AC GRID GENERATION USING BI-INPUT HYBRID INVERTER CIRCUIT

By

THAYALAN RAGUNAZAN

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

AC GRID GENERATION USING BI-INPUT HYBRID INVERTER CIRCUIT

by

Thayalan Ragunazan

A project dissertation submitted to the
Department of Electrical & Electronic Engineering
Universiti Teknologi PETRONAS
in partial fulfilment of the requirement for the
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

Approved:

_____

Supervisor: Zazilah May
Co-Supervisor: Dr Nor Zaihar Yahaya

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

June 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

_____

Thayalan Ragunazan

ABSTRACT

Whilst a normal inverter converts the DC voltage into AC voltage, an off grid inverter occupies input from either solar panel or wind turbine. This paper is about the design and simulation of a bi-input inverter using Photovoltaic Array and Wind power system. The overall design will result in a regulated AC output load for AC grid connected system. This paper also discusses on two circuits which are charge controller and inverter. It is found that regulated output AC voltage level of 110V and current 13A have been successfully simulated using MULTISIM Power Pro Edition 12.0 in which this design will then eventually provide good insight for further experimental validation process.

.

Keyword : *photovoltaic array, charge controller, inverter, wind turbine, AC Grid*

ACKNOWLEDGEMENTS

I thank to the lord, the most gracious and most merciful for giving me the strength and wisdom in completing this project. First and for most, I would like to express my gratitude to my supervisor, Dr. Nor Zaihar bin Yahaya, for his understanding and professional ways in assisting and giving his encouragement, guidance, comment and ideas that are useful towards the development of this project.

I would also like to acknowledge with much appreciation the crucial role of my friends for giving me such a great assistance with regards to this project requirements and specifications.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1
INTRODUCTION

In this section, the project background, problem statement, objectives, challenges, significant of project, contribution of the work done and the scope of research will be discussed.

1.1   Project Background

The need for a clean, environment friendly, renewable energy source is high. Electricity is one of the greatest creation by human beings, and one of the important energy for our daily life usage. There are two methods to generate electricity. First, is by using non-renewable source such as, coal, gas and petroleum (fossil fuels). Second, is by using renewable source such as hydropower, wind power, solar power and etc. Based on conventional sources of energy are rapidly depleting and the cost of energy is rising, photovoltaic and wind energy becomes a promising alternative source.

Due to the high need for the electricity generation by using renewable energy source, a study of two input inverter using hybrid PV/Wind power system is initiated to be done. Inverter is used to convert DC (direct current) source into AC(alternating current) source [1]. By using two inputs (solar and wind), the combination of these input sources will increase the overall efficiency of the power system.

1.2   Problem Statement

By using a two-input source, the efficiency will be higher. This is because the more current produced by the system, the faster it takes to charge the battery [2]. For a two input inverter system, where wind or solar power is not consistent, the output of the system will not be always stable. Therefore, there is a need to make sure that the output will be regulated for use of electrical appliances. This research is to create a

regulated AC output. This research is to create a regulated AC grid output voltage. The voltage will be 110V AC and 13A AC current.

1.3 Objective

The objectives of this project are:

a) to understand the theory and concept of a two input inverter for PV/Wind power system

b) to simulate the design of a an inverter for PV/Wind power system.

c) to design a new controller to control the charge in the rechargeable battery. DC current generated from the solar PV array and Wind turbine will be used to charge the battery [3].

d) to get a stable output of 50-60 Hz sine wave at the end of the simulation phase, with 110V AC voltage, 13A AC current

1.4 Challenges

Sunshine is not constant, and wind will not blow at the same speed every day. These are the environmental conditions of using PV cell and Wind turbine:

a) A thorough analysis has to be carried out in order to get a regulated output, so that utility loads can use a stable AC voltage.

b) The inverter has to supply the correct frequency of AC current as well.

c) A good controller method has to be selected to control the current to charge the battery.

This is because there are few controllers that use microcontrollers as a brain to control the current from the PV and Wind Turbine source. However, these controllers need a broader time frame in order to implement it perfectly based on research done on it. As a result, a different controller, which does not use microcontroller, can be implemented. A good inverter has to be designed to produce 110V AC voltage and 13A AC current, so that home appliances can work properly with the main supply.

1.5 Significance of Project

Sun and wind are clean energy sources. As a result, this project has advantage from other power generation system. This is because, wind and solar are clean form of

energy, which means, environmentally friendly. As the world is moving forward, there is a need for more clean power system to protect the environment. In other words, this project will create a good impact to people who are using clean energy because it can save precious amount of money. Although the initial cost of fixing the inverter is high, by utilizing the renewable energy source to generate electricity, the cost will be reduced, compared to using electricity from the TNB grid.

1.6 Contribution of Work

First of all, the idea of this research is based on simulation. However, this idea can be improvised, developed and sent to be marketed in the future. The design of an inverter by using a clean form of energy source will always give positive impact to the environment. This is because the output of the two input inverter does not contain smoke or other chemical effluents. In addition, in the long usage, by generating electricity in this way, it is cheaper compared to the conventional way which uses fossil fuels and other non-renewable sources. This is because user does not need to pay the electricity bills. If this research is commercialized, the prototype of the two input inverter can be fixed in a house easily. It is a very convenient device because it can be installed anywhere needed.

1.7 Scope of Research

Table 1: Required data for the system

Parts	Specification
Circuit representing charge controller	1 circuit module
Circuit representing inverter	1 circuit module

The scope of the study will be focusing on the simulation of two input inverter using hybrid PV/Wind power system. Table 1 shows the required modules needed for the simulation. There are two main circuits for the project: charge controller circuit and inverter circuit. Charge controller circuit acts as a controller for the whole system. The circuit will control the charge and discharge cycle of the battery. Inverter will produce regulated output of 110V AC and 13A AC current.

1.7.1 Block diagram of BI-Input inverter
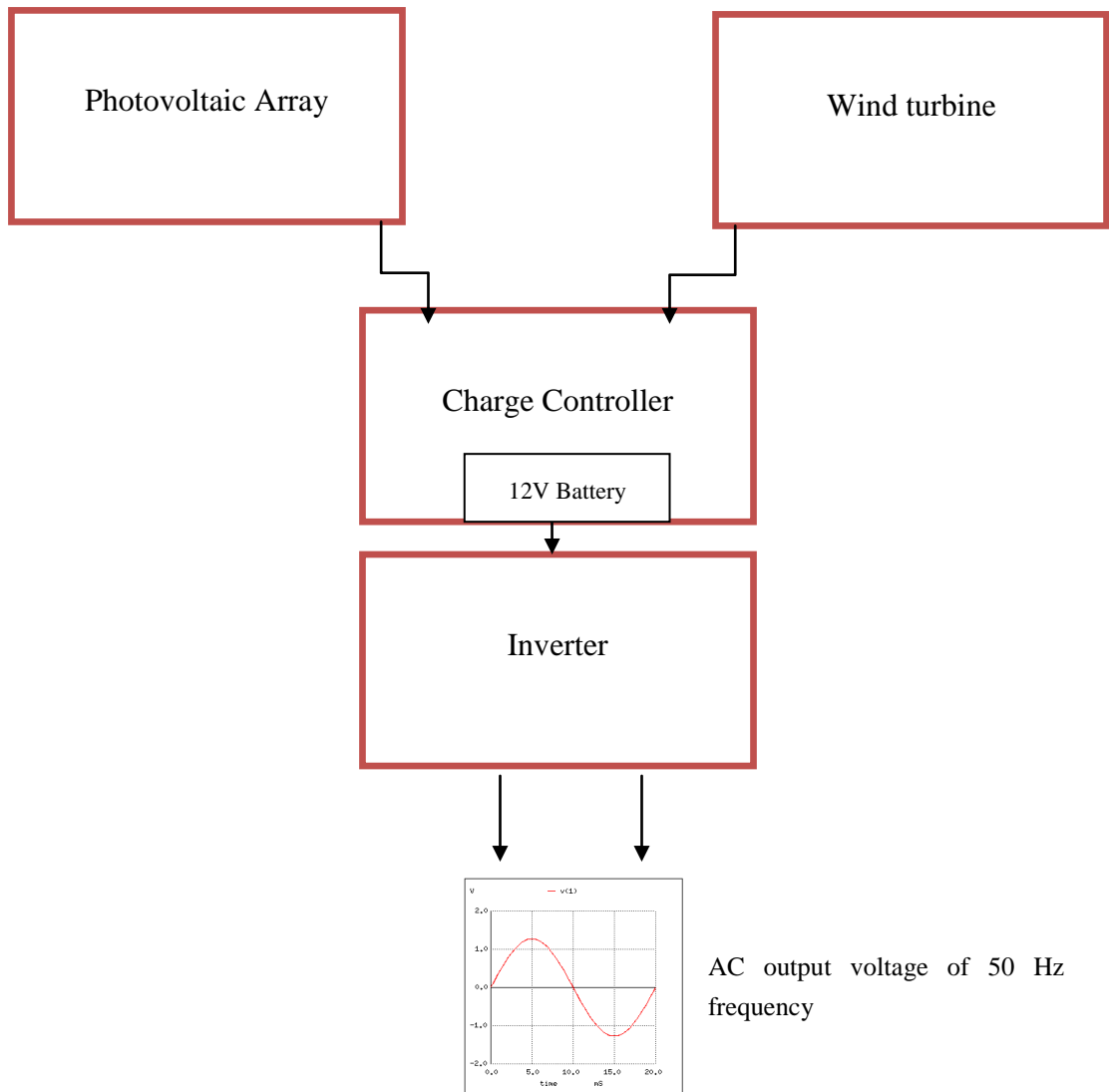
Figure 1: Block diagram of bi-input inverter

In Figure 1, Photovoltaic Array and Wind Turbine will be connected to the charge controller. Charge controller will keep a 12V battery in charged condition. Inverter will use the 12V battery for AC conversion.

