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A review of solar parabolic trough collector

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ABSTRACT

Solar energy is one among the freely available clean forms of renewable energy. Many technologies have been developed in India for extracting energy from assorted renewable energies, but the maximum extraction of thermal energy from solar energy is the most promising challenge. This paper focuses on the performance and efficiency of solar parabolic trough collector. It also reviews the pertinent applications of solar energy such as air heating system, desalination, refrigeration, industrial heating purposes and power plants. This paper will be useful for researchers concentrating on solar energy using parabolic trough collector.

Contents

1. Introduction

In modern era many countries started running behind renewable energy due to the scarcity of non-renewable energy, for various applications such as air heating, desalination, refrigeration, small scale and large scale industries and electric power generation. Although many developments are there for extracting the energy from various renewable sources, still most energy efficient techniques are to be constructed for trapping maximum energy. Solar energy is the most abundant source of energy which has been readily available in earth for thermal power generation, the lighting of houses and for industrial heating applications. Since scientific research and technology have been developed for the past few decades, the solar energy is becoming the most promising source of energy. Several developing countries have high level of solar radiation and countries like India, Egypt, Morocco and Mexico are moving to concentrating solar power for electricity. According to the Central Energy Authority of India on February 2014 the total installed capacity for electricity generation was 237,743 MW and the various sources are shown in Fig. 1. India requires a peak demand of 132,507 MW whereas peak met is 128,083 MW. Also, specifically, the state of Tamil Nadu has a peak demand of 935 MW electricity. Fig. 2 shows the electricity generation by in South India and includes five states namely Andra Pradesh, Karnataka, Kerala, Tamil Nadu and Puducherry showing a solar energy generation of about 13,127 MW of electrical energy.

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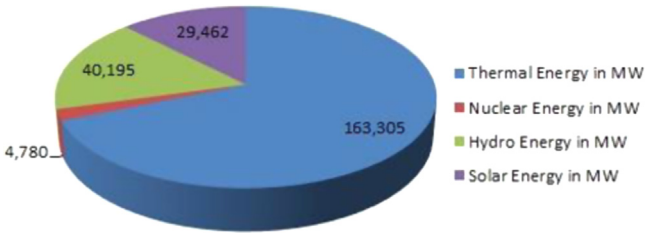

Fig. 1. Electricity generation in India from various energy sources [1].

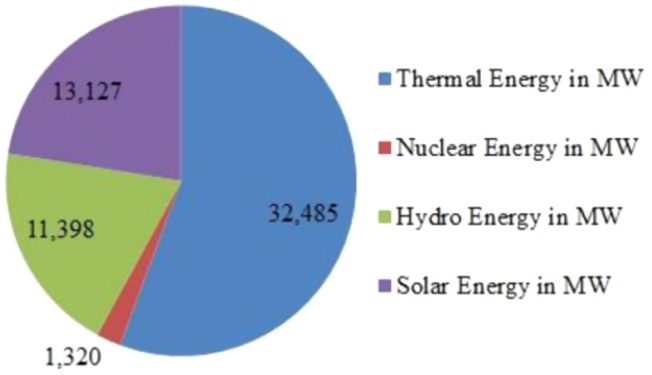

Fig. 2. Electricity generation in South India from various energy sources [1].

Fig. 3 specifically shows Tamil Nadu's contribution for electricity generation which shows 7946 MW of electricity generation [1].

In India an environmental analysis has been conducted in 58 places for the solar trough power plants [2]. India receives more than 5000 trillion kW h per year of solar energy with average daily global radiation of around 5 kW h/m^2 per day [3]. According to a National Renewable Energy Laboratory survey on April 2013, South India received an average of above 7.5 kW h/m^2 of solar radiation per day during December, January and February [4]. Currently many countries have started solar power plants for power generation and in a few years almost all countries will run in solar power. As per the Energy and Resources Institute India's current electricity capacity is 13,402 MW and by 2030 a electricity generation capacity of around 800,000 MW will have to be produced with a high contribution from renewable energy [5].

