DEVELOPMENT OF SENSORLESS SOLAR TRACKER SYSTEM

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ABSTRACT

Solar panel has been used increasingly in the recent years in converting the solar energy into electrical energy. The solar panel can be used either as a stand-alone system or as a large solar system that is connected to the electricity grids. Nowadays, humans are trying to consume more energy from the sun using solar panel. In order to maximize the conversion from solar to electrical energy, the solar panel has to be positioned perpendicular to the sun. Thus, the tracking of the sun's location and positioning of the solar panel is important. The goal of this project is to design a sensor-less solar tracking system, which can locate the position of the sun. The tracking system will move the solar panel so that it is positioned perpendicular to the sun for maximum energy conversion at all time. The method used in the system was based on the Falaq's knowledge in determining the Muslim's prayer time. This method will ensure the solar panel always follow the movement of the sun in order to produce the maximum energy output. In this project, the solar tracker is able to move in horizontal axis without using any sensors. The system consists of Arduino microcontroller, LCD display, motor driver, and a solar panel. This system produce more output energy than conventional solar panels without tracking systems and provides lower cost compared to a solar tracker system that uses a sensor. This system is the new technology introduced which is able to give a good impact to every consumer who is concerned about the performance of the solar panel.

ABSTRACT

Sejak kebelakangan ini, jumlah penggunaan panel solar telah meningkat dalam usaha menukarkan tenaga solar kepada tenaga elektrik. Panel solar boleh digunakan secara sistem tersendiri atau satu sistem yang besar dimana ia dapat disambungkan dengan grid elektrik. Pada masa kini, setiap pengguna ingin mendapatkan tenaga yang lebih daripada matahari dengan menggunakan panel solar. Dalam usaha untuk meningkatkan proses penukaran tenaga solar kepada tenaga elektrik, panel solar perlu berkedudukan serenjang dengan matahari. Oleh itu, matlamat projek ini adalah untuk menghasilkan satu sistem pengesan cahaya matahari tanpa sensor yang mampu mengesan kedudukan matahari. Sistem pengesan ini akan menggerakan panel solar supaya ia berada pada kedudukan yang selari dengan matahari untuk proses penukaran tenaga yang maksimum pada setiap masa. Kaedah yang digunakan dalam sistem ini adalah berpandukan ilmu Falaq yang turut digunakan dalam menentukan waktu solat. Sistem ini terdiri daripada mikropengawal Arduino, paparan LCD, pemandu motor, dan panel solar. Sistem ini akan menghasilkan lebih banyak tenaga daripada panel solar konvesional tanpa sistem pengesan dan hanya menggunakan kos yang lebih rendah jika dibandingkan dengan sistem pengesan cahaya matahari yang menggunakan sensor. Sistem ini merupakan satu teknologi baru yang diperkenalkan dan mampu memberi impak yang baik untuk setiap pengguna yang amat mementingkan prestasi panel solar.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Solar energy or photovoltaic energy (PV energy) is a very popular alternative power nowadays due to its renewable and free features. It is also used to generate and supply the electricity for commercial or residential usage. Due to the ever-increasing of the fossil fuel or gas price, other payment charges have also been affected such as the payment charges for electricity. Therefore, a lot of the researches have been conducted in order to develop other sources of energy that can replace the fossil fuel or gas. The photovoltaic energy is a form of solar energy which is considered as one of the alternative to produce energy. Because the solar panel that made up from the solar cells, the solar panels have the ability in converting the sunlight to electrical energy.

The performance of the solar cells in producing the electricity depends on the angle of the prevalence of the sunlight. It can be received well when the sunlight is perpendicular to the solar cells. However, the available solar cells today have its position fixed. It should moves within time to increase the efficiency of the solar cells in producing electricity. Therefore, this project will develop a simple solar tracker system which has been designed as the one way to improve its efficiency. This project consists of software and hardware implementation. It is divided into two parts which are mechanical parts and electrical parts. Both of the parts have been designed by considering the cost, performance, maintainability and capability.

1.2 Problem Statements

The performance of the solar system is based on the amount of the electricity that it can produce. The direction of the sunlight is not at stationary but it will move from time to time, depending on the movement of the sun. Mostly, the existed solar panel nowadays are install securely which means it is static and failed follow the movement of the sun. The performance of the solar panel is not impressive because it produces low output power. The output power will increase when the solar panel is perpendicular with the position of the sun. In order to improve the performance of the solar panel, solar tracker that uses the technology of sensor has been designed and sold in the market. However, the cost for the system is too high causing most of the people cannot afford the solar tracker system.

