ANALYSIS RESIDUAL VOLTAGE OF SURGE PROTECTION DEVICE(SPD) BASED ON GROUNDING AND COORDINATION

MUHAMAD SYAFIQ BIN BADRUL AZMAN

BACHELOR OF ELECTRICAL ENGINEERING WITH HONORS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

ANALYSIS RESIDUAL VOLTAGE OF SURGE PROTECTION DEVICE(SPD) BASED ON GROUNDING AND COORDINATION

MUHAMAD SYAFIQ BIN BADRUL AZMAN

A report submitted
in partial fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering with Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2019

DECLARATION

I declare that this thesis entitled "ANALYSIS RESIDUAL VOLTAGE OF SURGE PROTECTION DEVICE(SPD) BASED ON GROUNDING AND COORDINATION is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:	
Name	:	MUHAMAD SYAFIQ BIN BADRUL AZMAN
Date	:	28 MAY 2019

APPROVAL

I hereby declare that I have checked this report entitled "ANALYSIS RESIDUAL VOLTAGE OF SURGE PROTECTION DEVICE(SPD) BASED ON GROUNDING AND COORDINATION" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

ACKNOWLEDGEMENTS

In the name of Allah SWT, the most Beneficent and Merciful, all praises and glory be upon him. Blessing and greeting upon our beloved prophet Muhammad SAW, his family and companions. In preparing this report, I was in contact with many people, researchers, academicians and practitioners. They have contributed towards my understanding and thought. First and foremost, I wish to express my sincere appreciation to my main project supervisor, Dr. Farhan Bin Hanaffi, for encouragement, guidance critics and friendship. I am extremely indebted to him for his expert, sincere and valuable guidance extended to me. Without his support and interest, this project would not have been the same as presented here.

I take this opportunity to express my special gratitude and thanks to my fellow undergraduate students for their support. My sincere appreciation also extends to all my colleagues and others who have helped at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members.

ABSTRACT

This project was about impact surge protection device (SPD) based on residual voltage. Nowadays, the global stand with modern technology so that many microprocessors were used in daily life. By using SPD, the overvoltage will limit the overvoltage and reduce from damage the circuit. This project done in the low-voltage system. Every coordination between SPD and grounding resistance has different value of residual voltage. The important characteristic was when residual voltage must be lower than the load voltage withstands. For this reason, the residual voltage was important to make sure the electrical appliance in a good condition. Next, study about value grounding also important to make sure the surge current will flow to the earth. For methodology, simulation SPD circuit modelling was used in PSCAD software. PSCAD was used to analyse the characteristic of SPD and study oscillation phenomena when using different length cable between SPD. For the case study coordination of SPD, difference value of the distance between SPD were determined to get a better residual voltage. For the study on case of grounding method, the suitable value of grounding will be selected to observe analysis result about level protection of SPD. Having this study method, the value of residual voltage (U_{res}), level voltage protection (U_p), and value of withstand voltage (U_w) can be analysed. So, based on the analysis data the level protection SPD can be implemented by the correct SPD installation.

ABSTRAK

Projek ini berkaitan dengan impak alat pelindung kilat (SPD) berdasarkan sisa voltan. Pada zaman sekarang, dunia berdepan dengan teknologi moden jadinya terdapat pelbagai microprosessor digunakan dalam kehidupan seharian. Dengan menggunakan SPD, voltan berlebihan akan dapat dihadkan dan menggurangkan kerosakan pada litar. Projek ini akan dilakukan dalam system voltan rendah. Setiap koordinasi antara SPD dan rintangan pembumian mempunyai perbezaan nilai voltan sisa. Untuk menahan daripada kerosakan,sisa voltan perlulah rendah daripada muatan voltan. Oleh sebab itu, sisa voltan amat penting untuk memastikan barangan elektrik berada dalam keadaan baik. Seterusnya, kajian mengenai nilai peribumi juga sangat penting untuk memastikan aliran kilat dapat dialirkan ke bumi. Untuk methodologi, model litar simulasi SPD akan digunakan didalam perisian PSCAD. PSCAD digunakan untuk menganalisa ciri-ciri SPD dan mengkaji fenomena getaran apabila mengunakan jarak kabel yang berbeza antara SPD. Untuk kajian koordinasi SPD, nilai berbeza antara jarak SPD ditentukan untuk mendapatkan sisa voltan yang berbeza. Untuk kajian kes pembumian, nilai pembumian yang sesuai akan dipilih untuk menilai analisa keputusan mengenai tahap pelindungan SPD. Dengan menggunkan cara ini, nilai sisa voltan, tahap pelindungan voltan dan nilai ketahanan voltan dapat dianalisakan. Berdasarkan analisa data, tahap perlindungan SPD dapat dilaksanakan dengan pemasangan SPD yang betul.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

