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Energy Consumption of Solar-assisted Internally Cooled/Heated Liquid Desiccant Air-conditioning System in Hong Kong

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Abstract

Solar-assisted liquid desiccant air-conditioning system (SLDAC) has been considered as a promising application as traditional AC systems have many problems. In this paper, the operation performance of the SLDAC of a typical commercial building in Hong Kong was investigated, for evaluating the energy-saving potential. Combing the numerical model of individual component and inputting the weather data and load profile, the annual energy consumptions of SLDAC and traditional system could be obtained. The simulation results show that the electricity driven LDAC is not suitable for the commercial building due to the high energy demand in the regeneration. But, the solar-assisted system with thermal storage could provide promising energy saving potential. However, with the cooling tower as the only cooling source of the dehumidifier, the dehumidification capacity could not satisfy the requirement and only up to 12.5% of electricity consumption could be saved annually compared to traditional systems. Therefore, to improve the energy-saving potential, extra cooling source should be supplied for the application of SLDAC of buildings in Hong Kong.

Keywords: Solar ; Air-conditioning ; Dehumidification ; Liquid desiccant ; Commercial building ; Energy consumption ;

1. Introduction

Conventional air-conditioning (AC) system has many problems. The liquid desiccant AC (LDAC) system, handling the extra moisture independently with desiccant absorption, has been considered as a suitable alternative. Due to the high system efficiency, the internally cooled/heated dehumidifier/regenerator should be applied in the LDAC system. By applying with solar collectors and cooling tower, significant energy saving is expected of solar-assisted LDAC (SLDAC) system.

Hong Kong, as a high density city locating in a subtropical offshore region, is generally warm and humid throughout the whole year. Although many researchers investigated on the energy performance of LDAC or SLDAC in buildings [1-3], most of them concerned the packed-bed or solar collector/regenerator liquid desiccant system, and the research on the internally cooled/heated liquid desiccant system is limited. Additionally, only several researchers have been conducted on the operation

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performance of LDAC applied in buildings under the hot climate like Hong Kong [4, 5]. Therefore, it is necessary to find a way to reduce the energy consumption of AC system in buildings in Hong Kong.

In this paper, the annual energy consumption and performance of the SLDAC of commercial building in Hong Kong was studied and compared with the conventional system.

2. Methodology

The proposed SLDAC system mainly consists of an internally cooled/heated liquid desiccant ventilation system and an all-air cooling system, for handling the latent and sensible AC load of buildings separately. The system includes a liquid desiccant loop (pink line), two water loops (blue line) and two air loops (green line), as shown in Fig. 1.

With the quick prediction model [11], the outlet parameters of air, solution and heating/cooling fluid could be obtained directly with the given inlet parameters, including the outlet temperature of air, cooling/heating water and desiccant solution, the outlet moisture content of air and the outlet concentration and mass flow rate of solution. For defining the amount of vapour removed from the fresh air to the desiccant solution, the moisture removal rate of dehumidification ($\dot{m}_{removal,de}$) could be calculated as follows:

$$\dot{m}_{removal,de} = m_{da}(\omega_{da,in} - \omega_{da,out}) \quad (1)$$

where *m* refers to the mass flow rate, and w is the moisture content. The subscript *da* stands for the outdoor fresh air, and *in* and *out* mean the inlet and outlet characteristics.

Similarly, the regeneration rate ($\dot{m}_{removal,re}$), which is used to describe the amount of water evapourating from the solution to the air, could be expressed as:

$$\dot{m}_{removal,re} = m_{ra}(\omega_{ra,in} - \omega_{ra,out}) \quad (2)$$

where the subscript ra stands for the exhaust air from the air-conditioned rooms.

The cooling load handled with the cooling coil of SLDAC could be calculated as:

$$Q_{cc} = Q_c - m_{da}(h_{da} - h_{da,dc}) \quad (3)$$

where Q_c is the total cooling load of the building, and m_{da} means the minimum outdoor airflow rate required in the building. h_{da} refers to the enthalpy of ambient air and $h_{da,dc}$ is the enthalpy of the process air entering the cooling coil.

Combing the numerical model of individual component and inputting the weather data and load profile, the annual energy consumptions of SLDAC and traditional system could be obtained.

3. Results

Firstly, the annual primary energy requirement of the LDAC, without the introduction of solar thermal energy, was discussed. As shown in Fig. 2, as about 10% energy used for regenerating the desiccant solution, the primary energy consumption of the LDAC was around 4.7% higher than that of the conventional vapor compression cooling system (CVCS).

