# LEAD ACID BATTERY MANAGEMENT SYSTEM FOR SOLAR HARVESTING SYSTEM

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## ABSTRACT

The first solar energy was introduced in this decade and from that time, there are many new solar technology equipment was made in vehicle, lighting and other. Since then, various technologies have emerged to make solar based technology equipment with battery or other. However there are still limitations on the development process especially in terms of the battery management technology which includes battery technology. The phrase battery management means differently to different people, for us, battery management is how to manage all the battery voltage to be all same together and not so far difference when in used. Generally the energy battery management system of a solar equipment system includes the requirement to ensure that electrical power flow from the Photovoltaic to the loads will be monitored and optimised. Load behaviour significantly affects the solar equipment especially the battery. Hence, proper load battery management strategy is important to draw maximum power from the Photovoltaic module. A maximum power point tracker device must be used between the photovoltaic module and battery to boost the battery charging rate. Some back up batteries are needed in the system to eliminate unexpected system shutdown. As a result, an appropriate system that is focus on lead acid battery should be determined at the design stage to ensure for optimum battery management system can be built.

# ABSTRAK

Teknologi yang menggunakan kuasa solar yang pertama telah diperkenalkan di dalam abad ini, bermulalah dari situ, terdapat banyak jenis peralatan yang menggunakan kuasa solar yang baru seperti kenderaan, pencahayaan dan lain lain. Semenjak dari itu juga, pelbagai jenis peralatan yang menggunakan teknologi solar dikeluarkan dengan menggunakan peralatan teknologi dengan bateri nya sendiri. Walaubagaimanapun, terdapat sedikit masalah di dalam pembangunan teknologi solar ini terutamanya di dalam teknologi pengurusan batteri yang termasuk di dalam teknologi bateri. Frasa pengurusan bateri diterjemahkan di dalam pelbagai versi dan maksud di dalam pelbagai lapisan masyarakat, tetapi bagi kita, pengurusan bateri adalah satu sistem untuk bagaimana kita mahu mengawal semua voltan bateri yang disambungkan secara siri dan tidak banyak beza perubahan voltan diantara bateri apabila digunakan. Secara umumnya, sistem teknologi pengurusan bateri termasuklah kehendak kepada untuk memastikan perjalanan kuasa dari panel solar kepada beban dapat dikawal dan diambil tahu. Beban yang dipasang dan tingkah laku beban boleh memberi kesan yang negatif kepada peralatan teknologi solar terutamanya bateri yang dipakai. Maka dengan itu, system pengurusan bateri yang terbaik perlulah dipakai untuk memberi kuasa penuh daripada panel solar. Pengesan maksimum perlu juga diguna diantara panel solar untuk menaikkan kesan pengecas untuk bateri. Bateri penyokong juga perlu di dalam sistem untuk mengurangkan kesan jika terjadinya kuasa sistem hilang secara tiba tiba atau tak disangka sangka. Maka dengan itu, satu sistem pengurusan bateri yang difokuskan kepada bateri lead asid mesti dibina untuk memastikan sistem pengurusan bateri yang terbaik dapat dipakai.

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## LIST OF SYMBOL

| | |
|---|---|
| I | The discharge current (Ampere) |
| n | The battery constant (n=1.35 for typical lead-acid batteries) |
| Ti | The time to discharge at current I (Sec) |
| C1, C2 | The discharge rates at different discharge rate states |
| I1, I2 | The currents at the two different discharge rate states |
| V | The voltage (Volt) |

## LIST OF ABBREVIATION

| | |
|---|---|
| AB1 | After battery 1 |
| AB2 | After battery 2 |
| AB3 | After battery 3 |
| ASP | After solar panel |
| BMS | Battery management system |
| CPU | Central Processing Unit |
| DC | Direct current |
| EV | Electric Vehicle |
| GSM | Global System for Mobile Communications |
| HEV | Hybrid Vehicle |
| IC | Integrated circuit |
| LIPO | Lithium-ion polymer batteries |
| MATLAB | Matrix laboratory |
| MOSFET | Metal-oxide semiconductor field effect transistor |
| MPP | maximum power point |
| MPPT | Maximum Power point tracking |
| PCB | Printed circuit board |
| PEROM | programmable and erasable read only memory |
| P-N | Positive Negative |
| PV | Photovoltaic |
| RC | Radio-controller |
| RUL | Remaining Useful Life |
| SOC | State of charge |
| SOH | State of health |

| | |
|---|---|
| VRLA | valve-regulated lead–acid battery |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

The new technology have been influence our live since this recent year. There are green energy that comes from water, wind, and Sun. All of this technology has made our life easier and more save. This all are called reusable energy that do not pollute and will not run out. Energy that was making by fuel and gas will come to an end one day. Therefore we have to use the reusable energy to replace the energy that cannot last longer. One of the reusable energy that was growing faster was the solar energy. For that, the human being takes advantage of this by using sun as the energy that wanted to be reuse.