1.7.2 Relevancy of project

This project will focus on simulation of two-input inverter for Hybrid PV/Wind power system. This topic is related to the course of Power Electronics, plus the knowledge of Electrical Energy System, Circuit Theory, and Analog Electronic is

also needed for this project. Generally, this topic is fully related to the electrical engineering students which cover critical area in running simulation on circuit. Crucial knowledge on electronics components such as MOSFET, Power Diodes, Transistor and comparators is important.

1.7.3   Feasibility of project within the scope and time frame

The project is divided into three sections. Section one will be on finding, collecting, and reading of journals, technical papers, and books of the research topic. The second section of the project will be mainly on identifying, analyzing and choosing the related circuit for the inverter design. The third section of the project is the simulation and analysis phase.

CHAPTER 2
LITERATURE REVIEW

Renewable energy is energy which comes from natural resources such as sunlight, wind, rain, tides, and geothermal heat, which are renewable (naturally replenished). In this project, inverter will be used to extract electrical energy from this natural source.

Table 2: Parts in two input inverter

Module	Main description	Functionality
Charge Controller[4]	Charge controller will be used to protect the battery from over charging	Simple charge controllers stop charging a battery when the battery exceed a preset high voltage level, and re-enable charging when battery voltage drops back below the preset level
Photovoltaic Array[4]–[5]	Photovoltaic is the direct conversion of light into electricity at the atomic level.	Photoelectric effect that causes PV array to absorb photons of light and release electrons.
Wind turbine[4]-[5]	Wind turbine generates electricity when the blade moves by the force of air	Wind turbine can be used to convert the kinetic energy from moving air, into mechanical energy in wind turbine, and finally into electrical energy, DC output voltage

From Table 2, the functionality of the PV array, wind turbine and charge controller are explained. From this information, the knowledge to proceed with the research on simulation for two input inverter was gained.

2.1 Solar Cell
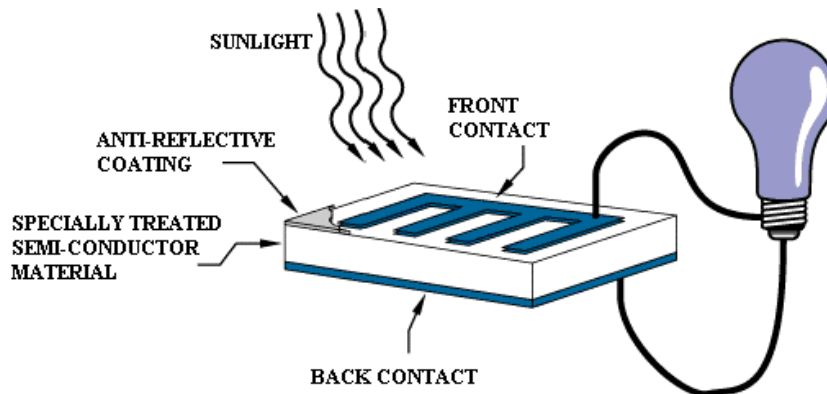
Figure 2: Working principle of photovoltaic solar cell [5]

Figure 2 shows the working principle of photovoltaic cell. Output is a DC voltage. Sunlight causes the electron to be released in the PV material, which induces current. Electricity is produced by solar cell if there is sunlight. Sunlight is the main input for the solar cell to produce electricity.

2.2 Photovoltaic Array
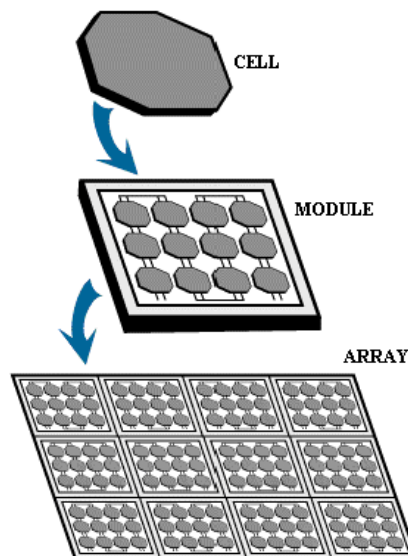
Figure 3: Formation of photovoltaic array [5]

Multiple modules can be wired together to form an array, which is shown in Figure 3. In general, the larger the area of a solar module or array, the more electricity that will be produced. Photovoltaic modules and arrays produce direct-current (DC) electricity. As useful as solar panels can be, it is clear that there are still problems that affect the

overall performance of such an array. It will not be efficient enough if it stands alone as a single energy source. This is what contributes to the practicality of the design. As a result, there is a need to use two energy sources which is wind and solar combined. A good controller is needed for this combination.

2.3   Wind Turbine

Figure 4: Wind Turbine [6]

Figure 4 shows the wind turbine model. Wind turbine generates electricity from the wind that spins the turbine blade [7]-[9]. The generator inside the wind turbine will spin and generate DC voltage. Inverter will be used to harness this energy from Wind and Solar to generate electricity for electric appliances, which mostly uses AC supply. Rechargeable battery will be used to store all the charges collected by the PV panel and Wind turbine.

2.4   Charge Controller

To control the charge going into the battery, a controller is needed.

Important functions of battery charge controllers and system controls are [10]:

a) <u>Prevent Battery Overcharge</u>: to limit the energy supplied to the battery by the PV array when the battery becomes fully charged.

b) <u>Prevent Battery Over discharge</u>: to disconnect the battery from electrical loads when the battery reaches low state of charge.

The ultimate goal is to get a stable oscillating output voltage of 50-60 Hz frequency, while keeping the battery in good condition. The connection of the system is explained briefly in the block diagram shown in Figure 1.

2.5   Rechargeable Battery

Depending on the size of the battery, it will usually take a minimum of 5-8 hours to charge a dead-battery from a solar panel producing 1 Amp of current. In order to most effectively charge a battery with a solar panel, we need to maximize the amount of current by keeping the panel pointed directly at the sun. In the two input inverter design, the more current produced by the system, the faster it takes to charge the battery [10]. As a result, the inverter will be able to use the voltage from battery for AC voltage conversion.
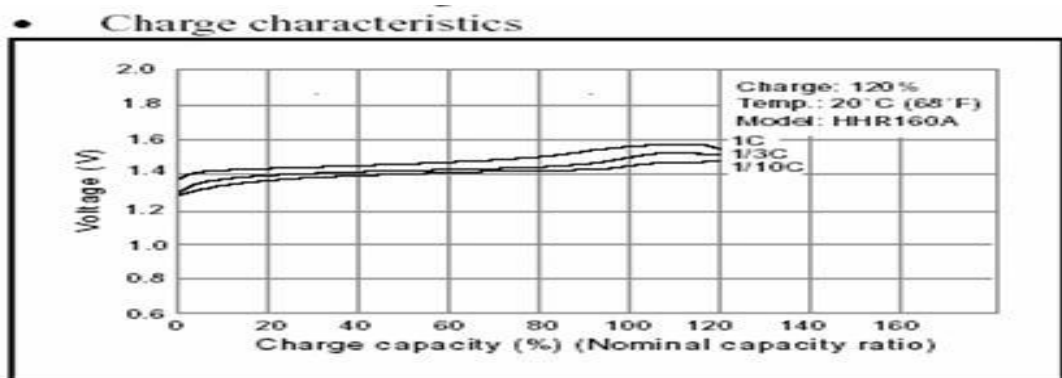

Figure 5: Charge Characteristics [11]

From Figure 5, if the nominal capacity of a battery is 160 mAh, for example, then 160 mA is called a "C". A C is the current that can be delivered by this specific battery during an hour. Batteries can be charged by circulating through the battery a current of one C, more than one C or a fraction of a C. Usually a fraction of a C is used and this means that several hours are needed until the battery is fully charged. The curve for NiMH batteries shows that the voltage increases slightly when the cell is gradually charged. These batteries can be overcharged with 20% more energy than its nominal capacity. A charge with one C leads to a slightly higher voltage in the cell as a charge with 1/3 C [11]. From Figure 5, it can be seen that the more current used to charge the battery, the faster it takes for the battery to reach its full charge condition. For a lead acid battery, the best result to get the charge condition is 0.2C [11].

2.6   Inverter Circuit

The value of 110V AC implies that this is a RMS voltage. RMS stands for "Root Mean Square" which is a way of averaging. The RMS value of a voltage represents the average value of voltage over time, and this value is important because standard

AC meter display RMS voltage. This means that the voltage that comes out from the wall outlet is RMS voltage. This is why RMS voltage needs to be calculated in this project.

In this case, 110V AC voltage means 110V RMS [12].

