# PHOTOVOLTAIC SYSTEM CALCULATION PROGRAM

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NOVEMBER 2008

"I hereby declared that I have read through this report and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronics and Drives)"

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Supervisor's Name : FAZLLI B. PATKAR

Date : November 2008

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**This Report Is Submitted In Partial Fulfillment of Requirements for the Degree of Bachelor in Electrical Engineering (Power Electronics and Drives)**

**Faculty of Electrical Engineering (FKE)**
**Universiti Teknikal Malaysia Melaka (UTeM)**

**November 2008**

"I hereby declared that this report is a result of my own work except for the excerpts that have been cited clearly in the references."

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Name : ZULFIKAR B. ABD KASIM

Date : November 2008

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# ABSTRACT

The purpose of this project is about to design and build a Photovoltaic (PV) power system calculation program in order to determine the optimal usage of equipment to install the system. The software implementation of the system has lead to a new computational tool, based on Microsoft Visual Basic. The developed software is very flexible for the user to calculate the requirements needed in designing PV system. This project will organize with both theory and practical application. The system is basically about generating electrical power from solar energy and will be store in the battery before utilize by the AC or DC loads. The project will be separate into design and analysis of the system. First task will consider the load profile sizing, the total power usage, usage hours and quantity of the units. Second task will consider the number of the PV module and battery to be used.

# ABSTRAK

Tujuan projek ini adalah untuk merekabentuk dan membina satu sistem pengiraan sistem kuasa bagi sebuah sistem solar. Ini adalah untuk memastikan kadar penggunaan peralatan yang optimum diperlukan untuk membina sistem tersebut. Penggunaan dan perlaksanaan sistem komputer telah menjurus kepada terhasilnya satu perisian yang baru, berdasarkan Microsoft Visual Basic. Perisian ini adalah amat fleksibel untuk pengguna untuk mengira beberapa keperluan di dalam merekabentuk sesebuah sistem solar. Projek ini akan menggabungkan teori kedua-dua antara teori dan praktikal. Sistem itu pada dasarnya berkenaan dengan penjanaan kuasa elektrik daripada tenaga matahari dan bateri akan menjadi sumber penyimpan tenaga sebelum dimanfaatkan tenaga itu oleh beban-beban AC dan DC. Projek ini merangkumi 2 aspek iaitu reka bentuk dan juga analisis untuk sistem tersebut. Skop kerja pertama ialah untuk mengira pensaizan profil beban, penggunaan jumlah kuasa, masa penggunaan dan kuantiti unit-unit. Skop kerja yang kedua pula ialah mengira jumlah modul PV dan bateri untuk digunakan.

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# LIST OF APPENDICES

# CHAPTER 1

# INTRODUCTION

## 1.1 Project Background

Photovoltaic (PV) offer consumers the ability to generate electricity in a clean, quiet and reliable way. Photovoltaic systems are comprised of photovoltaic cells, devices that convert light energy directly into electricity. Because the source of light is usually the sun, they are often called solar cells. Solar cells produce direct current electricity from light, which can be used to power equipment or to recharge a battery. The first practical application of photovoltaic was to power orbiting satellites and other spacecraft, but today the majority of photovoltaic modules are used for grid connected power generation. In this case an inverter is required to convert the DC to AC. There is a smaller market for off grid power for remote dwellings, roadside emergency telephones, remote sensing, and cathodic protection of pipelines [3].

The purpose of this project is preparing the calculation software in order to facilitate the installation of safe PV systems at a minimum of cost and effort for the inspector and the installer. The guidelines were written in Chapter 2 from the viewpoint that all PV systems installed for residential or commercial use should fundamentally include proper documentation, proper structural attachments, and proper wiring methods. When installations fail to meet these basic requirements, those systems will be wasted. The photovoltaic effect is the basic physical process through which a PV cell converts sunlight into electricity. Sunlight is composed of photons packets of solar energy. These photons contain different amounts of energy that correspond to the different wavelengths of the solar spectrum. When photons strike a PV cell, they may be reflected or absorbed, or they may pass right through. The absorbed photons generate electricity.

Another important part in this project, the software need to be design to let the people easy to design the accurate photovoltaic system that they need. Through it, knowledge in design and using programming language for interfacing should be learns and improves. In this project, the Microsoft Visual Basic 6.0 had been use to run the program.

