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LAPORAN PROJEK

SARJANA MUDA

SOLAR POWER BACKUP FOR HEAVY DUTY LIGHTING

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Bachelor of Electrical Engineering
(Control, Instrumentation and Automation)
JUNE 2012

" I hereby declare that I have read through this report entitle **Solar Power Backup For Heavy Duty Lighting** and found that it has comply the partial fulfilment for awarding the Degree of Bachelor of Electrical Engineering (Control, Instrument and Automation)"

Signature : ....

Supervisor's Name : **En Norhafiz Bin Salim**

Date : **June 25, 2012**

SOLAR POWER BACKUP FOR HEAVY DUTY LIGHTING

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A report submitted in partial fulfillment of the requirement for the degree of Electrical Engineering (Control, Instrumentation and Automation)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2012

I declare that this report entitle "Solar Power Backup For Heavy Duty Lighting" is the result of my own research except as excite in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : AHMAD FIRDAUS BIN IBRAHIM

Date : 25 JUNE 2012

Specially dedicated to my beloved mother

Radziah Bt. Ahmad

my beloved father

Ibrahim B. Mohammad

And

My Sibling

ACKNOWLEDGEMENTS

In the name of Allah S.W.T, the most Merciful and the most Gracious. With the deepest sense of gratitude to Allah blessing giving me the strength and ability to complete this final year project (FYP) and this is symbolic of the support and guidance from all my family and friends. I am glad for the opportunity to learn something new from this project.

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ABSTRACT

Solar power backup systems provides a viable means of power generation for applications like powering residential appliances, electrification of villages in rural areas, telecommunications, refrigeration and water pumping particularly in agricultural irrigation. Solar power generation is reliable. These systems provide silently operation and maintenance costs are very low for create no atmospherically pollution. The objective of this thesis is to explain the basic operation of a solar power backup system. PV array parameters are obtained from the datasheet provided by the manufacturer. The IGBT inverter is used to change the direct current (DC) input from the buck converter to alternating current (AC) signal. Beside, a maximum power point tracker (MPPT) has been used in part of this system to ensure that the PV array delivers optimum power and also regulate the voltage output. Two types of energy storage has been used as a backup supply when lower irradiation in this system are battery and supercapacitor . The system has been composed using MATLAB/Simulink simulation software and tested based on certain conditions to analyze its performance. The results show that the system is working accordingly

ABSTRAK

Sistem sandaran kuasa solar menyediakan cara penjanaan kuasa yang tersendiri untuk kegunaan seperti penggunaan kuasa untuk sistem perumahan, penukaran kepada kuasa elektrik untuk kampung-kampung yang terpencil, telekomunikasi, penyejukan, pengepaman air khususnya dalam sistem pengairan pertanian. Sistem ini boleh beroperasi secara senyap dan kos penyelenggaraan adalah sangat rendah di samping mengelakkan pencemaran atmosfera. Tujuan tesis ini adalah untuk menerangkan operasi asas sebuah sistem sandaran kuasa solar. Parameter modul solar diperolehi daripada helaian-data yang telah disediakan oleh pengilang. Penyongsang IGBT telah digunakan untuk menukar masukkan aru terus (AT) daripada modul solar kepada arus ulang-alik (AU). Selain itu, penjejakan titik kuasa maksimum digunakan di dalam model ini untuk memastikan modul solar membekalkan kuasa yang optimum dan juga mengawal voltan. Dua jenis bekalan kuasa telah digunakan iaitu bateri dan juga supercapacitor bagi membekalkan kuasa kepada sistem semasa ketiadaan cahaya. Sistem ini direka menggunakan perisian simulasi MATLAB/Simulink dan diuji berdasarkan keadaan tertentu bagi menganalisis prestasinya. Keputusan menunjukkan sistem ini dapat bekerja seperti yang ditetapkan.

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LIST OF ABBREVIATIONS

AC	-	alternating current
CSI	-	current source inverter
DC	-	direct current
MPPT	-	Maximum power point tracker
NiCd	-	nickel-cadmium
P&O	-	Perturbation and observation
PbH2	-	flooded lead-acid
PV	-	Photovoltaic
PWM	-	pulse-width modulation
rms	-	root-mean-square
SPWM	-	sinusoidal PWM
THD	-	total harmonic distortion
VRLA	-	captive electrolyte lead-acid
VSI	-	voltage source inverter

