"Saya/ kami akui bahawa saya telah membaca karya ini pada pandangan saya/kami karya ini adalah memadai dari skop dan kualiti untuk tujuan penanugerahan ijazah Sarjana Muda Kejuruteraan Elektrik (Kuasa Industri)."

Tandatangan : ....
Nama Penyelia : GAN CHIN KIM
Tarikh : 9 Mac 2005

SIMULATION OF SUN TRACKING PHOTOVOLTAIC MODULE IN TROPICAL COUNTRIES

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"Saya akui laporan ini adalah hasil kerja saya sendiri kecuali ringkasan dan petikan yang tiap-tiap satunya saya jelaskan sumbernya."

Tandatangan : Devienia
Nama Penulis : DEVIENIA LOUELLIS RAJIT
Tarikh : March 9th, 2005

For Michael S. E, who never cease to inspire me.

ABSTRACT

In a fixed photovoltaic (PV) panel, maximum absorption of solar energy will not be obtained because it depends on the amount of sunlight it is exposed to, considering the fact that the sun location is not always where we expect it to be. In order to solve this, the orientation and the tilt angle of the PV panel has to be adjusted so that the straight line of the sunlight is perpendicular to the panel at all time. The software created through this project is to simulate the exact coordinate of the sun as seen by the specific location on earth, in this case, tropical countries located in the equatorial zone. This software will not only show the power generated assessment between a fixed PV modules and sun tracking system, but also the location of the sun given by the present time and day.

ABSTRAK

Dalam sesuatu panel PV yang tetap, penyerapan tenaga solar secara maksimum sukar dilakukan kerana ia bergantung kepada jumlah pendedahannya pada sinaran matahari dan mengambil kira faktor bahawa kedudukan matahari tidak selalunya berada di satu tempat yang dijangkakan ia berada. Dalam mengatasi masalah ini, orientasi dan sudut condong panel PV perlu dilaraskan supaya sentiasa bersudut tegak dengan sinaran matahari pada setiap masa. Program yang dihasilkan dalam projek ini adalah bagi mengsimulasikan koordinat sebenar matahari berdasarkan pada kedudukan spesifik, di bumi iaitu dalam kes ini ialah negara-negara bermusim tropikal atau dalam zon khatulistiwa. Program ini bukan sahaja akan mempamerkan perbezaan jumlah tenaga antara panel PV tetap dengan sistem pengesan matahari tetapi juga memberikan maklumat megenai kedudukan matahari pada masa serta hari yang ditetapkan.

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CHAPTER 1

INTRODUCTION

The main purpose of this "Simulation of Sun-Tracking Photovoltaic Module in Tropical Countries" project is to simulate a sun-tracking program – able to locate the sun's position through out the year based on calculation and estimate power delivered in a location.

In a fixed PV panel, maximum electric power will not be generated from the photovoltaic panel. This is because the amount of power produced by a PV panel depends upon the amount of sunlight it is exposed to.

Daylight hour at the equator can come up to 12 hours of daylight and 12 hour of nighttime. So a fixed PV panel is only set at a certain angle to get the most of the sun during the peak sun hours, where as a sun tracking device is to track the sun's position from sunrise to sunset. This will be further explain in Chapter 3.

Different countries around the world would have different angles of sun radiation throughout the year. A fixed PV panel would have to be large in size, costly and inefficient in order to gain the most sunlight in a day. This can be solved by positioning the PV panel perpendicular to the sun's rays. Thus, estimation of the tilt angle of the PV panel has to be calculated and that the total amount of power can be known. One can also differentiate the power gained through fixed PV panel and power gain through sun-tracking device, so as to see the efficiency of power collecting through sun tracking.

The goal of this study is to prove, through theoretical calculations, that by tracking the sun location, maximum exposure to the sun and power can be obtain. This project will simulate and show the display of fundamentals of sun tracking when the users key in the input; country, geographic coordinates, clock time and date. Refer to Chapter 7 for the program display.

CHAPTER 2

LITERATURE STUDIES

There are other previous researches that have been done in attempt to improve energy gain from solar power. These studies aimed to prove that by sun-tracking system, one can improve power generate from solar energy.

A study was done where a mathematical model was used to estimate the total solar radiation on the tilted PV surface, and to [1] determine optimum tilt angles for a PV panel installed in Sanliurfa, Turkey. This study determined that the monthly optimum tilt angle for a PV panel changes throughout the year with its minimum value as 13° in June and maximum value as 61° in December. The study also investigated the effect of two-axis solar tracking on energy gain compared to a fixed PV panel. The daily average of 29.3% gain in total solar radiation results in an daily average of 34.6% gain in generated power with two-axis solar tracking compared to a south facing PV panel fixed at 14° tilt angle on a particular day in July in Sanliurfa, Turkey.