2.6.1   Voltage Calculation :

The RMS voltage can be calculated by using Eq. (1)

$$Vrms = \frac{Vp}{\sqrt{2}} \qquad (1)$$

From this formula, the peak value for the voltage can be found. In this study, 110V AC has 155Vpeak. The voltage will swing from +155V to -155V.

2.6.2   Current Calculation :

The RMS current can be calculated by using Eq. (2)

$$Irms = \frac{Ip}{\sqrt{2}} \qquad (2)$$

From this formula, the peak value for the current can be found. In this study, 13A AC has 18A Ipeak. The current will swing from +18A to -18A.

CHAPTER 3

METHODOLOGY

In this section, the flow of work done to meet the objectives of this project will be discussed.

3.1   Project Flow

```
        ┌─────────────────────────┐
        │          Start          │
        └─────────────────────────┘
                     │
                     ▼
        ┌─────────────────────────┐
        │     Topic Selection     │
        └─────────────────────────┘
                     │
                     ▼
        ┌─────────────────────────┐
        │    Research on topic    │
        │        relevance        │
        └─────────────────────────┘
                     │
                     ▼
        ┌─────────────────────────┐
        │    Literature review    │
        └─────────────────────────┘
                     │
                     ▼
        ┌─────────────────────────┐
        │ Charge Controller design│
        │     and simulation      │
        └─────────────────────────┘
                     │
                     ▼
        ┌─────────────────────────┐
        │    Inverter design and  │
        │        simulation       │
        └─────────────────────────┘
                     │
                     ▼
        ┌─────────────────────────┐
        │ Combined charge controller│
        │  and inverter simulation│
        └─────────────────────────┘
                     │
                     ▼
        ┌─────────────────────────┐
        │     Final report        │
        │      completion         │
        └─────────────────────────┘
                     │
                     ▼
        ┌─────────────────────────┐
        │          End            │
        └─────────────────────────┘
```
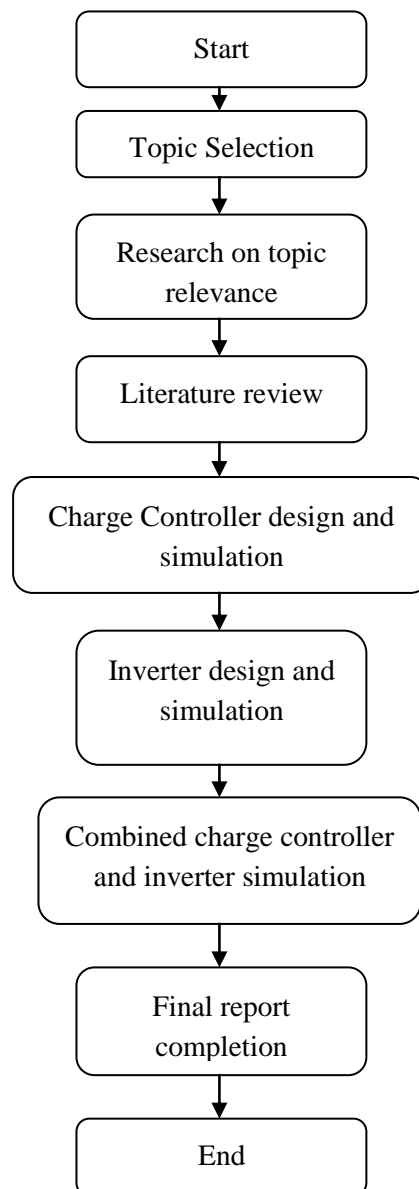
Figure 6 : Flow chart of work

This project is basically a simulation based. Specifically, it focuses on generating a stable output voltage out of two combined unstable inputs, which is sun light and wind. Firstly, a lot of reading was done on solar inverter and wind turbine inverter. Information was gathered regarding charge controller and inverter design. With the obtained information, the design phase of the charge controller was started. Then, the design was simulated. After finishing the charge controller design phase, the design phase for inverter was started. The finished inverter design was simulated. Finally, the charge controller and inverter circuit was combined and simulated. A project report was written at the end of the designing phase.

3.2   Software Tools used

Multisim Component Evaluator 11.0 and Multisim Power Pro Edition 12.0.0 are the main softwares used to carry out the simulation.
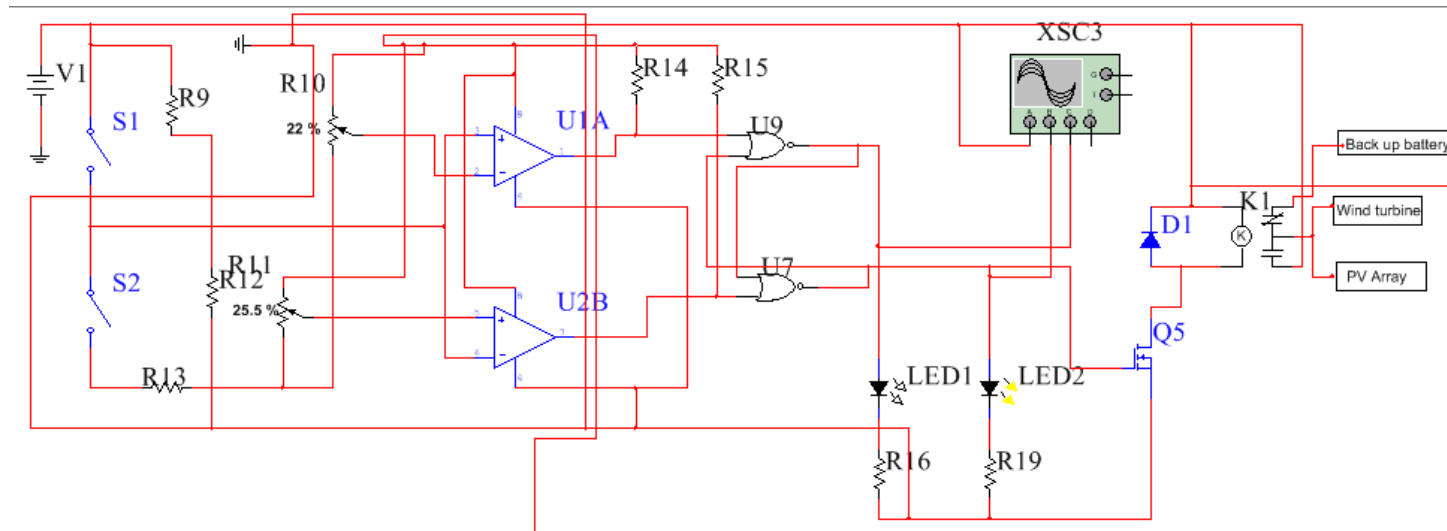
3.3 Charge controller circuit diagram

Figure 7 : Charge controller schematic [13]

Figure 7 shows the circuit diagram for the charge controller which will be simulated. There are two input sources, which is coming from the solar panel and wind turbine. The tripping point for the relay K1 to start charging the battery is 12V, which means, when the voltage of the battery is at 12V, the relay will trip to channel the current into the battery. On the other hand, when the voltage of the battery reaches 12.2V, the relay will trip to the backup battery, and stop charging the main battery. LED1 and LED2 will be used for indication purposes. Here, the inverter will be connected to the main battery.
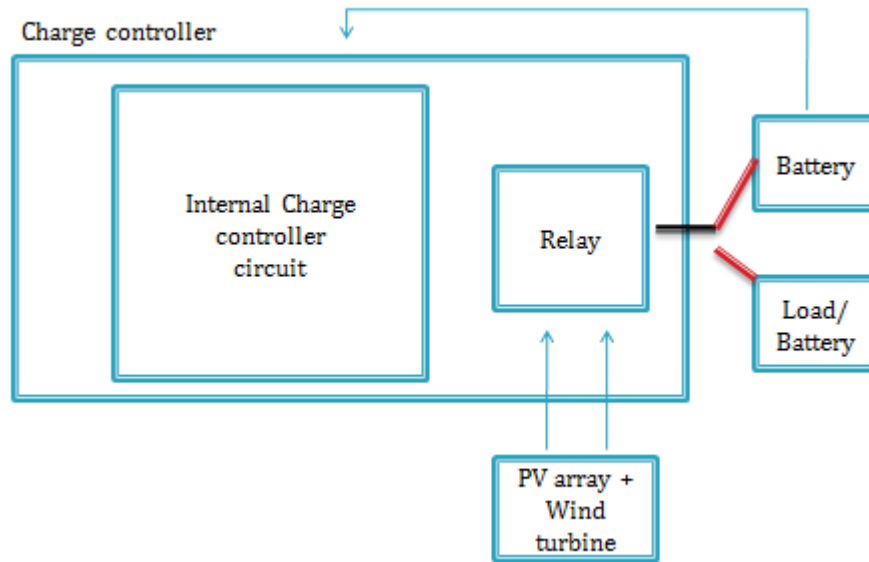
Figure 8: Simplified block Diagram of charge controller

Figure 8 shows the simplified block diagram for the charge controller circuit. From this diagram, PV array and Wind turbine are connected to the high current relay. The backup battery and rechargeable battery are also connected to the relay. The main battery will be connected to the charge controller so that charge controller can compare the battery's voltage to the preset values which is 12V and 12.2V. Based on the battery voltage comparison at the op amp U1A and U1B, the charge controller will decide whether it should direct the current from the wind turbine and PV array to the backup battery side or main battery.

