A DESIGN METHODOLOGY FOR A SELF-OSCILLATING ELECTRONIC BALLAST

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A Report Submitted In Partial Fulfilments of the Requirement of the Degree of Bachelor of Electrical Engineering (Power Systems)

Faculty of Electrical and Electronics Engineering

University Malaysia Pahang

June 2012

UNIVERSITI MALAYSIA PAHANG

BORANG PENGESAHAN STATUS TESIS♦

JUDUL: **A DESIGN METHODOLOGY FOR A SELF-OSCILLATING ELECTRONIC BALLAST**

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ACKNOWLEDGEMENT

First and foremost, I would like to thank God for His guidance and help, for it through His blessing that I am able to complete this project. Thank you for guiding me towards completing this project.

Next, I would like to take this opportunity to express my sincere thanks and acknowledge to my supervisor, Dr. Abu Zaharin B Ahmad, whose encouragement, guidance and support from the beginning until the end with his patience and knowledge enabled me to develop an understanding of the project. His invaluable guidance and advice in this project has been a source of inspiration through the course of this project.

Finally, I also like to express my sincere grateful to all lecturers and staffs of Electrical and Electronic Faculty and friends who helped me directly or indirectly contributed towards to accomplish of this project.

ABSTRACT

The lighting system provides many opportunities for cost-effective energy saving without any sacrifice. The system is now part of Energy Conservation program over the world and reduction of energy consumption by implementing energy conservation schemes is needed. Incandescent lamps convert just five per cent of energy into light and the remainder into heat where as fluorescent lamps turn 25 per cent of energy into light.

This project present a design methodology for develop a self-oscillating electronic ballast (SOEB) with using the mathematical modelling of SOEB. This project performs three different method design of electronic ballast. First method was using the zener diode, second using two-stage electronic ballast and lastly used the single-stage electronic ballast. The comparisons and discussions are carried out for all circuits designed. The differentials are used to define a suitable design for self-oscillating electronic ballast.

ABSTRAK

System pencahayaan memberi banyak peluang bagi penjimatan tenaga secara kos efektif tanpa sebarang pengorbanan. System ini sekarang merupakan sebahagian daripada program pemeliharaan tenaga (Energy Conservation) di seluruh dunia dan pengurangan penggunaan tenaga dengan melaksanakan skim pengekalan yang diperlukan.

Projek ini membentangkan satu kaedah reka bentuk SOEB dengan menggunakan model matematik SOEB. Projek ini melaksanakan tiga kaedah reka bentuk yang berbeza ballast elektronik. Kaedah pertaman menggunakan diod ziner, kaedah kedua menggunakan peringkat kedua ballast elektronik dan yang terakhir adalah peringkat pertama ballast elektronik. Perbezaan dan perbincangan dijalankan terhadap semua litar yang direka. Perbezaan ini adalah untuk menentukan reka bentuk yang sesuai untuk ballast elektronik ini.

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LIST OF ABBREVIATIONS

SOEB	Self-Oscillating Electronic Ballast
AC	Alternative Current
DC	Direct Current
PFC	Power Factor Correction
CF	Crest Factor
DCM	Discontinuous Conduction Mode
CCM	Continuous Conduction Mode
V	Voltage
A	Ampere
L	Inductance
C	Capacitance
R	Resistance
s	second
m	mili
μ	micro
n	nano

CHAPTER I

INTRODUCTION

1.1 Electronic Ballast

Electronic ballast is a device intended to limit the amount of current in an electric circuit. Why electronic ballast was choosing in this project? It is because the electronic ballast has a greater efficiency. For T8 lamps, the overall electronics ballast of efficacy can be as much as 15 % to 20 % higher than magnetic ballast systems.[1] Electronic ballast do not generate as much internal heat, thereby reducing losses within the ballast itself. In addition, the high frequency operation of the fluorescent lamp reduces the losses in straight tube fluorescent lamps. Electronic ballast has ability to drive more lamps. Single electronic ballast can drive up to 4 lamps and has eliminated the need of tandem wiring. Compared to conventional magnetic ballast, only up to 2 lamps can driven. The advantage of electronic ballast is reduced lamp flicker while the high frequency operation of the lamp cycles the lamp so rapidly that flicker is imperceptible. Electronic ballast are also lighter in weight where an electronic components as not as heavy as the core and coil construction used for magnetic ballasts. Then the lighting fixtures weigh less and can be more streamlined in design. Electronic ballasts for small diameter lamps (T5 or smaller) are available that detect the end of life of the lamp and shut it off before the lamp overheats enough to melt sockets and cause the lamp wall to crack and break. Electronic ballasts are helping save energy that is consumed worldwide for feeding fluorescent lamps. Besides reduce the consumption the low cost self-oscillating command circuits have the attractiveness of its simplicity.

This project presents design methodology in developing the self-oscillating electronic ballast (SOEB). Figure 1 shows one of the most common used circuit to supply fluorescent lamps. The SOEB behaviour as a nonlinear system but does not find expressions that represent the inherent nonlinear behaviour of SOEB. The nonlinear of SOEB does not allow one to define methodology derived from a linear-circuit analysis unless the necessary considerations are made. [2]

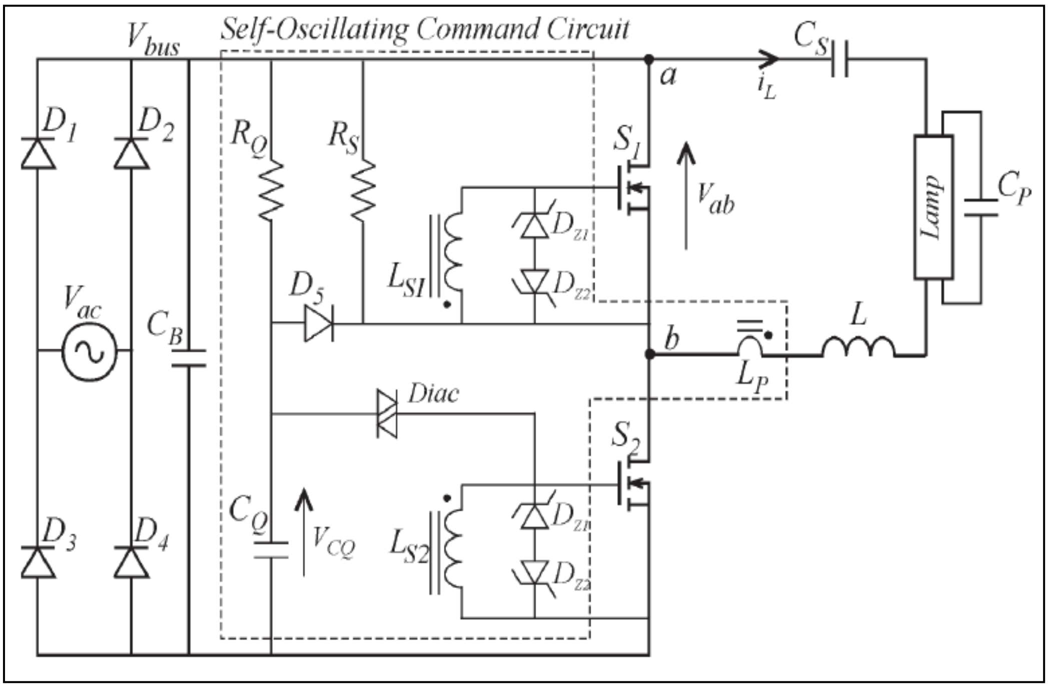

Figure 1.1: The Self-oscillating command circuit.

However, many different types and methods to design of electronic ballast have been proposed. Analyses of 3 types design methodology of SOEB are carried out; by using zener diode, two-stage electronic ballast and single-stage electronic ballast.

1.2 Problem Statement

1. The SOEB is analysed and designed from different perspectives circuit and methods.
2. The low cost and the simplicity of the SOEB design are vital.

1.3 Objective

The objectives of this project are:

i. To develop the different methodology circuit of self-oscillating electronic ballasts (SOEB).

ii. To simulate and analyse the proposed ballast circuitry.

iii. To compare the result of each proposed ballast circuitry.

1.4 Scope of Project

The scopes of this project are to design self-oscillating electronic ballast (SOEB). In addition, simulation the performance will be made using in ORCAD/PSPICE/Simulink and then analysed the results.

1.5 Outline of Thesis

Chapter I consists of the overview of the project, which includes the problem statement, objectives and scope.

Chapter II includes all the paper works and related research as well as the studies regards to this project. This literature reviews all important studies which have been done previously by other research work.

Chapter III illustrates the operation and the parameters involved in a design methodology for self-oscillating electronic ballast. The circuit topology that uses power electronics approach for SOEB is described in detail.

Chapter IV presents the simulation design of self-oscillating electronic ballast using ORCAD/PSPICE/Simulink. It also consists of the simulation results and discussion based on the performance of the self-oscillating electronic ballast produced.

Chapter V concludes the overall thesis and for future work.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter includes all the paper works and related research as well as the studies regards to this project. This literature reviews all important studies which have been done previously by other research work. The related works have been referred carefully since some of the knowledge and suggestions from the previous work can be implemented for this project. Literature review was on-going process throughout the whole process of the project. It is very essential to refer to the variety of sources in order to gain more knowledge and skills to complete this project.

2.2 Fluorescent Lamp

A fluorescent tube is low pressure mercury vapours discharge lamp containing an inert gas that consisting of argon or krypton at low pressure (below 1 atmosphere) plus a small measured dose of mercury. There is a filament at each end which when hot, emits electrons to sustain the discharge when the lamp is operating. The mercury vapours discharge produces ultraviolet light which is converted to visible light by the phosphors coating the inside of the glass tube. The glass blocks the exit of the ultraviolet radiation but allows the visible radiation through. [3]

A non-operating fluorescent tube will appear as an open circuit, since there is no electrical connection from one end to the other. To "strike the arc", a high voltage must be applied across the lamp which will ionizes the gas and this will instantly "cold start" the lamp and shorten its life by sputtering electron-emitting material from its cathodes. However, if the cathodes are first preheated to generate a space charge of electrons at each end of the lamp, the strike voltage is considerably reduced and lamp life will not be unduly compromised by the start-up. As soon as the discharge current flows, the lamp's electrical impedance will drop. It now becomes as negative impedance, where an increase in current is accompanied by a reduction in lamp voltage. Therefore that will be a current-limiting device in series with the lamp which compensates with a positive impedance characteristic to prevent current runaway and rapid destruction of the lamp.

