SINGLE AXIS ROTATION PV SOLAR PANEL TRACKING SYSTEM

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ABSTRACT

A sustainable energy supply is required in Malaysia to meet the increasing electricity demand with rapid growing in population and economy. Photovoltaic solar panel is most suitable alternative way to generate electricity in Malaysia where most of its location receives large number of solar radiation throughout the year. However, fixed solar panel is more preferred than tracking panel because it is cost effective. In present work, the power output and efficiency of single-axis tracking solar panel is compared with fixed solar panel by experimentally in East Coast Malaysia. A single-axis tracking panel produces higher power output than fixed panel up to 28W. During this time, the average efficiency of tracking panel was about 66.70% and fixed panel was 39.96%. Hence, the percentage increment on average power output using tracking panel reached up to 66.92% compare to fixed panel during this period. The tracking panel module efficiency was higher than fixed panel for the same period and can reach up to 28.9% at 6.00p.m. In conclusion, single-axis tracking panel is more efficient than fixed panel in premeridian and postmeridian. Thus, it produces higher power output than fixed panel which means it utilize the most of available solar radiation effectively and this will reduce payback period of the initial investment cost.

ABSTRAK

Satu bekalan tenaga yang berterusan diperlukan di Malaysia bagi memenuhi permintaan elektrik yang semakin meningkat berpunca dari penduduk dan ekonomi yang berkembang pesat. Panel solar Photovoltaic adalah cara alternatif yang paling sesuai untuk menjana tenaga elektrik di Malaysia di mana kebanyakan tempat menerima sinaran suria yang banyak sepanjang tahun. Walau bagaimanapun, panel solar tetap adalah lebih diutamakan dari panel mengesan trek cahaya matahari kerana ia adalah kos efektif. Uji kaji dijalankan untuk membanding kuasa keluaran dan kecekapan panel solar tetap dengan panel solar yang pengesan trek cahaya matahari dalam paksi tunggal di Pantai Timur Malaysia. Panel solar pengesan trek cahaya matahari dalam paksi tunggal menghasilkan kuasa keluaran yang lebih tinggi daripada panel tetap sebanyak 28W. Pada masa ini, kecekapan purata panel solar pengesan trek cahaya matahari adalah sebanyak 66.70% dan panel tetap adalah 39.96%. Oleh itu, peratusan kenaikan purata kuasa keluaran panel pengesanan matahari mencecah sehingga 66.92% berbanding dengan panel tetap dalam tempoh yang sama. kecekapan modul panel mengesan matahari adalah lebih tinggi daripada panel tetap bagi tempoh yang sama dan mencecah sehingga 28.9% pada pukul enam petang. Kesimpulannya, panel pengesan matahari dalam paksi tunggal adalah lebih berkesan daripada panel tetap di premeridian dan postmeridian. Oleh itu, ia menghasilkan kuasa keluaran yang lebih tinggi daripada panel tetap punca dari sinaran suria digunakan dengan lebih berkesan dan ini akan mengurangkan tempoh bayar balik kos pelaburan awal.

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LIST OF SYMBOLS

δ	Declination angle, °
ω_s	Hour angle, °
Φ	Latitude, °
N_{Max}	Monthly average of maximum possible sunshine hours per day, in hours
n	Leap year/ Non leap year + Day
M	Bending moment, Nm
V	Shear force, F
x	Distance along x axis, m
y	Distance along y axis, m
w	Load, N
σ_{all}	Allowable stress, Pa
σ_u	Ultimate stress, Pa
σ_{max}	Maximum stress, Pa
I	Moment of inertia, m^4
b	Base, m
h	Height, m
η_p	Average PV solar panel efficiency
P_o	Average power output from panel, W
P_{max}	Maximum power output of the panel, W
η_m	Module efficiency
A_c	Area of PV solar panel, m^2
G	Horizontal global irradiance, W/m^2
β	Angle made by the plane surface with horizontal

