STAND-ALONE HYBRID PHOTOVOLTAIC-WIND GENERATION SYSTEM PROJECT: PRACTICAL BASED APPROACH

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ABSTRACT

In the era of high energy prices, many people are looking to use alternative sources of energy. The energy can be generated from various sources such as nuclear, hydroelectric, natural gas, petroleum and renewable energy. Nowadays, the stand alone renewable energy is one of the efficient solutions to generate energy without any harm pollution. Renewable energy consists of a solar energy, wind energy, geothermal energy and hydropower. The combination of two or more types of renewable energy sources is defined as a hybrid energy system. This project is about study and analyzes the effectiveness of stand-alone hybrid for PV-Wind generation system installed at Faculty of Electrical Engineering, UTeM. The hybrid PV-Wind at UTeM is combination of wind turbine generator and solar PV system. It used to charge battery and power up the LED street lighting. The focus of this project is to investigate the effectiveness of the system installed by referring to important parameters and characteristics such as voltage, current, power, irradiance and wind speed value. The power analyzer meter has been used to measure and logged the output data such as current and voltage of the system. Besides that, the solar radiation meter has been used to measure the solar radiation and anemometer used to measure the wind speed. The relationships of all important parameters measured has been analyze and studied. Based on the result, it shows that this hybrid system is able to generate electricity effectively and operate as stand-alone system for the street lighting system.

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LIST OF ABBREVIATIONS

UTeM	-	UniversitiTeknikal Malaysia Melaka
VAWT	-	Vertical Axis Wind Turbine
HAWT	-	Horizontal Axis Wind Turbine
PV	-	Photovoltaic
FKE	-	Fakulti Kejuruteraan Elektrik

LIST OF SYMBOL

Ω	-	Ohm
A	-	Ampere
V	-	Volt
k	-	Kilo
W	-	Watt
m	-	Meter
mm	-	Millimeter
m/s		meter/second
mm^2		Millimeter square
W/m^2		Work/Meter square

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CHAPTER 1

INTRODUCTION

This chapter will discuss on the background of hybrid PV-Wind generator and also the importance of hybrid PV-Wind system for generate electrical. In addition, the problem statement, objective and scope will be brief in this chapter.

1.1 Background

Energy comes in various different forms such as light, heat, electric and other else. Energy may be transferred between various different forms. Nowadays there are another ways to obtained electrical energy which are more convenient, free pollution, unlimited and renewable like using solar energy, biomass energy, geothermal energy and wind energy.

Solar and wind is an intermittent energy sources as it varies over time and do not usually meet load demands at all times. Among these two types of renewable energy, wind is the more affected source compare to photovoltaic due to its variability. In generally, the photovoltaic system also depends on the weather conditions and only can operate in 12 hours in a day. These two unpredictable energy sources standalone system will produce fluctuated output energy and thus cannot ensure the minimum level of power continuity required by the load.

A hybrid system is defined as the combination of two or more types of electricity generation system. The project is based on combining PV system and wind turbine to form a renewable energy system for storage the battery. The hybrid PV-Wind system main important role in order to change the source of energy that use today.

The advantages of this hybrid PV-Wind system are environmental friendly, more independents system and low cost for maintenance. Moreover, the hybrid system is suitable to use in remote areas with no access to utility grid. However, there is also disadvantage of using hybrid system such as in most cases the system is over sized because it contains different types of power generation system.

1.2 Problem Statement

In recent years, the hybrid energy system has been designed to generate electricity from combination of solar panels and wind turbine. Although the solar and wind energy are known as dependable and widely available renewable energy sources in Malaysia, but the intermittent energy sources will cause the power generator to produce a fluctuating output.

Hence, before conduct this project the first step needed is to study the overall about the PV-Wind generator system. Besides, study and examine the new apparatus before used to ensure the project run with smoothly. The different type data of the solar radiation, wind speed and voltage charging that has been collected of PV-Wind generator system in FKE and to ensure this data have correlation coefficient between each other's .The various data collected are compared with forecasting weather to determine the effectiveness of PV-Wind generator system in FKE.