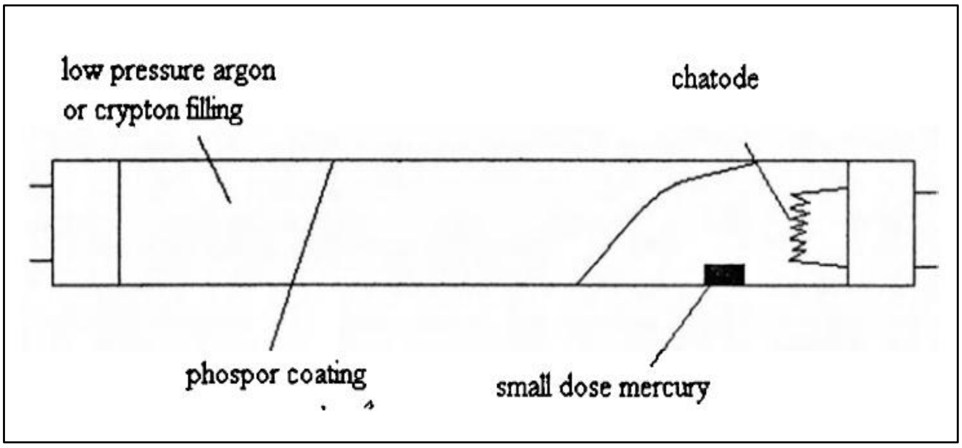

Figure 2.1 fluorescent lamp

2.3 Ballast

Ballasts are electrical device that convert line current into the proper voltage, amperage, and waveform to operate fluorescent lamps. Electrical distribution systems deliver fixed AC voltage (50 or 60 Hz) and expect connected electrical loads to limit the current drawn from the source. Ballasts use inductive and capacitive component because they impede alternating current with little power consumption. Resistive components generate high loss and are usually avoided. The mix of ballasts has been shifting steadily toward more efficient equipment over the past 15 years. [1]

Electronic ballasts have been available since at least the beginning of the 1980's. Replacing the most efficient low loss mains frequency switch start ballast with electronic ballast leads to reduced energy consumption and improved performance.

2.4 Two-stage Electronic Ballast

The traditional power stage circuit is two-stage electronic ballast. A two-stage approach a power factor correction (PFC) stage followed by a DC/AC inverter stage, is used. The two-stage approach has good performances such as a near-unit power factor and wide range of line input voltage variation. The main problem of two-stage approach is that it has more components and thus a high cost. [4]

Generally, the electronic ballast for a fluorescent lamp consists of a half-bridge inverter and a boost converter. The latter is placed on the input side of a half-bridge inverter t o reduce the harmonics included in the input current below the Class C limits of IEC standard. However, the additional dc-dc boost converter increases the number of electronic parts and the cost of ballast. Accordingly, the circuit is required to be simple to decrease the electronic parts and the cost.[5]

Although this approach can achieve a high power factor at the input and ensure a low lamp crest factor (CF) at the output, it requires three MOSFETs in the power circuit and two controllers in the overall system. The resulting circuit is costly and too large to be practical in CFL applications.[6]

2.5 Single-stage Electronic Ballast

The single-stage electronic ballast integrates a buck-boost converter stage with a half-bridge LCC series-parallel resonant inverter. Since two switches in the two stage electronics ballast are operated in synchronous and share its common terminal, it can be combines to only one switches used. This has simplified the overall circuit of two stage circuit. However, the operation of the buck-boost converter must be considered the discontinuous conduction mode (DCM), which is difficult to analyse. The buck-boost semi-stage operating in discontinuous conduction mode (DCM) inherently has high PFC. Furthermore; the shared switch usually suffers from high current stress because it needs to conduct the reflected load current and line current. A high-current rating device has to be used. [4,7]

2.6 Nonlinear Control Characteristics

The self-oscillating LC series resonant (as shown in Figure 2.2) parallel load inverter for electronic ballast application is investigated from a system point of view. Most of the topics in the literature are the circuit topology and loaded-resonant characteristic of inverter. For a self-oscillating inverter, its switching frequency is determined by itself. As we know, an important phenomenon in control theory and design is the occurrence of limit cycles. The precise determination of limit cycles is usually performed either by Hamel's method [9, 10] in the time domain or by Tsypkin's method [10, 11] in the frequency domain while the describing function method [12] provides an approximate solution. By modelling the self-oscillating circuit with lamp load as a nonlinear relay system, stability of self-oscillating can be analysed using the methods by describe function, Tsypkin method and Hamel method. [8]

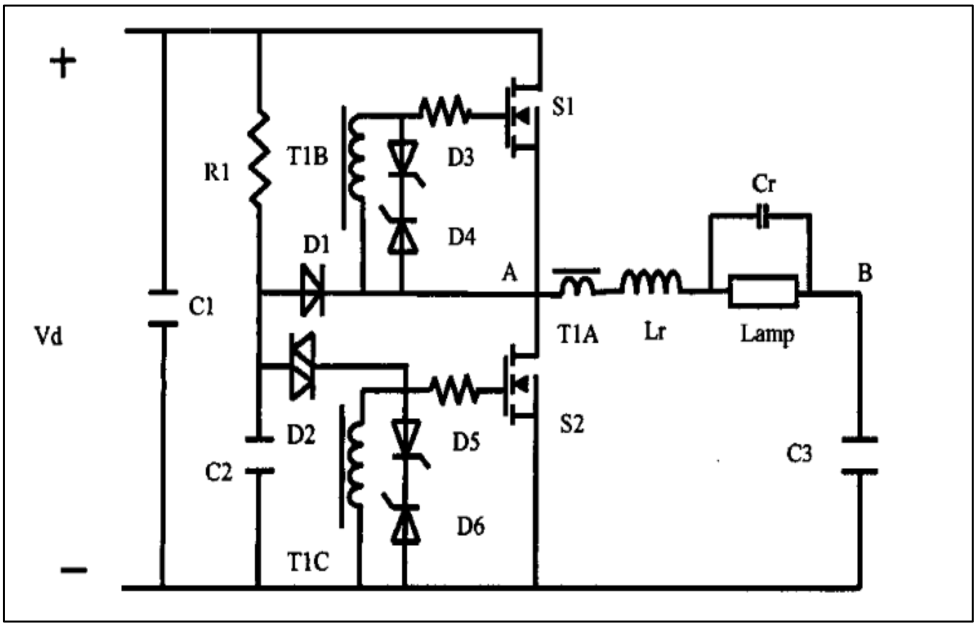

Figure 2.2 Self-oscillating half-bridge LC series resonant ballast [8]

2.7 High Frequency

The SOEB have two important drawbacks; first, the lamp current varies according the AC input voltage, causing undesired effects in the lamp brightness and second, the design method lack of precision at very high frequency operation (greater than 200kHz) mainly due to the Cgs parasitic capacitor. Nowadays, high frequency electronic ballast represents an important alternative to reduce the electric energy consumption in the form of artificial lighting. With the objective to reduce costs and increase the circuit robustness, many manufacturers prefer to use self-oscillating topologies instead of drivers based on integrated circuits. The SOEB can be analysed with the descriptive function method since these can be represented as a nonlinear system with a single and time invariant nonlinear component and a low-pass filter.[13]

CHAPTER III

METHODOLOGY

In this project are performed with three different circuits of self-oscillating electronic ballast (SOEB) are performed. First, the electronic ballast circuit was using the zener diode as a voltage regulator trigger to the switch devices as shown in the Figure 3.1. Second, the circuit that using the two stage of self-oscillating electronic ballast method is developed as shown in the Figure 3.2 and the third circuit is a use the single-stage of electronic ballast as shown in the Figure 3.3.

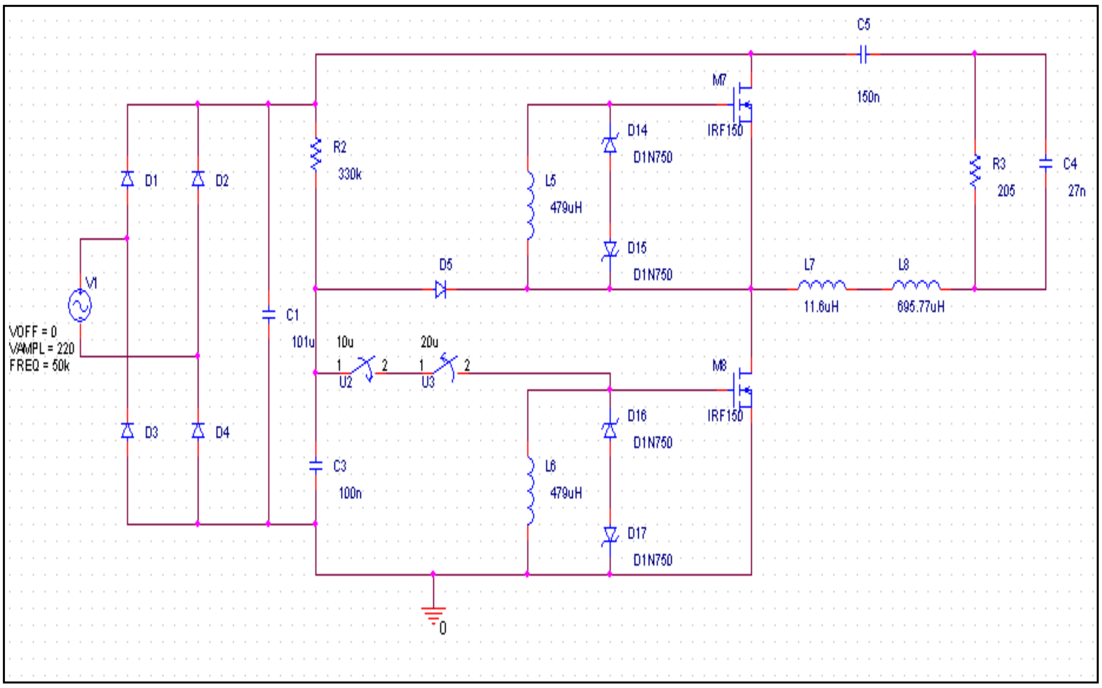

Figure 3.1 SOEB circuit with zener diode.