The first solar energy was introduced in this decade and from that time, there are many new solar technology equipment was made in vehicle, lighting and other. Since then, various technologies have emerged to make solar based technology equipment with battery or other. One of the system that small but are much needed are called the Battery management system. The system function is to control all the energy at the lead acid batteries module. This system will actually make the lead acid batteries module stabilise and not so much difference from one to another. The batteries module energy will become fluctuated when sometime cloud passing over the equipment that by mean the photovoltaic cell or the sun not shining well that day. This will make some trouble to the energy balance between batteries module. This condition always happened when we the equipment run for a long period with load or without load.

## 1.2 Background of study

Solar energy is so important in today life. Although the used of this kind of technology are still slow and less, this kind of technology can increase higher and will be the future energy for tomorrow for human being. Every country has made afford to introduce their solar power system technology to the world. Malaysia also has been introduced to the technology of solar system. Therefore, this system technology has getting increase in high demand. Many countries have built variety of solar technology equipment and giving opportunity to all the country in the world to show their technology.

The basic component of the solar car was photovoltaic cell, charger controller, Batteries lead acid, direct current motor, and battery management system. The most important part for the solar equipment was the battery management system. This system function is to hold the batteries stable between each other. The used of equipment for a long period of time will make the batteries energy fluctuated and this will become a problem. Therefore this problem must be tackle by making a BMS that can function well.

## 1.3 Problem Statement

Rechargeable batteries like lead acid always have trouble regarding to its Energy balance between batteries. This happened when the batteries cannot get enough current to maintain the batteries energy from being fluctuated. Simple example was the solar equipment that always is used in a long period of time. Solar cell need power from the sun to charge the batteries, therefore, small disturbing from sun light to the photovoltaic cell make the energy that needed by the batteries cannot be get. Cloud and sometimes the sun don't shine hard was the normally courses of the problem happened all the time. This problem must be tackle to make the lead acid batteries can be manage and works with long lasting and not easy to fail.

## 1.4 Research Objective

i. To built a model of batteries management system that can manage the lead acid batteries. This BMS can control and manage all the series of lead acid batteries or other type of rechargeable battery in the world. This BMS can manage the voltage with precise.

ii. To built a model that have input and output of simple system that was easy to carry, easy to connect and friendly user. This BMS will make it easy to the entire user that wanted to maintain and guard their lead acid batteries in solar energy equipment like solar heater, solar car and other type of things that usually used solar power.

iii. To build a model of BMS that can manage series of batteries rechargeable type that always have fluctuated output on batteries. This BMS will protect, guard and keep safe all the batteries and this will make it not easy to broken or fail.

## 1.5 Research Question

Today, the important of how to control and manage all the batteries in system that used solar energy to produce voltage can be seen all in many sectors like industrial, construction, electronic and automotive. Batteries that been used have many kinds of weakness that must be tackle and settle it before it can be used with steady and always in good condition. The difficulty happened when all the voltage in one of series of lead acid or rechargeable batteries are not same org fluctuated between each other. Therefore this will contribute to failing on the system all. Therefore a battery management system must be made to tackle this entire problem.

i. How to control and manage the energy in all of the lead acid batteries
ii. How to make sure that the battery management system can with stand all the problem regarding to the batteries that not consistence in energy balance

iii. How to built and create a battery management system model that can be used with long period and less problem

## 1.6 Research Hypothesis

Energy balance between batteries that being attach in series can be manage by Install the Battery management system circuit that can control all the measurement Spec in all of the batteries

## 1.7 Scope of Study

i. Battery management system for solar car or equipment. All the equipment that used solar powered energy will need rechargeable batteries. This all batteries need a good protector. There for this BMS will be the answer.

ii. Energy management for battery type lead acid and other type of rechargeable batteries.

iii. PIC Programming AT89C52. This PIC will be used vastly in this BMS system. The PIC will be programmed according to needs.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1. Introduction

Energy balances in batteries are so important and must be consider and control its behaviour. This chapter are focus on batteries management that used by the solar cell as an input direct current. Therefore, a suitable battery management system module will be creating to overcome this entire problem in management of the battery.

