

A converter is a device that can convert direct current to alternating current or vice versa. This research aims to obtain direct and alternating current from the same converter device, which can provide 220 VAC and 12 VDC at the same time using Proteus software modeling; to build a converter based on a typical converter; to compare the performance and efficiency of the converter by software and hardware. The converter was supported by a solar cell that charges the battery. The converter was modeled and developed in Proteus software. Based on the typical converter circuit, the real converter was designed and tested. In addition, the efficiency and performance between software and hardware were tested and compared. The efficiency of the software was 80.7% and the efficiency of the hardware was 70.3%, while the performance of the charger controller was different between software and hardware, knowing that this converter is designed to carry 60 watts. This inverter has been successfully modeled and designed as it can be used in emergency situations such as sudden power outages or used in rugged and remote places.



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Design and Implementation a Smart PV Inverter with Two Outputs (AC/DC)

Smart inverte in smart PV suystem off-grid



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Cover image: www.ingimage.com

Publisher:

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120 High Road, East Finchley, London, N2 9ED, United Kingdom

Str. Armeneasca 28/1, office 1, Chisinau MD-2012, Republic of Moldova,

Europe

Managing Directors: Ieva Konstantinova, Victoria Ursu

info@omniscryptum.com

Printed at: see last page

ISBN: 978-620-8-41803-8

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Acknowledgments

Firstly, I would like to thank God Almighty, then my dear parents who were a great support to me in all circumstances while I was writing this book. I also thank my wife and children who endured and encouraged me to complete this difficult study. I would also like to thank everyone who gave me the opportunity to write and publish in order to make this book a success. Finally, I would like to thank my brothers and friends who helped me make this journey a success, and everyone who raises their hands in supplication to God to bless me.

Abstract

Inverter is a device which can convert the direct current to alternating current or Vis-Versa. This research was aimed to get direct and alternating current from the same inverter device, which can provide 220 volt AC, and 12 volts DC in the same time using Proteus software modeling; to build an inverter based on modeled inverter; to compare the performance and efficiency of the inverter by software and hardware. The inverter was supported by a solar cell, which functioned to charge the battery. The inverter had been modeled and developed in the Protues software. Based on the modeled inverter circuit the real inverter was designed and tested. Additionally, the efficiency and performance between the software and hardware were tested and compared. The software efficiency was 80.7% and the hardware efficiency was 70.3%, while the charger controller performance was different between the software and the hardware, knowing that, this inverter was designed for a 60-watt load. This inverter was successful in the modeling and design, where it can be used in emergency situations such as sudden electric power cutting or using it in places rugged and remote areas which are not supported by public electricity network, when it can powered the AC loads such as television and radio, etc., by 220V, also it can be powered the DC loads such as lead lambs and mobile charger.

Keywords: Modeling, Design, Converter, Direct, Alternating, PV System.

CHAPTER I

INTRODUCTION

1.1 Background

In all kinds of renewable energy sources, such as wind, sun and fuel cells etc. Solar energy is the best energy sources to utilize, which mainly converts energy from the sunlight to electrical. Solar energy is clean and inexhaustible energy source without any pollution to the earth and the atmosphere.

The main benefit of solar system designing a reliable, stable, efficient and lower cost, photovoltaic power electronics system is the availability of reliable and quality power without relying on the utility grid. It also avoids the substantial costs in transmission and distribution, and the major benefit lies in fact that to reduces greenhouse gas emissions, responding to the increasing energy demands by establishing a new, high profiled industry.

To improve daily life quality especially in rural areas in particular, there are several engineering issues. They must be considered such as storage method, energy conservation and how to convert the energy, etc. In electric power, there are two types of electrical current, Direct Current (DC) and Alternating Current (AC).

Direct current is more important for most of electronic devices which need to power by direct current such as, television, radio, mobile charger, computer, medical devices, etc. But all of these devices work by alternating current right now by using electrical adaptor which contains rectifier and filtering circuit to change the current to DC current, which causing some loss of electrical power in the power conversion. The DC-DC converter topologies have received increasing attention in recent years for low power and high-performance applications. The advantages of DC-DC converters includes increased efficiency, reduced size, faster transient response and improved reliability [1,2].

Nowadays there are a lot of modern studies about DC house, to run all house devices by direct current due to decrease losing power in the conversion process. Inverter needed to convert the current sometime to AC or DC current, inverter performance is influenced by its design and construction. The output power is limited by design and the rating of the interconnecting components [3,4].

The reason of using AC current in all countries of the world because it can transfer to long distances without decreasing, and can raise the value of the electricity to high levels. These issues lead us to something important, i.e., combining two electronic devices (DC-DC Converter and DC-AC Inverter) into one electronic device that which has AC and DC output.

1.2 Problem Statement.

This research needs to be conducted because the inverter has very important tasks in the power system. Thus, this study will focus on the design of the inverter with output of AC and DC voltage. The rising price cost of fossil fuels and increase the demand is greater than supply make the researchers today looking hard to take advantage of renewable energy such as solar, wind, etc. The growing consumption of solar energy as an alternative energy has led to the increase of research and development in the field of electronic and electrical engineering.

If looked at the recent researches in the world which focused on taking advantage of clean energy it can be found that the most important element in these projects were the elements of power converter (inverter). The inverter that converts the DC volt to DC and AC volt were customized in terms of the effectiveness of the network capacity and quality of energy demand and determine the available input and output depends on the design of the inverter. For this reason, there will be a big effort to drag attention to choose the best-required material for the manufacturing and operation of these inverters.

1.3 Problem Limitation

The scope of this research is to find the best circuit for an inverter using Proteus software and to build the hardware based on it. Furthermore, the

performance of the circuit (simulation and hardware) will be compared in term of observed DC and AC voltage output under dynamic loads.

1.4 Research Objectives

The objectives of this study were:

1. To develop a model of an inverter that has direct and alternating current output in the same device using the Proteus software.
2. To build an inverter, based on modeled inverter
3. To compare the performance and efficiency of the inverter by software and hardware.

1.5 Contribution

The contributions of this study were:

1. To build an inverter with direct and alternating output current.
2. In case of no input power from the PV, the inverter was able to produce power (AC-DC) from the battery.
3. The results of this study will enrich the knowledge in electrical engineering field, especially in the power conversion field.

CHAPTER II

STUDY LITERATURE

2.1 Literature Review

Photovoltaic systems (PV system) use solar panels to convert sun rays into electricity. The system was made from one or more photovoltaic (PV) panels, a DC/AC power inverter and a tracking system that holds the solar panels, electrical interconnections, and mounting of other components. Figure 2.1 presents a simple diagram to explain the flow of electric current through the inverter in a PV system, solar cell produces DC voltage, the current which produced by the PV was flows through the inverter and converted into AC and DC current after passing some electronic parts. The AC volts from the inverter are directly transferred to the loads, while the DC volt was used to charge the battery. During the night or when the load is higher than solar panel ability to provide power, then the inverter is used to convert the DC power from the battery into AC power which used by loads.

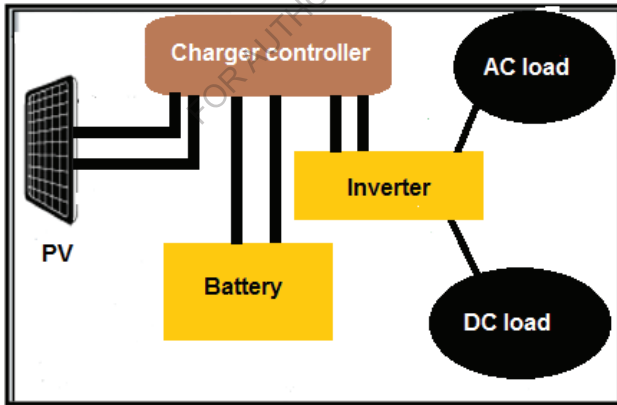


Figure 2.1 Simple Solar System Block Diagram.

