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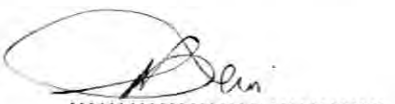
Signature	:	
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Date	:	March 2005

DEVELOPING COMPUTATION TECHNIQUE DETERMINING THE AMPERE-HOURS CAPACITY AND STORED ENERGY OF A BATTERY TO SET THE CHARGER CONTROL LIMITS OF PV POWER SYSTEM BATTERY.

MILLE YAP FU EE @ MILLY TOMPIOS

This Report Is Submitted In Partial Fulfillment Of Requirements For The Degree Of Bachelor In Electrical Engineering (Industrial Power)

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"I agree that this report is my own work except the quotation and summary, each that I mentioned the source "

Signature	:	
Author's name	:	Mille Yap Fu Ee @ Milly Tompios
Date	:	9 March 2005

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I would like to thank and express my deepest gratitude especially to my supervisor, Dr. Alita Dewi upon the invaluable support and wise counsel throughout the completion of this project. Hopefully, through the ideas, and information given, it can provide the useful needs in solving the battery over discharging problem in KUTKM.

I also like to extend my appreciation to my family and all my friends for their help and support. Thank you.

To my Beloved family.
Especially Mum, Dad and Ellane.

ABSTRACT

Photovoltaic system (PV system) is one of the application of solar energy which convert solar energy into electrical energy. The project cover the study of the problem which happened to the PV system battery in KUTKM which one of the battery used in the system is damage because of overcharging.

Ampere hours capacity and energy stored at the battery are considered as the most promising limits in the charging and discharging process in order to keep the life time of the battery. Precise calculation technique of ampere hours capacity and stored energy is the main issue of this project as the solution of the problem. A computation technique has been developed to do the calculation and give the more accurate calculation result to the battery charging control in the KUTKM PV system. This equation hopefully can used to controlling battery charging and discharging process in the system to avoid the same problem.

ABSTRAK

"Photovoltaic System" atau juga dikenali singkatan "PV Sistem" merupakan satu sistem yang mangaplikasikan tenaga suria sebagai sumber utama dan menukarkannya ke bentuk tenaga elektrik. Projek ini berkaitan dengan PV Sistem di KUTKM dan ia merupakan penyelesaian bagi masalah kerosakan bateri yang dihadapi oleh PV sistem di KUTKM.

Melalui kajian yang telah dijalankan, didapati masalah ketidak tepatan nilai sebenar kandungan tenaga yang diberikan oleh sistem kawalan (regulator) merupakan factor utama masalah ini berlaku. Bagi tujuan ini, satu teknik pengiraan persamaan matematik telah diterbitkan bagi mendapatkan kuantiti atau nilai sebenar tenaga yang tersimpan dalam sebuah bateri. Maklumat penting seperti mampatan asid dalam bateri turut diambil kira dalam menerbitkan persamaan ini. Dan diharapkan teknik pengiraan persamaan matematik ini dapat diaplikasikan dalam sistem kawalan pada PV sistem di KUTKM untuk mendapatkan nilai tenaga tersimpan bateri yang lebih tepat bagi mengelakkan masalah atau kejadian yang sama daripada berulang.

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CHAPTER 1

INTRODUCTION

1.1 Background

Storage batteries are indispensable in all stand alone solar electric system (PV system) as shown in figure 1. Their efficiencies and life time affect significantly the overall PV system performance and economics. Batteries specified especially for use in PV system have to be distinguished with standing of very deep discharge rate and high cycling stability.

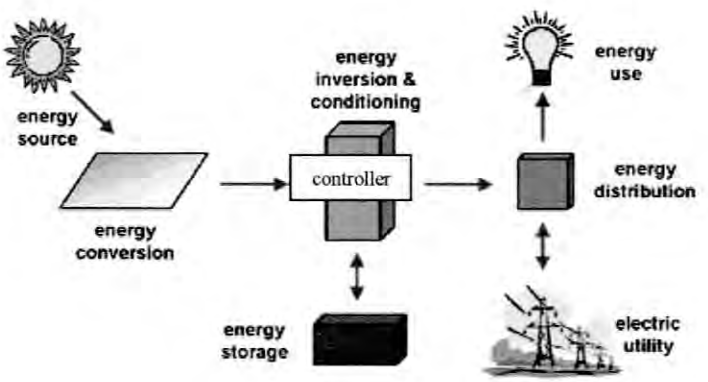

Figure 1: Major photovoltaic system components.

Battery cells should not be operated beyond the cut off voltage, because further discharge will result in increasing the internal resistance of the battery and

can result in permanent damage. On the other hand, overcharging the batteries until gassing leads also to cell damage. By developing the computation device or controller can protects the batteries against deep discharge and excessive overcharging.