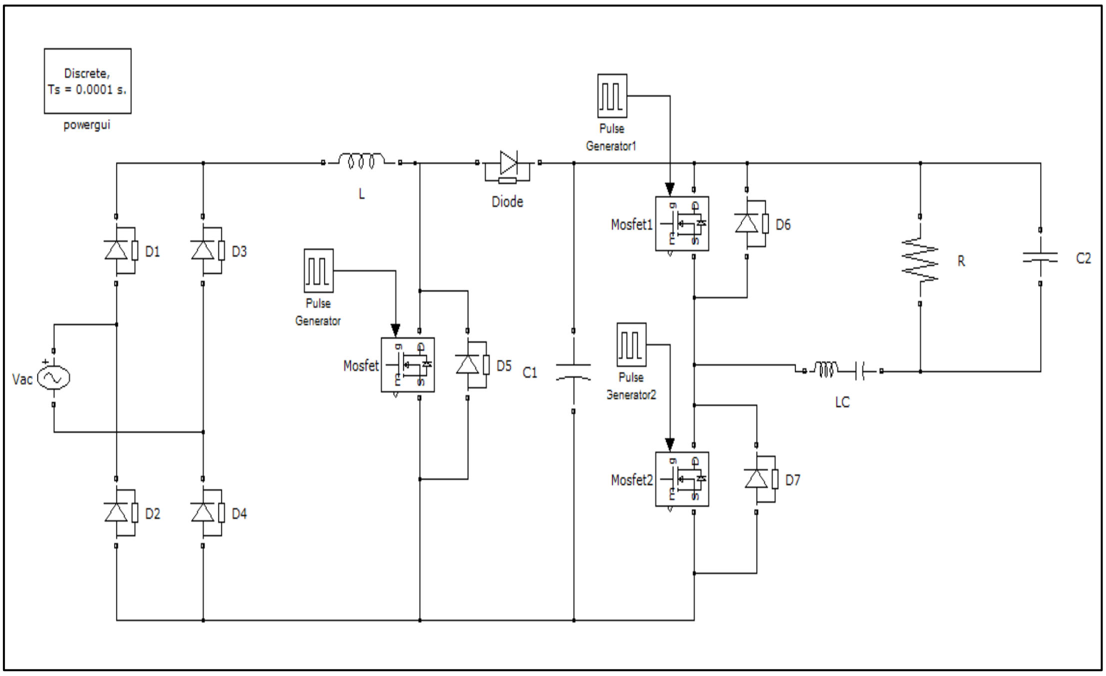

Figure 3.2 SOEB circuit with two-stage electronic ballast

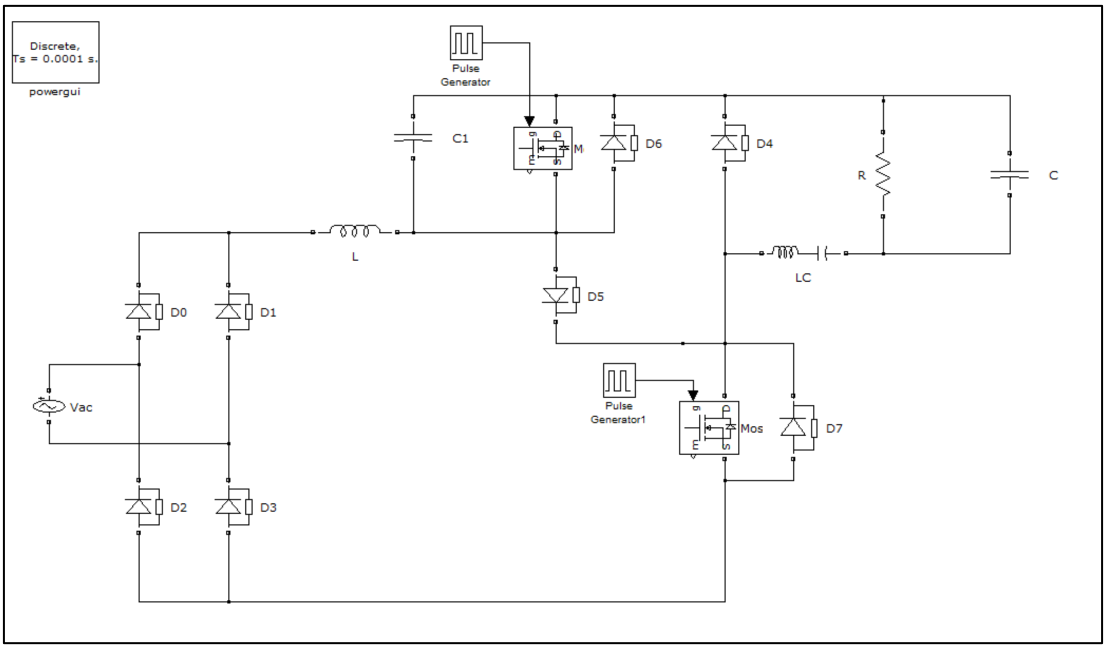

Figure 3.3 SOEB circuit with single-stage electronic ballast

In each SOEB circuit, there are three sub circuits inside i.e., rectifier, boost/buck-boost and resonant inverter circuit. The rectifier circuit as illustrated in Figure 3.4. The rectifier section is to convert the alternating current (AC), which periodically reverses direction, to direct current (DC).[11] However, the rectifier circuit may be classified into two categories, half-wave rectifier and full-wave rectifier. In this project was uses the full-wave rectifier with four-bridge diodes. A full-wave rectifier convert the whole of the input waveform to one of constant polarity (positive or negative) ay its output. Single semiconductor diodes, double diodes with common cathode or common anode, and four-diode bridges are manufactured as single components.

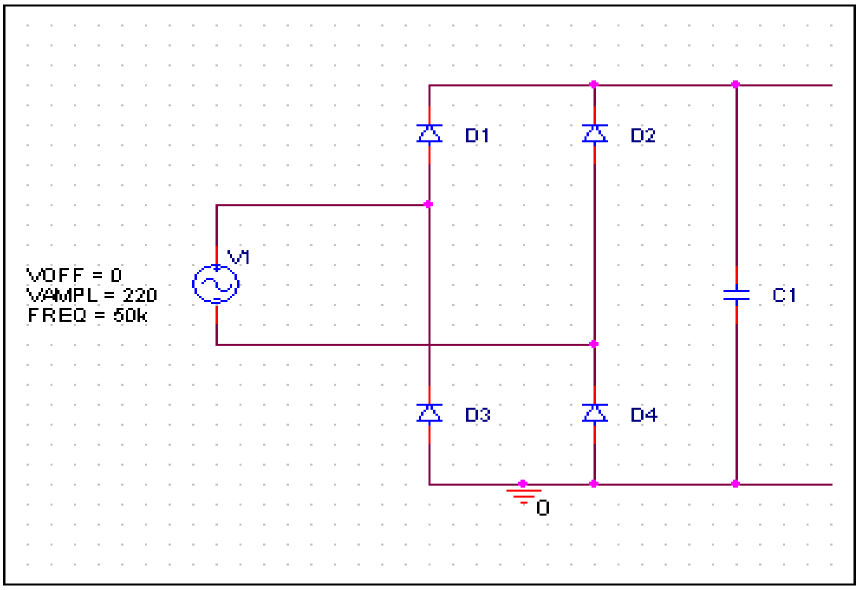

Figure 3.4 Rectifier circuit with four-bridge diode

The second circuit is a buck-boost converter, as shown in Figure 3.5 and a boost converter as shown in Figure 3.6. The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. The buck-boost converter changes mode based on the input voltage. If the input voltage > output voltage it operates in a buck mode; otherwise it is working in a boost mode.

A boost converter is a DC-to-DC power converter with an output voltage greater than its input voltage. A boost converter is sometimes called a step-up converter since it step-up the source voltage. It is a class of switched-mode power supply containing at least two semiconductor; a diode and a transistor, and at least one energy storage element, a capacitor, inductor or the two in combination.

The basic operation of boost converter is based on the switching characteristics of switch devices (MOSFET is conducting and non-conducting). The current is being drawn through the inductor when the MOSFET is conducting. At this time energy is being stored in the inductor. When the transistor stops conducting the inductor voltage flies back or reverses because the current through the inductor cannot change instantaneously. The voltage across the inductor increases to a value that is higher than the combined voltage across the diode and the output capacitor. As soon as this value is reached, the diode starts conducting and the voltage that appears across the output capacitor, is higher than the input voltage. The pulse must be set in different phase to drive the switch devices.

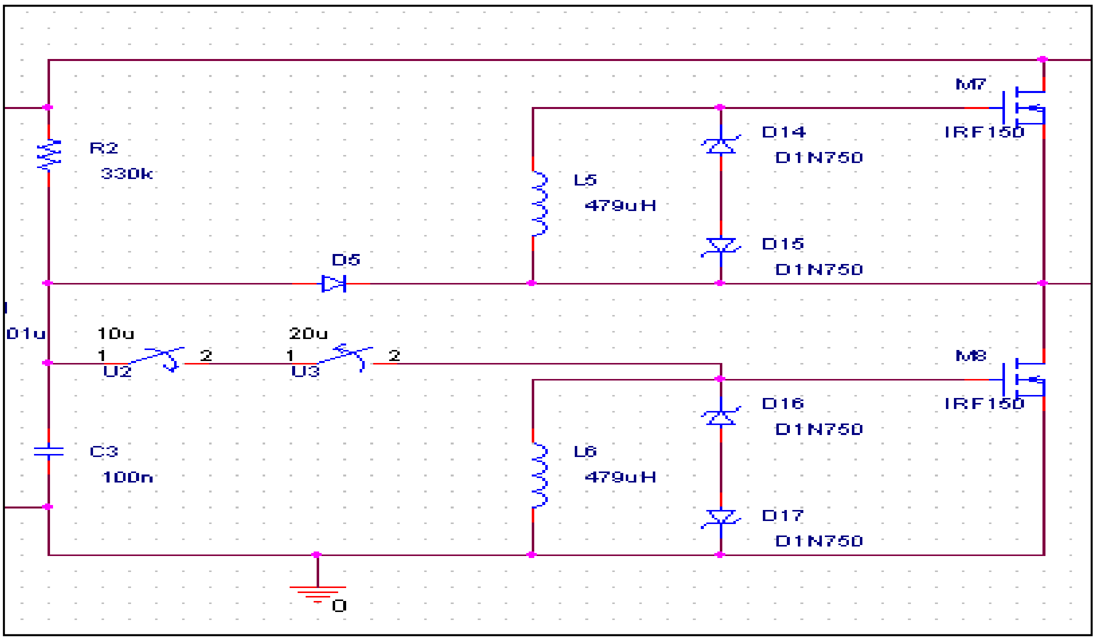

Figure 3.5 The buck-boost converter circuit with zener diode.

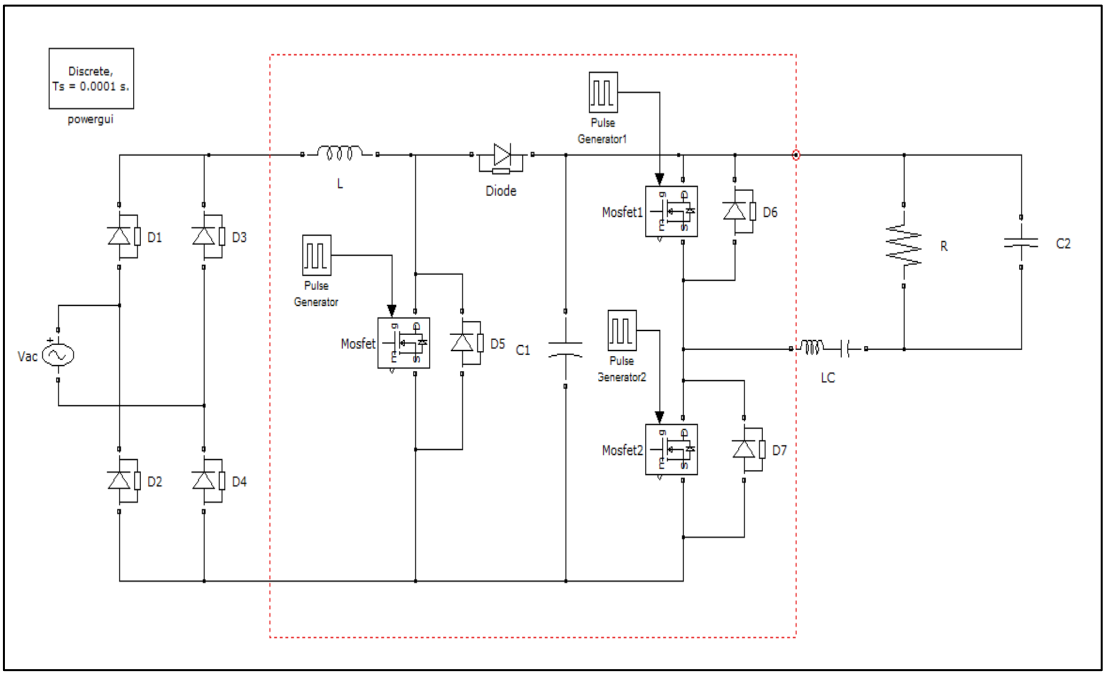

Figure 3.6 The boost converter circuit with two-stage electronic ballast

This project was creating to do the comparison with two different method of a boost and buck-boost converter, respectively. First method was using the back-to-back zener diode as a voltage regulator that triggers the MOSFET on and off as shown in a Figure 3.5. Back-to-back zener diode was function as the control pulse to the MOSFET. A zener diode is a special kind of diode which allows current to flow in the forward direction in the same manner as an ideal diode, but will also permit it to flow in the reverse direction when the voltage is above a certain value known as the breakdown voltage or zener voltage. MOSFET functions as the switching frequency of oscillating. Second method that uses in a two-stage of SOEB is a boost converter that using modulation pulse to trigger the switch devices as illustrated in Figure 3.6. The two-stage and single-stage electronic ballast are use boost converter to drive up the resonant filter based on the switching applied to switches device as represent as MOSFET.

