Large Scale Solar Hot Water Heating Systems for Green Hospital

POORYA OOSHAKSARAEI, BAHARUDIN ALI, SOHIF MAT, M. YAHYA, KAMARUZAMAN IBRAHIM, AZAMI ZAHARIM, KAMARUZAMAN SOPIAN

Solar Energy Research Instiute,
Universiti Kebangsaan Malaysia
43600 Bangi, Selangor,
MALAYSIA
Email: azami.zaharim@gmail.com,ksopian@eng.ukm.my

Abstract:- Concerns over the impact of the environment on the massive usage of fossil fuels, combined with soaring energy prices, triggered increased interest in the use of solar energy. Solar energy is abundant, provides an important saving to the consumer, and contributes to a personal comfort without environmental damage. One of the most attractive applications of solar energy is for hot water usage in the public and commercial sector. The available building surface for the residential, commercial and industrial sector is approximately 110,000,000 m^2. Hence, the potential for solar heaters for Malaysia is 75 GW(thermal). There are over 100 hospitals and hotels throughout the nation that the existing hot water system can be converted to solar assisted system and hence increase the market of the solar energy systems. Hospitals and hotels utilized over 30 % of the total energy consumption for water heating. A case study of such facilities is the Hospital Universiti Kebangsaan Malaysia (HUKM)) was presented. Presently, cold water enters the calorifiers directly, which are heated by LPG boilers. Boiling time is relatively long, hence larger amount of LPG is used and much amount of greenhouse gases is released. The hot water system for the hospital is provided by a boiler with a capacity of 2.1 million kcal/hr. The fuel used is LPG. A total of eight calorifiers are used. Each calorifier has a capacity of 13,500 litre/hr. The unit is running 24 hours a day. The average solar radiation for Kuala Lumpur is 16.92 MJ / m^2 / day. The evacuated tube collectors with all the required controls system have been proposed. Simple calculations on the energy output, savings on LPG and reduction of CO2 have been conducted. Prelimanary results indicated that the saving on LPG based on proposed system was more than 20%. With a prospect of 100 hospitals and hotels throughout the nation, this project shall improve public awareness in energy conservation in the hot water production of their buildings and increase the market of the solar energy systems.

Keywords:- Evacuated tubes, solar assisted hot water heaters, energy savings, greenhouse gas reduction

1 Introduction

Solar energy applications are oriented toward the applications of solar energy for domestic hot water systems, solar distillation of sea and brackish water, water pumping, drying of agricultural produce, solar industrial process heat, photovoltaic for remote applications, space heating and cooling (passive and active design), building integrated photovoltaic systems and products, daylighting, solar thermal electricity generation, and solar refrigeration [2,3].

In Malaysia, there are huge potential for the use solar hot water heating in hotels where 24.62% of the total energy consumption is for water heating. Other promising applications are the use of solar industrial process heat in textile factories, hospitals, food processing industries, animal husbandry, dairy, aquaculture, swimming pool heating and other manufacturing facilities [4]. This paper presents the feasibility of the use of large scale solar hot water heating system for hospitals. A case study was conducted using the existing system in Hospital Universiti Kebangsaan Malaysia, a modern teaching and R&D hospital.

2 Solar Irradiation In Malaysia

The monthly average daily solar irradiation in Malaysia is 4000 - 5000 Whr/m^2, with the monthly average daily sunshine duration ranging from 4 hr to 8 hr [5]. It can be seen, that the region Klang valley (Kuala Lumpur, Putrajaya, Seremban) has the lowest irradiance value. Penang (Georgetown, north-west coast) and Kota Kinabalu have the highest values. Figure 1 shows the annual average daily global solar irradiation for Malaysia.

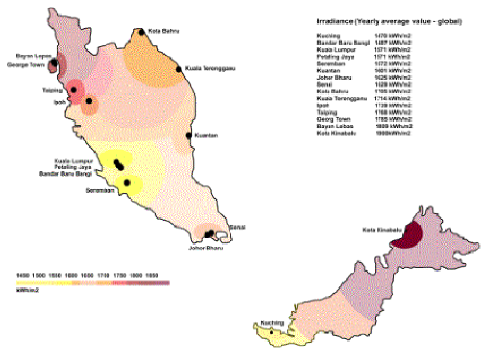

Fig. 1: Estimates of the Annual Average Daily Global Solar Irradiation

The solar hourly radiation and solar monthly average daily radiation on sloped surface are indicated by equations below (Isotropic sky)

$$I_T = I_b R_b + I_{d,iso}\left(\frac{1+\cos\beta}{2}\right) + \rho_g I\left(\frac{1-\cos\beta}{2}\right)$$

$$\bar{H}_T = \bar{H}_b \bar{R}_b + \bar{H}_d\left(\frac{1+\cos\beta}{2}\right) + \rho_g \bar{H}\left(\frac{1-\cos\beta}{2}\right)$$

