DEVELOPMENT OF AUTOMATIC LOAD-SHEDDING STRATEGY FOR STAND-ALONE PHOTOVOLTAIC SYSTEM

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Bachelor of Electrical Engineering

(Power Electronic And Drives)

June 2014

" I hereby declare that I have read through this report entitle "Development Of Automatic Load-Shedding Strategy For Stand-Alone Photovoltaic System" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive) "

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A report submitted in partial fulfillment of the requirement for the degree of Bachelor in Electrical Engineering
(Power Electronic and Drive)

Faculty of Electrical Engineering
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I declare that this report entitle "Development Of Automatic Load-Shedding Strategy For Stand-Alone Photovoltaic System" is the result of my own research except as cited I the reference. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ………………………………

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Date : ………………………………

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ABSTRACT

Nowadays, the use of solar energy are extremely developed and delivered worldwide. This project presents the development of automatic load-shedding strategy for stand-alone photovoltaic system. The design of this project shows the characteristics of solar energy and operation of load-shedding strategy. The main objective of this project is to implement the load-shedding strategy as an emergency controller for stand-alone photovoltaic system. To achieve the objective, research of basic understanding related to this project is very important to understand more about the characteristics of each element in this project. The circuit of the load-shedding system is designed in the SoftCad Eagle PCB Design software. The algorithm controlling the load-shedding scheme is developed in the Arduino IDE. Then, the coding programmed is burn in the microcontroller board and installed with the hardware. Output of this project can support the DC loads and load-shedding strategy scheme is performed based on the designed algorithm.

ABSTRAK

Pada masa kini, penggunaan tenaga solar adalah sangat maju dan tersebar di seluruh dunia. Projek ini membentangkan pembangunan strategi catuan beban secara automatik untuk sistem photovoltaic bersendirian. Reka bentuk projek ini menunjukkan ciri-ciri tenaga solar dan operasi strategi catuan beban. Objektif utama projek ini adalah untuk melaksanakan strategi catuan beban sebagai pengawal kecemasan untuk sistem photovoltaic bersendirian. Untuk mencapai matlamat tersebut , penyelidikan pemahaman asas yang berkaitan dengan projek ini adalah sangat penting untuk memahami lebih lanjut mengenai ciri-ciri bagi setiap elemen dalam projek ini. Litar sistem catuan beban telah direka dalam perisian SoftCad Eagle PCB Design. Algoritma mengawal skim catuan itu diprogramkan dalam perisian IDE Arduino . Kemudian, pengekodan yang diprogramkan telah dimuat turun ke dalam papan pengawal mikro dan dipasang dengan perkakasan. Pengeluaran projek ini boleh menyokong beban DC dan skim strategi catuan beban dilakukan berdasarkan algoritma yang direka.

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LIST OF ABBREVIATIONS

PV	-	Photovoltaic
PCB	-	Printed Circuit Board
DC	-	Direct Current
AC	-	Alternating Current
Si	-	Silicon
V	-	Volt
A	-	Ampere
W	-	Watt
MOSFET	-	Metal Oxide Semiconductor Field-Effect Transistor
LED	-	Light Emitting Diode
SRAM	-	Static Random Access Memory
EEPROM	-	Electrically Eraseable Programmable Read-Only Memory
I_{SENSE}	-	Sensed Current
V_{SENSE}	-	Sensed Voltage
V_{in}	-	Input Voltage

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The level of demand for electricity is very high as it is human necessities of life either during day time or night. Most of human daily routines such as work, economy, livelihood, healthcare and leisure depend on a constant power supply. Thus, even a temporary power failure can cause chaos, financial loss, and possible loss of life. There are several unexpected causes of power failure such as natural causes like weather, short circuit, components broken and others. However, in this modern day life, a lot of precaution steps are designed and implemented on the grid system to overcome the power failure. The islanded microgrid operation is one of the methods to keep certain places to receive power supply. This operation is supported by load-shedding scheduling which keeping the power system stability by turn off some of the loads. For this project, the application of load-shedding strategy for islanded microgrid system during power outages is implemented in a small scope where photovoltaic (PV) technology is used as a power supply. PV systems are low maintenance, provide a cleaner, environmentally friendly alternative, and very reliable source of power. It is often used as a back-up for the grid system or operates independently without grid connection. Successful stand-alone systems generally take advantage of a combination of techniques and technologies to generate reliable power, reduce costs, and minimize in convenience. Therefore, this stand-alone PV system will supply several loads and to keep the system balance, load-shedding strategy will be implemented in this system.