L	Length, m
m	Mass, kg
F	Force, N
R	Reaction, N
t	Thicknes, m
c	Centroid, m
E	Modulus of Elasticity
L_e	Effective length, m
P_{all}	Allowed force, N
P_{cr}	Critical force, N
g	Gravity force, m/s
T	Torque, Nm
N	North
E	East
H_o	Monthly average of daily extraterrestrial radiation on a horizontal surface, kJ/m2.day
H_g	Monthly average of daily global radiation on a horizontal surface, kJ/m2.day
H_d	Monthly average of daily global radiation on a horizontal surface, kJ/m2.day
H_b	Monthly beam radiation, kJ/m^2.day
a,b	Regression coefficients which vary from site to site
β_{opt}	Optimum angle

LIST OF ABBBREVIATIONS

UMP	Universiti Malaysia Pahang
PV	Photovoltaic
FYP	Final Year Project
SMA	Shape Memory Alloy
Ni-Ti	Nickel Titanium
CMOS	Complementary Metal Oxides
IC	Integrated Circuit
LDR	Light Dependant Resistor
PIC	Peripheral Interface Controller/ Programmable Intelligent Computer
DC	Direct Current
SMv	Sun's Real Movement
SEq	Progression of The Values Yielded by The Solar Equations
CEq	Evolution Obtained After The Corrections
PSM	Program Sarjana Muda
ASTM	American Society for Testing and Materials
CAD	Computer Aided Design
RPM	Revolution Per Minute
EUSART	Enhanced Universal Synchronous/Asynchronous Receiver/Transmitter
MCLR	Master Clear
ADC	Analog to Digital Converter

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Population of human increased drastically in the past half century, and now the human population is estimated to exceed 7 billion in the year 2012. A huge increasing in human population cause the demand of electricity increase rapidly. However, energy supply is far less than the actual demand in recent years as a result of industrial development and population growth. In additional, the fossil fuel as the primary energy source estimated drain in the future soon and global warming and pollution cause by fossil fuel affect human health. As a result, scientists and engineers work hard to find an efficient alternative energy such as solar, wind, ocean, geothermal, and nuclear to replace fossil fuel now days. Among all the alternative energy, solar energy is one of the most suitable green energy to replace fossil fuel due to its available constantly, naturally replenished, safe to use, save space and easy to install. Nevertheless, several problems annoying engineers and limit the popularity of the solar energy which are low efficiency of the solar panel, losses in reflection of sunlight toward solar panel, and the high cost to build the solar system.

Our earth rotates on its axis and equatorial plane is tipped 23.5° from the ecliptic plane, makes a slightly elliptical orbit surrounding the sun. Malaysia did not experience four seasons like other countries in a year. However, the position of the sun is changing everyday due to northern hemisphere tip towards or away from the sun and it affects the performance of the solar panel.

This project calls "Single Axis Rotation PV Solar Panel Tracking System". Solar energy is one of the most potential green energy to use to replace the current fossil fuel energy in our country. This project helps to maximize the power generating by solar system by setting the solar panel perpendicular to the sun ray. This project will use an electrical motor to turn the gearing system, a gearing system that moves the surface of the solar panel to be perpendicular to the sunlight to get the maximum intensity of light. This system is easy to operate and suitable to move the solar panel smoothly to increase the efficiency of solar energy.

1.2 PROBLEM STATEMENT

A solar system was installed as the main power source to charge the battery that operates the pump that cycle the water between solar collector and water storage tank in Universiti Malaysia Pahang (UMP) at Pekan, Pahang. However, the fixed solar panel can't fully utilize the most available solar radiation effectively and the desired amount of solar panels to charge the battery and area of installation are increasing. In order to maximize the advantage of solar energy and reduce the cost, the efficiency of solar panel needs to be increased. Solar panel builds by monocrystalline material has higher efficiency than thin film amorphous material, however, the cost to build the solar system also increase dramatically. Nevertheless, a simple mechanism tracking system may be the greatest solution to increase the efficiency of solar systems with relatively low cost.

