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Zulrahim Muhamad.

IMPULSE VOLTAGE GENERATOR
(LOW VOLTAGE IMPULSE)

Zulrahim Bin Muhamad

BEKP

2009

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"I hereby declare that i have read through this report entitle "Impulse Voltage Generator (Low Voltage Impulse)" and found that it has comply the pertial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

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Date : 08 MAY 2009

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IMPULSE VOLTAGE GENERATOR

(LOW VOLTAGE IMPULSE)

ZULRAHIM BIN MUHAMAD

A report submitted in partial fulfilment of therequirement for the degree of Electrical Engineering (Industrial Power)

Faculty Of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2009

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I declare that this report entitle "Impulse Voltage Generator (Low Voltage Impulse)" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	.....
Name	:	ZULRAHIM BIN MUHAMAD
Date	:	08 MAY 2009

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To my beloved father and mother

Muhamad bin Hassan

Siti Ramisah binti Jajuli

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ABSTRACT

This report covers the development of impulse voltage generator beginning the building of 2kV rectifier using two centre-tapped transformers in order to generate the 2kV impulse voltage. The wave shape that is being generated is the 1/1000μs impulse. The purpose of this project is to study the characteristic of voltage surges by generating an artificial lightning since lightning surges does not only propagate into high voltage transmission line but also into the low voltage line and electronic devices that can cause severe damages to the components. Although there is lightning protector devices invented such as Metal Oxide Varistor (MOV), the exposure to lightning impulse for several times can cause damages to the device due to the multiple overvoltage and overcurrent produced by these flashes. This surge is a transient electrical disturbance that is cause by lightning, switching operation or faults. Although a natural lightning stroke is actually made up of a multiple strokes, up to 27 strokes per flash, which were specified in the Standard Impulse Testing Procedures, the impulse voltage generator in this project producing only a single stroke. Due to the failure to of the rectifier to rectify the 2kV DC output, the further development of the project was being halted for a few months. The development was being continued after it has been decided to use a voltage multiplier for the supply purpose. Unfortunately, the wave shaping circuit does not work well and not even a single spark is created. Therefore, due to the lack of progress, the objective of the project does not been achieved.

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ABSTRAK

Laporan ini menerangkan tentang pembangunan penjana dedenyut voltan bermula dari pembinaan penerus 2kV menggunakan dua alat ubah ambilan-pusat dengan tujuan mendapatkan dedenyut voltan 2kV. Bentuk gelombang yang dihasilkan adalah dedenyut 1/1000μs. Tujuan projek ini adalah bagi mengkaji ciri voltan pusuan dengan mewujudkan satu kilat tiruan kerana pusuan kilat bukan sahaja boleh memrebak kepada talian penghantaran voltan tinggi tetapi juga ke talian voltan rendah dan peranti-peranti elektronik yang boleh menyebabkan kerugian teruk untuk menggantikan komponen tersebut. Walaupun terdapat peranti pelindung kilat seperti *Metal Oxide Varistor* (MOV), pendedahan pada dedenyut kilat untuk beberapa kali boleh menyebabkan kerosakan pada peranti tersebut akibat terdedah pada voltan lampau yang berbilang dan arus lebih. Pusuan ini adalah satu gangguan elektrik fana yang diseebabkan oleh kilat, operasi pensuisan atau litar pintas. Walaupun satu sambar kilat semula jadi adalah daripada satu pukulan berbilang, sehingga 27 pukulan setiap kilat, penjana dedenyut voltan dalam projek ini mengeluarkan hanya satu satu pukulan seperti yang telah ditentukan dalam Prosedur-prosedur Ujian Dedenyut Standard. Akibat kegagalan penerus untuk meneruskan isyarat arus ulang-alik 2kV, perkembangan lanjut projek ini menjadi terhenti untuk beberapa bulan. Pembangunan diteruskan selanjutnya dan setelah memutuskan untuk mengunakan satu pengganda voltan sebagai bekalan isyarat 2kV arus terus. Malangnya, litar pembentukan gelombang tidak berfungsi dan tiada percikan api yang terhasil. Oleh itu, akibat kurangnya kemajuan, objektif projek tidak tercapai.

