ENERGY SAVING POTENTIAL OF SOLAR COOLING SYSTEMS IN HOT AND HUMID REGION

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ABSTRACT

In this study energy consumption of conventional fan coil unit and five models of desiccant cooling system are evaluated for application in one seminar room in hot and humid area. The energy usage of FCU and desiccant cooling systems are detected by measurement and simulation respectively. The measurement results demonstrated that the average energy consumption of FCU per day is 61.8 kWh that 7%, 27%, and 66% of the total energy consumption of FCU belong to the fan, pump, and chiller, respectively. Simulation results shows that among the five proposed models, the one-stage hybrid desiccant cooling system (model C) can produce suitable conditions for the room.

Keywords: energy saving, solar cooling system, hot and humid.

INTRODUCTION

Energy efficiency strategies can be divided into two categories, namely, active and passive. Furthermore, building energy performance can be enhanced by applying either active or passive energy efficient strategies. For instance, heating, ventilation and HVAC systems, and electrical lighting can be classified under active strategies; conversely, enhancement of surrounding structures of a building, such as walls, windows, roofs, and so on, may be categorized under passive strategies [1]. Active strategies are implemented to reduce energy consumption of building units, such as heating systems, appliances, cooling systems, and lighting systems. Large portion (approximately 50% to 70%) of the total energy consumption in buildings in tropical climate is related to the AC systems [2]. Therefore, to find energy efficient building, evolution of energy saving in cooling system is necessary. High-energy consumption of conventional cooling system is related to integration of cooling and dehumidification process in cooling coil where highly chilled working fluid is needed [3].To save energy, dehumidification and cooling process can be performed separately in desiccant cooling systems[4].

Potential energy savings by desiccant cooling systems are related to energy saved by dehumidification with free solar energy. Desiccant cooling systems are among the most efficient solutions to save energy in this region because such systems use a natural solution (solar energy) for a natural problem (humidity) [5]. For instance, dehumidification in conventional cooling systems requires large amounts of energy; by contrast, dehumidification in desiccant cooling systems is performed using free solar energy. In addition, desiccant cooling systems applied to hot and humid areas provide several advantages, such as improved indoor air quality, reduced energy consumption of cooling system, separately controlled dehumidification and sensible cooling, and reduced CO_2 emission [6-10].

To achieve these advantages, we should analyze the configuration and the operation of desiccant cooling systems based on weather data, as performed in this study. Desiccant cooling systems generally consist of three main units, namely, chemical dehumidifier, cooling device, and thermal source for regeneration [11]. The configuration of a desiccant cooling system is based on the selection of its three main components among various options. This research investigates the energy-saving potential of various configurations of evaporative and hybrid desiccant cooling systems integrated with a solar component for single room in Malaysia.

MATERIAL AND METHODS

In this study, three levels of ASHRAE energy audit were used as methodology. In level 1, a general assessment of the building energy system can help identify the required data for energy consumption analysis. To understand the general view of apportioning energy usage in a building, a primary investigation is conducted. We also review the facility's utility bills and other operational data. Our results show that the AC system is the main energy consumer in the building. Our observations further reveal that most people in the building are forced to wear a jacket because of cold weather. Over cooling is attributed to the selection of a large cooling coil to reach the desired humidity of the building. Therefore, mechanical dehumidification in AC systems is accounted for high energy consumption in Malaysia. A general idea has been proposed to modify and improve cooling systems in Malaysia. Thus, energy saving can be achieved by changing conventional dehumidification or cooling. In the first step of energy monitoring, a case study is selected and includes one FCU as a conventional cooling system in a seminar room which specifically located at 2° 55′ 13.0″. To clarify the scope of the case study, we show the schematic boundary (Figure 1) of the case study, which includes a FCU boundary and a room boundary. The FCU boundary is equipped with four air lines, a cooling coil, a fan, chilled water supply (CHWS), and chilled water return (CHWR).