1.3 OBJECTIVE OF THE PROJECT

Below are the main objectives of "Single Axis Rotation PV Solar Panel Tracking System" project.

(i) To develop a single axis rotation sun tracking system for PV solar panel.
(ii) Selecting the suitable material for tracker fabrication.
(iii) To design, fabricate, and evaluate test rig, control system and performance between tracking and fixed panel.

1.4 PROJECT SCOPE

This project focused on design, fabricate, and evaluate a single axis rotation sun tracking system for PV solar panel. Therefore, the tracking system will cover the scope as follows.

(i) Conceptual design method of tracker.

(ii) System components and tracker fabrication using suitable and available materials.

(iii) Compare and evaluate the output of solar panel with and without tracking system from time 9am to 6pm at UMP, Pekan.

Gantt Chart for FYP 1

PROJECT ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Discuss with supervisor	■													
Verify the project title, objective and scope	■	■												
Literature survey	■	■	■	■	■	■	■	■	■	■	■			
Draft design					■									
Calculate the suitable dimension					■	■								
Modeling in software							■							
Selecting the suitable control system							■							
Preparation of control circuit								■	■					
Writing the control program coding										■	■	■		
Starting writing report				■	■	■	■	■	■	■	■	■		
Test run for the control system													■	■
Submit draft report and log book												■		
Presentation FYP 1														■

Gantt Chart for FYP 2

PROJECT ACTIVITIES	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Complete control circuit	■														
Complete test rig with control system		■													
Monitor tracking system			■												
Improve control system			■	■											
Preparation of evaluation				■											
Data collection for tracking and non tracking system				■	■	■									
Evaluation							■								
Report writing								■	■	■	■	■			
Draft report summation											■				
Draft report reparation												■			
Final draft report summation													■		
Slide presentation preparation													■	■	
Presentation															■

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discusses the background of study related to this project .This study including sun-earth relationship, type of PV panel, types of sun tracker and methods of tracking. Previously finding, rationale of the relevant study, methodology or research methods and theoretical background of those studies will include in this chapter. Most of the literature review and equations have been extracted from journals, books, and wed site. Literature reviews from those information sources avoid the same mistake happen like previous people done. Moreover, with these literature reviews, the project can be run smoothly.

2.2 MALAYSIA CLIMATE

Direct sunlight also knows as beam radiation refers to the solar radiation traveling in a straight line and reach the earth's surface without being scattered by the earth's atmosphere. Diffuse radiation refers to the sunlight that reach the earth's surface also but has been scattered by cloud in the sky. Meanwhile, total solar radiation or global radiation is the sum of beam and diffuse radiation that reach the earth's surface (Velautham, S. 2006). As cited in Monitoring results of Malaysian Building Integrated PV Project in Grid-connected Photovoltaic system in Malaysia, the average daily global solar irradiation in Malaysia is approximately 4.5 kWh/m^2. Moreover, Malaysia experience heavy rainfalls whole year, which between 2000mm to 2500mm per year. Below is the average total daily solar radiation distribution in Malaysia. It is clearly shown that the solar radiation distribution in Pekan is 15-16 MJ/m^2.