## 1.2 Problem Statement

Sunlight is one of the natural things that have their own energy called 'solar'. It will be an alternative solution to provide electricity. See figure 1.1. The amount of energy produced by a PV device depends not only on available solar energy but on how well the device, or solar cell, converts sunlight to useful electrical energy. This is called the device or solar cell efficiency. It is defined as the amount of electricity produced divided by the sunlight energy striking the PV device.

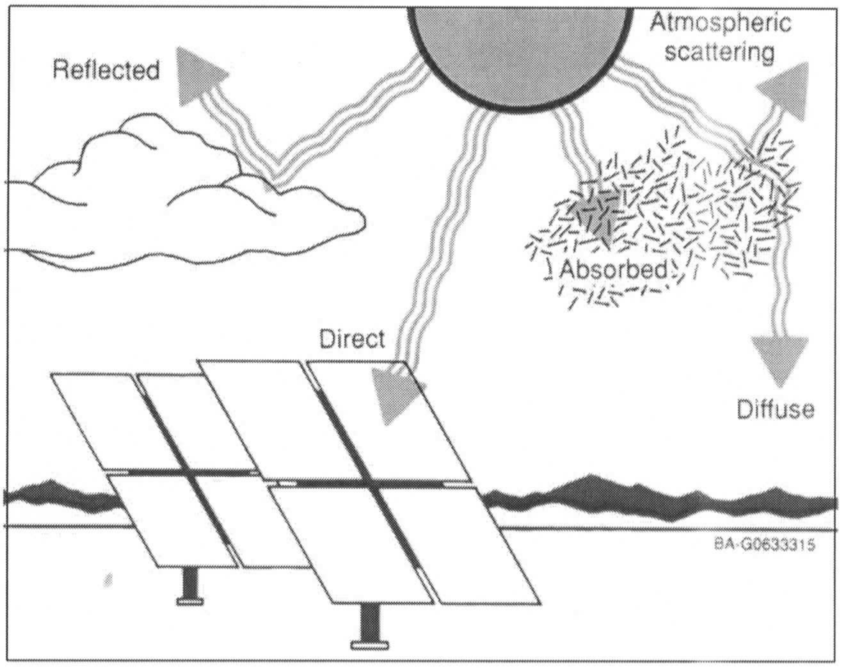


**Figure 1.1: Energy from the sun**

The intention of the project is focusing on solar application and how it can be use as an option of conventional power supply. Scientists have concentrated their R&D efforts over the last several years on improving the efficiency of solar cells to make them more competitive with conventional power-generation technologies.

## 1.3 Objectives of the Project

The main objectives are;

a) To design Photovoltaic System Calculation Software

For prompt estimation of solar potential, simple method for a calculation of a photovoltaic system will facilitate the reach the design features.

b) To determine characteristic of the charging current, load current and battery voltage.

By doing analysis of the system will make be able to characterize and quantify the charge controllers used in PV system. The operating environment for energy storage components in PV systems also will be characterized.

c) To make ease for people in designing Photovoltaic System

A calculation of important parts in designing PV system requires considerable input data. User just needs to key-in the required input data and it will automatically calculate.

d) To commercialize the use of solar system.

Research has been developed and it shown that people especially in Malaysia lack the knowledge about the advantages of using solar system. This project is developed to gain the knowledge of PV system among the publics especially among the UTeM's students.

## 1.4. The Relevancy of the Project

The relevancy of the project is viewed from three different perspectives, which PC application, scope and time frame and also software design.

### 1.4.1 PC Application

PC application is used as a medium to interface main controller and PC. It is also important to know how to use Microsoft Visual Basic. From Visual Basic, a program had been designed for calculating the system. When the program get the input from the data, it will automatically run the calculation to get the value needed.

### 1.4.2 Project feasibility within the Scope and Time Frame

In general, all scopes covered to complete the project are feasible for a final year student. The allocated time frame of approximately one year is sufficient to carry out the entire task required in the project. It summarized the allocated time frames for all tasks performed throughout the two semesters. There are three fundamental parts contributing to the major accomplishment of the project which is analysis of the system, software design and interfacing.

### 1.4.3 Software Design

The new scope covered in producing interfacing software using Microsoft Visual Basic 6 requires self-learned since it never been officially learned previously. In ensuring the feasibility of the scope, the related text books and existing programs are studied thoroughly. Half of the second semester is consumed to come out with the new software.