VOL. 12, NO. 18, SEPTEMBER 2017 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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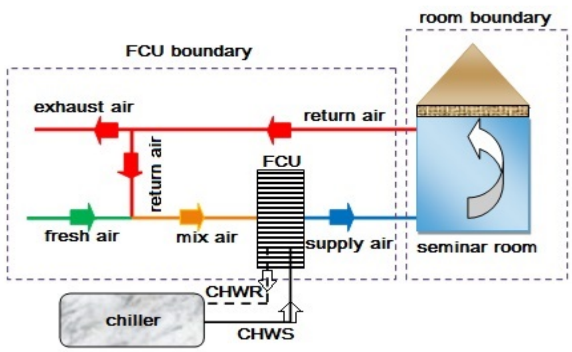

Figure-1. Case study boundary.

To bridge the research gap, we apply different configurations of the desiccant cooling system to a seminar room under optimum operating conditions by TRNSYS 16. The proposed cooling systems are includes five configurations, namely, A_1, A_2, B_1, B_2, and C, as shown in Figure-2, 3, 4, 5, and 6 which have been the preferred cooling systems for years. However, these configurations have not yet been applied to a seminar room in hot and humid areas, particularly in Malaysia. In this study, these configurations are simulated and applied to our seminar room model. Models A1 and A2 are selected to evaluate the basic desiccant cooling system based on Malaysian weather data. Although the components of these models are nearly similar, the air circulations of the systems differ. The two models are related to a one-stage solar desiccant cooling system with different ventilation and recirculation modes. To evaluate isothermal dehumidification based on Malaysian tropical weather, the two-stage solar desiccant cooling system with various ventilation and recirculation modes are considered as models B1 and B2. Model C is selected to evaluate the modality performance of a hybrid desiccant cooling system in Malaysia.

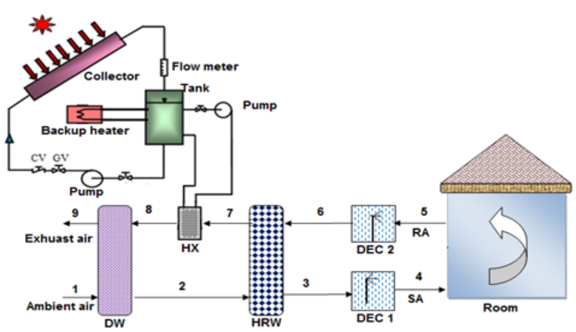

Figure-2. Schematic of one-stage evaporative desiccant cooling system (Model A_1).

The main difference between the one-stage and two-stage systems is related to the variation in dehumidification capacity, which can be defined as the humidity ratio that is removed from the air during dehumidification.

Dehumidification capacity is lower in the cooling systems with a one-stage desiccant than in the systems with a two-stage desiccant. During the simulation, the regeneration temperature can be established by adjusting and setting the required humidity ratio after dehumidification in DW; this temperature can be regarded as the humidity ratio set point.

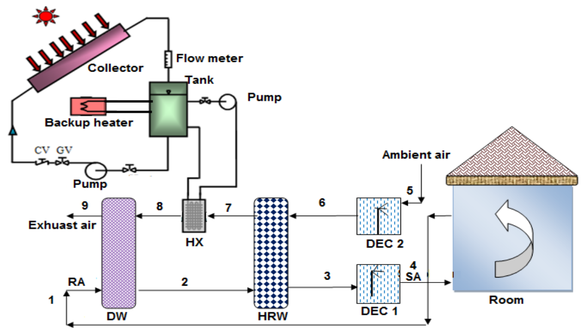

Figure-3. Schematic of one-stage evaporative desiccant cooling system (Model A_2).

