DEVELOPMENT OF SOLAR PHOTOVOLTAIC (PV) TEMPERATURE CONTROL SYSTEM FOR MUSHROOM HOUSE

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ABSTRACT

Solar photovoltaic (PV) is a technology that is often used in the agricultural industry as an alternative source of electrical energy to power up simple appliances throughout the farm. This technology however, are still far from the norm for Malaysian farmers. By looking at the mushroom agricultural industry, the main concern of mushroom growers in Malaysia when growing their mushroom is to control the temperature inside the mushroom growing hall as they are lacking in efficient method to control it and has to rely on manual unconventional method. This thesis aims to study and develop a working simulation of the PV powered temperature control system. It used the oyster mushroom as the preferred crop due to the growth in its market demand. A Matlab/Simulink tool was used to create a working model simulation to analyse the system performance in maintaining an optimal temperature of 28℃. The main components of the simulation are in the mathematical model used for the mushroom house subsystem which was designed based on the energy balance equations. The subsystem was then connected to a series of Simscape electrical components that produced air mass flowrate as an input to the mushroom house subsystem to complete its energy balance calculation. A series of simulation was run for an ON, OFF, and ON-OFF system setting and the result of the room temperature was analysed to study their behavioural pattern. The simulation results showed that the ON-OFF setting managed to control the room temperature under a range of 26.03℃ – 29.99℃ with standard deviation of 0.949634. The simulation was then compared with a fuzzy logic control system that maintained an adaptive and precise room temperature of around ±28.7℃ with a standard deviation of 0.633798. The simulation results concluded that a working solar-powered temperature control system for the oyster mushroom house is successfully developed.

ABSTRAK

Solar fotovolta ialah teknologi yang sering digunakan di dalam industri pertanian sebagai satu sumber tenaga elektrik alternatif yang menghidupkan menghidupkan peralatan pertanian. Sungguhpun begitu, penggunaan teknologi ini adalah masih jauh daripada kebiasaan petani-petani di Malaysia. Di dalam industri pertanian cendawan, kebimbangan utama pengusaha di Malaysia dalam menanam cendawan mereka adalah pada teknik pengawalan suhu rumah cendawan. Pada ketika ini, mereka masih tidak mempunyai kaedah yang cekap untuk mengawalnya dan terpaksa bergantung kepada kaedah yang tidak konvensional. Tujuan tesis ini ditulis adalah untuk mengkaji dan membangunkan satu simulasi sistem kawalan suhu berkuasa solar. Ia menggunakan cendawan tiram sebagai tanaman pilihan atas faktor permintaan pasarannya yang semakin meningkat. Aplikasi Matlab/Simulink telah digunakan untuk mencipta satu simulasi model yang berfungsi untuk menganalisis prestasi sistem dalam mengekalkan suhu optimum 28℃. Komponen utama simulasi ini bergantung pada model matematik pada subsistem rumah cendawan yang direka berdasarkan persamaan keseimbangan tenaga. Subsistem ini kemudiannya disambungkan kepada satu siri komponen elektrik Simscape yang menghasilkan kadar alir jisim udara sebagai input kepada subsistem rumah cendawan bagi melengkapkan pengiraan keseimbangan tenaga tersebut. Seterusnya, satu siri simulasi telah dijalankan dengan tetapan ‘buka’, ‘tutup’, dan ‘buka-tutup’ lalu hasil suhu bilik yang dihasilkan dianalisis untuk mengkaji corak tingkah laku mereka. Keputusan simulasi menunjukkan bahawa tetapan ‘buka-tutup’ berjaya mengawal suhu bilik di bawah julat 26.03℃–29.99℃ dengan sisihan piawai 0.949634. Simulasi ini kemudiannya dibandingkan dengan sistem kawalan logik kabur yang berjaya mengekalkan suhu bilik secara konsisten sekitar ±28.7℃ dengan sisihan piawai 0.633798. Keputusan simulasi ini merumuskan bahawa satu sistem kawalan suhu rumah cendawan yang dikuasakan oleh tenaga solar telah berjaya dibangunkan.

