THEORETICAL ANALYSIS OF SOLAR WATER HEATING SYSTEM

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THEORETICAL ANALYSIS OF SOLAR WATER HEATING SYSTEM

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Thesis submitted in partial fulfilment of the requirements
For the award of the degree of
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Faculty of Mechanical Engineering
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LIST OF SYMBOLS

A_c	collector area, m^2
A_{st}	surface area of the storage tank, m^2
C_p	specific heat of working fluid, J/kg ˚C
F_R	collector heat removal factor
F	solar fraction over a specified time horizon
h/d	height to diameter ratio of storage tank
I_g	global solar radiation intensity, W/m^2
I_d	diffuse radiation intensity, W/m^2
I_T	solar radiation intensity on tilted surface, W/m^2
J	fraction of net storage heat gain in a time step
K	fraction of makeup water supplied in a time step
K	thermal conductivity of storage tank insulation, W/mK
m_c	collector mass flow rate, kg/s
m_L	desired load mass flow rate, kg/s
m_R	storage makeup water mass flow rate, kg/s
m_{st}	mass flow rate from storage to load, kg/s
m_x	mass flow rate for mixing, kg/s
q_{aux}	auxiliary energy required, W
q_L	desired hot water load, W
Q_L	desired hot water load over a specified time horizon, J
q_{Ls}	load met by solar energy or energy extracted from the storage, W
q_R	energy added to storage through makeup water, W
q_s	solar useful heat gain rate, W
q_{stl}	rate of storage loss, W

R	maximum auxiliary heater power, W
R_b	tilt factor
T_a	ambient temperature, ˚C
T_L	desired load (hot water) temperature, ˚C
T_R	makeup water temperature, ˚C
T_{sat}	saturation temperature, ˚C
T_{st}	storage temperature at any instant of time, ˚C
T_{sti}	storage temperature at the beginning of a time step,
T_{stf}	storage temperature at the end of a time step, ˚C
t	time step in the analysis, s
t_{ins}	storage tank insulation thickness, m
t_t	storage tank wall thickness, m
U_{st}	storage heat loss coefficient, W/m^2˚C
U_L	collector overall heat loss coefficient, W/m^2˚C
V_{st}	storage volume at any instant of time, m^3
V_{sti}	initial storage volume in a time step, m^3
V_{stib}	initial Storage volume at the beginning of the day, m^3
V_L	volume of water withdrawn by load in a time step, m^3
V_R	volume of water replenished to the storage tank in time step, m^3
B	collector tilt, rad
Φ	latitude of location, rad
ρ	density of working fluid, kg/m^3
ρ_g	ground reflectance
ρ_t	density of storage tank material, kg/m^3
$(\tau\alpha)$	average transmittance absorptance product

LIST OF ABBREVIATIONS

ISO	international organization for standardization
LPD	liters per day
SWH	Solar water heating

ABSTRACT

Renewable energy is important for replace the using of electrical energy generated by petroleum. Energy consumption from petroleum must be reduced because of the limited petroleum resources and contribute of pollution to the earth. Solar power has become a source of renewable energy and solar energy applications should be enhanced. Solar water heating system was a practical application to replace the using of electrical water heater. More research is needed to increase capability and reduce production costs of solar water heating system and make the solar water heating system more efficient and practical. The objective of this project is to do investigation on solar water heating system in terms of mathematical theory to produce a mathematical model of solar water heating system. The analysis done by using a mathematical model developed to obtain data on temperature in the changes of flat plate collector area, storage tank insulation volume, piping size and mass flow rate of water. Efficiency of flat plate collector and storage tank insulation is calculated for any changes in size and volume. Solar fraction is calculated for any changes in the size of a flat plate collector and storage tank insulation in the consideration of changes in temperature and mass flow rate of water. Analysis showed the water temperature will increase with increasing area of flat plate collector, decreased with the increasing volume of insulated storage tank, and decreased with increasing size of the pipe. an These studies can provide data for the optimum design with high capacity and the mathematical models will facilitate the future study.