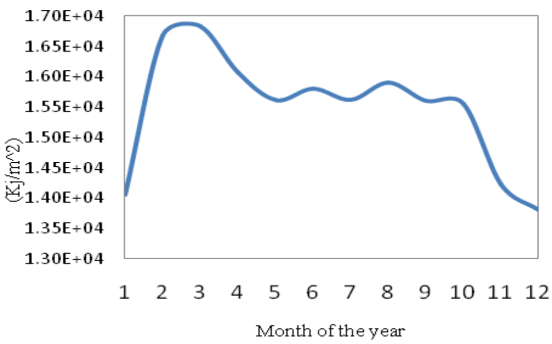

Fig. 2: Daily average solar radiations on horizontal surface

3 Potential For Solar Hot Water Heating In Malaysia

There are huge potential for in the residential, commercial and industrial sector. We are able to determine the Monthly average daily utilize ability of the system by applying the equation below [8]:

$$\bar{\phi} = \frac{\sum_{days}\sum_{hours}(I_T - I_C)^+}{\bar{H}_T \; N}$$

In sigma calculation, we only consider the positive values.

A monthly average critical radiation X_C is a useful parameter that determines the minimum level of solar radiation that is utilizable. This parameter has been defined as below [8]:

$$\bar{X}_c = \frac{I_c}{r_{T,n} R_n \bar{H}} = \frac{\text{Critical Level}}{\text{Avg. Radiation at Noon}}$$

There are over 100 hospitals and hotels throughout the nation that the existing hot water system can be converted to solar assisted system and hence increase the market of the solar energy systems. Hospitals and hotels utilized over 30 % of the total energy consumption for water heating. Other promising applications are the use of solar industrial process heat in textile factories, hospitals, food processing industries, animal husbandry, dairy, aquaculture, swimming pool heating and other manufacturing facilities.

The International Energy Agency's Solar Heating and Cooling Programme (IEA SHC) and several major solar thermal trade associations agreed upon a methodology to present the installed capacity of solar collectors in GWth. Because the conversion factor is nearly the same for all collector types, it was decided to use one factor that is 0.7 kW(thermal) per m^2 of solar collector area for all collector types (www.iea-shc.org). The available building surface for the residential, commercial and industrial sector is approximately 110,000,000 m^2. Hence, the potential for solar heaters for Malaysia is 75 GW(thermal).

4 Existing Hot Water Heating System

The Hospital Universiti Kebangsaan Malaysia (HUKM) is situated in Cheras. HUKM is about 10 km from the Kuala Lumpur city centre. It is one of the most modern state-of-the-art teaching hospitals for the Faculty of Medicine, University Kebangsaan Malaysia. The hot water system for the hospital is provided by a boiler with a capacity of 2.1 million kcal/hr. The fuel used is LPG. A total of eight calorifier are used. Each calorifier has a capacity of 13,500 litre/hr. The unit is running 24 hours a day. The existing HUKM hot water systems use a boiler and a calorifier or heat exchanger to produce a hot water. The systems are build with two loops as shown in Figure 3.

Primary Loop: Consist of circulation of hot water within the boiler and the calorifier, plus the expansion tank to replace the water loss during the circulation.

Secondary Loop: Consist of calorifier and end user distribution pipeline. Plus a make-up tank the replace the water loss during the circulation.

The reason of having this loops are to expand the life of the boiler by avoiding a shock temperature of the water supplied in the boiler. Only one boiler is on the operating mode while the other boiler is on a standby mode for back up 24 hours a day.

In the current system, each calorifier is dedicated to different user such as laundry, kitchen, wards, toilet and etc. The water consumed during the be replaced by the expansion tank, while the water consumed in the calorifier will be replaced by the make up tank. B1 will operate regularly and will always be in Hot-standby Mode when not operate while B2 will always on Cold-standby Mode and act as a back up boiler in case if B1 fails to operate.

