A SIMULATION STUDY OF DOMESTIC HOT WATER USING TRNSYS

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DECLARATION

I declare that this project report entitled "A simulation study of Domestic Hot water using TRNSYS" is the result of my work except as cited in the references.

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Date: 17/07/2020

APPROVAL

I hereby declare that I have read this project report and, in my opinion, this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Thermal-Fluids).

Signature: ....

Supervisor's Name: DR MOHD AFZANIZAM BIN MOHD ROSLI

Date: ....

DEDICATION

To my beloved mother and siblings.

ABSTRACT

The solar flat plate collector is a widely used application to harness the solar energy given by the sun for almost every industry. In this study, the flat plate solar collector used in Melaka City and the industry is investigated. The key to the successful performance of the flat plate collectors depends on the areas of the collector and also the number of collectors installed correctly into the position of the sun. The components, the inputs and the parameters affecting the performance of the flat plate collector are the temperature difference and the efficiency of the entire solar system. Thus, Transient Systems Simulation (TRNSYS) program simulation is conducted to reduce the experimentation time and avoid high experimental and design cost. The objectives of this project are to obtain the performance of flat plate solar collector by using TRNSYS as well as to determine the suitable number of collectors for domestic hot water in Melaka City by using Hottell-Whillier-Bliss equation in TRNSYS and also to find out the suitable surface areas of the flat plate solar collector according to the industry specifications and needs. A validation result of a journal studying the performance of flat plate solar collector installed in a location is carried out to find the temperature difference in the flat plate collector and also to prove that the TRNSYS simulation produce is acceptable. For the validation, the weather data of Karaikudi 2014 is generated to find out the performance of flat plate collector. The component such as the flat plate collector, the stratified tank, pump, diverter and tee piece input and parameter were inserted to produce a precise simulation outcome. The Temperature input and the Temperature Output (T_iColl and T_oColl) is compared to find out the performance. The same process is then repeated using the Melaka City weather data and simulated in terms of the T_iColl and T_oColl to find out how the flat plate collector perform in the city. To achieve the objective the temperature difference is taken with the high-temperature difference will indicate good performance level. For the second objective which is to determine the suitable number of collectors for domestic hot water in Melaka City, the annual fraction load data of Melaka city 2016 is taken. The data shows that Melaka city has an average monthly heating load of domestic hot water in Melaka. To find a suitable number of solar collectors, the normal efficiency of flat plate solar collector must be around 70%. The solar energy supply to the users is 78.42% which is higher than the optimum efficiency of the solar collector. The domestic hot water temperature that is produced using the TRNSYS is shown. A single flat plate collector of 2.5m^2 is enough for an average household in Melaka City. For the third objective, which is to find out the suitable surface areas of the flat plate solar collector according to the industry specifications and needs. The industry locations that have been chosen for this study is the Hospital Universiti Kebangsaan Malaysia in Cheras, HUKM. The simulation will use the series 5 MY-60 flat plate collector from MYSOLAR CONCEPT SDN BHD. Based on the simulation, the suitable total area needed to produce the hourly average of the storage tank water temperature is 1800m^2. This area includes a total of 360 number of panels required to be installed in the hospital with the maximum average area of 5m^2.

