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JUDUL: **AUTOMATED SOLAR TRACKING SYSTEM USING PLC**

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AUTOMATED SOLAR TRACKING SYSTEM USING PLC

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A thesis submitted
in fulfillment of the requirements for the award of the degree of
Bachelor of Electrical and Electronic Engineering (Power System)

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Date : 12 MAY 2009

To my beloved mother, father and Diana

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ABSTRACT

In our daily life, the need of energy increases each and every day. The source of electricity is commonly from motor generators that is generate from the source of coal or other element of fuel. Another new way in this era is by using solar energy. The solar energy convert solar irradiation to power that can be used in common electric appliances. Since solar is a new type of source, the usage of the solar is still small compare to the old conventional ways. The solar energy is converted when the solar cells on the solar panel detects light irradiation. However, the angle of the sun is proportional to the energy converted. If the sun is 90° vertical to the solar panel, the energy received is maximum compare to other angles. In this case, a project is developed to track the solar during the movement of the sun from morning till night. The ASTS (Automated Solar Tracking System) is developed by moving the solar panel during anytime of the day that the sun is available and the motor will move the panel to a 90° vertical angle directly to the sun. The system is controlled by OMRON Programmable Logic Controller which will process data from the sensor and convert it to output for the motor movement. As the result, a prototype of Automated Solar Tracking System is operated and able to achieve the objective of this project.

ABSTRAK

Dalam kehidupan harian, penggunaan tenaga bertambah dari hari ke hari. Punca tenaga elektrik sebahagian besar adalah daripada generator motor yang mendapat bahan bakat daripada pembakaran arang atau bahan bakar yang lain. Satu cara baru di zaman ini adalah dengan penggunaan tenaga solar. Tenaga solar adalah ditukar daripada radiasi cahaya matahari kepada tenaga elektrik yang boleh digunakan oleh perkakas elektrik yang biasa digunakan seharian. Disebabkan tenaga solar adalah satu sumber tenaga yang baru, oleh itu penggunaan tenaga solar masih sedikit berbanding dengan penggunaan tenaga daripada bahan bakar.Tenaga solar diproses apabila tenaga radiasi matahri dikesan. Walaubagaimanapun, sudut matahari berkadar terus dengan tenaga elektrik yang dihasilkan. Jika sudut matahari adalah 90° kepada solar panel, tenaga yang diproses adalah maksimum berbanding dengan sudut yang lain.Dalam kes ini, sebuah projek dibina untuk mengesan matahari apabila ia bergerak daripada pagi hingga ke malam. Projek ’Automated Solar Tracking System ’ dibina untuk mengesan matahari pada waktu pagi dan ia akan menggereakkan motor untuk memposisikan solar panel 90° kepada cahaya matahari. Sistem ini dikendali oleh OMRON ’Programmable Logic Controller’yang akan memproses data daripada sensor dan mendapatkan output untuk menggerakkan motor. Diakhir projek, sebuah prototaip Automated Solar Tracking System Berjaya dihasilkan yang mengikut objektif projek.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

The sun is a low cost source of electricity for instead of using generators, solar panel can convert direct sun rays to electricity. Conventional solar panel, fixed with a certain angle, limits their area of exposure from the sun due to rotation of the earth. Output of the solar cells depends on the intensity of the sun and the angle of incidence.

In pursuing to get the maximum energy converted from the sun, an automated system is required which should be capable to constantly rotate the solar panel. The Automatic Sun Tracking System (ASTS) is a project meant to solve this problem. It is completely automatic and keeps the panel parallel to the sun.

In this project, it the ASTS takes the sun as a guiding source. Sensors are used to constantly monitor the sunlight and rotate the solar panel to the maximum intensity of sunlight. PLC (Programmable Logic Controller) is used as a device for controlling the output for the motor. If the sun is not visible during a short period due to cloudy weather, the PLC is set with a program which will engage the motor rotation to halt which only will be reactivated due to a sensor which will detect availability of the sun to continue its next cycle.

1.2 RESEARCH OBJECTIVES

This study attempts to achieve the following objective:

i. To develop a solar tracker with optimum tracking from the sun.

ii. Positioning of solar panel through stepper motor control using PLC.

iii. Result for the efficiency of the device.

1.3 SCOPE OF PROJECT

This project is focused to develop and build an Automated Solar Tracking System (ASTS) by using plc to move the DC motor that will direct the solar panel from east to west and back to its initial. Therefore, the project scope is as follow.

i. An automated tracking system which detects the sun during daylight.

ii. Use PLC to move the motor clockwise or counterclockwise.

iii. Show result by differentiate with other angle reading.(45 , 90 , 135)

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1.4 PROBLEM STATEMENT

This study aims to seek the following research:

i. The sun is moving 180º from east to west so the light irradiation is varied due to the rotation cycle of the earth.

ii. A solar panel which is static for instant 45º (east/west) will only take the light irradiation w/m² at the first 90º or the end 180º therefore the maximum power for the solar panel does not occur.

1.5 THESIS ORGANIZATION

This thesis consists of five chapters. This chapter discuss about overview of project, objective research, project scope, problem statement and thesis organization.

Chapter 2 contains a detailed description and idea of Automated Solar Tracking System using PLC or other device. It will explain about the concept of sun tracking using LDR for maximum light power, the advantage of this system and the involved component in this project.

Chapter 3 includes the project methodology. It will explain how the project is organized and the flow of process in completing this project. Also in this topic discusses the methodology of the system, step to develop the system, and device used to measure the light irradiation and angle of solar panel during each data taken.

Chapter 4 will be discussing about the result obtained in this project and a discussion about the result.

Finally, the conclusions for this project are presented in chapter 5. This chapter also discusses about the recommendation for the project and for the future development.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Solar panel is a board that contains many solar cells. These two sensors are mounted in “V” shape as in figure 1 exactly in the middle of the solar panel. The automatic sun tracking is accomplished according to following 3-step diagram. There is 2 sensors used in this project. The idea of using the sensor is selecting two most appropriate types which in this case the use of LDR (Light Dependant Resistor) which sense light energy. Since these sensors give resistance proportional to light efficiency, we can use a circuit to conduct the system. [2]

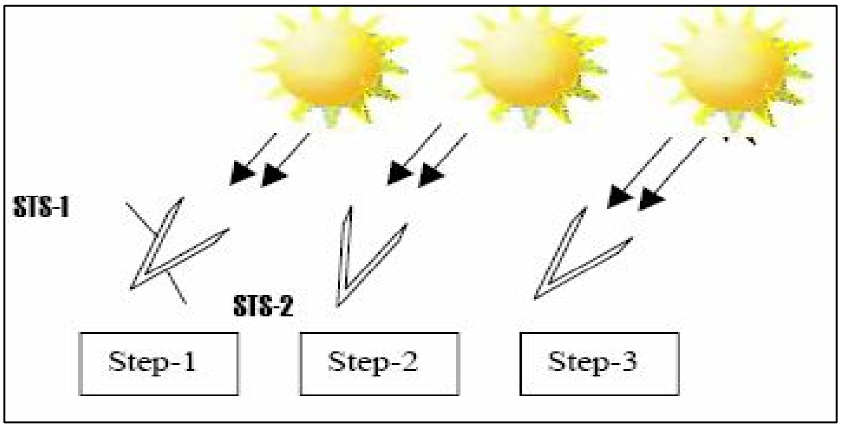
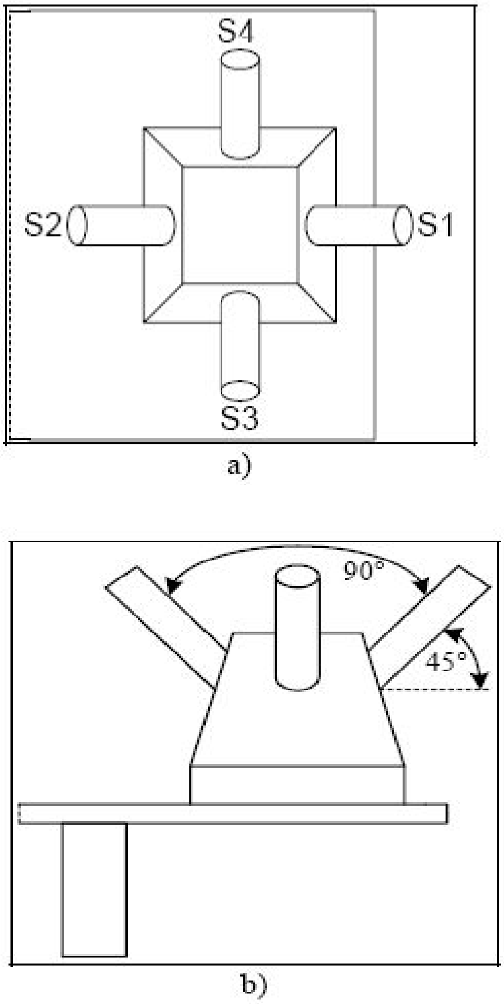


Figure 2.1: Basic Automatic Sun Tracking System.

Step-1 shows that when the sun is in front of solar panel, both sensors which is STS-1 and STS-2 are getting same amount of light. In step-2, after some time as the earth rotates the solar panel gets repositioned with respect to sun and STS-1 obtains less amount of light. At this point the STS-1 sends signal to the circuit. Then the circuit will sends data to the PLC and process it to rotate the stepper motor, result in the rotation of solar panel towards the sun. Finally step-3 shows the reorientation of solar panel. Finally step-3 shows the reorientation of solar panel. The process continues until the end of day.[2]



a)

b)

Figure 2.2: LDR assembly a) Top view b) Front

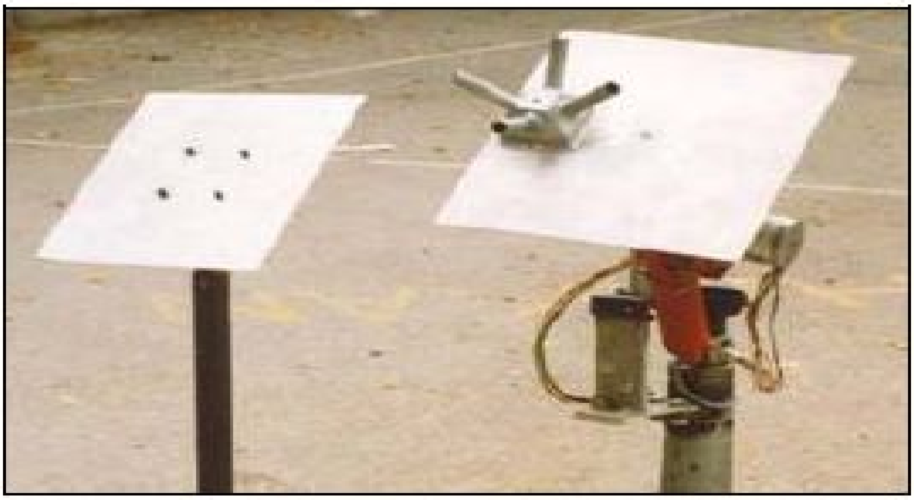


Figure 2.3: A photograph of ASTS.