In other study, the [2] performance of mono-crystalline silicon type PV modules has been investigated theoretically at different tilt angles and orientations in Cairo, Egypt. It is found that the optimum value of yearly maximum output energy at the maximum power point can be obtained from PV modules oriented facing south with a tilt angle in the range of 20° to 30°. The yearly maximum output energy of the PV modules mounted at the different tilt angles and orientations is obtained as a fraction of its optimum value at the optimum tilt angle and orientation.

Further research showed that other study was also carried out on sun tracking by peak power positioning for photovoltaic concentrator arrays. This is done by [3] designing a microcomputer-based solar tracking and control system (TACS) capable of maintaining the peak power position of a photovoltaic (PV) array for maximum efficiency and changing the position of the array relative to the sun. The data analysis of this system shows a deviation in maximum power of less than 1% during the day after accounting for other variations.

An experimental study was performed to [4] investigate the effect of using different types of sun tracking systems on the voltage-current characteristic and electrical power generation at the output of flat plate photovoltaic (FPPV). The results indicated that the volt-ampere characteristic on the tracking surfaces were significantly greater than that on the fixed surface. There were increases of electrical power gain range from 15.69% to 43.87% as compared with the fixed surface inclined 32° to the south in Amman, Jordan.

Study that considers design and [5] implementation of a computer-controlled sun tracking system has also been done to enhance the power output of photovoltaic solar panels. A PC-based fuzzy logic control algorithm utilizing the knowledge of the system behavior is designed in order to achieve the control objectives. The implementation of such a controller is realized by building an interfacing card consisting of sensor data acquisition, motor driving circuits, signal conditioning circuits and serial communications with the PC.

The difference between this research and other researches is that the program will be able to simulate the sun's position not only in one location (Malaysia) but also in other tropical countries. The sun's daily path is different between the sun's paths in equatorial countries with either northern or southern countries. Other objective of this research is to determine the difference of power gain between the tropical countries and also to prove that the calculations uses are reliable to point the sun's position correctly.

CHAPTER 3

BACKGROUND STUDIES

This chapter will further discuss the fundamental knowledge of solar energy, countries in the equatorial zones, equator coordinates and solar radiation so as to understand the problem statement given earlier.

3.1 Solar Energy

In order for this project to be successful, one must know the basic concept of solar energy, the importance of solar energy by knowing its advantages and how PV cells work. Today, because of advances in technology, the sun is use in many more wonderful and efficient ways. The first and probably most important way is the ability of the sun to produce electricity by the using of photovoltaic (PV) cells.

The "photovoltaic effect" is the basic physical process through which a PV cell converts sunlight into electricity. Sunlight is composed of photons which contains various amount of energy corresponding to the different wavelengths of the solar spectrum. When photon strikes a PV cell, the energy of the photon is transferred to an electron in an atom of the cell.

Pure silicon of crystalline structure is a poor conductor of electricity. To solve this problem, the pure crystalline silicon doped with impurities. When doped with phosphorous, the results silicon is called N-type ("N" for negative) because the prevalence of free electrons. The other part is doped with boron, which has only three electrons in its outer shells instead of four, to become P-type. Instead of having free electrons, P-type silicon ("P" for positive) has free holes.

An electrical field is created near the top surface of the cell where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of a PV cell, this electrical field provides momentum and direction to light-stimulated electrons, resulting in a flow of current when the solar cell is connected to an electrical load. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is proportional the intensity of sunlight striking the surface of the cell. The figure below gives a clear view of the work of PV cells.

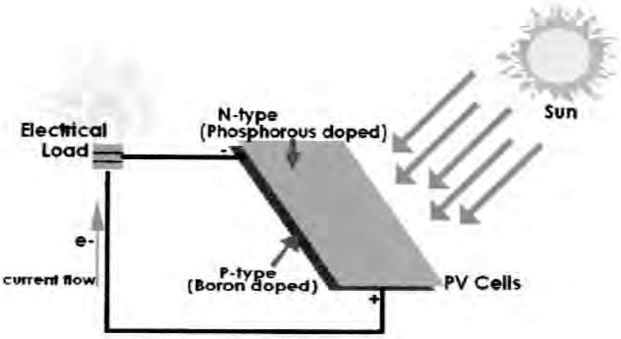

Figure 3.1.1: Diagram of photovoltaic cell.

Photovoltaic cells are connected electrically in series and/or parallel circuits to produce higher voltages, currents and power levels. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, and are the fundamental building block of PV systems. Photovoltaic panels include one or more PV modules assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels. Figure below gives a clear illustration of cell, module, panel and arrays.

