Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 1, Number 14; October-December 2014 pp. 96-98

http://www.krishisanskriti.org/jbaer.html

Review of Parabolic Trough Collector Technology and Recent Advancements

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Abstract—*Solar energy is a highly capable, self-sustain, clean and renewable energy. It could be proved as a best alternative for fossil fuels. Numerous technique and systems are available to extract this solar energy. Parabolic Trough Collector (PTC), one of those used to extract this energy. Recently various improvements found to enhance PTC's efficiency. This paper presenting those advancements, possibilities and future work. Years back PTC was used to extract solar energy in the form of Thermal only but now technology developments make it possible to use for Thermal as well as Electrical energy. Research work done and is going on to improve the whole system with integral advancements of various component and techniques i.e. physical design, material used, and type of energy extraction either it is thermal (By fluid) or electricity (By solar PV cell). Lots of work is done to find the solution such that energy could be handled with more accuracy it includes the method of energy conversion (Photonic to thermal and/or electrical), processing and application that results loss minimization.*

1. INTRODUCTION

In recent years global warming had shown its serious consequences i.e. melting polar Ice, rising water level and many more. There are many factors which contribute to it but all are not in human control. We can contribute to slowdown the rate of global warming by controlling those factors which are in our hands. Annually a very huge amount of Greenhouse Gases releases to our open atmosphere by combustion of Fossil Fuels. If we use more and more renewable energy sources it will leads to lesser Greenhouse Gas emission. One of the best renewable energy sources is Sun. Solar energy can be converted to one of the usable form of energy i.e. Thermal or Electrical, by numerous techniques. Parabolic Trough Collector (PTC) Technology proved its superiority over other technology because of a huge number of merits over other in recent days. In recent days technology evolved in such a way that we can use PTC for getting both type of energy extracted directly from solar radiation i.e. Thermal and Electrical. Thermal energy extracted by heat carrying fluid while Electrical energy by Photovoltaic cell. Both system of energy generation/conversion have their own drawbacks but by taking those simultaneously energy losses reduced up to a great extent. Electrical system has more usability but efficiency reduction due to temperature rise [10]. This hybrid system gives high grade energy as well as maximum fraction of loss extracted as low grade energy. Similarly various modifications have been done in recent days. Many are of in structural design; energy extraction technique and efficient use of the system make it more reliable.

PTC is basically a concentrator in which a semi-cylindrical sheet called reflector reflects incident solar radiation to its axis. A cylindrical tube called collector run through the axis, fluid which was flowing inside it used to gather thermal energy from concentrated solar radiation. The number of fluids tested as heat carrying fluid. Electrical energy fulfills almost all human needs. So that PV cells were introduced in PTC to get electrical energy. It gives few most powerful advantages namely:

i. Use of more precious cells having high efficiency, because concentrated solar radiation allows us to use less cell area.
ii. Excess amount of Photon energy dissipated as heat in solar cell, gathered by heat carrying fluid to be utilized.
iii. Fluid could be used to maintain cell temperature optimum, as with rise in temperature efficiency of solar cell get reduced [10].

Hybrid PTC has advantage of maximum energy extraction and conversion because of the elimination of one's drawback by other one. Wolf [30] and Florschuetz [13] introduced earliest the concept of hybrid PV/T system. As the issues of energy and environment become increasingly prominent in recent years, related researches on hybrid PV/T systems have been more and more significant.

2. PTC TECHNOLOGY

2.1 CPV/T

Photon is converted to electron by means of electronic principal called Photovoltaic effect. Photovoltaic power has been applied in a wide variety of specialized applications [22]. However, the cost of photovoltaic is so high that it cannot compete on a cost effective basis with conventional power generation. By concentrating the solar radiation, the intensity may be increased by few hundred times to some thousands time of its standard output. This will increase power density and decreased cost. A CPV/T (concentrating photovoltaic/ thermal) system is a hybrid photovoltaic and thermal power generation system. The solar cell is very crucial component of a CPV/T system and it determines systems performance. Systems with different concentration ratios adopt different solar cells to improve systems' performance.

