Modeling of a Hybrid Solar Radiant Cooling System in a High-Rise Building in Malaysia

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SUMMARY

The hybrid solar radiant cooling system is a relatively new air-conditioning(AC) technology in Malaysia as it is integrated with several systems, including the hybrid PV-T, solid desiccant dehumidifier and chilled ceiling. The main feature is that the chilled ceiling coupled with the chilled water copper pipes operates behind the ceiling. It has a potential in improving the thermal comfort as well as energy savings. The objective of this project is to carry out a fieldwork measurement and a case study of AC systems at a high-rise building. Next, the three systems, including the existing system in the building, the solar absorption and the solar radiant cooling system have been modelled using TRNSYS. In addition, the cost and the performance of each system are then evaluated in terms of energy savings and the payback period. The results show that the hybrid solar radiant cooling system consumes the least electrical energy (18% of the solar absorption, 80% of the existing system), and it is self-sustainable. The installation cost is higher than the existing system, but it has the least payback period in comparison to other systems, which is only one year. In a nutshell, the hybrid solar radiant cooling system is the best option to be implemented in the high-rise building as it is green, sustainable and economical.

PRACTICAL IMPLICATIONS

The results obtained can serve as an important design guide for building services engineers to design healthy and sustainable air-conditioning systems in the tropics.

Keywords: *Solar radiant cooling; chilled ceiling; PV-T; sustainable building; Malaysia*

INTRODUCTION

The photovoltaic/thermal (PV-T) hybrid solar system is a mixture of the photovoltaic and solar thermal system, which converts solar energy into both heat and electrical forms (Chow, 2010). The just mentioned system can be coupled with the hot-water system as water is heated up after going through the panel. Meanwhile, the efficiency of PV-T is maintained as the temperature of the panel's surface is cooled down by the hot-water system.

The chilled ceiling system is known as one of the radiant cooling system, which cools down the room with radiation and convection. Theoretically, it can overcome the weakness of the existing AC system in commercial buildings, in which it is high in energy consuming and maintenance cost, and could create discomfort to the occupants. In contrast, the chilled ceiling system provides a better thermal comfort to the occupants. It applies a chilled water piping system to cool down the room with a cheaper, lesser mechanical part, smaller space, lower sound level and more energy efficient (Hui and Leung, 2012).

Therefore, the PV-T and chilled ceiling have been integrated together and become a hybrid solar radiant cooling system in the current research. In order to discover its benefits, several analyses have been examined regarding its characteristics, including its performance, energy savings and economic analysis. A fieldwork measurement was conducted at the high-rise building to investigate the existing system's performance. The design of the new AC system, including this hybrid solar radiant cooling system is based on the geometrical layout of several floors of the high-rise building. The system is then modelled by TRNSYS. The system is simulated to test its ability in terms of energy savings and other performances such as the temperature, relative humidity and cooling loads. The payback period is calculated based on the performance data obtained to evaluate whether it is economical for these systems to be implemented in the tropics.

FIELDWORK AND MEASUREMENTS

In order to understand the proper design of the AC system, an investigation about the indoor air quality was carried out in several floors of the high-rise building. The room temperature, relative humidity and chilled water temperatures were measured so that the required indoor conditions are determined.

RESULTS

The preliminary result has indicated that option C, the hybrid solar radiant cooling system, has a significant advantage compared to the other two options.

CONCLUSIONS

Based on the fieldwork measurement, it can be concluded that the indoor environment in the high-rise building is in the bad conditions. The root-cause problem is the AC system failed to dehumidify the air adequately. It is recommended that the existing AC system to be retrofitted. Through modelling and simulation, it has proven that the hybrid solar radiant cooling system has a distinct superiority compared to other systems. It reduces the sensible heat by 37% compared to other systems. It consumes the least electrical energy and has the shortest payback period with a high return of investment.

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REFERENCES

Chow T.T. (2010) A review on photovoltaic/thermal hybrid solar technology, Applied Energy, Volume 87, Issue 2, February 2010, pp. 365-379

Hui, S.C.M. and Leung, J.Y.C. (2012). Thermal comfort and energy performance of chilled ceiling systems. *Preceedings of the Fujian-Hong Kong Joint Symposium 2012,* 29-30 June 2012, Fuzhou, China, pp. 36-48