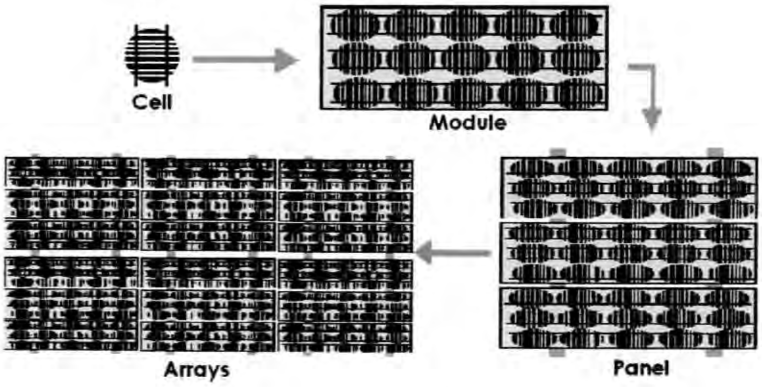

Figure 3.1.2: Photovoltaic cells, modules, panels and arrays.

The performance of PV modules and arrays are generally rated according to their maximum DC power output (watts) under Standard Test Conditions (STC). Standard Test Conditions are defined by a module (cell) operating temperature of 25o C (77 F), and incident solar irradiance level of 1000 W/m2 and under Air Mass 1.5 spectral distribution. Since these conditions are not always typical of how PV modules and arrays operate in the field, actual performance is usually 85 to 90 percent of the STC rating.

Today's photovoltaic modules are extremely safe and reliable products, with minimal failure rates and projected service lifetimes of 20 to 30 years. Most major manufacturers offer warranties of twenty or more years for maintaining a high percentage of initial rated power output.

3.2 Countries in the Equatorial Zones

Countries in the tropical zone are also categorized as countries with tropical climate and also known as tropical countries. Equatorial zone is where the part of the earth's surface between the Tropic of Cancer (23.5° North) and the Tropic of Capricorn (23.5° South). It is the two parallels of latitude of the equator, representing the points farthest north and south, which the sun can shine directly overhead and constituting the boundaries of the tropics. Figure 3.2.1 shows the image of the equatorial zone.

In geography, the equator is an imaginary line drawn around a planet, halfway between the poles, where the surface of the roughly spherical planet is parallel to the axis of rotation. The equator divides the surface into the Northern Hemisphere and the Southern Hemisphere.

At the equator the sun rises perpendicularly from the horizon and sets perpendicularly, regardless of the season. Also, the total path of the sun, day and night, is divided equally by the horizon. There are always twelve hours of daytime and twelve hours of night time at the equator.

Figure 3.2.1: Map of equatorial zone

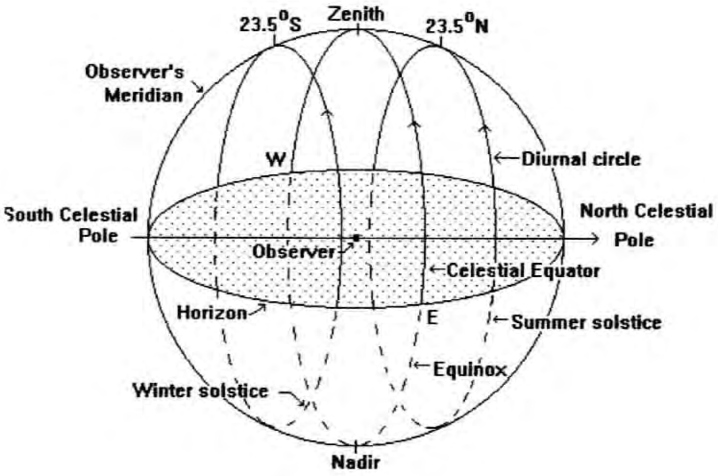

Figure 3.2.2: The daily paths of the Sun during the solstices and the equinoxes.

Figure 3.2.2 shows the daily or diurnal paths of the Sun during the solstices (21 December and 21 June) and the equinoxes (21 March and 21 September) as seen by an observer at the equator is shown in Figure 3.2.2. Solid lines are daytime, dashed lines are night-time. At all seasons on the equator, the daily paths of the Sun are divided equally above and below the horizon.

At certain times throughout the year the sun's positions not only varies from north and south, as we expect with change of the seasons, but also slightly east and west. This figure-8 path that the sun makes in the sky is called the analemma.

There are two reasons as to why the sun takes this path; (1) The earth is tilted on its axis 23.5° in relation to the plane of its orbit around the sun. (2) The earth does not orbit the sun in a circle, but in an ellipse. During June, the sun rises in the northeast and sets in the northwest, while in December it rises in the southeast and sets in the southwest. The analemma also shifts east-west, a phenomenon that should be known to people familiar with the equation of time.