LIST OF SYMBOL

$\frac{\Delta V_o}{V_o}$	-	Peak-to-peak output ripple voltage
a	-	idealinising factor
A	-	Gain
C	-	Capacitance
D	-	Duty cycle
e	-	electronic charge
E_o	-	constant voltage
$Exp(s)$	-	exponential zone dynamics
f_c	-	Carrier frequency
f_{cutoff}	-	The cutoff frequency
f_m	-	Modulating signal frequency
f_o	-	Output frequency,
f_s	-	Switching frequency
G	-	Irradiation
I	-	battery current
$i*$	-	low frequency current dynamics
I_{mpp}	-	Current at MPP
I_o	-	the dark saturation current and depending on temperature
I_o	-	Output current
I_{scn}	-	Short circuit current
It	-	extracted capacity
k	-	Boltzmann's gas constant
K	-	polarization constant or polarization resistance
K_I	-	Short circuit current temperature coefficient
K_V	-	Open circuit voltage temperature coefficient
L	-	Inductance
L_m	.	magnetization inductance

m_a	-	Amplitude modulation ratio
N_s	-	Number of series cells
P_{max}	-	Maximum Power rating,
Q	-	maximum battery capacity
R_m	-	magnetization resistance
R_o	-	Output resistance
$Sel(s)$	-	represents the battery mode
T_c	-	the absolute temperature of the cell
THD	-	Total harmonics distortion
V	-	the voltage imposed across the cell
V_i	-	Input voltage
$V_{m,carrier}$	-	the amplitude of carrier signal
$V_{m,reference}$	-	the amplitude of modulating signal
V_{mpp}	-	Voltage at MPP
V_o	-	Output voltage
V_{ocn}	-	Open circuit voltage

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Photovoltaic technology involves converting solar energy directly into electrical energy and it has widely used for a few decades. As a renewable energy, the solar energy have advantages of free, no pollution, low maintenance cost, distributed through the earth, and no noise due to the absence of the moving parts. Photovoltaic power system is generally classified by their function and configuration. This technology can be applied on a solar power backup system. The two types of PV systems are grid-connected and the other is stand alone system[7]. Stand alone system are designed to operation low power application. On the other hands, grid-connected system or utility is an interactive system are designed to operate high power application that parallel with and interconnected with the utility grid.

There are several components in a solar power backup system such as PV array, DC/DC converter, inverter and load. The configuration of the solar power backup system is depicted in figure 1.1.

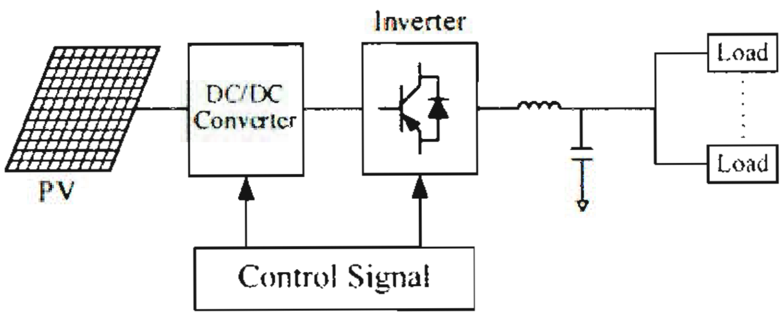

Figure 1.1: Configuration of a stand-alone PV generation system [7].

PV panel is a part of the system that converts sunlight to electricity. The DC-DC converter is used to proposed photovoltaic system to step up or step down and stabilize the output DC voltage. The inverters are DC-AC converter that used in a stand-alone PV system to convert DC power to AC power of magnitude and frequency. Signal controllers are used for DC-DC converter and inverter to achieve the maximum power output, regulated DC voltage, and the desired output voltage [7].

Environmental factor such as illumination and temperature are the factor influent for changing output power of PV array. The controller named maximum power point tracking (MPPT) is required to the environmental change. Two algorithm often used to achieve the maximum power tracking that the perturb and observe (P&O) and the other one is incremental conductance method.

1.2 Problem Statement

Energy is very important in life. It is also needed by man to run their daily lives. Many works cannot be done or finish without energy. The increasing in world population causes more energy to be used. The world demand for energy has increased. Which means the world is facing the new crisis that would be serious. It is called decrease of energy source. Nowadays, with the global economic growing rapidly, the traditional fuel energies such as coal, oil, gas and other conventional energy source are being reduce for large-scale using and mining. That will cause global warming and ecological environment deteriorating such as greenhouse effect, acidification of water cycle, and deforestation. Developing renewable energy is an effective way to solve this problem. The increasing of electricity tariffs is also a contributor to the production of renewable energy. The dependence on energy has been mentioned above has also affects the increase in tariffs set by the national electricity utility company. The rural remote areas are also facing the effect, because these areas have low incomes and the grid power supply is not fully extended.

1.3 Objective

The objectives of this project are:

1. To study the basic concept of a solar power backup including the components, topologies and control methods.
2. To simulate the operation of a solar power backup.
3. To analyze the performance of a solar power backup in fulfilling typical requirements on the DC and AC side.