1.3 Objective

The objectives to develop this project are:

1. To study the characteristic of hybrid PV-Wind generation.
2. To measure important parameters that related to the PV-wind hybrid generation system.
3. To analyze the effectiveness of PV-Wind generation system installed at FKE.

1.4 Project Scope

The project would involve the aspect that need to be focused on the PV-Wind generation system in FKE. The main apparatus that are used in this project are Power Quality Analyzer Meter, solar irradiance meter and anemometer. The project was conducted at behind of Machine Laboratory in FKE, UTeM. The data of solar radiation, voltage charging, wind speed and output current that has been collected weekly. The correlation coefficient of each data is to be shown in this project. This project will also show how to measure and analyze the data of PV-Wind generation system installed at FKE.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter briefly explains the hybrid PV-Wind generator system in term of stand- alone system. This can be referred from literature reviews from journal published. In addition, this chapter will present terms including, photovoltaic, wind generator and the method that can be used to examine the effectiveness this system in FKE.

2.2 Photovoltaic system

The word photovoltaic (PV) can divide into two parts which are “photo” means “produced by light” and “voltaic” refers to “electricity produced by a chemical reaction” [1]. From this, photovoltaic could literally be translated as light-electricity. A PV cell is small energy conversion system that converts the sun’s energy directly into electricity, which can be used to power equipment or to recharge a battery. The technology photovoltaic systems offer consumers the ability to generate electricity in a clean, quiet and reliable way.

Solar energy is cheap, clean and readily available natural energy resource. The amount of solar energy intercepted by the planet Earth is 170 trillion kW. The monthly average daily solar radiation in Malaysia is (800-1000 W/m^2), with the monthly average daily sunshine duration ranging from 4 hours to 8 hours [3]. Based on the previous research [3], the solar radiation resources have no impact for the winter season and electric current around the winter season was dominated by wind generator. Therefore the electric current pattern produced by PV array was significantly less in intensity while the shape of the pattern did not follow the solar radiation pattern [3].

PV cells are generally made either from crystalline silicon or thin film. Crystalline silicon cells are most common technology used representing about 90% of the PV market today. Three main types of crystalline cells are mono-crystalline, polycrystalline and ribbon sheets. The thin film technology has a lower production costs compared to the crystalline technology but substantially it has lower efficiency rates. The most important of the PV system are the cells which is the basic building block of the unit. The voltage is generated in a solar cell by a process known as the "photovoltaic effect"[4]. When photons are absorbed by a photovoltaic cell which contains a semiconducting material such as silicon or platinum, the energy from the photon is transfer to an electron in an atom of the "solar cell". The energized electron is then able to escape its bond with the atom and generates an electric current. This leaves behind a "hole". From the combining of P-N junction, the layer within the photovoltaic cell that is formed by the contact of P-type and N-type semiconductors that created an electric field. The holes move in the opposite direction from electrons and producing an electric current as figure 2.1.