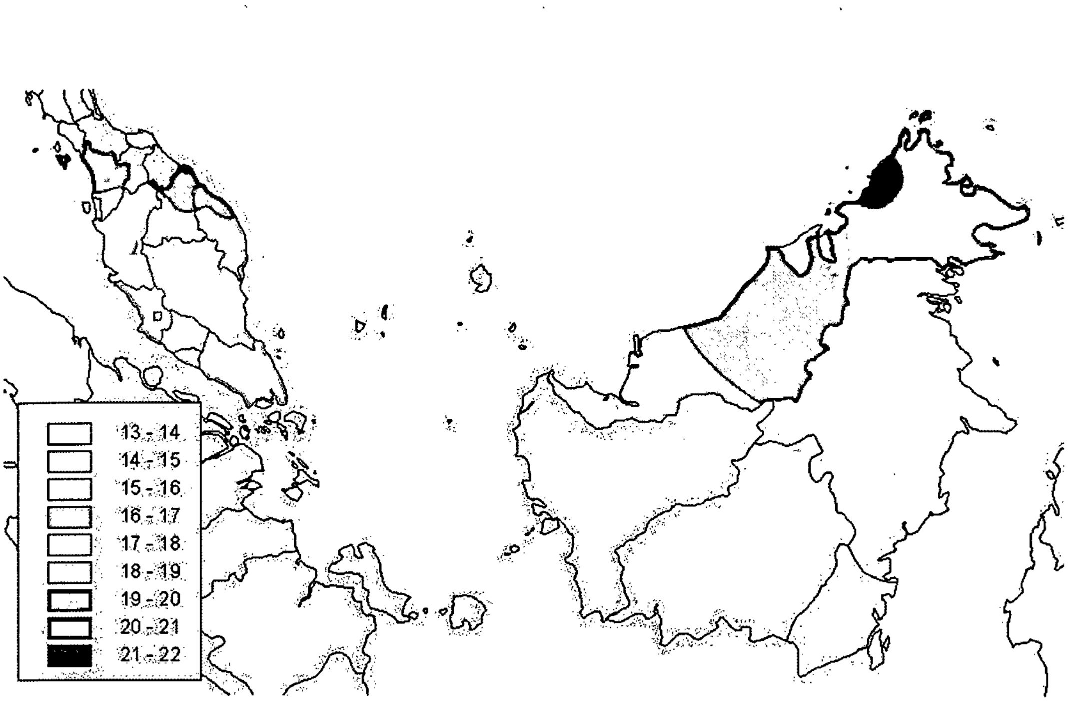

Figure 2.1: Malaysia Solar radiation distribution (Velautham, S. 2006)

2.3 SUN – EARTH RELATIONSHIP

Malaysia is a Tropical country which tropical region between 1° N and 7° N, and 100° E and 119° E. The weather of Malaysia remains relatively constant throughout the year. As cited in The Performance of Three Different Solar Panels for Solar Electricity Applying Solar Tracking Device under the Malaysian Climate Condition (Azhar Ghazali et al, 2012), sunlight is available for more than ten hours per day and the irradiation of direct sunlight is between 800W/m^2 and 1000W/m^2 with approximate six hour. Yet, as cited in Monitoring results of Malaysian Building Integrated PV Project in Grid-connected Photovoltaic system in Malaysia, the annual average solar irradiation was estimated to be approximately 1643 kWh/m^2/yr. From website index Mundi, the Electric power consumption in Malaysia was 3613.53 kWh per capita in 2009, according to a World Bank report, published in 2010. This means that energy from approximately 3m^2 of solar irradiation can support a Malaysian electrical consumption. According to the Malaysia meteorological department, the monthly average maximum direct sunlight that receives in Alor Setar is 8.7 hours while Kuching, on the other hand, only receive an average of 3.7 hours of direct sunlight in extreme case. On the average, Malaysia receives about 6 hours of sunshine per day.

2.4 SOLAR ENERGY

A sustainable energy supply is required in Malaysia to meet the increasing electricity demand with rapid growing in population and economy. Solar energy is one of the most potential renewable energy in Malaysia, whereby most of its location receives abundant solar radiation yearly (Azhari,A.W. et al., 2008). The photovoltaic (PV) solar panel is an alternative way to generate green electricity and becoming one of popular technology in Malaysia. Typically in Malaysia, the stationary PV solar panel is installed at fixed position at the rooftop of a building to harness energy from solar irradiation during daytime throughout the year. Conversely, Bari, S. (2001) noticed that not all Malaysian domestic consumers installed their PV solar panels at an optimum orientation and tilt angle. Eventually, it reduces the incoming solar irradiation onto panel to 10-35% less than properly installed solar panel. The optimum tilt angle of solar panel is depending on seasons, location, month by month basis throughout the year. However, the best position to receive irradiation of direct sunlight for the Northern Hemisphere countries this is due south, for countries on the Southern Hemisphere this is north. Thus, an optimum orientation and tilt angle can increase the yearly gains for installed fixed solar panel.