The Vmax at the −ve node at the op-amp U1A was set to 6.24V as a threshold voltage. The Vmin at the +ve node at the op-amp U2B was set to 5.95V as a threshold voltage. The output of both op-amp is 8V. As a result, by using Eq. (3) and Eq. (4).

$$X1 = \frac{R10}{R10 + R11} \tag{3}$$

$$X2 = \frac{R10}{R10 + R11} \tag{4}$$

As a result, the resistor R10 has to be set to 22% of 10kΩ. Resistor R11 must be set to 25.5% of 10kΩ.

Resistor R11 must be set to 25.5% of 10kΩ. Resistor R9 and R12 will form a voltage divider which will give half of the voltage to both the inputs of the op-amp UIA and U2B. The value for R9 and R12 can be calculated according to Eq. (5).

$$\frac{R12}{R9+R12}=\frac{1}{2} \tag{5}$$

As a result, resistor R9 and R12 has been chosen to be 3.3kΩ.R16 and R19 is set to be 560Ω as a load for the LED. R14 and R15 is pull-up resistor, and the value can range from 1k-5k. Table 3 shows the component in the charge controller circuit and their values.

Table 3 : Component values for charge controller circuit

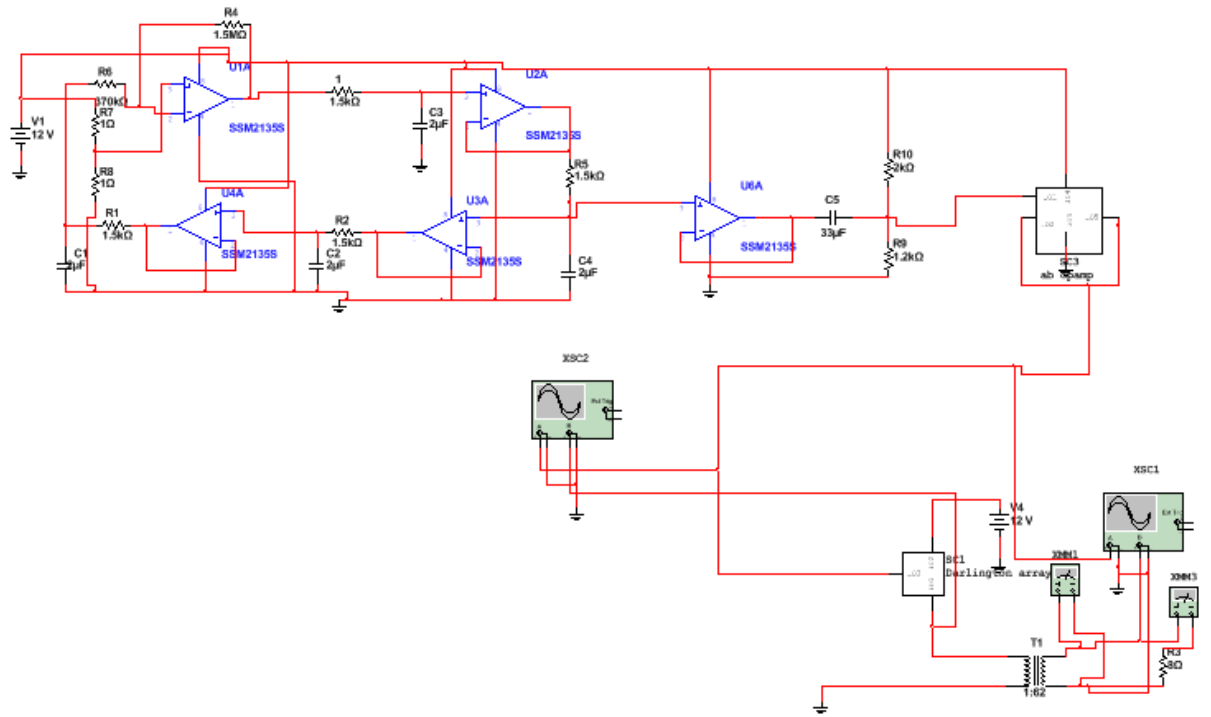| Components	Values
R9	3.3kΩ
R10	22%
R11	25.5%
R12	3.3kΩ
R14	3.3kΩ
R15	3.3kΩ
R16	560Ω
R19	560Ω

3.4 Finalized Inverter Circuit

Figure 9: Inverter circuit diagram for 53.1 Hz output signal frequency [14]

Figure 9 shows the circuit diagram for the inverter. Part A is actually a Bubba oscillator circuit. Bubba inverter circuit can produce a stable output voltage with 53.1 Hz frequency. Frequency calculation was done for the components in the circuit to achieve 53.1 Hz output frequency based on Eq. (6)

$$F = \frac{1}{2\pi RC} \tag{6}$$

where R and C will be the corresponding capacitor and resistor values. As a result, 1, R1, R2, R5, C1, C2, C3 and C4 were calculated using the formula above. R4 must be a high gain resistor [14] so that the gain A will be 4 according to Eq. (7).

$$\frac{R4}{R6} = 4 \tag{7}$$

R7 and R8 forms a voltage divider circuit to give 6V to the positive node of U3A op amp according to Eq.(8).

$$\frac{12 \times R7}{R7 + R8} = 6 \tag{8}$$

16

Table 4 : Components values for inverter circuit

Components	Values
1	1.5kΩ
R1	1.5kΩ
R2	1.5kΩ
R5	1.5kΩ
C1	2uF
C2	2uF
C3	2uF
C4	2uF
R4	1.5MΩ
R6	370kΩ
R7	1Ω
R8	1Ω

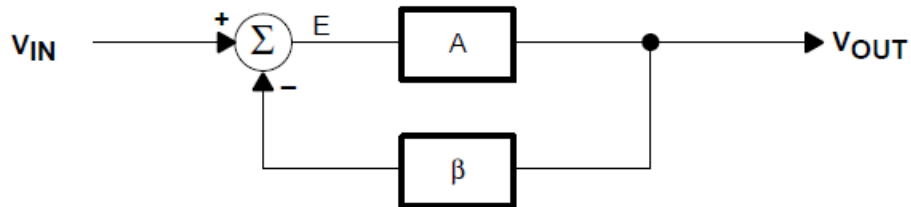Table 4 shows the value of the components in the inverter circuit.

Figure 10: Canonical form of feedback system with positive or negative feedback [14]

The canonical form in Figure 10, or simplest, form of a negative feedback system is used to demonstrate the requirements for oscillation to occur. Figure 10 shows the block diagram for this system in which VIN is the input voltage, VOUT is the output voltage from the amplifier gain block A, and β is the signal, called the feedback factor that is fed back to the summing junction. E represents the error term that is equal to the summation of the feedback factor and the input voltage. The corresponding classic expression for a feedback system is derived as follows. Equation (16) below is the defining equation for the output voltage and Eq. (9) is the corresponding error.

$$Vout = E \times A \tag{9}$$

$$E = Vin + \beta Vout \tag{10}$$

$$\frac{Vout}{A} = Vin - \beta Vout \qquad (11)$$

$$\frac{Vout}{Vin} = \frac{A}{1 + A\beta} \qquad (12)$$

The system goes unstable when the denominator in equation 7 becomes zero, which means that when $1 + A\beta = 0$, or $A\beta = -1$. The key to designing an oscillator is ensuring that $A\beta = -1$. This is called the Barkhausen criterion[14]. Satisfying this criterion requires that the magnitude of the loop gain is unity with a corresponding phase shift of 180° as indicated by the minus sign.

Four RC sections require $45°$ phase shift per section. Each of the RC sections contribute $45°$ phase shift, so taking outputs from alternate sections yields low-impedance quadrature outputs. When an output is taken from each op amp, the circuit delivers four 45° phase-shifted sine waves. The loop equation is given in Eq. (11). When $\omega = 1/RCs$, Eq. (11) reduces to smaller equation [14]. The gain, A, must equal 4 for oscillation to occur.

$$A\beta = A\left(\frac{1}{RCs + 1}\right)^4 \qquad (13)$$

$$|\beta| = \left|\left(\frac{1}{j+4}\right)^4 = \frac{1}{\left(\sqrt{2}\right)^4} = \frac{1}{4}\right| \qquad (14)$$

Four RC sections in the Bubba oscillator circuit will produce 180° shifted to produce full sine wave.

The inverter circuit [15] is connected to a 2 stage voltage follower. First stage is the voltage follower, second stage contains voltage follower in a sub circuit form. Then, before the sine wave goes into the transformer, it is passed through darlington pairs to increase the current. Darlington pairs are represented in a sub-circuit form as well. Transformer is used to step up the voltage to a desired level.
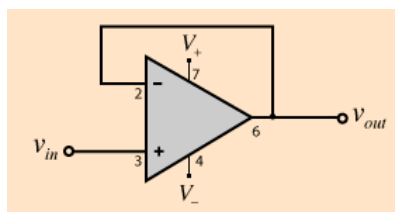
Figure 11: Voltage follower circuit [15]

Figure 11 shows the voltage follower circuit. The voltage follower with an ideal op amp gives effective isolation of the output from the signal source. The output draws very little power from the signal source, avoiding "loading" effects [15].