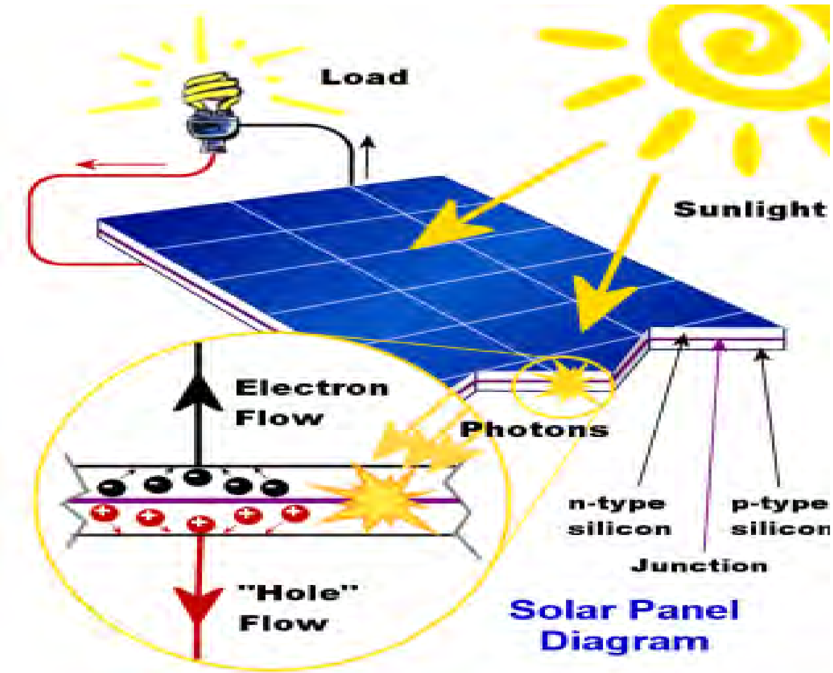

Figure 2.1:p-n junction solar cells

Photovoltaic cells are connected electrically in series or parallel circuits to produce higher voltages, currents and power levels. Most PV arrays use an inverter to convert the DC power produced by the modules into alternating current that can generated power for lights, motors, and other loads. The power can increase by connecting cells together to form larger units called modules. Modules in turn can be connected to form even larger units known as arrays. In this way, a PV system will meet almost any power need, no matter how small or great. The modules in a PV array are usually connected in series to obtain the more voltage or the module connected in parallel to allow the system to produce more current. Based on the previous research [5], one PV module of crystalline silicon that has been used to determine the optimum PV based on conversion efficiency and environment conditions. The Figure 2.2 shows the cell, module and array.

The purpose of this project is preparing the analysis data of effectiveness of PV-Wind generator in FKE. When installations fail to meet these basic requirements, those systems will be wasted. The major components of photovoltaic are solar array, inverter, battery, and protection device. The 120 W of solar panel are used as PV panel in FKE. The connection of PV array with sunlight with open circuit voltage is not greater than 30V. The rating current of this PV is 10A and the voltage of the PV system will cut-in when the voltage charging more than the battery voltage.

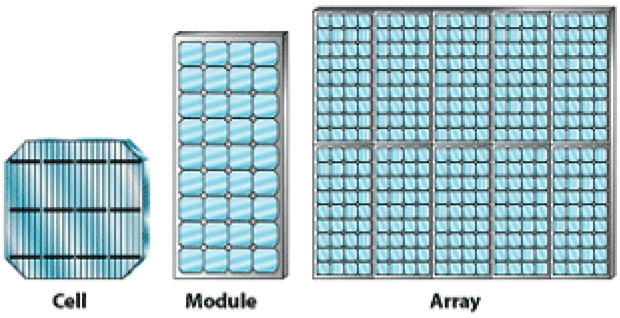

Figure 2.2: Design type of Photovoltaic

2.3 Wind Generator

Nowadays, wind energy is crucial for electricity companies as it is renewable and free resource. Wind energy also can define as the energy conversion in which of converting wind power to electrical power that use for power. Malaysia has good prospective in wind energy and have decided to opportunities for the wind energy to replace the fossil fuel which is non-renewable energy as a sources energy. Malaysia faces the four seasons such as southeast monsoon, northeast monsoon and two shorter periods of inter monsoon seasons. Hence, wind over in Malaysia is generally light with the speed less than 8 m/s.

Wind turbine is a rotating machine which converts the kinetic energy of wind into mechanical energy. The wind turbine consists of four main parts such as gearbox, motor, nacelle and yaw system. When the wind flows past the turbine's rotor blades, the blades turn and convert the wind energy into kinetic energy. This energy spins a rotor inside a generator and coverts into electrical energy. The more electrical energy generated the greater wind speed. Meanwhile, windmill is a machine that used mechanical energy. If mechanical energy is converted to electricity, the machine is called wind generator, wind turbine, wind power unit (WPU), and wind energy converter (WEC).