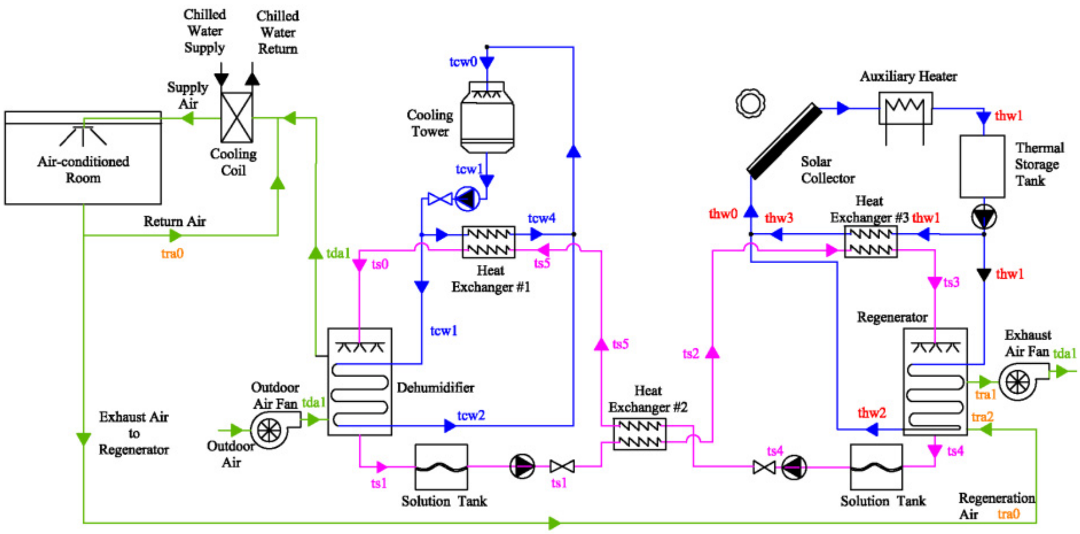

Fig. 1. Schematic diagram of system components of SLDAC

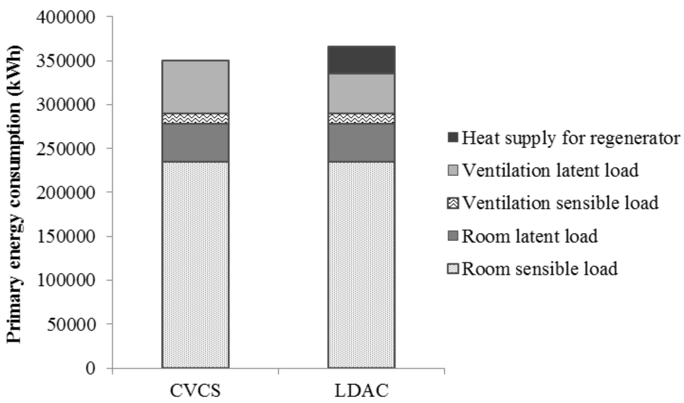

Fig. 2 Annual primary energy consumption of CVCS and LDAC

If the electric heater was applied as the heat source, the annual electricity consumption of LDAC was much higher than that of conventional system of the commercial. The main reason is that the heating efficiency of electricity (less than 1) is much lower than its cooling efficiency (about 3-4). In order to handle the high dehumidification load in commercial buildings, more electricity would be used to heat the liquid desiccant before entering the regenerator. Therefore, in commercial buildings in Hong Kong, the AC system with liquid desiccant ventilation system should not be driven by high grade energy, such as the electricity.

To reduce the energy use, solar energy applications are necessary for the LDAC. It should be noticed that the energy consumption of the solar-assisted systems is affected by the installation area of solar thermal collectors. As shown in Fig. 4, with the increase of installation area, the electricity consumption of LDAC applied in commercial buildings decreased. By applying the SLDAC in the commercial building, up to 7.9% of total electricity consumption for AC system could be saved with solar collectors. By adding the thermal storage, the saving percentage would improve to 12.5%.

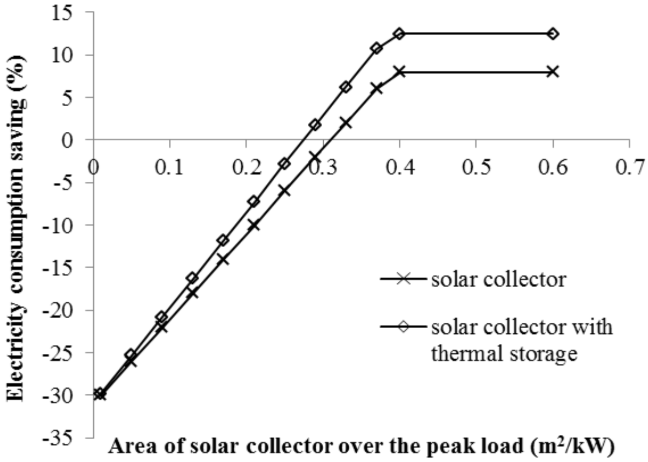

Fig. 4 Energy saving percentages of LDAC with different solar collector areas

The energy saving percentage of the proposed SLDAC, around 7.9%-12.5%, is not high. The main reason is that the actual moisture removal capacity could not satisfy the requirement, due to the high latent load and humid outdoor air.

4. Conclusion

With the numerical model of dehumidifier/regenerator and equations of other components, the operation performance of the SLDAC for commercial buildings in Hong Kong was simulated. Due to the high energy demand in the regeneration, the electricity driven LDAC is not suitable for the buildings, while the solar-assisted system with thermal storage could provide energy saving potential. The energy consumption of the solar-assisted systems is affected by the installation area of solar thermal collectors. However, with the cooling tower as the only cooling source of the dehumidifier, the dehumidification capacity could not satisfy the requirement, and only up to 12.5% of electricity consumption could be saved annually compared to traditional systems.

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