1.3 Objectives of the project

The objectives of this project are:

- To develop the prototype of solar tracker system that can track the sun movement and the LCD display monitor the angle of the solar panel.
- To design an automated solar tracker system that will move based on the Falaq's knowledge method.
- To analyse the performance of the solar tracker system that able to move without using any sensors and low cost.

1.4 Project Scopes

The scope of this project is focusing in designing and developing the prototype of the solar tracker system as the initial step in producing the real solar tracker system. This system may able to generate 100 Watt and can only move in a range of 45 degree to 135 degree. In addition, the solar tracker system will follow the movement of the sunlight based on the Falaq's knowledge method. It is designed without using any sensors in terms of reducing the cost. On the other hand, this solar system is designed that will enable the solar panels to move only in horizontal movement. The power window motor is used to control the horizontal movement of the solar panel while the LCD 16"x2" is to display the angle of the solar panel.

CHAPTER 2

LITERATURE REVIEW

2.1 Basic principles of solar system

Sunlight is made up of photons, small particles of energy. It passes through and absorbed by the materials of the photovoltaic solar or solar cells panel. Photovoltaic provides electrical current source under the influence of light or similar radiation [1]. The solar cells are pieces of silicon based materials which able to absorb the sunlight. When it absorbs the sunlight, it causes the electron to move. The electrons typically move in a certain direction known as current. The electricity produced from the solar panel is in the form of direct current (DC). The output from a single solar cells is small, therefore it is arranged together in a photovoltaic module whereas the module are grouped together to form an array. The output power is then used to charge inverters and the electrical energy produced can be used by appliances and other household electrical items. The photovoltaic solar are used in several ways which are primarily to power homes or interconnected with grid.

2.2.1 Solar system

Solar systems are one of the processes to convert the sunlight energy to electrical energy. Solar cell is the electrical devices that will produce the electricity. It is also known as the photovoltaic cell or photocell. The process of receiving and collecting the light is by using the solar panel. Most of the solar panel nowadays has the thickness range of 3 to 6 cm and in square shape for easy installation. The figures 2.1 below, shows the process of the system.

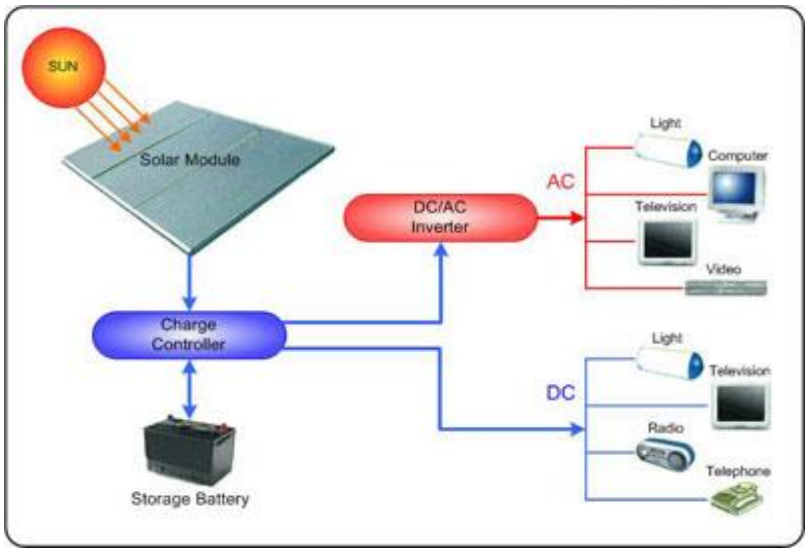
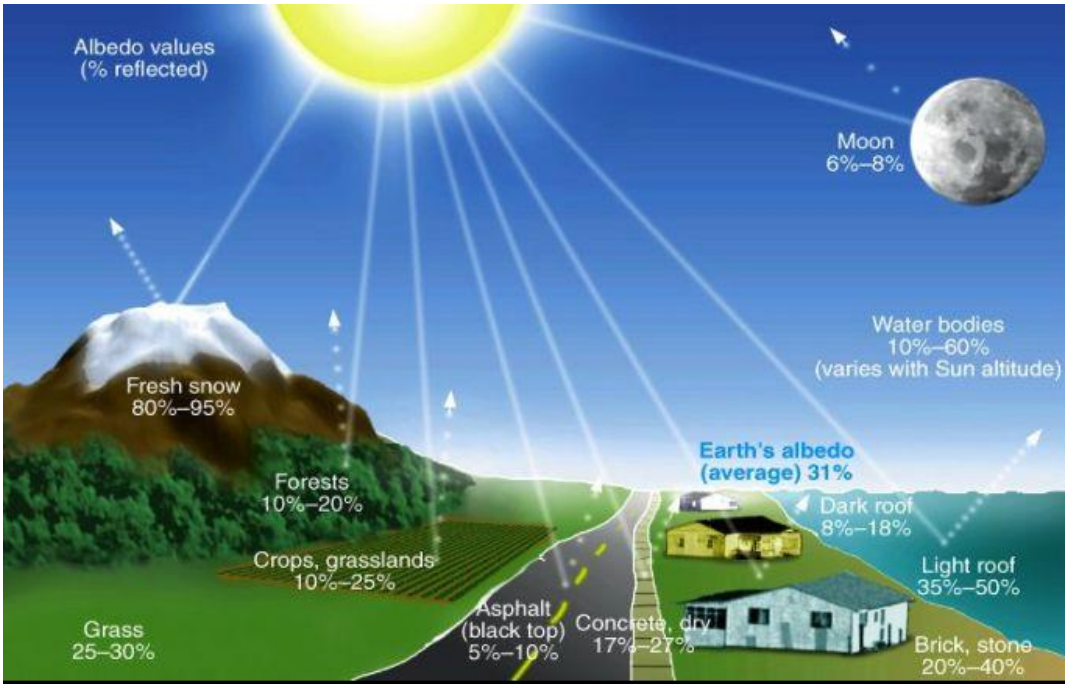