The last part in that circuit is a resonant circuit, as shown in Figure 3.7. The resonant circuit was consists with a capacitor with inductor in series and capacitor in parallel. Hence, the resonant circuit reflected the gate of the switch devices.

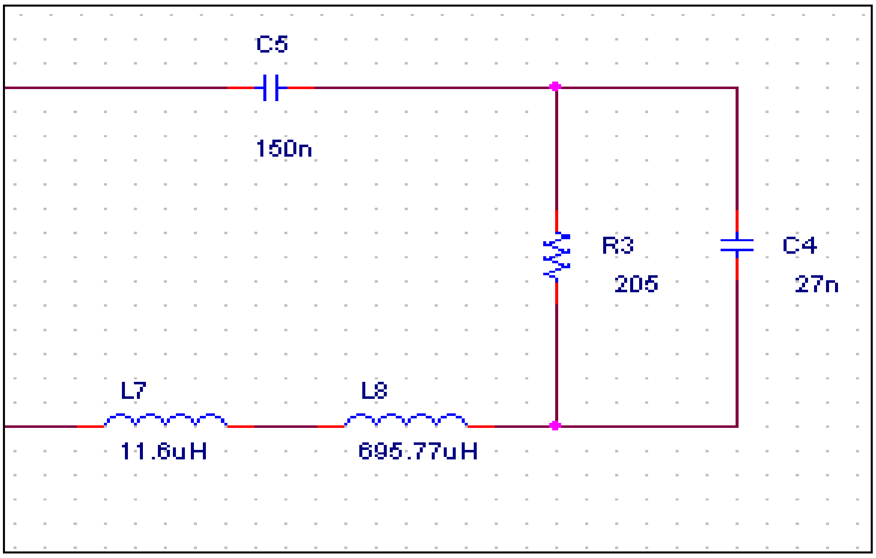

Figure 3.7 The LCC resonant filter circuit

CHAPTER IV

RESULT AND DISCUSSION

This chapter discusses all the results obtained and limitation of the project. All discussions concentrate on the result and overall performance of self-oscillating electronic ballast. In this project, ORCAD/PSPICE and MATLAB software has chosen to simulate the equivalent circuit. All circuit parameters are obtained from the calculation in literature review as shown in Table 4.1 and Table 4.2.

Parameter	Value
At rectifier	
a) C_1	101uF
At buck-boost	
a) R_2	330k Ohm
b) C_3	100nF
c) L_5	479uH
d) L_6	479uH
At resonant filter	
a) C_4	27nF
b) C_5	150nF
c) L_7	11.6uH
d) L_8	695.77uH
e) R_3	205 Ohm

Table 4.1 Parameter value for zener diode circuit

Parameter	Value
At rectifier a) L	 0.4mH
At boost converter a) C	 155uF
At resonant filter a) L_2 b) C_2 c) R d) C	 1.81mH 0.15uF 80 Ohm 27nF

Table 4.2 Parameter value for two-stage circuit

4.1 Zener Diode

The self-oscillating electronic ballast design with zener diode circuit was uses ORCAD/PSPICE software to simulation, as shown in Figure 4.1 and Figure 4.4. It is because at ORCAD/PSPICE software has a detail electronic component like as zener diode.

4.1.1 Simulation at rectifier

Figure 4.1 a shown the whole circuit of the self-oscillating electronic ballast. The main point in this subtopic is about the rectifier. The red point at rectifier in figure was shown the area to get the reading of the voltage waveform as shown in the Figure 4.2 and the green point to get the reading of current waveform as shown in the Figure 4.3. This SOEB circuit considering as relay control approach as represent as diac.

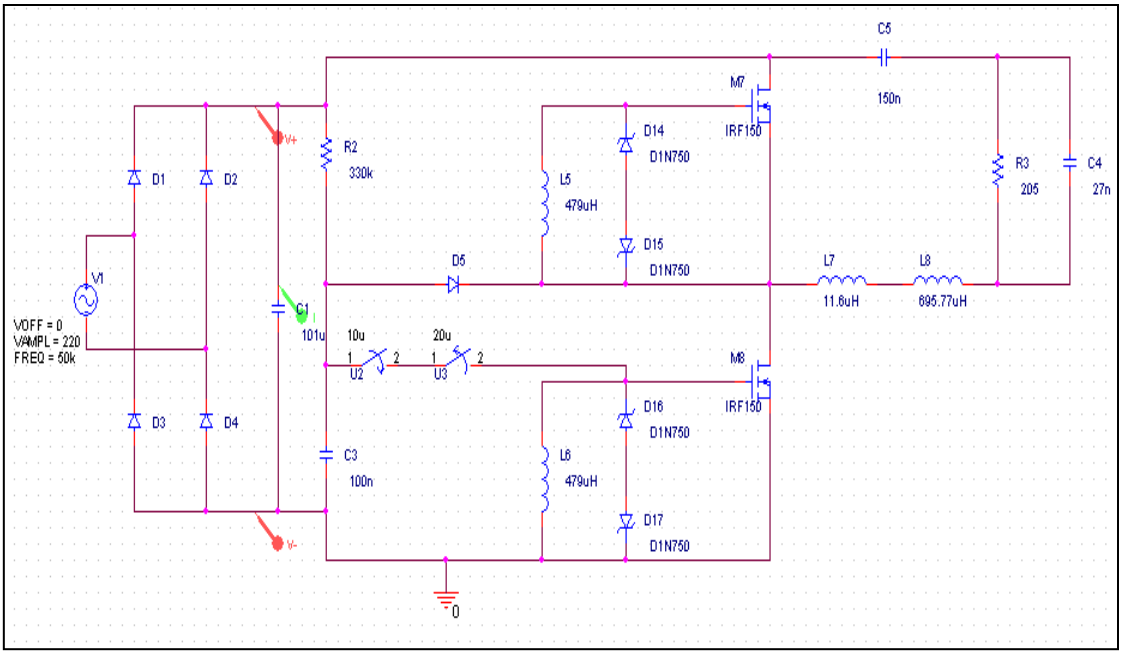

Figure 4.1 Simulation at rectifier

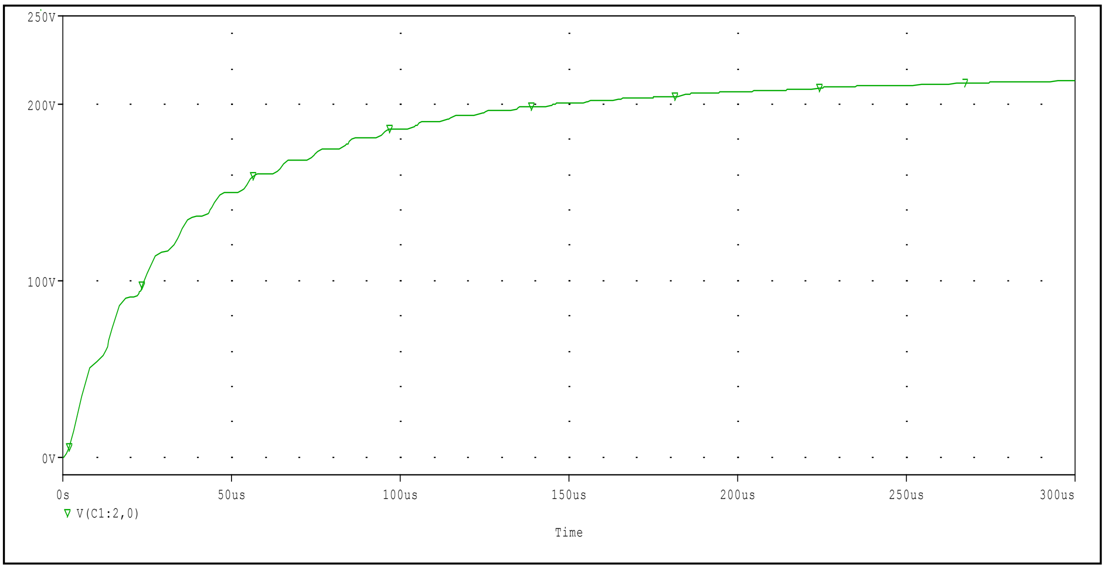

Figure 4.2 Voltage waveform for Figure 4.1

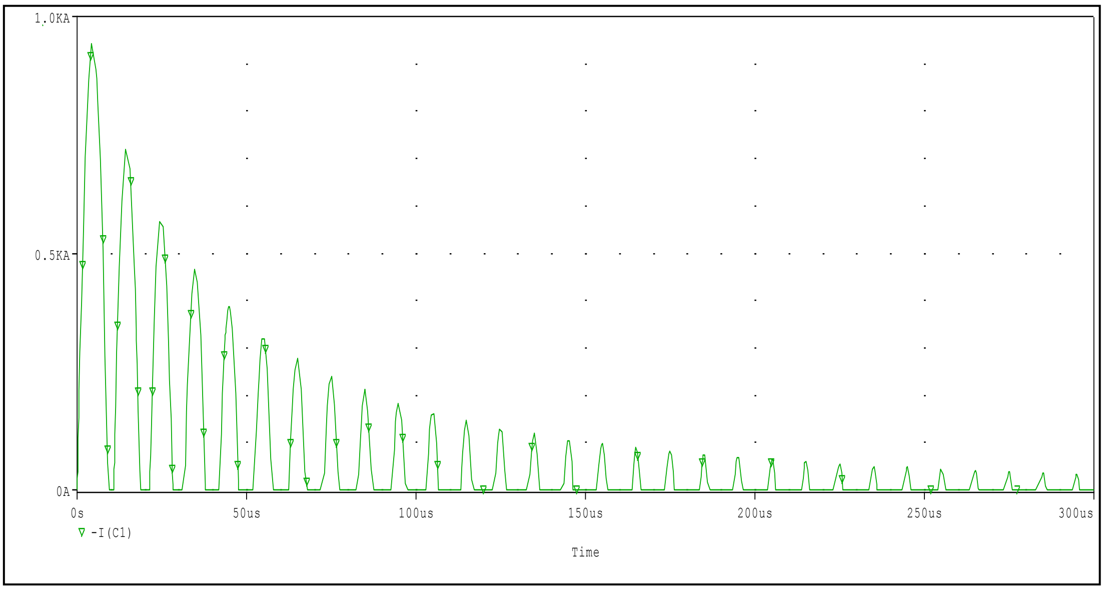

Figure 4.3 Current waveform for Figure 4.1

4.1.2 Simulation at resonant filter

Figure 4.4 a shown the simulated circuit where the point at the lamp. The green point at the resistance in figure was shown the area to get the reading of the voltage waveform as shown in the Figure 4.5 and the red point to get the reading of the current waveform as shown in the Figure 4.6.

