THE DESIGN OF HIGH VOLTAGE GENERATOR USING IGNITION COIL UP TO 50 KILOVOLT (kV)

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MAY 2006

"I hereby declare that i have read thus thesisand in my opinion this thesis is sufficient in terms of scope and quality for the award of the Degree of Bachelor in Electrical Engineering (Industrial Power)."

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This Report Is Submitted In Partial Fulfillment Of Requirements For The Degree of Bachelor In Electrical Engineering (Industry Power)

Fakulti Kejuruteraan Elektrik
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May 2006

"I declare that this thesis is the result of my own reserach except as cited in the references."

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Date : 4/05/2006

This is dedicated to my father Lt. Kol (R) Azmi Bin Md Darus and my dear mom Rusnani Bt Yahya. My siblings, Aimie Nizam Bin Azmi, Ainie Nadiah Bt Azmi and Aimie Nazerin Bin Azmi. May their world be filled with love and peace

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Thank You.

ABSTRACT

This project covered about the designing high voltage generator by using the ignition coil. The generator ignite voltage spark, up to 10kVand measured by special custom made probe before displayed the waveform on the oscilloscope. Although there are some experiments by using the ignition coil, the voltage determined is between 35 to 40KV, which is with a hyper close distance between the probe and the spark tip . First and foremost, verifying the output signal from the ignition coil. The confirmation need to be done as to make sure that the next experiment and work can be completely obey the output signal of the circuit. The designing process work smoothly in the time gap given since the signal is known. As this is a high voltage project, this part is important and compulsory. Then only the measurement part is applied. The measurement part is covered about the output voltage versus the distance. From the look-up table and the graph, the result is an exponential graph which means that the voltage parameters are inversing the distance. Since the driver used the 555 timer, the timer is tested due to two (2) different modes-astable and monostable. The timer output signal was displayed to make sure it will drive the igniters in the safe and correct mode. This project can be applied to act as a standard lightning surge model in the future if the original circuit is connected to certain specific route. It also will proceed as a tester in the electromagnetic compatibility and applied to the filtering part, where, by using Fourier series, we can develop a filter which can eliminate the unwanted frequency in the impulse signal.

ABSTRAK

Projek ini akan merangkumi tentang proses mereka penjana voltan tinggi menggunakan gelung pencetus (ignition coil). Penjana ini berjaya menjana kuasa voltan sehingga 10kV. Sengguhpun sebelum ini terdapat kajian yang menggunakan gelung pencetus ini untuk menjana kuasa, kuasa voltan dapat dijana diantara 35KV sehingga 40KV,dimana pada jarak yang terlalu dekat diantara poin pengukur dan cetusan arka dari pencetus itu. Langkah pertama yang diambil untuk menjalankan projek ini adalah dengan mendapatkan keluaran daripada gelung pencetus ini bagi menguji kesesuaian dan kebolehan litar yang ada untuk menjana kuasa. Eksperimen ini adalah melibatkan penjanaan voltan tinggi, jadi ciri-ciri kselamatan adalah amat dititik beratkan bagi memastikan tiada masalah akan timbul dan tidak akan menjejaskan penguji dan juga persekitaran. Seterusnya keluaran ini akan diukur dalam unit voltan dan juga kajian tentang hubungan diantara voltan dan juga jarak dapat dilakukan. Daripada kajian ini, adalah didapati bahawa, kadar voltan dan jarak akan menghasilkan graf eksponen, dimana membuktikan nilai voltan adalah berkadar songsang dengan jarak. Disebabkan pemula litar menggunakan komponen pemasa 555, pemasa ini akan diuji didalam dua (2) mod yang berbeza iaitu stabil dan mono stabil. Keluaran dari pemasa akan digunakan sebagai asas untuk memastikan pemula litar adalah selamat digunakan. Projek ini boleh dijadikan sebagai asas kepada kajian tentang kilat iaitu dengan menyambungkan siri litar asas projek ini dengan tambahan litar yang tertentu bagi menghasilkan kilat. Selain itu, projek ini akan bertindak sebagai penguji didalam kesamaan elektro magnetik dan juga boleh digunakan didalam menapis frekuensi yang tidak dikehendaki yang dikeluarkan oleh keluaran impuls.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

In this chapter, the project will be introduced as the literature review and the project objective will be reveal. This chapter will provide points and fact for further understanding in this project.