## 2.2. Battery Management System

Battery Management System (BMS) has become one of the chief components in solar equipment. The goals of BMS are to maximize both the runtime per discharge cycle, as well as the number of life cycles attainable for the life of the battery. Automotive battery management is very demanding, because it has to work in real-time in rapidly varying charge-discharge conditions as the vehicle accelerates and brakes, as well as work in a harsh and uncontrolled environment. In addition, it must interface with other on-board systems, such as the engine management, climate controls, communications, and safety systems. The functions of a BMS in a hybrid electric vehicle are multifaceted. They include monitoring the conditions of individual cells which make up the battery, maintaining all the cells within their operating limits, protecting the cells from out-of-tolerance conditions, compensating for any imbalances in cell parameters within the battery chain, providing information about the State of Charge (SOC), State of Health (SOH), and Remaining Useful Life (RUL) of the battery,

providing the optimum charging algorithm for charging the cells, responding to changes in the vehicle operating mode and so on. (Bharat et al, 2008)

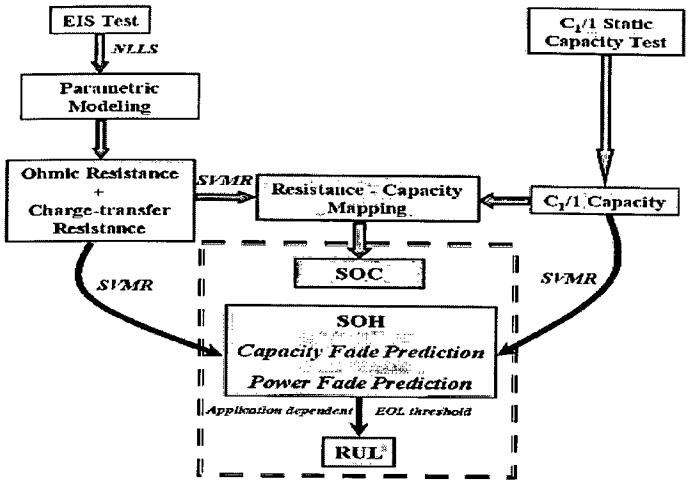


**Figure 2.1:** SOC, SOH, and RUL estimation framework (Bharat et al, 2008)

## 2.3. Battery Monitoring

The term "Battery Management" means active feedback to the battery. This may comprise control of current or voltage levels, control of recharge conditions, limiting of the operational windows with respect to SOC and/or temperature, battery temperature management, etc. "Energy Management (Electrical)" means housekeeping with the electrical energy, i.e. control of energy generation, flow, storage, and consumption. Without the essential information from Battery Monitoring, Energy Management may scarcely work. An appropriate Battery Management may significantly enhance and improve, but is not a precondition for, a successful Energy Management. Fig. 2.2 is shows the layer structure of Battery Monitoring generating Battery Status Information, Battery Management, and Energy Management. (Eberhard & Gerolf, 2003)

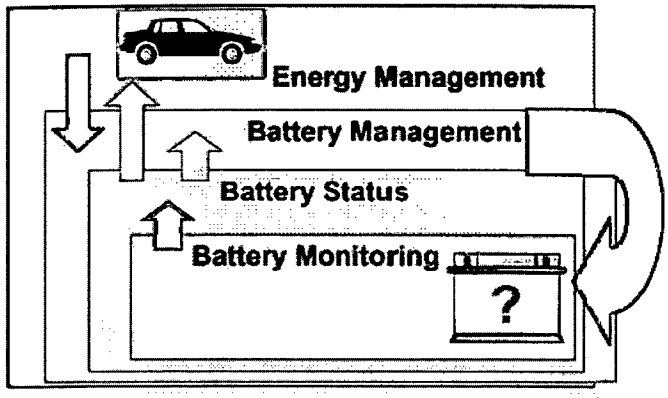


**Figure 2.2:** Layer structure of battery monitoring generating battery status information, battery management and energy management, and mutual data flow (Eberhard & Gerolf, 2003)