1.2 Problem Statement

As the demand of electricity has increase throughout the decade, the failure of power system will affect the daily routines. Therefore, the methods to overcome power outages are developed and delivered worldwide such as the usage of solar energy, wind energy and biofuels energy as a back-up system. However, another issue has come out, there is a rising interest on their impacts on power system operation and control as they have low reliability and flexibility. For this project, a PV stand-alone system is installed to supply several loads. At a certain time, power generated by the PV might be low than the power consumed by the loads due to the variation of irradiances level. At this moment, the power consumed by the loads will not be at rated value and make the power demand higher than power supply. Therefore, the load-shedding strategy is applied to the system to give the maximum power to the loads. The algorithms for the load-shedding will be determined based on the load demand and acceptable power range from PV. The number of load to be shed is important to ensure the stability of energy conservation.

1.3 Objectives

The aims of this project are as follow:

1. To design automatic load-shedding strategy for stand-alone photovoltaic system.
2. To develop the algorithms to control the load-shedding operation.
3. To study the energy conservation between load and supply under variation of conditions.

1.4 Scope of Research

This project primarily focuses on three parts; which are the type of PV system, the strategy for load-shedding and type of load. In this project, the system designed is stand-alone PV system without connection of energy storage. Other than this type of PV system is not included in this project. This project performs only on the implementation of hardware. The circuit of hardware is designed by using SoftCad Eagle PCB Design software while the programming is developed by using Arduino IDE. The algorithms developed for load-shedding will be determined based on the load demand and the acceptable power range from PV. Furthermore, this project use number of lighting as a DC loads. This project will not cover the AC loads. This project is implemented as a prototype of load-shedding strategy for islanded microgrid operation during power outages in a small scope. Only operations during islanded microgrid operation after power failure is covered.

1.5 Report Outlines

1. **Chapter 1 -** An introductory of the project consisting of the project problem statement, objectives, and scope.
2. **Chapter 2 –** Collection of theories that can be formulated and implemented in the project. Reviews of literatures from various sources that can be related to the project research and development.
3. **Chapter 3 –** Description of design methodology for the project development and progress.
4. **Chapter 4 –** Results of the project progress is described and the analysis of the results are discussed.
5. **Chapter 5 –** The conclusion and recommendation on the final stages of the project development.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Review related to this project are really important to have more understanding on research subject. Therefore, literature review from various sources of information such as technical report, books and journals for related topics are referred. In this chapter, the theory or basic principle of elements covered in this project are discussed. This includes fundamental characteristics, their functions, advantages and many more. For this project, the element or system developed are stand-alone photovoltaic system and load-shedding strategy.

2.2 Photovoltaic System

2.2.1 Definition

Genuinely, PV entail the process regarding the conversion of the radiant energy from the sun (solar energy) directly into the electricity [1]. Since the solar energy is the most abundant energy source on the planet, photovoltaic system can be classified as a vital technology that needs to be explored extensively in order to preserve our planet. PV sources can provide power supply to from the small electronics to homes and large commercial businesses. PV systems consist of various type of configuration such as grid connected PV system, direct PV system, stand-alone PV system and hybrid system [2].

2.2.2 Configurations

A PV cell is normally consists of a semiconductor diode whose p-n junction is exposed to light. Nowadays, most of PV which are more than 90% of them, are manufactured from Si modules constructed from small 4-12 inch crystalline or multicrystalline wafers [3]. Basically photovoltaic cell is made from several types of semiconductor such as monocrystalline and polycrystalline silicon cells. Silicon PV cells are composed of a thin layer of bulk Si or a thin Si film connected to electric terminals. One of the sides of the Si layer is doped to form p-n junction. A thin metallic grid is placed on the Sun-facing surface of the semiconductor [4].

The traditional Si solar cell is a homo junction device. It might have a p-type base with an acceptor (typically boron or aluminum) and a diffused n-type window/emitter layer (typically phosphorus). The Fermi level of the n-type side will be near the conduction (valence) band edge so that donor-released electrons will diffuse into the p-type side to occupy lower energy states there, until the exposed space charge (ionized donors in the n-type region, and ionized acceptors in the p-type) produces a field large enough to prevent further diffusion. To produce a back surface field (BSF) for hole collection and rejects the electrons, a very heavily doped region is used at the back contact. Figure 2.1 indicates the typical construction of the semiconductor part of a Si cell.