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LIST OF ABBREVIATIONS

SPD	-	Surge protector device
T	-	Duration of the voltage surge
MOV	-	Metal oxide varistor
AC	-	Alternating current
DC	-	Direct current
R	-	Resistor
C	-	Capacitor
SG	-	Spark gap
Vs	-	Supply voltage
Vo	-	Output voltage
Vc	-	Voltage at the capacitor
Tr	-	Transformer
I	-	Current
GDT	-	Gas discharge tubes
TVS	-	Transient voltage suppression
DPO	-	Digital phosphor oscilloscope
PMT	-	Photomultiplier tubes
Z	-	Impedance
X	-	Reactance
N	-	Number of turns
E	-	Potential difference
Y	-	Admittance
RMS	-	Root mean square
P	-	Power
MCB	-	Miniature circuit breaker

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CHAPTER 1

INTRODUCTION

1.0 Project Background

Although the development and performance of Surge Protector Device (SPD) are being upgraded every year, voltage surges are still one of the main reasons for the damages of equipments especially electronic devices. Voltage surge is a voltage impulse or wave which is superposed on the rated network voltage. A voltage surge disturbs equipment and causes electromagnetic radiation. Furthermore, the duration of the voltage surge (T) causes a surge of energy in the electrical circuits which is likely to destroy the equipment.

The purpose of this project is to develop an impulse voltage generator circuit that will generate an impulse output wave shape. This project was proposed for the use of surge protector device (SPD) experiments that involving low voltage impulse because the existing impulse generator is not suitable for low voltage SPD testing due to the huge construction of the equipment and its rating that only covers in high voltages. There are also sensitivity issues on conducting the test on low voltage SPDs in term of the sphere gap adjustments. Furthermore, it has been recognize that there are a limited number of studies on low voltage SPD compared to the high voltage SPD and direct lightning protective devices.

This impulse generator will be use to study of the characteristic of voltage surges by generating an artificial lightning since lightning surges does not only propagate into high voltage transmission line but also into the low voltage line and electronic devices that can cause severe damages to the components. Although there is lightning protector devices invented such as Metal Oxide Varistor (MOV), the exposure to lightning impulse for several times can cause damages to the device due to the multiple overvoltage and

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overcurrent produced by these flashes. This surge is a transient electrical disturbance that is cause by lightning, switching operation or faults.

Although a natural lightning stroke is actually made up of a multiple strokes, up to 27 strokes per flash, which were specified in the Standard Impulse Testing Procedures, the impulse voltage generator that will be develop is producing only a single stroke. There are several requirements regarding the impulse that is generated in this project which is a single impulse of 1/1000μs rated at 2kV. Those requirements are the standard testing for low voltage lightning impulse.

1.1 Problem Statement

The basic study in high voltage engineering is breakdown characteristic of a material due to overvoltage and overcurrent phenomenon. As for this particular project, the study is about breakdown characteristic of a material due to low voltage impulse. Prior to that, it is essential to develop a low voltage impulse generator that can produce an artificial lightning surge for the study purpose. The existing impulse voltage generator is for generating an impulse voltage at higher rating up to 20MV and the construction is very massive. Furthermore, the study of breakdown characteristic due to low voltage impulse is quite few compared to high voltage impulse. Thus, this project results a break through findings that can be beneficial to electrical and electronic technologies.

1.2 Objectives

From the project background and problem statements that were explain before, therefore the design and development of an impulse voltage generator that producing a low voltage impulse up to 2kV is performed. The result from this project is based on the below objectives:

- To construct an impulse voltage generator that can produce up to 2kV impulse voltage.
- To generate a single impulse voltage rated at 1/1000μs (artificial lightning).