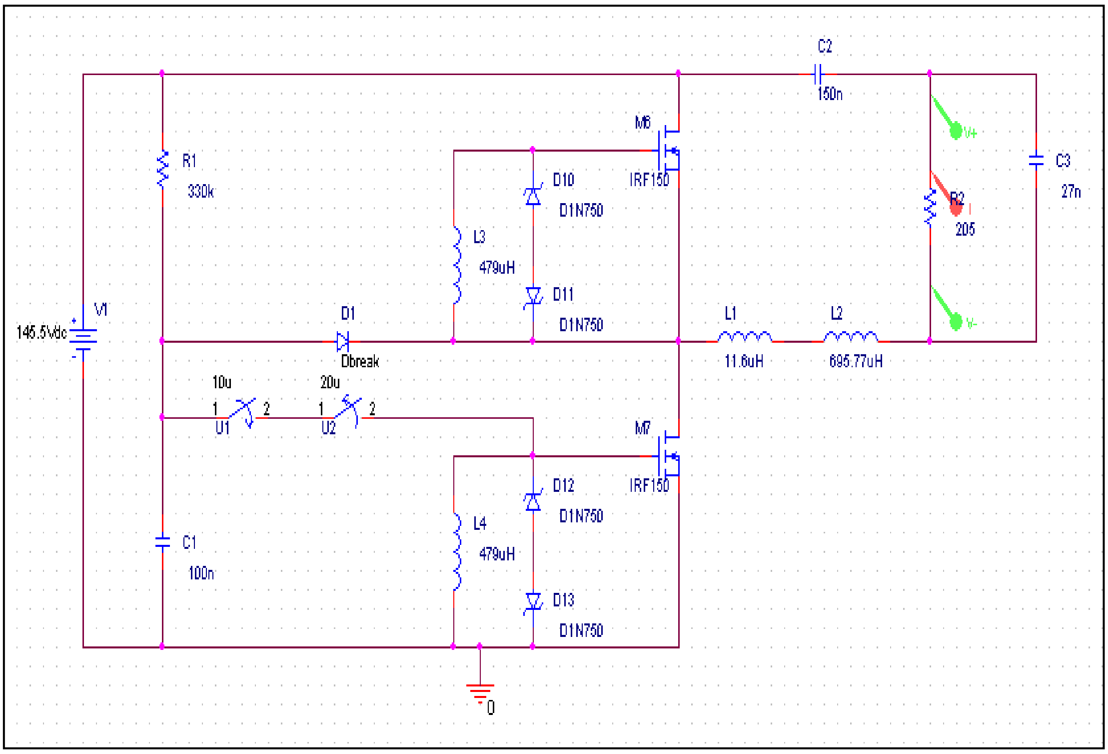

Figure 4.4 Simulation circuit at resonant filter

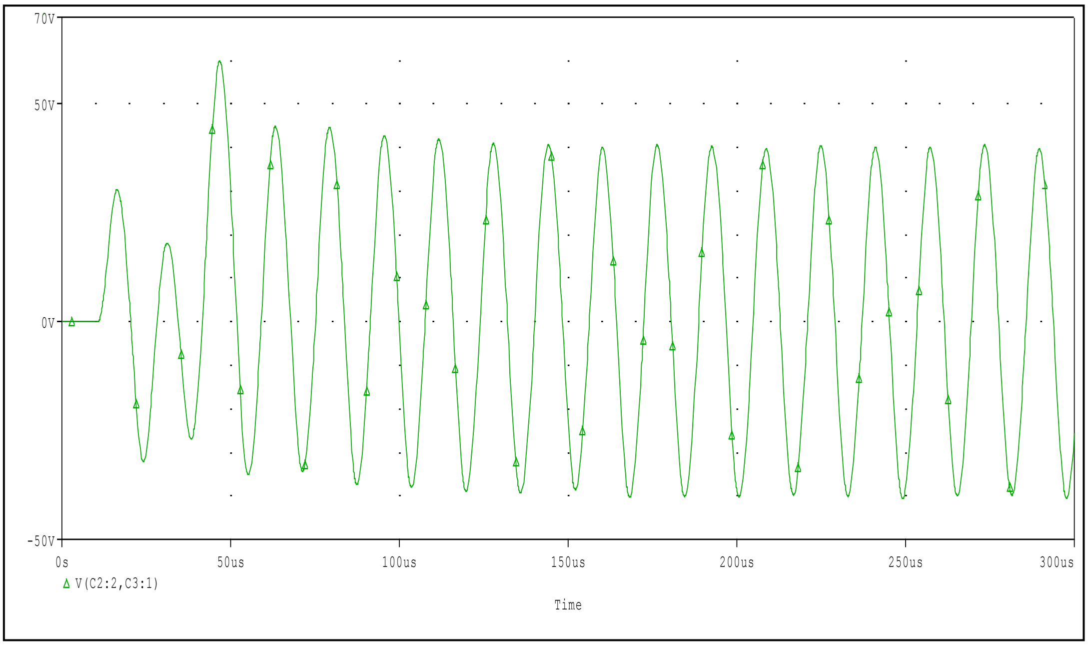

Figure 4.5 Voltage waveform for Figure 4.4

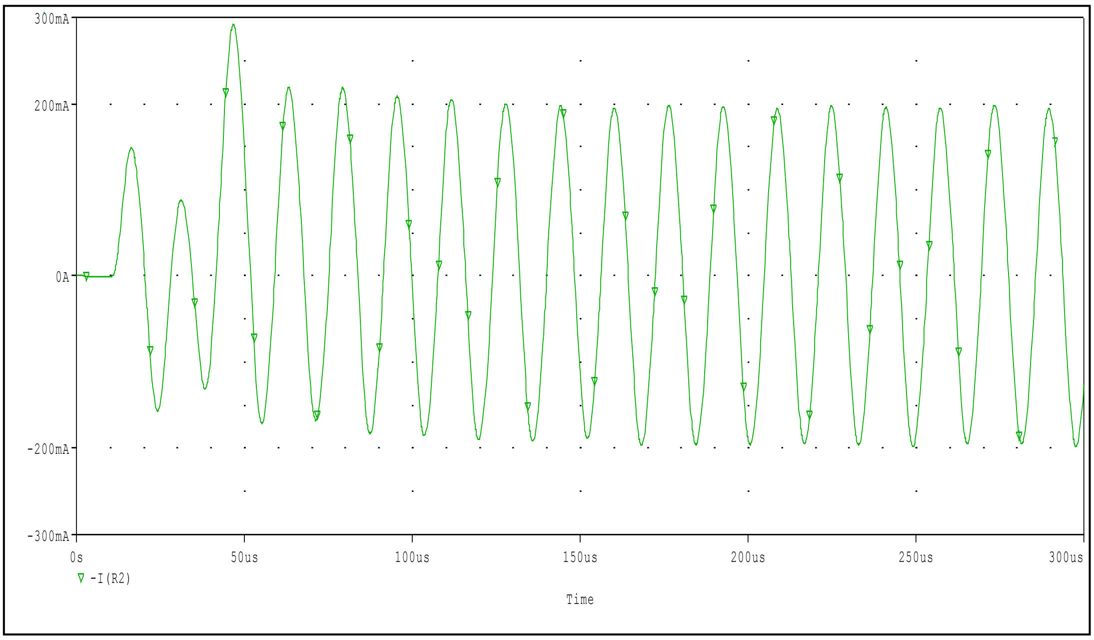

Figure 4.6: Current waveform for Figure 4.4

The fluorescent lamp is substituted by its equivalent resistance. The voltage of resistance is around 40V. The input voltage and the rectifier bridge, as well as the capacitor are substituted by a constant-voltage source, 220V. Two switches in series simulate the diac or the timer setting. After 10us, the switch U2 is turned on, applying a positive voltage in MOSFET. At time 20us, U3 is turned off, and the circuit remains oscillating without the starting operation. The voltage has the filter at starting as the Figure 4.5 and it become smooth after all.

4.2. Two Stage Electronic ballast

Simulation of two-stage electronic ballast circuit was chosen by MATLAB, as shown in Figure 4.7 and Figure 4.10. It is because MATLAB has controller component as the pulse generator. Function of pulse is give pulse to generate the MOSFETs.

4.2.1. Simulation at rectifier

Figure 4.7 a show the circuit where it is focus at rectifier section. Figure 4.8 was shown the voltage waveform of rectifier for two-stage electronic ballast and Figure 4.9 shown the current waveform of rectifier.

