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Efficiency maximization and performance evaluation of hybrid dual channel semitransparent photovoltaic thermal module using fuzzyfied genetic algorithm

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ABSTRACT

The work has been carried out in two steps; firstly the parameters of hybrid dual channel semitransparent photovoltaic thermal module has been optimized using a fuzzyfied genetic algorithm. During the course of optimization, overall exergy efficiency is considered as an objective function and different design parameters of the proposed module have been optimized. Fuzzy controller is used to improve the performance of genetic algorithms and the approach is called as a fuzzyfied genetic algorithm. In the second step, the performance of the module has been analyzed for four cities of India such as Srinagar, Bangalore, Jodhpur and New Delhi. The performance of the module has been evaluated for daytime 08:00 AM to 05:00 PM and annually from January to December. It is to be noted that, an average improvement occurs in electrical efficiency of the optimized module, simultaneously there is also a reduction in solar cell temperature as compared to un-optimized module.

1. Introduction

Now a days it is a demand of the whole world to explore the research in the field of non-conventional energy resources. Solar energy is one of them, by which we can remove the gap between demand and supply in the world. But we need to improve the efficiency of the solar panels. Lots of the researchers have been carrying the work on single channel PVT module. Very little work has been carried out on dual channel PVT module. The monthly analysis of PVT array has been presented by Evans. This was a long term analysis for evaluating the monthly average electrical output. He has presented a simplified method for calculating PVT array efficiency and it needs minimum information of the input [1]. A review study has been carried out on a wide range of renewable energy resources. The study has been done in terms of entropy, energy, exergy balance equation and exergy efficiency. Exergetic analysis and performance evaluation also have been carried out. Following exergy efficiency values have been reported after review study; the exergy efficiencies of a photovoltaic, solar collector and a hybrid solar collector are 11.2%, 4.4% and 13.3% respectively. It is concluded that the exergy is a medium to a sustainable development so, the exergy analysis is a very important tool that can be used for performance evaluation of renewable energy resources [2]. Optimization of the PVT module is play a vital role to improve the efficiency of the system. Cat swarm algorithm has been used for the optimization of single and double diode model. A comparative study has also been presented with the other techniques like; genetic algorithm. It has been observed that the parameters optimized with CSO has high accuracy and good agreement with the experimental voltage-current data [3]. With the continuation of the optimization technique, the work has been carried out on single channel glazed photovoltaic thermal system. The design parameters of the system have been optimized with genetic algorithm fuzzy system approach. During the course of the optimization the overall exergy efficiency has been considered as the fitness function. It has been reported that the genetic algorithm-fuzzy system approach is better than the genetic algorithm because it will take less time in the optimization process [4]. A novel design of the photovoltaic module has been presented which is based on the rational function. The presented model is suitable to find the I-V curve of thin film photovoltaic modules. A comparative study of the presented model has also been done with