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- To conduct test on single artificial lightning impulse on low voltage surge protector devices.
- To analyzes the effect and performance of low voltage SPD due to the exposure of indirect lightning.

1.3 Project Scope

The scope of the project are defined to meet the requirement of the Standard Impulse Voltage Testing Procedure.

- The amplitude of the impulse is rated at 2kV.
- To generate 1/1000μs. Standard testing for low voltage lightning impulse.
- The impulse that will be generated is only single stroke.

1.4 Project Report Outline

This project report consists of seven chapters which are explained below;

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Methodology

Chapter 4: Impulse Voltage Circuit Development

Chapter 5: Results

Chapter 6: Discussions of Results

Chapter 7: Conclusion

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Chapter 1 is the overview of the project research which includes the problem statement, objective and scope of the project.

Chapter 2 explain the literature review and theory background that related to this research. It explain the formation of lightning, impulse voltage generation, high voltage direct current supply, Capacitor and the test objects that can be used with this device. Studies on literature review helps in understanding the fundamental of impulse voltage and how it relates to the lightning.

Chapter 3 will discuss about the methodology that were adapted to this research by explaining the whole project procedure from the beginning where it will be presented in flow chart and following with a brief explanation

Chapter 4 covers the major parts of the experimental work that begins with the general safety procedure, the equipments used, the building of the circuit and then the measurement of the impulse.

Chapter 5 will be discussing the output of the experiment. All the recorded data are gathered before the analysis are beginning. This includes the output signal and its statement.

Chapter 6 is the part where all the data are analyzed. This includes the problem and explanation of the problems that occur during the project period.

Chapter 7 will conclude all the works and had been presented in previous chapter and all the results of the research project. This is followed by recommendations for the future study work.

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CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In order to get reference regarding the project, reviews of past studies, articles, documents, journal and books has been made. In this chapter, the studies that relates to the development of Impulse Voltage Generator is explained from the begining starting about how lightinig is created and how indirect lightning can cause damages to equiptments. The circuitary that used to built-up the generator is studied and explain along the chapter. It includes the equation to design the appropriate component to be use. The circuit is supplied using 2kV DC from 240V AC. The rectification of the voltage in prior experiment is detailed in the middle of this chapter in cluding the charging capacitors that were used. At the ending of this chapter, description of the test objects that is apply to this generator is clarified.

2.1 Lightning

Lightnings occur in thunderclouds which is the cumulonimbus. This clouds are form from the condensation process when hot moist air rises to atmosphere that are heated by the sun. As it risen, the moist of hot air mingles with colder air and condenses into water dropltes until cloud are forms. As the droplets becoming so huge, the cloud become a cumulonimbus cloud.

This cloud creates lightings which are the discharge of electric charges of giant capacitors; the cloud. The discharges are in the form of sparks or flashes. The discharge occurs between the clouds or the cloud to the ground. 90% or the discharges occur in the clouds during thunderstorms and only 10% the sparks strike the ground [1]. Researches has

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been conducted and found that the upper part of the clouds contain particles with positive charges at -20°C and the lower part contain negetive particles at -5°C degree celcius as shown in Figure 2.1(a). there are still some places in the lower part of the cloud that have positive charges that contributes to cloud-to-cloud strokes[2].

