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Modelling and analysis of the effect of different parameters on a parabolic-trough concentrating solar system

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Concentrating solar power technologies are potential energy-harvesting systems. This paper simulates and analyzes the design of a parabolic-trough concentrating solar system. Optimum measurements are sought for the receiver, and collector performance is investigated using three heat transfer fluids, namely, ammonia, nitrogen, and carbon dioxide. Receiver parameters are optimized to achieve the maximum thermal efficiency of the collector. The concentration ratio, collector aperture area, and mass flow rate of the fluids significantly influenced the collector's efficiency and the heat removal factor.

1. Introduction

Increase in population and wealth have led to greater energy consumption. Soaring oil prices, limited non-renewable resources, increased environmental awareness, and abundant renewable resources have drawn attention from all nations to take initiatives in utilizing renewable energy.[1–6] Solar power is among the renewable energy sources with the most potential. Solar energy can be intercepted and focused onto small receiving areas that can be exploited by a concentrating system. A concentrating system is beneficial for its low cost design, as well as the availability of components such as mirrors, receiver tubes, and compatible integration with fossil fuel technologies to form a hybrid system. A parabolic trough collector is one of the concentrating systems capable of generating electricity on a large scale,[7] as well as heating applications.[8] Parabolic trough collectors provide higher concentration levels compared to flat plate collectors.[9] System performance, which depends on design and material, is significantly influenced by factors such as mirror reflectivity, receiver absorptivity, heat transfer fluid and flow rate, tracking mechanism, and incident angle, among others.[10] Numerous studies on parabolic trough system that include its design and performance have been conducted. The least squares support vector machine method using numerical simulation demonstrated considerable success in modeling and optimizing the parabolic trough system.[11] Three-dimensional numerical simulation is similarly feasible and reliable in modeling parabolic trough systems.[12] According to Schmidt *et al.*, the concentration ratio of receivers, which is notably high in a spherical receiver, suits paraboloidal reflectors with point focus and 90° rim angle.[13] Semi-cavity and modified cavity receivers investigated in a 65° rim angle paraboloidal dish indicate 70–80% steam conversion efficiency at 450 °C.[14] In a recent analytical model development for the optimum length of nanofluid-based volumetric solar receivers, the temperature in the steam power cycle reached up to 400 °C.[15,16] An integrated combined-cycle solar power system using parabolic trough technique performs better than a conventional combined-cycle gas turbine power plant.[17] A concentrating system can produce steam to generate power through water (directly) or intermediate fluids. Intermediate heat transfer fluids significantly affect collector performance.[18,19] The concentrating mechanism can attain different concentration levels and can be operated at various fluid temperatures. Fluid temperature rises once concentration ratio is increased, which heightens thermodynamic efficiency.[20] A parabolic trough concentrating solar system (PTCSS) can be designed for low/medium/high temperature applications. A smooth 90° rim angle fibreglass-reinforced parabolic trough collector for hot-water generation is designed and developed by.[9] A study on the design and construction of five parabolic trough solar collectors with various rim angles in a low-enthalpy process indicated 67% maximum efficiency and around 110 °C can be gained at 90° rim angle.[21] Another parabolic trough system with aperture 0.8 m, length 1.25 m, and rim angle 90° is developed with fiberglass as the reflector and copper tube as the solar ray absorber; it generates 75 °C hot water.[9] To measure the performance coefficient of a refrigeration and cooling unit suitable for remote areas, a parabolic trough of aperture 1.26 m, aperture-to-length ratio 0.58, and rim angle 90° are used in a particular research; it generated a maximum of 120 °C.[22] A solnova solar power station with 833 m^2 aperture 150 m long parabolic collector generates 400 °C fluid temperature to produce power steam.[23] An analytical analysis on air-based cavity receiver for parabolic trough collector showed

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