PERFORMANCE OF SOLAR AIR-CONDITIONING SYSTEM USING HEAT PIPE EVACUATED TUBE COLLECTOR

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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Date: 6 DECEMBER 2010

STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

This is a study on the performance of solar air-conditioning system using heat pipe evacuated tube collector. The objective of this project is to analysis the performance solar air-conditioning system by determining the solar collector efficiency, coefficient of performance (COP) of the absorption chiller, and overall system efficiency and also the electrical energy consumption and operation cost for the system and compare it with the conventional air-conditioning system from the previous case study. The existing solar air-conditioning system is not competitive with electricity driven air-conditioning system because of their high investment and installation cost. Its overall thermal energy conversion efficiency is relatively low, and from an economical point of view, solar cooling and refrigeration are not competitive with the conventional systems. The experiment is conducted at Solar District Cooling Sdn. Bhd and data collected from building automation system for 30 days from 1st – 30th June 2010. The data analysed using the theoretical analysis and plotted in graph to discuss about it. The solar collector efficiency varies from 50 to 80% during day time and stored energy can be used during night time. The COP varies from 2.961-2.966 and the overall system efficiency is from 30 to 50%. The investment cost is higher and electrical consumption is relatively lower than conventional air-conditioning system. The economical view is profitable after 18 years and 7 months of installation and environmental view is green energy without pollution. Although all the above findings refer to a particular application in Malaysia, the similar results can be obtained in the country with high solar availability. Finally by considering the problem of pollution of the planet due to the burning of fossil fuels the adoption of solar energy to power absorption chillers, even with marginal economic benefits, should not be underestimated.

ABSTRAK

Ini adalah kajian prestasi sistem pendingin udara suria dengan menggunakan dievakuasi kolektor tenaga suria. Tujuan kajian ini adalah untuk menganalisis sistem pendingin udara solar dengan menentukan kecekapan kolektor, pekali prestasi (COP) dari chiller penyerapan, dan kecekapan sistem secara keseluruhan dan juga pengambilan tenaga elektrik dan kos operasi untuk sistem dan bandingkan dengan sistem pendingin hawa konvensional daripada kajian kes dahulu. Sistem pendingin udara suria tidak kompetitif dengan sistem pendingin hawa konvensional kerana pelaburan yang tinggi dan kos pemasangan. Sistem pendingin udara suria juga mempunyai kecekapan tenaga keseluruhan penukaran terma relatif rendah, dan dari pandangan ekonomi, pendingin udara suria dan pendinginan yang tidak kompetitif dengan sistem konvensional. Eskperimen dijalankan di Solar District Cooling Sdn. Bhd dan data yang dikumpul daripada sistem automasi bangunan selama 30 hari dari 01-30 Jun 2010. Data dianalisis secara teori dan diplot dalam graf untuk membincangkan. Kecekapan kolektor suria bervariasi dari 50 hingga 80% sepanjang siang hari dan tenaga yang disimpan boleh digunakan pada waktu malam. pekali prestasi (COP) dari chiller penyerapan adalah bervariasi dari 2,961-2,966 dan kecekapan sistem secara keseluruhan dari 30 hingga 50%. Kos perlaburan lebih tinggi dan penggunaan kuasa elektrik yang relative lebih rendah berbanding dengan system pendingin hawa konvensional. Pandangan ekonomi menguntungkan selepas 18.6 tahun pemasangan dan dari pandangan persekitaran adalah tenaga hijau tanpa pencemaran. Walaupun semua penemuan di atas merujuk pada aplikasi di Malaysia, keputusan yang sama boleh diperolehi oleh Negara sama iklim. Akhirnya dengan mempertimbangkan masalah pencemaran pelaksanaan tenaga suria untuk pendingin penyerapan tenaga kerja, boleh bermanfaat.

