A PROCESS INTEGRATION METHOD OF INTEGRATED SOLAR PHOTOVOLTAIC WATER PURIFICATION SYSTEM

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DEDICATION

This project report is dedicated to my parents, who taught me to never give up in pursuing knowledge. Thank you for your endless love, sacrifices, supports and advices.

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ABSTRACT

Water and energy are very important resources to be used for industrial, agricultural purposes, commercialization and residential household. Mainly, water in household are used for cleaning, cooking, drinking and washing. In Malaysia, demand of water supply increases per capita every year. Higher use of freshwater resource not only affects the environment but also incur cost such as increasing water tariff to the household bill. To decrease the amount of fresh water used, it is important to make use of alternative water sources such as greywater. Solar photovoltaic water purification system is a new technology which can purify greywater by using solar thermal to be recycled, at the same time generates electricity from solar photovoltaic. In this paper, a new process integration method is proposed to optimise the solar photovoltaic water purification system design and sizing for the building A set of new graphical tools are introduced. The tools can determine the sizing of the system such as storage tank before purification, capacity of solar water distillation and sizing of storage tank for purified water. Economic analysis is done to determine the capital cost of the system as well as the payback period. The system will be implemented in a four-occupant household in Malaysia, and another case study will be carried out of the same number of occupants in a dry and water scarce country, Papua New Guinea, to compare the cost between these two. In conclusion, implementation of integrated solar photovoltaic water purification system will have lower payback period in water scarce country as desalination of water is expensive causing high water tariff. Other factors that may affect the results are the number of occupant and their lifestyle.

ABSTRAK

Air merupakan sumber yang penting bagi kegunaan sektor industri, pertanian dan sektor kediaman. Bagi sektor kediaman, kegunaan sumber air adalah untuk mencuci, memasak, dan tujuan minum. Permintaan bagi sumber air meningkat setiap tahun di Malaysia, sejajar dengan peningkatan jumlah penduduk. Peningkatan kegunaan sumber air bukan sahaja menjejaskan alam sekitar, malahan ia akan menyebabkan peningkatan dalam bil bulanan rumahtangga. Sebagai alternatif, air sisa kelabu boleh digunakan. Air sisa kelabu yang terhasil dari sektor kediaman merupakan 50% dari keseluruhan sisa air. Produk yang terhasil dari sistem ini adalah air yang dirawat (bukan untuk kegunaan minum) dan elektrik yang terhasil dari fotovoltaik solar. Air akan dirawatan melalui proses penyulingan solar. Integrasi proses adalah digunakan bagi menentukan saiz sistem seperti saiz tangki simpanan air yang belum dirawat, kapasiti sistem penyulingan solar dan tangki simpanan air selepas rawatan. Tempoh bayaran balik bagi sistem dan kos modal dapat ditentukan dengan menjalankan analisis ekonomi. Kajian kes akan dilaksanakan ke atas kediaman di Malaysia dengan empat orang isi rumah. Analisis ekonomi akan dikira bagi mendapatkan kos modal dan tempoh bayaran balik sistem. Kemudian, sistem yang sama dilaksanakan kepada negara yang kekurangan sumber air seperti Papua New Guinea, bagi membandingkan perbezaan kos. Kesimpulannya, tempoh bayaran balik bagi integrasi proses solar fotovolataic dan rawatan air ini adalah lebih rendah bagi negara yang kekurangan air. Selain itu, bilangan isi rumah juga merupakan faktor penting bagi menentukan kapasiti sistem.

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FiT	-	Feed in tariff
NEM	-	Net Energy Metering
PNG	-	Papua New Guinea
PV	-	Photovoltaic
SEDA	-	Sustainable Energy Development Authority
SREP	-	Scaling up Renewable Energy Program
SOLWAT	-	Solar Water purification
UV	-	Ultraviolet

CHAPTER 1

INTRODUCTION

1.1 Introduction

Water and energy crisis are faced by most of developing countries. As world's population increases annually, demand of clean water and energy increases as well. Population growth also increases the industrial and agricultural sector which depends on water and energy to run. This chapter introduces research background that includes global outlook on water and energy demand, Malaysia's water demand as well as renewable energy for water purification purposes, followed by problem statement. Next, objectives and scope of the study focuses on using process integration to both power and water. Lastly, this chapter highlights significance of study to design solar powered water purification system for residential use.

