Abstract

The energy demand of building sector is approximately 27% of the global energy consumption, whereas India’s building sector consumes 29% of its total energy consumption. The heating and cooling loads of building consume a significant portion of the total building energy demand. However, the sector has a great potential in reducing its consumption by means of passive techniques as well as by energy generation within the building envelope. By taking the aforesaid facts into account, a detailed study has been performed on a 7.2 kWp off-grid building integrated semi-transparent photovoltaic thermal (BiSPVT) system, installed on a passive building. The passive building also incorporates a 2.4 kWp off-grid rooftop semi-transparent photovoltaic (RtSPV) system.

A comparison of performance has been done between the BiSPVT system with intermittent water flow and RtSPV system without water flow. A thermal model has been developed for the BiSPVT system with water flowing over the SPV array for intermittent duration i.e. 0945 to 1415 hour. The outcomes of thermal model have been found to be in good correlation with the experimental observations. Through the model, it has been found that the water of mass flow rate 0.60 kg/s reduces the temperature of PV cell by 20°C. The net measured electrical output of the BiSPVT system for a typical day with water flow has been found to be 10.14 kWh which is 1.44 kWh higher than that obtained from the RtSPV system. In addition to the higher electrical energy, the thermal energy generated by BiSPVT system is 379.82 kWh.

Further, the effect of number of air change on the performance of BiSPVT system has been studied. For convective cooling of room1, two exhaust fans have been installed in the system which produces the number of air change (N) in room. In this study, a simplified and computationally flexible thermal model based on only three energy balance equations has been developed. The average efficiency of SPV array in real time application is found to be
6.90% when loaded at maximum power point by the charge controller inbuilt in power conditioning unit. It has been found that N creates negligible decrease in PV cell temperature whereas with N=11 (day2) and N=22 (day3), the maximum room1 temperature has been found to decrease by 1.3°C and 1.9°C respectively. The total energy (electrical, thermal and daylighting) generated in ayear by the BiSPVT system has been found to be 8927.1 kWh.

The installation of BiSPVT system on roof provides an additional feature of sunbath which is of importance now-a-days. However, the high temperature of room1 will not attract the users for sunbath. In this regard, the feasibility of cost-effective movable insulation (MI) by using the simplified thermal model has been studied. Moreover, the effect of packing factor of SPV roof and the combinatorial effect of number of air change and MI has been investigated. The MI with zero air cavity produces higher reduction in temperature of room1 as compared with air cavity. Due to the increase in packing factor of SPV array, the electrical energy generation increases and the thermal energy generation decreases.

Due to the intermittent duration of sunshine hours and seldom match between PV generation and load, the use of battery bank is required which makes the off-grid system more complex as compared to grid tied PV system. Moreover, the batteries are the most vulnerable component in off-grid systems which lead to consumers not getting the promised energy. Therefore, a detailed analysis has been done on recommended multi stage battery charging with the help of experimental data. The details of current/voltage/power profiles at SPV array/battery/load side to gain an in-depth understanding on off-grid PV systems have been presented. Moreover, the possible reasons have been investigated for the early health deterioration of battery bank and the suggestions have been made to avoid such situations.