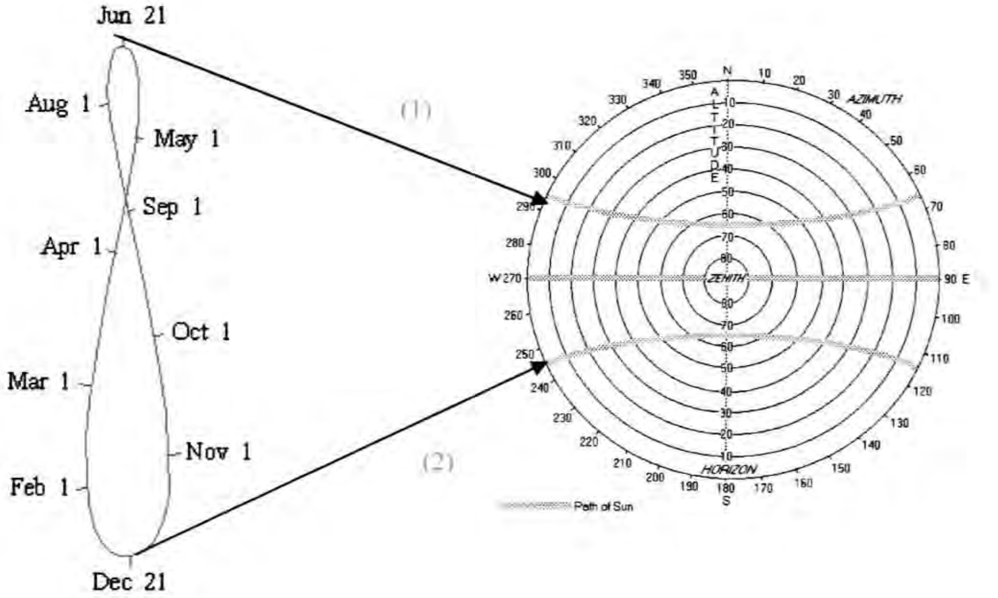

Figure 3.2.3: The sun's position on the respective day in a year.

Figure 3.2.4: A polar plot of the position of the Sun.

Referring to Figure 3.2.3 and Figure 3.2.4, the arrow (1) shows the path that the sun takes on the 1st of June from sunrise (east) to sunset (west). The arrow (2) shows the path that the sun takes on the 21st of December also from sunrise to sunset. Figure 3.2.4 shows a polar plot of the position of the Sun in the coordinates of the azimuth and altitude of the Sun as seen by an observer at the latitude in the equator.

The amount of solar radiation reaching the earth's surface varies greatly because of changing atmospheric conditions and the changing of the sun position, both during the day and throughout the year. Solar radiation received at Earth's surface is called insolation (**In**coming **Sola**r Radia**tion**).

The average amount of insolation decreases from the equator to the poles. This is because the low latitudes (near the equator) received relatively large amount of radiation all year, and at high latitudes (near the pole) the more oblique angle of the sun's rays together with the long periods of darkness in the winter, result in a low average amount of received radiation. Local geographical features, such as mountains, oceans and large lakes, influence the formation of clouds; therefore, the amount of insolation received for these areas may be different from the received by adjacent land areas.

Peak sun hour is defined as the number of hours per day when the insolation equals to 1000 W/m^2. This value represents the solar power received on a clear cloudless day and actually varies greatly due to atmospheric variables. It is proven that 60% of the insolation is found at the equator. The total insolation is highest at the equator especially in sunny, desert areas. Countries locate in the equator area has a average of solar radiation of 0.5 kW/m^2.

3.3 Equator Coordinates

In other to get the exact coordinate on the sun's position, these are the fundamentals to be considered.

(a) Latitude, Longitude and the Universal Time
(b) Declination Angle
(c) Mean Time, Solar Time and the Equation of time
(d) Hour Angle
(e) Altitude and Azimuth Angle

(a) Latitude, Longitude and the Universal Time

The lines that run east and west, parallel to the equator, are called latitude. These lines are written in degrees north and south of the equator. Each degree of latitude is divided into 60 minutes and each minute into 60 seconds. One degree of latitude measures about 69 miles on the earth surface. The equator is at 0 degree latitude, while the North Pole is at 90 degrees north and the South Pole is at 90 degrees south. Refer to Figure 3.3.1

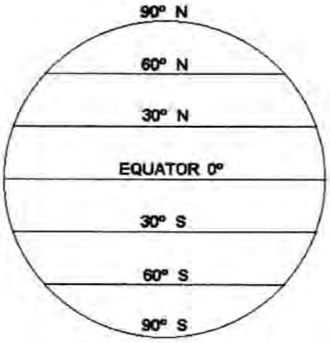

Figure 3.3.1: Latitude