SPD	-	Surge Protection Device
U_{res}	-	Residual Voltage
U_w	-	Withstand Voltage
U_p	-	Level Protection Voltage
I_n	-	Nominal Discharge Current
PSCAD	-	Power System Computer-Aided
MOV	-	Metal Oxide Varistor
GDT	-	Gas Disharge Tube
ρ	-	Soil Resistivity
l	-	Rod length
a	-	Area of rod
ε	-	constant 8.5419 x 10^{-12}
μ_0	-	constant 1.25664 x 10^{-6}

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Lightning is the visible discharge of static electricity, either between clouds or between cloud and earth. Lightning could strike anywhere on earth. High earth resistivity will be increased when a lightning strike occurs[1]. Lightning can cause overvoltage and damage the electrical system. It can directly strike to the system or indirectly by induce to the correlating point. If the lightning strike to the structure in certain areas, its possibility damages the system. If there was no lightning protection system present in the building, it will cause the electrical apparatus damage. Therefore, it necessary to protect electrical system apparatus from lightning current or surge. Thus, surges produce a very high voltage that can damages and disrupts the function of the electrical and electronic component.

Nowadays, the development of electronic technology is growing fast. Due to this, circuit or microprocessor based on electric and electronic devices are widely used in human daily life. Such as a computer system, which has many circuits that are have weak voltage withstand capability. Every type of electrical appliance is design with insulation to isolate the electrical voltage from the earth. The insulation strength depends on the rated voltage and types electrical component. Therefore, by knowing how to limit the overvoltage was the great economic and technical value because it can save the electrical appliance from damage.

Surge protection device (SPD) is using to limit the overvoltage and release the high current through the grounding in the low-voltage power distribution system. Therefore, to limit the overvoltage and achieve the purpose of protecting electronic equipment, SPD is widely used in low-voltage distribution system[1]. Many factors such as protection level SPD, installation mode, and coordination of SPD should be considered for installation of the SPD.

1.2 Motivation

Every house has an electrical route to the earth to protect a building and electrical circuit from any unwanted current and voltage damaged. Even though the building has lightning protection, the surge current still flows to the system. Lightning surge can cause failure of circuit breaker and power transitions between devices or damage equipment. In the case of lightning strikes, the best way to protect the electrical equipment is to disconnect electrical appliances when thunderstorm occurred. Otherwise, people needed to install SPD in order to protect the entire electrical equipment in low voltage from lightning surge. Nowadays, the protection of surges was essential as many microprocessors and electronic equipment is too sensitive to surge overvoltage were used in our daily life. Therefore, proper installation is required to protect the entire house with surge protection. In term of correct installation methods, the SPD are necessary to ensure that the electrical appliance always in good condition.

1.3 Problem Statement

The installation of SPD is a significant role in the surge protection of equipment. The problem could come out if the residual voltage flow at the load is over to load withstand voltage. Firstly, this factor is influence by coordination between SPD and different type grounding. The different loads and coordination between SPD make different surge across the SPD and load. If SPD is installed without consideration proper coordination, the equipment to be protected might be damaged due to overvoltage. This is because there are reflection phenomena on the cable between SPD and the load protected as describe in the IEC 61643-12. The other problem is residual voltage effects on value of grounding resistance. Grounding resistance will make the SPD operation make the SPD operation less efficient because the surge current cannot release to the ground faster. Therefore, the evaluation of coordination and grounding resistance value is needed to investigate the performance of the SPD. The higher value of grounding can make the current will flow to the load than flow to the ground.

Furthermore, the lightning surge in low voltage equipment can be affected by the grounding resistance. Hence, value grounding resistance related to the performance of the SPD.

1.4 Objective

The objective of project is:

i) To analyse different grounding model on SPD residual voltage.

ii) To analyse the effect of length for different grounding configuration.

iii) To analyse SPD residual voltage due to cable length between SPD and protection load with different grounding configuration.

