 30℃ temperature and increment of 4.5% at temperature 60℃ at volume concentration 0.001%. Water based Al_2O_3 with diameter 36nm showed an increment in 'k' at temperature range between 2 to 50℃. For MWCNT and water based nano fluid showed an enhancement in 'k' is independent on the temperature at low concentration of MWCNT. Some nano fluid like TiO_2 with diameter 21nm and water based nano fluid show and decrement in 'k' with increment in temperature over a range of 15-35℃. In CNT and water based nano fluids an increment in 'k' with length of the nano tubes like at $0.5\mu m$length of nano tube increment in 'k' was estimated to 14% and 45% increment was estimated in 'k' with length of $5\mu m$. The incremental behaviour of 'k' was found to be increased with increase of aspect ratio of nanotubes in water based CNT nano fluids. Water based nano fluid also show less enhancement in k as compare to E.G based nano fluids. To maintain the stability of nano particles, there is a requirement of surfactants, because they prevent the agglomeration of nano particles. SEM results show that water based CNT show reduction in 'k' with increase in ultra-sonication time due to the reduction in the length of the nano tubes, while in E.G based CNT show an incremental change in 'k' with increase in ultra-sonication time. They described that some change in temperature can become a cause of large error in thermal conductivity, apart from this agglomeration and settle down of

nano particles in base fluid can affect to the results of experiment.
G.C. Bakos et al. [12] concluded from Simulation results that variations of parabolic trough collector's efficiency are a function of some important parameters like heat transfer fluid, pipe diameter, intensity of solar radiations as well as exposed area of the collector and it has also been seen from the results that with increase of flux of heat transfer fluid, there is a noticed incremental change in efficiency. However, they also noticed that flux of flowing fluid cannot increase continuously because of decreasing solar flux with the change in time due to this decrement shown in temperature of fluid. Further with the increment in pipe length there is an effective decrease in efficiency value.
Tooraj Yousefi et al. [13] performed an experimental study with Al2O3-H2O nano fluid as working fluid is used for investigate the efficiency of flat plate collector and decided to take Volume fraction or concentration of nano particles as 0.2wt% and 0.4wt% with the particle diameter of 15nm along with the application of surfactant Triton X-100. Selective mass flow rates are 1, 2 and 3Lit/min. they found from results that nano fluid show an enhancement in efficiency as comparison to water. They concluded that heat removal factor (F_R) value for nano fluid is 0.6194 and 0.6086 with and without surfactant. They also concluded that adding surfactant into nano fluid has a positive effect seen on the efficiency of flat plate collector and found that the thermal efficiency of flat plate collector increasing by increase in mass flow rate. Results from performed experiments concluded that efficiency enhancement in collector is 28.3% at 0.2% weight fraction of nano particles along with the 15.63% efficiency enhancement with the application of surfactant due to enhancement in heat transfer.
K. Vignarooban et al. [14] found the effect of different types of heat transfer fluids available like air, water and thermal Oils, organic fluids, molten-salts and liquid metals etc. on solar thermal collector system components and concluded that, the highly important to evaluate the stability of used stainless steels and nickel based alloys for piping and container materials because heat transfer fluids, while flowing through the piping system show high impact on these materials and stability of these material while in contact with heat transfer fluids is very important from research point of view for the long life of concentrating solar power systems.
Gianluca Coccia et al. [15] found that industrial process heat applications ranging from 70 to 250ºC has been possible by the manufacture of low-cost parabolic trough collectors (PTCs), therefore in this construct a prototype of PTC with a 90º rim angle and a small concentration ratio of 9.25 built along with Fiberglass is used as the external shell and polystyrene used for inside fill component. They used receiver is of circular cross section and made up of aluminum, which is covered or evacuated with glass envelope and used the application automatic tracking system, which is based on a solar-position computer program. They evaluate the main features of prototype are its less cost, low weight and ease of manufacture.
J. Paetzold et al. [16] concluded that the flowing wind is greatly affect to performance of parabolic trough collector system. They also concluded that increasing concentration ratio, results in higher temperature achieved from receiver tube and concentration ratio is also increased due to increment in aperture area and found that heat losses by convection increased due to high wind speed flowing over the collector. They evaluated data from the series of test performed in wind tunnel and also from previous research work related to PTC and performed total 17 types of simulation for every geometry of parabolic trough by using CFD program with variable parameter i.e. depth of trough system with the variation in pitch angle i.e. -90° to 90° also with an increment of 15°. They evaluated that high quantity of aerodynamic forces and larger vortex are formed on backside of of trough, when pitch angle possess higher value above 15° and smaller from -60°. Forces exerts on PTC collector affect to the working performance of solar PTC system and found that with incremental change in depth of trough, results in incremental change in aerodynamic forces also measured in the PTC system.
Harwinder singh [17] performed an experimental study on the prototype of parabolic trough collector using MWCNT based Nano fluid. He takes different volume concentrations of 0.01% and 0.02% along with different volume flow rates i.e. 160L/h and 100L/h. He also evaluates the thermo physical properties of MWCNT based Nano fluid theoretically and he compared the thermal performance due to water and MWCNT based Nano fluid, while used as working fluid in parabolic trough collector system. Finally, he concluded that MWCNT based Nano fluid at 0.02wt% and at 160L/h showed higher thermal performance as comparison to other fluids at various concentrations and volume flow rates and concluded that the nano fluid has an ability to show higher efficiency along with high outlet temperature, while working as a working fluid in solar thermal collector. The phase change material can be used for thermal storage for a long period.
Agglomeration of nano particles can be avoided by using surfactants and by sonication method and pH value of Nano fluid highly affect to the efficiency of collector system.
The top covered along with different receiver materials and selective receiver coating has an ability to increase the life of reflecting surfaces and also help to minimize the heat losses from the receivers. And studied that low cost parabolic trough collector system can be used for industrial process heat applications and found that the efficiency of solar thermal collector highly depends upon various kind of working fluid used like conventional, micro fluid as well as nano fluid and further efficiency also depend upon the parameter of the collector design along with tracking mechanism i.e. automatic or manual. It has also been seen that size of nanoparticles, viscosity of fluid and thermo physical properties if Nano fluid has a high impact on the collector performance.
The main objective of this review paper is Evaluation of the performance of concentrated solar thermal collector on commercial basis with the help of various types of fluids with different volume flow rates and at different concentration and

