UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SOLAR HYBRID POWER SYSTEM MODEL USING ARDUINO WITH A SMART CONTROL AND MONITORING SYSTEM

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Industrial Power) with Honours.

by

ZAHIN WAZINI BIN ROLLAN AFENDY

B071410744

930127126315

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TAJUK: **Solar Hybrid Power System Model Using Arduino with a Smart Control and Monitoring System**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Power) with Honours. The member of the supervisory is as follow:

……

(Project Supervisor)

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ABSTRACT

The main purpose of this project is to develop a Solar Hybrid Power System Model using Arduino with a Smart Control and Monitoring System for community and can be used as a model for secondary school students to understand the concept of renewable energy working principles. The learning process is easier with Arduino as the main system controller that control a solar photovoltaic (PV) and wind energy system. The SCADA system was developed to provide a real time control and data acquisition with a human-machine interface (HMI) to connect the user to the controller. This project used a solar photovoltaic (PV) and mini wind turbine to represent renewable energy that can generate electricity to replace non-renewable energy. Additionaly, this project provides the students with information about renewable energy such as solar and wind that can generate electricity, which integrated with Visual Basic software as a graphic user interface (GUI). Furthermore, an MIT app Inventor application was used in order to control the output of this model via a smartphone. At the end of this project, the mini hybrid solar photovoltaic (PV) and wind energy system that serve as an educational training tool are working properly with Arduino as a controller and an MIT app inventor as the human machine interface (HMI). Thus, the students will be able to understand the concept of solar photovoltaic (PV) and wind energy as a renewal energy source.

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ABSTRAK

Tujuan utama projek ini adalah untuk membangunkan Model Sistem Kuasa Suria Hibrid menggunakan Arduino dengan Sistem Pemantauan dan Pemantauan Pintar untuk komuniti dan boleh digunakan sebagai model untuk pelajar sekolah untuk memahami konsep prinsip kerja tenaga boleh diperbaharui. Proses pembelajaran akan menjadi lebih mudah dengan Arduino sebagai pengawal sistem utama yang akan mengawal sistem "solar photovoltaic" (PV) dan sistem "mini wind turbine". Sistem SCADA telah dibangunkan untuk menyediakan kawalan masa nyata dan pemerolehan data dengan bantuan "Human Machine Interface" (HMI) untuk menghubungkan pengguna kepada pengawal sistem utama. Projek ini menggunakan "solar photovoltaic" dan "mini wind turbine" untuk mewakili tenaga boleh diperbaharui yang dapat menghasilkan tenaga elektrik untuk menggantikan tenaga yang tidak boleh diperbaharui. Tambahan pula, projek ini dapat membantu pengguna untuk memahami konsep tenaga boleh diperbaharui seperti tenaga suria dan angin yang boleh menjana elektrik dengan bantuan perisian "Visual Basic" sebagai "Graphic User Interface" (GUI). Tambahan lagi, aplikasi "MIT App Inventor" telah digunakan untuk mengawal keluaran model ini melalui telefon pintar. Pada akhir projek ini, sistem "solar photovoltaic" (PV) dan "mini wind turbine" yang berfungsi sebagai alat latihan pendidikan akan berfungi dengan Arduino sebagai pengawal utama dan aplikasi "MIT App Inventor" sebagai "Human Machine Interface" (HMI). Oleh itu, pelajar akan dapat memahami konsep "solar photovoltaic (PV)" dan mini "wind turbine" sebagai sumber tenaga pembaharuan.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

A	-	Total area of the device contact and peripheral bus-bar
A	-	Swept area of the rotor
AC	-	Alternating Current
a-Si	-	Amorphous Silicon Thin Film
CdTe	-	Cadmium Telluride
CIGS	-	Copper Indium Gallium Di-Selenide
Cp	-	Ccoefficient power
DC	-	Direct Current
E_{tot}	-	Total irradiance at standard reference conditions, 1000 Wm-2
GUI	-	Graphic User Interface
HAWT	-	Horizontal Axis Wind Turbine
HMI	-	Human Machine Interface
IDE	-	Integrated Development Environment
LED	-	Light Emitter Diode
MIT's	-	Massachusetts Institute of Technology
η	-	Efficiency
NREL	-	National Renewable Energy Laboratory
P_{max}	-	Maximum Power
PV	-	Photovoltaic
SCADA	-	Supervisory control and data acquisition
V	-	Voltage
VAWT	-	Vertical Axis Wind Turbine
ρ	-	Rho

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CHAPTER 1
INTRODUCTION

1.0 Introduction

This chapter will provide an overview of the project's background on energy sources to generate electrical power, the problem statements, the specific objectives and scope of the project.