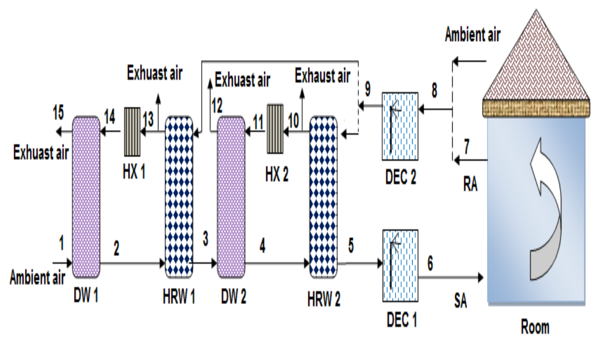

Figure-4. Schematic of two-stage desiccant evaporative cooling system (Model B_1).

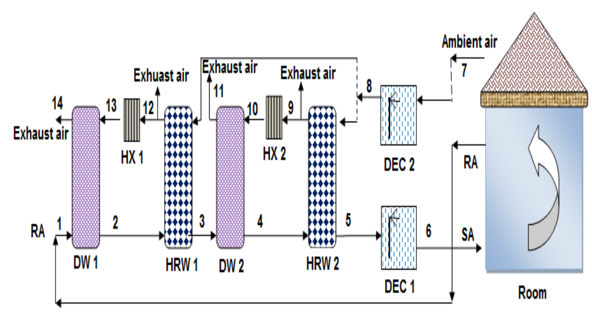

Figure-5. Schematic of two-stage desiccant evaporative cooling in recirculation mode (Model B_2).

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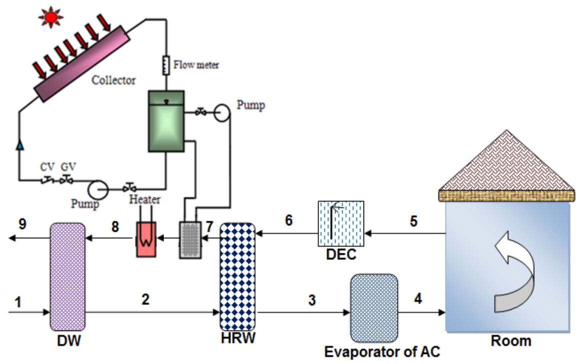

Figure-6. Schematic view of hybrid desiccant cooling system (model C).

The dehumidification set point for the cooling system with a one-stage desiccant is adjusted to 0.010 kg/kg. In the comparative evaluation of the one-stage and two-stage solar desiccant cooling systems, the humidity ratio set points for the first and second DWs in the two-stage ventilation and recirculation modes are 0.0100 kg/kg and 0.0050 kg/kg, respectively.

RESULTS AND DISCUSSION

To determine the energy consumption range of different models for one month, the trend of the total energy consumption of five models and FCU during the aforementioned period is detected and shown in Figure 7. The energy consumption of FCU changes from 89 kWh to 65 kWh during the month, and the range of change during the same period in models A1, A_2, B_1, B_2, and C are 32.2–40.2, 27.2–35.1, 40.1–46, 39.1–45.7, and 52–58.4 kWh, respectively. To compare the total energy consumption of each model with the energy consumption of FCU, the sums of the energy usage of all components of each model have been considered.

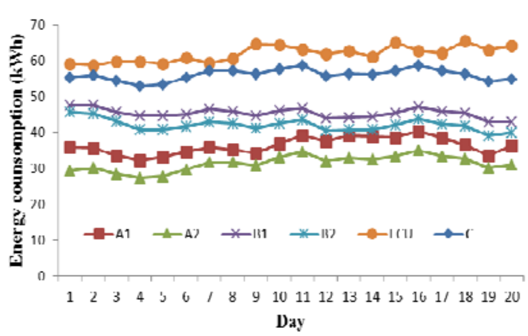

Figure-7. Energy consumption of different models during one month.