The DC converter topologies for low power and high-power applications have received increasing attention in recent years. The advantages of the converters were

improving efficiency, reducing size, faster transient response and improving reliability [3].

Modeled and simulated a DC-DC converter using semolina. The hardware was fabricated and tested. The simulation results were compared with the experimental results. The aim of their work was to develop an efficient DC-DC converter with high power density [5,6].

Found that in the circuit topology an inverter was combined with an IC circuit and transformer to increase the corresponding voltage gain. An additional inductor provided the reverse current path of the transformer to enhance the utility rate of magnetic core [7,8]. In addition, the voltage-clamped technology was used to reduce losses. Furthermore, the closed loop control methodology was utilized the proposed scheme to overcome the voltage drift problem of power source under the variation of loads. Thus, the proposed converter topology had a favorable voltage clamped effect and superior conversion efficiency.

In the year 2012 Devendra Panchalet.al, designed a machine to convert DC power from renewable energy source directly to AC power. This machine was proven very useful in PV system because it was suitable to work in low voltage and low current [9,10].

A device that converts DC power into AC power at desired output voltage and frequency was called an inverter. Phase controlled converters when operated in the inverter mode were called line commutated inverters. But line commutated inverters require at the output terminals an existing AC supply which was used for their commutation.

This means that line commutated inverters cannot function as isolated AC voltage sources or as variable frequency generators with DC power at the input. Therefore, voltage level, frequency and waveform on the AC side of the line commutated inverters cannot be changed. On the other hand, force commutated inverters provide an independent AC output voltage of adjustable voltage and adjustable frequency and have therefore much wider application [11,12].

2.2 Basic Theory

2.2.1 DC-AC Inverter

An inverter is an electrical device that converts direct current DC to alternating current AC, the converted AC can be at any required voltage and frequency with the use of appropriate transformer, switching, and control circuits. Solid-state inverters have no moving parts and are used in a wide range of applications, from small switching power supply in computers, to large electricity utility high voltage direct current applications that transport bulk power. Inverters are commonly used to supply AC power from DC sources such as solar panel or batteries. The inverter performs is opposite function of a rectifier [13,14].

A Current Source Inverter (CSI) is fed with adjustable current from the DC source of high impedance that is from a constant direct source. A voltage source inverter employing thyristor as switches, some type of forced commutation is required, while the VSI made up of using, power transistors, power mosfets or IGBTs, self-commutation with a base or gate drive signals for their controlled turn-on and turn-off. Voltage Source Inverters is one in which the DC source has small or negligible impedance. In other words, VSI has a stiff DC voltage source at its input terminals. A current source inverter is fed with adjustable current from a DC source of high impedance, i.e., from a stiff DC current source. In a CSI fed with a stiff current source, output current waves are not affected by the load [15,16].

From the view point of connections of semiconductor devices, inverters are classified as follows.

- Bridge Inverters
- Series Inverters
- Parallel Inverter

Bridge Inverters are classified as

- Half bridge
- Full bridge

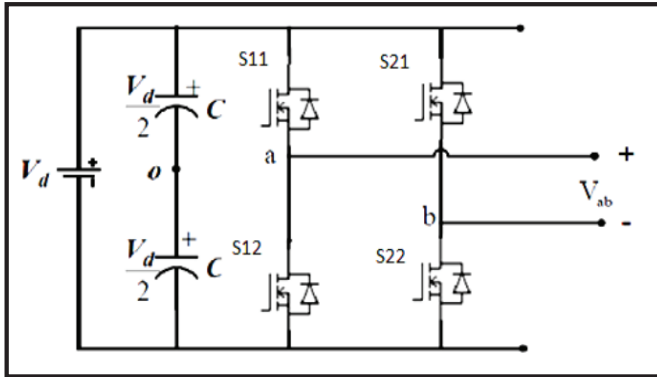


Figure 2.2 Schematic of a Single Phase Full-Bridge Inverter.

The SPWM switching schemes are discussed in this section, which improve the characteristics of the inverter. The objective is to add a zero-sequence voltage to the modulation signals in such a way to ensure the clamping of the devices to either the positive or negative DC rail; in the process of which the voltage gain is improved, leading to an increased load fundamental voltage, reduction in total current distortion and increased load power factor [17,18].

The major purpose of the PWM inverter is to generate a variable voltage and variable frequency (VV, VF) one or three-phase voltage from a DC voltage. Levels of VSI consist of some power semiconductor switches with anti-parallel diodes. In the widely used pulse width modulation (PWM) methods, the inverter output voltage approximates the reference value through high frequency switching of the six power semi-conductor switches [19,20].

2.2.2 DC-DC Converter

In recent years, DC-DC converter switch steep voltage ratio is usually required in many industrial applications, the front-end stage for clean energy sources, the DC backup energy system for an uninterruptible power supply (UPS), high-intensity discharge (HID) lamps for automobile headlamps, and the telecommunication industry [21,22].

The conventional boost converters cannot provide such a high DC-voltage ratio due to the losses associated with the inductor, filter capacitor, main switch, and output diode. Even for an extreme duty cycle, it will result in serious reverse recovery problems and increase the rating of the output diode. As a result, the conversion efficiency is degraded, and the electromagnetic interference (EMI) problem is severe under this situation. In order to increase the conversion efficiency and voltage gain, many modified boost converter topologies have been investigated in the past decade. Although voltage-clamped techniques are manipulated in the converter design to overcome the severe reverse-recovery problem of the output diode in high-level voltage applications, there still exist over large switch-voltage stresses, and the voltage gain is limited by the turn ON time of the auxiliary switch, presented a boost soft-single-switch converter, which has only one single active switch. It is able to operate with soft switching in a pulse width modulation (PWM) way without high voltage and current stresses. Unfortunately, the voltage gain is limited below four in order to achieve the function of soft switching coupled inductors were employed to provide a high step-up ratio and to reduce the switch-voltage stress substantially, and the reverse-recovery problem of the output diode was also alleviated efficiently [23,24].

In this case, the leakage energy of the coupled inductor is another problem as the main switch was turned OFF. It will result in a high voltage ripple across the main switch due to the resonant phenomenon induced by the leakage current. In order to protect the switch devices, either a high-voltage-rated device with higher RDS (ON) or a snubbed circuit is usually adopted to deplete the leakage energy.

Consequently, the power-conversion efficiency will be degraded. Can be introduced a family of high-efficiency, high-step-up DC-DC converters by only adding one addition diode and a small capacitor. System configuration of a high efficiency voltage-clamped DC-DC converter Alleviate the reverse-recovery problem. However, a snubbed circuit is still required in the output diode terminal with extra energy losses [25,26].

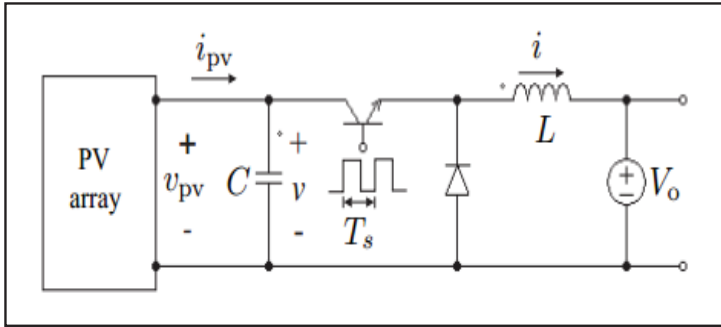


Figure 2.3 Simple Circuit Diagram of DC Converter (Villalva and Filho 2008).