1.1 Background

The main objective of this project is to develop a Solar Hybrid Power System Model Using Arduino with Smart Control and Monitoring System for community. It can be used as a model for the secondary school students to understand the concept of renewable energy principle. Renewable energy is an unlimited energy and it is supposed to be the main source of energy supplies in Malaysia. The learning process will be easier with the use of the microprocessor Arduino as a main system controller that control the solar photovoltaic (PV) and wind energy system. The SCADA system will be developed to provide a real-time control and data acquisition with a human-machine interface (HMI) to connect the user to the controller. Students nowadays do not have enough information on the renewable energy. They do not aware that coal, oil and natural gas that have been used as the energy sources cause such a big negative impact to the environment. This project will use the solar photovoltaic (PV) and wind energy to represent the renewable energy that can generate electricity to replace the non-renewable energy. In addition, this project will provide students with the

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information about the renewable energy such as light and wind which can produce electricity. At the end of this project, a mini hybrid solar photovoltaic (PV) and wind energy system that act as an educational training tool is expected to be working with Arduino as a controller and an MIT app inventor as a human machine interface (HMI) properly. Thus, the students will be able to understand the concept of solar photovoltaic (PV) and wind energy concepts as a source of energy that can be renewed.

1.2 Problem Statement

The students nowadays lack information on the renewable energy and they do not know that the non-renewable energy that is being used in our daily life such as coal, oil, and natural gas. This non-renewable energy causes a negative effect to our environment. An excessive usage of the non-renewable materials for the electricity generation will cause the earth to face greenhouse effect and global warming. Moreover, the cost for electricity generation is increasing day by day because of the economic issues. Using a renewable energy is the best solution to overcome this issue.

1.3 Project Objectives

The objectives of this project are:

1) To design and develop Solar Hybrid Power System Model using Arduino with Smart Control and Monitoring System,
2) to analyze the output power of the solar photovoltaic (PV) and mini wind turbine system prototype,
3) to validate the solar photovoltaic (PV) and mini wind turbine system prototype that can generate electricity (up to 15W).

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1.4 Project Scope

The aim of this project is to design and develop a mini bay prototype hybrid solar PV and wind energy system with an Arduino controller and SCADA system for educational purpose. The scopes involved are as follows:

1) Monitoring the output power generated by a solar photovoltaic (PV) and vertical axis wind turbine (VAWT),
2) use a vertical axis wind turbine and solar photovoltaic (PV),
3) use Arduino Uno as a controller with an MIT App Inventor as a human machine interface (HMI).

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CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

This chapter is about learning how the renewable power source can produce electricity. However, a PV solar and wind turbine are the main principles of this project with a specific goal to assemble a framework for educational purposes.

2.1 Power Plant

A power plant, also known as a power station, a powerhouse, a generating plant or a generating station is an industrial facility for the generation of electricity to meet consumers' demand. There are many types of power plant today such as the fossil fuel power plant, the solar thermal power plant, the geothermal power plant, the wind power plant, the nuclear power plant and hydroelectric power plant ("Electric Power eTool: Illustrated Glossary - Power Generation Plants," n.d.). Although the power plants may appear as a complex system but the basic process is just to generate electricity. Most power plants generate heat to produce steam which drive the turbines to generate electricity. Nuclear fission, natural gas and coal are the main fuels used in the world. Besides, there are other energy that can be used to generate electricity, which are the potential energy, the wind energy, the solar energy and chemical energy. This energy is classified as renewable energy. They have two basic components at the power plant system. First is the furnace boiler that is designed to burn fuels and capture the resulting heat energy. The second part of the system is the steam turbine generator that work to convert the heat energy captured by the steam into electrical energy. The

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rotor inside the turbine is connected to a main shaft and spins the magnets with a coil inside a generator. Lastly, electricity produced from the power plant can be transmit to consumers through the electric grid system.

2.2 Hybrid Power System

On this earth, there are many energies that can be used to generate power. In a hybrid power system, a combination of two or more energy or source is used to produce power. It depends on the availability of resources in certain places. The combination is set up to increase the efficiency of the power produced and face all geometrical problem like unpredictable weather conditions. A lot of combination have been done in order to generate electricity wisely and supply the electric power with a high efficiency. An example of a hybrid power system is a photovoltaic combined with a wind turbine. This combination can counter the weather condition in winter, the wind turbine will produce more output power and in summer, the solar panel will be able to produce the peak output power.