**1.5 Expected Result**

From the research of the project, the expected result that can be show is the Photovoltaic System Calculation Program. It consist the item of the characteristic and application relate on the planning through the project. From the analysis, I can get a set of data measurement. It is very important for experimental use of having a lab manual on solar system application and also for the improvement of the system. Other than that the system also hope will give benefits to our real application at our campus especially at our faculty area.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Overview

This chapter will explain the about the literature review and the theory of the project. These will explain about the theory and the guidelines to ensure that the photovoltaic power systems are properly specified and installed according to its design potential. It also includes the criteria that describe a quality of the system, the design and installation considerations to achieve this goal.

## 2.2 Photovoltaic System

Photovoltaic (PV) power systems convert sunlight into electricity. Solar electric or photovoltaic technology uses the sun's energy to make electricity. The word itself, "photo" means "produced by light" and "voltaic" refers to "electricity produced by a chemical reaction [1]." PV technology produces electricity directly from the electrons freed by the interaction of sunlight with certain semiconductor materials, such as silicon, in the PV module. The electrons collected to form a direct current (DC) of electricity.

The PV system is using solar cell to generate electricity. Many cells may be wired together to produce a PV module and many modules are linked together to form a PV array. PV modules sold commercially range in power output from about 10 watts to 300 watts and produce a direct current. Refer to Appendix B.

It usually consists of one or more modules connected to an inverter for a complete PV system. It changes the PV's direct current (DC) electricity to alternating current (AC) electricity to power the electrical devices and to be compatible with the electric grid. Batteries are sometimes included in a system to provide back-up power in case of utility power outages. PV cells can be made from several processes or technologies. They all do the same job, which is to produce electricity from sunlight.

The performance of the PV systems depends on the current situation. It is producing power in certain time because they work only when the sun is shining. More electricity is produce on a clear, sunny day with more sunlight and with a more direct light angle, as when the sun is perpendicular to the surface of the PV modules. Cloudy days can significantly reduce output. It is means that no power is produced at night. PV systems work best when the sun is higher in the sky and the days are longer. Because of these variations, it is difficult for PV systems to provide all the power that we need, and are typically used in conjunction with utility-supplied electricity.

### 2.2.1 Basic Principles in Designing a Quality PV System

There are a few principles should be taken into consideration in design PV system. It is includes;

1. Select a packaged system that meets the needs. Criteria for a system may include reduction in monthly electricity bill, environmental benefits, desire for backup power and initial budget constraints. Size and oriented of the PV array to provide the expected electrical power and energy.
2. Ensure the area or other installation site is capable of handling the desired system size.
3. Specify sunlight and weather resistant materials for all outdoor equipment.
4. Locate the array to minimize shading from foliage, vent pipes, and adjacent structures.
5. Design the system in compliance with all applicable building and electrical codes.

6. Design the system with a minimum of electrical losses due to wiring, fuses, switches, and inverters.
7. Properly house and manage the battery system, should batteries be required.
8. Ensure the design meets local utility interconnection requirements.

### 2.2.2 Steps to Follow When Installing a PV System

The installation process is key to providing lasting performance. PV systems include a multiplicity of parts that all have important functions. These are several steps that include in term of installing proper PV system;

1. Ensure the area or other installation site is capable of handling the desired system size.
2. Install equipment according to manufacturers specifications, using installation requirements and procedures from the manufacturers' specifications.
3. Properly ground the system parts to reduce the threat of shock hazards and induced surges.
4. Check for proper PV system operation by following the checkout procedures on the PV System Installation Checklist.
5. Ensure the design meets local utility interconnection requirements
6. Have final inspections

## 2.3 System Design Considerations

### 2.3.1 Approaches for using PV's

#### 2.3.1.1 Stand-Alone System

The system requires batteries to store power for the times when the sun is not shining. It does not use electric utility power. The stand-alone system is termed a "separate system" by the electric utility. However, a "separate system" in the utility's terminology can exist in a home that also has utility power as long as they are completely separated [4]. See figure 2.1.