However, the properly installed fixed panel is also operating less efficient at some point compared to tracking panel due to the sun's motion on daily and yearly basis. Therefore, employing a tracking panel will generate higher electricity and more efficient as compared to fixed panel. (Chang, T.P, 2009; Lubitz,W.D., 2011; Ma, Y.,Li, G.,& Tang, R., 2011)

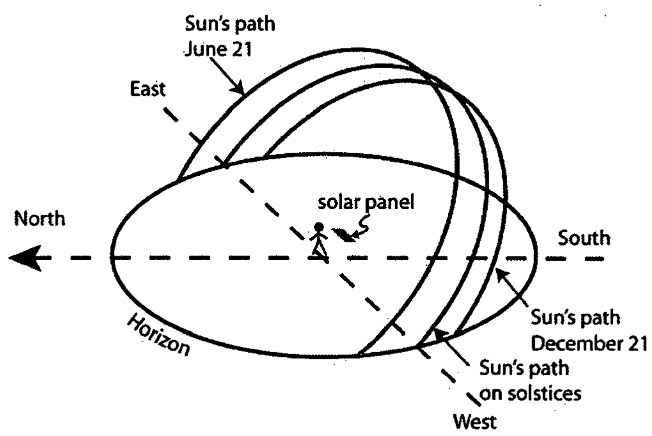

Figure 2.2: Sun positions in the northern hemisphere countries and the sun path (Mahdi E,J. et al. 2011)

2.5 DECLINATION ANGLE (δ)

Equatorial plane is tipped 23.5° from the ecliptic plane. As Earth revolves around the sun, the orientation produces a varying solar declination. Declination (δ) is the angle subtended by a line joining the centers of the earth and the sun with its projection on the earth's equatorial plane. Winter season happens when the northern hemisphere tip away from sun meanwhile the summer season when the northern hemisphere tip toward the sun.

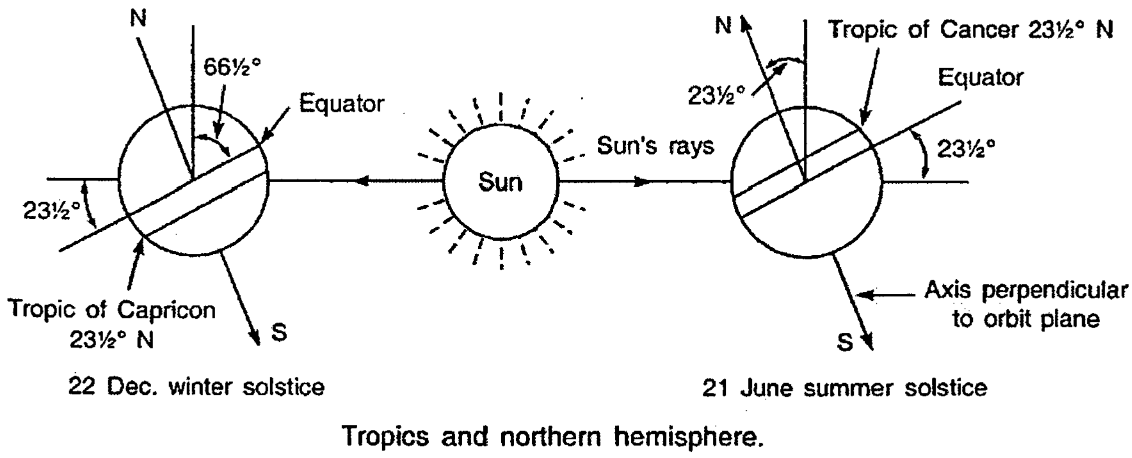

Figure 2.3: Sun-Earth relationship (Sharani,P., 2012)