ABSTRAK

Tenaga boleh diperbaharui amat penting bagi menggantikan penggunaan tenaga elektrik yang dijanakan oleh petroleum. penggunaan tenaga daripada petroleum perlu dikurangkan kerana sumber petroleum semakin terhad dan menyumbag kepada pencemaran yang merosakan bumi. Tenaga suria menjadi salah satu sumber tenaga yang boleh diperbaharui dan aplikasi tenaga suria perlu dipertingkatkan. Sistem pemanasan air suria menjadi satu aplikasi yang praktikal untuk digunakan bagi menggantikan pemanas air menggunakan elektrik. Lebih banyak kajian perlu dilakukan bagi meningkatkan keupayaan dan mengurangkan kos penghasilan system pemanasan air suria supaya lebih cekap dan praktikal. Objektif projek ini adalah untuk membuat kajian terhadap system pemanasan air suria dari segi teori dengan mendapatkan persamaan matematik dari segi keseluruhan untuk menghasilakan model matematik bagi system pemanas air suria. Analisis akan dibuat dengan menggunakan model matematik yang dihasilkan bagi mendapatkan data perubahan suhu terhadap perubahan luas plat pengumpul datar, perubahan isipadu tangki simpanan berpenebat, perubahan saiz saluran paip, dan perubahan kadar aliran jisim air. Kecekapan untuk plat pengumpul datar dan tangki simpanan berpenebat akan dikira untuk setiap perubahan saiz dan isipadu. Pecahan suria akan dikira untuk setiap perubahan saiz plat pengumpul datar dan tangki simpanan berpenebat dengan mengambil kira perubahan suhu dan kadar aliran jisim air. Analisis menunjukan suhu air akan bertambah dengan pertambahan luas plat pengumpul datar, menurun dengan pertambahan isipadu tangki simpanan berpenebat dan menurun dengan petambahan saiz paip. Kecekapan akan bertambah dengan pertambahan luas plat pengumpul datar dan berkurang dengan pertambahan isipadu tangki simpanan berpenebat. Kajian ini dapat memberi data untuk rekabentuk yang optimum dengan keupayaan yang tinggi dan model matematik akan memudahkan kajian pada masa akan datang.

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The solar energy is the most capable of the alternative energy sources. Despite this hopeful evaluation of the potential of solar energy, considerable technical and economic problems must be solved before utilization of solar energy can occur. The solar power development will depend on how we deal with a number of serious constraint, including scientific and technological problem, marketing and financial limitations, and political. In addition, the education of engineers will have to changes its focus from non-renewable fossil-fuel technology to renewable power source. There has been a general agreement that the most significant of the renewable energy sources is solar radiation.

Thermal conversion is a technological scheme that utilizes a solar radiation. When a dark surface is placed in sunshine, it absorbs solar energy and heats up. Solar energy collector working with sun facing surfaces will transfer energy to the water that flow through it. To reduce heat loses to atmosphere and to improve it efficiency, one or two sheet of glass are usually placed over the absorbed surface. This type of thermal collector suffers from heat losses due to radiation and convection. Such losses increase rapidly as the temperature of the working fluid increases. Improvement such as the use of selective surfaces, evacuation of the collector to reduce heat losses, and the special glass is use to increase the efficiency of the absorber.

Solar water heating (SWH) is a proven and famous renewable energy technology and has been used in many countries of the world. The SWH system

investigated consists of mainly three parts, namely a flat plate solar collector, a heat exchanger (storage tank) and a circulating pump. Solar water heating system have been the famous application that using solar radiation as an energy sources that using thermal conversions.

This project will analyze the Solar Water Heating System based on the theoretical analysis from the mathematical model. The mathematical model will be consider all the part of the solar water heating system to find the solar water heating system temperature when the size and the behavior of solar water heating is changing.

1.2 PROBLEM STATEMENT

In today's modern world, where new technologies are introduced every day, electrical energy use is increasing quickly Fossil fuel particularly petroleum fuel is the major contributor to electrical production. Quickly depleting reserve of petroleum and decreasing air quality raise question about the future. Solar can be use as a clean alternative energy to reduce electrical production and is promising in the effect to establish environmentally friendly for electrical system. So far, many extensive studies investigated solar water heating system and become the famous application for home and building.

The using of solar water heating system not familiar in Malaysia and the people in Malaysia still not realize about the practical of using solar water heating systems. It's important to study about the power produce to heat the water using solar water heating system and proving about energy saving of solar water heating system.

1.3 PROJECT OBJECTIVE

The objectives of this analysis are to:

i. Find the mathematical model of solar water heating system.
ii. Find the change in water temperature from variable behavior of all part in solar water heating system.
iii. Find the efficiency and fraction of design using mathematical model.

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