further comparison between the results outcome from the collector system theoretically and experimentally later. Evaluation and comparison of the performance by using different receiver material and different glazing materials for solar concentrator. Storage capability of the solar thermal power plant for the storage of heat for the usage of non-sun shine hours can be increased by the phase change materials.

Various types of evacuation tubes around receiver and metal glass seal at the end of the receiver can be used for the prevention of heat loss from the receiver. Further insulated material can be used to prevent the heat loss from the pipes in which fluid is flowing.

Evaluation of the various thermal properties of various fluids used as a working fluid like thermal conductivity, viscosity, density along with the evaluation of various flow parameters, which are responsible for better thermal performance of collector during their working in the system.

3. Experimentation & data collection

This section is deals with the experimental as well as theoretical data, which comes out from the evaluation of performance of solar thermal collector system by using different fluids and different collector receiver material along with different type concentrator glazing. Further this section also contains the experimental results for the different types of storage medium used for increasing the heat storage capability of the thermal power plant and it will be discussed later in brief. This section includes the results of experimental study, which is based upon the analysis of parabolic trough collector system using Nano fluid [17].

Some results are concluded during the experimental study, which was held on PTC prototype in Thapar university and finally evaluates that thermo physical properties of MWCNTs based nano fluid far expressive than base or conventional fluids like water, ethylene glycol. Further it has also been seen in this study that MWCNT and water based nano fluid with volume concentration i.e. 0.01% and 0.02% showed less value of important thermo physical properties specific heat and density. While thermal conductivity of MWCNT based nano fluids is always seems to be higher than water at the decided concentration.

It has also been seen that useful heat gains by nano fluid and water, while used as working fluid in collector system is fully dependent upon the volume flow rate, specific heat and also upon temperature difference measured during experimental working. It has also been observed by the author of thesis that in case of nano fluid mixture highest dominant factor is temperature difference, which is dependent upon incoming solar intensity throughout the experimental time and higher solar intensity results in higher amount of temperature difference. It has been concluded from figure that nano fluid mixture with 0.02% volume concentration and at 160L/h volume flow rate showed maximum useful heat gain overall among other fluids [17]. Experimental work concluded that obtained maximum value of instantaneous efficiency for MWCNT based nano fluid mixture at 0.01% and 0.02% vol. concentration and at 160L/h volume flow rate is 96.49% and 96.46% [15]. It has been observed during experimental work maximum instantaneous efficiency possessed by nano fluid mixture with 0.01% and 0.02wt% at 160L/h volume flow rate among other fluids. It has been also being observed from experimentation that water at 160L/h also showed highest value of instantaneous efficiency at some points as compare to other fluids like water at 100L/h and nano fluid with different volume flow rates i.e. 160L/h & 100L/h [17].