The declination angle for an nth day may be calculated from the following simple relationship given by *Cooper* (*1969*):

$$\delta \text{ (in degrees)} = 23.45^\circ \sin\left[\frac{284+n}{365} * 360^\circ\right] \tag{2.1}$$

Where n is the total number of days counted from first January till the date of calculation. The figure below descried the variation of declination angle δ with the *nth* day of the year. The graph clearly shows that the declination angle δ is a sine graph. The zero declination angles δ on March 22(fall) and September 22(spring). Besides that, the minimum declination angle δ change from value –23.5 ° December 22 to +23.5 ° on Jun 22.

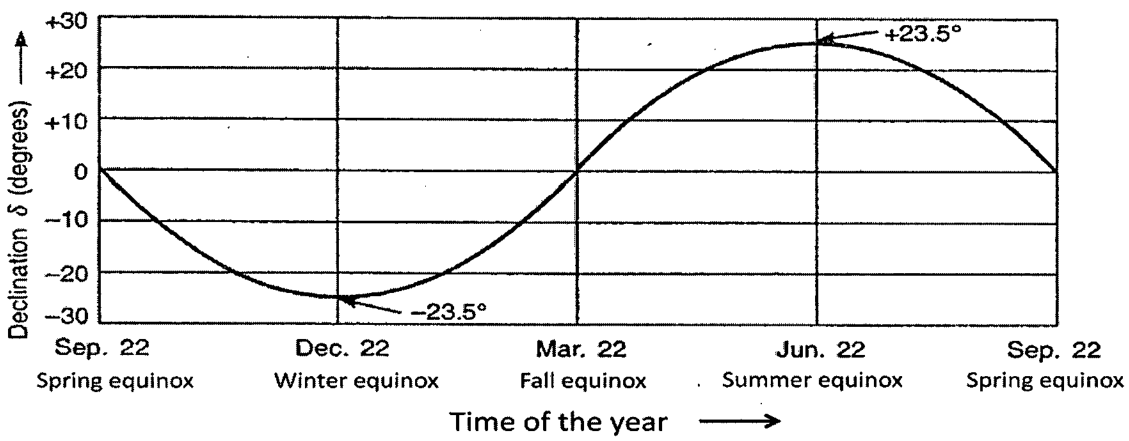

Figure 2.4: Variation of declination angle δ with the *nth* day of the year (Sharani,P., 2012)

Variations of the declination angle affect the optimum tilt angle of solar panel toward the sunlight. During winter season, the solar panel should be mounted at a greater tilt angle in order to get the maximum irradiation of sunlight. Furthermore, the tilt angle of solar panel should be mounted at a smaller angle to achieve the optimum performance. For spring and fall season, the declination angle is zero, in order to maximize the energy production, the solar panel should mount at an angle between winter and summer seasons. The figure below shows the relationship of the declination angle of the varied seasons with the tilt angle of the solar panel.