1.2 Objective

The objective of this final project is to develop a computation technique to determine the ampere-hours capacity and stored energy of PV system battery in KUTKM.

The important functions represented in battery voltage with electrolyte temperature, specific density and with depth of discharge as well as the degradation of ampere-hour capacity in function of increasing the discharging current have been measured and illustrated. According to the objective of this project, this paper presents an computation technique for derivation of a mathematical algorithm for determining the ampere hour capacity of the battery in KUTKM PV system.

1.3 Problem Statements

Below are the problem statements for this project:

1. Realiable algorithms of ampere-hours capacity and stored energy calculation.

2. Measuring charge level of the battery to the charging and discharging process.
3. To know the calculation that must be used to find the value of Ampere-hour capacity and stored energy, so that we can apply it in the regulator controlling charging and discharging process in battery of PV system.

1.4 Project Scope

This project is related to the PV system in the KUTKM laboratory. The computation technique is going to implement in the existing PV system as the solution on the problem happened in the system which one of the battery was broken because of overcharging.

1.5 Methodology

In order to achieved the objective of this final project and to answer the problem as mentioned before, the following methodology is going to be carried out:

1. Literature study
2. Developing mathematic model and algorithm of Ampere-hour capacity and stored energy.

The intention of doing literature study is to get the knowledge or information about:

1. How the PV system working and also the component related.
2. The technology of battery used in the PV system. For example type of the battery, voltage value, current value and other related information that needed before start to develop the equation related to the performance of battery and the algorithm to obtained reliable performance of battery.
3. The type of the battery in KUTKM and all the related information about the PV system in KUTKM.

CHAPTER 2

PHOTOVOLTAIC SYSTEM

2.1 Introduction

Photovoltaic system (PV system) is an integrated assembly of solar module and other components. The solar module provides direct current (DC) electrical energy to the power conditioning subsystem, which is consists of a regulator and an inverter. The power conditioning system then converts the DC electrical energy into appropriate form to supply the load. Components such as batteries used for storage of electricity and as a backup for excessive power demands or during unanticipated long sunless period. Figure 2 depicts the diagram of the Stand-alone PV system.

Photovoltaic (PV) is an important energy technology for many reasons. As a solar energy technology, it has numerous environmental benefits. As a domestic source of electricity, it contributes to the nation's energy security. As a relatively young, high-tech industry, it helps to create jobs and strengthen the economy. As it costs increasingly less to produce and use, it becomes more affordable and available. And there are many more reasons, as we shall see.

Few power-generation technologies have as little impact on the environment as photovoltaic. As it quietly generates electricity from light, PV produces no air pollution or hazardous waste. It doesn't require liquid or gaseous fuels to be transported or combusted. And because its energy source—sunlight—is free and abundant, PV systems can guarantee access to electric power.

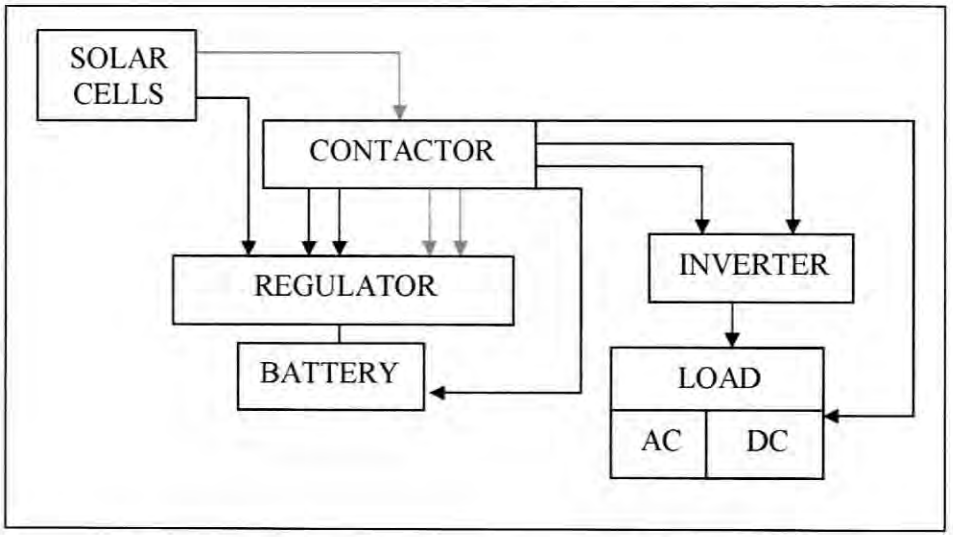

Figure 2. Diagram of stand-alone PV system.