Image Processing provides a comprehensive set of reference-standard algorithms and graphical tools for image processing, analysis, visualization, and algorithm development. You can restore noisy or degraded images, enhance images for improved intelligibility, extract features, analyze shapes and textures, and register two images. Image Processing Toolbox supports engineers and scientists in areas such as biometrics, remote sensing, surveillance, gene expression, microscopy, semiconductor testing, image sensor design, colour science, and materials science. It also facilitates the learning and teaching of image processing techniques. Image processing is any form of signal processing for which the input is an image, such as photographs or frames of video the output of image processing can be either an image or a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal-processing techniques to it.[2]

2.2 Light Dependent Resistor

A photoresistor or light dependent resistor or cadmium sulfide (CdS) cell is a resistor whose resistance decreases with increasing incident light intensity. It can also be referenced as a photoconductor. [7]

A photoresistor is made of a high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump into the conduction band. The resulting free electron (and its hole partner) conduct electricity, thereby lowering resistance. [7]

A photoelectric device can be either intrinsic or extrinsic. An intrinsic semiconductor has its own charge carriers and is not an efficient semiconductor, e.g. silicon. In intrinsic devices the only available electrons are in the valence band, and hence the photon must have enough energy to excite the electron across the entire bandgap. Extrinsic devices have impurities, also called dopants, and added whose ground state energy is closer to the conduction band; since the electrons do not have as far to jump, lower energy photons (i.e., longer wavelengths and lower frequencies) are sufficient to trigger the device. If a sample of silicon has some of its atoms replaced by phosphorus atoms (impurities), there will be extra electrons available for conduction. This is an example of an extrinsic semiconductor. [7]

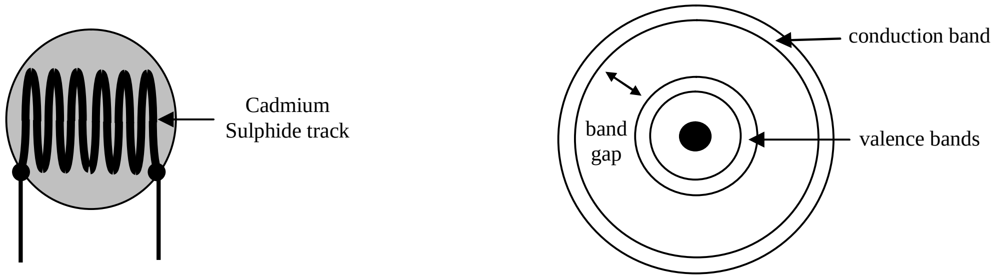


Figure 2.4: Structure of a Light Dependent Resistor, showing Cadmium Sulphide track and an atom to illustrate electrons in the valence and conduction bands.

2.3 Direct Current Motor

There are several types of DC motors that are available. Their advantages, disadvantages, and other basic information are listed below in the Table 2.1.

DC motor works by converting electric power into mechanical work. This is accomplished by forcing current through a coil and producing a magnetic field that spins the motor. The simplest DC motor is a single coil apparatus, used here to discuss the DC motor theory. [1]

The voltage source forces voltage through the coil via sliding contacts or brushes that are connected to the DC source. These brushes are found on the end of the coil wires and make a temporary electrical connection with the voltage source. In this motor, the brushes will make a connection every 180 degrees and current will then flow through the coil wires. At 0 degrees, the brushes are in contact with the voltage source and current is flowing. The current that flows through wire segment C-D interacts with the magnetic field that is present and the result is an upward force on the segment. The current that flows through segment A-B has the same interaction, but the force is in the downward direction. Both forces are of equal magnitude, but in opposing directions since the direction of current flow in the segments is reversed with respect to the magnetic field. At 180 degrees, the same phenomenon occurs, but segment A-B is forced up and C-D is forced down. At 90 and 270-degrees, the brushes are not in contact with the voltage source and no force is produced. In these two positions, the rotational kinetic energy of the motor keeps it spinning until the brushes regain contact. [1]

One drawback to the motor is the large amount of torque ripple that it has. The reason for this excessive ripple is because of the fact that the coil has a force pushing on it only at the 90 and 270 degree positions. The rest of the time the coil spins on its own and the torque drops to zero. The torque curve produced by this single coil, as more coils are added to the motor, the torque curve is smoothed out. [1]

The resulting torque curve never reaches the zero point and the average torque for the motor is greatly increased. As more and more coils are added, the torque curve approaches a straight line and has very little torque ripple and the motor runs much more smoothly. Another method of increasing the torque and rotational speed of the motor is to increase the current supplied to the coils. This is accomplished by increasing the voltage that is sent to the motor, thus increasing the current at the same time. [1]

Table 2.1 Advantages and disadvantages of various types of DC motor

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Type	**Advantages**	**Disadvantages**
Stepper Motor	Very precise speed and position control. High Torque at low speed.	Expensive and hard to find. Require a switching control circuit
DC Motor w/field coil	Wide range of speeds and torques. More powerful than permanent magnet motors	Require more current than permanent magnet motors, since field coil must be energized. Generally heavier than permanent magnet motors. More difficult to obtain.
DC permanent magnet motor	Small, compact, and easy to find. Very inexpensive	Generally small. Cannot vary magnetic field strength.
Gasoline (small two stroke)	Very high power/weight ratio. Provide Extremely high torque. No batteries required.	Expensive, loud, difficult to mount, very high vibration.

2.4 Omron 24Vdc Relay.

A relay is a simple electromechanical switch made up of an electromagnetic and a set of contacts. Relays are found hidden in all sorts of devices. In fact, some of the first computers ever built used relays to implement Boolean Gates.[4]

Relays are amazingly simple devices. There are four parts in every relay:

- Electromagnet
- Armature that can be attracted by the electromagnet
- Spring
- Set of electrical contacts

The following figure shows these four parts in action:

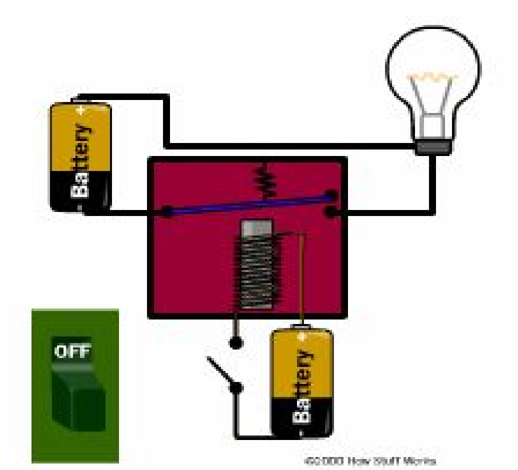


Figure 2.5: Simple relay circuit.

In this figure, you can see that a relay consists of two separate and completely independent circuits. The first is at the bottom and drives the electromagnetic. In this circuit, a switch is controlling power to the electromagnet. When the switch is on, the electromagnet is on, and it attracts the armature (blue). The armature is acting as a switch in the second circuit. When the electromagnet is energized, the armature completes the second circuit and the light is on. When the electromagnet is not energized, the spring pulls the armature away and the circuit is not complete. In that case, the light is dark.[4]

When purchase relays, you generally have control over several variables:

- The voltage and current that is needed to activate the armature
- The maximum voltage and current that can run through the armature and the armature contacts
- The number of armatures (generally one or two)
- The number of contacts for the armature (generally one or two -- the relay shown here has two, one of which is unused)
- Whether the contact (if only one contact is provided) is normally open (NO) or normally closed (NC)

2.5 PROGRAMMABLE LOGIC CONTROLLER

A programmable logic controller (PLC) or programmable controller is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, amusement rides, or lighting fixtures. PLCs are used in many industries and machines, such as packaging and semiconductor machines. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. Programs to control machine operation are typically stored in battery-backed or non-volatile memory. A PLC is an example of a real time system since output results must be produced in response to input conditions within a bounded time, otherwise unintended operation will result.[8]

A small PLC will have a fixed number of connections built in for inputs and outputs. Typically, expansions are available if the base model has insufficient I/O.Modular PLCs have a chassis (also called a rack) into which are placed modules with different functions. The processor and selection of I/O modules is customized for the particular application. Several racks can be administered by a single processor, and may have thousands of inputs and outputs. A special high speed serial I/O link is used so that racks can be distributed away from the processor, reducing the wiring costs for large plants.[8]

PLCs may need to interact with people for the purpose of configuration, alarm reporting or everyday control. A Human-Machine Interface (HMI) is employed for this purpose. HMIs are also referred to as MMIs (Man Machine Interface) and GUI (Graphical User Interface).A simple system may use buttons and lights to interact with the user. Text displays are available as well as graphical touch screens. More complex systems use a programming and monitoring software installed on a computer, with the PLC connected via a communication interface.[8]

PLCs have built in communications ports usually 9-Pin RS232, and optionally for RS485 and Ethernet. Modbus or DF1 is usually included as one of the communications protocols. Others' options include various fieldbuses such as DeviceNet or Profibus. Other communications protocols that may be used are listed in the List of automation protocols.Most modern PLCs can communicate over a network to some other system, such as a computer running a SCADA (Supervisory Control And Data Acquisition) system or web browser.[8]

PLCs used in larger I/O systems may have peer-to-peer (P2P) communication between processors. This allows separate parts of a complex process to have individual control while allowing the subsystems to co-ordinate over the communication link. These communication links are also often used for HMI devices such as keypads or PC-type workstations. Some of today's PLCs can communicate over a wide range of media including RS-485, Coaxial, and even Ethernet for I/O control at network speeds up to 100 Mbit/s.[8]

PLCs are well-adapted to a range of automation tasks. These are typically industrial processes in manufacturing where the cost of developing and maintaining the automation system is high relative to the total cost of the automation, and where changes to the system would be expected during its operational life. PLCs contain input and output devices compatible with industrial pilot devices and controls; little electrical design is required, and the design problem centers on expressing the desired sequence of operations in ladder logic (or function chart) notation. PLC applications are typically highly customized systems so the cost of a packaged PLC is low compared to the cost of a specific custom-built controller design. On the other hand, in the case of mass-produced goods, customized control systems are economic due to the lower cost of the components, which can be optimally chosen instead of a "generic" solution, and where the non-recurring engineering charges are spread over thousands or millions of units.[8]

For high volume or very simple fixed automation tasks, different techniques are used. For example, a consumer dishwasher would be controlled by an electromechanical cam timer costing only a few dollars in production quantities.[8]