Figure 2.1: The process of solar tracker system [11]

2.1.2 Solar Energy

Solar energy is radiant energy acquired from the sun. Since it provides the world directly or indirectly with almost all of its energy, it is considered as vital for living things. In order to provide the sustainable energy to the world, solar energy is stored in fossil fuels and biomass, and is responsible for powering the water cycle and producing wind. The sun radiates every day, and sends out an enormous amount of energy. The sun radiates more energy in one second than people have used since the beginning of time. Solar comes from within the sun itself.

Solar energy is considered as a renewable energy source. Renewable sources of energy are resources that are continually renewed by nature, and hence it will never runs out. Solar power is considered as renewable due to the nuclear (fusion) reactions that the sun are expected to keep generating sunlight for many billions of years [2].



Figures 2.2: Solar energy reflected on the earth's surfaces [12]

2.1.3 Solar cell

Solar cell that also known as photovoltaic cell or photocell had been discovered by the French physicist, Edmund Becquerel in 1839.The physicist found that, the voltage produced when one of the two identical electrodes in a weak conducting solution was illuminated. The first solar cell that produces electrical currents which can be measured was in 1953, developed by bell laboratories. Solar cell can generate electricity due to its semiconductor devices. When the light falls in the solar cells, the electricity will be produced. Solar cells are divided into a few types which are single-crystal silicon, polycrystalline silicon and amorphous thin film structures. The type of the solar cell that generally used is silicon type. Silicon is an intrinsic semiconductor in its purest form, although the intensity of its semiconductor is highly increased by introducing small quantities of impurities [3].

2.1.4 Photovoltaic effect

In general, the photovoltaic effect (PV) can be described as a generation of an electromotive force (voltage) within the range of materials non-homogeneity during light illumination with an appropriate wavelength. Only in specially prepared structures, the

effect is high enough and can be applied for conversion of electromagnetic radiation into electricity [4]. It is also known as the basic physical process through which a PV cell converts sunlight directly into electricity. PV technology works anytime the sun is shining, but more electricity is produced when the light is more intense and when it strikes the PV modules directly, which is when the sunrays are perpendicular to the PV modules.

Unlike the solar system for heating water, PV does not produce heat to make electricity. Instead, PV cells generate electricity directly from the electrons freed by the interaction of radiant energy with the semiconductor materials in the PV cells. Sunlight is composed of photons. When it strikes a PV cell, it can be reflected or absorbed, the energy of the photons is transferred to electrons in the atoms of the solar cell, which is a semiconductor. The newfound energy makes the electrons able to escape from its normal positions associated with the atoms to become part of the current in an electrical circuit. By leaving its positions, the electrons cause holes to form in the atomic structure of the cell into enabling other electrons to move. Special electrical properties of the PV cell, a built in electric field, provides the voltage needed to drive the current through a circuit and power up an external load such as a light bulb [2].