In a typical PV system, there is usually a DC–DC converter, which is designed responsible for driving power out of the front-end PV panel. The function of this DC–DC converter is to adjust its impedance seen by the PV panel to be close to the corresponding impedance of the PV panel, thus maximizing the output efficiency [27,28].

2.2.3 Electric Transformer

A transformer is a four-terminal device that transforms an AC input voltage into a higher or lower AC output voltage. Transformers are not designed to raise or lower DC voltages. A transformer is composed of electrical equipment designed to transfer energy by inductive coupling between its winding circuits. A typical transformer has two or more coils that share a common laminated iron core. The first one is referred to as the primary coil, and the second coil is called the secondary. In the analysis of the estimate reliability, the electrical transformers should be considered as complex systems consisting in many subsystems, magnetic, electric, insulation, etc. [29].

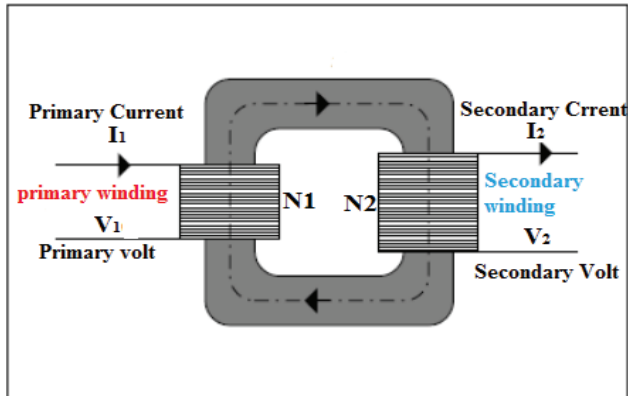


Figure 2.4 Internal form of Electric Transformer.

The resulting model, though sometimes termed equivalent circuit based on linearity assumptions, retains a number of approximations. Analysis may be simplified by assuming that magnetizing branch impedance is relatively high and relocating the branch to the left of the primary impedances. This introduces error, but allows combination of primary and referred secondary resistances and reactance by simple summation as two series impedances.

Transformers are essential components in the electrical power system, a typical transformer consists of coils of copper or aluminum conductors (that may be insulated with paper insulation for larger units), which are wound around a magnetic core. Transformers are filled with dielectric fluid, which has two important functions [30].

It was demonstrated that the use of these transient suppressor significantly reduces the peak overvoltage and voltage steepness by a factor of two during lightning surges. The proposed transient suppressor also has the ability to eliminate inrush current effectively. In practice, since distribution transformers are used to step down voltage level from high voltage to low voltage, thus, the proposed transient suppressor can be applied to the high voltage system by increasing the insulation level of the transient suppressor. Further works are the experimental verification, transient suppressor optimization, and consideration of other application of the proposed transient suppressor of transmission systems [31].

CHAPTER III

RESEARCH METHODOLOGY

3.1 Materials

In this study, depended on two stages, Software and Hardware, as for the software program used electronic circuit simulation (PROTEUS) which will explain later and how to use it. In the hardware stage used electronic measuring devices to measure and analysis data, such as multimeter, voltmeter and oscilloscope, etc. They had been used after installing electronic parts on the motherboard and connect the power source to see the results.

3.2 Methods and Scheme of Research

This research consists of three parts. First part was developing an inverter model and doing simulation. Second part was building a hardware based on the modeled inverter. The last part was a performance comparison between simulation result and result from the hardware.

3.3 Modeling and Simulation.

The first step in modeling and simulation was selecting the proper software, Proteus software was chosen for this research because it was the more complete software for electronic circuits and systems. The simulation was done to study the influence of electronic parts on the stability of DC and AC output voltage.



Figure 3.1 Logo of Proteus Software

In Proteus software, there were many options to modify the circuits to control the output voltage, from direct current to alternating current. In addition, Proteus was able to give the results of the simulation and analyze it. Based on the results, the user may able to modify the circuit to get the best results to be used to build the hardware.

Figure 3.2 shows the inverter circuit, which has DC input from a PV system and one AC output. This diagram was translated into Proteus software and will be modified by adding other output (DC output). As there were many different topologies in connecting PV panel to inverter, which have been developed and used over the past few decades, several components such as battery, diodes, variable resistors, were needed to be added for modification. After being modified, the new circuit was simulated. The section 3.1.1, 3.1.2 describes the CD4047 (oscillator) integrated circuit and IRFZ44 transistor used in the simulation, as well as for building the hardware.

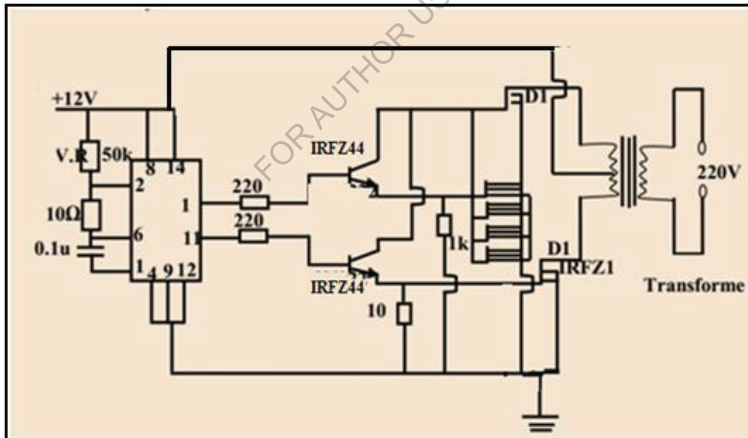


Figure 3.2 Simple Inverter Circuit Diagram.

3.3.1 Data Sheet for CD4047 Oscillator.

CD4047BC is a low power stable/unstable. A general description is written as follows:

The CD4047B is capable of operating in stable, as well as, in unstable mode. It requires an external capacitor (between pins 1 and 3) and an external resistor (between pins 2 and 3) to determine the output pulse width and output frequency during the unstable mode. Stable operation is enabled by a high-level table input or low level on the stable input. The output frequency at (50% duty cycle) at Q and Q output is determined by the timing components. A frequency twice that of Q is available in the oscillator Output; a 50% duty cycle is not guaranteed.

Unstable operation is obtained when the device is triggered by low to high transition at the positive trigger input or high to low transition at -trigger input. The device can be triggered by applying a simultaneous low to high transition to both the +trigger and trigger inputs. A high level on reset input resets the outputs Q to low, Q to high.

a. The features of this IC are:

- Wide supply voltage range: 3.0V to 15V
- High noise immunity: 0.45 VDD (typ.)
- Low power TTL compatibility: Fan out of 2 driving 74L or 1 driving 74LS

b. Below are the special features of the IC:

- Low power consumption: special CMOS oscillator configuration
- Stable (one-shot) or unstable (free-running) operation
- True and complemented buffered output
- Only one external R and C required

c. Applications

Frequency discriminators, timing circuits, time-delay applications, envelope detection, frequency multiplication, frequency divide.

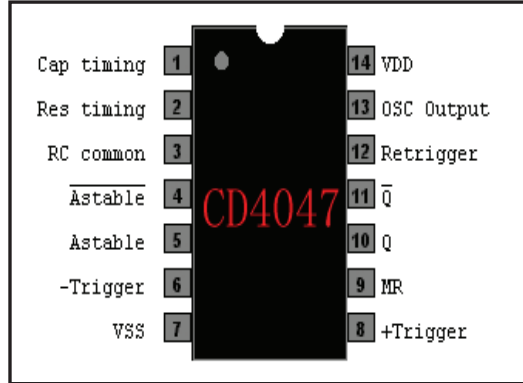


Figure 3.3 Connection Diagram of CD4047 Integrated Circuit.

Table 3.1 presents the absolute maximum ratings of the IC (DC4047) parameters, while table 3.2 presents the recommended operating conditions of V DC, supply voltage (VDD), input voltage (VIN), etc.