A microcontroller-based design would be appropriate where hundreds or thousands of units will be produced and so the development cost (design of power supplies and input/output hardware) can be spread over many sales, and where the end-user would not need to alter the control. Automotive applications are an example; millions of units are built each year, and very few end-users alter the programming of these controllers. However, some specialty vehicles such as transit busses economically use PLCs instead of custom-designed controls, because the volumes are low and the development cost would be uneconomic.[8]

Very complex process control, such as used in the chemical industry, may require algorithms and performance beyond the capability of even high-performance PLCs. Very high-speed or precision controls may also require customized solutions; for example, aircraft flight controls.Programmable controllers are widely used in motion control, positioning control and torque control. Some manufacturers produce motion control units to be integrated with PLC so that G-code (involving a CNC machine) can be used to instruct machine movements.[8]

PLCs may include logic for single-variable feedback analog control loop, a "proportional, integral, derivative" or "PID controller." A PID loop could be used to control the temperature of a manufacturing process, for example. Historically PLCs were usually configured with only a few analog control loops; where processes required hundreds or thousands of loops, a distributed control system (DCS) would instead be used. As PLCs have become more powerful, the boundary between DCS and PLC applications has become less distinct.[8]

PLCs have similar functionality as Remote Terminal Units. An RTU, however, usually does not support control algorithms or control loops. As hardware rapidly becomes more powerful and cheaper, RTUs, PLCs and DCSs are increasingly beginning to overlap in responsibilities, and many vendors sell RTUs with PLC-like features and vice versa. The industry has standardized on the IEC 61131-3 functional block language for creating programs to run on RTUs and PLCs, although nearly all vendors also offer proprietary alternatives and associated development environments.

Digital or discrete signals behave as binary switches, yielding simply an On or Off signal (1 or 0, True or False, respectively). Push buttons, limit switches, and photoelectric sensors are examples of devices providing a discrete signal. Discrete signals are sent using either voltage or current, where a specific range is designated as *On* and another as *Off*. For example, a PLC might use 24 V DC I/O, with values above 22 V DC representing *On*, values below 2VDC representing *Off*, and intermediate values undefined. Initially, PLCs had only discrete I/O.[8]

Analog signals are like volume controls, with a range of values between zero and full-scale. These are typically interpreted as integer values (counts) by the PLC, with various ranges of accuracy depending on the device and the number of bits available to store the data. As PLCs typically use 16-bit signed binary processors, the integer values are limited between -32,768 and +32,767. Pressure, temperature, flow, and weight are often represented by analog signals. Analog signals can use voltage or current with a magnitude proportional to the value of the process signal. For example, an analog 4-20 mA or 0 - 10 V input would be converted into an integer value of 0 - 32767.[8]

Current inputs are less sensitive to electrical noise (i.e. from welders or electric motor starts) than voltage inputs.As an example, say a facility needs to store water in a tank. The water is drawn from the tank by another system, as needed, and our example system must manage the water level in the tank.[8]

Using only digital signals, the PLC has two digital inputs from float switches (Low Level and High Level). When the water level is above the switch it closes a contact and passes a signal to an input. The PLC uses a digital output to open and close the inlet valve into the tank.[8]

When the water level drops enough so that the Low Level float switch is off (down), the PLC will open the valve to let more water in. Once the water level rises enough so that the High Level switch is on (up), the PLC will shut the inlet to stop the water from overflowing. This rung is an example of seal in logic. The output is sealed in until some condition breaks the circuit.[8]

```
|   Low Level      High Level                 Fill Valve      |
|------[/]------|------[/]----------------------(OUT)---------|
|               |                                             |
|               |                                             |
|               |                                             |
|   Fill Valve  |                                             |
|------[ ]------|                                             |
|                                                             |
|                                                             |
```

Figure 2.6 PLC Program

In this system, to avoid 'flutter' adjustments that can wear out the valve, many PLCs incorporate "hysteresis" which essentially creates a "deadband" of activity. A technician adjusts this deadband so the valve moves only for a significant change in rate. This will in turn minimize the motion of the valve, and reduce its wear.A real system might combine approaches, using float switches and simple valves to prevent spills, and a rate sensor and rate valve to optimize refill rates and prevent water hammer. Backup and maintenance methods can make a real system very complicated.

PLC programs are typically written in a special application on a personal computer, and then downloaded by a direct-connection cable or over a network to the PLC. The program is stored in the PLC either in battery-backed-up RAM or some other non-volatile flash memory. Often, a single PLC can be programmed to replace thousands of relays. Under the IEC 61131-3 standard, PLCs can be programmed using standards-based programming languages. A graphical programming notation called Sequential Function Charts is available on certain programmable controllers. Recently, the International standard IEC 61131-3 has become popular. IEC 61131-3 currently defines five programming languages for programmable control systems: FBD (Function block diagram), LD (Ladder diagram), ST (Structured text, similar to the Pascal programming language), IL (Instruction list, similar to assembly language) and SFC (Sequential function chart). These techniques emphasize logical organization of operations. While the fundamental concepts of PLC programming are common to all manufacturers, differences in I/O addressing, memory organization and instruction sets mean that PLC programs are never perfectly interchangeable between different makers. Even within the same product line of a single manufacturer, different models may not be directly compatible.[8]

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

This chapter explains detail about the methodology of the whole system and flow of step to perform the automated solar tracking system for result efficiency from the solar. This chapter describes on circuit and device used in the project and steps for each upcoming result.

3.2 SYSTEM DESIGN

In figure 3.1 shows the overall system design for the Automated Solar Tracking System (ASTS). The device used is consist of two Light Dependent Resistor (LDR) circuit, one relay circuit, two limit switch , one dc motor and a Programmable Logic Controller (PLC). The LDR 1 circuit detects the availability of sun during 6 am till 6 p.m. Once it detects the sun, the motor will move from east to west (clockwise). LDR 2 which is placed inside the black cylinder on top of the board is used to detect positioning of the sun during daylight. Once it detects the sun, it will then stop the motor on that angle so that the board is vertical to sun for maximum sun irradiation. Every time the sun moves, the angle will change and the LDR 2 detects it until the motor rod touch the limit switch 1(west) which will turn the motor rod back to initial condition. Relay circuit is used to move the motor clockwise and counter-clockwise where the input of the relay is a 24Vdc form the output of PLC. Limit switch 2 detects the motor rod once it returns to its initial condition (east). The output of limit switch 1 and limit switch 2 is connected to PLC where it will then trigger the relay and move the motor counter-clockwise.

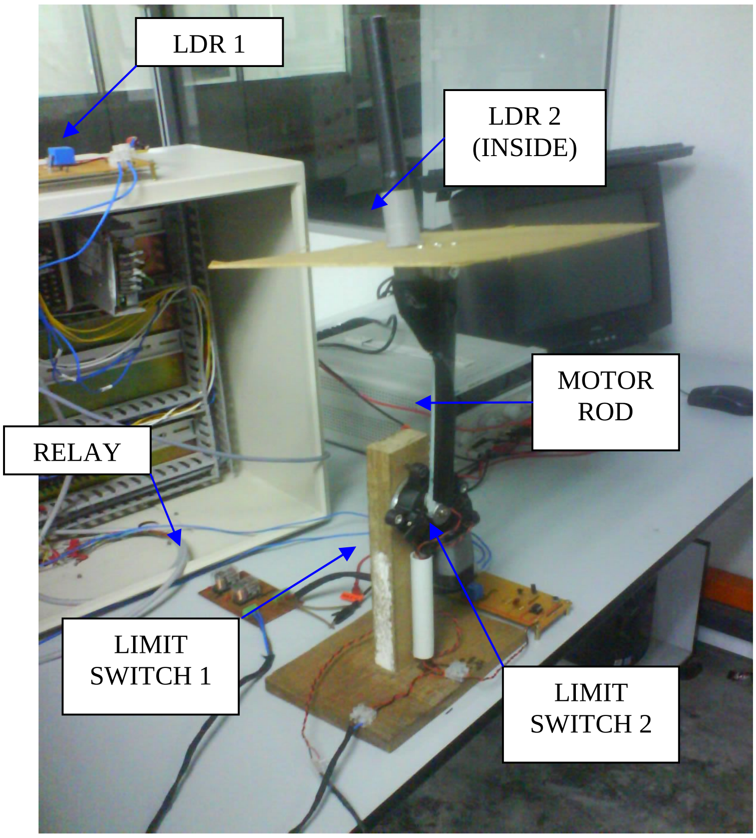


Figure 3.1: Automated Solar Tracking System.

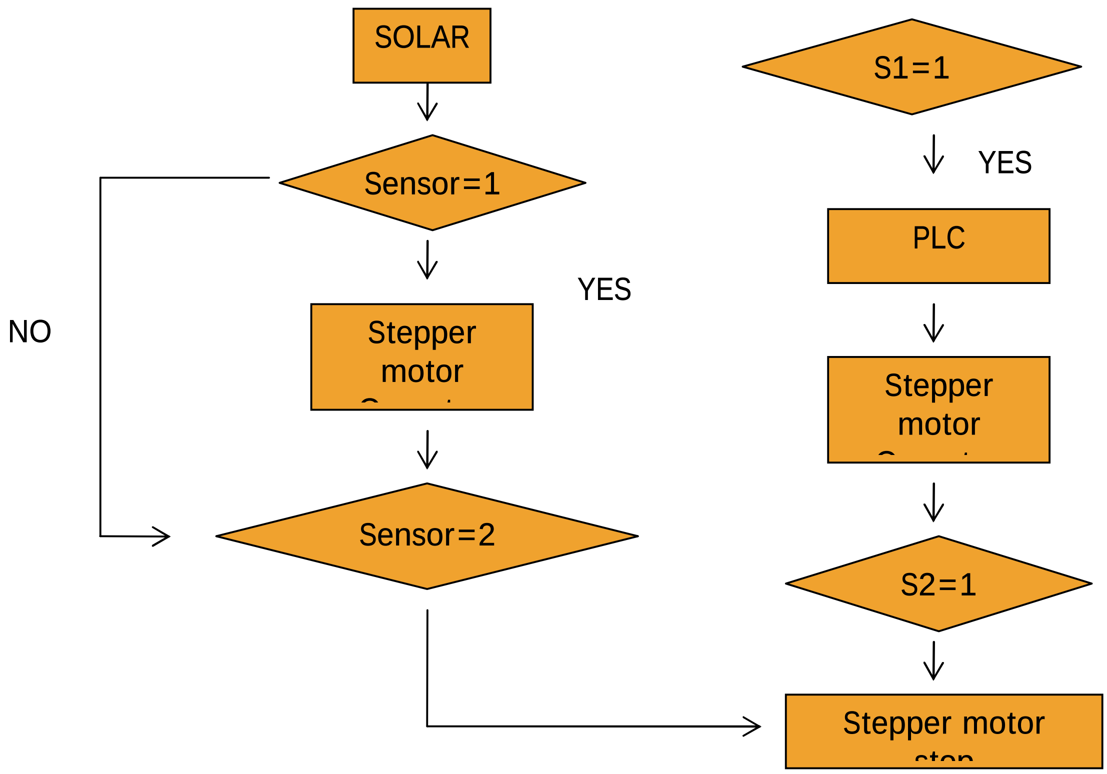


Figure 3.2: Flow chart of overall system.