2.1.5 Solar Tracker System

The single axis solar tracker device ensures the optimization of the conversion for solar energy into electricity by properly orienting the PV panel in accordance with the real position of the sun. The project had been developed with operation of the experimental model of the device based on a principle of DC motor intelligently controlled by a dedicated drive unit that moves a mini PV panel according to the signals received from two simple but efficient light sensors [6].

In other research found that PIC16F877A microcontroller, sensors, servo motor, and digital compass have been used in order to develop an automatic Solar Tracker Robot (STR) which is capable to track the maximum light intensity. The solar energy conversion efficiency can be maximized by receiving the optimum light on the solar panel. The method applied which the STR will automatically adjust the position of the robot so that is

always faces the same direction. This system will enable the solar panel to receive the optimum sunlight if external force is applied to move the STR [7].

Other than that, the previous study made shows that a pair of sensors will be used to point the east and west of the location of the light. This sensor is used to ensure the solar tracker to be able to navigate at the best angle of exposure of the sunlight. In order to develop a simplified diagram of a horizontal axis and active tracker type of solar tracker fitted to a panel, DC motor that controlled by the AT89C51 microcontroller program have been used as the centre of the drive [8].

In the other studies, four light dependent resistors (LDRs) have been applied to sense the sunlight in order to move East-West and South-North direction. Dual axis solar tracker system is developed to produce the maximum output of the solar panel. This system had been developed by proposing a new micro-controller based on solar tracking system and can be operated as independent of the geographical location of the site of setting up. The control system containing a control board, a control program, a power supply board, one DC motor interface board and a set of sensors [9].

By referring the previous study that related with this project, the main objectives for the project is similar which is to track the sun position in order to gain optimum energy from sunlight to PV panels. In order to improve the performance of the solar tracker system, the solar panel need to keep moving by following the movement of the sunlight. But, there might be some difference component and process for each of the project. Comparing to previous studies as above, this project is created and developed by calculating the angle of the sun and move towards it instead of using any sensor to detect the sunlight. In addition, an Arduino board had been selected and applied as the controller to control the whole system. Moreover, this solar tracker system may able to move only in horizontal axis.

2.1.6 Research summary

Table 2.1: Summary of the previous project

No.	Name of the project	equipment	axis
1	Design of a Solar Tracker system for PV Power Plant.	• 2 Light sensor • Dc motor	• Single axis
2	Solar Tracker Robot using Microcontroller.	• Light sensor • Servo motor	• Single axis
3	Solar Tracking System.	• 2Light sensor • Dc motor	• Single axis
4	Microcontroller Based Solar-Tracking System and Its Implementation.	• 4 LDR • DC motor	• Dual axis

2.1.7 Market analysis

Table 2.2: Conventional solar tracker systems [21, 22, 23]

NAMES	SYSTEM	DETAILS
XIAMEN – MINI SOLAR TRACKER		• Uses PV sensor • Efficiency: Excellent • Price: USD135

SIGNAL INTERNATIONAL CO. – SOLAR TRACKER SYSTEM		• Uses Light Dependent Resistor (LDR) sensor • Efficiency: Excellent • Price: USD150
DURARACK AT-SOLAR TRACKER		• Manual adjustable ball screw with gear box. • Efficiency: Good (0˚ to 60˚) • Price:USD110

2.2 Arduino microcontroller

The Arduino microcontroller is simple to use and can be applied in various types of applications. Arduino is an open source and available in the market with reasonable price. Arduino operates by receiving inputs from various types of sensors and can produces the desired output by controlling lights, motor and actuators. Arduino programming language is used to program the microcontroller on the board. It can be connected with the supply from the computer or other power supply such as rechargeable batteries.

There are many types of microcontroller that can be used to control the project by manipulating the input and will produce the desired output. There might some advantages and disadvantages to differentiate each types of the microcontroller. But nowadays, Arduino microcontroller is the one of the most popular microcontroller that is uncomplicated for a beginner to explore. It is designed for beginners that have no

experience in creating the software and electronic controller. Moreover, there are some examples and tutorials available in the main website of the Arduino microcontroller.