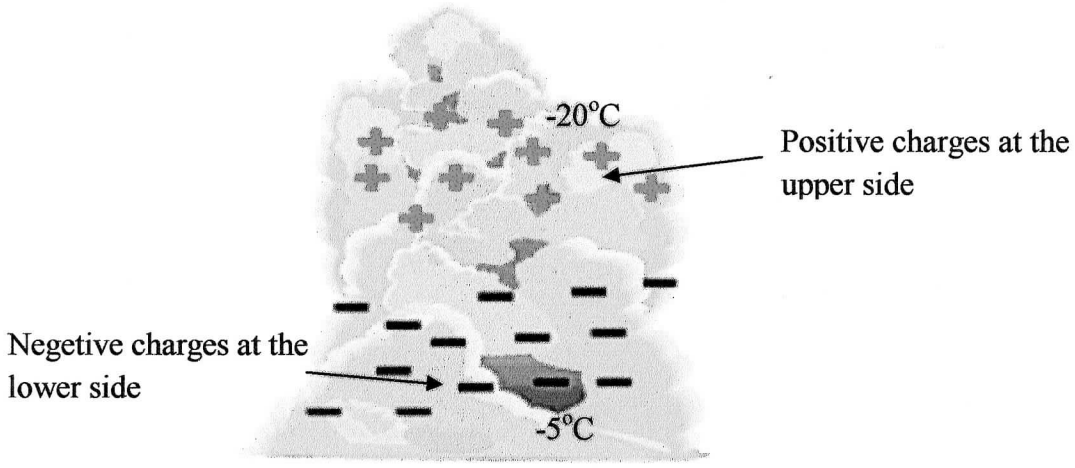

Figure 2.1(a): Cumulonimbus cloud

As the cumulonimbus cloud moving, it gathers positive charges on the ground creating a pool of positive chargesas shown in Figure 2.1(b), image 1. When the cloud reach to a tall object such as tall buildings, transmission lines, lightning electrodes and for example in the Figure 2.1(b), image 2, a tree, the positive charges tend to gather to the highest point of the object creating a high potential different between the cloud and the ground. Due to the high potential, the negetive charges breakdown between the moist ionized air creating a streamer towards the groud that progresses in about 50m before it halt due insufficient charges at its head. After a short while in about 100μs, the streamer start again and making progress to its length and creating branches until it stops. This process called 'stepped leader' repeated several time for about 20ms at the same path.

As this stepped leader stroke progresses to the ground, shown in Figure 2.1(b), image 3, connecting the cloud and the ground, electric transfer occur which is the lightning. After the initial lightning stroke, if enough charge is leftover, additional lightning strokes will use the same channel and will give the bolt its flickering appearance.

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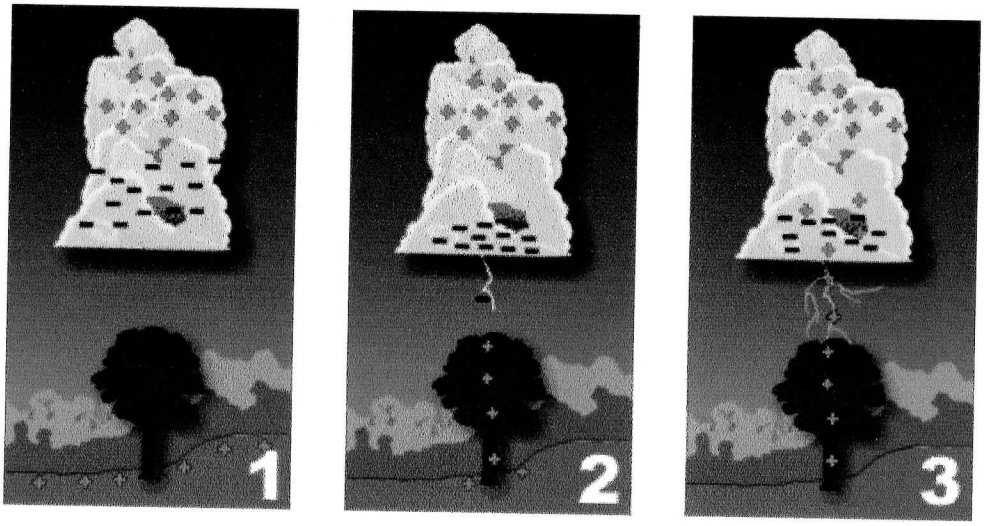

Figure 2.1 (b): Process of lightning

2.2 Impulse Voltage Generation

For the lightning impulse testing of basic arrangements but also of different electrical components a purely capacitive load can be assumed. The impulse voltage shape generated by an impulse voltage test generator circuit can be described by two exponential functions with different time constants. Whereas the impulse front time T_1 is essentially determined by the resistance of the front resistor R_s located in the impulse voltage test generator and the load capacitance C_t, as shown in Figure 2.2, the time to half-value T_2 is determined by the impulse capacitance of the impulse capacitor C_i and the resistance of the tail resistor R_p being part of the impulse voltage test generator.