This circuit is a useful first stage for the inverter circuit. This is because, without using the voltage follower circuit, the sine wave at the output part of the inverter becomes less in magnitude with reference to time, as shown in Figure 12 and 13.

As a result, the formula for the output will be as Eq. (15)

$$Vout = Vin \tag{15}$$

where Vout is output voltage and Vin and Vin is input voltage to the voltage follower.
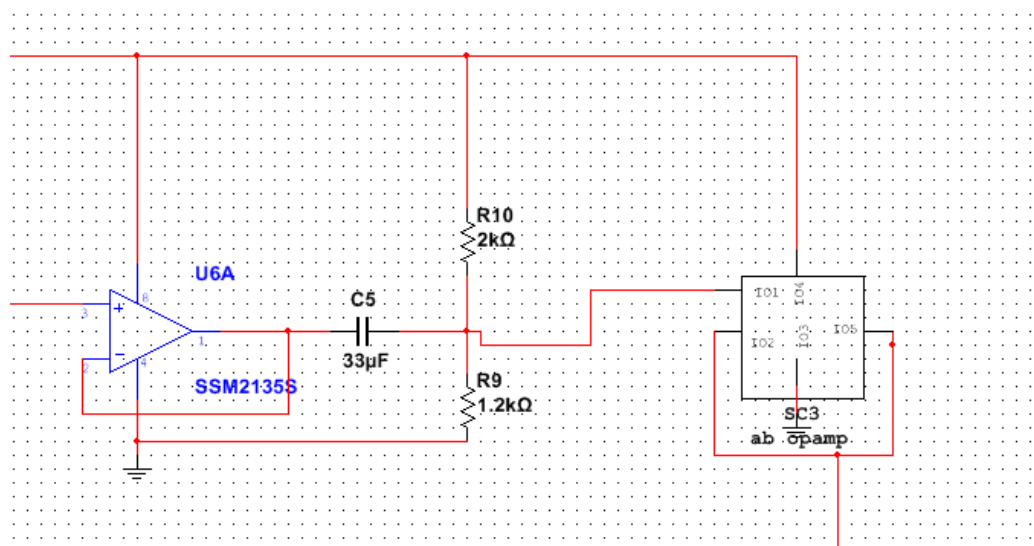

Figure 12: Voltage follower in sub-circuit form

Figure 12 shows the op amp in the sub-circuit form. From here, it can be seen that the combination of voltage follower have been represented by a box which is called "ab opamp" in the circuit above.
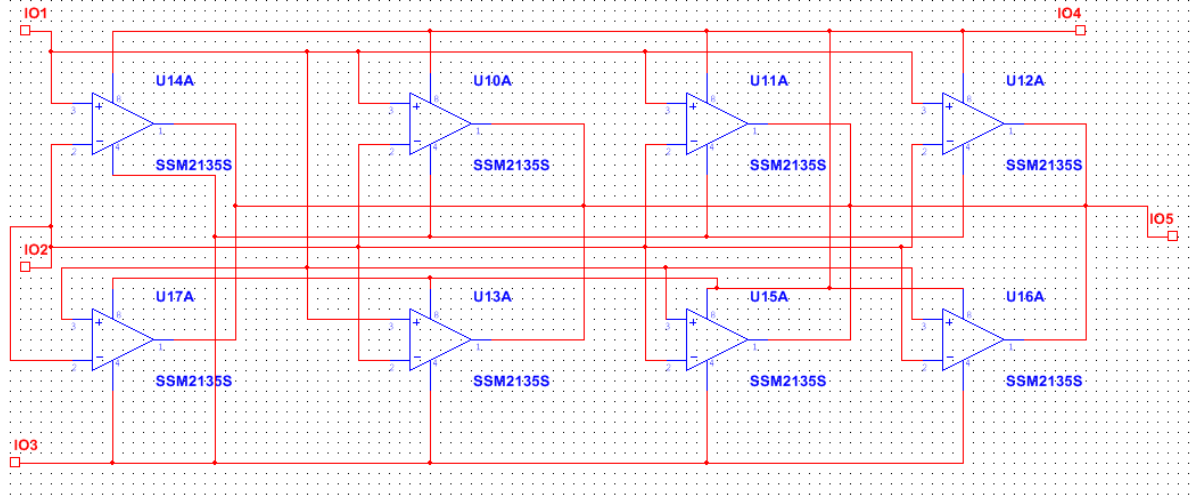
Figure 13: Voltage follower sub-circuit contents

Figure 13 shows the content of voltage follower sub-circuit. From here, it can be seen that there are 8 voltage follower circuit used in the inverter circuit.
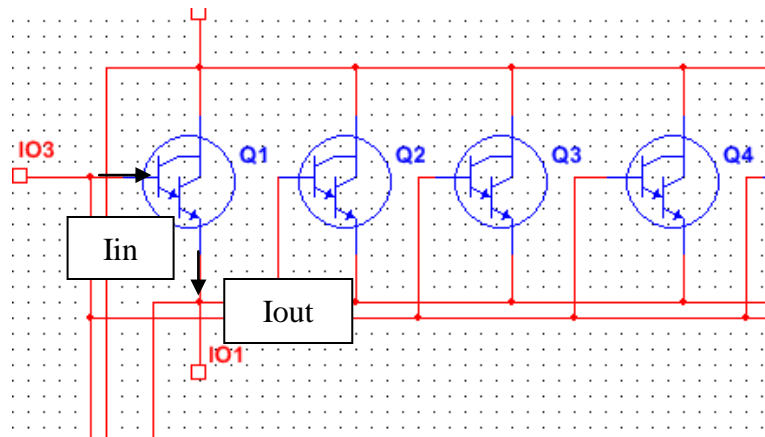

Figure 14: Darlington pair sub-circuit

Figure 14 shows the content of the darlington pairs sub-circuit. Darlington pairs are used to increase the current of the signal. There are two transistors connected together to form one darlington transistor so that the current amplified by the first is amplified further by the second transistor. The overall current gain is equal to the two individual gains multiplied together [16]-[17]. The overall DC or low frequency current gain for the Darlington pair will be as Eq. (16)

$$\frac{Iout}{Iin} = \beta1 + \beta2 + \beta1\beta2 \tag{16}$$

where $\beta1$ and $\beta2$ is the gain for both transistor in the darlington pair.

Thus at low frequencies, the Darlington pair is approximately equivalent to a single transistor with a current gain greater than β^2.

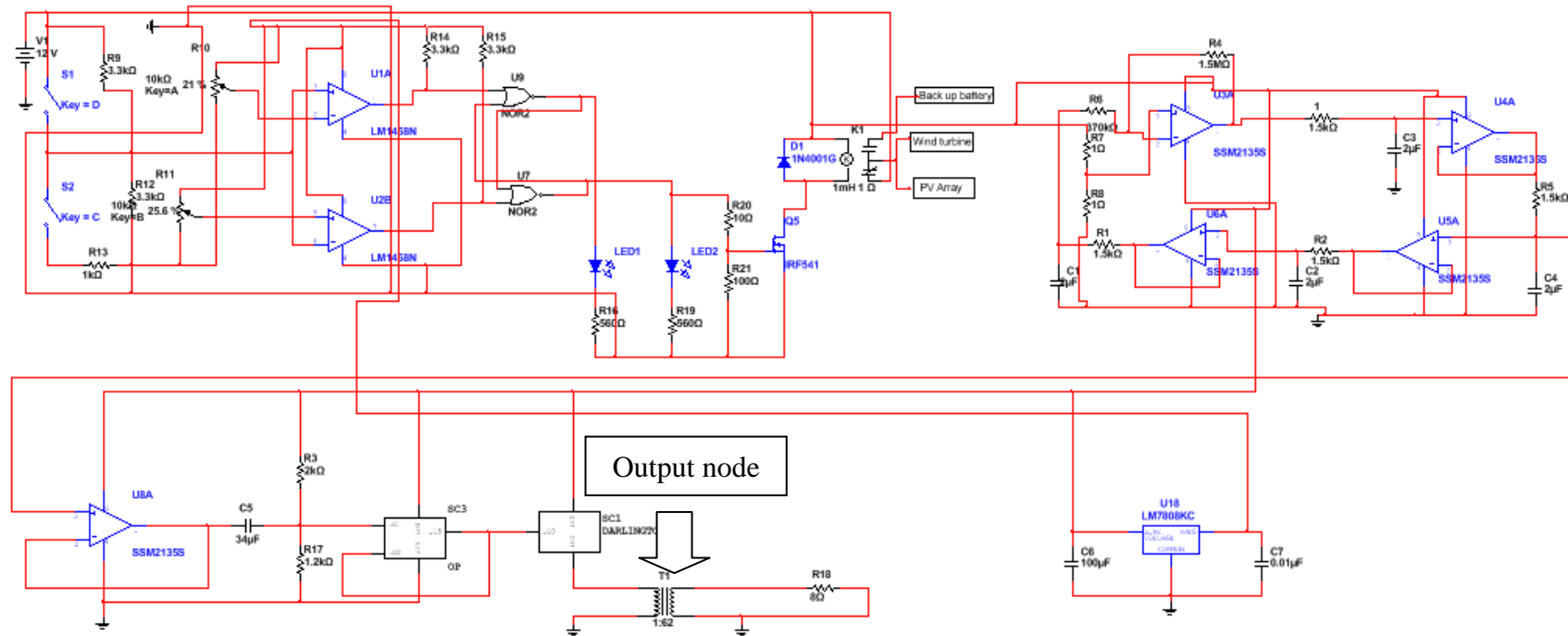## 3.5 Finalized overall circuit for Two Input Inverter

Figure 15: Combination of inverter circuit and charge controller circuit

Figure 15 shows the overall circuit for the two input inverter system. From here, it can be seen that the charge controller and inverter is connected to the 12V battery. The output node will produce sine wave signal with 53.1 Hz frequency, 110V AC voltage and 13A AC current.

