UNIVERSITI
TEKNOLOGI
PETRONAS

INTERIM REPORT

FINAL YEAR PROJECT 2013

“DESIGN AND SIMULATION OF HIGH CURRENT POWER SUPPLY FOR OFFSHORE INSTRUMENTATION”

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ABSTRACT

The seabed logging (SBL) method which employs marine Control Source Electromagnetic (CSEM) sounding is an effective method in detecting hydrocarbon beneath the seabed layer. The marine CSEM sounding uses horizontal electric dipole (HED) to transmit signal to the receivers which are lying on the sea floor. This project involves the design of power supply to drive the HED which acts as a transmitter. The specific requirements have been met having DC output current with the peak of 1250 A and -1250 A with frequency of 0.125 Hz. The DC pulsating voltage has been found to be less than 20 V and -20 V. The design procedures are explained in details.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Seabed Logging (SBL) is one of the methods intended for oil and gas exploration. This SBL method uses marine Control Source Electromagnetic (CSEM) sounding to detect the presence of hydrocarbon beneath the seabed. Marine CSEM is usually related with another method intended for the same purpose but with different approach that is magnetotelluric (MT). Generally, marine CSEM is more applicable in deeper waters by using the horizontal electric dipole (HED) transmitters and receivers whilst marine MT is designed for shallow water [1].

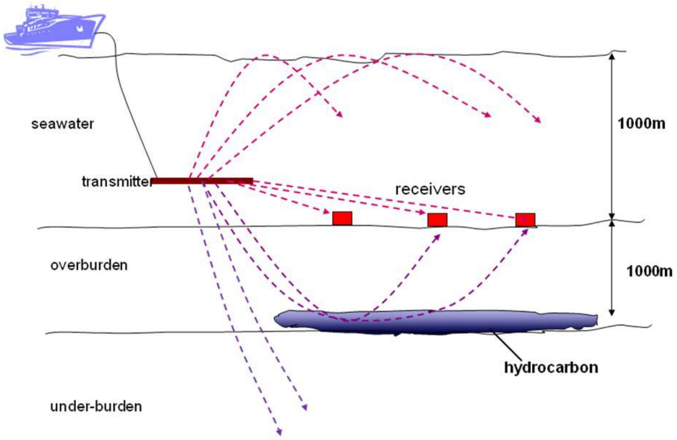


Figure 1: Marine CSEM method [2]

According to [2] and [3], CSEM uses HED as the antenna that transmits low frequency of 0.125 to 10 Hz for hydrocarbon reservoir detection. As can be seen in Figure 1, the HED is towed above the receivers located on the seabed while transmitting the signal to receivers.

In order to drive the HED transmitter in marine CSEM method, power supply having specific specifications is required. This project is about designing power supply to drive the transmitter at the load fulfilling specific requirements of impedance and frequency. The output must be a pulsating DC current peak of 1250 A and -1250 A and DC pulsating voltage of less than 20 V and -20 V.

1.2 Problem Statement

The design of power supply specifically for deepwater oil and gas exploration is currently in demand, but not yet available. The main concern is to design the accurate power supply to generate sufficient current and voltage at the load. In marine CSEM method, in order for the EM wave to reach 2500 m-3000 m beneath the seabed, the wave uses low frequency in the range of 0.125 Hz-10 Hz [2]. On the other hand, high current is needed to penetrate deep down to the ocean floor, whereas low frequencies are needed to provide sufficient signal penetration deep to the targets [4]. Thus, a new power supply that fulfills the requirements in producing high current is designed and simulated.

1.2 Scope of Study and Objectives

The main objective of this project is to design high current power supply. Nevertheless, in completing the main objective, detailed studies on some issues with regards to the main objective are essential for better analysis and understanding.

Particularly, this project will focus on:

- i) Understanding SBL, Control Source Electromagnetic CSEM and high current application of power supply module design.
- ii) Designing specific high current low voltage load power supply module.
- iii) Designing control circuit for high current and low voltage application to regulate the output.
- iv) Performing simulation procedures with the designed circuit.
- v) Analyzing the output load based on the required specifications.

1.4 Significance of the project

SBL is an emerging method for deepwater hydrocarbon detection and can be considered as the most updated approach in oil and gas exploration for deep water environment. Applying to the bright future of SBL method, it is very significant to carry out the project. On the other hand, this project follows the new design requirements for power supply from PETRONAS, as the leading Oil and Gas Company in Malaysia. Thus, this project will look into suitable approach in analyzing the best power supply module as the backbone for the real application design.

1.5 Feasibility of the project

This project is carried out using only simulations, without employing prototype fabrication. Thus, the time frame of two semesters for FYP 1 and FYP 2 is very feasible to complete the project. The final output will be the simulation of the designed power supply with detailed analysis. During FYP 1, the focus is to work on literature review and understand the details for power supply module design whilst FYP 2 will mostly involve simulation and analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Power supply

In real world application, every electronics device is powered by DC power source from battery or DC power supply. Most of the equipments require voltage source that is well filtered and regulated.

The sources of power consumption are categorized as [5]:

i. dynamic power (active power or switching power)
ii. static power (leakage power)

According to [6], there are some requirements in power supply design:

i. To perform source and load isolation
ii. High power density in order to reduce the size and weight
iii. To control the direction of power flow
iv. To ensure high conversion efficiency
v. Low total harmonic distortion input and output waveforms for small filters
vi. Controlled power factor (applicable for AC voltage source)

Depending on the types of applications and the properties, every circuit or device will have specific output and input requirements. The output requirements are the utmost important to be focused in this project to ensure that the designed power supply is effective. According to [7], the outputs can be divided into:

i. Regulated output: Constant output voltage within a specified range in the input voltage and the output loading.
ii. Isolation: The output and input might be required to be electrically isolated.
iii. Multiple outputs: Positive and negative outputs that might have different voltage and current ratings. These outputs might need to be isolated from each other.

2.2 Types of power supplies

In general, there are several types of power supplies that are widely used in industry [8]:

i) A simple unregulated power supply consisting of transformer, rectifiers and reservoir capacitors.
ii) A linear regulated power supply
iii) A switch mode power supply

2.2.1 Linear Regulated Power Supplies

DC power supply is an integral part of the various types of electronic equipment. DC equipment is usually divided into a DC power supply and the DC switching power supply. DC linear power supply is the earliest and most widely used kind of power.

Linear power with lower production costs can achieve high stability and very small ripple, and there is no interference and noise of the switching power supply, but its efficiency is relatively low. Nowadays, the linear power supply is still widely used in scientific research, the field of electrical, electronic circuit, electroplating, broadcast television transmission, communications, college universities, laboratories and other essential equipment by the electronic circuit.

2.2.2 Switched Mode Power Supplies

A switched mode power supply (SMPS) is an electronic power supplies that uses equipment called switching regulator in order to effectively convert electrical power. The techniques of power supply design had evolved from linear power supplies to SMPS which is considered to be more practical. This is due to the fact that the size of power transformers and other components are significantly reduced in SMPS which cannot be achieved by linear power supplies. Considering this factor, SMPS design can produce very compact and lightweight power supplies that is very practical to be used.

SMPS is divided into several types of topologies which vary in terms of the characteristics, advantages and disadvantages in order to fit the specific power supply applications. Among of them are:

i) <u>Non isolated topologies</u>

Non isolated topologies SMPS do not contain transformer in which there is no isolation between the input and output. The most common non-isolated topologies are buck converter, boost converter and buck-boost converter. These three converters have the simplest configuration which contains only inductor, capacitor, transistor and diode.

ii) <u>Isolated topologies</u>

In isolated topologies, the input is isolated from the input. The presence of high frequency transformer provides isolation or barrier, which can tolerate from a few hundred volts up to several thousands. The most common isolated topologies are flyback and forward converter.