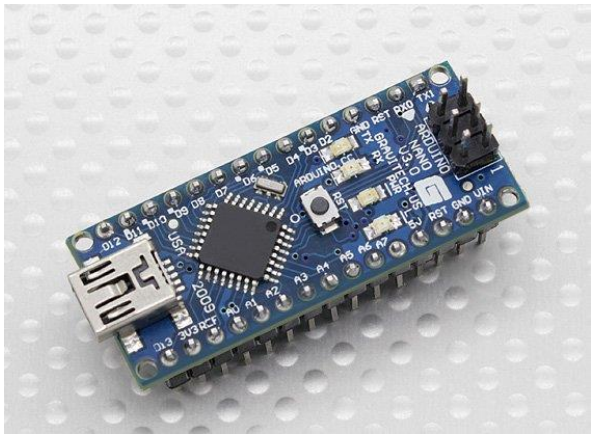


Figure 2.3: Arduino NANO

Figure 2.4 Arduino UNO

2.3 Power window motor (DC motor)

DC motor is needed in order for the solar panel's movement. DC motor runs on direct current electricity. It can operate directly from rechargeable batteries [5]. Power window motor is the most suitable type of the DC motor to be used. It is easier to move forward and reverse since the solar panel will move in horizontal movement. Rated current and voltage for this type of DC motor are 12V and over 8A. The power window motor can be controlled by using the Arduino microcontroller.

Figure 2.5: power window motor

2.4 Single axis solar trackers

Single axis tracking systems realizes the elevation for a solar power system. It can move in one plane either vertically or horizontally. It makes the system less complicated and less expensive than a double axis solar tracker. In addition, it is optimally balances the performance with long term reliability, high durability and minimal maintenances. The DC motor and gears control the movement of the solar tracker in order to optimize the utilization of the solar energy [10].

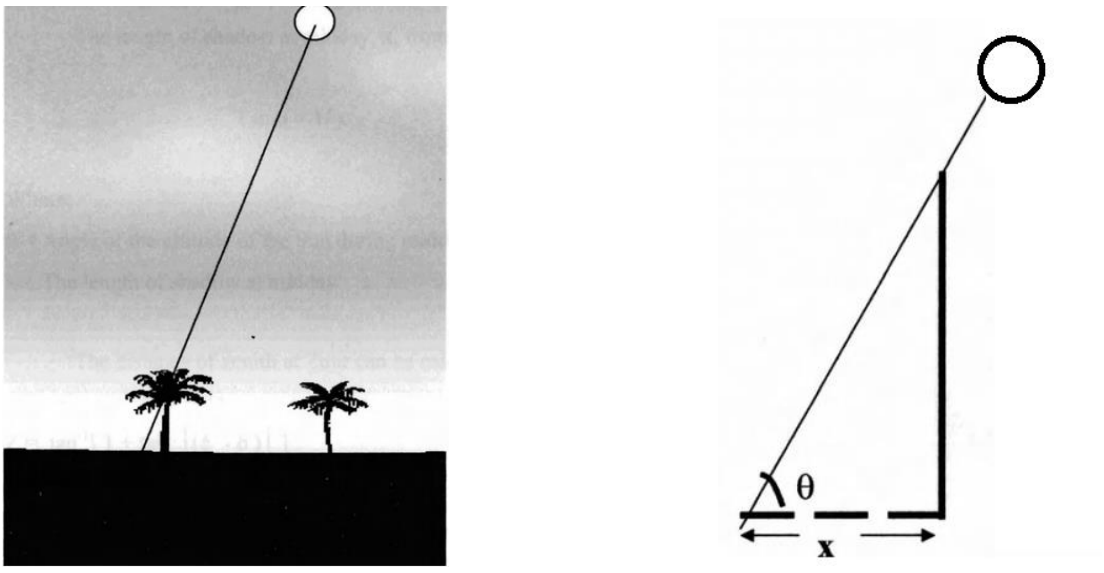
2.5 Falaq's knowledge

Muslim people are required to perform daily prayers 5 times a day. The prayer time is determined by the changes of the sun's position. In order to determine the position of the sun, Falaq's knowledge is applied. The formula of the Falaq's knowledge as shown in formula below [13]:

$$Tan\ \theta = \frac{1}{x} \qquad (2.0)$$

θ = angle of the altitude of the sun

x = length of the shadow of the object



(a) (b)

Figure 2.6 : Length of the shadow of the object [13]

2.6 Solar panel performances

The amount of output power is determined the performance of the solar panel. The output power of the solar panel will be compared with the rated output power in order to know the efficiency of the solar panel. Besides, the current and power output is approximately proportional to the sun intensity. At a given intensity, the output current and voltage of the solar panel are determined by the characteristics of the load. Figure 2.6shows the relation of the output current and voltage of the solar panel. There is the simplest solar panel operating point at a given temperature and light intensity. The increasing of the temperature will increase the output current but significantly decrease.