3.6 Gantt Chart and milestone

Fyp1

Table 5 : Gantt chart for the project implementation for FYP 1

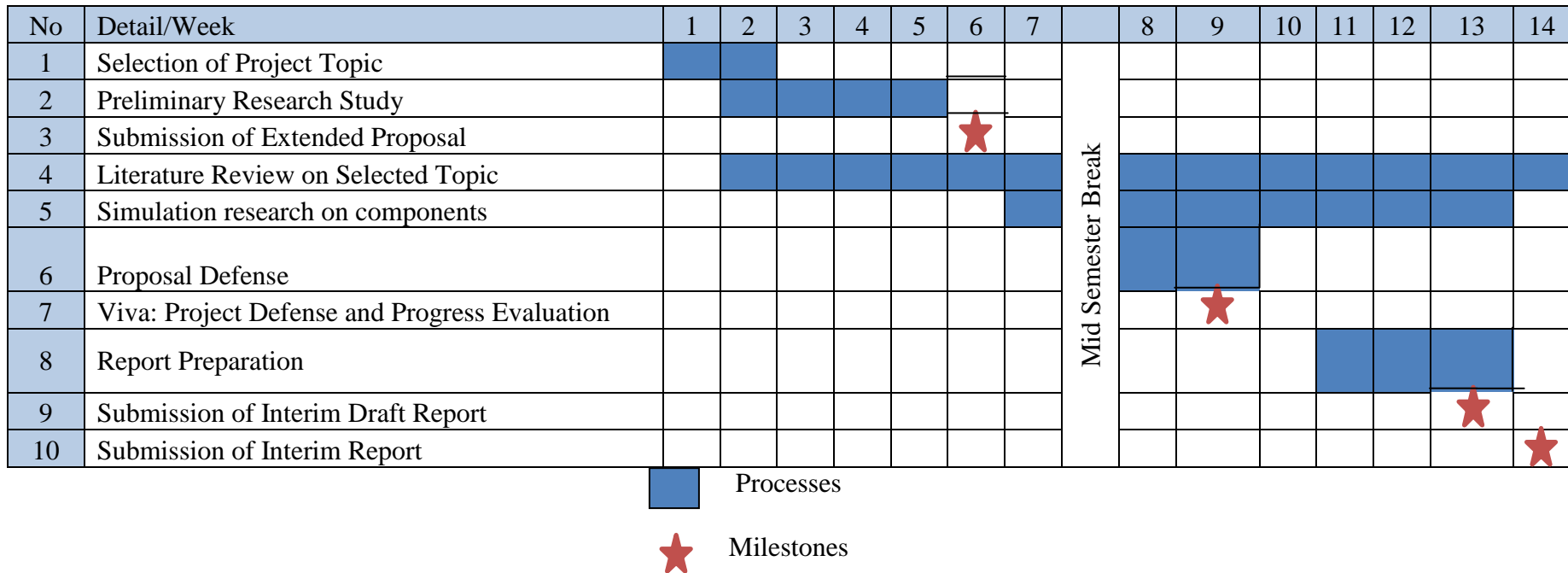| No	Detail/Week	1	2	3	4	5	6	7	Mid Semester Break	8	9	10	11	12	13	14
1	Selection of Project Topic	▓	▓													
2	Preliminary Research Study		▓	▓	▓	▓										
3	Submission of Extended Proposal						★									
4	Literature Review on Selected Topic		▓	▓	▓	▓	▓	▓		▓	▓	▓	▓	▓	▓	▓
5	Simulation research on components							▓		▓	▓	▓	▓	▓	▓	
6	Proposal Defense									▓	▓					
7	Viva: Project Defense and Progress Evaluation										★					
8	Report Preparation												▓	▓	▓	
9	Submission of Interim Draft Report														★	
10	Submission of Interim Report															★

▓ Processes

★ Milestones

Table 5 shows the Gantt Chart for FYP1 of this project. There are 10 activities to be completed during this semester for the FYP1(final year project 1). All the activities for the project were completed as per Gantt Chart.

Table 6 : Gantt chart for the project implementation for FYP 2

No	Detail/Week	1	2	3	4	5	6	7	Mid-Semester Break	8	9	10	11	12	13	14
1	Project work: Perform literature review and designing of inverter circuit	�														
2	Simulation progress on inverter circuit							▓		▓						
3	Submission of Progress Report									●						
4	Modeling finalized inverter circuit										▓	▓	▓			
5	Tune finalized inverter circuit to get desired output												▓	▓	▓	
6	Pre-EDX												●			
7	Submission of final report and VIVA															●

Table 6 shows the Gantt Chart for FYP 2. There are 7 activities to be completed in this semester for the FYP2(final year project 2). The project is completed as per Gantt Chart.

CHAPTER 4

RESULTS AND DISCUSSION

In this section, the results for the charge controller and inverter circuit will be discussed.

4.1 Result and Discussion for Charging Phase of Charge Controller
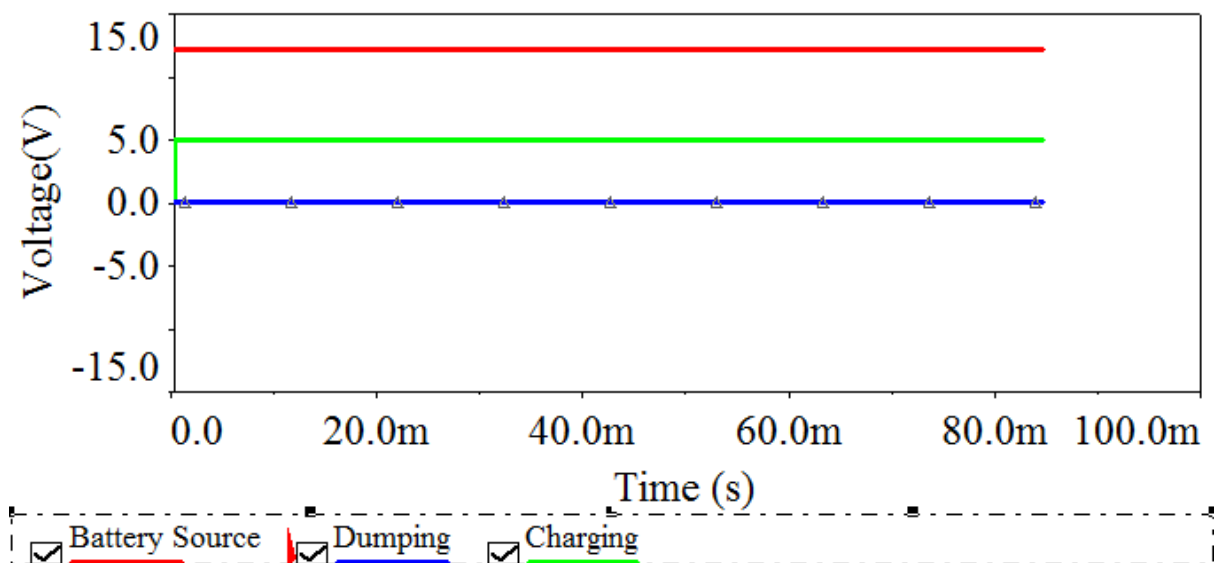

Figure 17 : Result for charging cycle

In this part, the output of the charge controller and inverter will be discussed and analyzed. For the charge controller, the charging and discharging phase will be discussed. For the inverter, the improvement has been done and the corresponding results will be discussed. Both charging and discharging phase analyses are referred to the same circuit connection as in Figure 7. In Figure 7, an oscilloscope was connected in the charge controller circuit. By referring to Figure 7, Channel A of the oscilloscope was connected to the battery source, Channel B was connected to the 'gate' of the MOSFET which controls the relay and Channel C is connected to the LED1 which indicates the Charging mode.

Figure 17 shows the result obtained from the simulation on charge controller. The tipping point for the charge controller was set to be 12 V and 12.3 V. As explained in

Figure 7, when the voltage of the battery is 10 V, channel C receives 5 V and channel B receives 0 V. When the 'gate' voltage of the MOSFET is 0 V, the relay will not trip. As a result, the current generated by wind turbine and PV array will be directed to rechargeable battery. Hence, the battery will be in charging mode.