2.3 Existing designs of high current power supplies and converters

2.3.1 Self-Commutated AC to DC Converter

In this converter, the switching units have bidirectional switching characteristics with self commutating performance. These two features are available in order to achieve the output of DC current in negative and positive directions. Referring to Figure 2, function of the snubber capacitor is to control the snubber circuit loss. This condition is achieved by discharging the energy from the snubber capacitor to the load efficiently. On the other hand, the snubber capacitor utilizes the duration of the off-state of switching unit to recharge through the power MOSFET. This DC power supply produces output ratings of 10 V, 20 MA and 20 seconds operation time [9].

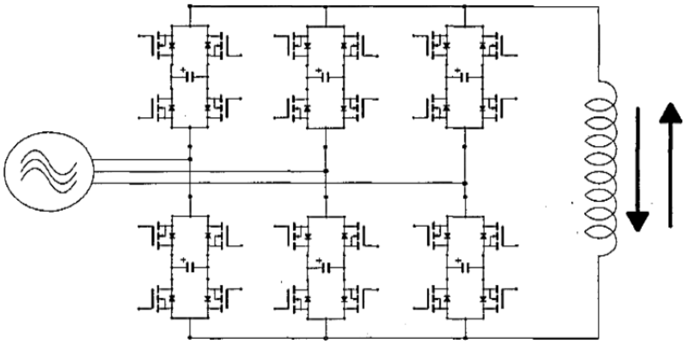


Figure 2 : Self-commutated AC/DC Converter [9]

2.3.2 High Current Low Voltages Converter

Referring to Figure 3, the main objective of the circuit design is to have output voltage and current which varied from 0 V to 15 V and 0 A to 1000 A respectively. When the output requirements are achieved, superconducting corrector magnets in particle accelerators will be excited. In this circuit, a full bridge IGBT topology is combined together with Zero Voltage Transition (ZVT) converter. ZVT converter basically acts as power supply and the covert manage to produce high efficiency output with small ripple [10].

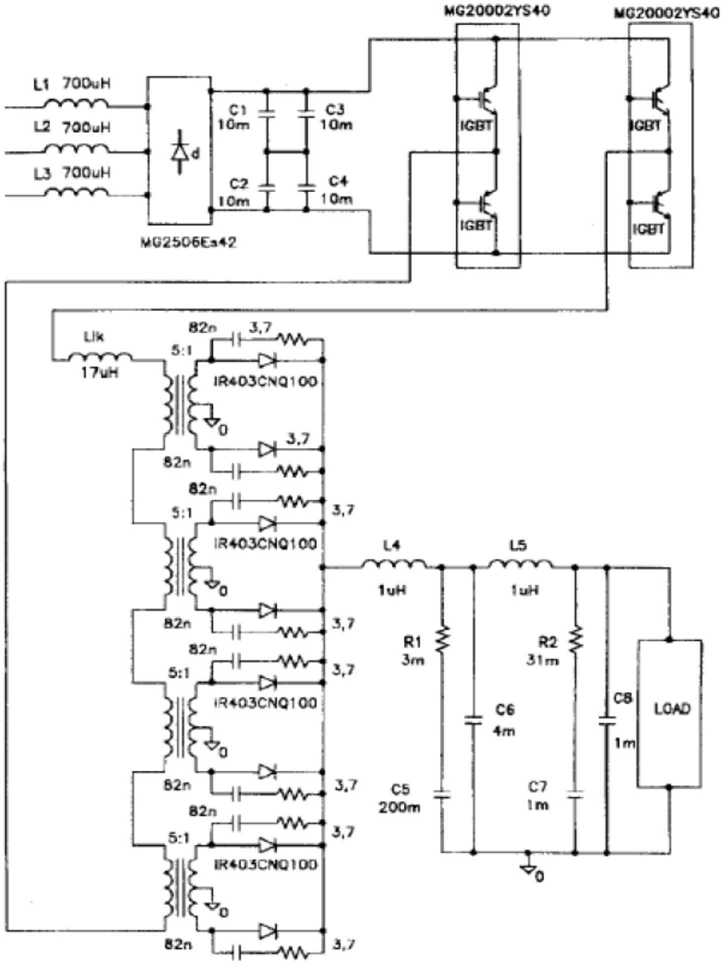


Figure 3 : High Current Power Supply Converter [10]

2.3.3 Compact High Voltage Low Frequency Power Supply

Referring to Figure 4, the circuit for compact high voltage low frequency power supply has several output requirements which are listed below [11]:

i) Variable output frequency from 0.1 to 2 Hz.

ii) Variable output power from 0 to 3 kW, with two output voltage levels; 750 V, 4 A, or 3000 V, 1 A.

iii) Standard input voltage of 220 V and 50/60 Hz.

iv) Galvanic isolation between input and output.

v) Low cost and weight for portability.

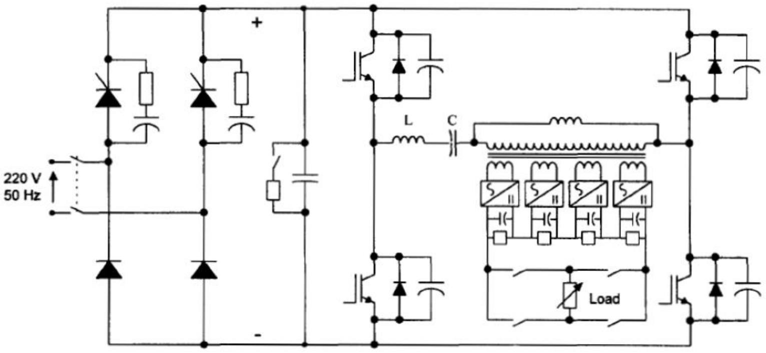


Figure 4 : High Current Low Voltage Power Supply [11]

2.4 Sine Wave to Square Wave Converter

The transmitter in marine CSEM method usually transmits square wave as this wave form can be generated easily having the ability to transfer maximum energy to the subsurface of seawater. This condition is achieved due to the transmitter current running at its peak amplitude at all times except for possible switching intervals [12]. In general, sine wave to square wave converter circuit can be easily built by using amplifier, transistor, logic gate or comparator.

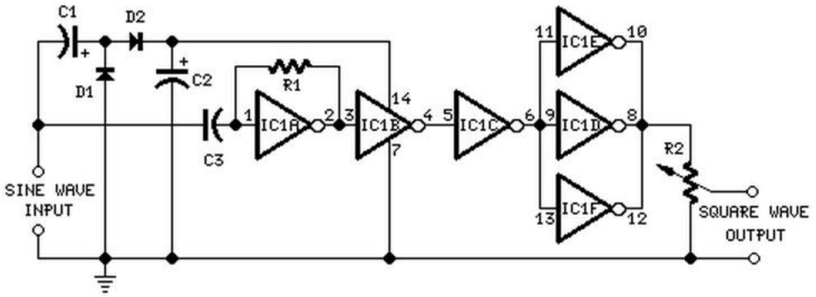


Figure 5: Self powered sine to square wave converter [13]

Table I: Components specifications for self powered sine to square wave converter [13]

R1	1 MΩ ¼ W Resistor
R2	100 kΩ Linear Potentiometer
C1, C2	100 µF 25 V Electrolytic Capacitors
C3	10 nF 63 V Polyester Capacitor
D1, D2	1N4148 75 V 150 mA Diodes
IC1	4069 Hex Inverter IC

The circuit that is shown in Figure 5 is capable to convert sine wave from existing generator to square wave without power source. Thus, the circuit can be directly connected to a sine wave generator to test the functionality. Referring to Figure 5, the input sine wave is fed into C1, C2, D1 and D2 which supply power to the IC. IC1A amplifies input sine wave and IC1 inverter squares the signal output [13]. The information that is shown in Table I is the list of components specifications used to build the circuit of self powered sine to square wave converter as shown in Figure 5.