1.4 Scope

The scope of this project is to design a solar power backup system that is used as the power supply for heavy duty lighting. The components models for stand-alone PV system are PV module, battery, supercapacitor, charge controller, battery, inverter and load. The block diagram of the solar power backup system is as shown in Figure 1.4.

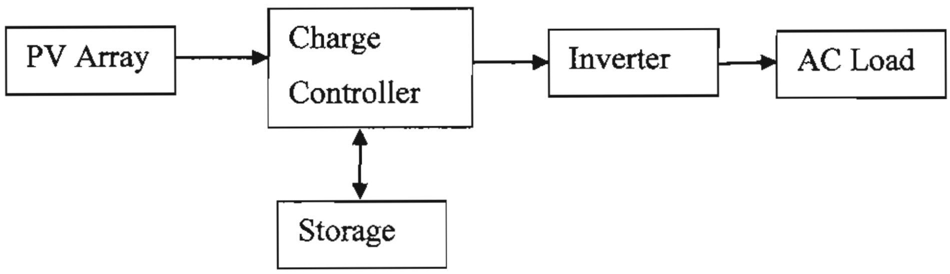

Figure 1.2: Block diagram of solar power system

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The basic components of a PV system are PV array, Charge controller, battery, inverter and ac load. All parts of the component has its own types and control methods. In this chapter, each part of the component will be discuss based on previous research in order to get the best methods for this project. The past projects that relate to this project will be a reference to reviewed, analyzed and understood in terms of functionality. Figure 2.1 views the basic component of a PV system.

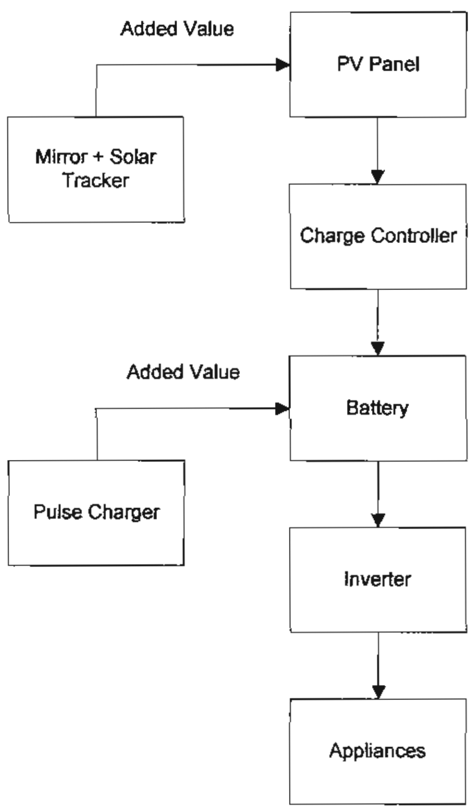

Figure 2.1: PV System Built For Analysis

A PV system installation typically includes an array of PV modules or panels, an inverter, batteries and interconnection wiring [1]. As an off-grid system or stand-alone system as in figure, it is designed to provide electricity to a home without drawing on supplemental power from the electrical utility.

2.2 Characteristic of PV Array

PV panel is a package interconnected of photovoltaic cell that converts sunlight to electricity. Because a single photovoltaic module can only produce a certain amount of wattage, installation intended to produce larger electrical power capacity require an installation of several modules or panels and this is known as a photovoltaic array [1]. PV cell is the fundamental of PV array that are built before creating a group of modules. The PV cell is a specially designed PN junction or Schottky barrier device[2]. Figure 2.2 illustrates structure of a photovoltaic cell with silicon(PN junction).

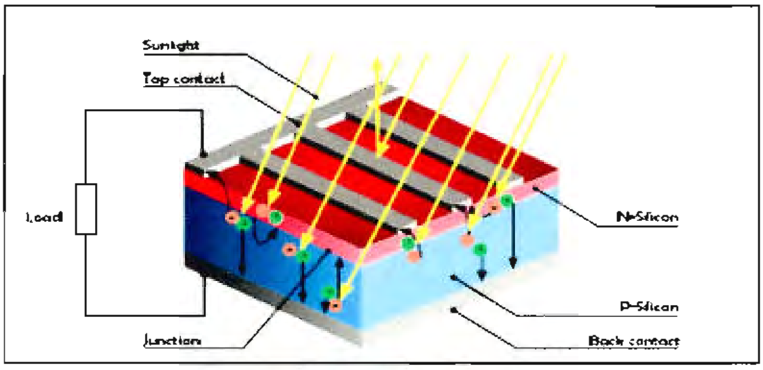

Figure 2.2: Structure Of A Photovoltaic Cell With Silicon(PN Junction) [2].