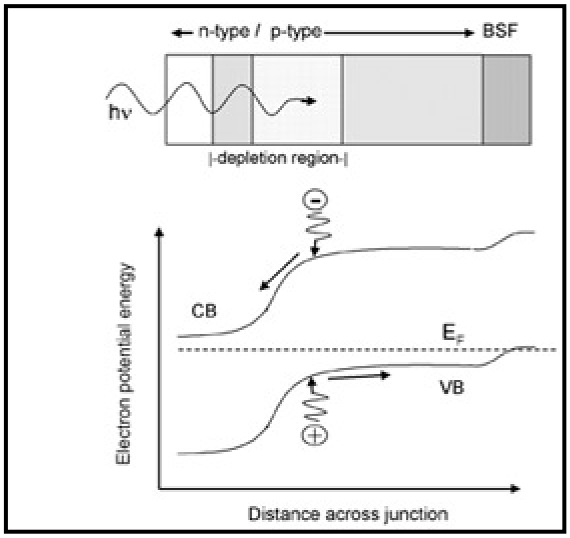

Figure 2.1: The Diagram Of Solar Cell Structure And Energy Band [3]

Most of the PV panels are covered with an aluminum frame around the edge, with the size about 600 mm wide, 1200 mm tall and 25 mm thick. These panels are combined together to form a PV array. The crytalline-type panel are the most efficient which operates at about 25% efficiency by maintaining the cool temperature. These type of panels are created from crystalline silicon cells which covered by a grid of wire to aid the electrical energy flow to the terminals. Besides that, there are cheaper PV panels compare to crystalline panels called thin film technologies panels. Material like amorphous silicon can be applied as a film without the need for a glass covering such as glass or plastic. However, the efficiency of thin film technologies panel is about 10% which is much lower than crystalline [5].

Some of PV systems need an inverter and batteries as one of the equipments, depend on the system requirement. The inverters are used to convert the DC value of

PV panels to AC value for AC system. The batteries are mostly needed for stand-alone PV systems which the place is not provided with connection to the electricity grid. These batteries keep the electrical power as a back-up when the PV panels cannot manage to supply adequate electricity. The grid connected systems need a metering system to calculate the amounts of electricity comes from the grid and also from the PV.

2.2.3 Operation

PV generates electricity by converting it directly from solar radiation through an electronic process that occurs in certain types of material called semiconductor. Solar energy release the electrons in these materials and can be induced to travel through an electric circuit which then powering electronic devices or supply electricity to the grid [6].

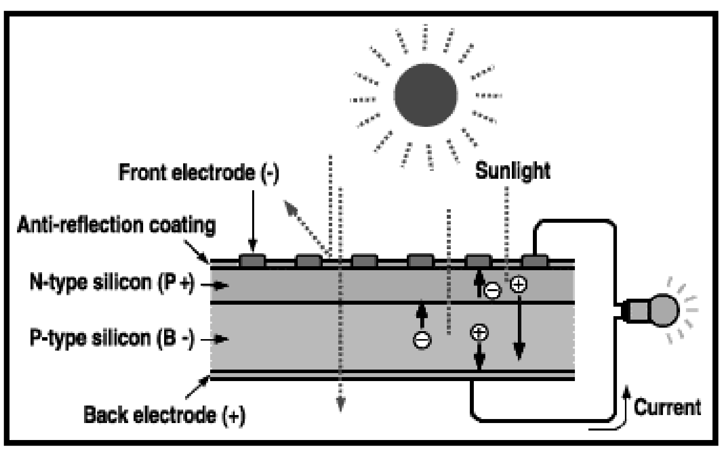

Figure 2.2: Basic Construction Of PV Systems [8]

The photons energy from the sun strike and ionize the semiconductor material causing the electrons have high energy to break free of their atomic bonds. Then, the electrons are forcely move in one direction which create a flow of electric current [7]. The layers are placed within the cell opposite charges to prevent the negatively charged electron return to positively the positively charged holes. However, the electrons can move back to the positively charged holes by flowing through the external circuit, thus causing the electricity to flow [8].

The ‘p’ and ‘n’ types of semiconductor which are similar to ‘positive’ and ‘negative’ because of their plenty of holes or electrons are sandwiched together [9]. When the p-type and n-type semiconductors are joined together, the extra electrons in the n-type material move to the p-type, and the holes thereby empty during this process move to the n-type. These two semiconductors act as a battery since there is flow of hole and electron, thus creates an electric field at the surface where they clash (junction). Figure 2.1 illustrates the detail of electron and hole at n-layer and p-layer.

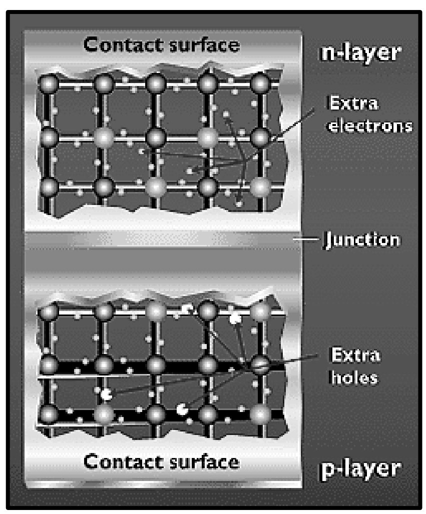

Figure 2.3: Basic Structure of Semiconductors [9]

The rate of electric carriers generation depends on the flux of incident light and the capacity of absorption of the semiconductor. The capacity of absorption depends mainly on the semiconductor band gap, on the reflectance of the cell surface (that depends on the shape and treatment of the surface), on the intrinsic concentration of carriers of the semiconductor, on the electronic mobility, on the recombination rate, on the temperature, and on several other several factors [4].