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the model reported in the literature [5]. The design parameters of solar generation system have been optimized with NSGA-II multi objective techniques. The proposed system was capable of combined cooling, heating with the generation. Sensitivity analysis has also been performed to observe the changes in fuel and electricity prices [6]. It is very important to find out the affect of the design parameters on the cooling of PVT module so a review study has been performed on different methods reported in the literature for a hybrid photovoltaic module. They have discussed various operating and design parameters which affects the cooling performance of PV module [7]. The cell temperature is a major issue in solar panel and is responsible to reduce the efficiency of the solar cells. A novel cooling method has been reported which uses the Peltier effect. They have developed the model and simulated it in the MATLAB to observe the temperature within the system. In the approach a thermo-electric module is used into the back side of the photovoltaic cell and it is also assumed that the power required to run the thermo-electric module is obtained from the cell. It has been observed that the proposed module is capable to keep the cell temperature at low level [8]. Optimization of design parameters of single channel glazed photovoltaic thermal array has been presented, with the help of evolutionary algorithm. Overall exergy gain is an objective function during the course of optimization. There is a 87.86% improvement occurring in instant overall exergy gain as compared to un-optimized system given in literature. It also has been observed that 69.52% and 88.05% improvement occurs in annual overall exergy gain and annual overall thermal gain respectively as compared to the system given in literature [9]. As the cooling of the PVT module is concern, the different types of fluid are used such as air and water. An expression for outlet water temperature has been derived. An analysis has also been done in terms of overall thermal energy and overall exergy. It has been considered that, the N numbers of partially covered photovoltaic thermal-compound parabolic concentrator collectors are connected in series. It has been reported that the overall exergy efficiency of the system is maximum in the month of January as compared to June due to less thermal losses [10]. After the theoretical and analytical study of the PVT module it is very important to simulate the results to get the design of the system, which is very close to experimental design. A simulation based study has been presented for water-cooled PVT collector. It is reported that in any operating condition, there is a possibility to obtain optimum water inlet temperature to get maximum total exergy which is generated by the system. A thermo-economic analysis has also been done to evaluate the price of thermal energy generated by the proposed system [11]. For getting the best absorption of heat different shapes and size of cooling channel may be used. The configuration of the hybrid photovoltaic thermal collector has been presented, which is made with sheet and tubes and test has been conducted at the unit of applied research in Renewable Energy Ghardaia, Algeria. It is reported that the proposed design is a better heat absorption and lower production cost as compared to other hybrid collector model given in literature [12]. There are different types of PVT systems are available like unglazed glazed, opaque and semitransparent and have different advantages and disadvantages in terms of electrical and thermal energy. So it is necessary to study the different types of PVT systems. The comparative study has been conducted on different types of photovoltaic thermal collectors like; glazed PVT tiles, unglazed PVT tiles and conventional hybrid PVT collectors, which is based on the overall thermal gain, overall exergy gain and carbon credits. It has been reported that the annual overall exergy gain of glazed and unglazed PVT tiles is 53.8% and 9.6% as compared to conventional PVT collectors respectively. It has also been observed that the annual overall thermal gain and the exergy gain of unglazed PVT tiles is improved by 27% and 29.3% as compared to glazed PVT tiles [13]. The performance of the collector has been observed in different conditions for different working modes. A novel design of tri-functional photovoltaic thermal collector has been presented. The proposed model works in two modes; photovoltaic air heating and photovoltaic water heating. The mode will be selected according to the seasonal needs. It is observed that the electrical efficiency and daily thermal efficiency is 10.2% and 46% respectively in photovoltaic air heating mode while it is 36% in photovoltaic water heating mode as compared with the collector given in literature [14]. As the PVT module is concerned, the electrical and thermal both analysis is important. Design and development of the thermal-electrical model has been presented and the observations are compared with published experimental data. A study is performed to observe the effect of different design parameters like; length, duct depth, flow rate and packing factor in electrical and thermal performance. The proposed model is simulated and analyzed thermal and electrical performance of the proposed system for Dhahran, Saudi Arabia. It has been observed that there is a 1% improvements in annual thermal gain for flat photovoltaic thermal finned as compared to unfined. On the other hand, the improvement in annual electrical gain for flat photovoltaic thermal finned is 3% higher than unfined [15]. Double pass facade may be a good option as compared to single pass facade for space heating. Performance evaluation of semi transparent double pass facade photovoltaic thermal module for space heating has been proposed. Thermal model has been developed for proposed system using energy balance equations. Analysis has been carried out for annual energy gain and annual electrical gain of the proposed system. It has been observed that the annual electrical and thermal energy is 469.87 kW h and 480.81 kW h respectively. The overall annual thermal energy generated by the system is 1729.84 kW h. It is also reported that the room temperature increased up to 5–6 °C as compared to the ambient air temperature [16]. Lots of research on photovoltaic thermal module has been carried out over the last 30 years. The historic overview and thematic overview of this research has been presented and it addresses the different research issues of photovoltaic thermal system [17]. A dynamic model of PVT system is good agreement with the experimental data for real operating conditions. A novel design of a dynamic model of air based photovoltaic thermal system has been presented. The model simulates real operating conditions of the system with experimental data collected from BIPV module installed in two buildings. The air outlet temperature and electrical power are very close to experimental data. The study in changing working conditions also has been performed on PVT system. It is inferred that the thermal efficiency and first law efficiency, increased linearly with the increase in ambient temperature while the electrical efficiency and second law efficiency decreases [18]. A review study has been performed on solar collectors and thermal energy storage in solar thermal applications. Different types of solar collectors and energy storage systems has been reviewed and discussed. Thermal energy storage system has been reviewed on the basis of material selection, design criterion and different heat transfer enhancement technologies while the solar collectors has been reviewed on the basis of heat loss reduction, optical optimization, different sun-tracking mechanisms and heat recuperation enhancement. The present and future solar power station overview also has been reported [19]. The different combination of the channel affects the cooling of PVT module. The study of the series combination of N PVT water collectors, partially covered with photovoltaic module for two different configurations like; photovoltaic module at the lower portion (Case A), photovoltaic module at the upper portion (Case B). During the study, the expression for exergy efficiency and instantaneous thermal efficiency have been derived. The performance of both the configuration has been compared. It has been reported that both cases give nearly the same results at a moderate mass flow rate for a