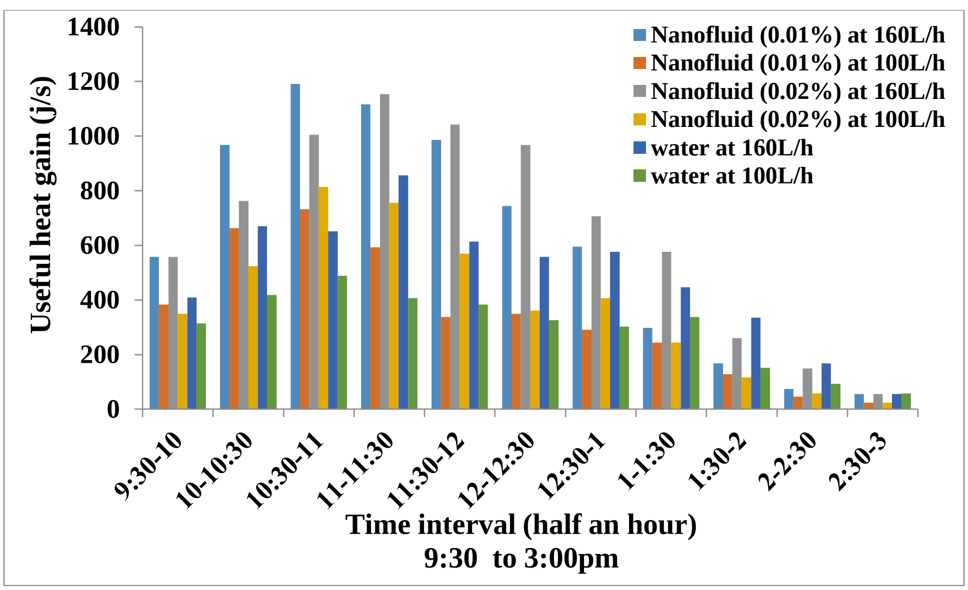

Figure 1: Experimental variation in useful heat gain by nano fluid and water at different conc. and volume flow rates [17]

It has been concluded from experimental work that maximum thermal efficiency for nano fluid mixture with at 100L/h volume flow rate is 11.36% and 10.31% measured. It has been also concluded that nano fluid mixture with 0.01% volume concentration at 100L/h possessed higher value of overall thermal efficiency as comparison to nano fluid mixture with same concentration and at 160L/h. Further nano fluid mixture 0.02% vol. concentration showed different behaviour, it means that nano fluid mixture at 160L/h showed higher value of overall thermal efficiency as comparison to thermal efficiency possessed by nano fluid mixture with same concentration (0.02%) at 100L/h and thermal efficiency achieved by nano fluid mixture with 0.01% vol. concentration at different volume flow rates. Thermal efficiency dependent upon the important parameters like temperature difference, total mass of liquid fluid through receiver collector system, specific heat of the fluid and most important total solar global radiation comes on the collector system. The changes come in all these parameters results in the changes come out in the performance of thermal efficiency [17].