2.5 Transformer

A transformer uses the concept of magnetic field to change AC electrical power to higher or lower voltage level. Two or more sets of wire coils are wrapped around a single magnetic core, without direct contact between each set of coil. One of the windings which are the primary winding is connected to power source while the other winding which is secondary winding is connected to the loads [14]. Figure 6 shows the transformer winding example:

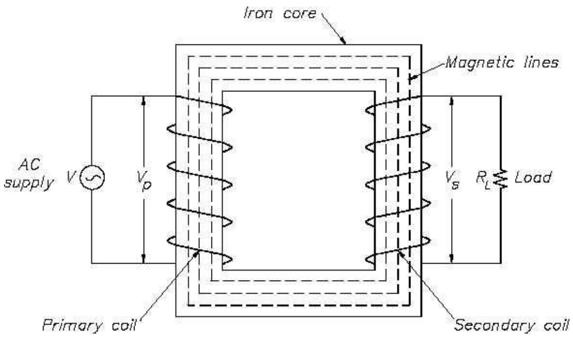


Figure 6: Transformer winding [15]

The transformer is used to reduce the output voltage and also to obtain high output current. This is possible by referring to Eq. (1):

$$P_{out} = V_P I_P \cos\theta = P_{in} \qquad (1)$$

From Eq. (1), V_P is the primary voltage; I_P is the primary current and θ is angle between voltage and current. The Eq. concludes that the output power (P_{out}) of an ideal transformer is equal to its input power (P_{in}). This condition can be achieved when all the input power is transferred from primary coil to secondary coil through the magnetic coil.

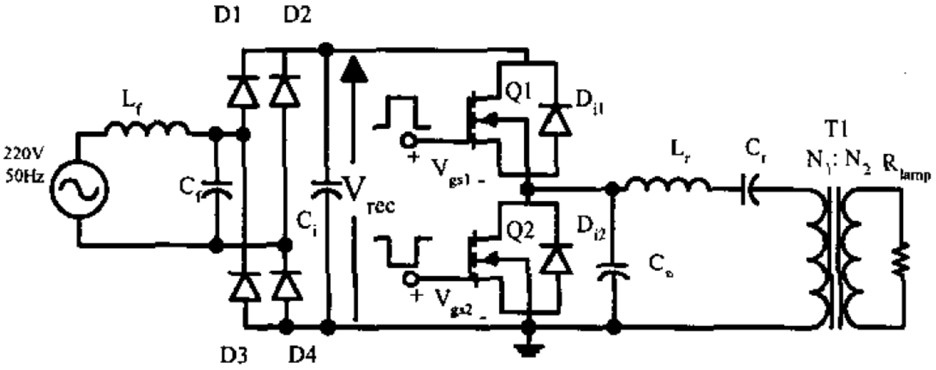


Figure 7: Electronic Transformer circuit [16]

Figure 7 is the ET circuit that will be used in this project. According to [16], the functionality of the proposed ET circuit is divided into 3 different parts:

i. EMI filter – inductance (L_f) and capacitor (C_f)
ii. Conventional bridge rectifier – diode (D1, D2, D3, D4)
iii. Class-D zero-voltage-switching (ZVS) inverter – transformer (T1), halogen lamp (R_{lamp})

For this project, electronics transformer (ET) is the most appropriate transformer to be used in the circuit construction as the device is available in the simulation software. This ET deploys the same function as the normal transformer, which is to change the voltage level.

2.6 Low Pass Filter

As stated in Section 1.2, the HED transmitter in marine CSEM method emits low frequency signal. Thus, a low pass filter is required to filter the signal, allowing only low frequencies to pass through the filter. The low pass filter helps by filtering the frequencies which are more than the cutoff frequency denoted as f_c. The formula to calculate f_c is given in Eq. (2):

$$f_c = \frac{1}{2\pi\tau} = \frac{1}{2\pi RC} \qquad (2)$$

Referring to Eq. (2), the value of f_c depends on the value of resistor (R) and capacitor (C). The most basic low pass filter consists of resistor, capacitor and inductor which are connected in series or parallel.

From [17], in low pass filter design for high current, the damping resistor of high current LC filters is not in the DC path, but in series with the filter capacitor due to high heat losses. The proposed low pass filter is designated for 150 V, 1500 A magnet power supplies as can be seen in

Figure 8. Referring to the circuit in

Figure 8, an inductor is included as additional resistance for high current design.

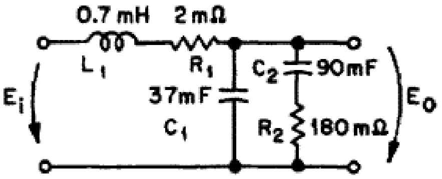


Figure 8: Low pass filter for high current [17]

2.7 Controller for high current low voltage circuit

Controller circuit is very important to ensure that the output current will be well regulated at the desired value. Generally, controller circuit will involved operational amplifier which is known as current feedback operational amplifier (CFOA). CFOA is a type of electronic amplifier in which the inverting input is sensitive to current.

The Class AB high current output stage has been designed into a current feedback operational amplifier. A simplified circuit schematic of the operational amplifier is shown in Figure 9. Referring to Figure 9, the output stage is designed to be intrinsically stable without any additional compensation. The input stage is a complementary diode input emitter follower. The input emitter follower collector currents drive complementary current mirrors which provide current gain of approximately one. Emitter degeneration resistors are employed to improve the gain mirror accuracy and matching. The mirror outputs are connected directly to the input of the output stage. Compensation capacitors CC1 and CC2 establish a single dominant pole for the overall amplifier and are set to values which maximize bandwidth when the op-amp is configured for a voltage gain of 2 with a feedback resistor value of 1 kΩ [18].

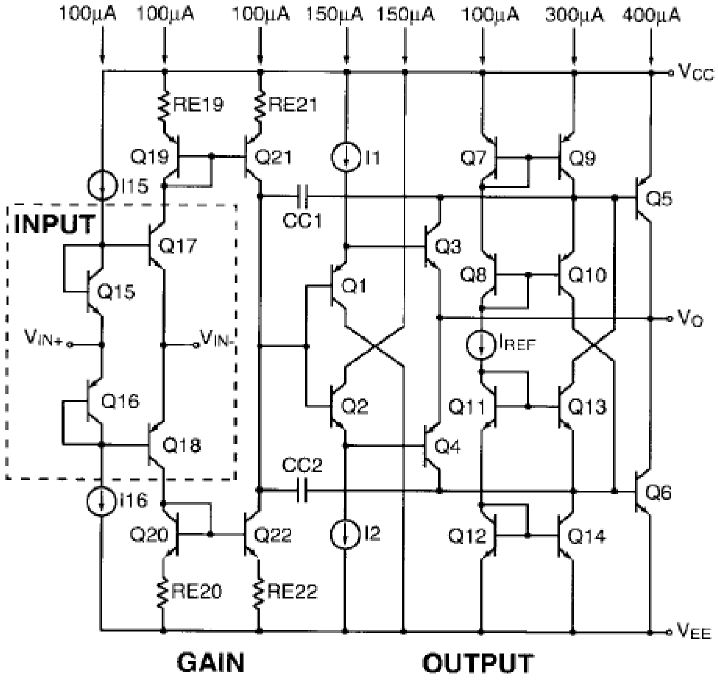


Figure 9 : Current feedback operational amplifier simplified schematics [18]

The following Table II shows the summary of literature review that is completed until the time of writing. The literature review manly covers about the power supply basics and the existing designs of power supplies.