The solar collector has the capability to absorb the solar radiation and convert it to heat, transferring it to the working fluid. The working fluid may be air, water, oil or some organic solvents. The heat energy which is in the form of thermal energy in the working fluid of the solar collector can directly be utilized for different applications. Solar collectors are of various types namely, Flat-plate collector with reflectors, Parabolic Trough Collector (PTC), Compound parabolic collector and Fresnel lens concentrating collector. Flat plate collectors are mostly used for hot water generation because of its temperature range of about 120–140 °C. The efficiency of solar flat plate collectors was improved by using spherical silicon solar cells [6]. In PTC the temperature of the focal line or absorber tube can be as high as 350–400 °C. Solar collector's efficiency is based on the concentration ratio which is the ratio of the effective area of the aperture to the surface area of the absorber. Generally a traditional power plant requires an enormous amount of non-renewable energy sources such as coal or petroleum products, hence the usage of surplus available renewable energy reduces the non-renewable energy consumption resulting in a reduction of pollution. The extraction of excess available solar energy results in future developments. Since the PTC has higher heat absorption

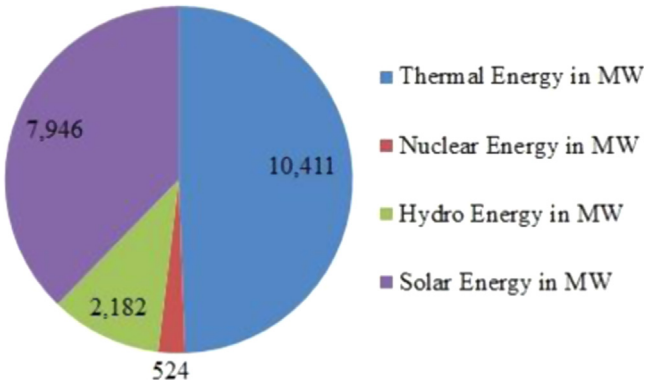

Fig. 3. Electricity generation in Tamil Nadu from various energy sources [1].

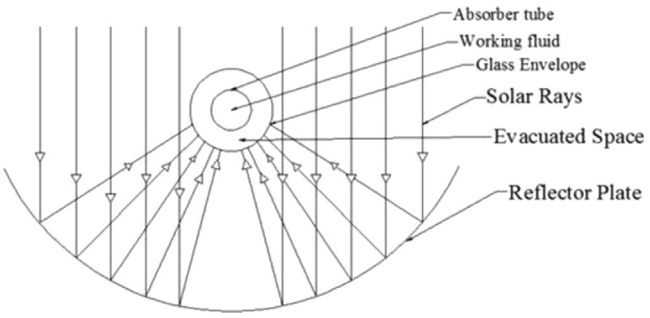

Fig. 4. Schematic diagram of Solar parabolic trough collector.

than the flat plat collector, the quests have been sought to do further analysis on PTC.

2. Performance analysis of parabolic trough collector

Solar parabolic trough collector (SPTC) consists of an absorber (working fluid chamber), a concentric transparent cover and a parabolic reflector plate. The absorber is fixed permanently at the focus of the parabolic concentrator. The concentric transparent cover is used to protect the absorber tube from the heat losses and hence a vacuum pressure is maintained. The parabolic concentrator is placed on a rigid structure and the solar tracking mechanism is placed on the rigid structure to track the solar radiation by the parabolic concentrator. Fig. 4 shows the schematic diagram of SPTC.

Garcia-Cortes et al. focused on the reflecting plate with rigid link of PTC and specified that the main factor for deformation of solar collector is self-weight [7]. Numerous researchers have studied the design performance issues of solar PTC structures and parabolic concentrator. Eckhard and Michael have studied the self-weight issues and done a performance enhancement by experimental prototype testing [8]. Vasquez Padilla et al. have done a one dimensional heat transfer analysis on parabolic trough solar receiver and concluded that the reduction of 41.8% of convective heat loss result in an improvement of performances [9]. Edenburn has done a performance study on cylindrical parabolic collector by comparing theoretical evaluation with the experimental result [10]. Naeeni and Yaghoubi have performed wind flow analysis on PTC by changing the orientation of the collector with wind velocities of 2.5, 5, 10 and 15 m/s. The resultant force acting on the collector structure was found to be normal and the pressure fields acting around the collector are found 15–20 times lesser than the collector aperture area [11]. Rojas et al. have focused on a capillary system on the absorber tube for direct steam generation which can