## 2.4. Integrated VRLA-Battery Management System

In cases where the number of the backup batteries is large such as for UPS, this system enables us to put all the information of each battery together by connecting in series the master units of the battery-management system. Meanwhile the data is collected from each battery deterioration judgement unit as for engine generators, communication equipment terminals and security device terminals that are located in different floors. On the occasion of a failure, the alarm signal from each battery-management unit is transmitted through dial-up public lines or wireless lines to an operator in one remote location. An operator can always monitor all the units by telemeter of the battery's voltage and its lifetime through these dial-up lines. We can also use Web as a means of communication. (Ichiro et al., 2000)

## 2.5. Battery Management System

Management of a battery network requires the monitoring of the state of the system in maintaining healthy operational conditions and timely operational alarms. Involved management systems also include battery charge manipulation, allowing for testing and charge maintenance to occur. The three main categories of management

have been identified as battery operation management, network communication management, and battery and network data management. Fig. 2.3 indicates an organization to the battery management hierarchy. Battery operation management involves the monitoring and control of facets related to process operation. The processing of raw battery data to produce higher level derived battery data and information such as battery state of charge, reserve time, and the monitoring of interface module performance and efficiency falls under this category. Network communication management involves monitoring features of the CAN, such as adding or configuring network nodes and messages as well as maintaining acceptable performance of the CAN.

Another aspect of network communication management is the remote downloading and upgrading of node software. Storage of raw and derived data, network configuration parameters as well as alarms and events falls under the category of battery and network data management. Data compression and minimization is also an important feature of this form of management due to the restricted and limited memory capacity of the embedded devices. An effective and efficient compression method would allow larger temporal amounts of data to be stored at the lower data layers before being passed to higher data layers. One common element of each form of management is the processing of relevant alarms and events, which are generated when user defined or pre programmed fault conditions occur.

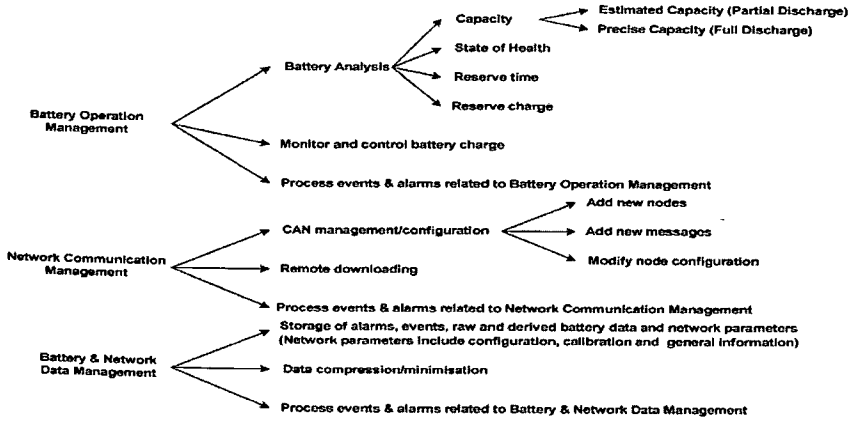


**Figure 2.3:** Battery management system task organization (Eberhard & Gerolf, 2003)

## 2.6. Photovoltaic

Photovoltaic (PV) generation is becoming increasingly important as a renewable source since it offers many advantages such as incurring no fuel costs, not being polluting, requiring little maintenance, and emitting no noise, among others. PV arrays produce electric power directly from sunlight. With the advent of silicon P-N junction during the 1950s, the photoelectric current was able to produce power due to the inherent voltage drop across the junction. This gives the well-known nonlinear relationship between the current and voltage of the photovoltaic cell. From this nonlinear relationship of the photovoltaic cell, it can be observed that there is a unique point, under given illumination, at which the cell produces maximum power, the so-called maximum power point (MPP). This point occurs when the rate of change of the power with respect to the voltage is equal to zero (Eberhard & Gerolf, 2003).

The output power of PV cell varies with depending mainly on the level of solar radiation and ambient temperature corresponding to a specific weather condition. The MPP will change with external environment of PV cell. An important consideration in achieving high efficiency in PV power generation system is to match the PV source and load impedance properly for any weather conditions, thus obtaining maximum power generation. The technique process of maximum power point is been tracking which is called maximum power point tracking (MPPT) (Jiyong & Honghua,1998).