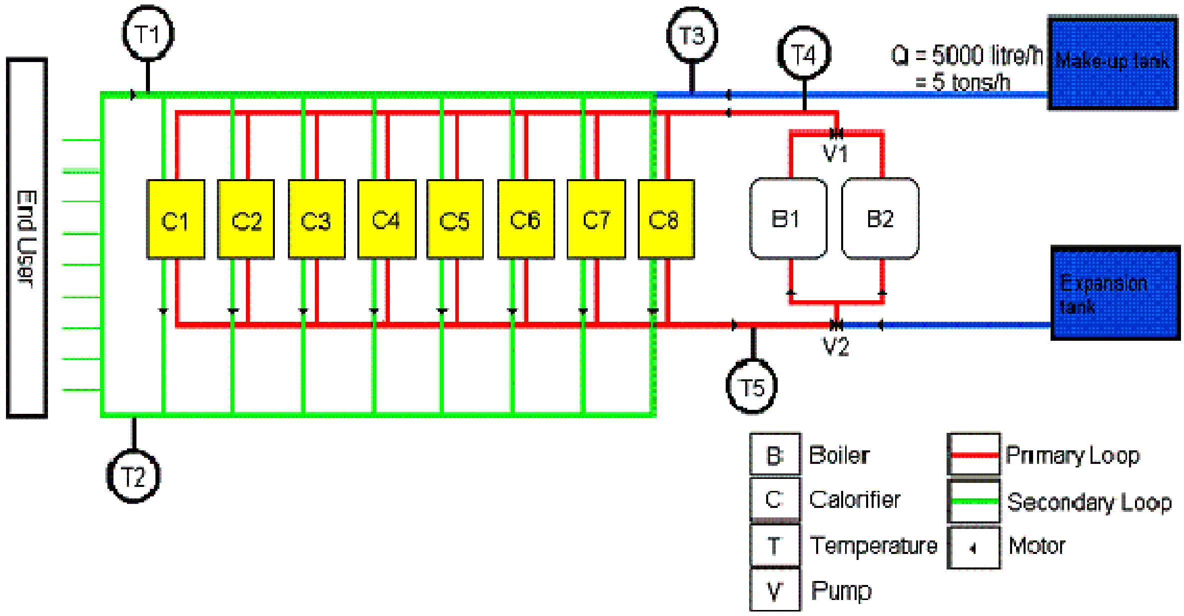

Fig. 3: Schematic of Existing Hot Water Heating System in HUKM

circulation is then replaced by the water stored in the make-up tank. All 8 calorifier simultaneously operate based on the demand from the end user. An average of 5000 litter of water is consumed every hour (based on energy audit result from 3rd ~ 9th March '04). The water distributed to the user, point T2, must between the ranges of 50°C ~ 60°C. While the hot water fed in to the calorifier from the boiler known as Primary Hot Water Supply (PHWS), point T4, must be at 90°C. The water from the make-up and expansion tank is town water with temperature in the region of 25°C (point T3).Whenever the calorifier detects a temperature drop in the SHWR (< 50°C), point T1, it will send a signal to pump V1 to feed in a hot water with the temperature of 90°C. At the same time the boiler will start to burn water until the water flow in the Secondary Hot Water Supply (SHWS) reach the set temperature of 60°C. The water loss during this process in the boiler will

5 Proposed Solar Heating System

Similar settings applied to this mode except the function of the make-up tank is replaced by the Solar Evacuated Tube (SET) as shown in Figure 4. It is recommended to maintain the make-up tank and feed normal water into the SET instead of calorifier. This will ensure reserve storage in case of water supply shortage. On the other hand, the use of make-up tank will enable us to control the water pressure into the SET. SET has been considered as a

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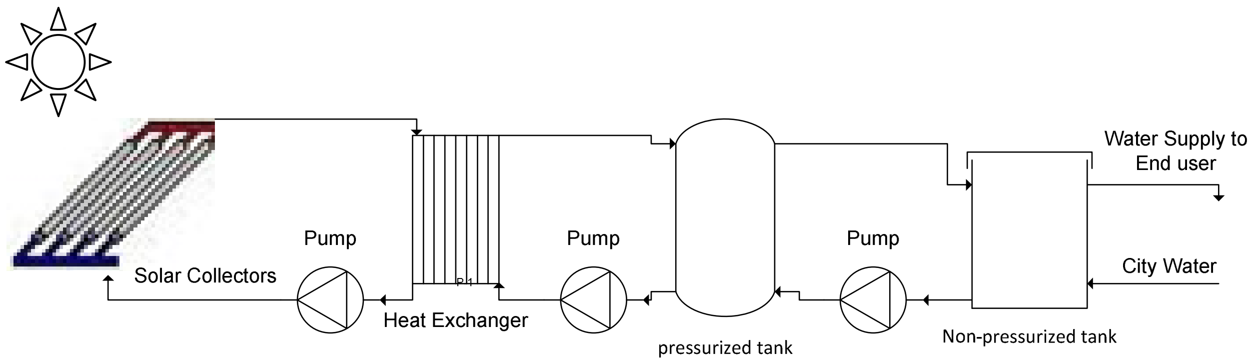

Fig. 4: Proposed Solar Assisted Heating System

6 Evacuated Tube Solar Collector

A solar thermal collector uses the sun's energy to heat the water directly. Typically, it consists of a manifold and a collector. The solar thermal collector module recommended in this proposal consists of series of evacuated U-type pipe solar thermal collectors housed in high-vacuum glass tube.