Table II: Summary of literature review

No	Authors	Ref. No	Title	Contents	Issues
1	N. U. T. M. R. W. P. Mohan (2003)	[7]	Power electronics : converters, applications, and design.	The types of power supply outputs	• Regulated output • Isolation • Multiple output
2	D. Self (2009)	[8]	Power supplies and PSRR," in Audio Power Amplifier Design Handbook	Types of power supplies that are widely being used in industry	• A simple unregulated power supply consisting of transformer, rectifiers and reservoir capacitors. • A linear regulated power supply • A switch mode power supply
3	G. Jian, Z. Jie, and Z. Li (2012)	[9]	Design of a DC Linear Power Supply with Adjustable Voltage	The Linear regulator power supply	Shows the working principle diagram of a conventional linear power supply
4	T. Matsukawa, K. Shimada, M. Shioyama, S. Nomura, C. Neumeyer, S. Tsuji-Iio, et al (1999)	[10]	Low voltage, high current DC power supply with self commutated converter using power-MOSFET	Self Commutated AC to DC converter	The switching units have bidirectional switching characteristics with self commutating performance element in order to make the DC current of the converter output in both positive and negative direction.
5	E. J. Dede, G. Garcera, V. Esteve, J. M. Benavent, J. A. Carrasco, and A. Ferreres (1996)	[11]	On the design of a high current power supply for superconducting magnet	High current low voltages converter	• Have an output voltage varies between 0 and 15 V and currents between 0 and 1000 A • To achieve the output required with high efficiency, a full bridge IGBT topology featuring ZVT converter with isolation in high frequency is used

6	A. Jaafari and G. Joos (1995)	[12]	A compact high voltage low frequency power supply	Compact high voltage low frequency power supply	The compact high voltage low frequency power supply circuit is designed to meet the output specifications.
7	RED Free Circuit Design (2013)	[14]	Self-powered sine to square wave converter	Square wave input voltage	• Sine wave to square wave converter circuit can be easily built by using amplifier, transistor, logic gate or comparator. • Capable to convert sine wave from existing generator to square wave without power source
8	K. Jirasereeamornkul, I. Boonyaroonate, and K. Chamnongthai (2003)	[17]	High-efficiency electronic transformer for low-voltage halogen lamp	Electronic transformer (ET) circuit	• EMI filter – inductance (L_f) and capacitor (C_f) • Conventional bridge rectifier – diode (D1, D2, D3, D4) • Class-D zero-voltage-switching (ZVS) inverter – transformer (T1), halogen lamp (R_{lamp})
9	W. F. Praeg (1970)	[18]	A High-Current Low-Pass Filter for Magnet Power Supplies	Low pass filter for high current	• Proposed low pass filter is designated for 150 V, 1500 A magnet power supplies • Damping resistor of high current LC filters is not in the DC path, but in series with the filter capacitor due to high heat losses • Inductor is included as additional resistance for high current design.
10	Bales, J (1996)	[19]	A low-power, high-speed, current-feedback op-amp with a novel class AB high current output stage,	Current feedback operational amplifier controller	• Involved operational amplifier which is known as current feedback operational amplifier or denoted as CFOA. • The output stage is designed to be intrinsically stable without any additional compensation

CHAPTER 3

METHODOLOGY

3.1 Research Methodology and Procedures

Referring to Figure 10, this project will cover the following activities towards the completion of FYP 1 and FYP 2:

1. Research and literature review

   This is the most crucial part to get familiar with the terms and processes involved in SBL method, focusing on CSEM technique. The literature review is done by referring to the journals, technical papers, thesis and other sources of references to get information on the previous researches that had been done.

2. Proposal writing

   The objectives and problem statement are stated clearly on the proposal. The scope of study must be relevant and feasible with the available duration and must be deliverable.

3. Experimental design

   Gathering data and information for this project is done from studies and calculations to come up with the most effective design. Circuit and electronic networks are designed in this stage for simulation.

4. Simulation testing

   Simulations are done by using MATLAB, PSpice and Multisim. The results are analyzed.

5. <u>Design improvement and modification</u>

   Improvement on the design should be done if the preliminary result does not meet the requirements. The process is repeated until satisfactory result is obtained.

6. <u>Result analysis</u>

   The final result is analyzed to understand the behavior of the design. In the end, the result should be pulsating DC current peak of 1250 A and -1250 A with 0.125 Hz frequency. DC pulsating voltage must be very small which are less than 20 V and -20 V.

3.2 Flowchart

Figure 10 shows the project flowchart for the whole duration of FYP 1 and FYP 2. The project procedures will be developed based on this flowchart.

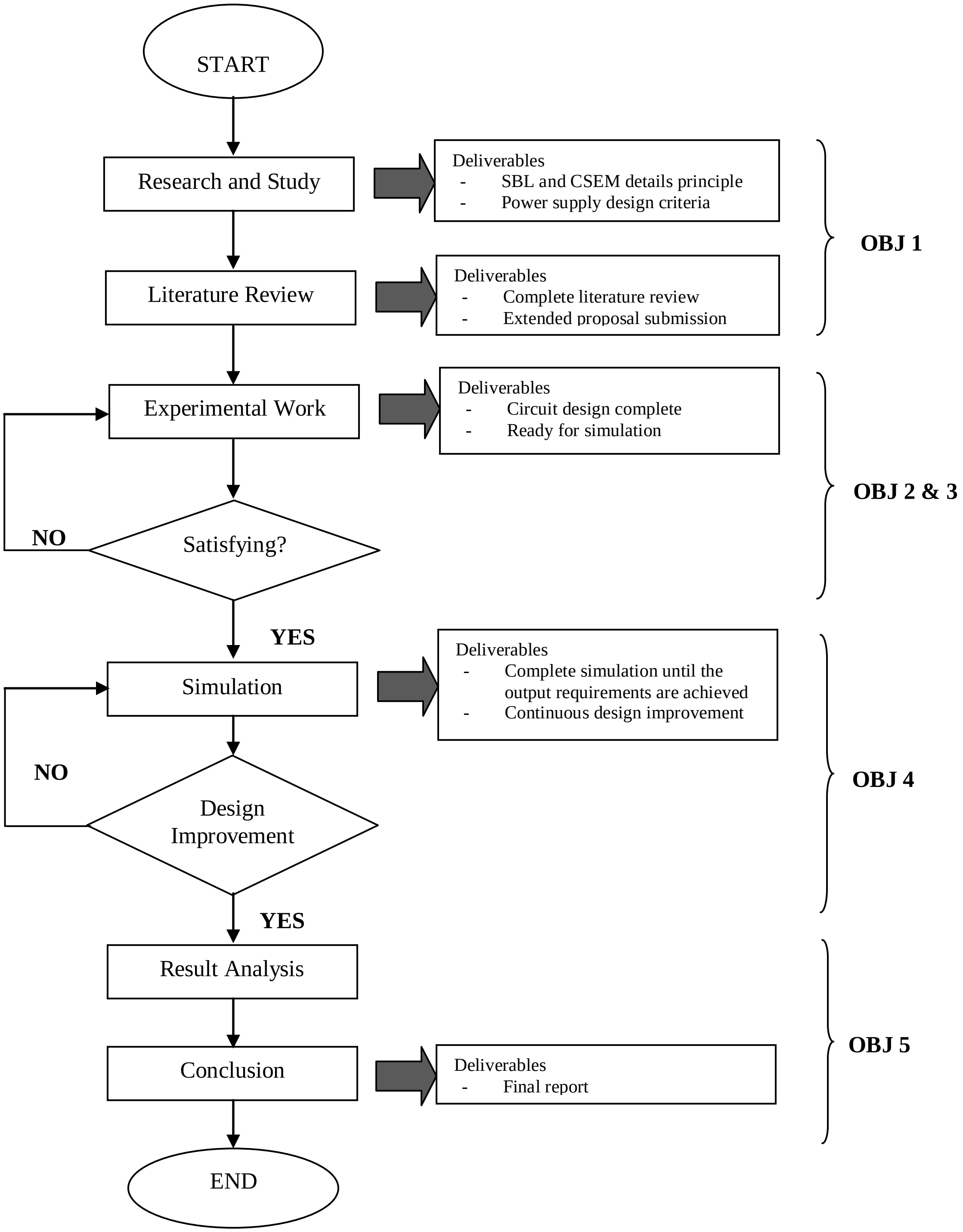


Figure 10: Project Flowchart for FYP 1 and FYP

*Gantt Chart is provided as Appendix A

3.3 Key Milestone

Figure 11 shows the key milestone that will be completed during FYP 1.