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LIST OF SYMBOLS

ηc	solar collector efficiency
η	overall system efficiency
ρ	density of water (kg/m3)
t	time (second)
β	Slope
γ	Surface azimuth angle
γ_s	solar azimuth angle

LIST OF ABBREVIATIONS

SDC	Solar District Cooling
BAS	Building Automation System
NASA	National Aeronautics and Space Administration
ETC	evacuated tube collector
COP	coefficient of performance
COPmax	maximum coefficient of performance
Tin	inlet collector water temperature (ºC)
Tout	outlet collector water temperature (ºC)
Tave	average collector temperature (ºC)
Tamb	ambient temperature (ºC)
I	insolation (W/m^2)
G	global solar irradiance (W/m^2)
Gb	direct solar irradiance (W/m^2)
Gd	diffuse solar irradiance (W/m^2)
V	volume of the heat storage water tank (m^3)
Cp	specific heat of water (J/kg ºC)

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Air-condition is the most energy consuming service in buildings in many equatorial countries such as Malaysia. Malaysia has an equatorial climate, It has good sunshine, warm and wet weather throughout the year. The demand of cooling increases by every year and the solar powered air-conditioning is an alternative way to meet the demand in buildings in an energy efficient way. The solar thermal technologies are used to collect the energy of the sun to provide thermal energy for solar water heating, solar pool heating, solar space heating and cooling, and industrial process pre-heating.

The Solar District Cooling Sdn. Bhd (SDC), an evolving company incorporated in Malaysia, is dedicated to provide leading technology solutions for renewable energy. The company building consists of four storeys. The ground floor the common area (main lobby, lift lobby and VIP room) is served by solar air-conditioning system. The solar air-conditioning system is fully automatic and it is observed by Building Automation System (BAS). BAS is located at SDC control room and it is used to record data and observe the maintenance of the system.

1.2 PROBLEM STATEMENT

Nowadays, some modern buildings are running on solar powered air-conditioning system, and the main reason is to conserve the electrical energy. The current problem faced by solar air-conditioning system are;

I. The overall thermal energy conversion efficiency is relatively low, and from an economical point of view, solar cooling and refrigeration are not competitive with the conventional systems.

II. The existing solar air-conditioning system is not competitive with electricity driven or gas-fired air-conditioning system because of their high investment and installation cost. The investment cost only can be reduced if the performance is improved which will lower the investment cost eventually. The improvements can be made such as the reduction of the solar collector area with higher efficiency energy collector.

III. The solar air-conditioning system is highly dependent upon solar parameters such as solar insolation incident on a horizontal surface, solar radiation incident on an equator-pointed tilted surface, and daylight hours. Besides that, air temperature, wind speed, and cloud are factors that affects on solar air-conditioning system.

1.3 OBJECTIVE

The objectives of this project was to;

I. Performance analysis of the solar air-conditioning system at SDC
   a. Obtain the efficiency of heat pipe evacuated collector.
   b. Determine the coefficent of performance (COP) of absorption chiller.
   c. Detemine the overall performance of a solar air conditioning system at SDC.

II. Calculate the electrical energy consumption and operation cost for the system and compare it with the conventional air-conditioning system from the previous case study of SDC.

1.4 SCOPES OF THE PROJECT

The scopes were:

I. Equipments :
   a) Absorption Chiller
      Model: Sanyo LCC-E01
      Capacity: 30RT
      Feature: Market leader with advanced technology in Li-Br absorption chiller, complying JIS B 8622-2002.

   b) Sunda Evacuated Tube
      Model: SDC SEIDO 1-16
      Feature: SPF certified patented "Thermal-Compression Sealing Technology" prevents heat loss and protect from corrosion. Aluminum Nitride Coating ensures more than 92% high solar absorption.
      Performance tested accordance to EN 12975.

   c) The solar air-conditioning system data was collected from BAS.

d) The solar parameters were obtained from NASA surface and solar energy science data at latitude 2.983º and longitude 101.617º the location of the SDC.

II. Cooling Space

a) Ikhasas Office Building – the ground floor common area (main lobby, lift lobby and VIP room) is served by solar air-conditioning system approximately 6000 ft^2 or 557 m^2.