2.3 Solar Photovoltaic

Solar energy is a clean and infinite source of energy or free power. Besides, it is clarified as a renewable energy that can generate electricity. The word photovoltaic is a combination of two words which are the “photo” and “voltaic”. The word “photo” represented the sunlight and “voltaic” is the electricity. The photovoltaic system uses a solar cell to convert the solar energy into an electrical energy. The solar cell is usually made of silicon; a semiconductor material which can conduct electricity under some conditions. By refer at figure 2.1, a solar cell consists of two silicon panels that are sandwiched together which the first layer is an N-doped type and second is the P-doped type. To allow an electron flow, a contact is installed at the front and back of solar cell. The glass layer is used at the top of solar cell to protect all layers and electrical contacts (Markvart & Castañer, 2012).

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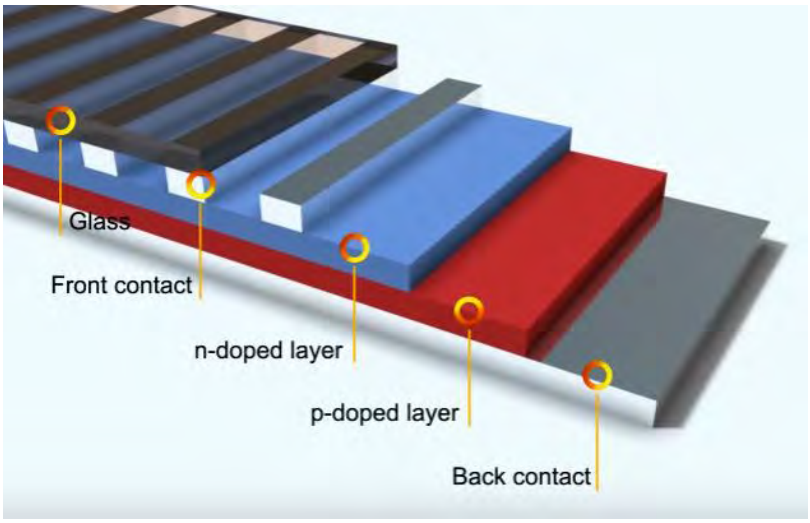

Figure 2.1: A Solar Panel Structure

2.3.1 Solar Photovoltaic Working Principle

According to Markvart and Castañer (2012), solar photovoltaic or solar cell is combination of two layers of a semiconductor; an N-doped and P-doped layer. Figure 2.2 shown the solar cell working principle, which is some interactions will happen when both of the semiconductor parts are combined. Went the N-type region and P-type region contact with each other, some electrons will move towards the positive side and some positive charge of holes will move towards the N-type region. The travelling of electrons and holes to another side will create a new layer between these two regions and that layer is called depletion layer or depletion region. At this depletion layer, electrons and holes will not travel to another side because the depletion layer is formed. So, when a photon energy or sunlight strikes the depletion layer area, electrons and holes will be generated and excite the electrons to move towards the connected wire or contacts. Now, the electrons and holes take a part of connecting wire or contact and an electricity will be generated.

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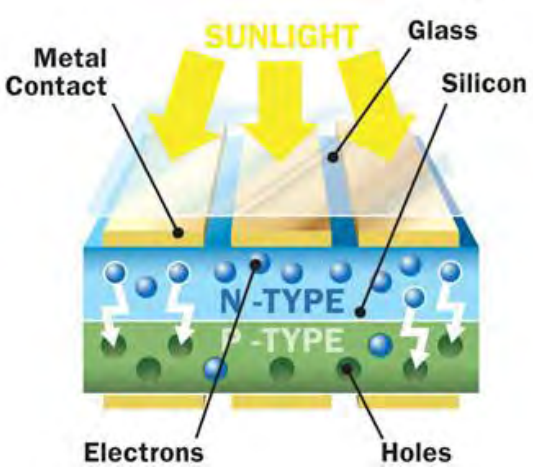

Figure 2.2: The Solar Cell Working Principle

2.3.2 Types of Solar Cell

There are a lot of companies or researchers focusing on solar cell. The solar cell or solar panel comes with a various types of panel with their own advantages. There are three common types of solar panel used today (Energy, 2015),

i. Monocrystalline panel

Monocrystalline is the first material used in the photovoltaic cell and remain the most common used (Hersch & Zweibel, 1982). It is made up of a single-crystal silicon by Czochralski process (Sharma, Jain, & Sharma, 2015).It has typically an efficiency of 17% to 18% (Sharma et al., 2015). Monocrystalline has a better efficiency compared to other types of solar cell.