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LIST OF SYMBOLS AND ABBREVIATIONS

T_{mg}	-	Mushroom Growth Temperature
$T_{optimal\ mg}$	-	Optimal Mushroom Growth Temperature
$T_{fruiting}$	-	Fruiting Temperature
P_{max}	-	Maximum Power
V_{mpp}	-	Voltage At Maximum Power Point
I_{mpp}	-	Current At Maximum Power Point
V_{oc}	-	Open Circuit Voltage
I_{sc}	-	Short Circuit Current
I_r	-	Irradiance
T_{cell}	-	Solar Cell Temperature
T_{amb}	-	Ambient Temperature
G	-	Solar Irradiance
NOCT	-	Nominal Operating Cell Temperature
C_{air}	-	Specific Heat Capacity Of Air
ρ_{air}	-	Density Of Air
V_{mh}	-	Volume Of The Mushroom House
$\dot{q}_s$	-	Heat Generated By Mushroom
$\dot{q}_m$	-	Heat Gained From Equipment
$\dot{q}_{so}$	-	Solar Heat Gain
$\dot{q}_h$	-	Heat Generated By Cooler
$\dot{q}_w$	-	Heat Loss Due To Conduction Through The Wall And Roof
$\dot{q}_f$	-	Heat Loss Through The Perimeter Of The Floor
$\dot{q}_e$	-	Heat Loss Due To Energy Change From Sensible To Latent Heat
$\dot{q}_{vent}$	-	Heat Loss Through Ventilation
U_{mh}	-	Overall Heat Transfer Coefficient Of Mushroom House
A_{mh}	-	Total Surface Area Of The Mushroom House
T_{mh}	-	Muhsrooom House Room Temperature

T_{amb}	-	Muhsrooom House Ambient Temperature
$\dot{q}_{upperwall}$	-	Heat Loss Through Upper Wall Area of Mushroom House
$U_{polyethylene}$	-	Thermal Coefficient for Polyethylene
$A_{polyethylene}$	-	Area Of Polyethylene
$\dot{q}_{lowerwall}$	-	Heat Loss Through Lower Wall Area of Mushroom House
$U_{concrete}$	-	Thermal Coefficient for Concrete
$A_{concrete}$	-	Area Of Concrete
$\dot{q}_{roof}$	-	Heat Loss Through Roof Area of Mushroom House
U_{roof}	-	Thermal Coefficient for Roof Area
A_{roof}	-	Area Of Roof
ρ_{air}	-	Air Density
C_{air}	-	Spesific Heat Capacity Of Air
NAE	-	Natural Air Exchange
F	-	Perimeter Heat Loss Factor
P	-	Length Of The Floor Perimeter
$\dot{q}_{c}$	-	Heat Loss Through Cooling
$\dot{m}_{air}$	-	Air Mass Flowrate
T_{c}	-	Temperature Of The Cool Air
$T_{mh,0}$	-	Initial Mushroom House Temperature
T_{room}	-	Mushroom House Room Temperature
CFM	-	Cubic Feet Per Minute
t_{m}	-	Motor Torque
SEDA	-	Sustainable Energy Development Authority
RE	-	Renewable Energy
PV	-	Photovoltaic
DHT	-	Digital Humidity and Temperature
IDE	-	Integrated Development Environment
DC	-	Direct Current
I/O	-	Input/Output
SRAM	-	Static Random Access Memory
EEPROM	-	Electronically Erasable Programmable Read-Only Memory
STC	-	Standard Temperature Condition

NREL	-	National Renewable Energy Laboratory
ASAE	-	American Society Of Agricultural Engineering
MS2680:2017	-	Malaysian Standard 2680:2017
NRAES	-	Natural Resource, Agriculture, And Engineering Service
VDC	-	Voltage Direct Current
BLDC	-	Brushless Direct Current
RPM	-	Revolution Per Minute
EMF	-	Electromotive Force
MMD	-	Malaysian Meteorological Department
P&O	-	Perturb And Observe
MPPT	-	Maximum Power Point Tracking
PMDC	-	Permanent Magnet Direct Current