3.3 HARDWARE IMPLEMENTATION

This section will discuss on components used for the ASTS which is the Light Dependant Resistor circuit, 24Vdc relay circuit and the connection from the PLC to the limit switches, relay and LDR circuits.

3.3.1 CIRCUIT OF LIGHT DEPENDANT RESISTOR

The circuit is use as a sensor to detect solar for the whole system. The output from this circuit is a relay which will work as a switch that connects the logic ‘1’ to the plc. They are two LDR circuits used. One is to detect sun availability and the other for sun positioning. Variable resistor (22kΩ) is varied to 3.16kΩ for the circuit to detect sun ray only. This must be check so that the circuit won’t respond to other light source (etc. torchlight, fire, and lamp). The circuit works with a 9Vdc power supply.

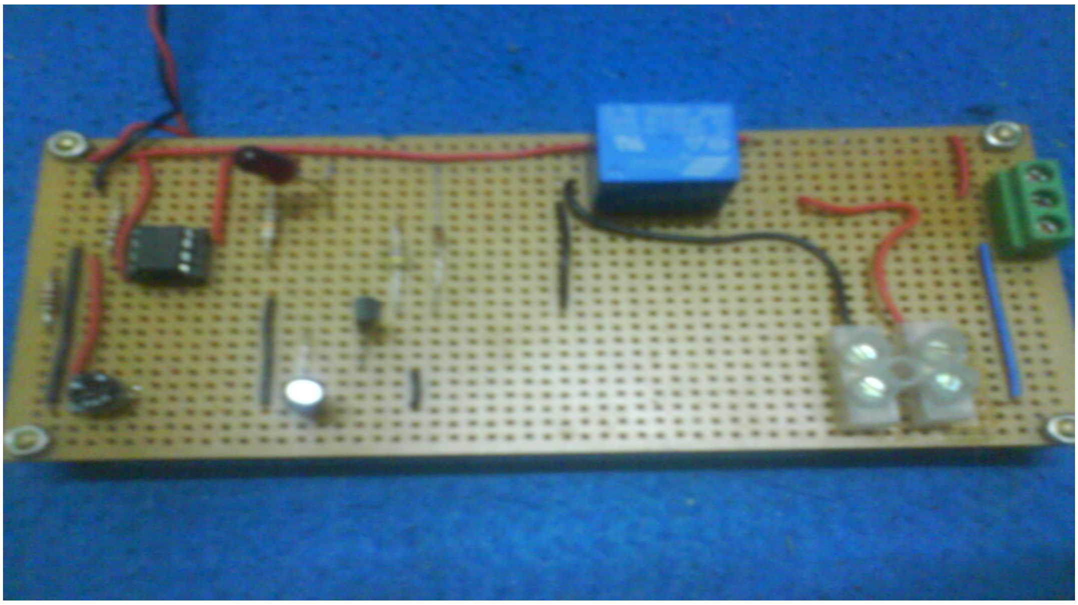


Figure 3.3: Light Dependant Resistor circuit picture.

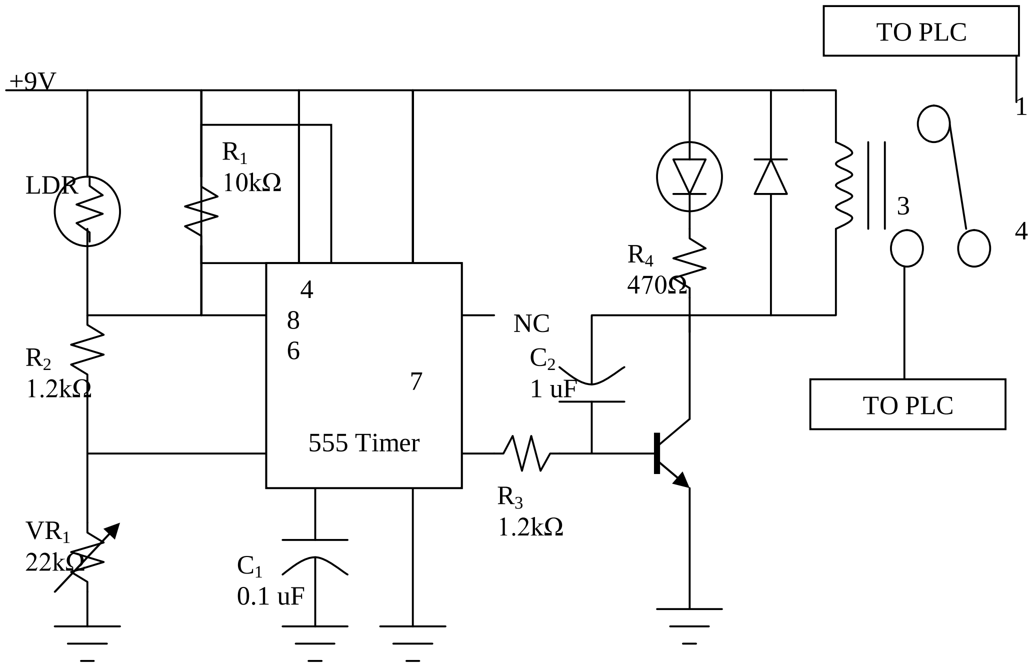


Figure 3.4: Light Dependant Resistor circuit.

3.3.2 CIRCUIT OF DC MOTOR WITH RELAY

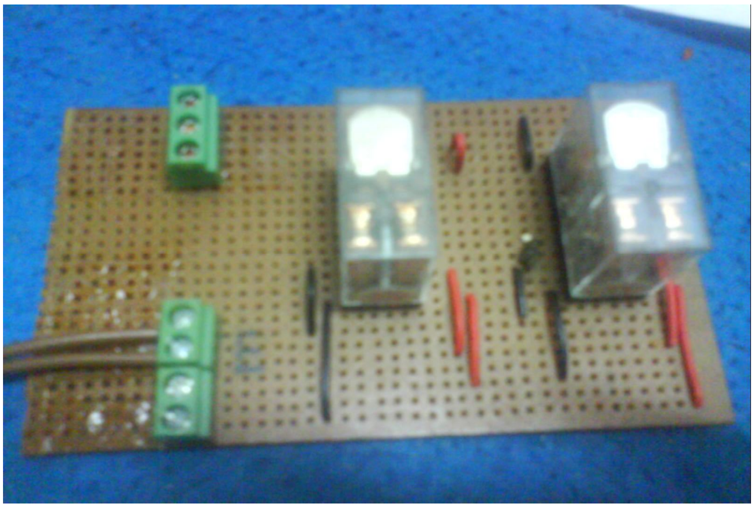


Figure 3.5: Relay circuit picture.

Circuit in Figure 3.6 shows the connection of DC motor to relay for clockwise and counter-clockwise motion. This is construct so that the system will start back from the origin during daylight and ends during night time. R1 represent relay 1 and R2 represent relay 2. Relay 1 is connected to output address 100.01 of the PLC and relay 2 is connected to output address 100.02.

Relay 1 (R1) triggered due to 24Vdc supply from the PLC. This will connect the motor to move clockwise. When relay 2 (R2) is triggered, the motor will move counter-clockwise. The source for the motor is 2.2V with high current of 3.2A. This is because using a DC motor we need to control the speed of the motor by varying the voltage and current to the desired speed which in this case the motor need to move very slowly so that it could detect the sun in every angle from east to west.

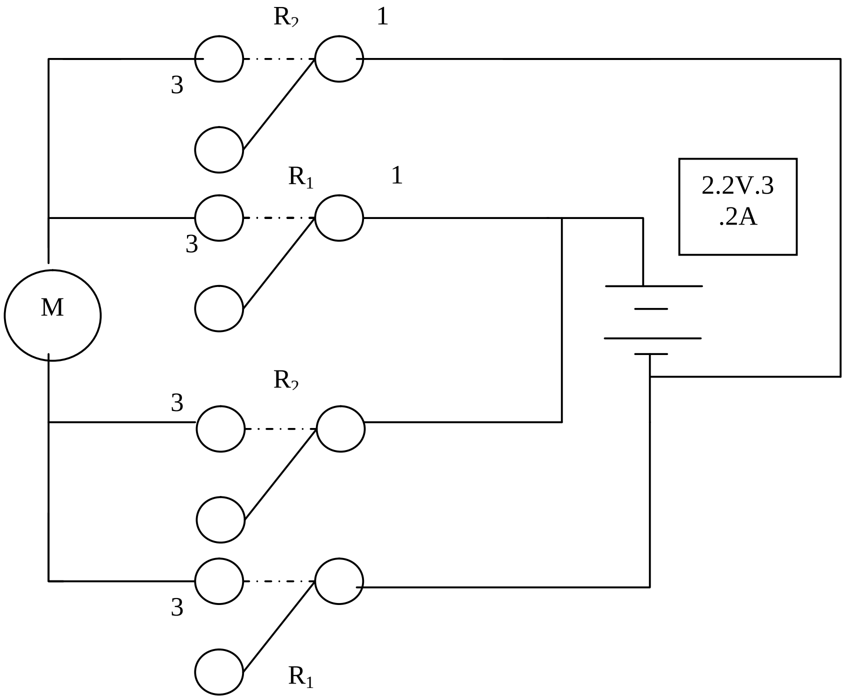


Figure 3.6: Connection to motor from relay. (Clockwise and counter-clockwise)

3.3.3 CONNECTION FOR PROGRAMMABLE LOGIC CONTROLLER.

LDR 1 is connected to PLC input port 0000 and LDR 2 to PLC port 0001.Limit switch 1 to port 0002 and limit switch 2 to port 0003.Relay 1 is connected to output port 100.01 and relay 2 to output port 100.02.