Title selection process the beginning of the semester. The supervisor and the title are assigned for each student by 31 May 2013.

RESEARCH AND STUDY

Research and study are done to understand about SBL and power supply design for high current and low voltage application. The study will cover:

a) Background about SBL and CSEM
b) Basics and techniques of power supply design

LITERATURE REVIEW

Literature review is done by referring from books, journals and research paper. The details that have been reviewed are:

a) Power supply
b) Sine wave to square wave converter
c) Transformer
d) Low pass filter
e) High current low voltage controller

EXTENDED PROPOSAL

Submission of extended proposal draft to supervisor is done. After the draft had been reviewed, corrections will be made before final submission. For softcopy extended proposal submission, it is done through Turnitin.

PROPOSAL DEFENSE

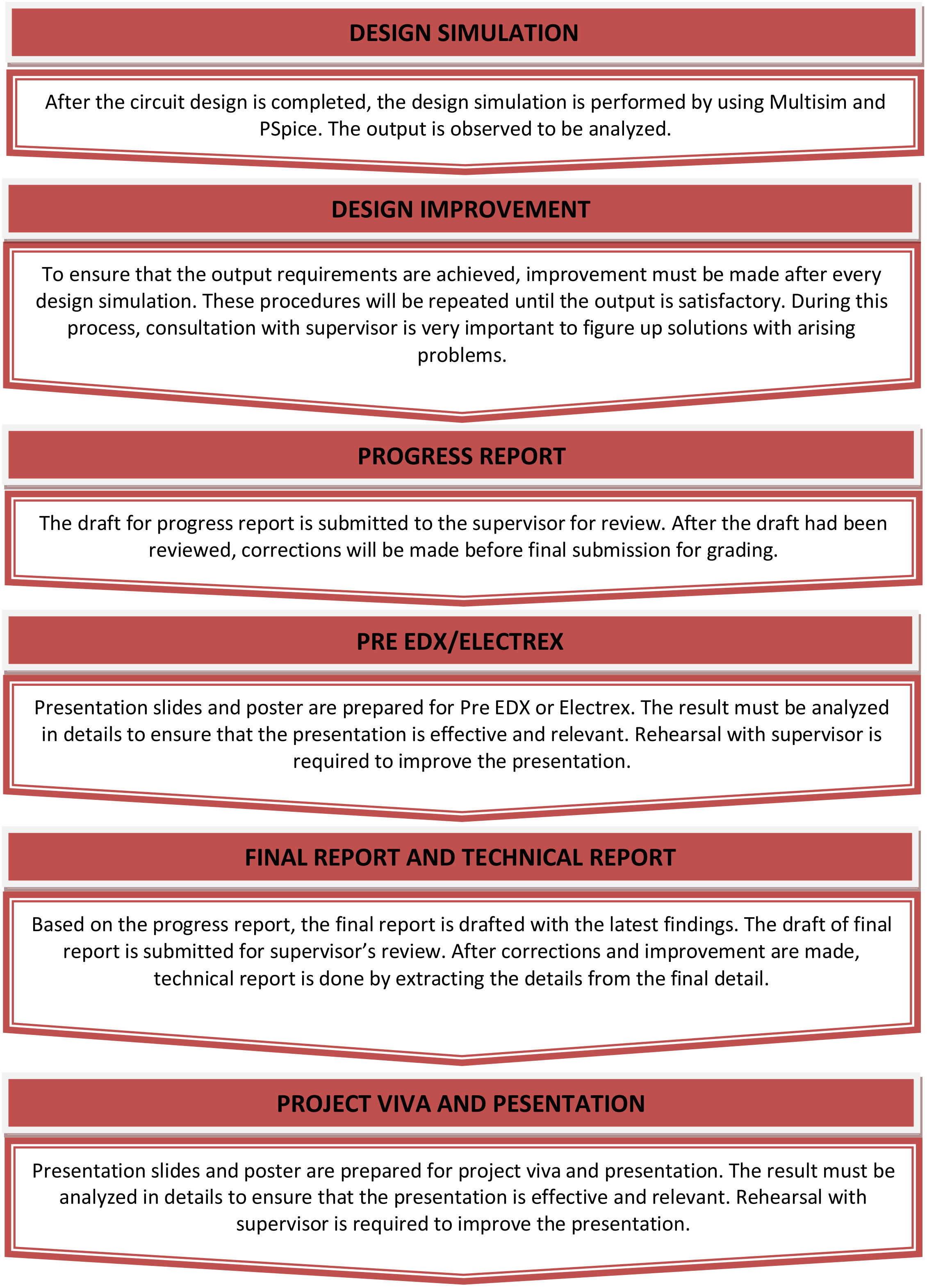
Slide presentation is prepared for Proposal Defense. The objective and relevancy of the project must be clearly stated and understood. Proper discussion with supervisor beforehand is very important to ensure the success of the presentation.

INTERIM REPORT

Based on the extended proposal, the interim report is drafted with the latest findings. The draft of interim report is submitted for supervisor's review. After corrections and improvement are made, the Interim report is submitted to supervisor.

Figure 11: Key Milestone for FYP 1

Figure 12 shows the key milestones that will be completed during FYP 2.



DESIGN SIMULATION

After the circuit design is completed, the design simulation is performed by using Multisim and PSpice. The output is observed to be analyzed.

DESIGN IMPROVEMENT

To ensure that the output requirements are achieved, improvement must be made after every design simulation. These procedures will be repeated until the output is satisfactory. During this process, consultation with supervisor is very important to figure up solutions with arising problems.

PROGRESS REPORT

The draft for progress report is submitted to the supervisor for review. After the draft had been reviewed, corrections will be made before final submission for grading.

PRE EDX/ELECTREX

Presentation slides and poster are prepared for Pre EDX or Electrex. The result must be analyzed in details to ensure that the presentation is effective and relevant. Rehearsal with supervisor is required to improve the presentation.

FINAL REPORT AND TECHNICAL REPORT

Based on the progress report, the final report is drafted with the latest findings. The draft of final report is submitted for supervisor's review. After corrections and improvement are made, technical report is done by extracting the details from the final detail.

PROJECT VIVA AND PESENTATION

Presentation slides and poster are prepared for project viva and presentation. The result must be analyzed in details to ensure that the presentation is effective and relevant. Rehearsal with supervisor is required to improve the presentation.

