



**UNIVERSITI PUTRA MALAYSIA**

**DEVELOPMENT OF LOW POWER CONVERTER  
SOLAR-BASE SYSTEM**

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**DEVELOPMENT OF LOW POWER CONVERTER SOLAR-BASE SYSTEM**

**By**

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**Thesis Submitted in Fulfilment of Requirement for the  
Degree of Master of Science in the Faculty of Engineering  
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**November 2001**



**Dedicated to**

*My*

*Parents, Brothers, Sisters, Wife and Daughter*



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in  
fulfilment of the requirement for the degree of Master of Science

**DEVELOPMENT OF LOW POWER CONVERTER SOLAR-BASED SYSTEM**

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**November 2001**

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**Faculty: Engineering**

With the recurrent oil crises and the new environmental boundary conditions for energy production and use, the photovoltaic, PV, system development can be a very promising strategic solution, which releases together with the photovoltaic energy cost effectiveness goal, an actual clean, renewable, and alternative energy option. However, the continues decline in photovoltaic module prices in the international market gives more attention to design the supplementary equipment with low cost and high reliability, such as battery charger and DC-to-AC inverter.

The objective of this project is study the effect of irradiation and temperature on the output of solar module and to design, construct, and test battery charger and DC-to-AC inverter for stand alone system. The proposed stand-alone system consists of 5



solar panels, a battery charger, a sealed lead acid battery, a DC-to-AC inverter, and AC loads.

The solar energy has been converted to an electric energy using a panel of photovoltaic cells. The electric energy stored in a sealed lead acid battery 30Ah, 12V. The storage process was controlled by an electronic charger, which has been designed and developed for this purpose.

A low cost, PWM inverter has been designed and constructed using power BJT switches and electronic components that are common and cheap to convert the stored DC energy to an AC one, and to provide the AC voltage for a small and medium AC loads. Both charging and discharging of the stored energies have been examined, and good results have been obtained.

Results of the experimental and simulation work showed that there was a good agreement between the hardware and software. This indicated that the proposed stand-alone system was successfully developed.

Abstrak tesis yang dikemukakan kepada senat Universiti Putra Malaysia sebagai memenuhi syarat keperluan untuk ijazah Master Sains

**PEMBANGUNAN PENUKAR KUASA RENDAH BAGI PENGGUNAAN  
SISTEM BERASASKAN SOLAR**

Oleh

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Dengan berlakunya kekurangan minyak dan kondisi pembaharuan kuasa yang terbatas, pengeluaran dan pembangunan untuk menggunakan photovoltaic sistem ialah satu penyelesaian yang paling baik, yang mana boleh melepaskan secara bersama-sama dengan kuasa photo voltaic yang efektif, bersih, diperbaharui dan kuasa alternatif yang baik. Walau bagaimanapun, kejatuhan harga modul fotovolta dalam pasaran antarabangsa akan memberikan perhatian yang lebih untuk merekabentuk alatan tambahan dengan kos yang rendah dan ketahanan yang tinggi, seperti pengecas bateri dan penukar arus terus ke arus ulang alik.

Objektif penyelidikan ini ialah untuk mempelajari kesan penyinaran dan suhu pada keluaran solar modul dan untuk merancang, membina pengecas bateri dan penukar arus terus ke arus ulang alik untuk sistem yang berdiri sendiri. Sistem berdiri

sendiri ini terdiri dari 5 solar panel, pengecas bateri, bateri asid plumbum terkedap, penukar arus terus ke arus ulang alik, dan beban arus ulang-alik.

Kuasa solar telah diubah kepada kuasa elektrik dengan menguna panel sel fotovolta. Kuasa elektrik disimpan di dalam , bateri asid plumbum terkedap 30 Ah, 12 V. Proses penyimpanan ini dikawal dengan sebuah pengecas elektronik, yang sudah dirancang dan dibina untuk tujuan ini.

PWM penukar telah dirancang dan dibina dengan menggunakan kuasa suis BJT dan komponen-komponen elektronik yang dasar dan dengan kos rendah untuk merubah penyimpan kuasa arus terus kepada yang arus ulang alik, dan meyediakan voltan arus ulang alik untuk beban-beban arus ulang alik yang kecil dan menengah.

