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Life-cycle evaluation of different types of cooling systems in buildings

Aotian Song[a], Lin Lu[a]*, Tao Ma[b]

[a]Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong
[b]Institute of Refrigeration and Cryogenics, Shanghai Jiao Tong University, Shanghai, China

Abstract

Cooling system represents a growing market in buildings worldwide, with a particularly significant growth rate observed in commercial buildings. Solar driven cooling system can be a promising alternative to traditional electrical cooling system. It can be used in combination with solar thermal collectors or photovoltaic collectors to release the duty caused by electrical cooling system. In this study, the performance of three different solar cooling systems is examined, namely: 1) a solar electrical, 2) a solar thermal and 3) a traditional electrical cooling system. The first system employs photovoltaic module to drive a conventional electrical chiller. The second system uses solar thermal collectors to drive a heat driven adsorption chiller and the third one utilizes the grid power to feed the electrical chiller. Assessment of life-cycle costs of these three systems are conducted to verify the best option for buildings. A case study in Hong Kong is conducted to assess the three cooling systems.

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1. Introduction

Energy consumption of building sector accounts for approximately 40% of final energy consumption in the worldwide [1], and 14.6% was taken by the cooling load. Conventional cooling systems was driven by use grid electricity. Nowadays solar cooling system offers a sustainable and reliable solution, which can be divided in two main categories: solar thermal cooling and solar electric cooling [2-3]. Recent years, many researchers had taken the

* Corresponding author. Tel.: (+852) 3400-3596; fax: (+852) 2765-7198.
E-mail address: vivien.lu@polyu.edu.hk (L. Lu)

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possibility of operating an adsorption chiller with solar energy into account both numerically and experimentally, for example [4-5]. The performance of a solar powered adsorption air–conditioning system, installed in the green building of Shanghai Research Institute of Building Science, was investigated by Zhai et al. [6]. Meanwhile, several researchers had compared the performance of solar thermal cooling systems with solar electrical cooling systems [7]. However, there is a limited study comparing the performance of solar electrical cooling systems with adsorption solar thermal cooling systems.

In this paper, assessment of life-cycle costs of the solar electrical cooling system, solar thermal cooling system and traditional cooling system are conducted to verify that which is the best option for buildings. TRNSYS building energy model is used to calculate the operation cost of these three cooling systems.

2. Description of the examined cooling system

2.1. Solar thermal cooling system

Fig. 1(a) shows a conceptual solar thermal cooling system. It includes four parts, i.e. solar thermal collector, storage tank, adsorption chiller and building user. Solar thermal collector is employed to collect the solar energy and then convert the solar energy into heat. The storage tank, considered as hot heat transfer medium, receives the heat collected from solar thermal collector. Adsorption chiller, which is powered by heat, supplies the cooling to the building user. A detailed and comprehensive description of adsorption chiller's operation principle can be found in [8].

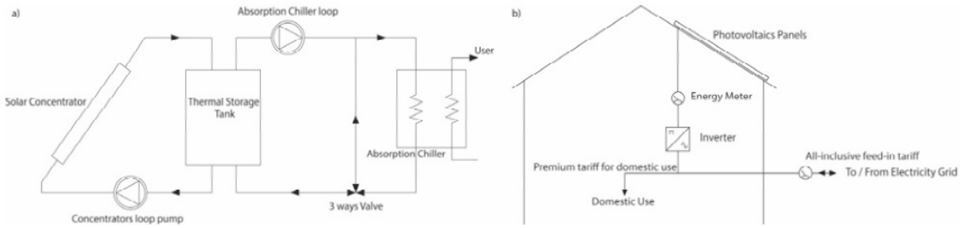

Fig. 1. (a) Solar thermal cooling system; (b) Solar electrical cooling system [9]

2.2. Solar electrical cooling system

Fig. 1(b) shows a conceptual solar electrical cooling system. It consists of four main parts - i.e., photovoltaic module, inverter, electrical chiller and building user. The photovoltaic module is used to collect the solar energy and then convert it into electrical energy. It is found that the electricity produced in the PV module is in the type of DC. The inverter converts it into AC to drive the electrical chiller. The chiller supplies the cooling to the building user.

3. Model of the examined cooling system

The TRNSYS software is used to model and simulate the hourly cooling load of building based on the typical meteorological (TMY) weather data of Hong Kong. The building energy model could also simulate energy consumption and temperature variations of the system. In this study, the daily working hour of HVAC system is from 8:00am to 20:00pm and the cooling season is from March to November. From December to February, the free cooling is used to supply the cooling to fulfill the thermal comfort.

3.1. Model of solar thermal cooling system

The solar thermal collection can be computed by Eq. (1) [10, 11]. Where, W_{sc} is the power of solar thermal collector which could be calculated by Eq. (2), A_a and η_{sc} is the total aperture area and efficiency of solar thermal collector, I is the hourly irradiance (kWh/m2), CL_{peak} is the cooling capacity of adsorption chiller, COP_{ad} is the COP of adsorption chiller. The needed aperture area of solar thermal collector can be calculated by Eq. (3).