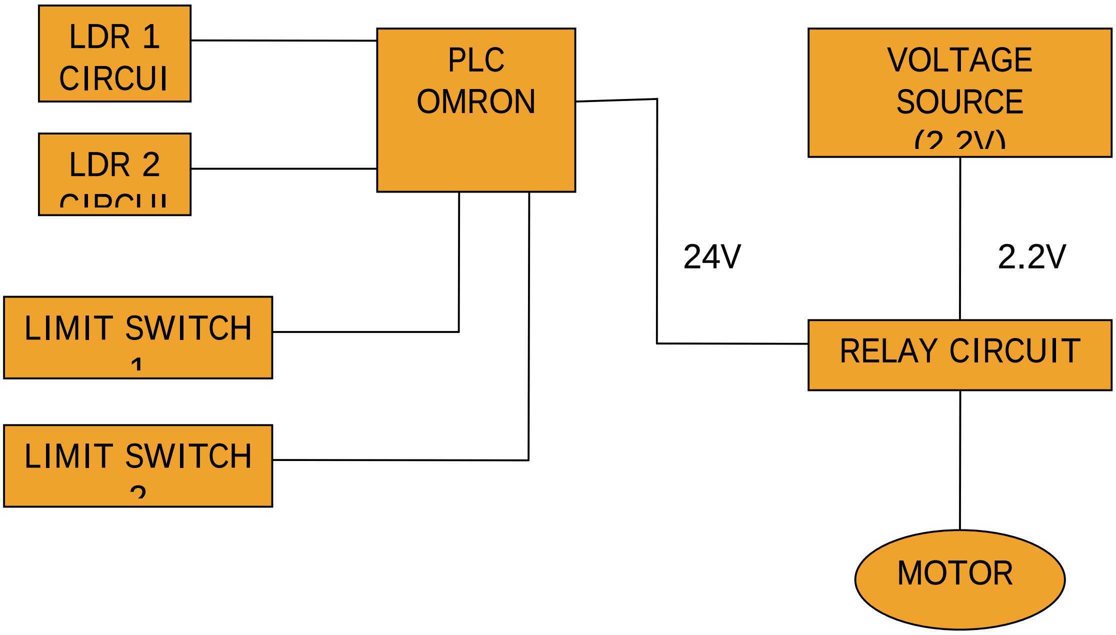
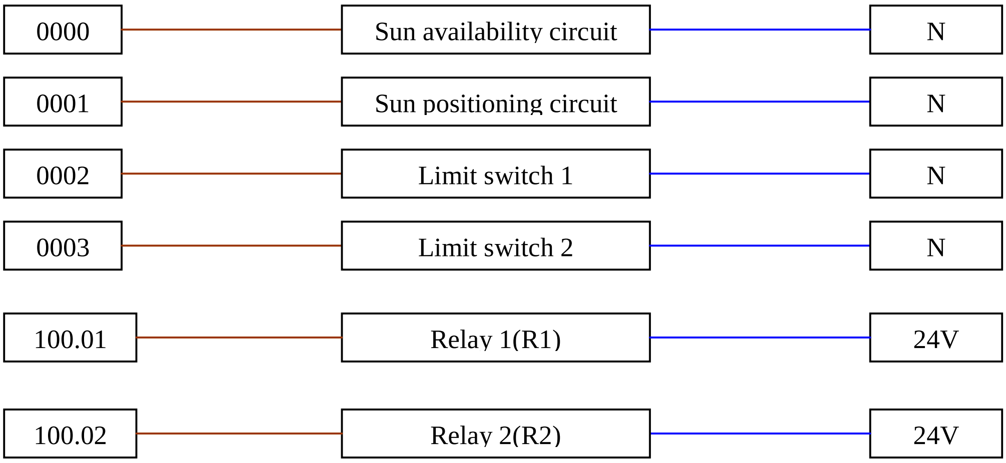


Figure 3.7: Overall connection of PLC.



0000	Sun availability circuit	N
0001	Sun positioning circuit	N
0002	Limit switch 1	N
0003	Limit switch 2	N
100.01	Relay 1(R1)	24V
100.02	Relay 2(R2)	24V

Figure 3.8: Connection of PLC port input and output.

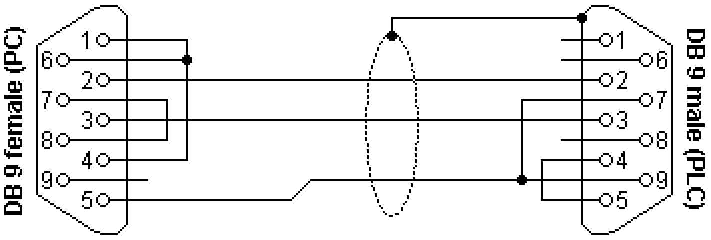


Figure 3.9: DB 9 RS232 programming cable.

DB9 RS232 cable is connected to a computer to transfer the program for the PLC. It’s divided to two parts which is the male and female part. The connectors are connected to the RS 232 of both PLC and computer.

3.4 ASTS IMPLEMENTATION TO REAL CONDITION.

Using the system above, irradiation, voltage, current and temperature of the sun is measured using a solar measuring device MACSOLAR and Compass clinometer from SUUNTO to measure the angle of reading.

Every 15 minutes, reading of solar and angel is taken from both devices. This is due to check the efficiency of the ASTS device due to real time implementation. Every result is taken in irradiation, voltage percent, current percent, temperature, and angle. In theory for a still solar panel which is in this case 45 degrees, 90 degrees and 135 degrees, the result should be in this form of graph.

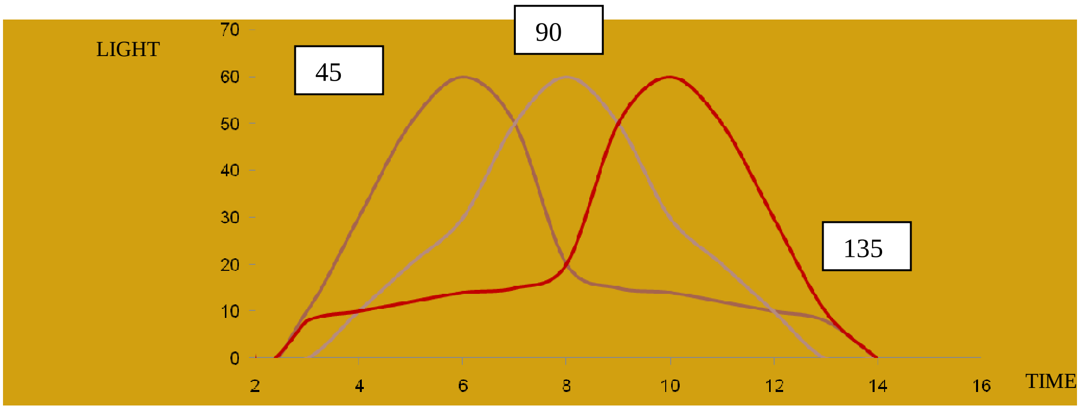


Figure 3.10: Theoretical reading for solar panel on still condition.

3.4.1 MEASURING IRRADIATION, VOLTAGE, CURRENT AND TEMPERATURE USING MACSOLAR.

3.4.1.1 MACSOLAR E (economy)

A photovoltaic solar electric panel generates DC power when it is exposed to sunlight. DC electrical power wattage is the product of voltage and current. The power generated by any solar panel in full sunlight depends on the resistance of the electrical load connected to it. Resistance is measured in Ohms unit. The relationship between current, voltage and resistance is referred to as Ohm's law. The current through a resistor is the applied voltage divided by the resistance.

Current = Voltage / Resistance

An issue that pops up is the amount of power generated by one panel. The conservative method of measuring the power output of a solar panel is to connect resistors of various values to the panel and measure the voltage. The measurements can be used to calculate the power output. The same measurements can be used to plot the power output and construct a performance graph for the panel. However today, the calculation and measurement are made easy with the high-tech innovation of various solar measuring devices. MacSolar is one of the solar measuring devices available in the market.

3.4.1.2 INTRODUCTION

MacSolar is a useful gadget especially for solar engineers, architects and hobby users. The MacSolar aids in the direct and uncomplicated measuring of the actual intensity of light. The sensor, power supply and display are integrated in a handy and compact gadget. Thus, the information on the light conditions at various locations of an object can be acquired. In addition, typical nominal data of a solar module such as voltage, current or power are also determinable by the MacSolar. The user can thus obtain immediate information about the composition and concept of a photovoltaic system.

MacSolar E is used in fulfilling this project. The basic version of MacSolar E features a sensor for measuring global radiation, a sensor for measuring temperature, a display and operation unit and a solar power supply. This basic version also permits the measurement of light intensity and temperature by using the direct measuring mode. In addition, also available is a mode for registering maximum values. Values are necessary for calculating solar plants, also within the field of building physics and solar training facilities. A long term measurements are not possible hence MacSolar E is dispensed without mounting fixture.

The rated power of the solar panel is 180mW*1. In active mode, the power consumption is as high a s 4mW. It can endure temperature as low as -20 to 50°C The max ambient humidity is 90%. The dimensions of a MacSolar without mounting are 130 x 90 x 30mm which is equal to 5.1 x 3.5 x 1.2 inches with weight of 170g or 6 oz. Further details are as follows:

T_{module} = 0…+50°C)
Overall accuracy =T < 3K ± 1 digit (-25…+75°C)

Table 3.1: Measuring Range / Resolution

	P_{tot}	T
Unit	W/m^2	$^{\circ}C$
Values	0 … 1500	-40 … +85
Resolution	1	0.1

3.4.1.3 PRINCIPLE OF OPERATION

The monocrystalline silicon solar cell which additionally takes over the energy supply of the device facilitates the measurement. The internal microprocessor provides automatic correction in order to obtain fundamental precision after calibration of each unit in a solar simulator.

The MacSolar performs 6 different measurement readings or functions. To choose the function is simply by adjusting at the “Function” key. Ptot is for light intensity which stands for power of total light radiation per square meter. Light spectrum does not affect result even in the most expensive light measurement device such as the pyranometer. In the case of silicon sensors as used in the MacSolar, the device has to be calibrated to a certain light spectrum. The MacSolar is calibrated to the solar spectrum and thus will give exact values of Ptot when exposed to daylight. Calibration is done with a solar simulator, “Standard Test Conditions” (STC) with AM1, 5 spectrum, Ptot = 1000 W/m2 (at 25 °C) which is similar to direct sunlight at noon in Middle Europe.

The panel temperature, °C, is as rated on the solar cell measuring unit at the back of the MacSolar and corrected due to the selected temperature coefficient, tc. The measured value corresponds to that of a solar panel at a similar position as the MacSolar in relation to the heat flow.

Power module, Pn, is the electric power in the operating point (MPP) of a silicon solar module at a defined light intensity and module temperature. The value of Pn is displayed in % and is applicable only to mono- or polycrystalline-13. The MacSolar can internally store data for up to 20 months (time interval 1h, tb1) and up to 2 months (time interval 0,1h, tb2).