Table 3.1 Rating for IC (CD4047) Parameters

Parameters of IC CD4047	
DC Supply Voltage (VDD)	-0.5 V to +18VDC
Input Voltage (VIN)	-0.5 V to VDD+0.5VDC
Storage Temperature Range (TS)	-65 °C to +150°C
Power Dissipation (PD)	
Dual-In-Line	700
Small Outline	500
Lead Temperature (TL) (Soldering, 10 seconds)	260°C

Table 3.2 recommended for operating conditions and electrical characteristics provide conditions of actual device operation.

Table 3.2 Explain the Best Operating Conditions

Best Operating Conditions of IC CD4047	
DC Supply Voltage (VDD)	3V to 15VDC
Input Voltage (VIN)	0 to VDDVDC
Operating Temperature Range (TA)	-40°C to +85°C
VSS =0V unless otherwise specified.	

3.3.2 Data sheet for IRFZ44

Figure 3.4 is the N-channel mosfets IRFZ4047 electronics diagram, the third generation of power mosfets was designed with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness

The package is universally preferred for commercial-industrial applications at power dissipation levels to approximately 50 W. The low thermal resistance and low package cost of the TO-220AB contribute to its wide acceptance throughout the industry.

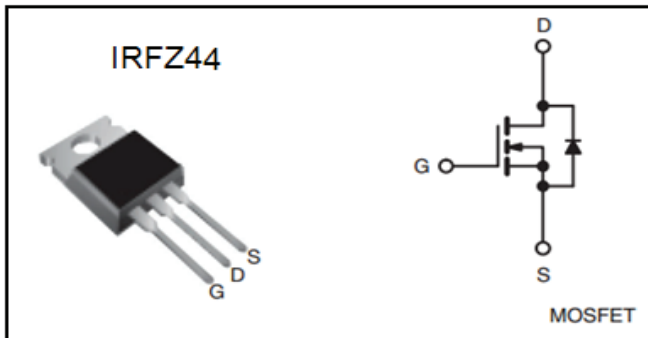


Figure 3.4 Mosfet IRFZ44 Connection Diagram.

a. Features of IRFZ4047 BC MOSFET

- Dynamic DV/Derating
- 175 °C operating temperature
- Fast switching
- Ease of paralleling
- Simple drive requirements

The ratings used in IRFZ44, such as the maximum volt, power consumption and temperature, showed in table 3.3

Table 3.3 Ratings Data for IRFZ44

ABSOLUTE MAXIMUM RATINGS ($T_C = 25\text{ }^\circ\text{C}$, unless otherwise noted)					
PARAMETER	SYMBOL		LIMIT	UNIT	
Drain-Source Voltage	V_{DS}		60	V	
Gate-Source Voltage	V_{GS}		± 20		
Continuous Drain Current ^a	V_{GS} at 10 V	$T_C = 25\text{ }^\circ\text{C}$	50	A	
Continuous Drain Current		$T_C = 100\text{ }^\circ\text{C}$	36		
Pulsed Drain Current ^a			I_{DM}		200
Linear Derating Factor			1.0	W/°C	
Single Pulse Avalanche Energy ^b			E_{AS}	100	mJ
Maximum Power Dissipation	$T_C = 25\text{ }^\circ\text{C}$		P_D	150	W
Peak Diode Recovery dV/dt ^c			dV/dt	4.5	V/ns
Operating Junction and Storage Temperature Range			T_J, T_{stg}	- 55 to + 175	°C
Soldering Recommendations (Peak Temperature) ^d	for 10 s			300	
Mounting Torque	6-32 or M3 screw			10	lbf · in
				1.1	N · m

3.4 Software Operation and Simulation.

The modeled circuit in Proteus consists of an oscillator type of IC CD4047 integrated circuit, IRFZ44 transistors, a step-up transformer, a filter stage and some electronic parts. The electronics parts and components which were used to model the inverter were presented in table 3.4. As they contain electronic parts such as

resistors, capacitor, diode, transistors, transforms and an integrated circuit, by describing in detail in terms, type, number and value of each piece.

Table 3.4 Electronic Components Used in Simulation

NO	Name	Quantity	Description
1	R1	1	10 K ohm
2	R2	1	100 K ohm
3	R3	1	Variable resistor 50 K ohm
4	R4	1	1 K ohm
5	R5 – R13	7	33 K ohm
6	C1	1	220uf
7	C2	1	0.1u
8	C3	1	10000pf
9	C4	1	2000uf
10	T1 -- T8	8	IRFZ 44
11	Diode	1	AO5 MIC
12	Transformer	1	UP Transformer 12V -- 220V
13	IC CD4047	1	MULTIVIBRATOR –OSCILLATOR

The circuit in figure 3.5 was modified with some electronic components by adding some resistors, capacitors; transistors type IRFZ44, IC CD4047 transformer, etc. The power of the circuit was changed from 50 watts to 60 watts, while the output voltage of the circuit was also changed into 2 types, i.e., 12 DCV and 220V AC.

Numbers of transistors were increased, from 2 IRFZ44 transistors to 8 IRFZ44 transistors. This was done to amplify the voltage and to take advantage from the

pulse width modulation. These transistors were divided into two parts, i.e., 4 transistors were connected to the output of pin 10 (voltage source for them gates) and the output of these transistors was connected with the part 1 of the transformer. The rest of the transistors were connected to pin 11 (voltage source for them gates) and the output of these transistors is connected with part 2 of the transformer. The following figure shows the electronic circuit diagram after development.

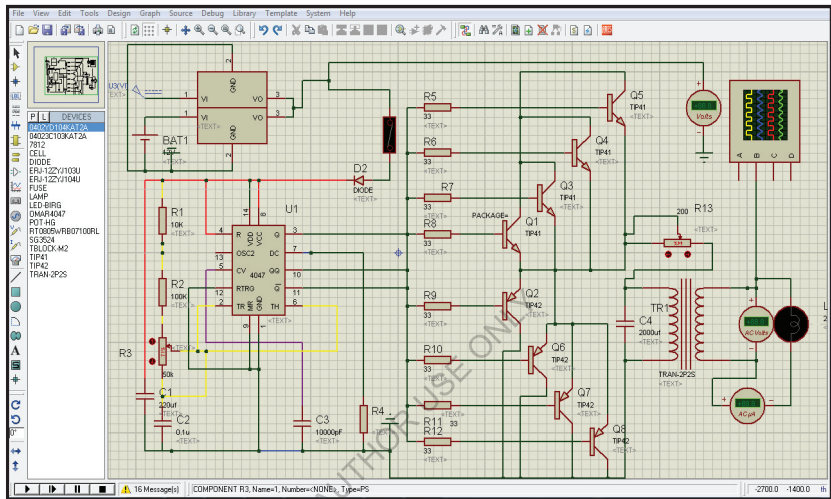


Figure 3.5 Modified Circuit in Proteus Software

The input of the PV was connected with charge controller to charge the battery with 12 V DC. Current flowed to the electronic circuit at pin 14 entering of integrated circuit CD 4047.