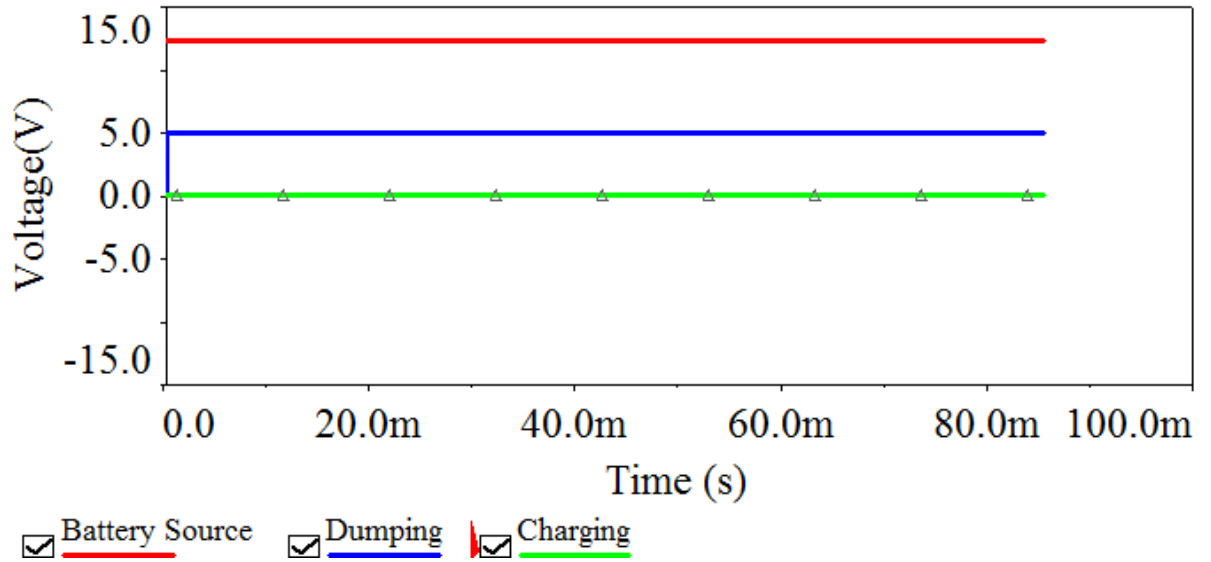## 4.2 Result and Discussion for Discharging Phase of Charge Controller

Figure 18 : Result for discharging cycle

Figure 18 shows the voltage of the battery is 15 V whilst channel C receives 0 V and channel B receives 5 V. When the 'gate' voltage of the MOSFET is 5 V, the relay will trip. As a result, the current generated by wind turbine and PV array will be directed to load. Hence, the battery will be in discharging mode. From both results, we can conclude that the charge controller does the work on deciding the charging and discharging cycle for the battery. Hence, the life cycle of rechargeable battery can be maintained for a long period of time.

4.3 Analysis for Finalized Inverter Circuit

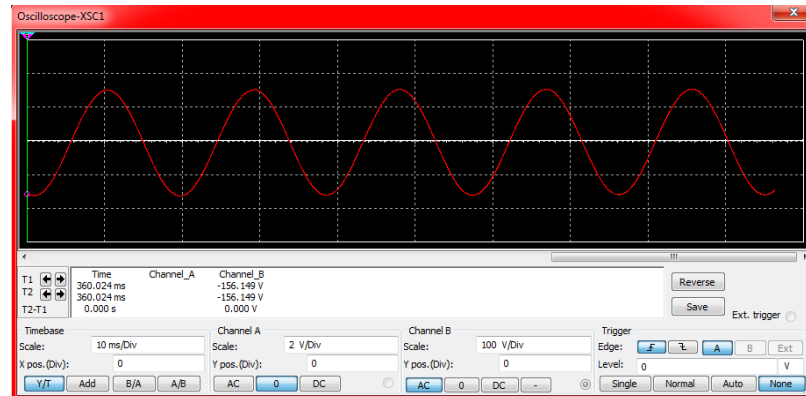### *4.3.1 First stage analysis of inverter circuit with less output current*

Figure 19 : Output waveform of inverter

Figure 19 shows the output waveform at the output of the inverter. Result shows a Vp-p of 311V or 111V AC or 111V RMS
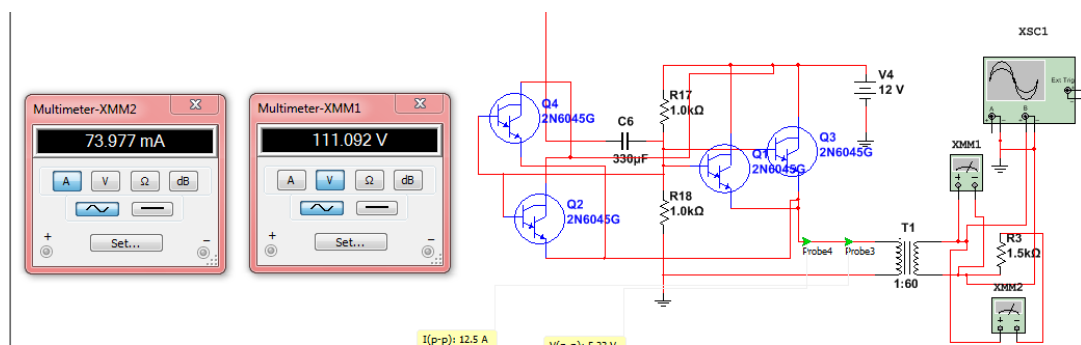

Figure 20 : Multimeter reading at output part (111 VAC, 73mA)

Apart from the waveform, Figure 20 shows the multimeter reading at the output part of the inverter. The RMS voltage is 111V RMS, 73mA Irms. So the AC voltage and AC current is 111V AC, 73mA I_{AC}.

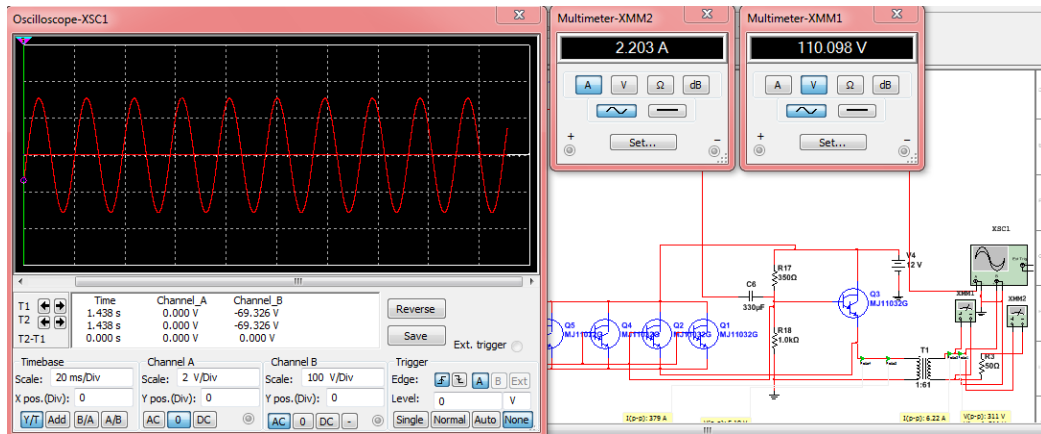### 4.3.2 Second stage analysis of inverter circuit with increased output current

Figure 21: Multimeter reading at output part (110 VAC, 2.2A)

Figure 20 above shows the results of the upgraded inverter circuit. 10 darlington pairs have been used in this circuit. From here, the multimeter reading shows 2.2A current and 110V AC voltage. This amount of voltage and current can be used to drive various loads.

4.3.3 Third stage analysis of inverter circuit with achieved targeted output current
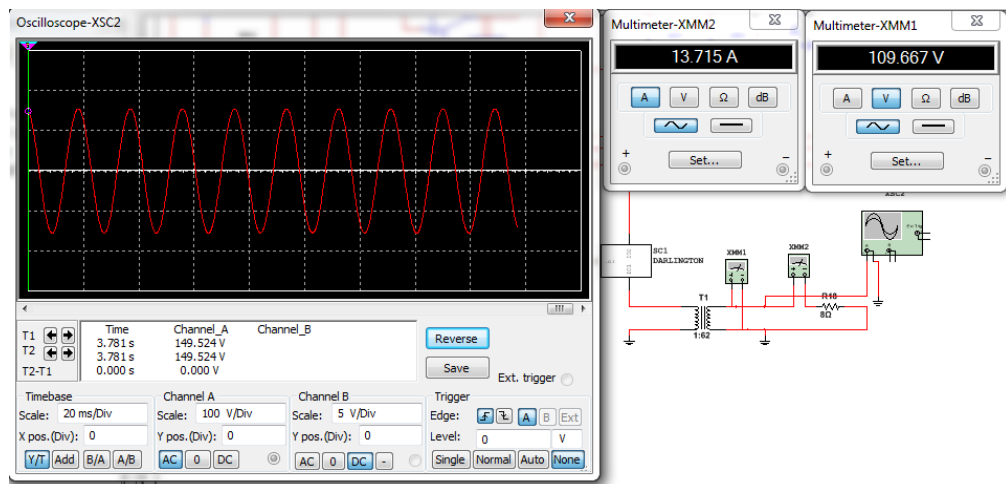

Figure 22 : Multimeter reading at output part (109.667 VAC, 13.7A)

Figure 22 above shows the upgraded inverter circuit which caters 110V RMS and 13.7A RMS. 67 darlington pairs have been used to increase the current in the circuit. This should be enough to be used as a power point in houses for small appliances. Details of the output are:

1. Freq = 53.1 Hz
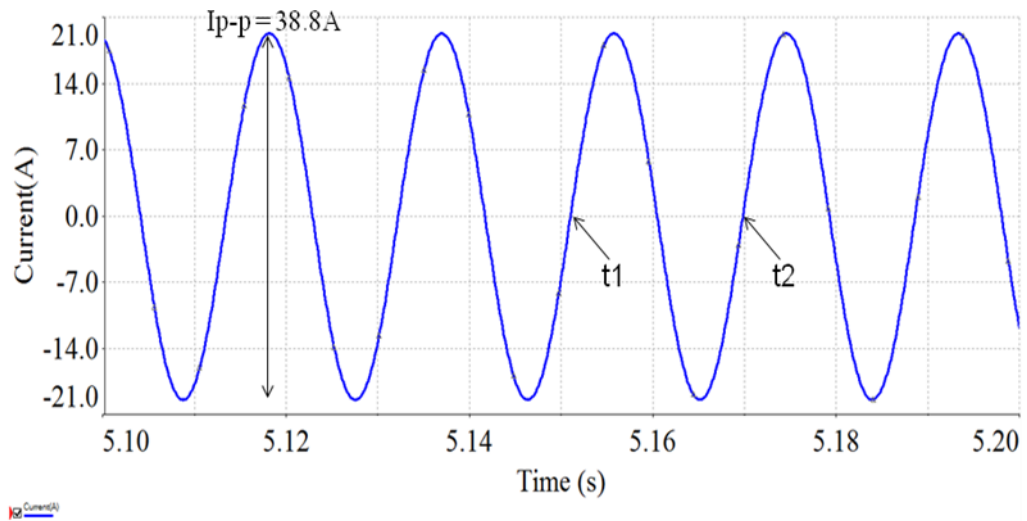2. V AC = 110V
3. I_{AC} = 13.7A

Figure 23 : Transient response for output current

Figure 23 shows the transient response for output current. The current swings from +19.4 Ip to -19.4 Ip. By using Eq. (2),

Ip-p = 38.8A

Ip = 19.4A

Irms = 13.7A

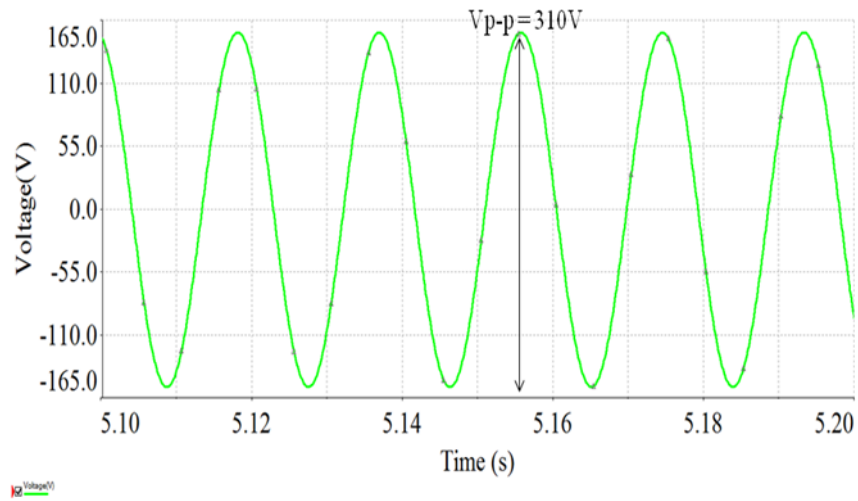As a result, it is proven that the AC current is $\cong$ 13A AC.

Figure 24 : Transient response for output voltage

Figure 24 shows the transient response for output voltage. The voltage swings from +155 Vp to -155 Vp. By using Eq. (1),

Vp-p = 310V

Vp = 155V

Vrms = 109.6V

As a result, it is proven that the AC voltage is $\cong$ 110V AC.

CHAPTER 5
CONCLUSION

During the literature review and research on this project, all of the objectives have been achieved. They are:

I. to understand the theory and concept of a two input inverter for PV/Wind power system

      a) Managed to understand the concept of the two input inverter

II. to simulate the design of an inverter for PV/Wind power system

      b) Managed to design and simulate the inverter circuit

III. to design a controller for the two input inverter

      c) Managed to design and simulate the controller circuit

IV. to get a stable output of 50-60 Hz sine wave at the end of the simulation phase

The objective of creating an inverter which will output signal with 50 Hz frequency has been achieved. Moreover, the signal is rated at 110V AC voltage and 13A AC current, which is suitable to be used as main supply of electricity. From here, it can be seen that the charge controller circuit and inverter circuit have been designed and tested in the simulation process. Based on the simulation results, it is shown that the proposed inverter circuit configuration has proven it's functionality to generate a stable AC 110V / 13A load, which is indeed suitable for grid network application at 50Hz. Experimental verification would be the subsequent step to justify the simulation studies.

CHAPTER 6
RECOMMENDATION

The future work for the inverter is to increase the efficiency. Therefore, MPPT (maximum power point tracker) controller can be used. Solar-voltaic arrays are among the most efficient, cost-effective, and scalable "green" alternatives to fossil fuels, and researchers are almost daily announcing new advances in photovoltaic technology. But successful application of photovoltaic still depends on strict attention to power-conversion efficiency. MPPT controller uses a more advanced algorithm and microprocessor that controls the operation of the controller. By using MPPT, maximum power can be extracted from the solar module or wind turbine, which makes the battery charging faster and better performance.

REFERENCES

[1] V. Yuvaraj, R.Rozario, & S.N. Deepa, "Implementation and control of multi input power converter for grid connected hybrid renewable energy generation system", *Student Pulse Academic Journal,* vol. 3, no. 6, pp. 2-4, June 2011.

[2] - "Solar powers is the future.com", Retrieved April 5, 2012 from http://www.solarpoweristhefuture.com/how-to-charge-a-battery-with-a-solar-panel.shtml

[3] B.S Kjaer, K.J Pederson, F. Blaabjerg, "A review single-phase grid connected inverters for photovoltaic modules", *IEEE Transactions on Industrial Applications,* Vol.41, No.5, pp. 1292, June 2011

[4] I. Daut, M. Irwanto, Y.M Irwan, N.Gomesh, Rosnazri & N.S Ahmad, "Potential of solar radiation and wind speed for photovoltaic and wind power hybrid generation in Perlis, Northern Malaysia"*, The 5th International Power Engineering and Optimization Conference*, pp. 148-152, 2011

[5] R.S Bientz, "Development of Hybrid Photovoltaic-Wind System for Academic Purposes*", ISES 2005 Solar World Congress, Orlando, FL. USA*, pp. 32, 2005.

[6] A. Itagaki, H. Okamura & M. Yamada, " Preparation of Meteorological Data Set Throughout Japan For Suitable Design of PV Systems", *3rd World Conference on Photovoltaic Energy Conversion*, pp. 2074 – 2077, 2003

[7] S.A. Ahmed, "Wind energy as a potential generation source at Ras Benas, Egypt", *Renewable and Sustainable Energy Reviews*, vol.14, pp. 2167-2173, 2010, Retrieved August 8, 2012 from http://www.sciencedirect.com/science/article/pii/S1364032110000614#

[8] Chaniago, K.; Selvaraj, J.; Rahim, N.A., "Implementation of Single-Phase Grid Connected Inverter Using TMS320F2812", *3rd IEEE Conference on Industrial Electronics and Application, Singapore*, pp. 1498-1502, 3-5 June 2008.

[9] R.S Bientz, "Development of Hybrid Photovoltaic-Wind System for Academic Purposes*", ISES 2005 Solar World Congress, Orlando, FL. USA*, pp 32, 2005.

[10] Nur Juwaina Ayuni BT.Mohd. "Photovoltaic charge controller*", EngD* thesis, Universiti Malaysia Pahang, May 2009.

[11] – "Batteries for Mobile Robots", Retrieved August 8, 2012 from http://robocup.mi.fu-berlin.de/buch/chap6/ComparisonBattery.html

[12] N. N. Bhargava and D. C. Kulshreshtha. "Basic Electronics & Linear Circuits" *Tata McGraw-Hill Education*, p. 86. ISBN 978-0-07-451965-3, Retrieved August 8, 2012 from http://www.certified-easy.com/aa.php?isbn=ISBN:0074519654&name=Basic_Electronics_and_Linear_Circuits

[13] M. Davis, "How I home built an electricity producing Wind turbine", Retrieved March 20, 2012 from http://www.mdpub.com/Wind_Turbine/

[14] R. Manchini, R. Palmer, "Sine Wave Oscillator", *Texas Instruments, Dallas, Texas*, SLOA060, March 2001.

[15] -, "Voltage Follower − Non-Inverting amplifier with unity gain", Retrieved August 7 from http://terpconnect.umd.edu/~toh/ElectroSim/VoltageFollower.html

[16] B. Pandey, S. Srivastave, S.N Tiwari, J. Singh & S.N Shukla, "Qualitative analysis of small signal modified Sziklai pair amplifier", *Indian journal of pure an applied physics*, vol.50, pp 272-276, April 2012.

[17] A.H David, Fellow, " Darlington's contribution to transistor circuit design", *IEEE Transactions On Circuits and Systems-I: Fundamental Theory and Application,* vol.46, no. 1, pp. 102-104, January 1999