3.4.1.4 OPERATION

To get direct measurement, the sensor is orientated towards the correct location by positioning the MacSolar accordingly in the holder or in the hand. The temperature should have reached a constant value before getting the measurement. This ensure correctly determine of Pn, Un, In. The measured value can be read directly on the display. Other way of reading the measurement is by pressing the “Hold” key for a short time. Required function can be selected by pressing the “Function” key. The stored measurement can then be read. The calculation of the values of Pn, Un and In is affected by the parameters set by means of the special functions Si and tc. Hence, the Si and tc must be given attention too.

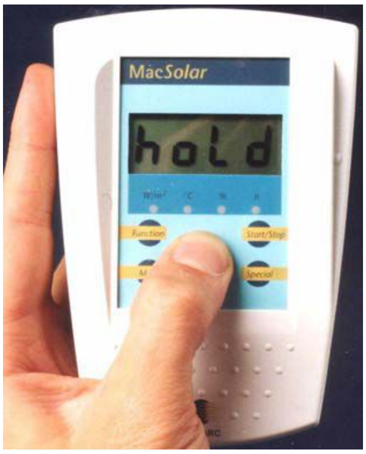


Figure 3.11: MACSOLAR solar measuring device.

3.4.2 MEASURING THE ANGLE OF SOLAR PANEL FOR EFFICIENCY.

Every reading from the ASTS device solar panel, the angle of it board is measured. This is to proof that the ASTS device actually move from one point to another.

3.4.2.1 CLINOMETER. (SUUNTO)

The clinometer is an optical gadget for measuring elevation angles above horizontal. The most common instruments of this type currently used are compass-clinometers from Suunto or Silva. Compass-clinometers are basically magnetic compasses held with their plane vertical where a plummet or its equivalent will point to the elevation of the sight line. There is also a hand spirit level clinometer, where the object sighted and the level bubble can be seen consecutively, hence the index can be set accurately. A spirit level is so-called because of the existence of alcohol in a tube of large radius, in which the bubble moves to the highest point.

3.4.2.2. INTRODUCTION

Compass-clinometers from Suunto are used in the project to measure the slopes for the vertical angle of the panel. The various applications determine the scales to be used. A Secant scale clinometer, for instance, allows determination of correct horizontal distances and compensation for slope when the percent scale for height measurements is used.

Figure 3.12: The Clinometer. (SUUNTO)

This handy gadget can be used to measure vertical angles for cellular and satellite installations, to measure slopes for grading or preliminary surveying, heights of trees, towers, buildings and more. Suunto clinometers feature two scales in five configurations: Percent and Degrees, Percent and Topographic, Degree and Topographic, 15m and 20m, Percent and Secant and Graduations. Scale readings can be expected to 10 minutes of 1/5% that is when readings are made around the zero level. Suunto clinometers are made of solid aluminium housing with jewelled bearing assembly. For smooth accurate readings, they are also featured with damped scale, parallax-free lens and 1/4” X 20 threaded tripod socket. The dimensions of this gadget are 2-3/4” x 2” x 5/8 with weight of 4.2 oz. The other details are as follows:

Degree : 0-90° in 1° units.
Percent : 0 to 70% in 1% units
72 to 150% in 2% units
Topo : 0 to ±200' with a 66' baseline.

3.4.2.3 PRINCIPLE OF OPERATION

A clinometer used the principles of a levelling rod. A levelling rod can be home-made. A clinometers has no powerful telescope, hence the reading of the rod must be evident from a distance if it is used as self-reading rod. With the levelling rod, the HI can easily be obtained. The index is set to 0° and the clinometer becomes a level. Sight the rod from close by, and read the HI. This can be done by simply making a mark on a wall just in front and then measuring its height.

The determination of the difference in elevation of two points is called levelling. It is carried out with the clinometer set at 0°. The place where you stand with the level is called a turning point, TP. Your rod person holds the rod on the first point, and you make a back sight, BS, by reading the rod. The reading is the HI above the first point. Now the rod is held on the second point, and a foresight, FS, is taken. Foresights and back sights should be roughly equal in distance. The difference in elevation of the two points is BS - FS. This procedure is illustrated in figure 1. If both points cannot conveniently be viewed from one TP, a chain of turning points is used, with an intermediate elevation between each one. The difference in elevation is the sum of the back sights less the sum of the foresights. If the sights are short, such as those that are practical with the clinometer, the curvature of the earth will be taken into account automatically.

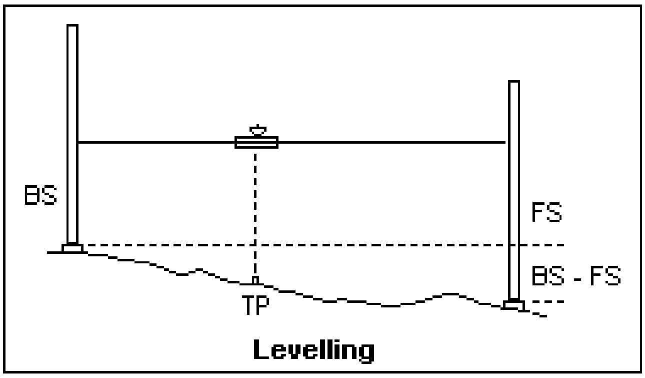


Figure 3.13: Levelling

The procedure for finding the slope of the sun using a percent scale clinometers, sight should be parallel with the ground, either upslope of down slope, to a target. A point on the target is aimed which is equal to the height of eyes above the ground.

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter will cover the result and discussion of the sun irradiation. After the apparatus and hardware are all set, the hardware is tested to ensure that the operation comply with the desired function. In addition to that, with the aid of Suunto clinometers and MacSolar solar measuring device the sun irradiation is measured and organized in tables. The graphs for the sun irradiations are relates with the hardware efficiency in this section.

4.2 Hardware Implementation

The hardware implemented is tested the sensitivity to the existence of light. The motor moves 180° and stops when it detects the existence of light. A small voltage is supplied to the motor in order to get a slow movement of motor. This increased the efficiency of the hardware. The LDR circuit is supplied with a 9Vdc to activate it. As the LDR detect the existence of light, it sends signal to stop the rotation of the motor. The motor is designed to rotate 180° only due to the fact that sun moves from east to west.

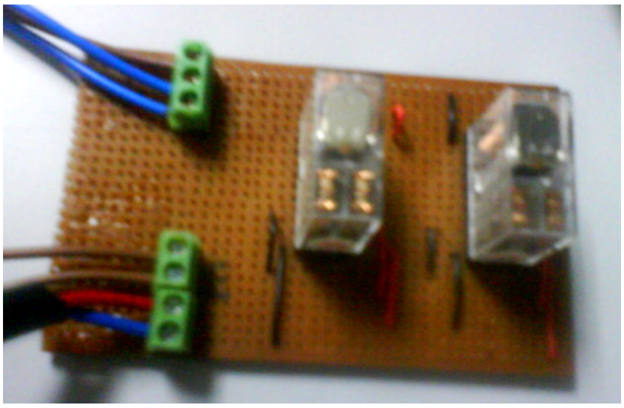


Figure 4.1: Relay circuit for motor

The figure below shows the angle of the device around the 1300 to 1400 hour which is 80° to 90°. The hardware operates as its function is planned to be. It rotates and stops when it detects sunlight's existence.

Figure 4.2: ASTS device for irradiation reading.

4.3 Sun Irradiation Analysis

After the Automated Solar Tracking System (ASTS) is finalized, the solar cell voltage, solar power, temperature and light intensity is measure with the external aid of Suunto clinometers and the MacSolar solar measuring device. The graphs of the results are analyzed. All the results are taken at four different angles which is 45°, 90°, 135° and the device angle.

4.3.1 Analysis for Solar Power

From the graph shown below, the maximum solar power is charged at 45° at the 1045 hour. The minimum solar power is the most at angle 135° during the morning. In the afternoon, the minimum solar power is the most at angle 45°. At angle 90°, the graph shows quite an expectable and fair result at which the graph at morning and afternoon is fairly going down slowly and at equal steep. As can be seen, the maximum power charges are obtained at the angle which the device is set to. This device implemented tracks the solar source automatically and its angle is unquestionable having the abilities to provide the optimum solar power from the source.

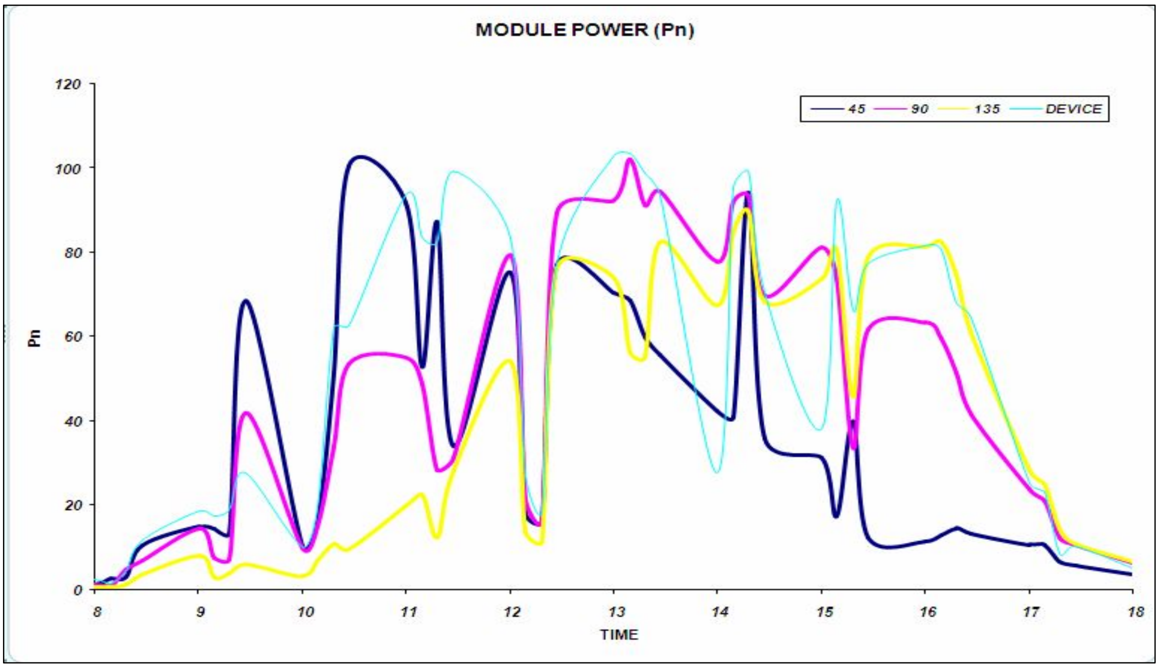


Figure 4.3: Graph of module power (Pn)

Table 4.1: Data of module power %(Pn)