3.5 Building the Hardware

The second part of this research was to build an inverter based on the simulation results using the Proteus software. The inverter that would be built has two duties. First duty was to convert the DC power from the PV system to 220-volt AC power to provide power directly to the load. The second duty was converting the DC power from the PV system to 12-volt DC to charge the battery. First step, was selecting the necessary electronic parts such as IC, transistors, resistors, coils, capacitors, diodes, etc. The next step was installing and wiring the electronic parts

on the main board, according to proper position the electronics parts. The last step was welding process and making connection to complete the circuit. The components which were used to build the hardware is presented in table 3.5

Table 3.5 Electronic Components Used in Experimental

No	Name	Quantity	Description
1	R1	1	47 K
2	R2	1	470 K
3	R3	1	2 K
4	R4	1	1 K
5	R5 – R13	1	33 K ohm
6	C1	1	220uf
7	C2	1	2A822K
8	C3	1	3104J
9	Led	1	12V
10	Diode	1	AO5 MIC
11	Zener Diode	1	ZD5V1
10	T1 - T8	8	IRFZ 44
11	Transformer	1	UP Transformer 12V > 220V
12	IC CD4047	1	MULTIVIBRATOR/ OSCILLATOR

3.5.1 Solar Cell Specifications

- Nominal ratings
- Max power (+15% - 5%) 60 W
- Open circuit voltage (voc) 22. V
- Short circuit current (Isc) 3.90 A

- Voltage point of maximum power (VMPP) 17.4V
- Current point of maximum power (IMPP) 3.45A
- Maximum system voltage 600 V
- Over current protection 7.5 A

3.5.2 Charger Controller

The function of the charger controller in this circuit design was to charge the batteries and to provide DC power, using the electricity produces by PV panels. The voltage from the PV panels was regulated in the charge controller. Type of charger controller used was CM1524Z and it can be used in maximum amperes was 15Amp and 12-24 volts, so the output voltage of this charger controller was 12 V DC.

3.5.3 Battery

Battery used in this device was specialized in solar system, which does not easily damage. The battery voltage was 12 V DC, 5 Ah. Thus, the battery power was 60 watts.

$$P = V \times I \Rightarrow P = 12 \times 5 = 60W \dots\dots\dots (3.1)$$

3.5.4 Electrical Transformer Used

The transformer used in this study, as shown in figure 3.6 was a step-up transformer with 5 Amp, and it consisted of two coils, i.e., primary coil and secondary coil, the output of transistors was connected to the primary coil of the transformer. Before being connected to the transformer, the bases of transistors were connected to pin 10 and 11 of the IC4047. The secondary coil of the transformer was the output of the transformer. The output voltage in the secondary coil in the transformer was the 220VAC. The transformer had other pole, called as a central

terminal of the transformer (CT), which was connected to the positive terminal of the battery. This terminal was used to generate a magnetic field in the transformer.



Figure 3.6 Electric Transformer Used

The transformer used in this circuit has amperes was 5 Amps, which meant the device that was designed for maximum power was 60 Watt. The battery can be changed to 24V and the transformer can be changed to 20 Amps to increase the inverter power, which mean the power will be 480 watts.

a. Calculation for the Used Transformer

Following figure shows the simple diagram of the transformer which explains the primary coil, secondary coil, input and output.

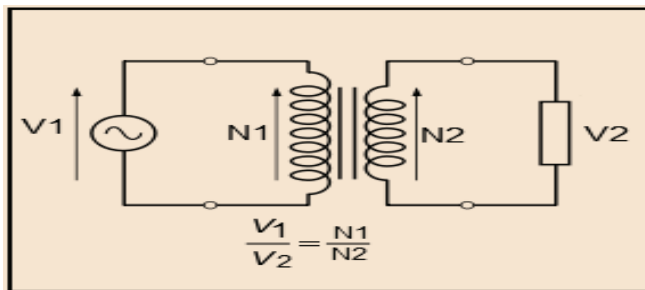


Figure 3.7 Simple Diagram of Electric Transformer

The sectional area of this transformer is important to know the number of twists in this transformer; thus, the cross-sectional area can calculate as equation follows:

Sectional Area = (Length × Width) of the sheets metal transformer

$$\text{Sectional Area} = 5.25 \text{ cm} \times 10 \text{ cm} = 52.5 \text{ cm}^2 \dots\dots\dots (3.2)$$

The voltage in each twist of the coils was determined by using equation 3.3.

$$\text{Voltage in each twist} = \text{PF} \times \text{frequency} / (\text{cross sectional area})$$

With the, PF value = 0.9, frequency = 50, and cross-sectional area = 52.5 cm² respectively, then the voltage at each twist was calculated as below:

$$\text{The voltage at each twist} = \frac{0.9 \times 50}{52.5} = 0.857 \dots\dots\dots (3.3)$$

Input voltage of the primary transformer was 12 VAC and output voltage of the secondary transformer was 220 VAC.

The numbers of twists in primary and secondary transformers were calculated in the equations below:

$$\text{The number of twists in primary coils} = \frac{12}{0.857} = 14.02 \text{ twists} \dots\dots\dots (3.4)$$

$$\text{The number of twists in secondary coils} = \frac{220}{0.857} = 256.7 \text{ twists} \dots\dots\dots (3.5)$$

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3.6 Flow Chart of the Research Methodology

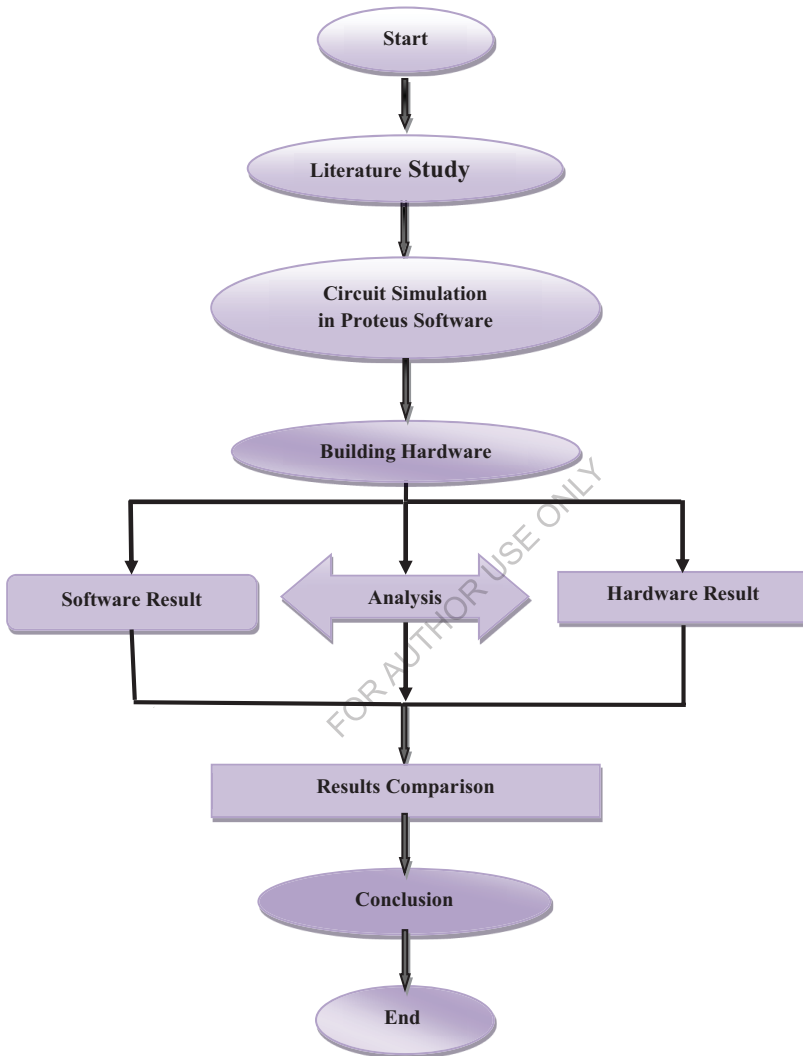


Figure 3.8 Flowchart of Research Methodology.

CHAPTER IV

DATA AND ANALYSIS

This experiment focuses on the input voltage from the photovoltaic, where the PV volt was DC volt, but it was unstable volt at a constant value. The voltage is up and down, depends on the solar cells, sunrays, and load value. The independent variable for this PV system is the source of the power which is influenced by the atmosphere condition (cloudy, foggy, or shiny) and the characteristic of the solar cells. The input power of the PV system is influenced by inverter design to provide power to the loads.

