ABSTRACT

Energy is a key motivating factor in everyday lives for the formation of wealth and the evolution of economy. The production of energy and economic growth are strongly intertwined due to the accelerating advancement in modern technologies. Currently, renewable and non-polluting energy consumption is at a great demand. This prompts the researchers for a search of alternative energy sources to improve the energy feasibility, increase energy affordability, and tackle climatic change. Solar energy is the most abundant and inexhaustible energy resource. In recent years, there has been a lot of interest in converting solar energy into heat energy in a constructive way that is mostly useful for thermal applications. The solar water heating is the most popular method of solar energy extraction because of its technological sustainability and economic attraction. The study of energy conversion methods based on the first law of thermodynamics, are insufficient to satisfy today's energy needs. Whereas employing the second law of thermodynamics to modify the solar system design specifications and procedures provides a base for better solution.

The exploration of hidden thermal losses in each subsystem of the solar water heater and the estimation of energy efficiency, entropy generation, exergy destruction and exergy efficiency for each subsystem of solar water heating system are of indispensable task to analyze the performance of the system. Hence, many researchers developed several mathematical models to estimate the exergy efficiency of the system, based on second law of thermodynamics through the determination of hidden thermal losses and the effect of various parametric studies of the solar water heater. This dissertation presents steady state behavior of the solar energy conversion processes of solar water heater by investigating the thermal losses in each component,

minimizing the overall loss coefficient and optimizing the cost of the system product, which are widely used in many industrial applications.

The steady state behavior of invisible heat dissipation in each subsystem of the solar water heater with flat plate collector is examined by incorporating the idea of energy, entropy and exergy analysis of the thermal system. Moreover, the heat analysis is studied at each stage, with the output from each stage acting as input for the subsequent stages. To account the irreversibility in each subsystem and to capture large amount of solar energy, the existing model is modified by: introducing the honeycomb structure between the glass plate and the collector plate, and insulating the outlet water pipe. Exergy efficiencies were determined for each stage of solar water heater, and the results of entropy generation and exergy destruction are compared to both the present and modified models. The obtained results shows that an increase in the exergy efficiency of the collector plate, water pipe, and storage tank, from 5.181 % to 5.298 %, 1.354 % to 1.914 %, and 1.280 % to 1.832 %, respectively.

Exergy analysis provides the quantitative and qualitative aspects of energy and identifies the causes of exergy destruction of the system. Apart from that, the exergy efficiency mainly depends upon the overall loss coefficient of the system. Thus to enhance the efficiency of the system, it is crucial to minimize the overall loss coefficient. Employing the Lagrange multiplier optimization technique, the top loss coefficient of the flat plate solar collector is minimized, which improves the exergy efficiency of the collector plate from 1.65 % to 3.7 %, 2.55 % to 5.54 %, 2.95 % to 5.58 %, 1.76 % to 3.42 %, 1.36 % to 2.82 %, and 1.16 % to 2.2 % respectively in the different time intervals. Further, the top loss coefficient is computed by empirical formulas and the proposed results for both the methods are compared with the pre-existing models.

Identifying the improved performance of flat plate solar collector for developing better solar energy conversion procedure has become significant. In recent days, many researchers had examined different aspects of flat plate solar collector using novel methodologies for enhancing design requirements and evaluating collector's efficiency. Also, the performance of solar flat pate collector is affected by many factors like weather system, tilting angle, mass flow rate, mounting structure, overall loss coefficient. Analyzing and fine-tuning these factors will effectively increase the performance of the collector. Thus, implementing the genetic algorithm, the overall loss coefficient is optimized and the obtained findings for different time intervals enhances the collector's efficiency from 1.65 % to 4 %, 2.55 % to 5.92 %, 2.95 % to 6.15 %, 1.76 % to 3.6 %, 1.36 % to 3.06 %, and 1.16 % to 2.93 % respectively. The results are statistically validated by using the completely randomized design with the pre-existing models.

Apart from the effectiveness of solar water heater, it is essential to estimate the reasonable total cost of the system. As cost is a major factor, engineering economics must be addressed, while constructing a thermal system. The total cost is determined based on the system performance, the volume and type of solar collector used, the cost of fuel sources, and the average operational cost. An exergoeconomic model is developed and the exergoeconomic cost of the system is minimized using the Genetic algorithm optimization technique. Finally, the system's exergy efficiency is calculated in order to validate the maximum performance. The results exhibits that the respective energy and exergy efficiency are 63.93% and 12.655%.

A modified energy conversion procedure is proposed for solar water heater with flat plate collector to investigate the hidden losses based on energy, entropy and exergy analysis. Different optimization procedure technique is proposed to minimize the overall loss coefficient of the system to

enhance the efficiency of solar water heater. The efficiency is validated by conducting the statistical tests and comparative studies are carried out for the proposed model with the pre–existing models. The total annual cost of the solar water heater is also estimated.