TIME/ANGLE	45°	90°	135°	DEVICE
0800	4.350	3.425	1.500	5.050
0900	27.850	17.850	5.250	20.800
1000	44.625	28.150	7.625	38.675
1100	66.525	40.850	20.725	89.750
1200	46.625	51.675	38.950	51.650
1300	63.650	95.050	67.100	99.700
1400	53.325	83.350	77.625	73.225
1500	25.250	62.600	69.750	68.600
1600	13.050	54.025	74.900	73.650
1700	8.375	16.975	19.675	16.850

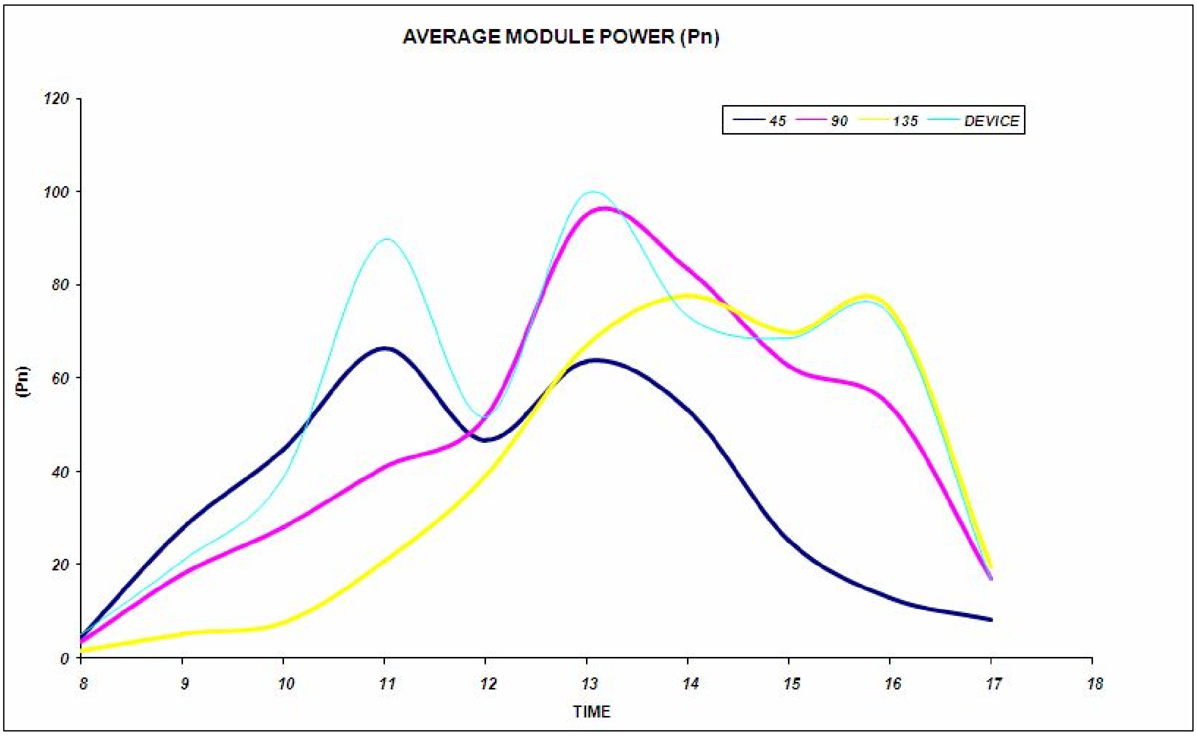


Figure 4.4: Graph of average module power (Pn)

4.3.2 Analysis for Solar Cell Voltage

From the graph shown below, the maximum solar cell voltage can be obtained at almost all the angle as the different between each solar cell voltage gotten from the various angle are of not much different. For instance, at 1000 to 1100 hour, it can be seen that the graphs are going fairly the same pattern for all the angles except for 135° this is due to the vast different of sun exposure to that particular angle. Note that 135° angle is facing the west. Hence it is expected that at 135°, the minimum solar cell voltage is produced during the morning. In the afternoon, the minimum solar power is the most at angle 45° due to its position facing the east. The graph of angle 90° run smoothly and almost equally to following the pattern of graph of the device angle. However, it is noticeably that the graph of the device angle possesses the higher yet optimum solar cell voltage charge.

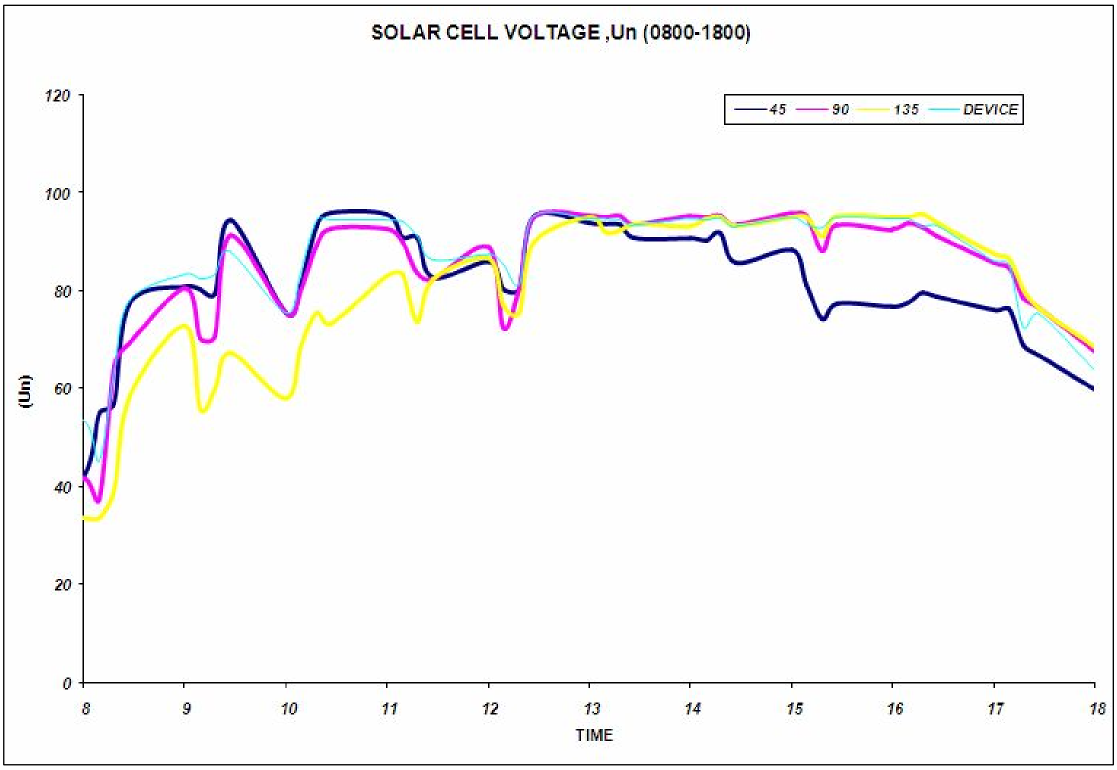


Figure 4.5: Graph of solar voltage % (Un)

Table 4.2: Data of voltage % (Un)

TIME/ANGLE	45°	90°	135°	DEVICE
0800	58.025	53.425	41.325	60.200
0900	83.850	78.300	64.050	84.350
1000	86.575	84.425	68.950	87.200
1100	90.100	87.250	80.675	91.525
1200	85.550	84.275	82.325	87.425
1300	93.000	94.925	93.300	94.400
1400	89.750	94.825	94.175	94.400
1500	80.400	93.250	94.250	94.225
1600	78.350	92.650	95.025	94.025
1700	72.075	81.375	82.800	79.900

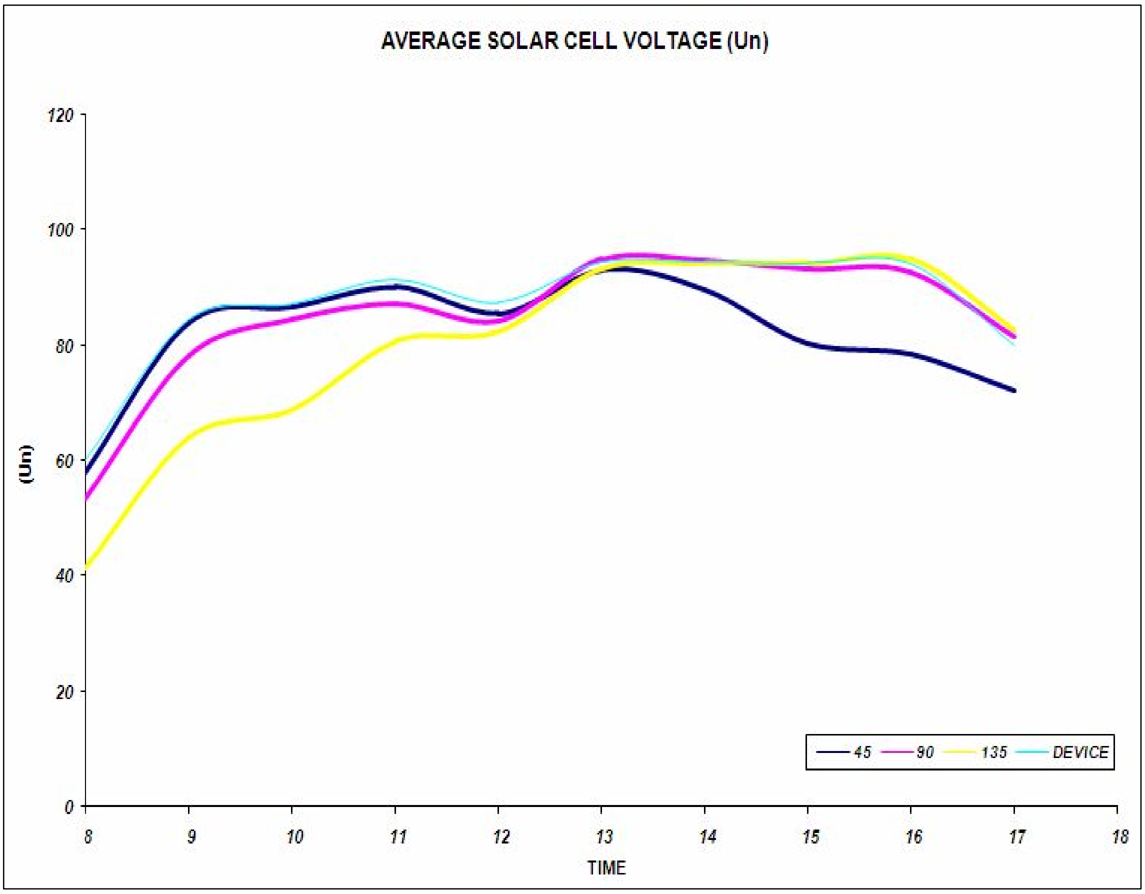


Figure 4.6: Graph of average solar voltage % (Un)

4.3.3 Analysis for Temperature

From the graph shown below, the maximum temperature is at the 1145 hour of the device angle which is 52.2°C. The other three angles also agree that the latter mentioned hour is the peak temperature. From the figure, it is presumed that the angles do not affect temperature as much as they affect the solar cell voltage and power. The fact that 135° angle is facing the west and angle 45° facing the east provide almost the same pattern and value of temperature compare to the device angle.