III. The data analysed using theorectical formula calculation to obtain the efficiency of heat pipe evacuated, coefficient of performance of absorption chiller, energy consumption, and operation cost.

IV. The experimental duration was for 30 days from 8.00 am until 6.00 pm from 1st-30th June 2010.

1.5 LIMITATION

I. The parameters of the system cannot be changed because its running automatically and at fixed parameters.

CHAPTER 2

LITERATURE REVIEW

2.1 SOLAR AIR-CONDITIONING SYSTEM

In earlier studies performance of solar air conditioning system based on solar photovoltaic can be either a rankine engine or an electric motor. It is reported that, it has relatively low thermal conversion efficiency, which is about 10–15%, depending on the type of cells used (Kazmerski, 1997). In addition, considering an identical refrigeration output, the solar photovoltaic systems were four to five times more expensive than those powered by solar thermal utilization (Wang, 2002). Therefore, at present time, the most of the solar air conditioning system are using solar thermal utilization. In most of the solar cooling systems, single-stage or double-stage lithium bromide absorption chillers driven by hot water were commonly used (Li et al., 2001). The solar evacuated tubes or other high grade solar collectors were used to provide a hot water temperature of 88–90 ºC as a heat source to drive the chiller. Experimental data on the performance of such systems were reported (Bong et al., 1987).

2.1.1 System description

The SDC solar air-conditioning system is SEIDO 1-16 heat pipe evacuated tube collector to collect the energy from the sun. The system uses water as the medium to collect the energy from the solar collector and the water piping system is well insulated. The SANYO LCC-E01 double effect absorption chiller with a pair of lithium bromide and water is used to absorp the energy and turn it into cooling effect. The system has hot and chill water storage tank about $8m^3$ each and both are well insulated. The cooling tower used to bring down the temperature of the absorption chiller cooling water. The system is fully automatic and it only starts to operate when the hot water storage tank temperature reached at 60 ºC(SDC, 2008).

However, the system still requires some electricity to operate its pumps and fans. Some auxiliary conventional source is also required from time to time to maintain its operation during periods of insufficient sunshine. The schematic diagram of the system is shown in figure 2.1.