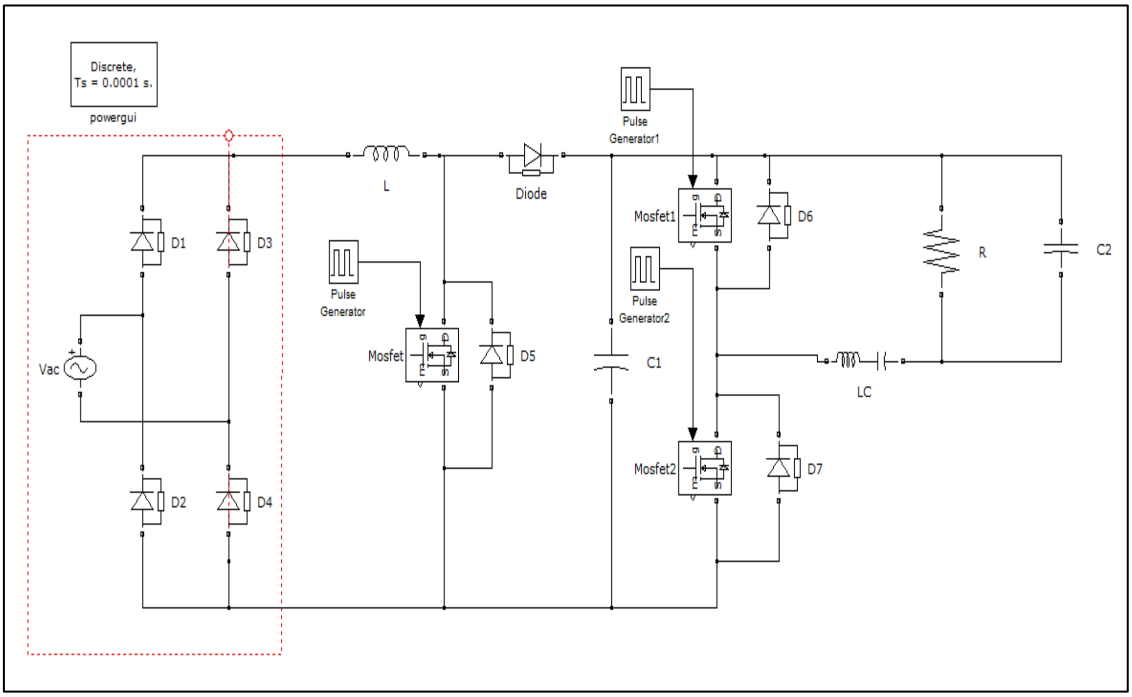

Figure 4.7 Simulation circuit at rectifier for two-stage SOEB

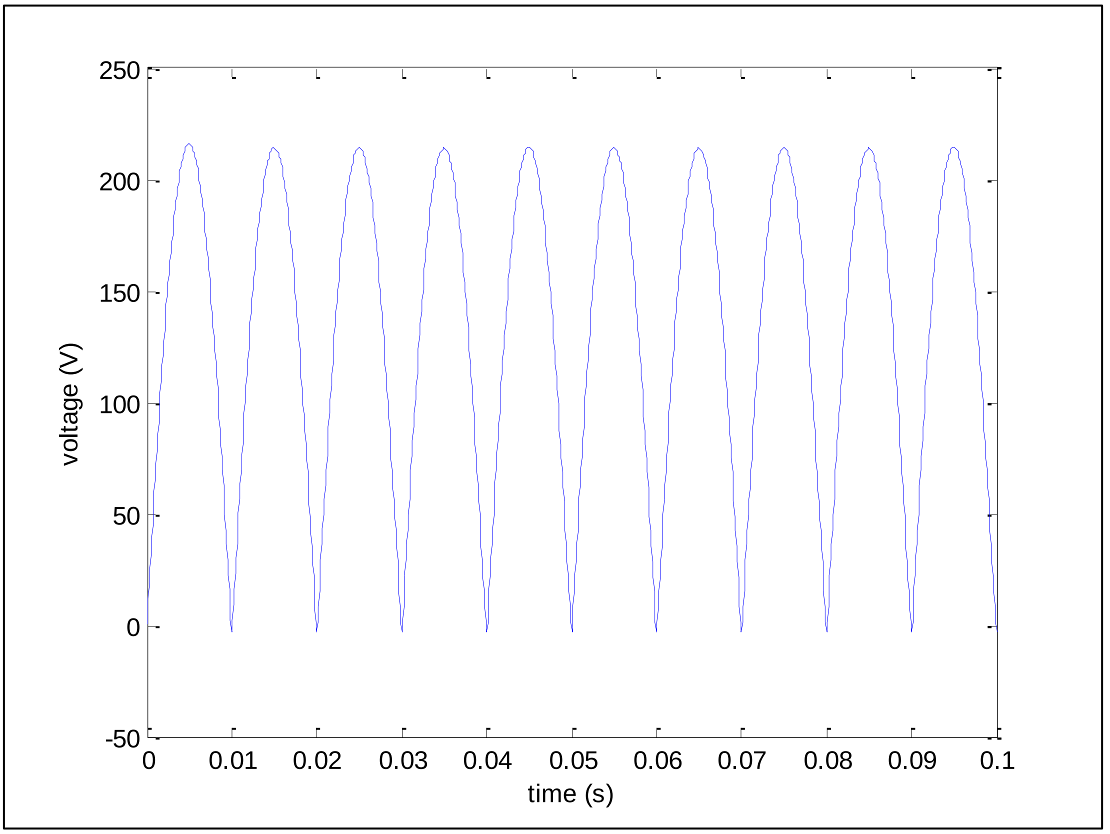

Figure 4.8 Voltage waveform for Figure 4.7.

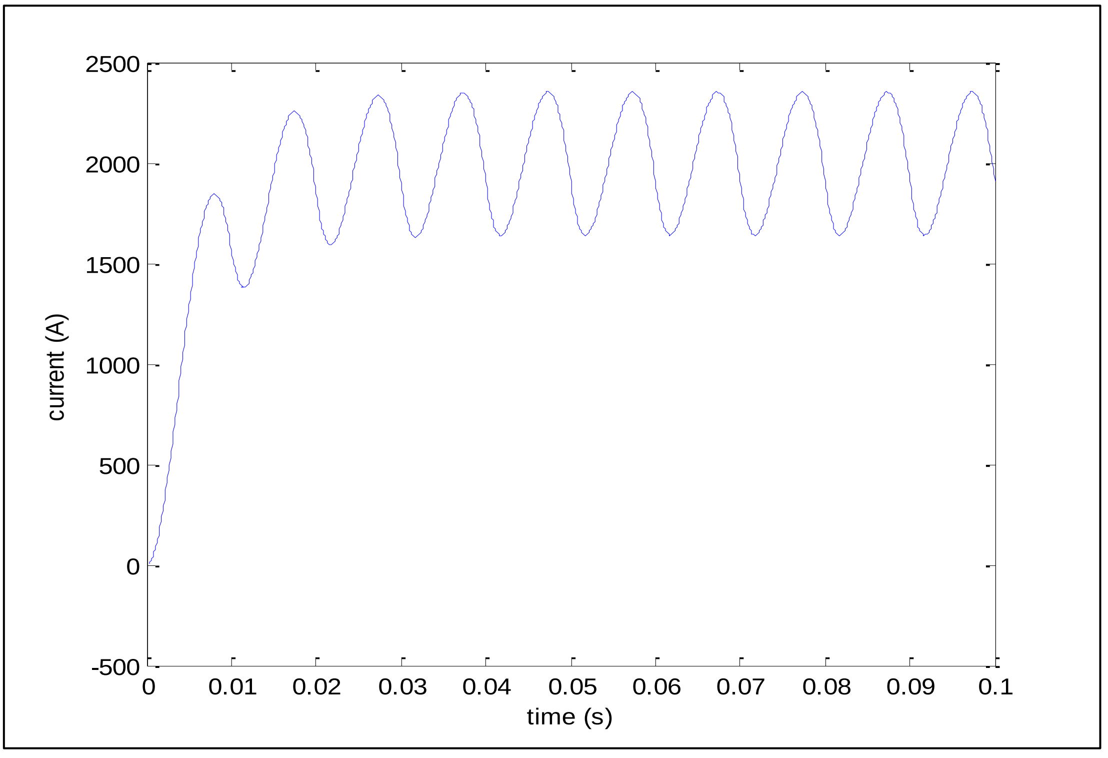

Figure 4.9 Current waveform for figure 4.7

4.2.2. Simulation at resonant filter

Figure 4.10 a show the circuit where it is focus at resonant filter section. Figure 4.11 was shown the voltage waveform of lamp for using two-stage electronic ballast and the current waveform of the lamp as shown in Figure 4.12.