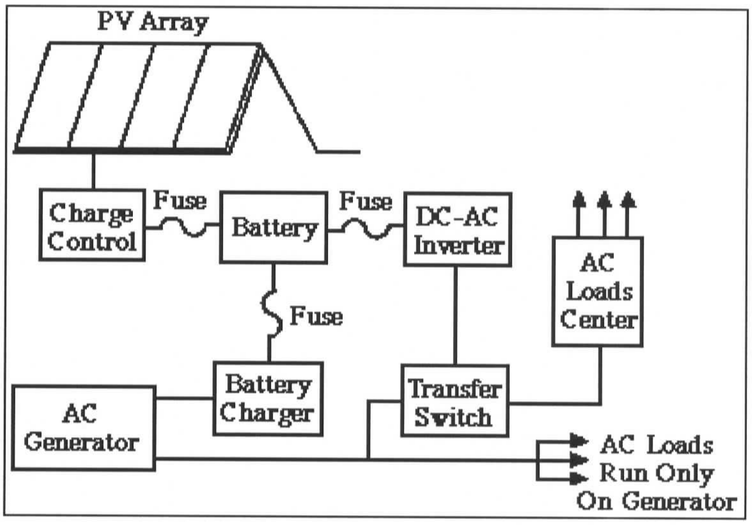


**Figure 2.1: Stand-Alone PV System**

#### 2.3.1.2 Grid- Interface System

This kind of system use power from the central utility when needed and supplies surplus home-generated power back to the utility.

**Grid-Interactive Only (No Battery Backup)**

This type of system only operates when the utility is available. Since utility outages are rare, this system will normally provide the greatest amount of bill savings. However, in the event of an outage, the system is design to shut down until utility power is restored. See figure 2.2.

Typical System Components

1) PV Array: A PV Array is made up of PV modules, which are environmentally-sealed collections of PV Cells which is convert sunlight to electricity. The most common PV module that is 5-to-25 square feet in size and weighs about 3-4 lbs./ft2. Often sets of four or more smaller modules are framed or attached together by struts in what is called a panel. This panel is typically around 20-35 square feet in area for ease of handling on a roof. This allows some assembly and wiring functions to be done on the ground if called for by the installation instructions.

2) Balance of system equipment (BOS): BOS includes mounting systems and wiring systems used to integrate the solar modules into the structural and electrical systems of the home. The wiring systems include disconnects for the DC and AC sides of the inverter, ground-fault protection, and overcurrent protection for the solar modules. Most systems include a combiner board of some kind since most modules require fusing for each module source circuit. Some inverters include this fusing and combining function within the inverter enclosure.

3) DC-AC inverter: This is the device that takes the dc power from the PV array and converts it into standard ac power used by the house appliances.

4) Metering: This includes meters to provide indication of system performance. Some meters can indicate home energy usage.

5) Other components: utility switch (depending on local utility)

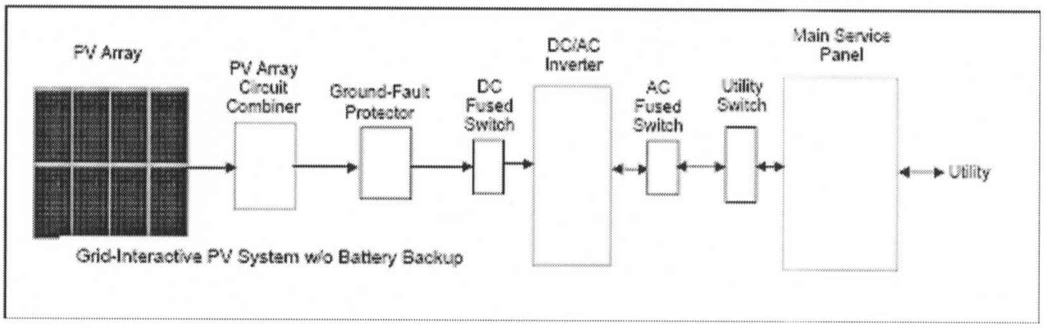


**Figure 2.2: Grid-Interactive Only (No Battery Backup)**

**Grid-Interactive With Battery Backup**

This type of system incorporates energy storage in the form of a battery to keep "critical load" circuits in the building operating during a utility outage. When an outage occurs, the unit disconnects from the utility and powers specific circuits. These critical load circuits wired from a sub panel that is separate from the rest of the electrical circuits. See figure 2.3. If the outage occurs during daylight hours, the PV array is able to assist the battery in supplying the house loads. If the outage occurs at night, the battery supplies the load. The amount of time critical loads can operate depends on the amount of power they consume and the energy stored in the battery system. A typical backup battery system may provide about 8kWh of energy storage at an 8-hour discharge rate, which means that the battery will operate a 1-kW load for 8 hours. A 1-kW load is the average usage.

<u>Typical System Components</u>

In addition to components listed in Grid-Interactive Only (No Battery Backup), a battery backup system may include some or all of the following:

1. batteries and battery enclosures
2. battery charge controller
3. separate sub panel(s) for critical load circuits