1.1 Motivation and Scenario

Why is it important to setup high voltage equipment? Actually, the project of designing the high voltage equipment was explored nearly 2 decades ago. High voltage technologies are divided into certain part of such as power system, industry and also research laboratory. The most successful type of project is the high voltage transmission lines. The transmission lines were created in a high voltage in order to make sure the voltage received is high enough to supply to the consumer due to losses factor. In Malaysia, the transmission lines voltage will reach up to 500KV while in the United States the transmission line voltage will exceed 1500KV.

The ignition coil project was invented due to the existence of modern cars. The modern cars will use the igniter to detonate the spark plugs to run the car process, while for microwave oven, the high apparatus will be used in the triggering circuit to supply the microwave oven enough voltage to operate. In the medical part such as MRI-scan and X-Ray, the high voltage is used to activate adequate power to scan and examine human body as well as life creatures.

As a conclusion, the high voltage is important to the life of human being, beginning from the daily routine such as generation of power to in the power station,

to the useable cars and microwave oven and also as a guardian to the human being in the medical part such as MRI and X-Ray.

1.2 Objective

The circuit which is used to design the high voltage generator is not verified yet, therefore this project will determine either the circuit is valid or not, and if the circuit is valid, what is the consequences of this circuit to the ignition coil and also a little bit studies on a high voltage behaviour and safety

The output signal of the circuit is unknown. For completing this project the output signal of the circuit is clarified by simulate the circuit in the Pspice/Multisim software. The estimation signal is impulse, but it need a little more study on how the output will affect the whole circuit or affect the measurement part. The circuits however have it own safety component that will prevent any bad consequences.

The measurement of the High Voltage need to be settle up, a new probe to evaluate the generator design need to be prepared. This measurement probe was used in a lot of other measurement to any other devices that related with high voltage. The measurement part is an important part in order to calculate and quantify the output and the real value that we acquire from the simulation is coordinate with the testing and experiment value.

1.3 Scope of Work

In this experiment and project, certain scope of work have been set up to ensure the project will be go with the flow and in the scope of electrical engineering.

1.3.1. Choose the Appropriate Driver Circuit

There are a lot of driver circuits to drive the igniter to produce spark. Due to this condition, a lot of studies need to be done in order to pick the best driver circuit and to make sure that the circuit is save for the tester and also environment.

1.3.2. Measurement the Output

In order to get the output value and signal, the circuit needs to be simulating using electrical software. For the hardware part, it needs to be measured. To measure this hardware a simple and useful device need to be come out.

1.3.3. Clarify the Signal

The signal that comes out from the measurement part will be clarified. The signal is unknown, so by doing some research and study the literature review, the output can be clarified and based on the theoretical research, the output from measurement is differentiate either the signal obey the basic theoretical signal or not.

1.3.4. Build the Look-up Table

The look-up table is build when the measurement output is done, this is to make sure that the output spark is not harm and also it is save to connect the custom made probe to the oscilloscope, the look-up table should include the main characteristics of the voltage which is the Voltage vs. Distance.

1.4 Problem Statement

The problem in this project is the output signal of the ignition coil is unknown, since it is compulsory to proceed to the other works, it needs to be done first. The look-up table for voltage versus distance needs to be clarified, so that the effect of high voltage to the electrical apparatus can be determined. After the entire output signal has been determined, the measurement can be applied, in order to resolve the output voltage from the igniter.

1.5 Methodology

To achieve the objective of this project and answer the problems as mentioned in the previous sub-chapter, the following methodology are going to be carried out in this project:

1) Project Planning
2) Literature study
3) Determining the output signal
4) Confirmation and implementing the hardware
5) Measurement using probe

1.6 Literature Review

The literature study is done for the purpose of learning and researching as much as possible, in terms of this project application, about the basic ignition coil, the output signal of the igniter, the maximum voltage of the igniter and also the driver circuit for the igniter. The main references are;

T.H Darnell (1932) [1] have done this complicated experiment in order to find the results of an extensive series of measurement on the secondary voltage induced in an ignition coil of typical construction under a variety of operating conditions. The result will show that the theoretical predictions up till now made as to the behavior of this type of apparatus are in satisfactory agreement with the observed fact. What Darnell have done is an inspection on the secondary voltage, whish indicates that in general it is composed of two (2) oscillating components that is;