This research will observe the AC output volt during fluctuate input volt; observe variables of AC output such as current, voltage, and power. After being calibrated and observed all pieces and electronic components, can be determined the best components and specifications to design the inverter.

4.1 Comparison between Simulation and Experiment Results

Simulation and hardware were compared to collect the used components and collect the final results. Observed and compared to the performance, as well as measuring the input and output of the volt and ampere for the inverter and the solar cell used, as well as calculating the power of the loads before and after connecting to the inverter. And therefore, will be compared to the inverter device at every load, with more focus on the device efficiency which designed for it.

Also, it is necessary to remember that there is a difference between the simulation of electronic circuit by the computer program and the real electronic circuit. Where, all the pieces of software are used by ideal specifications such as value, capacity, voltage, current intensity, maximum power, etc., but in hardware there is an error ratio for every electronic component, in terms value, power loss, and maximum power used, also there is the effect of temperature on the electronic pieces when the current passes through it.

4.1.1 Circuit Simulation

Figure 4.1 shows the red pulses which indicate positive voltage and then it changes into blue color which indicates negative voltage to show the oscillation process.

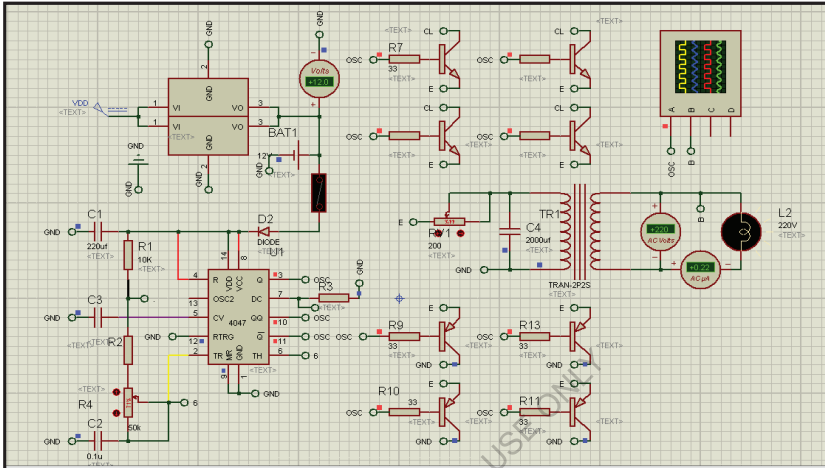


Figure 4.1 The Developed Inverter in Proteus Software

There was only one pulse per half cycle and the width of the pulse was varied to control the inverter output. Square wave reference signal and frequency determined by R3, the frequency of the carrier wave determines the fundamental frequency of the output voltage.

By modifying resistance from 0 to 50 K ohm, the pulse width can be varied from 0 to 100 percent. A square wave inverter is an inverter with an output wave in square form. This output waveform can be modified by adding a filtering stage to produce a sine wave form which can be used in AC loads

Figure 4.2 explains the square wave which gets from IC 4047 before being connected with the IRFZ44 transistors in Proteus software. This is the required wave form from the integrated circuit IC CD4047, it was such as preliminary wave form, the voltages in this wave was started from +2.67volt in the positive part and go to -2.67 volt in the negative part where the volt level was 1volt for every square that is meant the peak to peak equal 5.34 volts.

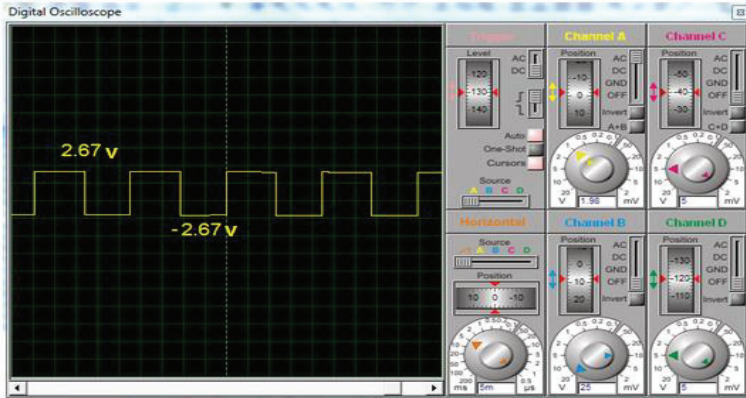


Figure 4.2 Square Wave from IC 4047 before Connected with Transistors.

After connecting 8 transistors type IRFZ44 to the circuit, the output wave was amplified, and needed a lot of modifications and filtering until becoming a pure sine wave. Figure 4.3 shows the new wave came out before any filtering or amendments, the wave started from +3.50 volt in the positive part and go to -3.50 volt in the negative part which mean the peak to peak equal 7 volts, that was a result of carried out by the transistors of the amplified process of wave obtained from the integrated circuit 4047. In this case needed the filtering stage to filter and purify the wave and change it to pure sine wave which can be used in AC load.

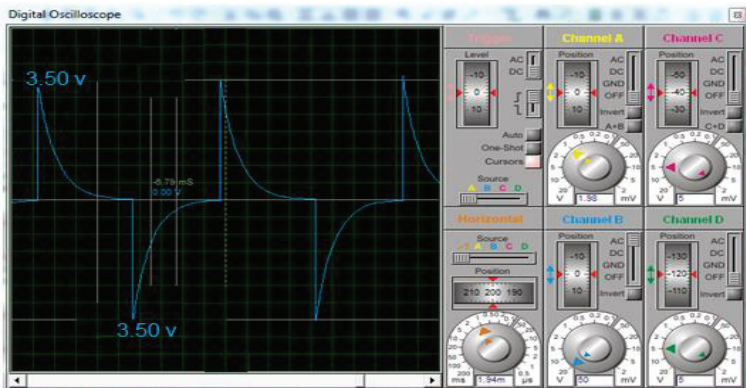


Figure 4.3 The Output Waveform before Filtering.

To get a pure sine wave a capacitor was connected parallel between the terminals of the transformer which was 2000 micro farads and connected variable resistor with 200-ohms value on the first part of transformer which helped to get a pure sine wave with 220 VAC.

Figure 4.4 explains the sine waves after the filtering stage, the sine wave in red color was produced after transistors and filtering stage before connecting electric transformer, value of this wave was 140 mV, also the sine wave in blue color was produced after amplification process after being connected to the electric transformer, the level of this wave was 310 volt which mean equivalent of 220-volt AC by the following equation.

$$V_p = 220 \times 1.41 = 310 \dots \dots \dots (4.1)$$

Required frequency was 50 hertz, which can be obtained through the resistor R3, where the wave time period was 20 ms as following equation.

$$F = \frac{1}{t} \dots \dots \dots (4.2)$$

$$F = \frac{1}{20\text{ms}} = 50 \text{ Hertz}$$

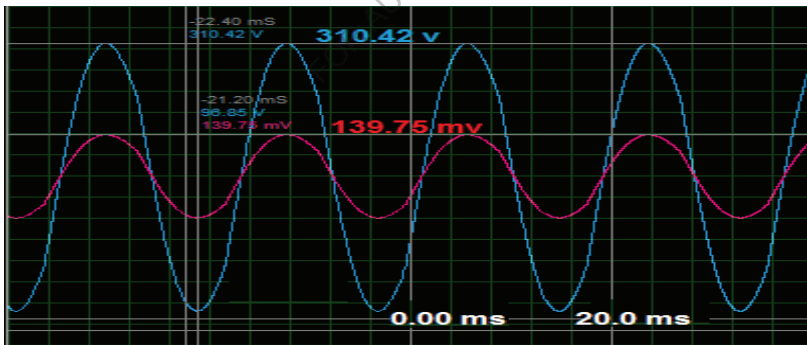


Figure 4.4 Pure Sine Waves Form.