The wind turbines can be separated into two basic types determined by which way the turbine spins. The wind turbines that rotate around a horizontal axis are more commonly called a wind mill, while vertical axis wind turbines are less frequently used are Savonius and Darrieus. The Vertical-axis wind turbine (VAWT) and Horizontal-axis wind turbine (HAWT) are the type of wind turbine where commonly used in the world.

A Horizontal axis wind turbine (HAWT) has a similar design to wind mill, it has blades that look like a propeller that spin on the horizontal axis. The Horizontal-axis wind turbines (HAWT) consists of motor raft and electrical generator which is must be pointed into the wind. It comprises a gearbox which turns the slow rotation of the blades into the speedy rotation that is suitable to drive an electrical generator which show the figure 2.3 below. The wind turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds and the blades also are placed a considerable distance in front of the tower. When in high winds, the blades will to bend for reduces the wind resistance.

Horizontal axis wind turbines have blades that are designed perpendicular to the direction of wind. This efficient design will increases wind power throughout the entire rotation. However, the blade span of horizontal wind turbine is larger than vertical axis machines which limits placement confined spaces. It is essential to realize that wind resource evaluation is a critical element in projecting turbine performance. Generally, the annual average wind speed of Horizontal axis wind turbine is 5 m/s which are required for grid connection. Meanwhile, annual average wind speeds of 3 to 4 m/s may be adequate for non-connected electrical and mechanical applications [6].

Figure 2.3: Horizontal Axis Wind Turbine (HAWT)

The Vertical axis wind turbine (VAWT) has two or three blades and the main rotor shaft arranged and run in vertically. Besides that, generator is mounted at the base of the tower and blades are wrapped around the shaft. The main advantage of this system is the wind turbine does not need to be pointed into the wind to be effective. In other words, VAWT can be used in the high variable wind direction and collect wind from every direction. The turbine generator and gearbox can be placed lower to the ground for making maintenance easier and lower the construction costs. The wind speed is slower at a lower altitude and less wind energy. There are two types of VAWT which are Darrieus wind turbine and Savonius wind turbine. The Darrieus wind is commonly called “Eggbeater” turbines, because it looks like a giant eggbeater. The Darrieus wind turbine has good efficiency but produce a large torque ripple and cyclic stress on the tower which contributes to poor reliability. Besides, it generally required some external power source or an additional Savonius rotor to start turning, because the starting torque is very low. The other types of VAWT is Savonius wind turbine which is the Savonius is a drag type turbine and it commonly used in cases of high reliability in many things such as ventilation and anemometers. This is because this turbine is a drag type turbine which is less efficient than the common HAWT. The Savonius are excellent in areas of turbulent wind [7].

There are many types of generator can be used such as Honey Well model WT 6500 [5]. This type of generator do not need tower and it can installed on top of any roof. There are others type of generator that has been used from previous research such as synchronous generator [8] and permanent magnet synchronous generator [9].The vertical axis wind turbine was installed behind of lab electrical machine in FKE and it also can produce power in low windy areas. From the figure 2.3, the wind turbine at FKE has been used of the DS300 model which combined an S-type of Savonius rotor and three airfoil blades of egg beater shape Darrieus[10]. The generator is connected in 3-phase permanent magnet synchronous generator. The output rated power of this wind turbine that can produced is around 300W and the speed of rotor is 12 m/s. From researcher of (Wenxia Pan, WenzhongGao, Eduard Muljadi) [11], when the wind speed increased the real power of the generators also increased in the system and supplied to the batteries.

Figure 2.4: VAWT DS300

2.4 Hybrid PV-Wind generator system

A hybrid system is defined as the combination of two or more types of electricity generation system. For this case the PV system is combining with wind turbine system to form a renewable energy system to generate the electricity. A standalone PV or wind power system is not able to provide sufficient power to the load connected due to intermittent energy source. To accommodate every requirement of energy and providing stabilize output power to the consumers, a hybrid system with energy storage is the best choice for generate the electricity. The advantages of using renewable energy hybrid system are it can cause no pollution and these energy sources are widely available in Malaysia.