Figure 12: Key Milestone for FYP 2

3.4 Software required

To simulate the circuit design, the following software is required:

i. MATLAB R2009: for calculation of parameters
ii. PSpice OrCAD Capture 9.2 Lite Edition: for circuit design and simulation
iii. Multisim Analog Devices Edition 10.0.1: for circuit design and simulation

3.5 Proposed Topology

To complete this project, a set procedure is developed to obtain the required output. The procedures are illustrated in the Figure 13:

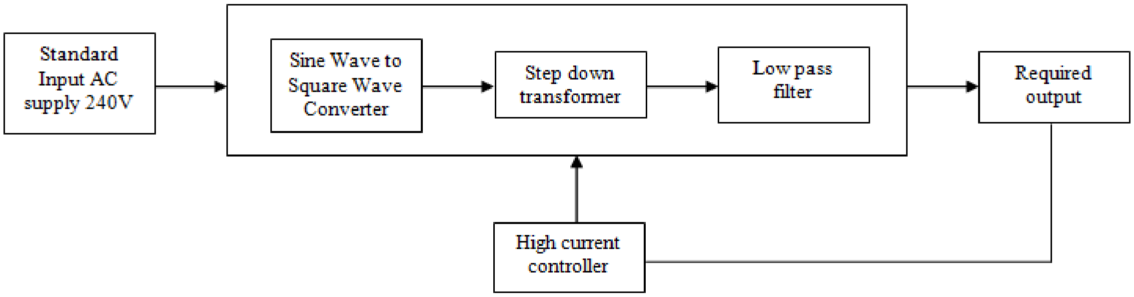


Figure 13: Project block diagram

From Figure 13, the power supply input voltage is fed with sine wave and current to square wave signal. As the input is 240 V AC, the voltage must be reduced using step down transformer. Low pass filter will filter the frequency to allow only low frequencies to pass through. The controller will regulate the output to ensure that the output meet the requirements.

3.6 Transformer configuration

Figure 14 shows the first circuit that is simulated which is intended to configure the rating for the step down transformer. The three phase power supplies are connected with ratings of 230 V at 0.125 Hz. Then, the circuit is stepped down using linear transformers TX1, TX2 and TX3 with 6:1 turn ratio to increase the current. The reason that the output frequency of 0.125 Hz is used for the ratings is due to the fact that there is no low pass filter circuit to filter the high frequency signal. Thus, in order to ensure that the period for the simulation result satisfies the requirements, the output frequency is used directly to the power supply rating. The design of low pass filter will be conducted in the next step of the circuit design.

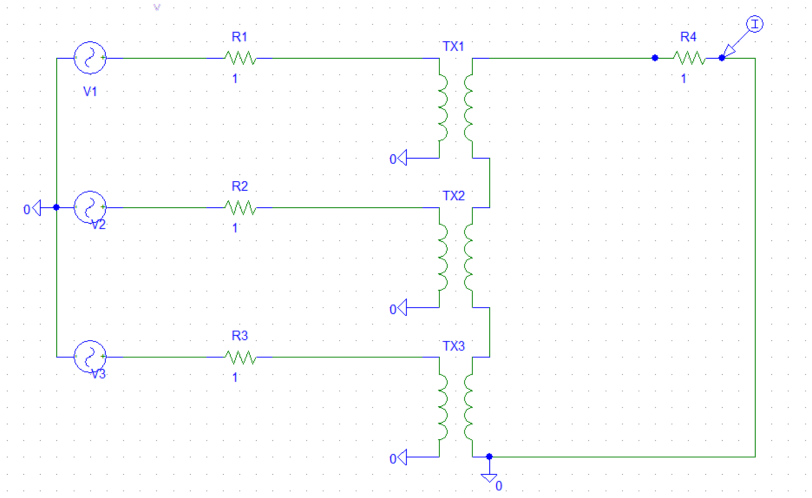


Figure 14: Transformer configuration circuit

Referring to Figure 14, linear transformer is chosen as it does not change the waveform of the input. RA, RB and RC resistors are placed at the supply to avoid short circuit current. The transformer turn ratio is determined by using Eq. (1), and adjusted with the maximum allowable turn ratio in the circuit simulation that will give maximum output current. The output current waveform of the transformer can be observed in Figure 16 of Chapter 4. Thus, the first step to increase the current by reducing the voltage is completed.

3.7 Preliminary design of power supply

Figure 15 shows the preliminary design for the high current low frequency power supply. In this design, the 3 phase power supplies are used with the same as previous ratings of 230 V at 0.125 Hz frequency. The sine wave to square wave converter is replaced with current limiter component in PSpice simulator. This current limiter component will limit the current with a very high gain to produce a near rectangular current waveform. The sine wave to square wave converter will be designed in the next step of the project procedures. The resistors are connected to each power supply to avoid short circuit current. The significance of the circuit designed in Figure 15 is to ensure that the general idea of the proposed topology is functioning. As can be seen from Figure 15, all parts of the proposed topology are included in the circuit except for low pass filter and sine wave to square wave converter. These two circuits are replaced with the simpler parts that are available in PSpice simulator.

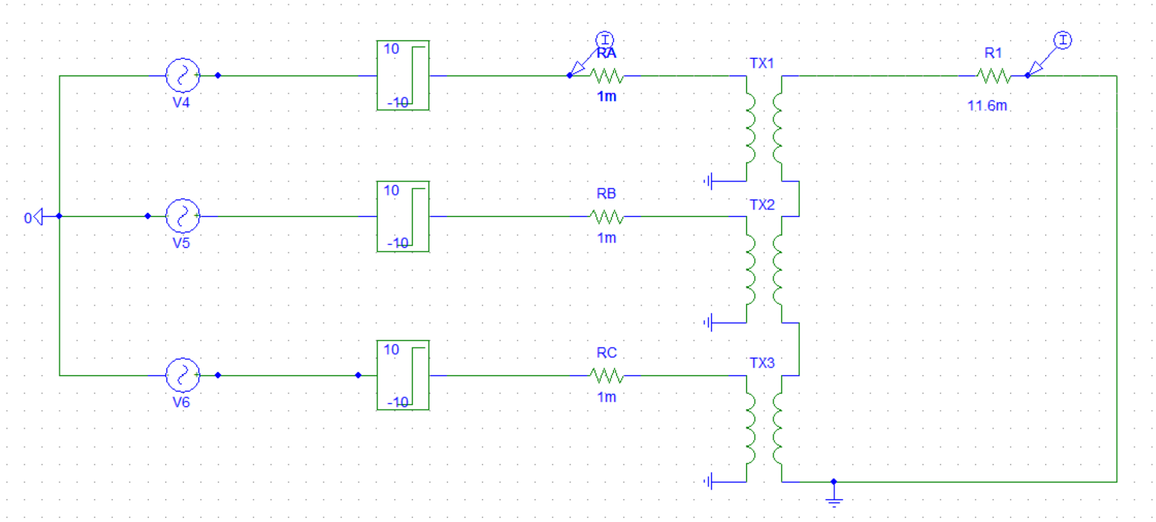


Figure 15 : Preliminary power supply design

The output current waveform of the circuit in Figure 15 can be observed in Figure 17 of Chapter 4. Thus, from the circuit simulation, it is concluded that the proposed topology is working perfectly and we are ready for the next step of the circuit design.

3.8 Further planning for FYP 2

Referring to the whole Methodology chapter, some preliminary designs and simulation are already completed. However, there are some designs that are yet to be done and these circuit designs will be completed in FYP 2. Eventually, additional information will be provided in details in FYP2 reports. Among the plans for FYP 2 are listed below:

i) Design of the sine wave to square wave converter for high current and low voltage application.

ii) Design of the low pass filter for high current and low voltage application.

iii) Testing of the feedback current controller circuit to be implemented in the complete circuit design.

Thus, it can be concluded that the project progress is right on track. Considering the time frame and workload left for FYP 2, it is assured that the whole project plan can be completed within the time frame.

CHAPTER 4

RESULT AND DISCUSSION

For FYP 1, the preliminary simulation is done to ensure that the project progress is right on track. Further recommendations and complete design of the circuit will be completed during FYP 2. Referring to the Gantt Chart in Appendix A, some of the milestones and objectives have been successfully achieved towards the completion of FYP 1.