The tube has large dimensions with an outer diameter 100 mm and a length 2000 mm. It is made of borosilicate glass, which is clear and has high transmittance more than 90% for solar irradiation. The tube is evacuated to 1 mPa to eliminate convection thermal heat lost through the glass.The U-type pipe is made of copper and mounted in absorber plate. To achieve the highest efficiency, the absorber is magnetron sputtered with an aluminum nitride (AI-N-0) selective coating, which transforms over 92% of the incoming solar radiation into heat and the thermal emission coefficient is less than 8%.

The heat transfer rate in each riser tube is calculated using the following equation [6,7]:

$Q=mc_P\ (T_{out}- T_{in}) = U_0A_0(T_{out}- T_{in})$

Where

$$\frac{\ln\left(D_o/D_i\right)}{2\pi k_w L})$$

preheating system. It increases the temperature of secondary loop as much as possible; then, calorifier boosts it up to preset value that is 70^{oC}. If the temperate to the user is high enough, the boiler remains on standby mode. In case of high water demand temperature drops and trigger tart the boiler. This process, which is similar to the current system, will continuously occurred until the SET able to supply the hot water.

The internal convective heat transfer coefficient hi is related to equation below from which the Nusselt number is calculated

$$Nu = \frac{h_i D}{k}$$

The thermal performance of the solar water heater is calculated using the (Hottel and Whiller, 1958; Bliss,1959) equation as follows:

$$\eta = F_R(\tau\alpha) - F_R U_l \frac{T_{in} - T_a}{H_t}$$

The heat removal factor (FR), transmittance–absorptance product (τα) and overall heat loss coefficient (Ul) has been calculated (Duffie and Beckman, 1974).

Inside the U-tubes and Heat exchanger the turbulent flow heat transfer data obtained by equations beow:

For Reynolds number < 2300 (fully developed L/D>10)

Nu=3.66 (constant wall temperature)

Nu=4.364 (constant heat flux)

And with Dittus–Boelter equation for Re > 10,000

$$Nu = 0.023Re^{0.8}Pr^{0.4}$$

7 The Collector Array

U-type solar evacuated collector manufacturers recommend that the maximum number of solar panels in series should not exceed more than 6 (16 Tubes in each panel). The system is to be split into 17 blocks; each block consists of 6 sets of solar collector modules. Each solar collector module consists of 16 sets of evacuated vacuum tube. This make up a solar thermal collector system consisting of 1,530 evacuated vacuum tube in total.

Splitting the system into 17 blocks increases the overall efficiency. Besides, it gives a high flexibility to trace and evaluate the performance of the system.

result indicates that the proposed system is adequate to increase the temperature of the city water 10 to 15 degree Celsius.