1.2 Research Background

Global warming is a major concern that affects the environment and human population. Global warming is a result of greenhouse effect, which is caused by greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The release of these gases is often associated with human activities. One of them is the burning of fossil fuel to produce electricity.

Malaysia is a developing country which still use coal burning as one of the highest sources in producing electricity for the country. However, the country is still looking for ways to produce electrical energy that is cleaner and environmentally friendly by implementation of policies on renewable energies. By 2030, Malaysia aims to produce 20% electricity from renewable source (SEDA, 2019).

One of the renewable sources that have potential to be implemented in Malaysia is solar energy. Monthly solar radiation in Malaysia varies from 400 to 600 MJ per squared meter (Mekhilef, et al., 2012). As solar energy varies throughout the states, northern states such as Kedah, Penang, Kelantan and Sabah receive higher solar radiation compared to Johor and Sarawak.

Solar energy may be harnessed in two ways; by using solar thermal or solar photovoltaic (PV). Solar thermal utilizes the heat from solar energy for heating purposes whereas solar PV consists of array of cells which generates electrical power by harnessing solar into direct current (DC) through materials that exhibit photovoltaic effect. Details of solar PV will be discussed in Chapter 2. This paper focuses on both solar PV and disinfection using solar thermal.

One of the effects of global warming is climate change. Climate change affects the rainfall pattern and intensity thus poses challenges of functioning of lakes and reservoir used as main water supply in Malaysia (Zakaria, 2008). This, combined with increasing population growth may lead to low water supply and even water scarcity.

An average Malaysian consumes an average of 210 litres of clean water per capita day instead of 165 litres per capita per day recommended by World Health Organization (Jye, 2018). Demand of clean water supply in Malaysia increases as population grows. Compendium of Malaysian Statistics 2017 produced by Department of Statistic Malaysia shows that the water demand supply in 2017 had increased by 377 million litres per day from 16 536 million litres per day in 2015 (Department of Statistics,2017).

Greywater accounts for 50 percent of total waste water produced from a household (Leong, 2016). Greywater can may be reused as non-potable water if treated. Applying integrated solar PV and water purification system, produces treated greywater as well as electricity. Method used to purify water is by solar distillation. Greywater enters the column is heated using waste heat from the solar PV panel and vaporizes. It then condenses to produce treated water.

1.3 Problem Statement

Water and electricity are both as equally important for a household. Clean water is needed for various purposes in household. Thus, greywater recycling system is proposed to be used for non-potable purposes. For electricity demand, renewable solar energy is proposed to be implemented as Malaysia has high amount of solar radiation. Using solar energy has the advantages of low maintenance and produces clean energy with no emissions. Integrating both solar photovoltaic and water purification, both demands can be met.

Process integration method is applied to both water and electricity to optimize the system and to determine the minimum amount of water and electricity to be supplied externally from tap water and grid.

Also, sizing of the system is very important as oversized or undersized system produces inefficient outcomes. For instance, oversized system may cause higher total cost of system. Economic analysis is done determine the total cost of the system and feasibility of the study

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1.4 Objectives

1. To develop a process integration method for an integrated solar PV water purification system.
2. To estimate sizing of integrated solar PV water purification system.
3. To determine total cost of the system and payback period.

1.5 Scope of Study

Population growth of a country increases the water and electricity demand. To decrease water and electrical demand of a residential house, the scopes are as follows:

State of the art analysis on water purification and solar photovoltaic (PV).

a. Sources of water for integrated PV water purification system is greywater. Product from the system would be treated water for non-potable use and electricity generated from solar.
b. A numerical targeting method is developed to find out minimum amount of fresh water and external electrical energy to be supplied to an integrated PV water purification system.
c. Data collection for this study will be based on literature review. Data is estimated using formulas based on number of occupants.
d. All the calculations are solved using Microsoft Excel.
e. Economic analysis of the system is carried out to determine capital cost and payback period of the system.

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