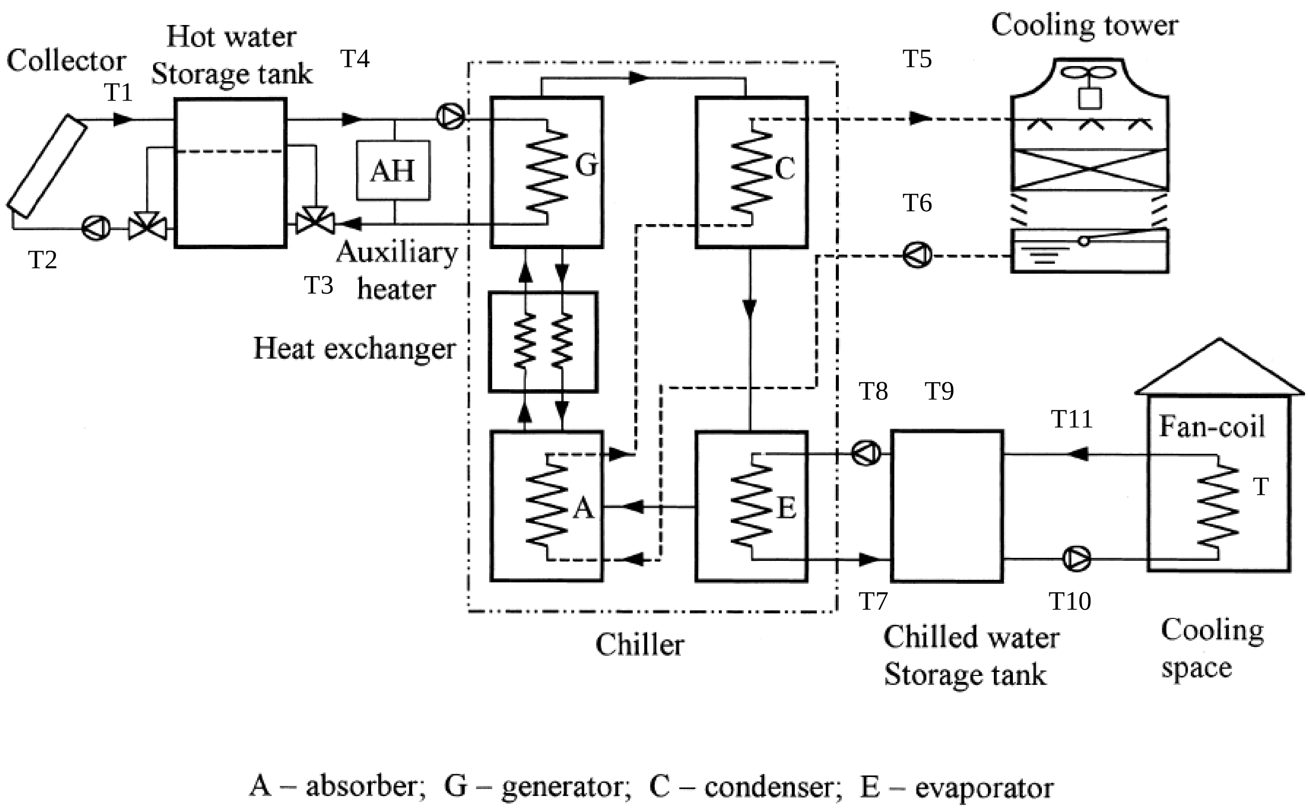

Figure 2.1: The schematic diagram of the solar air-conditioning system.

[Source: Li et al., 2000]

The flow of solar air-conditioning is shown in figure 2.1. The hot water cycle, the water is pumped up to solar panels to collect the heat energy from sun by hot water tank pump with an inlet temperature of water, T_2. The outlet temperature of water, T_1 from solar panels stored at hot water storage tank. The hot water from storage, pumped by hot water chiller pump into absorption chiller at temperature, T_4. The water returns to the storage tank at temperature, T_3. The cycle continues until reach the minimum temperature of 60ºC and stop automatic below the minimum temperature.

The condenser water at temperature, T_5 is pumped by condenser water pump to cooling tower enter into absorption chiller at temperature, T_6. The chill water cycle, water is pumped into absorption chiller at temperature, T_8 from storage temperature, T_9 and released out of chiller at temperature, T_7 stored into chilled water storage after pass pressure valve, P_1 and P_2 with modulating valve, V_1. The chill water temperature, T_{10} is flow the five fans at temperature, T to cool the environment and enters to chilled water storage tank and completed the cycle.

The solar air conditioning system is observed by Building Automation System (BAS). BAS is used determine the need of maintenance and record the data of the system. The BAS observation of the system is shown in figure 2.2.

The BAS will take the reading of the system every 5 minutes and stored the data into specially allocated server and data storage devices. The system also can be monitored by using this BAS for maintenance and operational view.