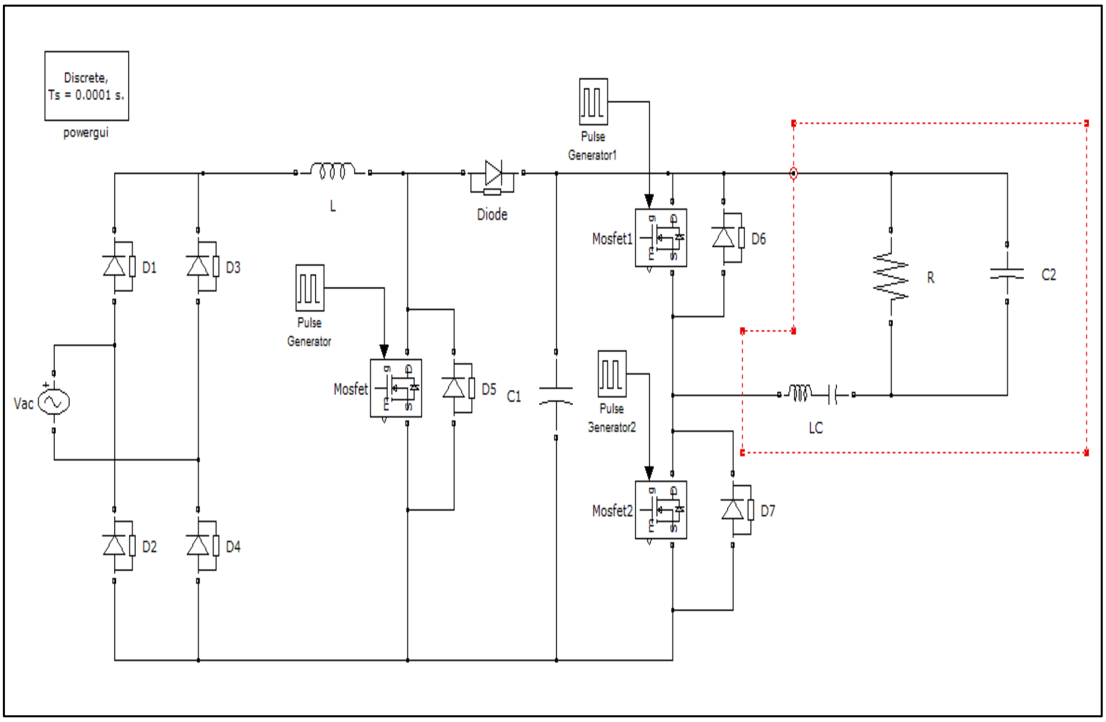

Figure 4.10 Simulation circuit at resonant filter

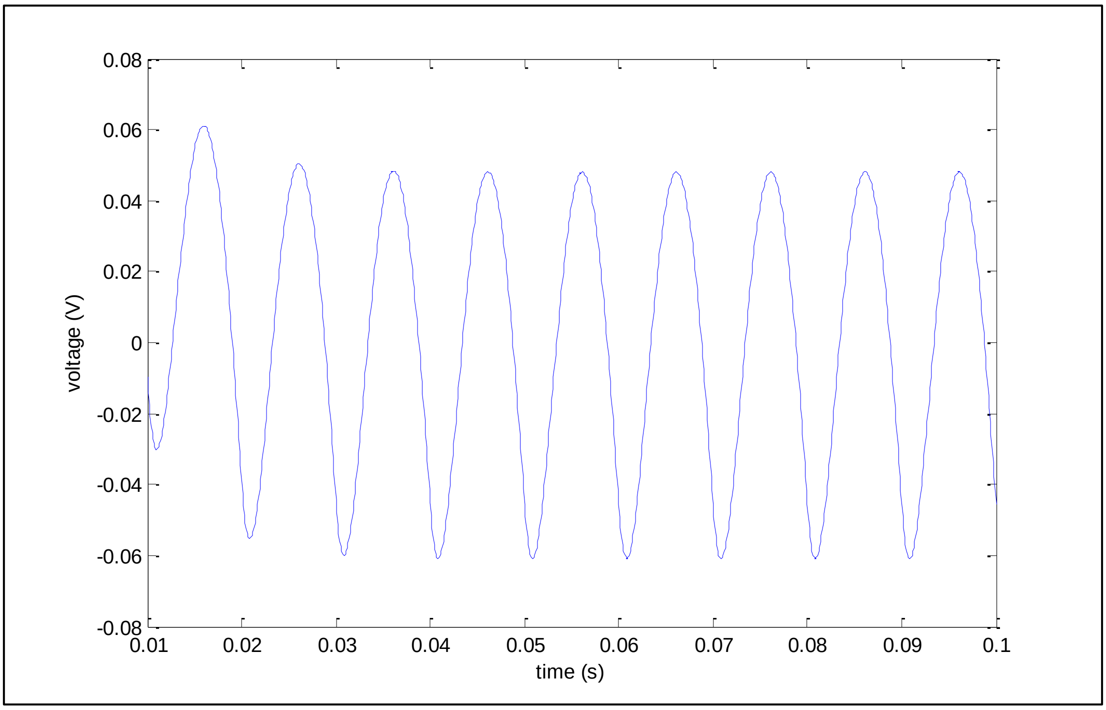

Figure 4.11 The voltage waveform for Figure 4.10

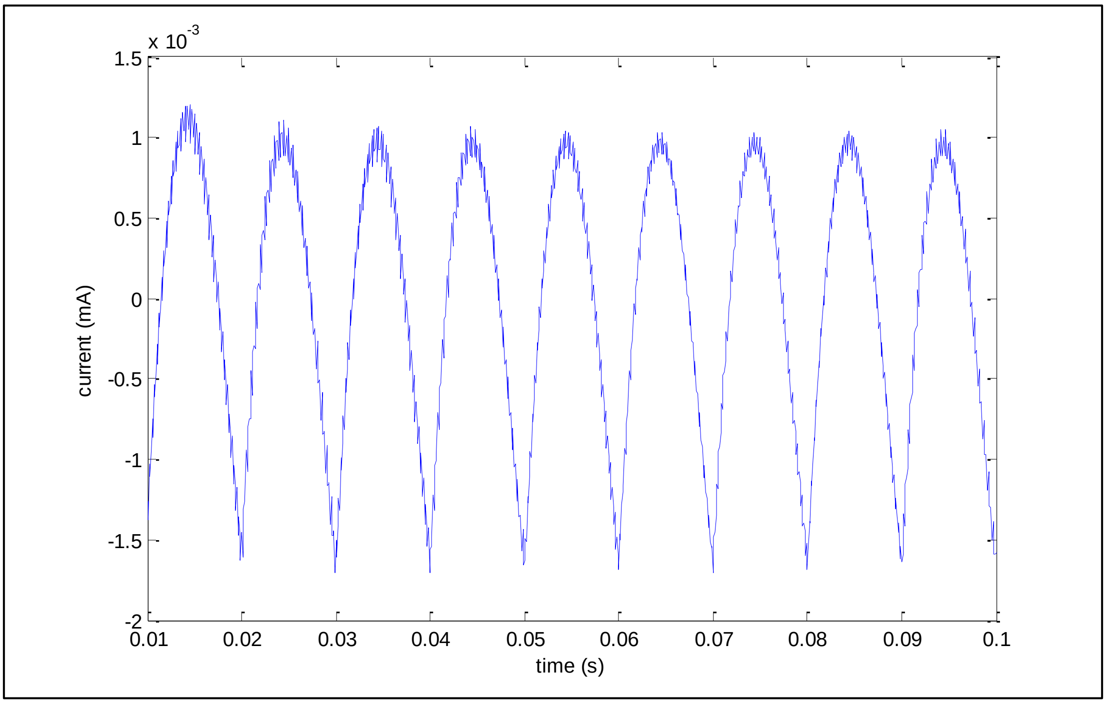

Figure 4.12 The current waveform for Figure 4.10

Simulation of two-stage electronic ballast was chosen by MATLAB, as shown in Figure 4.7 and Figure 4.10. It is because MATLAB has controller component as the pulse generator. Function of pulse is give pulse to generate the MOSFETs.

The fluorescent lamp is same as simulation of zener diode where it's substituted by its equivalent resistance. The voltage of resistance is around 0.5V. The input voltage and the rectifier bridge, as well as the capacitor are substituted by a constant-voltage source, 220V.

4.3 Single-stage Electronic Ballast

Simulation of single-stage electronic ballast circuit an also was chosen by MATLAB, as shown in Figure 4.13 and Figure 4.16.

4.3.1 Simulation at rectifier

Figure 4.13 a show the circuit where it is focus at rectifier section. Figure 4.14 was shown the voltage waveform of rectifier for single-stage electronic ballast and Figure 4.15 shown the current waveform of rectifier.