1.5 Scope of Project

In this project, the power system computer-aided design (PSCAD) software has been used to analyze the residual voltage between coordination SPD and grounding configuration. The selected installation of SPD was in the building at low voltage for single phase. Next, this project used MOV type of SPD to analyze the data. Thereby, MOV behavior can show by the non-linear voltage current characteristic. The grounding system TT system connection has been used in this project. Grounding configuration value cover in this project was 10Ω, 50 Ω, 150Ω, 500Ω and 1000Ω. This range of ground resistance value was chosen since Malaysia's soil resistance was not very high. Furthermore, this research focuses on lowland area rather than a sandy area such as the beach. Other than that, length of connecting cable between SPD will vary 3 different lengths which was 1m, 5m, and 10m. The type of load resistance was used in this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Surge Protection Device

SPD is a device to protect electrical equipment from overvoltage transient and SPD will divert the current to the ground caused by lightning or switching action. Generally, the electronic equipment uses were very small in voltage and power level to operates. Which means a small surge current or transient voltage is enough to cause high temperature and breakdown of the voltage to the electronic equipment. Connection SPD must be installed parallel with the load. Thus, once transient overvoltage appears in the system, the impedance of the SPD decreases so the surge current will flow through SPD bypassing the equipment or load.

According to IEC 61643-12[2], the SPD can be divided by two types which is voltage limiting type of SPD and voltage switching type of SPD. The voltage limiting type of SPD that has high impedance when no lightning surge, but it will reduce it continuously by increase the surge current and voltage. Common example component using in the limiting type SPD are varistor and avalanche diodes. The voltage switching SPD has higher impedance when no surge present, but it will drop the impedance in response to voltage surge. Common example component using in the switching type SPD are spark gaps, gas tubes and thyristors. The limiting transient voltage waveform when lightning surge using SPD shown in Figure 2.1 and the response of voltage switching type SPD shown in Figure 2.2.

Figure 2.3 shows that the 8/20 µs waveform for indirect impact lightning strikes. The applied current waveform when the lightning occurs which is the front time or rise time is 8µs. The second number is the half peak value or tail times is 20µs.

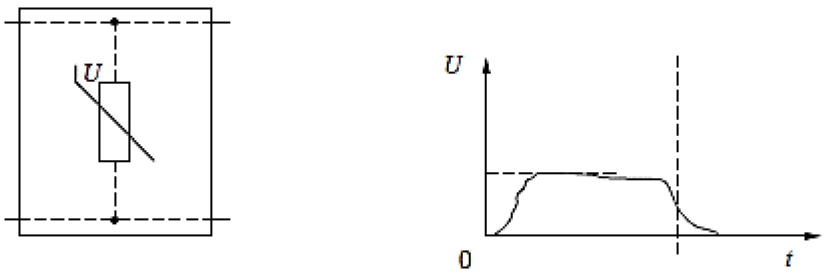


Figure 2.1: Response Of Voltage Limiting Type SPD[2]

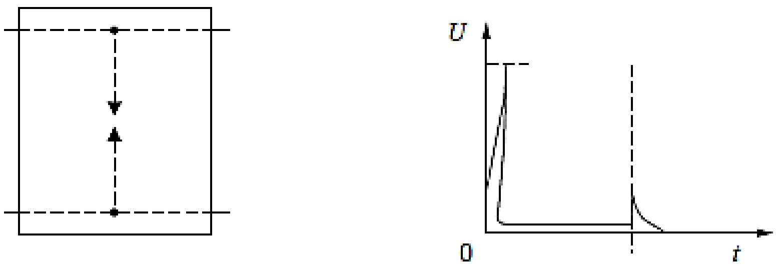


Figure 2.2: Response Of Voltage Switching Type SPD[2]

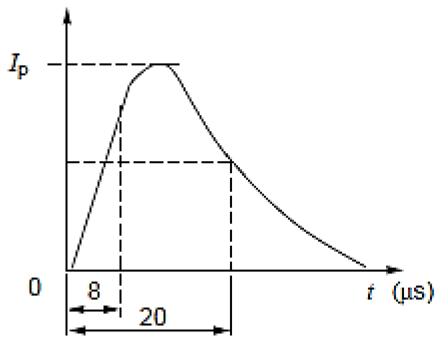


Figure 2.3: 8/20µs Current Waveform[2]

Gas discharge tubes (GDT) and metal-oxide varistor (MOV) are the most common component of SPD. GDT and MOV have their own characteristic to be effective surge protection device.