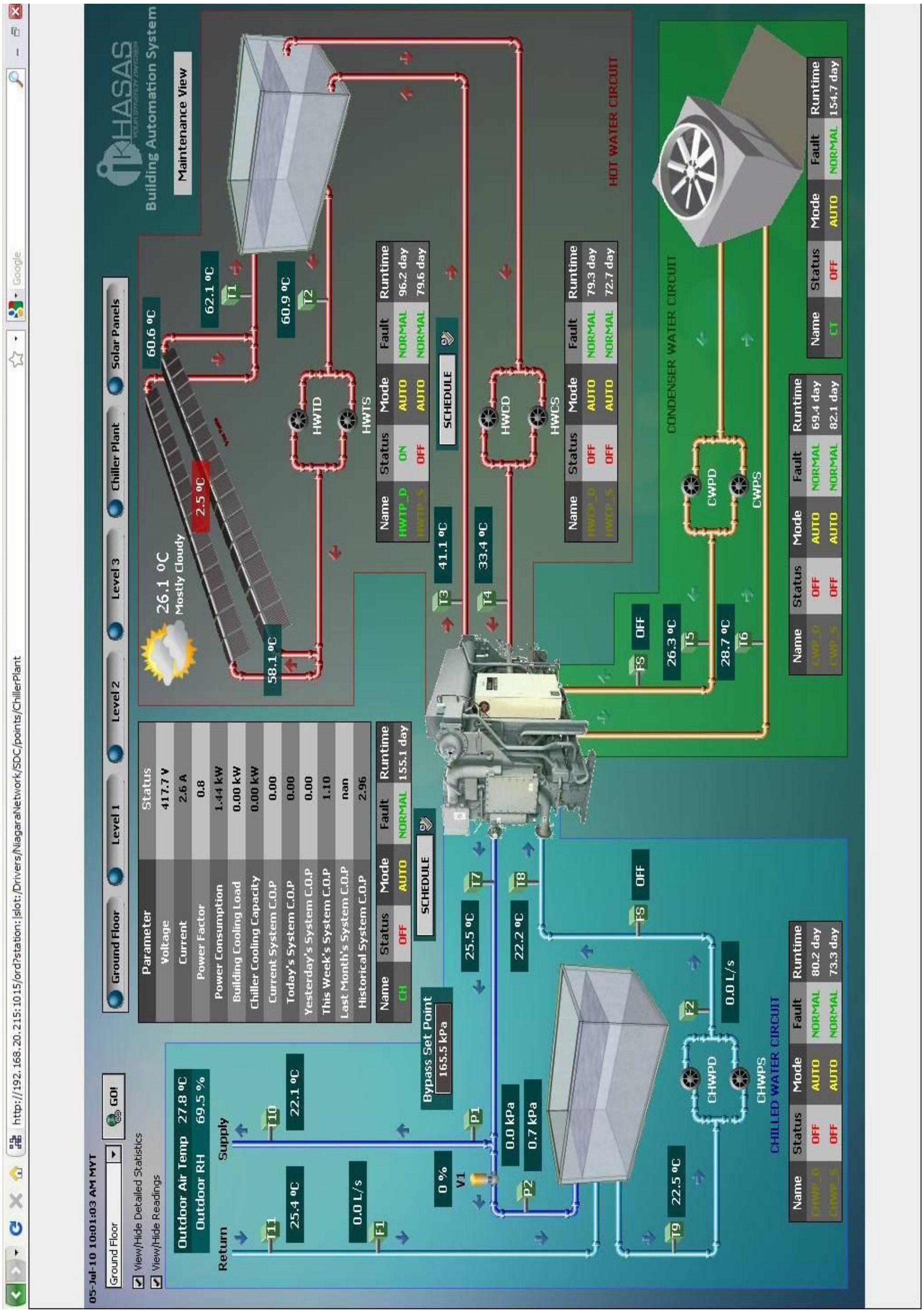

Figure 2.2: The Building Automation System of the solar air-conditioning system.

[Source: SDC, 2008]

2.2 SOLAR COLLECTOR EVACUATED TUBE

The evacuated solar collector are efficient compared to the flat plate collector. The evacuated solar collector are useful for commercial and industrial heating applications and it is an alternative to flat plate collector especially in areas where it is often cloudy. The each tube has the air removed from it (vaccumised) to eliminate heat loss through convection and radiation. The glass tube contains a flat aluminum or copper fin which is attached to a metal pipe. The fin is covered with a selective coating that transfers heat to the fluid that is circulating through the pipe. The fin colour is dark blue. There are two main types of evacuated tube collectors (Budihardjo et al., 2009):

Figure 2.3: Direct-flow evacuated-tube collector.

[Source: Kratzenberg et al., 2006]