ABSTRAK

Pengumpul plat rata suria adalah aplikasi yang digunakan secara meluas untuk memanfaatkan tenaga solar yang diberikan oleh matahari untuk hampir setiap industri. Dalam kajian ini, pengumpul suria plat rata digunakan di Melaka City dan dalam industri diselidiki. Kunci kejayaan para pengumpul plat rata bergantung kepada bidang pemungut dan juga bilangan pemungut yang dipasang dengan betul ke kedudukan matahari. Komponen, input dan parameter yang mempengaruhi prestasi pengumpul plat rata adalah perbezaan suhu dan kecekapan keseluruhan sistem solar. Oleh itu, simulasi program Transient Systems Simulation (TRNSYS) dijalankan untuk mengurangkan masa percubaan dan mengelakkan percubaan tinggi dan kos reka bentuk. Objektif projek ini adalah untuk mendapatkan prestasi pengumpul suria plat rata dengan menggunakan TRNSYS serta untuk menentukan bilangan pengumpul yang sesuai untuk air panas domestik di Melaka dengan menggunakan persamaan Hottell-Whillier-Bliss dalam TRNSYS dan juga untuk mengetahui kawasan permukaan yang sesuai bagi pengumpul suria plat rata mengikut spesifikasi dan keperluan industri. Keputusan pengesahan jurnal yang mengkaji prestasi pengumpul suria plat rata yang dipasang di lokasi dijalankan untuk mencari perbezaan suhu pada pengumpul plat rata dan juga untuk membuktikan bahawa menghasilkan simulasi TRNSYS boleh diterima. Dalam pengesahan, data cuaca Karaikudi 2014 dijana untuk mengetahui prestasi pengumpul plat rata. Komponen seperti pengumpul plat rata, tangki bertumpuk, pam, penyongsang dan input dan parameter potongan tee dimasukkan untuk menghasilkan hasil simulasi yang tepat. Input Suhu dan Output Suhu (TiColl dan ToColl) dibandingkan untuk mengetahui prestasi. Proses yang sama kemudian diulang menggunakan data cuaca Bandaraya Melaka dan disimulasikan dari segi TiColl dan ToColl untuk mengetahui bagaimana pengumpul plat rata di bandar. Untuk mencapai objektif perbezaan suhu diambil dengan perbezaan suhu tinggi akan menunjukkan tahap prestasi yang baik. Untuk objektif kedua yang menentukan bilangan pengumpul yang sesuai untuk air panas domestik di Melaka City, data beban pecahan tahunan bandar Melaka 2016 diambil. Data menunjukkan bahawa bandar Melaka mempunyai purata pemanasan bulanan air panas domestik di Melaka. Untuk mencari bilangan pengumpul suria yang sesuai, kecekapan biasa pengumpul suria plat rata mestilah sekitar 70%. Bekalan tenaga solar kepada pengguna adalah 78.42% yang lebih tinggi daripada kecekapan optimum pengumpul suria. Suhu air panas domestik yang dihasilkan menggunakan TRNSYS ditunjukkan. Satu pengumpul plat tunggal sebanyak $2.5m^2$ *cukup untuk isi rumah purata di Melaka. Untuk tujuan ketiga, iaitu untuk mengetahui kawasan permukaan yang sesuai bagi pemungut plat rata rata mengikut spesifikasi dan keperluan industri. Lokasi industri yang telah dipilih untuk kajian ini ialah Hospital Universiti Kebangsaan Malaysia di Cheras, HUKM. Simulasi ini akan menggunakan pengumpul plat rata MY-60 siri 5 dari MYSOLAR CONCEPT SDN BHD. Berdasarkan simulasi, jumlah luas yang diperlukan untuk menghasilkan suhu setiap jam dari tangki simpanan suhu 1800m2. Kawasan ini termasuk sejumlah 360 panel yang perlu dipasang di hospital dengan purata purata maksimum* $5m^2$.

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LIST OF ABBREVIATIONS

TRNSYS	Transient Simulation Software
T_iColl	Inlet temperature of the collector
T_oColl	Outlet temperature of collector
TMY	Typical Meteorological Year
Gh	Global horizontal radiation ("GHI")
Dh	Diffuse radiation arising from the upper hemisphere reduced by the direct solar radiation from the sun's disk and its surroundings (6° aperture)
Bn	Direct normal radiation (DNI, beam) arising from a narrow solid angle of 6° centred around the sun's disk
Ta	Air temperature (2 m above ground)
Td	Dewpoint temperature
FF	Wind speed (FFE, FFN longitudinal and latitudinal part of the wind speed)
EVT	Evacuated Tube
FPC	Flat Plate Collector

LIST OF SYMBOLS

NOMENCLATURE

A = collector area, m^2

F_R = collector heat removal factor

I = intensity of solar radiation, W/m^2

T_c = collector average temperature, °C

T_i = inlet fluid temperature, °C

T_a = ambient temperature, °C

U_L = collector overall heat loss coefficient, W/m^2

Q_i = collector heat input, W

Q_u = useful energy gain, W

Q_o = heat loss, W

Greek Symbols

η = collector efficiency

τ = transmission coefficient of glazing

α = absorption coefficient of plate

Subscripts

m **=** mass flow rate of fluid through the collector, kg/s

CHAPTER 1

INTRODUCTION

1.1 Background

Renewable energy resources are contributing to the sustainability of energy supply which is why the usage of renewable energy is shooting up each year. The increase of renewable energy will reduce the rate of global warming issues which is because of gas emission due to energy gain from fossil fuels [1]. Malaysia has annual solar radiation of 1643kWh/m^2 and sunshine 4-5 hours per day. Currently, solar energy in Malaysia is frequently for the water pump, domestic hot water heating system crops drying [2].

Solar photovoltaic and solar thermal systems are groups of direct solar energy technology. Solar photovoltaic is used for the generation of hot air where else solar thermal systems are used for the generation of electricity. However, a photovoltaic thermal collector can carry out a simultaneous generation of both electrically and thermally. It has the advantage to increase the overall photovoltaic thermal efficiency while also saving good space.