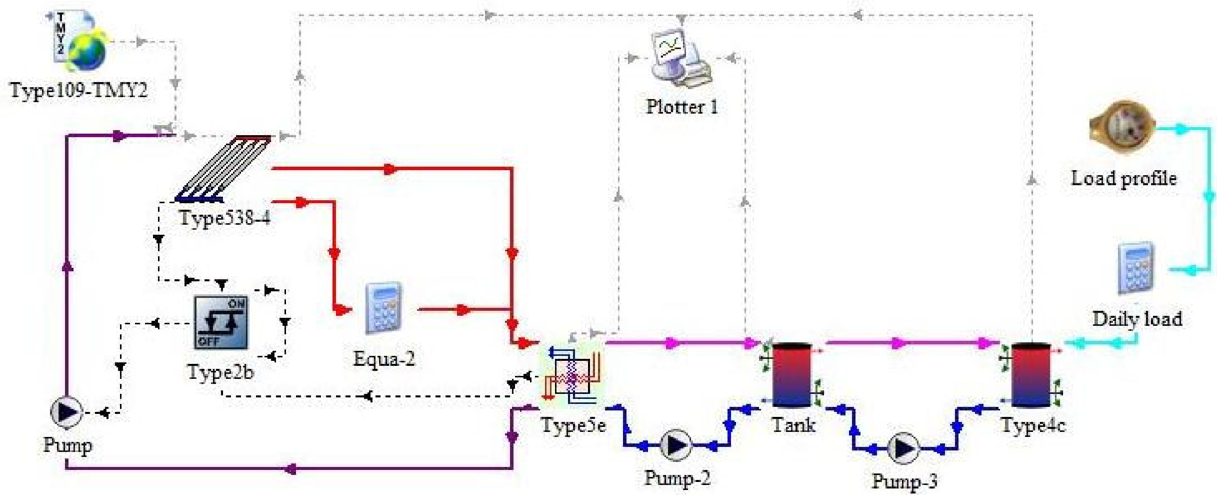

Fig. 5: Simulation Environment of TRNSYS software

9 The Savings and Greenhouse Gas Reduction

Incorporating the Solar Hot Water System to the commercial hot water system heated by LPG boilers, there would be a large potential in energy saving and greenhouse emission reduction. For Kuala Lumpur, annual average solar insolation is reasonably high. Annual average solar insolation, in Kuala Lumpur is 16.92 MJ / m² / day Base on annual average solar insulation and solar collectors average efficiency at 70%, actual performance might varies subjected to climate changes and end-user applications.

Liquefied Petroleum Gas (LPG) is commonly used in boiler for water heating; generally every kg of LPG generates around 40 MJ of energy. Supplement with solar collectors, significant saving on LPG can be achieved. Burning fossil fuels such as coal for electricity production, and LPG for water heating both release large amounts of carbon

These blocks are to be connected to a heat exchanger of hot water storage tanks (to be built). The heat from the solar collectors is transferred here, only when the water temperature reached the predetermine value.

8 TRNSYS Simulation

Simulation of the proposed system has been developed in TRNSYS simulation software. The

dioxide (CO2) into the atmosphere, thus contribute to environmentally harmful phenomenon.

In average, water heating accounts for around 30% of CO2 emissions. By installing solar hot water system, the CO2 emission can reduce by more than 20%.

9 Conclusions

One of the most promising applications for solar energy is the production of hot water for commercial and domestic usage. It will provide hot water for very many years, at minimal energy costs, because the free sun’s energy will supply most of the energy needed. It will reduce the utilities bill, and will also avoid the production of many tonnes of greenhouse gasses. The main objective of installing the solar assisted hot water heating system are (a) supplying solar thermal collectors to preheat hot water for existing commercial hot water service (b) demonstrating the use of solar heat pipe energy as an economical alternative compare to water heating by fossil fuels (c) reducing the amount of LPG used (d) reducing greenhouse gases emission (e) providing an advanced practical platform for solar thermal research. There are over hundreds

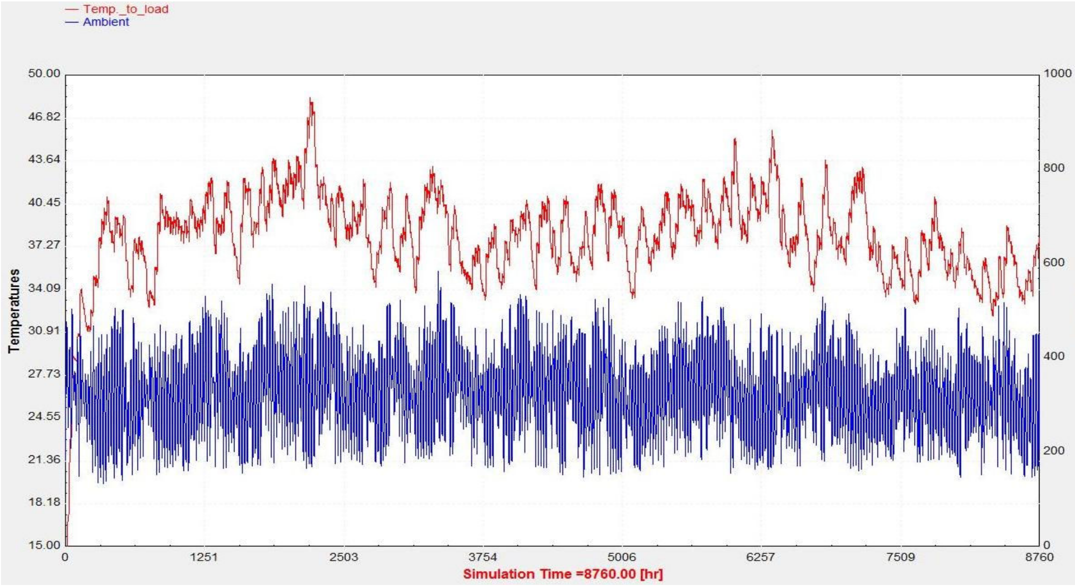

Fig. 6: Simulation Result of TRNSYS software

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