2.1.1 Photovoltaic Cells / Solar Cells

Solar cells convert sunlight directly into electricity. Solar cells are often used to power calculators and watches. It is mostly made of silicon, a material extracted from the sand which is similar to those used in computer chips. When sunlight strikes a PV cell as shown in Figure 3 or when sunlight is absorbed by the cell that has been chemically treated, an electron is dislodge forming an electrical current through wires attached to the cell. In other words the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the *photovoltaic (PV) effect.* The more cells added, the higher the current and voltage. A number of PV cell laid side by side form a rectangular shape called "module" several modules together form an "array" as shown in Figure 4.

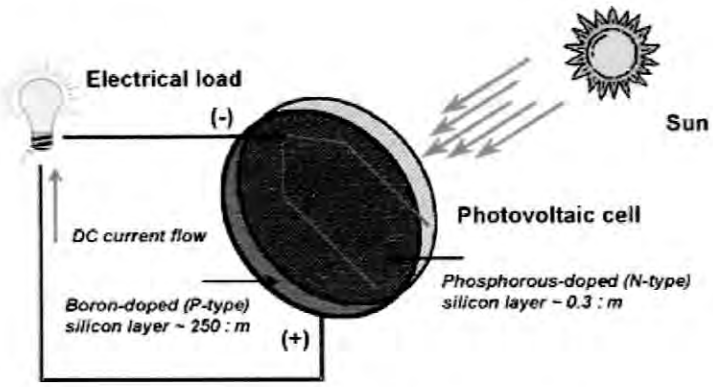

Figure 3. Diagram of photovoltaic cell.

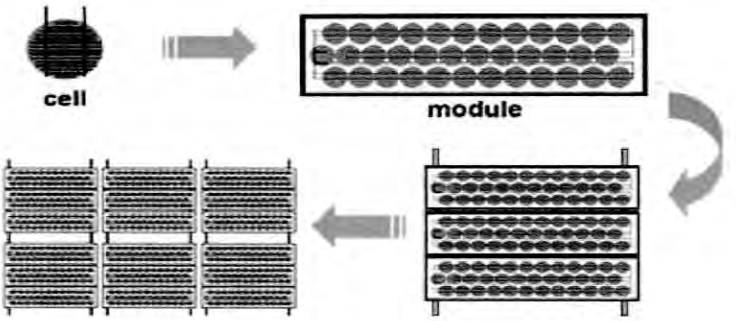

Figure 4. Photovoltaic cells, modules, panels and arrays.

2.1.2 Battery

2.1.2.1 Battery types

The two types that have been mostly used for PV system are lead-acid and nickel-cadmium. Due to higher cost, lower cell voltage (1.2V), lower energy efficiency and limited upper operating temperature (40°C), nickel-cadmium batteries have been employed in relatively few system. Their use is based mainly on their long life with reduced maintenance and their capability of standing deep discharge without damage. The lead-acid battery will remain the most important storage device in the near future, especially in PV systems of medium and large size. It is a lead

sulfuric acid or lead dioxide electrochemical system, whose overall reaction is given by the following equation.

$$Pb + PbO_2 + 2H_2SO_4 \underset{\text{Charge}}{\overset{\text{discharge}}{\rightleftharpoons}} 2PbSO_4 + 2H_2O \qquad (2.1)$$

2.1.2.2 Lead-acid battery characteristics

The nominal voltage of a lead-acid cell is 2V, while the upper and lower limits of discharging and charging open circuit voltage at 25°C cell temperature are 1.75 and 2.4V, which corresponds to 10.5 and 14.4 V for a 12V battery respectively. The maximum acceptable battery cell voltage decreases slightly with increasing temperature. Cell voltage and specific gravity of the acid solution are mainly a measure for the state-of-charge of the battery cell. The depth of discharge (DOD) is the observe of state-of-charge. As measurement result in IV.3.3 and IV.3.4 show, cell voltage decrease almost linearly with depth of discharge until a point called cut off voltage is reached.

Battery cells should not be operated beyond the cut off voltage, because further discharge will result in increasing the internal resistance of the battery and can result in permanent damage. On the other hand, overcharging the batteries until gassing leads also to cell damage. By developing the computation device or controller of ampere hours capacity can protects the batteries against deep discharge and excessive overcharging.

Battery store the electrical energy generated by the solar modules. Sufficient storage capacity must be provided to meet specific load requirements and to account for diurnal and seasonal variations in solar isolation. The main ones used in solar systems are the lead acid batteries and the nickel cadmium batteries.

In a solar system, batteries provide various functions depending on whether the application is Grid-Connected or Off-Grid. For Grid-Connected applications, batteries provide backup electricity in the event the grid loses power. For Off-Grid applications, batteries are essential for providing power during the night or during overly cloudy
conditions.