4.2 Hardware Construction

After finishing the model in Proteus software, electronic parts were installed on the mother board based on the software design, where were needed some of changing and adjustments in the values and electronic parts to operate the inverter

to get 220 AC volt such as resistors and capacitors, table 3.4 and table 3.5 show the values and electronic components which were used in software simulation and hardware construction. Data shown on the main board in front of each piece as indicated the type of piece as set out in table 3.5

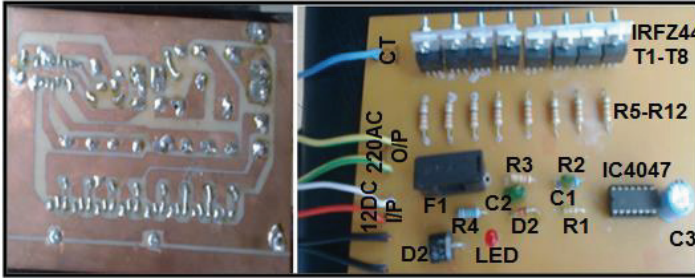


Figure 4.5 Electronic Parts Installed on the Motherboard

After components welding on the motherboard finished, the inverter device was started to assembly, components needed to produce the AC and DC output current were, solar cell, charger controller, battery, the electronic circuit, and power transformer, where they were connected and tested in case of connect and disconnect for the solar cell and the battery, the result was shown in the table 4.1, figure 4.6 shows the final form of the inverter device designed.

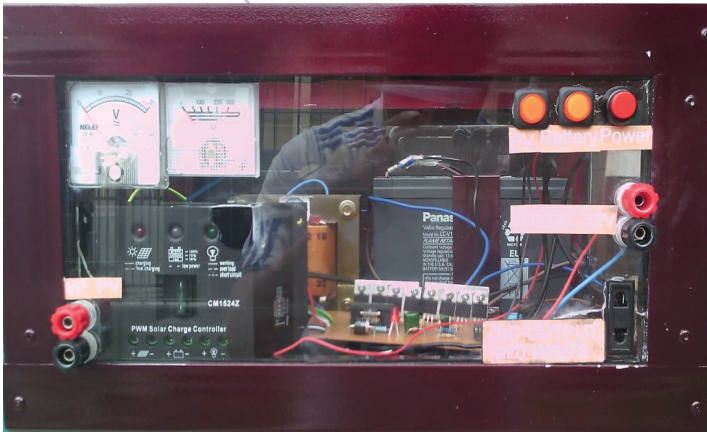


Figure 4.6 Final Inverter Device Configuration

4.2.1 Result of Connecting and Disconnecting between PV and Battery

In the simulation, when the PV was connected or disconnected the inverter can work normally, also if the battery was connected or disconnected the inverter can work normally too, but if they disconnected together at the same time the inverter can never work. While in the hardware if the PV was connected or disconnected the inverter can work normally, but if the battery was disconnected the inverter can never work. It means that the function of the PV and the charger controller in this experiment only to charge the batteries.

Table 4.1 Results of Connecting between PV and Battery without Loads.

Simulation				Hardware			
PV	Battery	DC V	AC V	PV	Battery	DC V	AC V
Connect	Connect	12	220	Connect	Connect	12	220
Disconnect	Connect	12	220	Disconnect	Connect	12	220
Connect	Disconnect	12	220	Connect	Disconnect	0	0
Disconnect	Disconnect	0	0	Disconnect	Disconnect	0	0

Also noted that, the solar panel which was used with the same specifications mentioned previously in chapter III was measured by both cases (open loop circuit and close loop circuit). Where measurements were for four loads as follows 50, 60, 100, 150, while the weather was sunny, stable and the sky was clear. It was observed that when the PV was disconnected with circuit (open loop circuit) the output of PV volt was stable at 15.8 volt, but after connected with different loads, the result was various based on the power of the loads, whenever the power of load increases the current intensity increases too, where the relationship between voltage and current was inverse, while the relationship between the power of load and current intensity was proportional. In other words, if load power increases the pass current will increase too, and vice versa, while the volt value of the battery was constant at 12 volts because the PV offsets the shortage of drop voltage from the battery by charger controller. The results have been clarified in the following table.

Table 4.2 Result of Open and Closed Loop PV with Different Loads

PV (Open Loop)	PV (Closed Loop)	Battery Volt	Power of Load
15.8 V	11.9 V	12 V	150 W
15.8 V	12.5 V	12 V	100 W
15.8 V	12.8 V	12 V	60 W
15.8 V	12.9 V	12 V	50 W

4.2.2 Comparing of Software Result with Different Loads

The inverter was designed for 60-watt power load, where the battery and transformer ampere were 5 Amps, and the input volt was 12 volts as explained previously. The measurement loads in the simulation was for six loads with values as follows 50, 60,70,80,90,100 watt, the loads were measured and tested for the voltage, current, power consumption, and the efficiency for every load.

The following calculations show the voltage, current, power, and the efficiency for every load. Taking into account, I_d = ideal current of the load, I' = actual current of the load, V_d = ideal volt of the load = 220V, V' = actual volt of the load, P_L = real power of the load, P' = consumption power of the load, Eff = efficiency.

1. At load 50 Watt

When the load was 50-watt, actual volt became 201 V.

$$I_d = \frac{P_L}{V_d} = \frac{50}{220} = 0.227$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{201}{220} \times 0.227 = 0.207 \text{ A}$$

$$P' = V' \times I' = 201 \times 0.207 = 41.68 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_L} = \frac{41.68}{50} \times 100\% = 83.3\%$$

2. At load 60 Watt

When the load was 60-watt, actual volt became 198 V.

$$I_d = \frac{P_L}{V_d} = \frac{60}{220} = 0.272$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{198}{220} \times 0.272 = 0.244 \text{ A}$$

$$P' = V' \times I' = 198 \times 0.244 = 48.47 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_L} = \frac{48.47}{60} \times 100\% = 80.7\%$$

3. At load 70 Watt

When the load was 70-watt, actual volt became 192 V.

$$I_d = \frac{P_L}{V_d} = \frac{70}{220} = 0.318$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{192}{220} \times 0.318 = 0.277 \text{ A}$$

$$P' = V' \times I' = 192 \times 0.277 = 53.28 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_L} = \frac{53.28}{70} \times 100\% = 76.12\%$$

4. At load 80 Watt

When the load was 80-watt, actual volt became 188 V.

$$I_d = \frac{P_L}{V_d} = \frac{80}{220} = 0.363$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{188}{220} \times 0.363 = 0.31 \text{ A}$$

$$P' = V' \times I' = 188 \times 0.31 = 58.3 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_L} = \frac{58.3}{80} \times 100\% = 72.8\%$$

5. At load 90 Watt

When the load was 90-watt, actual volt became 180 V.

$$I_d = \frac{P_L}{V_d} = \frac{90}{220} = 0.409$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{180}{220} \times 0.409 = 0.334 \text{ A}$$

$$P' = V' \times I' = 180 \times 0.334 = 60.23 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_L} = \frac{60.23}{90} \times 100\% = 66.9\%$$

6. At load 100 Watt

When the load was 90-watt, actual volt became 167 V.

$$I_d = \frac{P_L}{V_d} = \frac{100}{220} = 0.454$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{167}{220} \times 0.454 = 0.344 \text{ A}$$

$$P' = V' \times I' = 167 \times 0.344 = 57.44 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_L} = \frac{57.44}{100} \times 100\% = 57.44\%$$

4.2.3 Comparing Hardware Results with Different Loads

Also, the measurement of loads in the experiment was like the measurement of loads in the simulation, where were for six loads with the same values of 50, 60,70,80,90,100 watt, the loads were measured and tested for the voltage, current, power consumption, and the efficiency for every load.