CHAPTER 1

INTRODUCTION

1.1 Background of study

As the world's population increases, the global demand for energy usage also increases proportionally. This is due to the economic growth especially in large emerging countries which will account for 90% of energy demand growth to 2035 (OECD, 2012). Meeting this energy requirement using fossil fuels (oil, natural gas and coal) based technologies has its environmental and socioeconomic consequences. Environmental concerns range from environmental pollution and degradation to global warming and the attendant climate change, while the socioeconomic implications involve the depletion of scarce non-renewable resources and even wars between nations in the quest for these resources. To mitigate these problems, humanity must resort to the use of sources of energy that are non-polluting, renewable and sustainable.

Among the sources of renewable energy available, solar energy has shown the most significant demand among citizens in Malaysia with a total of 97.63% consumer application received by the Sustainable Energy Development Authority (SEDA) in 2015 as compared with biogas, biomass, small hydro, and geothermal (SEDA, 2015). Figure 1.1 shows the national Renewable Energy (RE) goal proposed by SEDA taken from their 2011 annual report (SEDA, 2011).

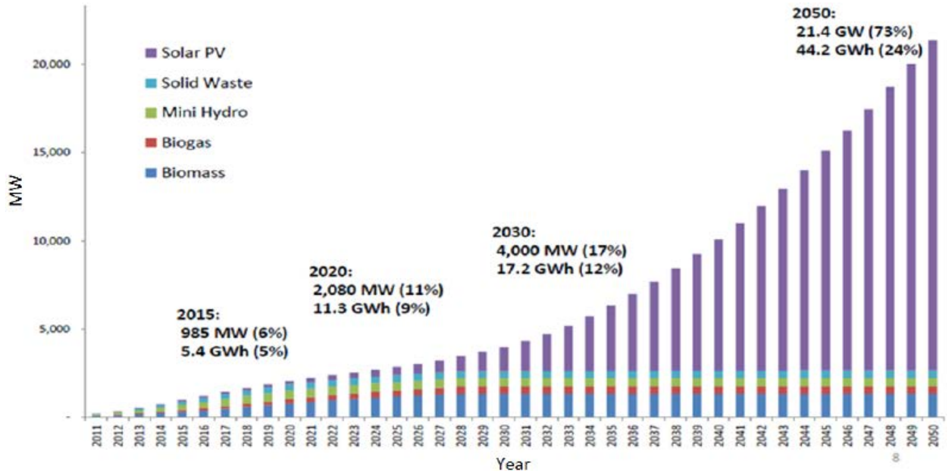

Figure 1.1: SEDA national renewable energy goal (SEDA, 2011)

Solar based electricity is applied in building, telecommunication, and agriculture industry and mainly used to operate electric appliance such as light bulbs, fans, air-conditioner, and water heaters. Alternatively, solar thermal could also be used to generate electricity aside from being tFhe option to process chemical and space heating. It can be used in building, chemical, and business-related industries. It is very important to apply solar energy towards a wide variety of applications, thus providing energy solution by modifying the energy proportion, improving energy stability and sustainability, and conversion reduction, enhancing system efficiency.

The greenhouse is a structure that nowadays is used in agriculture to grow plants with the best quality. Recently, solar energy is used for heating greenhouses so that such greenhouses are known as solar greenhouses and the solar energy can be used to provide light to the greenhouse. Efficient use of resources is one of the major assets of eco-efficient and sustainable production, in agriculture.

This study aimed to present a simulation of temperature monitoring and control, and some of the benefits of solar energy system in the greenhouse applied to oyster mushroom cultivation.