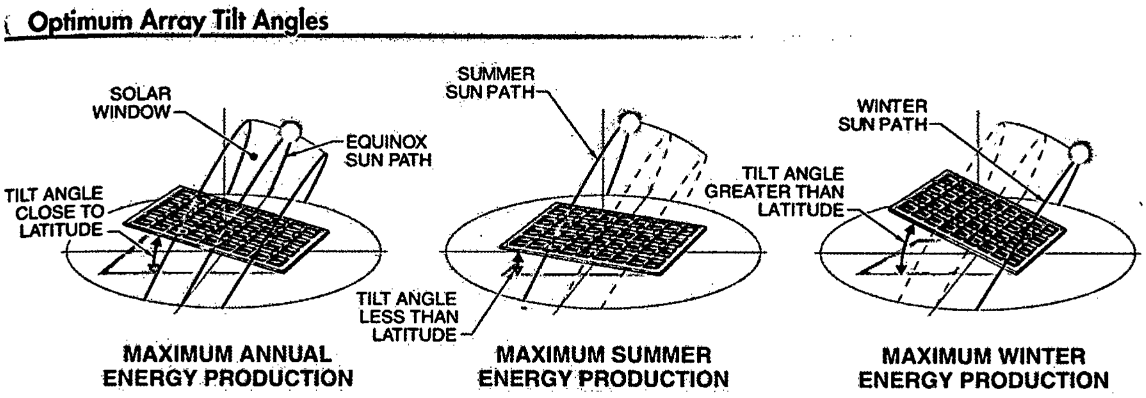

Figure 2.5: Maximum array tilt angles of varied seasons (Sharani,P., 2012)

2.6 HOUR ANGLE FOR SUNRISE, SUNSET, AND MONTHLY AVERAGE OF MAXIMUM POSSIBLE SUNSHINE HOUR PER DAY

Hour angle, the angular displacement of the sun east or west of the local meridian due to rotation of the earth on its axis at 15° per hour; morning negative, afternoon positive. The hour angle for sunrise, sunset are depend on the latitude and declination angle of the location. In order to calculate the hour angle, we have to obtain the information latitude and declination angle of the location. Hour angle can be computed by the following equation as cited in Daily Global Solar Radiation Estimate Based on Sunshine Hours (A.M. Muzathik et al, 2011):

$$\cos \omega_s = -\tan \Phi \tan \delta \quad (2.2)$$

$$\omega_s = \cos^{-1} (-\tan \Phi \tan \delta) \quad (2.3)$$

Where Φ is the latitude (ϕ) – slope (β) and δ is the declination of the location. The positive value of hour angle shows it is sunrise while negative values of hour angle to show it is sunset. Sunlight is parallel to the sea level with a 90° of zenith angle which means that the total hour angle between sun rise and sun set is $2\omega_s$.

Since 15° of hour angle corresponds to one hour, monthly average of maximum possible sunshine hour per day (N_{Max}) in hour can be calculated from the equation:

$$N_{Max} = \frac{2}{15}\cos^{-1}(-\tan\Phi \tan\delta) \quad (2.4)$$

2.7 PHOTOVOLTAIC TECHNOLOGY

Photovoltaic (PV) technology is a technology that converts the solar energy into electrical energy. Photovoltaic did not request mechanical moving parts during the convection. Unlike the Solar Collectors, flat plate and evacuated tube collector, photovoltaic technology does not convert the solar energy to heat and generate electricity but directly convert it to electric energy. Marliyani Binti Omar (2009) explains the photovoltaic effect in a simple way, photon from sunlight strikes the PV cell which is semiconducting material, such as silicon, energy transfer from photon to electrons and knocked loose the electrons. Therefore electrons move into a higher state of energy and cause holes to form in the atomic structure of the cell, other electrons can move into the hole. If the PV cell connects to a positive and negative side, forming a complete electrical circuit, thereby electricity is created.

2.8 SOLAR PANEL

In order to generate enough electrical energy to support electrical device, PV cells are connect together and form a unit call photovoltaic module. Photovoltaic module is a commercial component that users can buy it directly from the shop. Moreover, combination of photovoltaic modules forms a photovoltaic array can future improve the power that generate. The range of power output of a photovoltaic module is about 10 watts to 300 watts which depending on the material. As cited in Renewable Energy Powered Organic Rankine Cycle (Sanjayan Velautham, 2006), laboratory experiment show that the efficiency of solar cell can reach approximately 30 %. However, it only achieves around 18 % efficiency in commercial solar cells.