Solar energy changes for the production of domestic hot water that includes hot water processing and water pre-heating ahead of other types of thermal intake. Until 2002, there were 10000 domestic solar water heaters used in Malaysia (most of them used are from thermosyphon type) with an annual growth rate of 10-15%.

However, for the generation of electricity in rural areas and net metering productions where the systems received a large sum, it is very much noticeable hat the solar PV implementations in Malaysia are reduced to mainly standalone PV systems [3].

The thermonuclear reaction is the energy from the sun in its core and its radiated into space which will eventually reach the earth. There are some variations in the earth atmosphere when the amount of solar radiation reaches the top of the atmosphere due to the intensity of solar radiation which is opposite to the sun distance and because of the earth distance from the sun changes during the year. The solar constant is known as the average solar radiation at the upper limits of the earth's atmosphere which usually taken to be 1,388 watts per square meter 4871 kilojoules per square meter per hour, 1.940 calories per square centimetre per minute or 1.94 langleys per minute.

Direct or beam radiation is radiation emanating within a cone which involves the sun's disc. When the radiation overcome the clouds, air particles and the floor ground it will be called as the diffused radiation. The intensity of solar radiation at a given location on the earth will vary every second. To get the full efficiency of a solar collector from the horizontal, the collector should be made 90 degrees to the solar rays all day long.

According to this study [4], another way of utilizing the solar energy is the through thermal collectors, in which solar energy is transformed into useful heat energy in many different applications by using solar collectors [5]. Finding the area and sizing of the Solar water heating system requires a huge number of input data, which is hard to get all the times. Also, the high performable designed system will always do better in providing the volume of domestic hot water. The difficulty in finding the collector areas require the amount of cold and hot water mix at a certain temperature level. In this study, solar water heating systems (SWHS) is chosen as a tool of solar thermal energy conversion., to reduce the energy usage in the considered residents. The prime objective of this study is to find out the performance of flat plate solar collector by using a simulation software called TRNSYS based on the user input data and as well to study the temperature outlet of hot water using Hottell-Whillier-Bliss equation.

1.1.1 Final energy consumption by aggregated categories in residential sector 2016.

YEAR: 2016 / UNIT: KTOE	NATURAL GAS	LPG	KEROSENE	ELECTRICITY	TOTAL
Space Cooling	-	-	-	327	327
Water Heating	-	-	-	70	70
Lighting	-	-	3	233	236
Cooking	1	538	-	117	655
Appliances	-	-	-	1,586	1,586
TOTAL	1	538	3	2,333	2,875

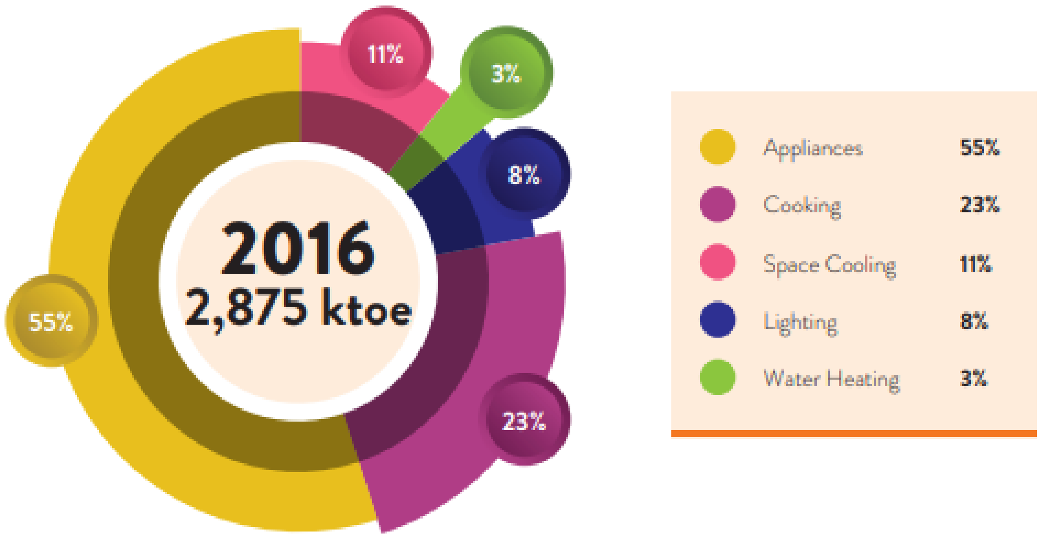

Figure 1.1.1 Adapted from National Energy Balance 2016, Malaysia Energy Commission

Based on Figure 1.1.1 the highest energy consumption for the residential sector is appliances. Cooking comes in second with 25% for the residential sector for the final energy consumption of 2016. This is followed by space cooling with 11% and lighting by 8%. Finally, domestic hot water heating comes with the lowest percentage of 3% for residential use. Mostly domestic hot water is used in homes for bathing and cleaning purpose that the reason for the usage in residential [6].