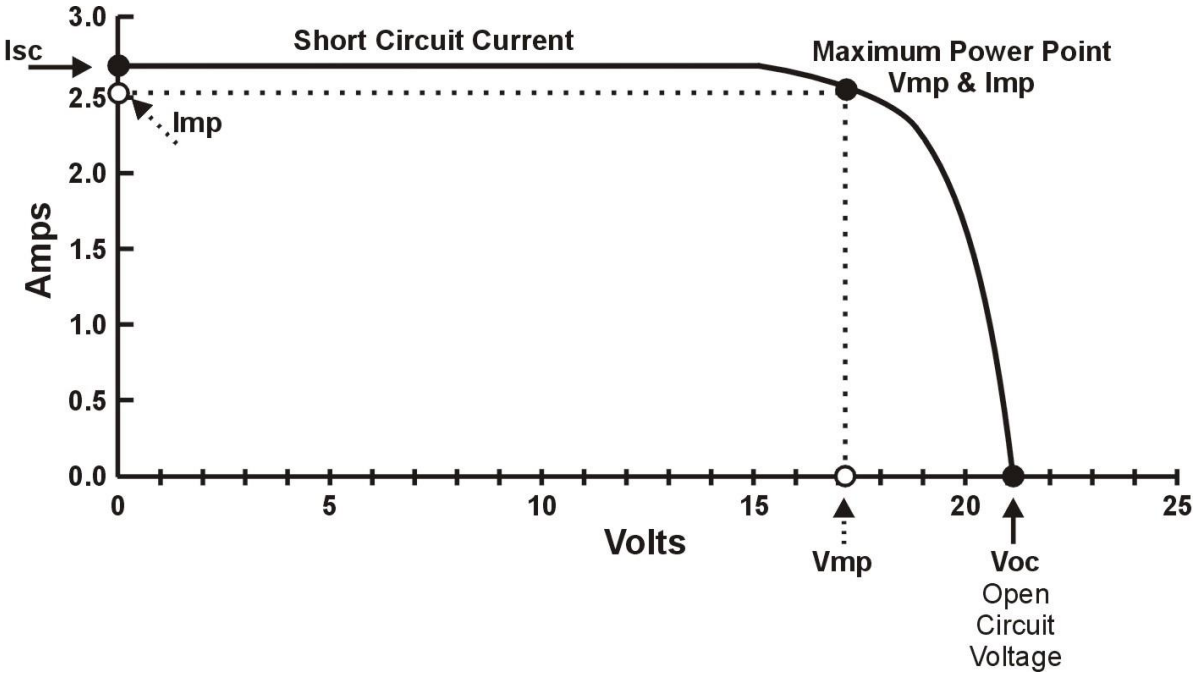


Figure 2.7 : I-V curve [16]

A solar panel, which is rated at 22 volts will produce output less than, its rated power when used in a battery system. It is because the working voltage will be between 18 and 21 volts. Power is the product of volts multiplied by the amps, the module output will be reduced. This is important to remember when sizing a PV system. Lastly, the power efficiency of the solar panel also need to be determined and can be calculated using [15]:

$$A = \frac{P2-P1}{P1} \; X \; 100 \qquad (2.1)$$

$$B = \frac{\sum(P2-P1)}{\sum P1} \; X \; 100 \qquad (2.2)$$

P1= power produced by the fixed solar panel (watt)

P2 = power produced by the fixed solar panel (watt) that attached with the solar tracker

CHAPTER 3

DESIGN METHODOLOGY

3.1 Project Methodology

The project is divided into two parts which is Projek Sarjana Muda (PSM 1) and Projek Sarjana Muda 2 (PSM 2). For PSM 1, students need to find the related information to the project. Each of the students needs to start with the literature review part which is required for the students to find any information or any previous works or project that related with the title. All the theories, backgrounds, objectives and scopes of the project have to be clarified in order to plan the expected outcomes of the project. From the journal reading, students will be able to identify the problem statement of the project which will require the solution to overcome the problem. Followed by, a plan for the future works to ensure the works are on schedule thus enabling the student to complete the research on time.