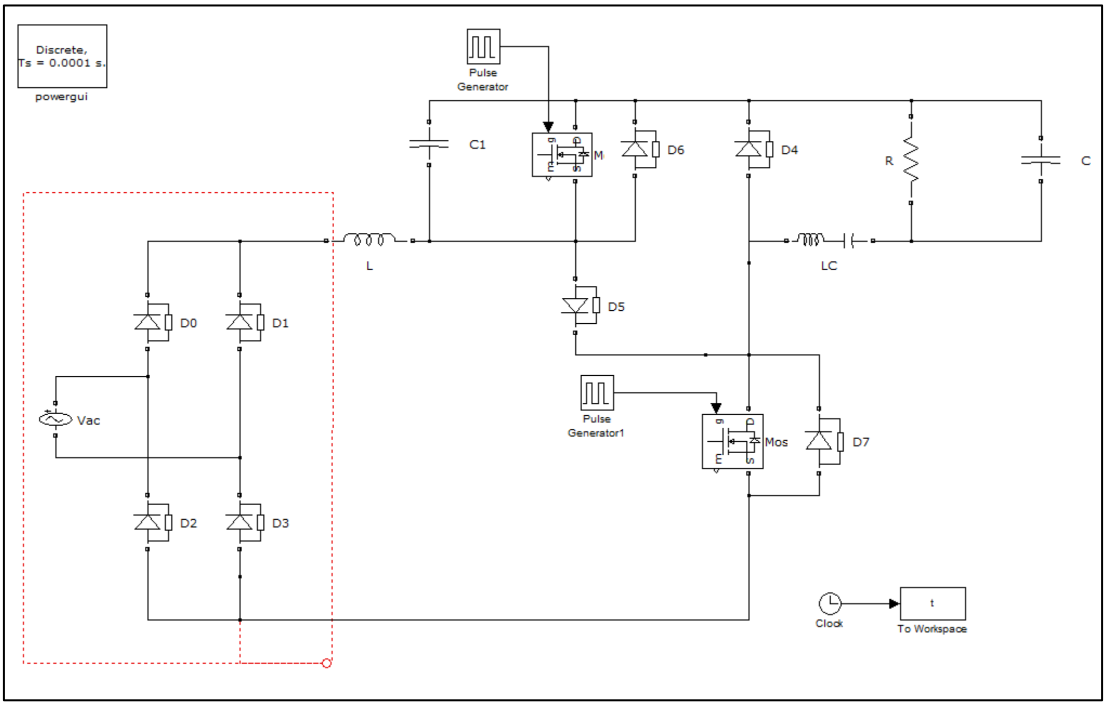

Figure 4.13 Simulation circuit at rectifier for single-stage electronic ballast

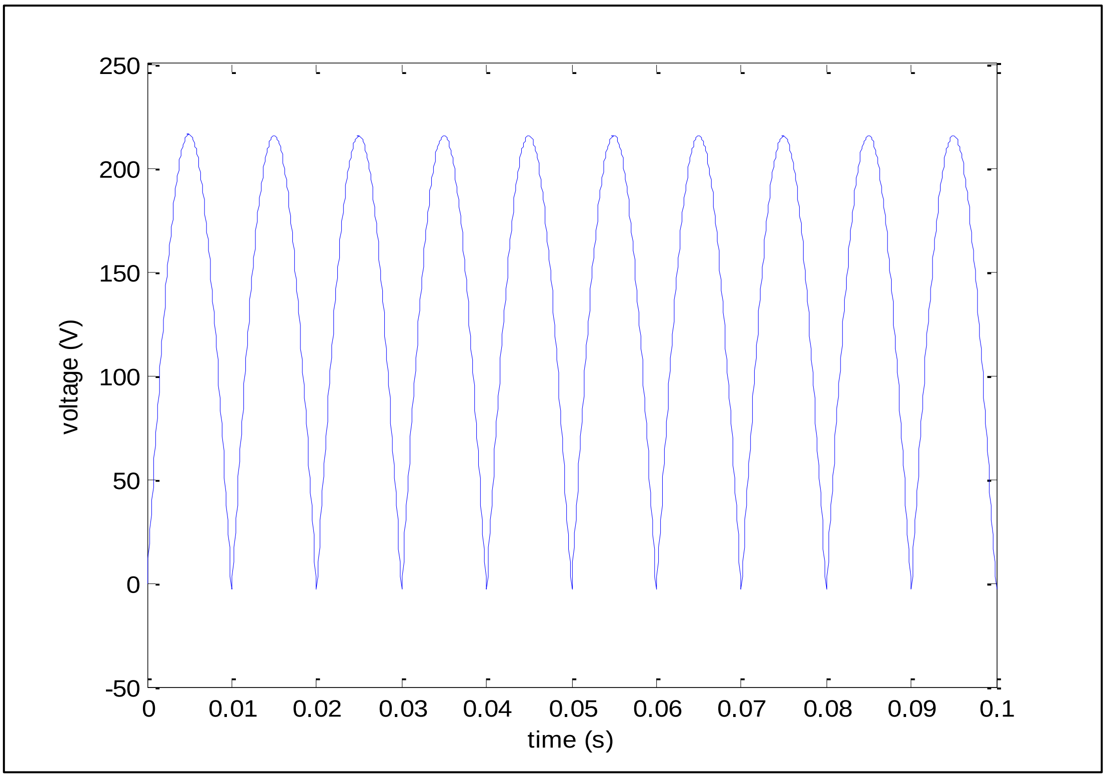

Figure 4.14 The voltage waveform form circuit in Figure 4.13

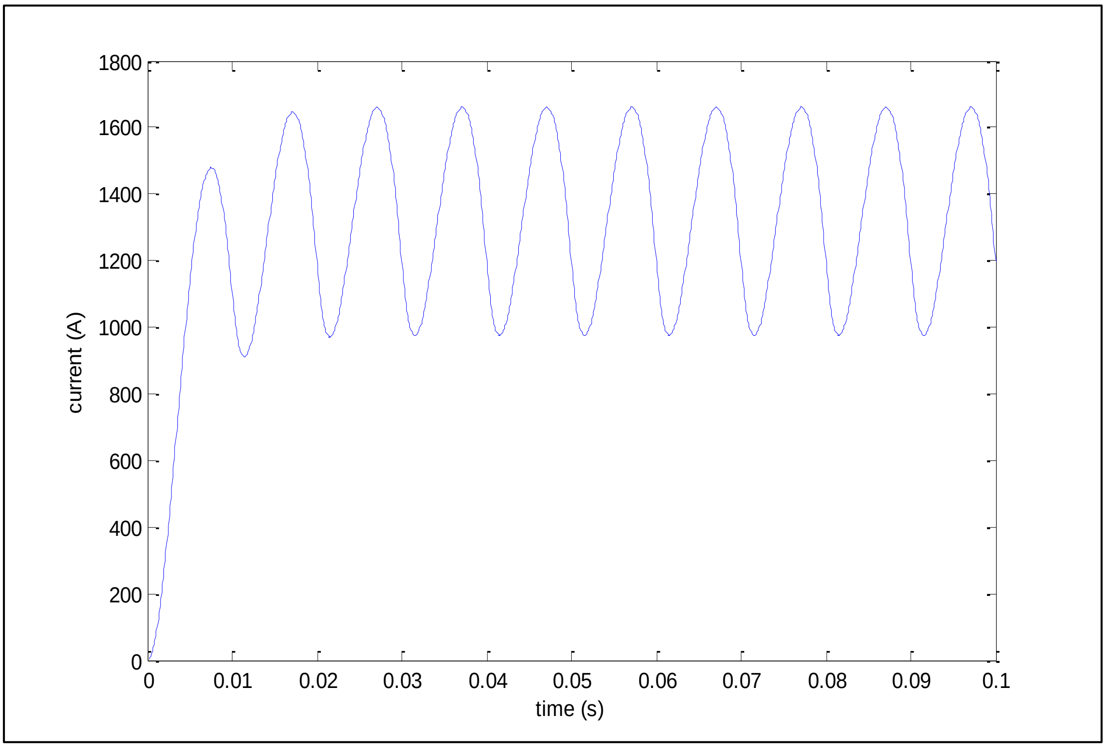

Figure 4.15 The current waveform from circuit in Figure 4.13

4.3.2 Simulation at resonant filter

Figure 4.16 a show the focus circuit at resonant filter section. Figure 4.17 was shown the voltage waveform of lamp for using single-stage electronic ballast and the current waveform of the lamp as shown in Figure 4.18.

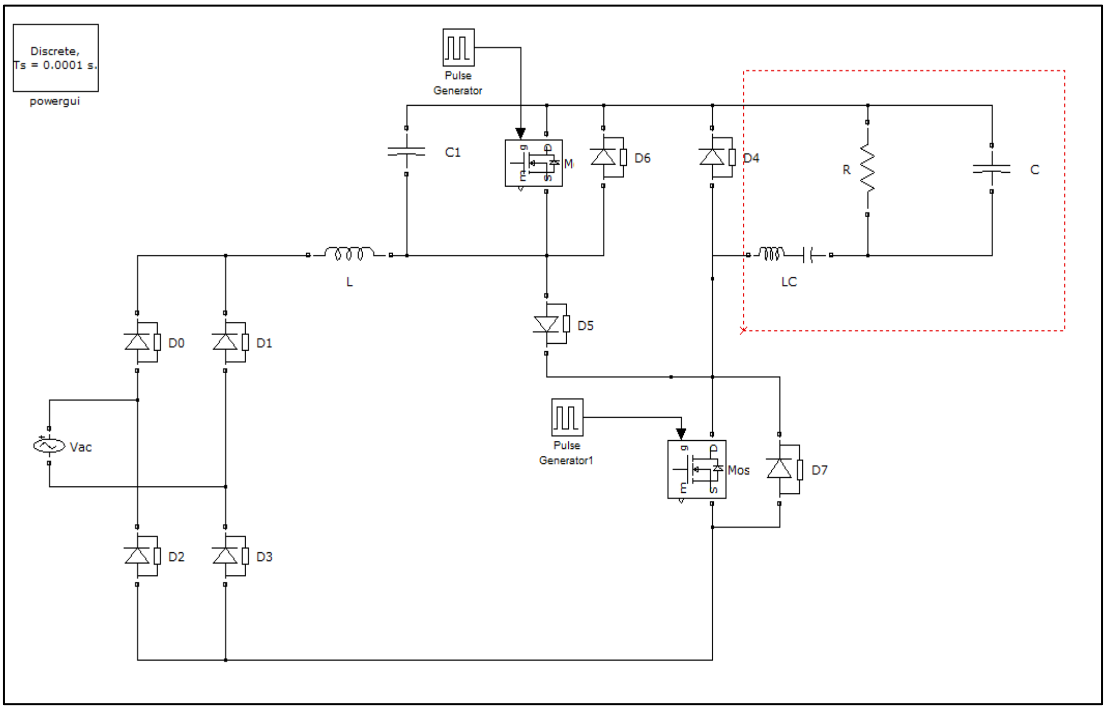

Figure 4.16 Simulation at resonant filter for single-stage electronic ballast

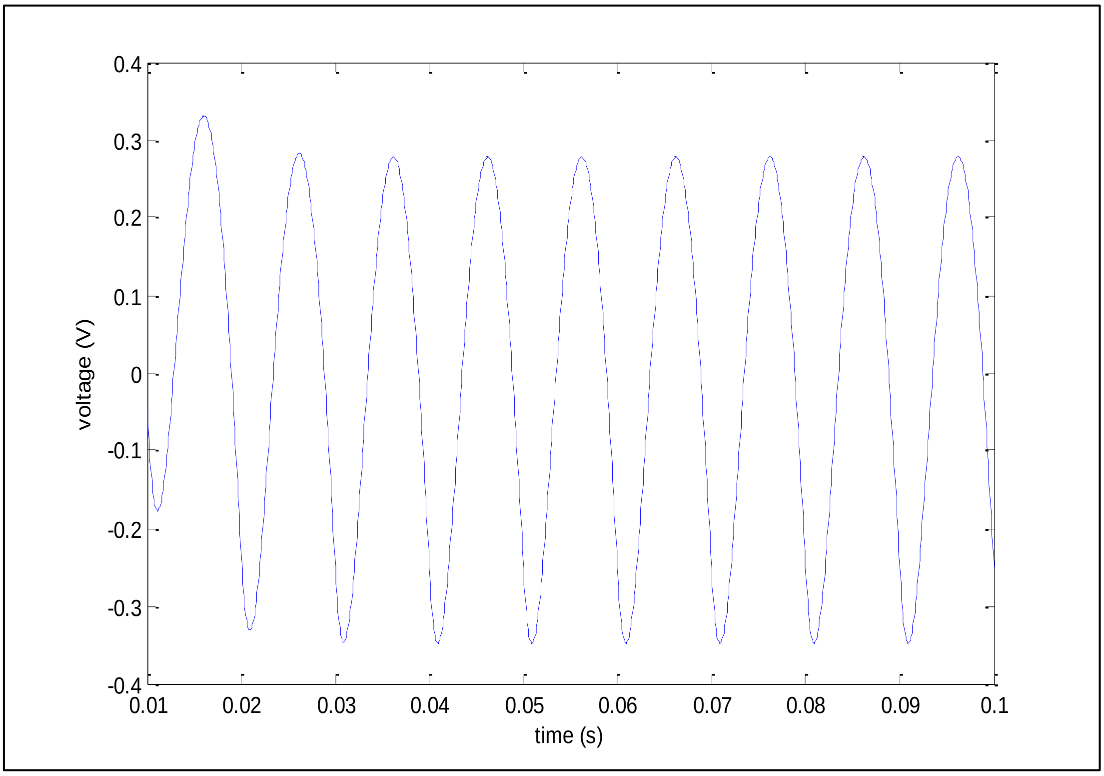

Figure 4.17 The voltage waveform for circuit at Figure 4.16

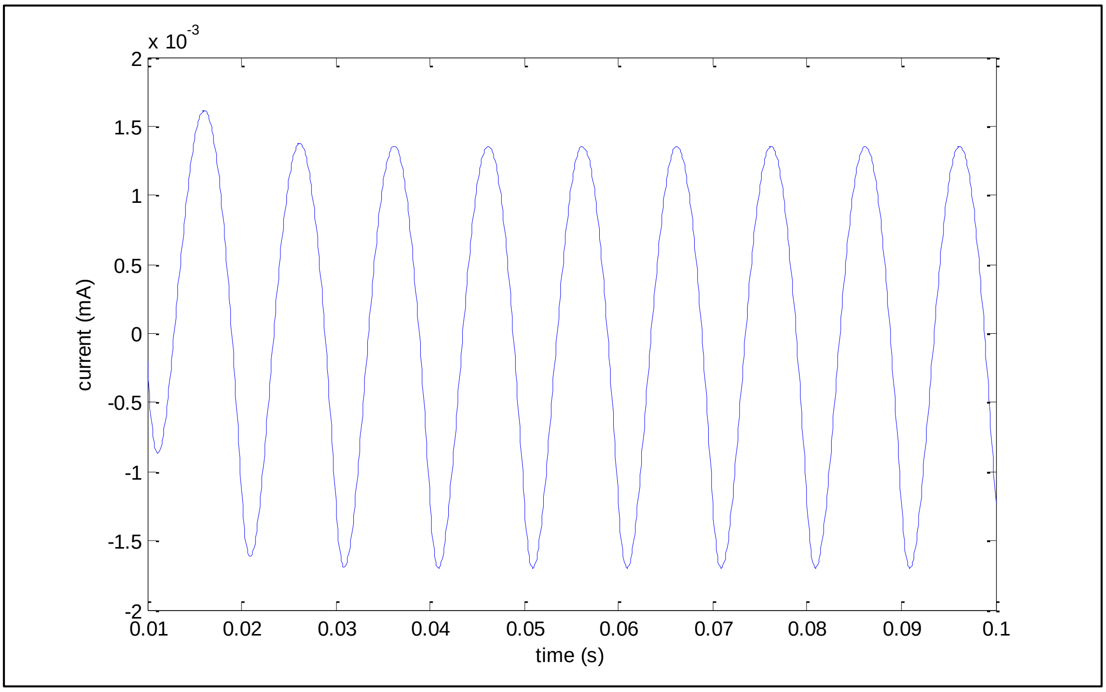

Figure 4.18 The current waveform for circuit at Figure 4.16

The voltage value of the SOEB design by using single-stage electronic ballast is 0.28 V. This value is a smaller than the value voltage of two-stage electronic ballast. Single-stage electronic ballast is reducing the number of component where they are only using two switching than the two-stage electronic ballast used three switching in the circuit. Since two switches in the two-stage electronic ballast are operated in synchronous and share its common terminal, it can be combines to only one switches used.

CHAPTER V

CONCLUSION

Three types of SOEB circuit have been developed and implemented through simulation. It is shown that both circuits have capabilities to drive the lamp effectiveness. In order to design the SOEB circuit, three main circuits must take into account, which difficult to integrate since its operation involve switching characteristics. The design of SOEB by using zener diode can reach the bigger voltage and higher resistance than the design of SOEB using two-stage electronic ballast and single-stage electronic ballast where it only reach the small voltage and small resistance. The high voltage and higher resistance will produce a small current value.

Single-stage electronic ballast is a simplification from the two-stage electronic ballast. Single-stage electronic ballast has produced the low cost of SOEB than the two-stage electronic ballast because the single-stage is reducing the number of component from the common circuit of two-stage electronic ballast.

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