Keputusan-keputusan dari hasil kajian dan kerja simulasi memperlihatkan hasil yang bagus antara perkakasan dan perisian. Ini menunjukkan sistem berdiri sendiri telah berjaya dibina.

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## TABLE OF CONTENTS

	<b>Page</b>
<b>DEDICATION</b>	ii
<b>ABSTRACT</b>	iii
<b>ABSTRAK</b>	v
<b>ACKNOWLEDGMENTS</b>	vii
<b>APPROVAL</b>	viii
<b>DECLARATION</b>	x
<b>LIST OF TABLES</b>	xiii
<b>LIST OF FIGURES</b>	xiv
<b>LIST OF PLATES</b>	xvi
<b>LIST OF ABBREVIATIONS</b>	xvii
<b>CHAPTER</b>	
<b>I</b>	
<b>INTRODUCTION</b>	1
Prologue	1
Importance of the Project	2
Objective of the Project	3
Thesis Layout	4
<b>II</b>	
<b>LITERATURE REVIEW</b>	5
History of Photovoltaic	5
Fossil Fuels Challenge of CO <sub>2</sub> Pollution	6
Environmental Benefits of Renewable Energy	7
Renewable Energy in Malaysia	8
Why PV?	9
Solar Energy Applications	10
General Construction of the Photovoltaic System	10
Solar Cells	12
Factors Affecting the Electrical Characteristics	24
Battery	26
Battery Charger Basic	26
Inverter	27
Inverter Types	28
Inverter Circuit Topologies	30
BJTs	35
Power Diode	39
Summary	41



<b>III</b>	<b>MATERIAL AND METHODS</b>	<b>42</b>
	Solar Module	42
	12 Watt Solar Panel	43
	Multijunction Amorphous Silicon	47
	Flat Plate Array	48
	Measuring Solar Radiation and Temperature	51
	Measuring Discharge Performance	52
	Battery Charger	54
	Sealed Lead Acid Battery	56
	Inverter Circuit Design	58
	Power Circuit	58
	Control Circuit	65
	Pspice Simulation	71
	Circuit Preparation	73
<b>IV</b>	<b>RESULTS AND DISCUSSION</b>	<b>74</b>
	Solar Module	74
	Discharging Battery	78
	Battery Charger	80
	Half Bridge Inverter	83
	Software	83
	Hardware	86
	Total Harmonic Distortion (THD)	93
<b>V</b>	<b>CONCLUSION AND FUTURE RECOMMENDATION</b>	<b>95</b>
	<b>REFERENCE</b>	<b>97</b>
	<b>APPENDIXES</b>	<b>100</b>



## LIST OF TABLES

<b>Table</b>		<b>Page</b>
1	Electrical Characteristic of Solar Panel (A13P)	44
2	Dimension of Solar Panel (A13P)	45
3	The Data for Irradiant Temperature, Open Voltage and Short Circuit Current for Solar Module	75
4	The Data for Battery Discharging	79
5	The Data for Battery Charging Directly from Solar Module	80
6	The Data for Sealed Lead Acid Battery Charger	81
7	IEEE 519 Current Distortion Limits	94



## LIST OF FIGURES

<b>Figure</b>		<b>Page</b>
1	Single Inverter Grid Connected System	11
2	Structure of a-si Photovoltaic Module Fabricated on Glass Substance	13
3	Solar Declination	16
4	Solar Cell Structure	17
5	Equivalent Circuit of Solar Cells	19
6	The Effect of the Collector Tilt Angles	21
7	I-V and P-V Characteristic of Solar Panel	23
8	Current-Fed Inverter	29
9	Voltage-Fed Inverter	29
10	Half Bridge Inverter Circuit Output Voltage and Current Waveform of the Half Bridge Inverter	30 32
11	Single-phase Full Bridge Inverter	34
12	Bipolar Junction Transistor Structure and Circuit Symbol	36
13	Static Voltage-Current Characteristics of the BJT	37
14	Base Current and Collector Current Waveforms for Turn-On and Turn-Off a BJT	38
15	Reversed-Biased Safe Operation Area for BJT	39
16	V-I and Reverse Recovery Characteristics for Diode	40
17	Block Diagram of Development of Battery Charger and Inverter System for Solar-Base System Application	42
18	Cross Section of Polymer Injection Framing for A13p	45
19	Schematic Diagram of a-si Multijunction Cell	
20	Array Terminology	50
21	Block Diagram of Direct Charging	53
22	Solar Battery Charger Diagram	55
23	Power Stage Circuit of the Half Bridge Inverter	58
24	Electrical Analog of Heat Sink	60
25	IC 555 Timer Circuit	68
26	Complete Circuit Diagram of the Inverter	69
27	Complete Constructed Circuit of the Proposed System	70
28	Pspice Schematic Diagram for the Inverter with Resistive Load	72
29	Pspice Schematic Diagram for the Inverter with Inductive Load	72
30	Current Produced vs. Module Surface Temperature	77
31	Current Produced vs. Solar Radiation	77
32	Open Circuit Voltage vs. Module Surface Temperature	78
33	Discharging Curve Performance for Sealed Lead Acid Battery	79
34	Simulated Output of the Inverter with Resistive Load	84
35	Simulated Output of the Inverter with inductive Load	85
36	Pulse Signal Waveform from Timer 555	86