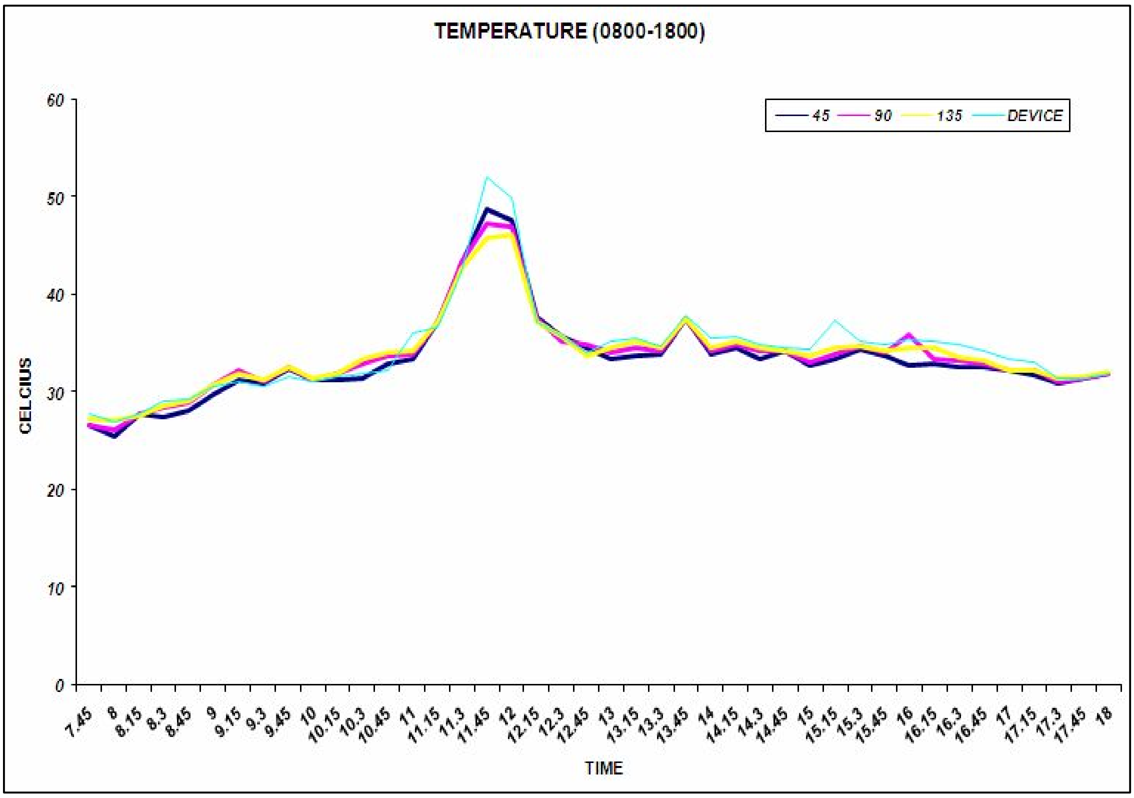


Figure 4.7: Graph of temperature (°C)

4.3.4 Analysis for Light Intensity

From the graph shown below, the maximum light intensity is averagely at the 1300 hour of the device angle, which is, Ptot : 1045.25. The vast different of the device angle efficiency in measuring the light intensity is shown at the 1100 hour. The value at this point is so much higher than the other three angles. At angle 45°, the light intensity is having the average small amount at all hours. However, in the morning the angle 135° shows the lowest light intensity due to its position facing to the west. The angle 90° shows almost optimum value of light intensity except for the morning time as in the afternoon the graph pattern is fairly exact to the graph produce by the device angle.

Table 4.3: Data of light intensity (w/m)

TIME/ANGLE	45°	90°	135°	DEVICE
0800	66.25	56.25	31.75	75.00
0900	313.00	211.25	80.00	243.75
1000	480.00	317.5	106.50	419.75
1100	718.75	458.50	251.25	968.00
1200	538.75	542.75	335.25	569.75
1300	678.00	992.25	711.25	1045.25
1400	421.25	871.25	816.25	899.00
1500	213.50	659.00	716.00	826.25
1600	164.50	578.00	782.00	775.50
1700	114.00	204.50	232.00	203.50

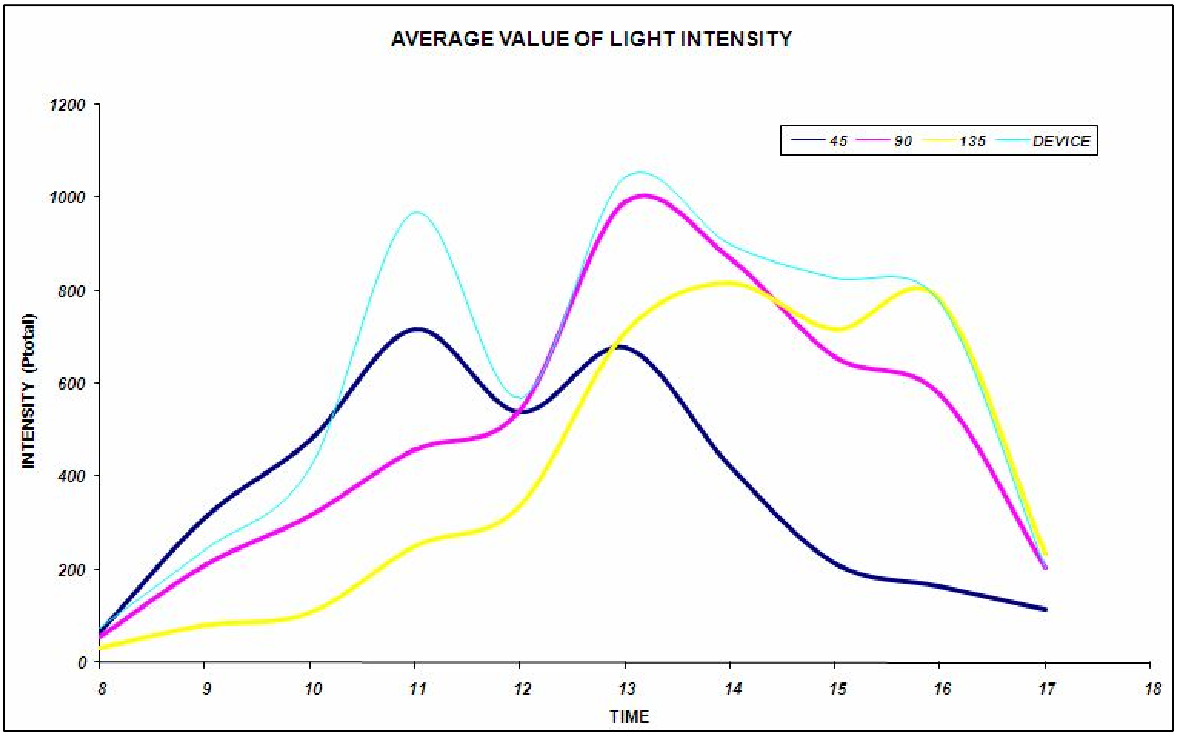


Figure 4.8: Graph of average light intensity (°C)

4.4 Discussion

The sun’s angle and its intensity on earth is affected by location of the place on the earth’s surface. During daytime, the sun is directly overhead and radiation travels through least amount of atmosphere while traveling to the earth's surface. As the sun moves closer to the west, intensity of the radiation decreases. At a high elevation, the amount of atmosphere that the solar rays travel through is lesser and therefore energy produce is higher.

Light from the sky dome may be direct, diffuse or global. Global is indeed the sum of direct and diffuse light. For direct light, a sun following tracker is the most efficient solar radiation measurement for it. From the project it is presumed that the water vapor which produce in the early morning and after the rain influence the amount of solar irradiation. The clouds also influence the irradiation somehow. The most remarkably influences is the time of the day.

Irradiant is the power of electromagnetic radiation that hits the earth’s surface at per unit area. When a point source radiates light uniformly in all directions and there is no absorption, then the irradiance drops off in proportion to the distance from the object squared, since the total power is constant and it is spread over an area that increases with the square of the distance from the source.

Solar energy is being used around the world for powering numerous applications. Solar energy is produced by collecting sunlight and converting it into electricity. The large flat panels made up of many individual solar cells are the most often used nowadays. However, the supreme way to produce optimum solar cell voltage and power are produce is having a sun following tracker.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

From various measurement of time during the day, the Automated Solar Tracking System (ASTS) shows the difference of light irradiation, voltage, and current for every reading to still positioning. The ASTS moves the solar panel from east to west and back to origin by the end of the day. This shows that the Programmable Logic Controller used control the clockwise and counter clockwise of the motor by connecting to a relay circuit.

The goal of this project is to develop a tracking system that may move the solar panel for maximum efficiency from the sun. Result shows of four different reading and proven that the ASTS receive more energy in unit of light irradiation, voltage percent and current percent than other still positioning during the availability of the sun.

Each of the reading were done by actual time and place with the ASTS device were placed and every 15 minutes, the reading of each components were taken by using a special measurement device of MACSOLAR. Due to performing the ASTS without a real solar panel, the device clearly shows that the tracking system positioning at every angle changed rapidly with the movement of the sun.

5.2 RECOMMENDATIONS

It is recommended that the future development to develop a complete project with installing a solar panel that can actually measure the voltage by converting it to an electric device. This may actually creates the whole new device which could be used in daily or factory electric source since the sun is an energy that won’t finish.

The accuracy of the ASTS can be increase by changing the motor from DC motor to either stepper motor or servo motor. This is because these type of motor can easily be controlled by any device with the speed of it depends on the pulse width modulation and driver circuit which result in a small angle of turn per seconds. Accuracy of device is proportional to the power received by the solar panel so the higher the accuracy is, resulting the solar panel parallel to the sun will result in maximum power for the whole day.

The accuracy of the ASTS can also be increased by adding more sensor to the device. Since only one Light Dependant Resistor circuit is used, the accuracy only falls into this one particular sensor. However, if several sensors were used, we can differentiate the difference of reading so that we could actually take the best reading of light irradiation at a time.

Programmable Logic Controller used is not actually suitable since it’s actually design for factory appliances. We could than use the smaller type of PLC and from there it is more practical to use the ASTS for daily usage. PLC NAIS which is 10 times smaller in size form the PLC OMRON is one of the PLC that is suitable for the next future development.

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