4.1 Results for completed simulation

The output current waveform of the circuit in Figure 14 is shown in Figure 16.

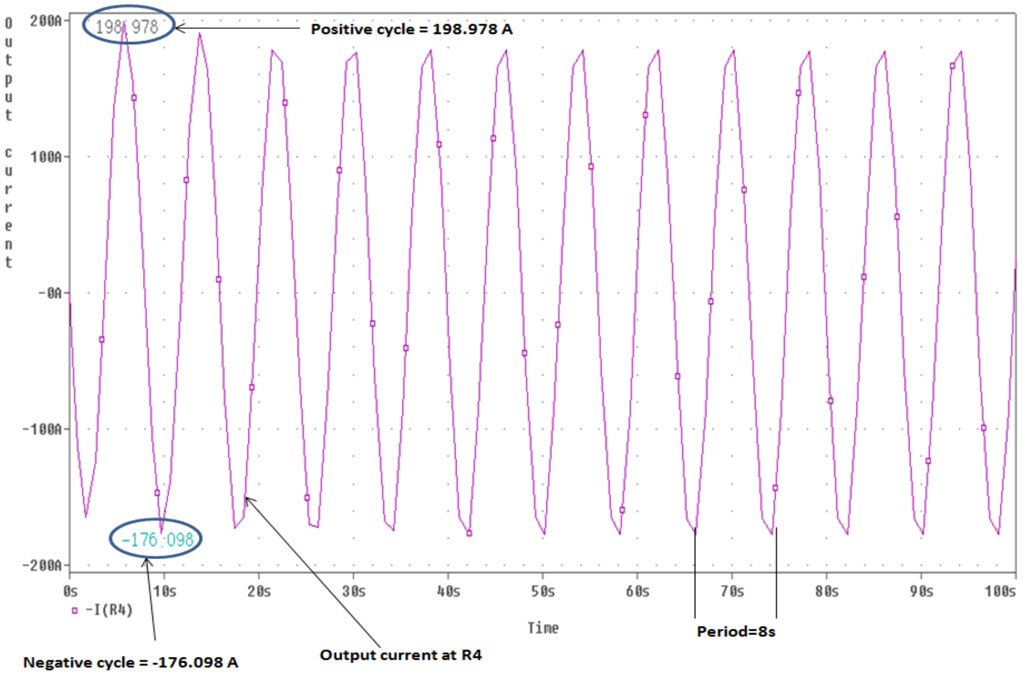
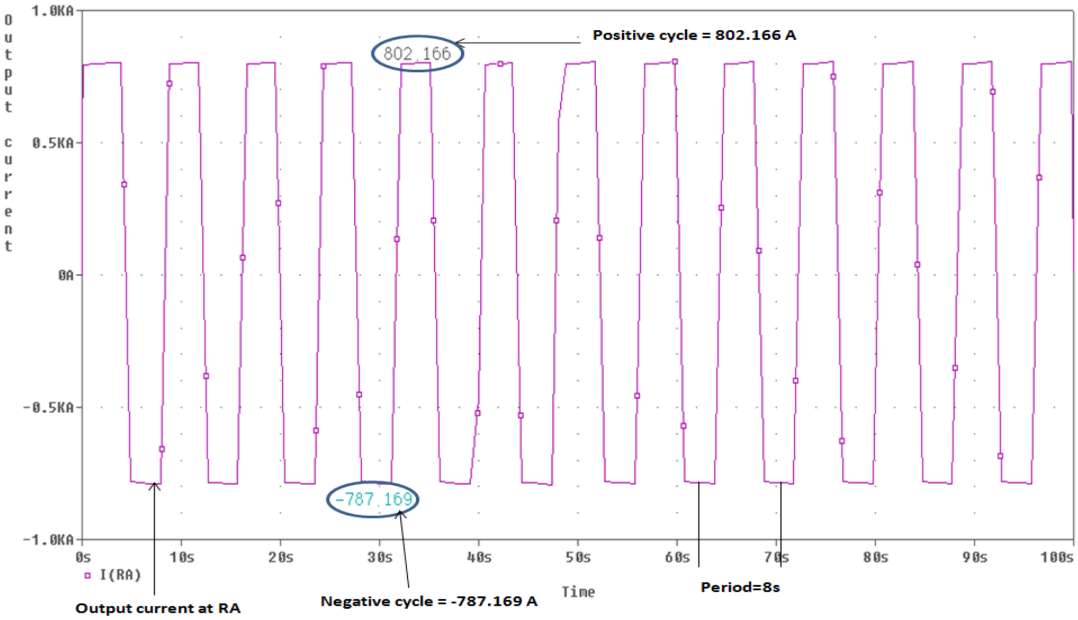


Figure 16 : Output current of the circuit in Figure 14

Referring to Figure 16, the output current is quite high which is 198.978 A at positive cycle and -176.098 A at negative cycle. The purpose of simulating this output is to ensure that the transformer can step up the current as high as possible. The current at R1, which is before going through the transformer, has very small value of ±80 A at the positive and negative cycle. Thus, as the current is being step up, the objective of simulating the circuit in Figure 14 is achieved.



Positive cycle = 802.166 A

Output current at RA

Negative cycle = -787.169 A

Period=8s

Figure 17 : Output current of the circuit in Figure 15 (RA)

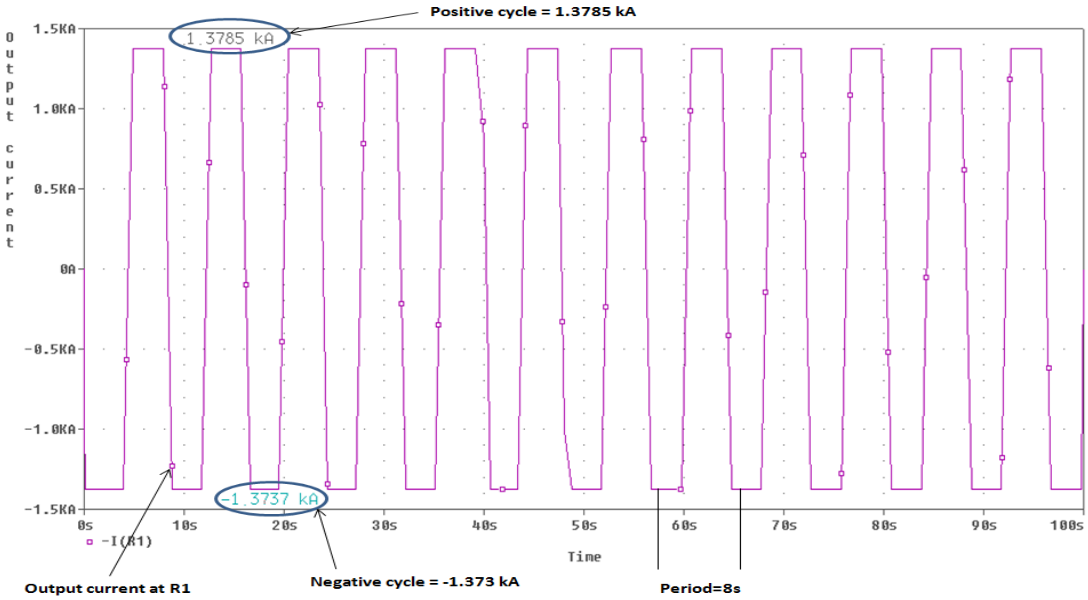


Figure 18 : Output current of the circuit in Figure 15 (R1)