38	Output Signal Waveform from Counter 1	87
39	Output Signal Waveform from Counter 2	87
40	Output Signal Waveform from Flip-Flop	88
41	The Output of the Transformer without Load	89
42	The Output of the Transformer with Lamp 7.5 watt	90
43	The Output of the Transformer with Lamp 15 watt	91
44	The Output of the Transformer with Lamp 40 watt	92



## LIST OF PLATES

<b>Plate</b>		<b>Page</b>
1	Five Solar Panels in Parallel and Mounted on Support Structure	46
2	Solar Module with Instruments	47
3	Solar Module Connected to the Battery Directly	53
4	Construction Circuit of Battery Charger	55
5	Solar Battery Charger	56
6	Construction Control Circuit of Half Bridge Inverter	62
7	Complete Circuit of the Inverter with 7.5 watt lamp	63
8	Complete Circuit of the Inverter with 15 watt lamp	64
9	Complete Circuit of the Inverter with 40 watt lamp	66



## LIST OF ABBREVIATIONS

AC	Alternate Current
Ah	Ampere hour
ARC	Anti-reflection Coating
a-Si	Amorphous Silicon
BJT	Bipolar Junction Transistor
C	Capacitor
CSI	Current Source Inverter
D	Diode
D1	Light Emitting Diode
$f$	Frequency
FF	Fill-Form
HZ	Hertz
$I_{sc}$	Short Circuit Current
DC	Direct Current
eV	Electron Volt
KTOE	Kilo Ton Oil Equivalent
L	Inductance
$P_c$	Power Loss
Ppm	Parts per million
PV	Photovoltaic



PWM	Pulse Width Modulation
Q	Transistor
R	Resistance
S	Switch
S1	Switch 1
S2	Switch 2
SOA	Safe Operation Area
T	Temperature
$T_{rr}$	Reverse Recovery Time
VIS	Voltage Source Inverter
$V_{OC}$	Open Voltage Circuit
$\theta$	Thermal Resistance
$\delta$	Solar Declination





# **CHAPTER I**

## **INTRODUCTION**

### **Prologue**

This thesis is in three parts. The first is a study of the photovoltaic (PV) system and related topics, such as solar radiation and the solar cell. The photovoltaic effect is the direct conversion of light energy into electricity by solar cells. Electricity is a high quality energy, suitable for almost every type of application.

The second and main part is the design and construction of a charger for sealed lead acid batteries. The charger comprises of two units - a power processor and battery control. The power-processor is based on step-down DC-to-DC converter topology, while the battery control is based on constant voltage mode control.

The third part is the design and construction of a DC-to-AC half bridge inverter – a circuit to convert DC, or direct current, from a battery to AC, or alternating current, for home applications, such as lighting and radio.

### **Importance of the Project**

A PV system is a very attractive primary energy producer as its source of power - the sun - is virtually inexhaustible, universally available and not subject to any business or political monopoly. PV modules are solid-state devices that passively convert sunlight to electricity. By adding modules, a PV system can be built to any size, and it is highly reliable and requires little maintenance. Of all the energy sources, photoelectricity poses the lowest environmental and safety risk.

Photoelectricity is more important in developing countries where much of the population live in dispersed rural communities. Electrification of the areas is difficult and costly and generally not economic for the small power loads required.