The well-known diode equation describes the operation of the shaded PV cell. When the cell is illuminated, electron-hole pairs are produced by the interaction of the incident photons with the atoms of the cell. The electric field created by the cell junction causes the photon-generate delectron- hole pairs to separate, with the electrons drifting into the n-region of the cell and the holes drifting into the p-region[2]. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons are captured in the form of electric current *Iph* (photocurrent). Figure 2.3 illustrates the circuit equivalent for a single PV cell.

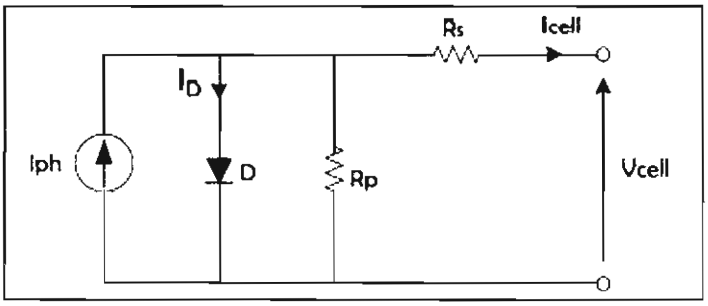

Figure 2.3: PV Cell Equivalent Model [2].

The circuit contains a current source. I_{ph}; a diode connected in parallel; and resistance, R_s that are connected in series which represents the resistance inside cell and the connection between the cells. Based on the circuit above the following equation can be derived:

$$I = I_{ph} - I_D = I_{ph} - I_o \left[exp\frac{e(V+IR_S)}{akT_c} - 1\right] \qquad (2.1)$$

Where:

a = idealinising factor

k = Boltzmann's gas constant,

T_c = the absolute temperature of the cell

e = electronic charge

V = the voltage imposed across the cell

I_o = the dark saturation current and depending on temperature

The PV cell characteristics vary with external factors including temperature and solar irradiation level. To incorporate these effects into the model, two additional relations are used. Output current varies with solar irradiation and temperature through:

$$I = (I_n + K_I \Delta T)G/G_n \qquad (2.2)$$

Where I_n is the nominal PV cell output current (at 25 °C and 1000 W/m^2), K_I is the current/temperature variation coefficient (A/°C), ΔT is the variation from the nominal temperature (25 °C) and G_n is the nominal solar irradiation (1000 W/m^2). The value of K_I

is relatively small and this makes the cell output current linearly dependent on solar radiation level more than temperature. The reverse saturation current, *Io* in (2.2), is strongly dependant on temperature. The following relation can be used to model that effect [3]:

$$I_o = \frac{I_{sc,n}+K_I\Delta T}{\exp\left(\frac{q(V_{oc,n}+K_V\Delta T)}{akT}\right)-1} \tag{2.3}$$

Where $I_{sc,n}$ is the nominal short circuit current of the PV cell, $V_{oc,n}$ is the nominal open circuit voltage, K_I and K_V are the current and voltage temperature variation coefficients, in A/°C and V/°C, respectively. Figure 2.3 shown the I-V characteristics of the cell are under different solar irradiance levels and at different temperatures. The short circuit current varies linearly with solar irradiance while Temperature has a more pronounced effect on the open circuit voltage [3].

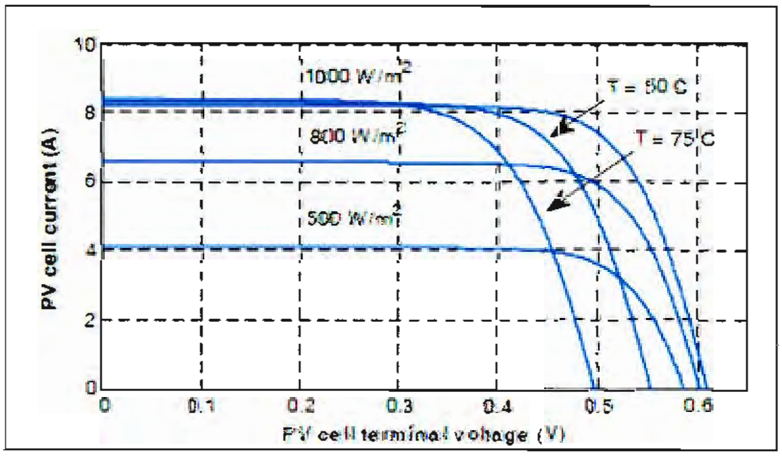

Figure 2.4: PV cell I-V characteristics for different solar irradiation levels (continuous lines) and different temperatures (dashed lines)[3].