1.2 Problem Statement

Malaysia has a favorable agro-climatic condition for industrial production of mushroom. Due to its tropical environment and high humidity, mushroom growing activities can be done with higher success rate with minimal environmental consideration as compared to other countries. However, it does not come without challenges. Among the difficulties faced by Malaysia mushroom entrepreneurs include poor supply, increasing price of raw materials, pest attack, diseases, and poor mushroom quality (Rosmiza et al., 2016). For most cases, the main concern of mushroom growers in Malaysia when growing their mushroom is to control the temperature inside the mushroom growing hall. As mushroom farming is considered a very labor-intensive work (Bakar, 2009), various researches and experimentation on creating an automated mushroom house has previously been made and consider.

Most of the mushroom farmers in Malaysia are a small-scaled farmer with low labors. In a quote from Mr. Saiful Amri, a mushroom grower, consultor, and entrepreneur in Benut Pontian, Johor, said that mushroom growth is heavily influenced by its surrounding temperature and humidity when they are left to spawn inside their mushroom houses. A study conducted by Hoa et. Al (2015) stated that the optimal temperature for mushroom growth is 28^{o}C where the growth rate will start to decline as the temperature risen (Hoa et al., 2015). Mushrooms cultivated outside of its design temperature will lead to slow growth and poor-quality crop. In order to handle this issue, Mr. Saiful Amri, also revealed that the current practices commonly applied by farmers is by regularly spraying water on floor by using normal water hose. This spraying process is manually done and there is no standard procedure in how to measure and maintain mushroom house temperature. The indicator used to determine the house temperature relies solely on the worker experiences; feels and interpretation of “cool” when they are in the mushroom house. This practice demands unnecessary time and effort from the cultivator as well as increasing the risk of green moss infection towards the growing mushroom on the case that the sprayed water made contact with it. Due to this labor-intensive work in monitoring and controlling, it is suggested to create an automated control system for the specific task.

Climate factor is a critical factor that need to be considered in growing mushroom. This will bring an affect towards the quality of the mushroom. Natural environment such as temperature during the day either on a hot day and the rain is affecting the temperature and moisture in the mushroom house directly. The suitable temperature in growing a high quality of mushroom varies by species but is generally in between 25°C - 30°C (Oei, 2005).

As a mean to increase the productivity and quality of greenhouse users in Malaysia, a solar powered temperature and humidity control system will be developed in order to automatically control the greenhouse climate. This will potentially reduce the workload of workers and effectively reduce their operating cost albeit it being a long-term investment in term of electrical cost benefit. A solar powered approach is selected as a means to spread and normalize the usage of green technologies among the agricultural industries

1.2 Objective

This research has three objectives as listed below:

i) To investigate the temperature and humidity inside of an oyster mushroom house
ii) To develop an ON-OFF and fuzzy logic controller base temperature control system for mushroom house powered by photovoltaic solar collector
iii) To compare the result between the ON-OFF and fuzzy logic temperature control system

1.4 Scope of Study

There are seven scope of studies that will be followed throughout the research which is:

i) Temperature and humidity monitoring session will be held at Saifulam Agro Farm, in Benut, Pontian johor, for real world data

ii) A small-scale mushroom house replica will be built at Fakulti Kejuruteraan Mekanikal dan Pembuatan (FKMP), UTHM for monitoring and experiment session

iii) Data collection on each site will be recorded for a minimum of 2 days under two weather condition which is sunny and cloudy

iv) The ON-OFF and fuzzy logic controller temperature control system will be developed by using the Matlab/Simulink software

v) Simulation parameters for building and equipment properties will be based on the Malaysian criteria of standards while environmental parameters will refer to the meteorological state in Johor, Malaysia to determine the system feasibility on local climate.

vi) The fuzzy setting will use the mamdani inference process, min AND method, max OR method, min Implication, probability OR aggregation, and smallest of maximum (SOM) defuzzification process.

vii) Four different settings will be simulated and compared which is ON signal, OFF signal, ON-OFF signal and fuzzy signal setting

1.5 Significance of Study

This research is made in order to produce a means of improving the productivity and sustainability of the agriculture industry specifically in terms of workers efficiency and crops production quality. At the end of this research, a working simulation of an automated temperature control system will be made. The said system can be used as the base concept in building a fully functional system which will have a diverse application of greenhouse be it for small-medium scaled industry to major industries in Malaysia. Depending on the type of application, the automated temperature control system could significantly lessen the workload of workers while the renewable energy approach is a step further in realising the national renewable energy goal.