Malaysia lies in the centre of the tropics, just above the equator between latitudes  $1^{\circ}20' N$  to  $6^{\circ}40' N$  and longitudes  $99^{\circ}35' E$  to  $103^{\circ}20' E$ . It possess the requisite sunshine with which to exploit photoelectricity.

Another attraction about photoelectricity is that amorphous silicon absorbs sunlight extremely well, so that only a very thin layer is required (about  $1 \mu m$  as compared with  $100 \mu m$  or so for the crystalline cell), allowing considerable savings in the silicon wafer used for the solar cell.

The battery charger provides constant voltage charging as the most efficient and fastest way of charging sealed lead acid batteries. The charger must be simple in design to minimize maintenance in the rural areas where it is likely to be used.

As the bulk of electricity used today is AC, the inverter is a very important requisite in a PV system to convert DC from the storage battery to AC for use.

### **Objectives of the Project**

This project has four objectives.

1. Study of the PV module - the effect of sunlight intensity and cell temperature on conversion efficiency. The study will encompass factors such as geographical location, collector orientation throughout the day and atmospheric transparency.
2. Designing a battery charger for sealed lead acid batteries using solar energy.
3. Designing a DC-to-AC single phase half bridge inverter to convert DC to AC for home use.
4. Simulating a DC-to-AC single phase inverter using Pspice software.

## **Thesis Layout**

The thesis is divided into five chapters. Chapter 1 introduces the work and states the objectives.

Chapter 2 reviews the literature on the environmental benefits of renewable energy, solar radiation and the solar cell, battery charger and the general structure of a DC-to-AC converter.

The work done, including designing, construction and testing separately each component of the battery charger and inverter, and simulation of the DC-to-AC inverter, is presented in Chapter 3.

The performance of the battery charger, inverter and simulation are discussed in Chapter 4. Finally, Chapter 5 gives the conclusion and suggestions for future work.

## **CHAPTER II**

### **LITERATURE REVIEW**

#### **History of PV**

The physical effect underlying photovoltaics (PVs) was first observed by Becquerel (1839) when he produced a current by exposing silver electrodes to radiation in an electrolyte. Adams and Day (1877) described the effect in more detail later when they exposed selenium electrodes to radiation and produced a current.

In the 20<sup>th</sup> century, work by Lange (1930), Grondall (1933) and Schottky (1930) on selenium and cuprous oxide cells led to the photographic exposure meter and many other photo cell applications.

In 1954, Chapin and co-workers at Bell laboratories, USA developed the first solar cell based on crystalline silicon with an efficiency of 6%. This efficiency was increased to 10% within a few years. The first viable use for solar cells was in satellite power supply, and PV convincingly proved its worth in this application.

The main driving force for the widespread use of PV for terrestrial power supply came in 1973 with the first oil crisis, and PV conversion has since become a significant element in most renewable energy programmes.



## Fossil Fuels and the Challenge of Carbon Dioxide Pollution

The combustion of fossil fuels releases CO<sub>2</sub> to the atmosphere and this is increasingly seen as one of the major causes of global warming. A 1000 MW coal-fired power plant emits 270 kg/second of CO<sub>2</sub>. In pre-industrial times, the atmospheric CO<sub>2</sub> concentration was <290 parts per million (ppm) but by 2000 it was 377 ppm and by 2050 is expected to be double or triple the pre-industrial level. The CO<sub>2</sub> concentration is expected to peak towards the end of the 21<sup>st</sup> century, by which time most of the world's fossil fuels would have been consumed. Such a dramatic increase in atmospheric CO<sub>2</sub> concentration will almost certainly result in significant warming of the earth (Danial *et al.*, 1983).

It is estimated that in 2025 the global CO<sub>2</sub> emission will be 2.4 times that of the present, but to stabilize the atmospheric concentration at the current level would require a more than 60% reduction from the present emission. The developed countries are the main villains with their 20 per cent of the world's population emitting more than half the CO<sub>2</sub> (Shuzo, 1993).

The earth receives an enormous amount of solar radiation daily. To maintain its temperature, the planet must radiate off the equivalent energy. But radiation has a wavelength inversely proportional to the fourth power of the temperature of its source. Thus the very hot sun emits shortwave radiation, and the very much cooler earth longwave radiation. CO<sub>2</sub> is transparent to shortwave radiation but absorbs the long wavelengths, including that emitted by the earth, thus trapping the heat. The