In 2004, the Renewable Research Institute of Australia National University performed a detailed study on a Trough Concentrating Photovoltaic/Thermal (TCPV/T) system. The efficiency of the solar cell array reached 22% and the cost of electricity generation was reduced by 40% compared with the traditional PV system [8,9]. Earlier more work has been done on designing the concentrating collector as well as developing new solar cells [18,29]. Kribus [20] presented the evaluation and design of the miniature concentrating PV (MCPV) approach, and analyzed the heat transport system, the electric and thermal performance, the manufacturing cost, and the resulting cost of energy. Zhai [33] gave a hybrid solar heating, cooling and power generation system based on screw expander and silica gel–water absorption chillier, and analyzed the exergy, energy and its cost. Wu [31] proposed a parabolic dish/AMTEC (alkali metal thermal to electric converter) solar thermal power system, and the overall conversion efficiency could reach up to 20.6% with a power output of 18.54 kW.

2.2 Reflector

It reflects all incoming solar radiation to a fix axial line. Its design matter most because a minor defect will create major problem on collector. This problem raises many folds if we talk about PV/T system, as non-uniform radiation create thermal gradient which may seriously harm the solar cell. Here reflector works for both visible and invisible spectrum, visible spectrum for solar cell and invisible for thermal. Different materials experimented for optimum reflection.

2.3 Collector

Various designs examined to get maximum system efficiency. Many structural parameter i.e. absorber-tube or glass-envelope diameter, rim angle, aperture width, mirror reflectivity, receiver geometry optimized to improvements in the optical and thermal efficiency of PTC [2,14,17,19,23,26,27]. Few designs for collector using secondary optics namely aplanatic mirrors, Reflective glass surface, Reflective annulus insulation and tailored seagull were examined by Men Wirz et al. [23*]. These are quite useful for PTC Thermal system and needs more improvements to be used for PTCPV/T system. Francesco Calise et al. [15] had given a design for PTCPV/T system. It has a linear triangular receiver placed inside the collector tube. PV cells mounted on its two side wall and Heat Transfer Fluid will flow inside this triangular receiver. Collector tube or protective glass cover and other design optimization done by Bakos et al. [1].

2.4 Heat Transfer Fluid

This one is another important parameter of PV/T system. In conventional PTC fluid extract and carries thermal energy from solar radiation but here in advance PTCPV/T, It extracts heat from PV cells also to maintain cell temperature. Recently Nano technology introduced to make it more efficient, by Nano fluid, Nanotube [32]. Numerous flow path, pattern and fluid already examined and are going on to find optimum solution for maximum thermal efficiency. Feng Shan et al. [12] had given different combination of fluid flow path and their effect on efficiency. Synthetic oil proved better HTF as compare to Nitrogen [21].

3. INTEGRATION

Direct integration of PTC with water desalination system, domestic water heater, combined steam and/or organic Rankine cycles make better use of produced energy [11,16]. Mittelman et al. [12] investigated the theoretical viability of integrating CPVT, based on triple-junction cells, with solar heating and cooling based on a single-effect $LiBreH_2O$ ACH. The electrical efficiency ranged approximately between 19% and 23% (as a function of the PVT operating temperature, varying between 65^{o}C and 120^{o}C). On the other hand, the thermal efficiency of the PVT was stably slightly lower than 60%. Some models developed for CPVT collectors to integrate with solar heating and cooling system for the simultaneous production of heat, cool and electricity [3,4,5,6,7,25] and the possibility to use solar thermal energy in excess to drive a desalination unit [16].

4. CONCLUSION

PTC has potential to fulfill giant energy need of human. With introduction of PV, PTC became more attractive. The GaAs solar cells have an excellent performance under concentrated solar radiation. The solar cells are the key parts for the PTCPV/T (Parabolic Trough Concentrating Photovoltaic) system. Different types of concentrating solar cell have their own optimum concentration ratio. The GaAs cells exhibit good performance characteristics at higher concentration ratio while the polysilicon cells showed poor performance characteristics under concentration. Proper use of Nanofluid could make the system more efficient.

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