In FKE hybrid system, the combination of vertical axis wind turbine of DS300 with 120W solar panel is to obtain the energy storage in battery as Figure 2.6. The wind turbine (DS300) power system connects to AC-DC rectifier. The function of this rectifier is converting alternating current (AC) source to direct current (DC) source using power diode or by controlling the firing angles of controllable switches. The wind turbine (DS300) is Vertical Axis Wind Turbine (VAWT) which the maximum speed of generator can reach 12 m/s and rated output power is 300W [10]. The DS300 wind turbines are equipped with special designed power controllers with built-in Maximum Power Point Tracking (MPPT) function to maximize the power generation in wind turbine. From the comparison between the previous researches [9], MPPT was mostly applied to the hybrid PV-Wind system. By using the MPPT, the wind charge controller can show a very high degree of transfer efficiency (>92%) and higher charge currents as compared to standard charge controllers. The MPPT systems are used mainly in system where source of power is nonlinear such as wind turbine. The Vertical Axis Wind Turbine (VAWT) of DS300 connected to the hybrid charger (WS320) in 3-phase permanent magnet generator as Figure 2.7.

In Figure 2.4 the hybrid charger controller (WS320), there is parts that can connect supply to battery bank and wind turbine. From the hybrid charger (WS320), the light “LED” on the hybrid charger will turn up when the voltage of wind more than 4.5Vac and the light “LED” will turn off when the voltage of wind is below 3Vac. It mean that when the light “LED” turn up, the voltage wind is in charging and the light “LED” will turn off when the voltage of wind is not in charging condition. The light “LED” also will turn slow flash when the rotor speed is more than 750rpm and the rotor will brake in 10 minute as a protection method of over speed protection. The operating temperature of hybrid charger (WS320) is around -10°C until 50°C. The voltage charging from hybrid charger will flow to the battery for supply the voltage.

Figure 2.5: Hybrid Charge (WS320)

In the FKE hybrid system, the solar panel of 120W system is connected to DC-DC converter to step up the power generated. This solar panel is connected to the solar lighting controller “SunLight-10”. The “SunLight-10” of solar lighting controller is combines the “SunSaver” which design with a microcontroller for digital accuracy and fully automatic lighting control operation. The PWM battery charging has been optimized for longer battery life. The battery of 24V with the current rating of 10A and 20A, and also load of 25W connected to this solar lighting controller “SunLight-10”.

From the Figure 2.6, the “SunLight-10” is fully automatic solar lighting controller that includes electronic functions to protect both the controller and the PV system [12]. The controller is designed to operate for long intervals and unattended. The operating temperature of the “Sunlight-10” is around -40°C to 85°C.In addition, operational control "Sunlight-10" also includes a digital rotary switch to select between 10 different lighting control operating time as 2h, 4h, 6h, 8h, 10h, 10h/1h, 4h/2h, 6h/2h, D / D for controlling the operation of street lighting. The “SunLight-10” uses an advanced series PWM charge control for controlling the average volts, current, or power delivered to load. When the battery is disconnected during daytime in 12 hours, the PV array will continue to provide power to the controller. This is because “SunLight-10” will immediately go into PWM and provide power at a constant voltage to the load. The condition will continue as long as sufficient power is available from the PV array. The light “LED” on the “SunLight-10” will turn to green light when the solar or battery is charging. The light of “LED” will turn to red when no charging occur or low voltage charging.

Figure 2.6: Solar Lighting Controller (SunLight-10)

The optimum capacity of the battery storage is 100Ah with 24V. The connection battery in parallel with each other and the total of all battery storage is 48V. When the battery storage achieved 24V which is the optimum voltage storage, the voltage will supply to the load of 25 W. The microcontroller will reset when the battery voltage below 8V although the test button in LVD push ON. It means that the street light or load of 25W would not to light up although lighting control has been set. The load will light up after sunset follow lighting control operation that has been chosen.