2.3 Stand-alone PV System

2.3.1 Definition

Stand-alone PV systems is designed to operates independently, not involving with electricity grid connection [10]. These system can be powered by PV generator alone or combine with utility source as an additional source such as wind and engine-generator and these system are called PV-hybrid system. PV system is designed either to supply the AC load or DC load or both with the aids of appropriate components [11].

Stand-alone PV system is used worldwide and it is the most popular system compare to other PV system. Stand-alone PV system mostly installed to a totally mains-isolated application as the energy provided is enough to power the application [12]. The installation of stand-alone PV system is not only popular in the town area, besides that it is also popular in the remote rural area [13]. Especially the remote locations where the connection to the electricity grid is either not possible or expensive. They are most cost effective when electricity requirements are relatively low. Stand alone systems include a battery bank, inverter, battery charger and a fuel generator set [5].

2.3.2 Configurations

Designing the stand-alone PV system configurations needs a confirmation of which components to connect in the system. The components used depend on the type of the loads (AC or DC load, heavy or light), load requirement (critical oc noncritical, reliability, cost), and its geographical location [14]. The additional equipments as a balance of the system and safely transmit the electricity to the load.

The main component in the system is PV array. It will convert the solar energy into electricity. As the energy generation and consumption do not generally coincide, energy storage is required in most stand-alone systems [15]. The solar energy generated during daylight is not fixed, it change depends on the intensity of the sunlight. Energy need to be stored to ensure the stability of the system. Charge controller is important as it consist of DC/DC converter that will take optimum power from PV array and adjust it to the charge voltage of the battery. Inverter is needed when the type of load is AC load. Since the output power drive from PV is in DC, thus inverter converts the DC power to AC power to feed the AC load.

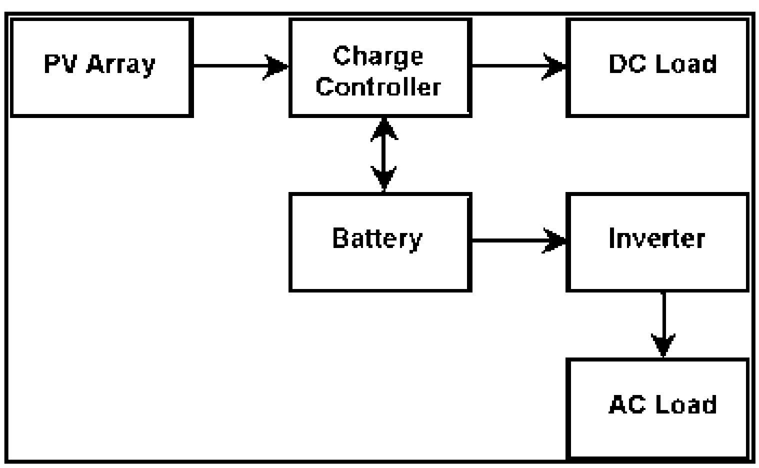

Figure 2.4: Stand-Alone PV System With DC And AC Loads [16]

2.4 Load-shedding Strategy

2.4.1 Definition

Energy efficiency has become an issue debates where several factors may disrupt the effiency of the system such as deregulation of electrical energy distribution, the increasing price of electricity, and the implementation of rolling blackouts [17]. These factors affect the stability of the whole power system. For example when a sudden large industrial load is switched on, it will disrupt the grid system and the system become unstable. Particularly, the differences between the generated power and the load demand caused by disturbance which reduces the generation capacity of the system, thus affect the frequency of the system. The voltages become unstable when the power system unable to meet the reactive power demands of the loads [18].

The stability of the system need to be control where the load-shedding strategy can be an emergency control operation. The load-shedding strategy is designed to curtail the system load during emergency situation to control the stability of the system [19]. The loads are curtailed until the available generation could supply the remain loads. Load-shedding strategy balances the real and reactive power supply and the load demand in the system to prevent from the excessive frequency or voltage decline.

The location bus for the load-shedding will be determined based on the load importance, cost, and distance to the contingency location. The acceptable algorithms are developed based on the number of LS steps, amount of load that should be shed in each step, the delay between the stages, and the location of shed load.