(1)- Relatively small amplitude with a high frequency
(2)- Relatively large amplitude and low frequency

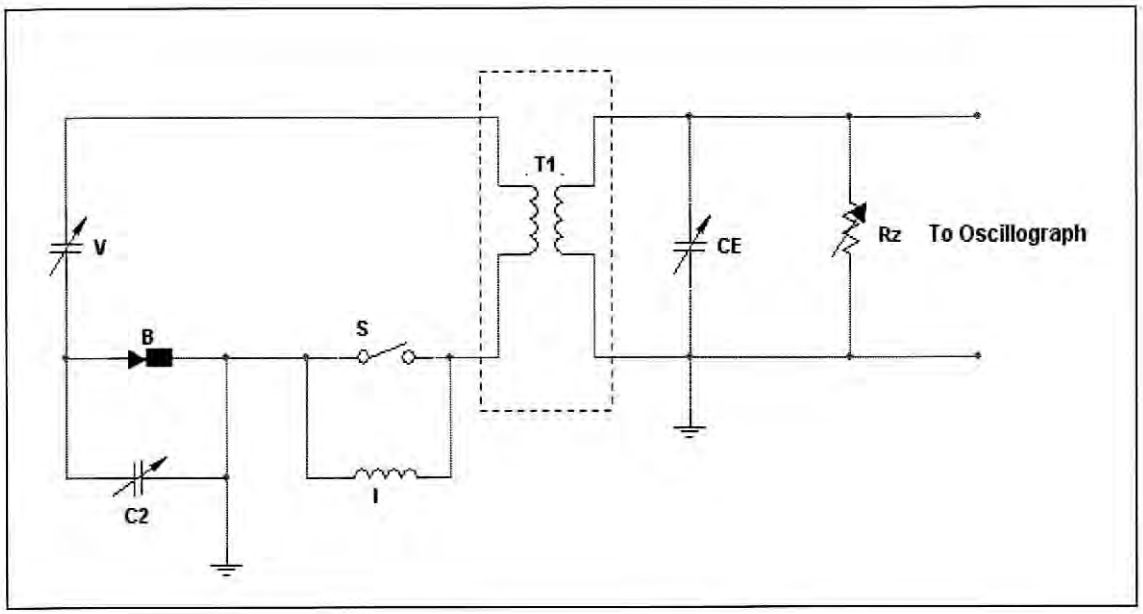

Figure 1.1: Connections used in Measurement in the Secondary Voltage Induced

Samuel M. Goldwasser (1990) [2] write in his journal that the danger to our body is not only in our body providing a conducting path, particularly through our heart. Any involuntary muscle contractions caused by a shock, while perhaps harmless in them, may cause collateral damage. There are likely to be many sharp edges and points inside from various things like stamped sheet metal shields and the cut ends of component leads on the solder side of printed wiring boards in this type of equipment. In addition, the reflex may result in contact with other electrically live parts and further unfortunately consequences.

From Mitchell International (1998) [3], write about the Bosch ignition coil which is usually used in the BMW cars and also Audi, in the article text, reporting about the description on the ignition coil and the most important thing is the testing including the testing on rotor resistance check, spark plug resistance wire, ignition coil resistance check, and also the pick-up coil check. Also stated in the article about the main resistance that need to be checked in the ignition coil which is the primary windings and also the secondary windings.

CHAPTER 2

FUNDAMENTAL BEHIND THE PROJECT DESIGN

In this chapter, the fundamental and the project preface based on the major component which is used in this project. The component theory and the theory for the probe and measurement side will be discussed further through this chapter. The circuit operation will be converse and the component will be disclosed.

2.1 Theory

In this project the main method is to know well about the ignition coil. It is because this coil will act as the main equipment in this project. Followed by the probe and the measurement process to authenticate and verify the project.

2.1.1 Ignition Coil

An ignition coil is essentially an autotransformer with a high ratio of primary to secondary windings. Referring to autotransformer, meaning that the primary and secondary windings are not actually separated but they share a few of the windings. The ratio of secondary to primary turns in an ignition coil is somewhere around 100:1. The ignition coil is operated directly off a 12 volt source. However, the ignition coil does not work like an ordinary transformer. An ordinary transformer will produce output current at the same time that input current is applied. An ignition coil actually does most of its work as an inductor. When the ignition coil is connected to the battery, the inductor is 'charged' with current. It takes a few milliseconds for the current to build up the magnetic field - this on account caused by

the increase in magnetic field. During this short charging period, maybe a thousand volts are produced at the high voltage terminal, not enough to actually cause a spark.