1. At load 50 Watt

When the load was 50-watt, actual volt became 190 V.

$$I_d = \frac{P_L}{V_d} = \frac{50}{220} = 0.227$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{190}{220} \times 0.227 = 0.196 \text{ A}$$

$$P' = V' \times I' = 190 \times 0.196 = 37.24 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_c} = \frac{37.24}{50} \times 100\% = 74.5\%$$

2. At load 60 Watt

When the load was 60-watt, actual volt became 185 V.

$$I_d = \frac{P_L}{V_d} = \frac{60}{220} = 0.272$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{185}{220} \times 0.272 = 0.228 \text{ A}$$

$$P' = V' \times I' = 185 \times 0.228 = 42.18 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_c} = \frac{42.18}{60} \times 100\% = 70.30\%$$

3. At load 70 Watt

When the load was 70-watt, actual volt became 177 V.

$$I_d = \frac{P_L}{V_d} = \frac{70}{220} = 0.318$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{177}{220} \times 0.318 = 0.255 \text{ A}$$

$$P' = V' \times I' = 177 \times 0.255 = 45.28 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_c} = \frac{45.28}{70} \times 100\% = 64.68\%$$

4. At load 80 Watt

When the load was 80-watt, actual volt became 167 V.

$$I_d = \frac{P_L}{V_d} = \frac{80}{220} = 0.363$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{167}{220} \times 0.363 = 0.273 \text{ A}$$

$$P' = V' \times I' = 167 \times 0.273 = 45.63 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_c} = \frac{45.64}{80} \times 100\% = 57.04\%$$

5. At load 90 Watt

When the load was 90-watt, actual volt became 158 V.

$$I_d = \frac{P_c}{V_d} = \frac{90}{220} = 0.409$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{158}{220} \times 0.409 = 0.293 \text{ A}$$

$$P' = V' \times I' = 158 \times 0.293 = 46.41 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_c} = \frac{46.41}{90} \times 100\% = 51.56\%$$

6. At load 100 Watt

When the load was 90-watt, actual volt became 154 V.

$$I_d = \frac{P_c}{V_d} = \frac{100}{220} = 0.454$$

$$I' = \frac{V'}{V_d} \times I_d = \frac{154}{220} \times 0.454 = 0.317 \text{ A}$$

$$P' = V' \times I' = 154 \times 0.317 = 48.94 \text{ W}$$

$$\text{Eff} = \frac{P'}{P_c} = \frac{48.94}{100} \times 100\% = 48.94\%$$

4.2.4 Results of Comparison between Software and Hardware

After getting simulation and experiment results of each load through the actual volt, actual current, and actual power consumption, the inverter efficiency in case of software and hardware was compared between them as shown in the table 4.3 Which shows the efficiency of each load, while the inverter was designed for 60

watts, where the power of the battery and the transformer used was 60 watts, noted that the actual efficiency of this inverter device was 70.3%

Table 4.3 Efficiency Results between Software and Hardware.

4.2.5 Efficiency Curves of Software and Hardware

Figure 4.7 shows the efficiency curves between the software and hardware, where the red curve was for hardware efficiency and the green curve was for the software efficiency. The obvious difference is that the inverter efficiency in the software more than efficiency in the hardware if it is considered that the inverter device was designed for 60 watts, seen that the actual hardware efficiency was 70.3, but software efficiency was 80.7 while the difference between them was 10.4%, but in both cases the efficiency was in two parallel lines, if it increases in software it will increase in hardware and vice versa.

Simulation					Experiment				
Real power of load	Actual volt	Actual current	Consumption power	Efficiency	Real power of load	Actual volt	Actual current	Consumption power	Efficiency
50	201	0.211	43.36	83.3%	50	190	0.196	37.24	74%
60	198	0.244	48.47	80.7%	60	185	0.228	42.30	70.3%
70	192	0.277	53.28	76.12%	70	177	0.255	45.28	64.6%
80	188	0.300	54.65	72.8%	80	167	0.280	45.63	58.7%
90	180	0.312	52.470	66.9%	90	158	0.292	46.18	51.3%
100	167	0.282	38.73	57.44%	100	154	0.317	48.94	48.9%

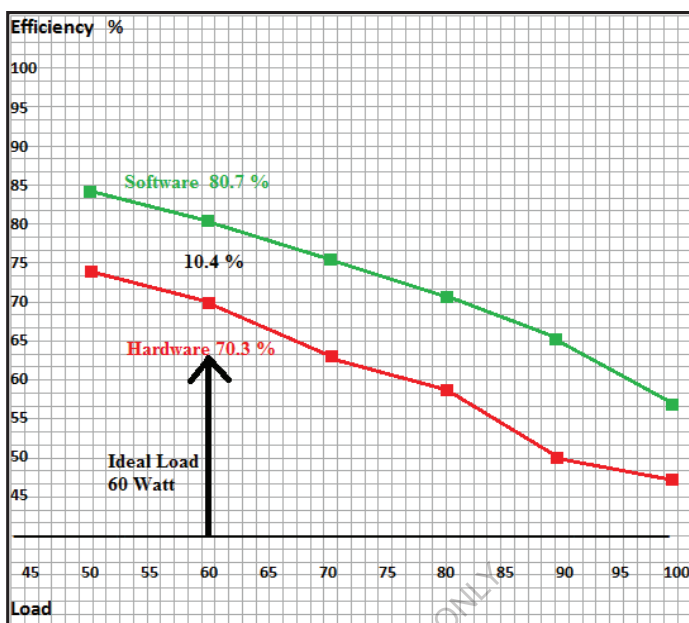


Figure 4.7 Efficiency Curves between Software and Hardware

Software efficiency was higher than the efficiency in the real circuit because there are some reasons as follows:

1. Electronic parts and components used in the simulation, such as Proteus software, have been installed by ideal specifications, such as the value, capacity, maximum current, maximum volt, maximum power, and power loss, etc. And there is no effect of the temperature in the Proteus software, therefore all the received results were ideal results based on modeling circuit.
2. Electronic components and parts always have an error percentage of its industry in terms of its actual value, such as resistors, capacitors, coils, and the parts which make from semiconductor such as diodes, transistors and integrated circuits, etc. The real electronic parts are affected by temperature, where every piece has its specific temperature, and it cannot be used in higher temperature. Also, in the real circuit, there is power loss which loses in connecting status, power conversion by electrical transformers in terms of increasing or decreasing the voltage and current, and wires impedance, etc.

CHAPTER V

CLOSING

5.1 Conclusion

Based on the simulation using Proteus software and the experiments using the real hardware, some conclusions can be derived as follows

1. The model of an inverter with direct and alternating current output in the same device using Proteus software developed successfully, and the result was encouraged to design the real inverter device.
2. Real inverter device was designed and built successfully based on the modeled inverter on the software.
3. The comparison of performance and efficiency of the modeled inverter by software and designed inverter by hardware proved that the software efficiency was higher than hardware efficiency by ratio 10.4 %, where the software efficiency was 80.7 % and the hardware efficiency was 70.3 %, and the performance of the battery in the software was different from in the hardware.

5.2 Suggestions

After finishing the circuit simulation by Proteus software and the real circuit by hardware, there are some of suggestions such as below:

1. It is proposed that, the power of this device may be able to be developed to reach a high value of power, such as 1000 or 1500 watt, where it needs more addition and test.
2. Also, it is proposed to increase the value of both outputs, DC and AC, for example, increasing the DC output to 12, 18, 24, 32 volt and increasing the AC output to 110, 220, 380 volt, which it needs more research and hard work in software and hardware.
3. In the future, some researchers might be able to conduct some attempt to increase the level of the efficiency more than 70.3%, where it needs electronic

pieces which have more efficiency in its specifications and precision in manufacturing. And it also depends on the source of input power which will support this device.

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