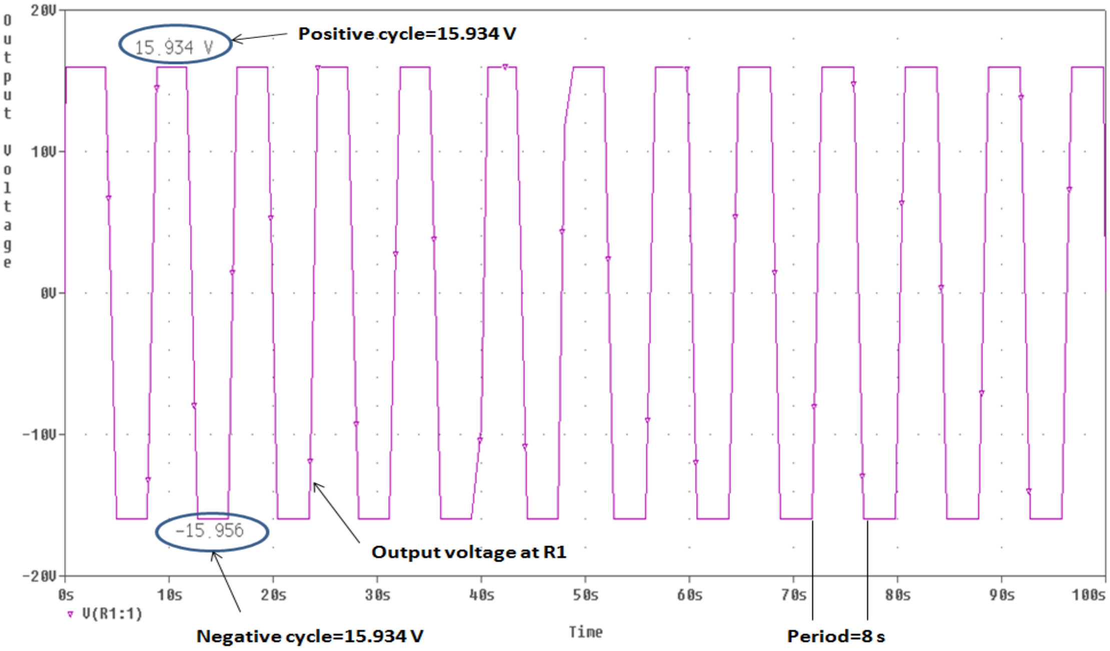


Figure 19 : Output voltage of the circuit in Figure 15 (R1)

Referring to Figure 17, the output current at the resistor RA is 802.166 A, which is considered as high current. After going through the step down transformer, the current is increased to 1.3785 kA as can be seen in Figure 18. The output is approaching the required output which is 1.25 kA. The output current has approximately achieved its targeted values which are 1.3785 kA and -1.3737 kA for R1 output, exceeding by 128 A at positive cycle and -124 A at negative cycle of the targeted values 1250 A and -1250 A alternating output current. The output waveform is also in almost perfect alternating square wave shape, with 8 s period for each cycle which equivalent to 0.125 Hz frequency.

Referring to Figure 19, the output voltage is 15.934 V and -15.956 V at both positive and negative cycle. As stated in Section 3.1, the pulsating voltage is required to be very small which is less than 20 V and -20 V for positive and negative cycle respectively. Thus, the target for the output voltage is achieved with stable pulse amplitude.

However, in this stage of the design, the frequency of the supply is directly changed to 0.125 Hz. In practice, a square wave converter is needed in the design. After that, the current limiter is used to limit the current to certain appropriate range, and also to have a perfect square waved signal by controlling the current limiter gain. Subsequently, step down transformers will be used to increase the output current until it reaches ±1250 A.

Although the preliminary simulation produces the output current that is not fulfilling the requirement, there will be more improvement after including the controller circuit and also after some detailed analysis. The controller circuit will be designed in the next stage of this project.

Table III: Result analysis summary

Preliminary Result	**Output Requirement**	**Difference**	**Tolerance**	**Alternative**
1.3785 kA and -1.3737 kA	1.250 kA and -1.250 kA	128 A	Maximum tolerance is 2 % of the target which is 25 A differences.	Include controller circuit to regulate output.
15.934 V and -15.956 V	Less than 20 V and -20V	The voltage output requirement is fulfilled.		

Referring to Table III, the maximum tolerance that is allowed for output current is only 2 % of the output requirement, which are 25 A differences. Thus, in order to compensate the current large differences, controller circuit will be included in the complete circuit design to regulate the output. Meanwhile, the requirement for output voltage is met and thus will be maintained in the future simulations.

CONCLUSION

The Seabed Logging (SBL) which applies marine Control Source Electromagnetic (CSEM) sounding is a very reliable technique in oil and gas exploration. The design of power supply for HED transmitter is very important in order to ensure that the transmitter is working perfectly in detecting hydrocarbon reservoir. In this project, the input power supply is converted into square wave before it is fed into step down transformer. Then, the signal is fed into low pass filter to allow only low frequencies to pass through. To regulate the output, the signal is fed into high current low voltage controller to ensure the output is in excellent state. After preliminary simulation, it is found that the output current to be 1.3785 kA and -1.3737 kA, exceeding by 128 A at positive cycle and -124 A at negative cycle of the targeted values 1250 A and -1250 A alternating output current. Meanwhile, the output voltage is found to be 15.934 V and -15.956 V at both positive and negative cycle which is fulfilling the requirement. Thus, the future plans that will be completed in FYP 2 are mainly in designing the circuits for sine wave to square wave converter, lowpass filter and feedback current controller in order to further improved the simulation result. For the time being, the key milestone and objective intended for FYP 1 are achieved.

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APPENDICES

APPENDIX A: FYP 1 Gantt Chart

ACTIVITIES		MAY		JUNE				JUL						AUG		
		20	27	3	10	17	24	1	🟥	8	15	22	29	5	12	19
1.0	**TITLE SELECTION AND CONFIRMATION**	🟩	🟩						🟥							
2.0	**BACKGROUND STUDY**			🟩	🟩	🟩	🟩	🟩	🟥							
2.1	Seabed Logging (SBL)			🟨					🟥							
2.2	Control Source Electromagnetic (CSEM)				🟨				🟥							
2.3	Basics of power supply design					🟨	🟨	🟨	🟥							
3.0	**LITERATURE REVIEW**			🟩	🟩	🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟩	🟩
3.1	Power Supply			🟨					🟥							
3.2	Sine wave to square wave converter				🟨				**B**							
3.3	Transformer					🟨			**R**							
3.4	Low Pass Filter						🟨		**E**							
3.5	Controller for high current low voltage circuit							🟨	**A**							
4.0	**EXTENDED PROPOSAL (10 %)**					🟩	🟩		**K**							
4.1	Extended proposal preparation					🟨	🟨		🟥							
4.2	Extended proposal submission						28-Jun		🟥							
5.0	**PROPOSAL DEFENSE (40 %)**							🟩	🟥	🟩						
5.1	Proposal defense preparation							🟨	🟥	🟨						
5.2	Viva: Proposal defense and progress evaluation								🟥	12-Jul						
6.0	**INTERIM REPORT (50 %)**								🟥			🟩	🟩	🟩	🟩	🟩
6.1	Interim report preparation								🟥			🟨	🟨	🟨	🟨	
6.2	Draft report submission								🟥						🟨	
6.3	Improvement on draft report and report submission								🟥						🟨	🟨

MILESTONE		MAY		JUNE				JUL						AUG		
		20	27	3	10	17	24	1	🟥	8	15	22	29	5	12	19
1	Understanding Seabed Logging (SBL), Control Source Electromagnetic (CSEM) and high current application of power supply module design							🟩	**B**							
2	Designing specific high current low voltage load power supply module								**R**			🟩				
3	Designing control circuit for high current and low voltage application to regulate the output								**E**				🟩			
4	Experiments, data collection and analysis								**A**						🟩	
5	Report writing								**K**							🟩