1.1.2 Final energy consumption by aggregated categories in the commercial sector.

UNIT: GWh	CATEGORY	SPACE COOLING	WATER HEATING	LIGHTING	OTHER USE	TOTAL
C1	Wholesale & Retail Trade	2,116.80	45.33	1,116.87	1,253.76	**4,532.76**
C2	Transportation & Storage	959.50	5.82	436.57	751.66	**2,153.75**
C3	Accommodation & Food Service	630.02	127.18	331.29	548.17	**1,636.83**
C4	Information & Communication	1,651.15	150.75	762.45	1,588.44	**4,152.78**
C5	Selected Services	2,270.49	-	1,254.17	1,880.72	**5,405.92**
C6	Professional, Scientific & Technical	194.35	-	118.65	272.92	**585.92**
C7	Travel Agencies & Tour	8.65	0.01	2.92	9.28	**20.86**
C8	Public Administration	2,946.31	262.71	1,418.34	2,267.82	**6,895.18**
C9	Education	1,339.60	-	673.90	1,139.99	**3,153.49**
C10	Human Health & Social Activities	2,120.27	200.57	1,103.11	1,516.59	**4,940.04**
C11	Arts, Entertainment & Recreation	343.17	40.51	223.79	284.82	**892.29**
C12	Other Service Activities	1,860.37	201.76	1,074.17	1,599.88	**4,736.19**
	TOTAL	**16,440.66**	**1,034.62**	**8,516.23**	**13,114.06**	**39,106.00**

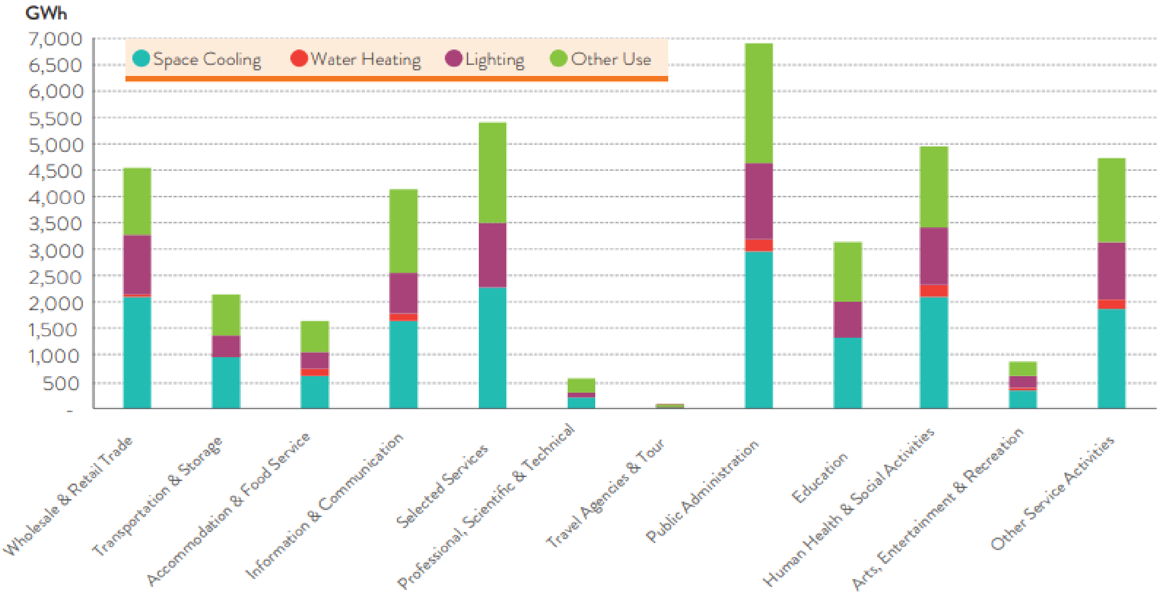

Figure 1.1.2 Adapted from National Energy Balance 2016, Malaysia Energy

Based on Figure 1.1.2 the highest energy consumption for commercial use is space cooling. Both the residential and the commercial use prefer cooling of spaces for human comfort by solar with the cooler either within the space or external to it. The domestic hot water heating is the lowest for commercial use which is the same for residential. The usage