For PSM 2, the students are required to produce the result and apply necessary analysis for the result which will be recorded later on. The result can determine whether the project is successful or not. Based on the results, students are required to come up with the conclusion of the project and recommend improvements to improve the result of the project. The flow chart below shows the step of the solar tracker system project.

3.2 Project flow chart

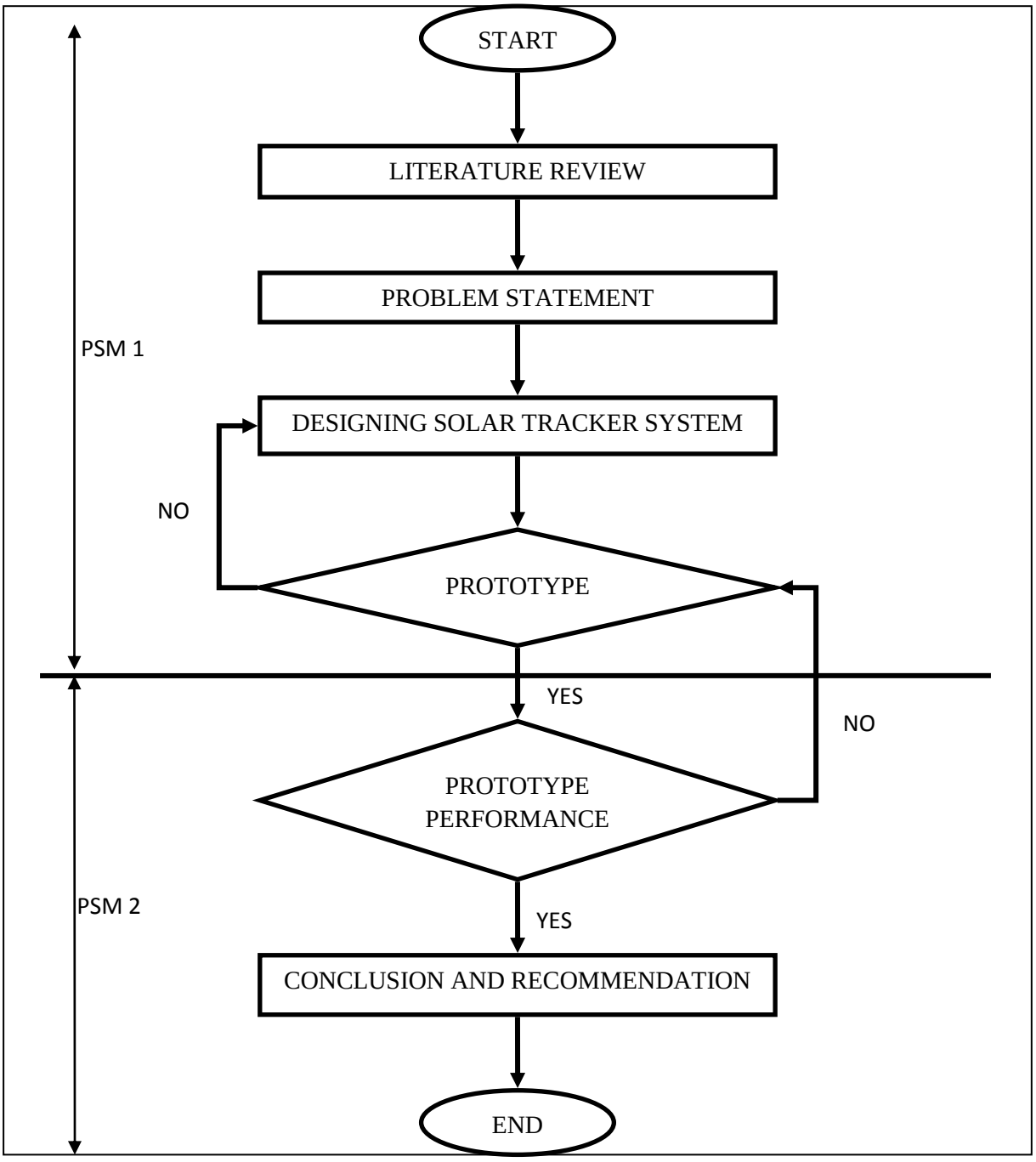


Figure 3.1: The Process of the Projek Sarjana Muda