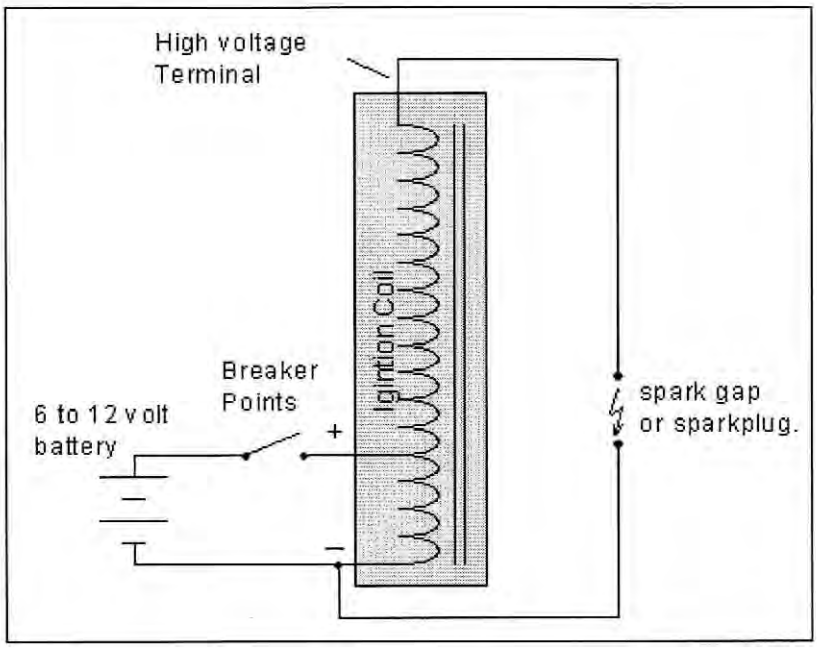

Figure 2.1: Basic Autotransformer

The actual spark is generated when the breaker contacts open. For an ideal inductor, the current and voltage relate by:

$$V = L\,dI \qquad (2.1)$$

Where V is voltage, L is inductance (in henrys) and dI is the rate of change of the current.

Thus, seeing that L is constant for the inductor, the abrupt change in current will cause a very large voltage to be produced. This produces a very short, very high voltage spike. Of course, the change in current is on the primary side, but because the primary and secondary coils have a large mutual inductance (this is where the transformer part comes in), the spike on the order of 100 or more volts on the primary will appear, and 10000 volts on the secondary. Even the primary side of the coil can give you a bit of a jolt if you hold the wires wile disconnecting power. Also note that any contacts you will use will get a lot of sparks, also on account of this.

2.1.1.1 Reports from the TH Darnell (1932) [1]

In a car, the high voltage terminal goes to the distributor, which is just a fancy high voltage rotating switch, for selecting which of the spark plugs needs to be fired. This is much cheaper than having one ignition coil for each cylinder. Modern cars of course all use electronic ignitions instead of the unreliable 'points' used in small engines or cars from the 70's. However, the ignition coil still works the same way, so you should be able to use an ignition coil even from a modern car. The main thing that has changed is that the 'points' have been replaced with fancy computer gadgetry and power electronics.

Five (5) different measurements was experiment in this report, there are;
(1)- Series with varying primary voltage
(2)- Series with varying breaker capacity
(3)- Series with varying shunted secondary capacity
(4)- Series with varying shunted secondary resistance
(5)- Secondary voltage-primary current oscillograms
Different types of graphs from different experiment are achieved. However, the basic outputs for secondary windings voltage can be determined as;