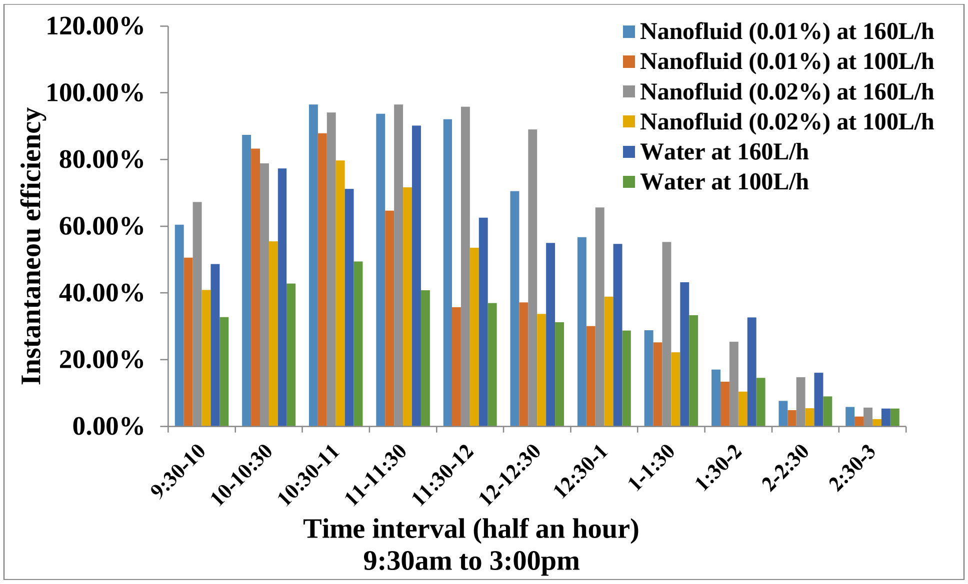

Figure 2:Experimental variations of instantaneous efficiency [17]

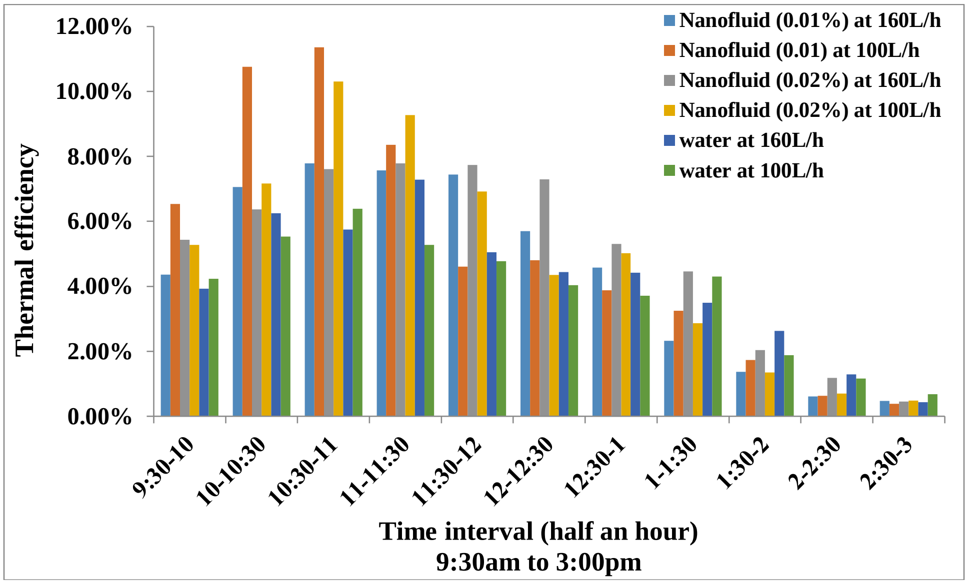

Figure 3: Experimental variations in overall thermal efficiency for different fluids [17]

4. Results and Discussion

Solar concentrating collectors can be used for the electricity generation on large scale and in various applications like device for the use in night or cloudy days also an important aspect for the construction of efficient solar thermal power plant in future. Nano fluid s are the efficient fluids, which have a capability to enhance the thermal performance of every solar thermal collector systems due to greater thermo physical properties of Nano fluid s like thermal conductivity so it is possible to enhance the efficiency of the hybrid as well as simple collector system by the combination of various types of Nano fluid s, which are made up of mixing the nano particles with different base fluids or conventional fluids like water, ethylene glycol, synthetic oil and combination of both water and ethylene glycol.

5. Conclusions

Concentrated solar thermal power is a highly prominent and proven technology to meet the current world's electricity demand, therefore advancements in the technology is greatest requirement for the better performance. Many aspects like different fluids conventional as well as nano fluid along with the improvement in thermal collector design parameters can show high thermal performance. Improvement in the thermal storage system by using phase change material is very important aspect from the research point of view because it has an ability to decrease down the cost of overall solar thermal power plant. industrial process heat. Therefore, improvement in the solar thermal collector performance is highly important from research point of view so that an efficient solar thermal device can be developed. Further Improvement in thermal storage

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