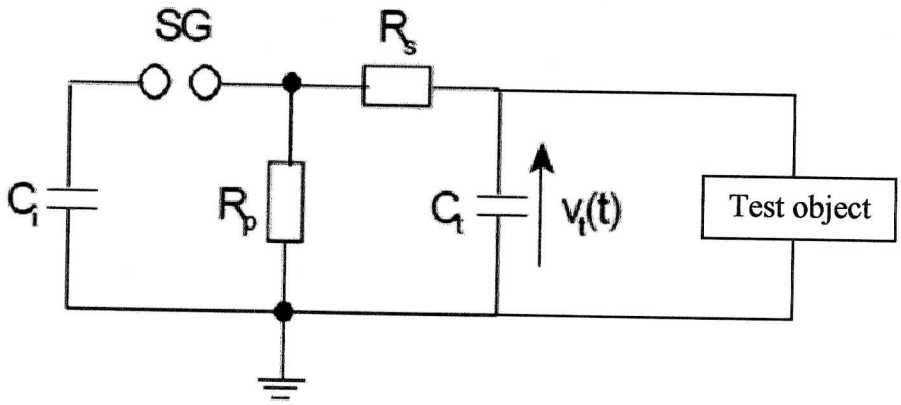

Figure 2.2: Circuit to control the impulse shape and the placement of the test object

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C_i : Impulse capacitance

C_t : Capacitance of the load (including voltage divider)

R_p : Tail resistor

R_s : Front resistor

SG : Switching spark gap

The standard lightning impulse of 1.2/50μs in Figure 2.3 is the typical wave form of the double exponential. T_1 is the time between 10% and 90% of the impulse amplitude but in the case that 10% of the amplitude is not clear, T_1 is defines as 1.67T as shown in Figure 2.3. T_2 is the time of T' to 50% if the amplitude.

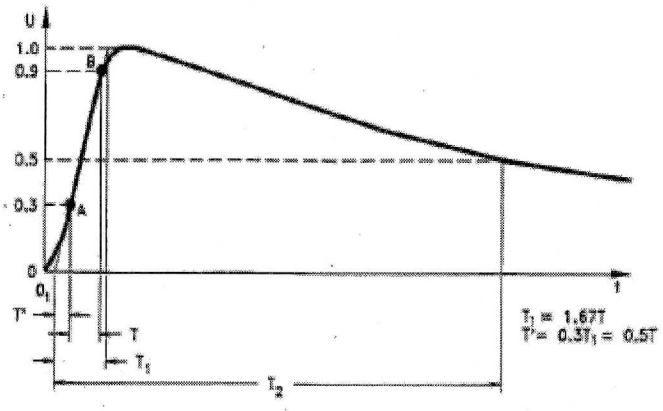

Figure 2.3: Standard lightning impulse 1.2/50 with time parameter T1 and T2

2.3 High Voltage Dirrect Current Supply

The generator is supplied with 2kV DC and the main supply for this voltage is a 240V AC. The step-up process and rectification process can be done with several ways. Related to this project, the 2kV DC is achieved by using two serial rectified center-tapped transformers and voltage multiplier.

A center tapped transformer has a wire that is connected to a point half way along one of the windings of the transformer. In a transformer rectifier, with a center tapped transformer and two diodes as in Figure 2.4, it can form a full wave rectifier that allows

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