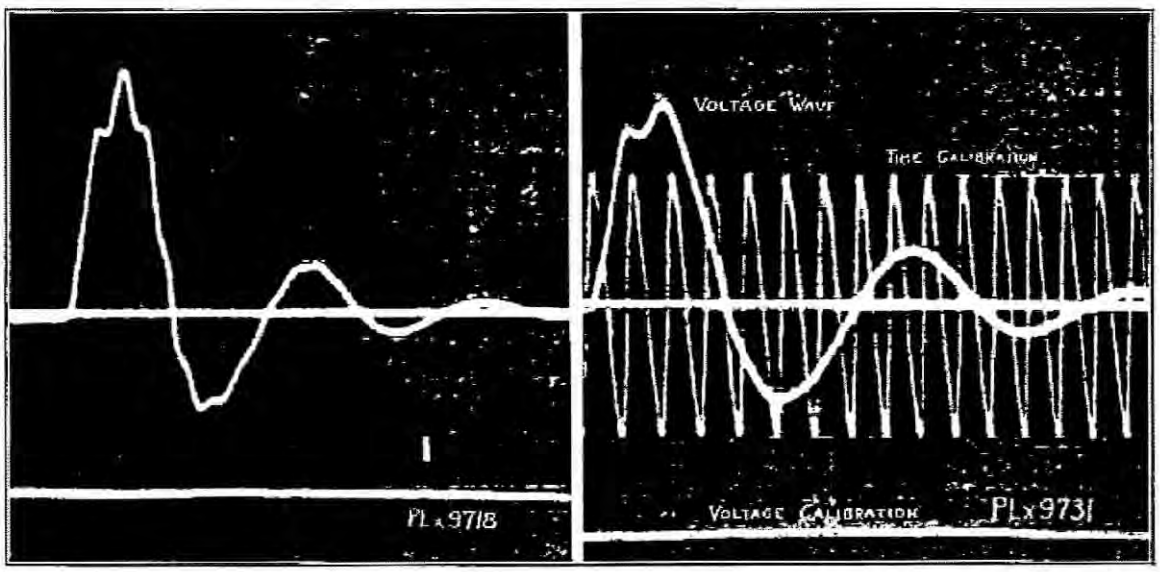

Figure 2.2: Secondary Voltage Waves versus Time Under Normal Condition

As the main conclusion from this report is, by qualitatively at least, there is very little about the electric features of the operation of an ignition coil which has not been explained and predicted by mathematical theory. By quantitatively, actual result differs somewhat from the theoretical, although as shown in the case of component frequencies of the secondary voltage wave, there is excellent agreement.

2.1.1.2 Basic Circuit for generator Using Ignition Coil

This circuit (below) should be good for about 10-20kV, depending on the ignition coil that we use. Here is another very easy ignition coil circuit which runs from line voltage as well. It uses a TRIAC and a DIAC and can produce extremely high voltages (up to 40kV) from 120VAC input. Higher voltages can be obtained by increasing the .1uF capacitor to .3uF or .4uF. Make sure the capacitor is below 1uF, if you do not the coil will probably be ruined.

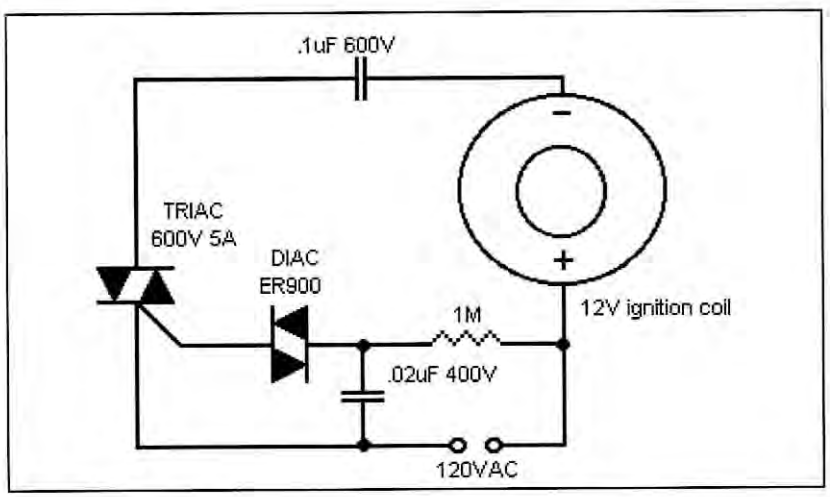

Figure 2.3: Simple Basic Generator

2.1.1.3 Conventional coils

The conventional (Kettering) spark ignition system in automotive applications uses a coil which performs the dual functions of energy storage and voltage step up. It is typically about a 100:1 turn's ratio. DC power is applied, producing a current of about 5 Amps through the 8 mH primary inductance, storing about 100 mJoule of energy. When the current is interrupted the points opening, (The