1.6 Thesis Outline

This thesis proposes the use of PV technology to power a temperature control system inside a greenhouse by using fuzzy logic control method. The proposed control method is then compared with the traditional ON-OFF control method. The thesis consists of five chapters in which the root problem is discussed in details and the proposed system are fully explained.

Chapter two makes a literature review on the existing academic literatures and studies related to the topic of greenhouse temperature control. It includes on the type and properties of greenhouses, crops harvesting nature, simulation techniques, and temperature control methods.

Chapter three discusses the methodology in which this study is conducted. It presents the research flow chart and the research approach that is used throughout the study. This chapter will also explain the mathematical models involved and how the parameters of each variable is selected.

Chapter four shows the simulation results for the mushroom house temperature monitoring and control system. A variety of system settings will be simulated and compared in order to determine that the system is indeed working as intended. All the simulations are made using Matlab/Simulink computer software.

Finally in chapter five, an overall conclusion is done and all the outcomes of the thesis are stated.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter mainly discusses and reviews previous academic literature and studies which directly related with the theoretical practices and explanations relevant to greenhouse temperature control system. The previous studies on the automated greenhouse monitoring system were used as a guideline to accomplish this research as it helps to point out some useful information regarding the research topic such as the development of the temperature monitoring and control system.

2.2 Solar Energy Technologies

Solar energy can be converted into electrical energy by using two approaches. The first which is through a photovoltaic technology while the latter is by using solar capture heating system. A photovoltaic system uses semiconductors to directly convert the sun rays into electricity. Compared with the heating method, the PV approach is known to generate a higher value of investment. The heating method on the other hand, runs on the thermodynamic processes to convert the electrical powers into mechanical energy. This is done by using heat exchanger equipment. Although it is previously not known to be as investable as the photovoltaic system, recent advancement in the solar energy field presents the thermal method as another alternative for power supply and generation.

2.2.1 History of Solar Technology

Zhu et al. (2011) in his review paper has simplified the history of the solar technology. Chronologically, the concept of solar powered technology usage can be traced back to as early as the 7th century B.C. where the concept of solar powered energy is manifested through the usage of magnifying glasses which are used to concentrate the sun rays to make fire. 4 centuries later, the Greeks and Romans uses the same energy source to light torches for religious purpose through mirror reflection methods called the burning mirrors. A century after, Archimedes theoretically improvised the same principle for war purpose which is to set fire on wooden ships although no proof of such feat existed.

In 1767, the first solar collector was made by a Swiss scientist named Horace de Saussure which were later used by Sir John Herschel to cook food during his South Africa expedition in the 1830s. The early solar thermal energy technology called the Stirling system were made in 1816 by Robert Stirling. The system uses solar thermal electric technology that concentrates the sun thermal energy in order to produce power. In 1839, French scientist Edmond Becquerel made a huge discovery involving the photovoltaic effect while experimenting with an electrolytic cell made up of two metal electrodes placed in an electricity-conducting solution. The amount of electricity generated increased when exposed to light.

The solar visionaries took a step further in the 1860s when a French mathematician named August Mouchet proposed an idea involving solar powered steam engines. Along with his assistant, Abel Pifre, the managed to construct the first ever solar powered engines two decades later which eventually became the predecessor of modern parabolic dish collectors. However, it is not until 1873 that Willoughby Smith made the stepping stone discovery regarding the photoconductivity of selenium, a solid material that produces electricity when exposed to light. The discovery is deepening in 1876 when William Grylls Adams and Richard Evans Day proven that a solid material could change light into

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