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ii. Polycrystalline panel

A polycrystalline panel is also known as a multi-crystalline panel. Polycrystalline is a combination of a variation of crystals that are coupled in a single panel. It is the most popular solar cell with a 48% of production in 2008 (Sharma et al., 2015). The polycrystalline panel is cheaper and has simple manufacturing process compared to the monocrystalline. However, it has less efficiency but with a better performance during hot days (Maehlum, 2015).

iii. Thin film (amorphous silicon) panel

A thin film panel can be categorised under three types, an Amorphous Silicon Thin Film (a-Si), a Cadmium Telluride (CdTe) Thin Film Solar Cell and a Copper Indium Gallium Di-Selenide (CIGS) Solar Cells. Thin film is a solar cell that is produced by placing one or more thin layers of a photovoltaic composite. The thin film solar cell is different from other solar cells because it is more flexible and can be set into a variety of different surfaces, curves and straights (Sharma et al., 2015).

The difference type of solar cell has a different percentage of its efficiency. Figure 2.3 shown The Comparisons of Efficiency of Technologies.

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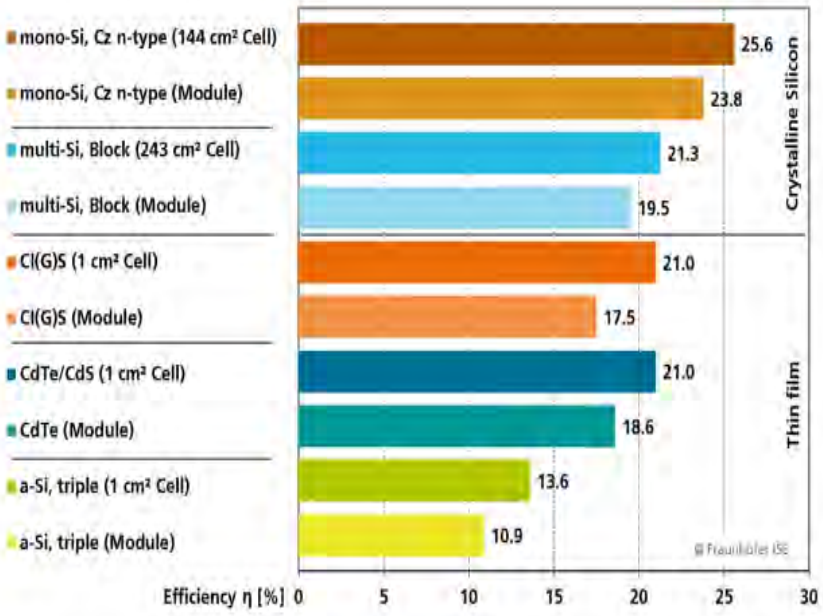

Figure 2.3: The Comparisons of Efficiency of Technologies (Energy, 2015)

2.3.3 Solar Cell Efficiency

Solar efficiency is one of the hottest issues in the world. Efficiency is the ability of a product to do or produce something without wasting materials, time or energy. In other words, solar cell efficiency is how much energy from the sun can be converted into an output of electrical power via a photovoltaic. The main goal of manufacturing a solar cell is to provide the maximum electrical energy or with a high efficiency to consumers. U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) (2013) states, there are several factors should be focused more in order to achieve high efficiency of the solar panels.

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i. Wavelength

The main factor that cause inefficiency in solar panel is the wavelength. The solar panel must respond to the entire spectrum of sunlight to achieve the maximum power produced. When the sunlight strikes to the surface of solar panels, some proton or light energy are reflected and do not enter the solar cells. So, not all photon pass through the material to separate electrons from their atomic bonds to produce charge carriers in order to generate electricity.

ii. Recombination

Recombination is a process when an electron is combined with a hole continuously. Due to the recombination process, electrons emit some energy in the form of heat or light. That energy is absorbed by the nearest electron and breaks the covalent bond to be free. A direct recombination occurs when the photon energy generated the electrons and recombination process will happen to encounter holes. It is fundamental that it can reduce the solar cell efficiency. An indirect recombination is a process which electrons and holes encounter an impurity. The crystal material has a defect that it allows the recombination of electrons and holes and releases their energy to become heat.

iii. Temperature

In the real world, the solar panels must be able to endure a constant temperature changes due to the unpredictable weather. The variation of the temperature is tough on the solar panels because their electrical connection is made of metal. When the temperature rises and fall day after day and year after year, different expansion and contraction rate in that metal can cause those connections to break. The high ambient temperature has an impact on the solar panel performance

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