## 2.7. Photovoltaic P-N Junction

Photovoltaic cells consist of a silicon P-N junction that when exposed to light releases electrons around a closed electrical circuit. From this premise the circuit equivalent of a PV cell can be modelled through the circuit shown in Fig. 2.4. Electrons from the cell are excited to higher energy levels when a collision with a photon occurs. These electrons are free to move across the junction and create a current. This is modeled by the light generated current source (Iph). The intrinsic P-N junction characteristic is introduced as a diode in the circuit equivalent (Jiyong & Honghua, 1998).

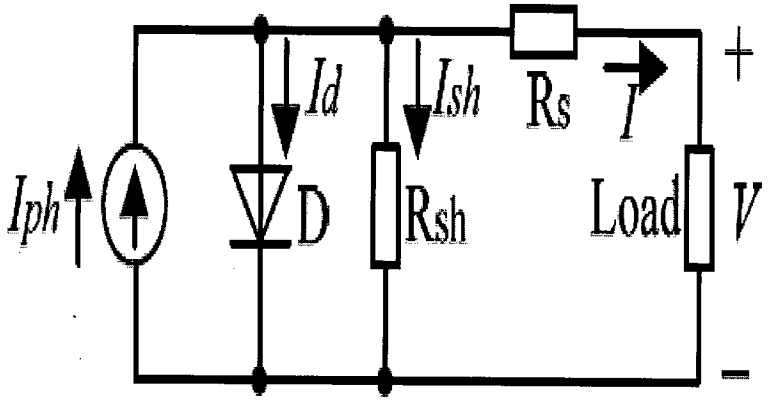


**Figure 2.4:** Photovoltaic cell equivalent circuit (David, 2012)

## 2.8. Photovoltaic Charging System with MPPT

A photovoltaic charging system with MPPT function is composed of solar battery, battery management module, CPU dominating module. When charging the battery, solar battery generates electricity which is stored in battery by the sun radiation, surplus electric power is used to supply for the monitoring unit when taking use of electricity, battery releases the stored energy supply for the system to ensure the system runs without power-down. CPU dominating module maintains the maximum power output of the array and manages the battery optimally. The dominating module regulates the DC / DC module to ensure the maximum power output of the solar battery array.

The dominating module which is responsible for the group's macro-charging cycle management sends orders through the I 2C interface to battery management module, including setting up the charge and discharge mode of battery management module, calibrating the battery power and so on, as well as gets status information of the battery from the battery management module, including the battery voltage, the charge current, electricity left over and so on. Since the I 2C interface finds address through software, it will need no additional data lines to expand battery's capacity and only set aside the battery slot. (Lixin et al, 2008)

## 2.9. Energy Storage

Energy storage for PV systems commonly consists of batteries to store and discharge electrical energy as needed. However, each time a battery is charged or discharged, some energy is lost from the system. Batteries vary by type, depth of discharge, rate of charge, and lifetime (in PV applications). The most common types of batteries used with PV systems are lead-acid, but other more exotic and expensive batteries are sometimes used, such as nickel metal hydride. A new area of PV battery applications is emerging in which the PV battery is used for backup power when the utility grid fails for grid-tied PV systems. This application has unique battery charging and maintenance requirements. Batteries are usually installed in well-ventilated locations such as garages, utility rooms, and outbuildings to minimize the potential for capturing explosive concentrations of hydrogen gas and to minimize possible hazards from electrolyte spills. (Taylor & Francis, 2012)

## 2.10. Batteries Balance

Balancing is the most important concept concerning the life of the battery system because without the balancing system, the individual cell voltages drift apart over time. The capacity of the total pack also decreases more quickly during operation, which results in the failure of the total battery system. This condition is especially severe when the battery has a long string of cells (high-voltage battery systems) and frequent regenerative braking (charging) is done via the battery pack. Imbalance of cells in battery systems is very common and is the result of many sources. The sources fall into two major categories such as internal and external. The internal sources include manufacturing variance in physical volume, variations in internal impedance, and differences in self-discharge rate. The external source is mainly caused by some multi rank pack protection ICs draining unequally from the different series ranks in the pack.

Thermal difference across the pack is another external source because it results in different self-discharge rates of the cells. Balancing methods can be either passive or active. Passive balancing method can only be used for lead acid and nickel-based batteries because lead-acid and nickel-based batteries can be brought into overcharge conditions without permanent cell damage. When the overcharge is not very severe, the