In Figure 8, the average amount of total energy use of each system is compared with the total energy consumption of FCU per day. Model A_2 exhibits the lowest energy consumption compared with the other systems because of the low energy requirement for one-stage dehumidification. The energy consumption of models B_1 and B_2 are higher than those of models A_1 and A_2 because models B have two energy consumers (DW and HRW). Among the five proposed models, model C has the highest energy consumption with 55.83 kWh per day, followed by models B_1, B_2, A_1, and A_2 with 44.56, 40.88, 35.75, and 31.69 kWh, respectively.

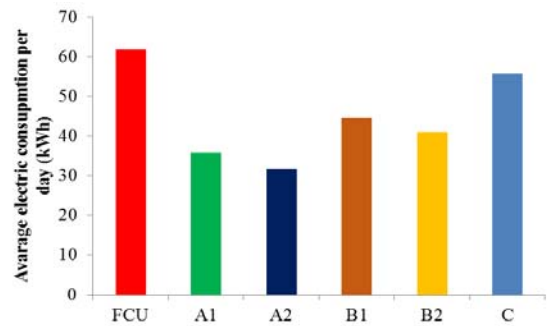

Figure-8. Average electric consumption in one day.

Energy is saved by using different configurations of desiccant cooling system in the seminar room. The average amount of saved electricity from the use of different models is shown in Table 1, which is based on kWh per day. Model A_2 saves the most energy with 30 kWh per day, followed by models A_1, B_2, B_1, and C with 26.11, 20.97, 17.30, and 6.03 kWh, respectively.

Table-1. Average electricity saving per day by application of different models on seminar room.

Model	Average electricity saving per day (kWh)
A_1	26.11
A_2	30.16
B_1	17.30
B_2	20.97
C	6.03

Among the performance indicators, energy conservation and the thermal condition of the room are important to select a model of an efficient cooling system. The energy-saving percentage and temperature of the room using different models are shown in Figure 9. Although models A_2 and A_1 do not produce suitable amounts of supplied air, these models save the most energy with 48% and 42%, respectively. Model C saves the least energy. However, this model produces suitable temperature and humidity for supplied air. The temperatures of the room under models B1 and B2 are 25.5 °C and 25.2 °C, respectively; whereas their energy-saving percentages are 17.3% and 20.97%, respectively.

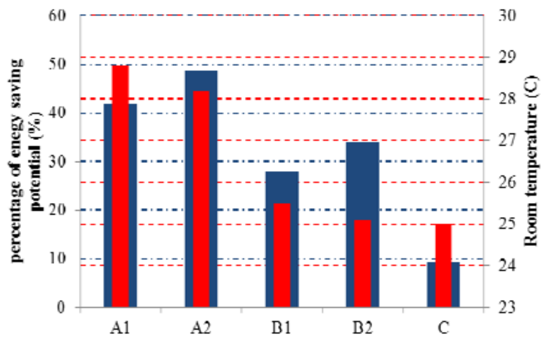

Figure-9. Comparison percentage of energy saving of different models.

Therefore, the high energy-saving potential of models A_1 and A_2 is not useful because of the high room temperature generated by these models. By contrast, the energy-saving potential of models B_1, B_2, and C can be considered because of the room temperature range when these models are used in the seminar room.

CONCLUSIONS

This paper presents investigation of energy saving potential of different configuration of solar cooling system in hot and humid region. A FCU have been considered for measurement as case study reference. Five solar cooling models have been simulated by TRNSYS 16. The simulation result demonstrates that among the five proposed models, the greatest energy saving of 30 kWh per day is obtained by model A_2, followed by models A_1, B_2, B_1, and C with 26.11, 20.97, 17.30, and 6.03 kWh, respectively. Therefore, model A_2 has the highest energy saving potential among the models, although it is unable to produce standard indoor conditions.

ACKNOWLEDGEMENTS

The authors would like to thank the Institute of Product Design & Manufacturing (IPROM), Universiti Kuala Lumpur, and Solar Energy Research Institute (SERI), University Kebangsaan Malaysia for providing the laboratory facilities and technical support.

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