Abstract

Energy is an essential requirement for the technological and industrial development of any nation. Among the various energy sources, solar energy and biogas have been identified as clean, safe, sustainable, abundantly available energy source with least environmental constraint. The production of biogas from organic waste is a temperature dependent process. There are three optimum temperature ranges for generating methanogens which is responsible for production of biogas. These are: psychrophilic ($\leq$ 293 K), mesophilic (303 – 313K) and thermophilic (323 K – 333 K).This may be achieved by heating of feedstock in the biogas digester through a heat exchanger in which primary working fluid is water and same is heated with solar thermal collector. Since solar energy varies widely during the day and also dependent on weather as well as season of the year, utilizing the solar energy in continues manner is difficult. Further, geometry, shape and size of the water tubes (riser tube) play an important role in heat transfer. Thus there is a need to undertake detail experimental as well as numerical study on type of collectors (straight and bent tube) on performance of solar water heating system. The fluctuating nature of solar energy restricts its demand for various applications. Integrating the solar collector with the thermal energy storage system (TES) using paraffin wax as phase change material is favourable solution to smoothen the inconsistency.

The application of the integrated solar thermal system for biogas production process with controlling device is feasible to maintain the biogas digester at 308 ± 2 K. This was done with the help of controlling devices such as solenoid valves, Arduino microcontroller, motor driving modules, thermostat and DC voltage supply along with the solar water heating system and thermal storage. The C language program with necessary algorithms helped to develop the relationship between the temperature of the biogas digester and shell tank. This algorithm was essential for diverting the water flow away from the shell tank when the shell temperature exceeds the desired limit.

Similarly when the shell temperature falls below desired limit, the solenoidal valves are modulated to operate for the same. During this, the heat energy is stored/released in/from the LHS system.

The results from the controlled experiment revealed that the temperature of the fluid inside the shell varied from 308.9 K – 314 K and the biogas digester temperature varied in between 308.1 K – 309.2 K. Similar experiments were also performed for checking repeatability. It was noticed that the shell tank temperature varied from 309.2 K – 313.4 K whereas this variation in biogas digester was from 308.3 K – 309.1 K. The maximum temperature fluctuations in the biogas digester for all cases of controlled experiments were found to be 1.1 K which recommended for growing mesophilic methane-forming bacteria without affecting the stability of the process. This shows that the developed system is an alternate solution to increase the biogas production by supplying uniform temperature required for the same.

Additionally, the maximum error deviation in the prediction of outlet water and absorber plate temperature was observed to be less than 6% and 4%, respectively for both straight and bent tube collectors. Both the experiment and the numerical results showed the superiority of the bent tube arrangement in contrast to straight tube. Similarly, the numerical and experimental results of the paraffin filled LHS revealed a maximum deviation of ~ 5 K during charging and ~7 K during the discharging process. The low value of error establishes the confidence in the predictive capabilities of the developed numerical model.