The following factors must be considered in selecting a battery for any given solar system.

- Voltage Requirements
- Current Requirements
- Operating Schedule
- Operating Temperature
- Size and Weight
- Ampere-Hour Capacity
- Required Life
- Cost

Selecting the appropriate battery for a system is an important. Since a PV system's anticipated life exceeds 30 years, over the system's lifetime, the battery will require replacement two, three, or more times; making it the most expensive component of most systems. Battery characteristics vary greatly. The type of battery and how it is cycled in the system will affect both system performance and battery lifetime. BP Solar has a wide range of batteries which are all specifically designed for use in solar systems.

2.1.3 Inverter

An inverter used to convert the direct current (DC) from the array or battery to single or three phases alternating current (AC) to run the AC appliances and

equipment. AC output has one big advantage: the great range of loads and appliances available. The disadvantages are the inverter's complexity and inefficiency.

Thyristor inverters usually operate with other devices for restart when the DC input voltage reaches a set minimum, protection against short circuits and overloading and maximum power point tracker.

Adding an inverter to a system obviously increases its expense. It also makes it more complex, and therefore decreases its reliability. A PV system is inherently reliable in part because of its simplicity; every component added in the system's power path reduces overall system reliability. This factor is particularly important at remote sites with critical loads. Modern inverters are sophisticated pieces of solid-state components.

Beyond performing reliably, the task of the inverter is to reproduce the characteristics of utility power as closely as possible. It must convert DC to AC, beside of duplicating, as closely as possible, the frequency of the utility power, synthesizing an AC waveform which will operate loads accurately and efficiently, delivering enough power to meet short-term demand peaks, such as motor starting surges, and maintaining reasonable output voltage and frequency regulation despite fluctuations in load and input voltage.

2.1.4 Charge Regulator

Charge regulator are link between the modules, battery and load. They protect the battery from overcharge or excessive discharge. Overcharging cause the battery voltage terminal raises and gassing become excessive. If these happen, it can damage the plates, loss of water from the electrolyte, build-up of gas pressure and over

heating. Voltage terminal higher than required voltage during charging also can damage the appliances. Some batteries e.g nickel cadmium and sealed cell need different methods of charging. Using self regulating modules affect the charging rate. Battery is not charged as quickly as possible and the charging current is low in cloudy weather.

Other elements such as mounting structures used to hold the solar modules security in place. There are ground, root and pole mounting versions that are available. Proper wiring and connections must be specified for every segment of the system to assure best performance.

The main function of a charge regulator or controller is to fully charge a battery without permitting overcharge while preventing reverse current flow at night. If a non-self-regulating solar array is connected to lead acid batteries with no overcharge protection, battery life will be compromised. A simple charge regulator contains a transistor that shunt the PV charging circuit, terminating the charge at a pre-set high voltage and, once a pre-set reconnect is reached, opens the shunt, allowing charging to resume. Solar Charge Regulators are an important component of any solar system for higher efficiency, longer battery life and low maintenance. Our range of high quality solar charge regulators give full protection against overcharging and over discharging.

2.2 PV System in KUTKM

There is seven set of Stand Alone Solar System in Kolej Universiti Teknikal Kebangsaan Malaysia. Which every set consists of:

1. Solar Module (Type : BP275F)

2. Inverter (Type : Selectronic's LD200-12)
3. Regulator (Type : GCR800M)
4. Battery (Type : Sonnenschien Dryfit Lead-acid SB12/100 (GEL))
5. Load (12Vdc and 240Vac – 1 x 60W Bulb)

The solar is the source of this system. Once the solar panel which is the heart of the system been hit by the light of the solar, this electrical field provides momentum and direction to light-stimulated electrons which resulting in a flow of current when the solar cell is connected to an electrical load. The contactor is used to protect the system from any unrespectable condition such as lightening. Once the energy been sent to the regulator, the regulator will received the energy and check the status of the system. If the load is connected, the system will check either the connected load is DC load or AC load. If it is a DC load, it will send the energy direct to the load. And if the AC load is connected, the inverter will transfer the DC to AC before supplied it to the load. If there is no load connected to the system, the regulator will check the status of the battery, either the capacity is full or not. If the information received saying that the battery is still need to be charge, the energy will deliver and stored in the battery, but if the battery is full the regulator will just stop the charging process.

The battery is used in the system during night time and during sunless period. There is four circuit breaker connected to the system. It is used to protect all the component in the system. Which the breaker will break the fuse if the current through it was bigger than the limit that set to the circuit breaker. Figure 5 depicts the step by step of the overall function of the PV system in KUTKM and Figure 6 show all the components related to the Portable Stand Alone Solar System in KUTKM.