2.1.1 Gas Discharge Tube (GDT)

GDT usually consist of two or three electrodes in a glass or ceramic, inert gas filled package shown in Figure 2.4[3]. The electrodes are aligned with a small gap between GDT. When the voltage across the electrodes exceeds a certain value, an arc will occur in the tube. Based on the result, it can create a low current path. GDT with three or more electrodes can be constructed with a single volume of gas by providing holes in the internal electrodes. GDT has two regions, which is glow region and normal glow region.

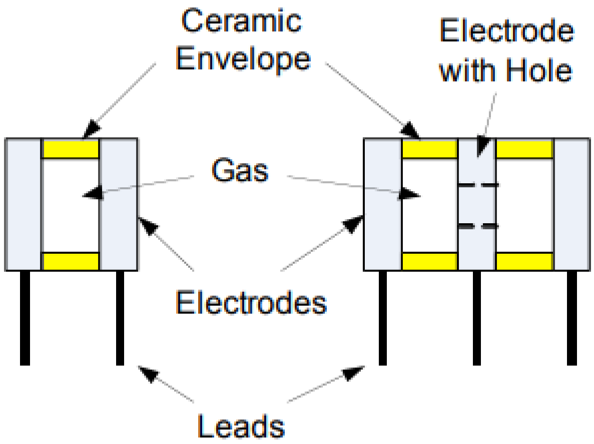


Figure 2.4: Simple Cross Section of Two and Three Lead GDT[3]

A typical V-I curve for GDT shown in Figure 2.5[4]. At point A, GDT turns it conditions from an insulating state to a conducting state. Once a potential reached the transient voltage, the voltage across the GDT will collapse and causing negative incremental resistance. Next, glow region occurs at the segment of the curve between point B and point D. Normal glow region will produce when the voltage across GDT at point B to point C is approximately independent of the current. When the current increase at point D to point E, the GDT voltage drop to the level arc voltage where it remains until the surge passes away. The arrestor remains conductive until its current falls below its level. After the current surge has disappeared, the current is reduced to extinguish the current arc.

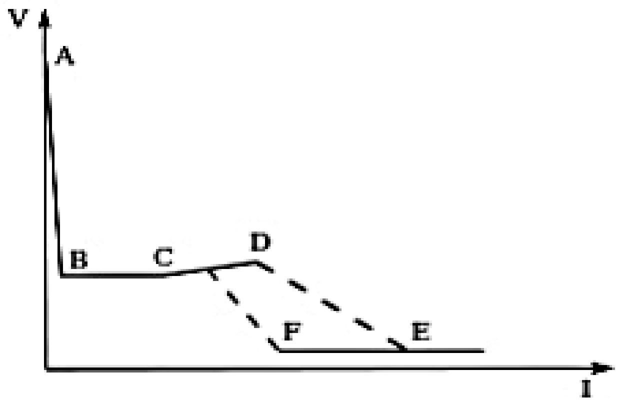


Figure 2.5: Typical V-I Relationship For Gas Discharge Tube[4]

2.1.2 Metal Oxide Varistor (MOV)

MOV is the most commonly used type of varistor. It is made from a mixture of zinc oxide and other metal oxides like cobalt, manganese and so on. MOV will be kept undamaged between two electrodes which are basically metal plates. This structure acts like diodes and connected in series or parallel to ensure a nonlinear performance. MOV is designed to handle a large amount of current for the microsecond surge time frame. MOV is the most commonly used to protect heavy devices from transient voltages. For this reason, MOV was the best choice and widely used for surge arrester. MOV characteristic can be divided by three main regions which is low electric-field region, medium electric-field region and high electric-field region[4].

At the low electric-field regions, which are before a surge, a low voltage is applied at the varistor terminals. The diode does not conduct the current and the varistor will act as an insulator. Next, at the medium electric-field region, the current suddenly increases when the electric field reaches the value over 100 KV/mm. In these regions the current will varies from 1mA to 1kA[4]. Lastly, in the high electric-field region, which is during the lightning surge, MOV changes from very high impedance to a short circuit. The MOV at these regions does two things such as provide short circuit path for the surge current to flow to the ground. Secondly, the MOV will cut off the over transient voltage to the safe level[5].

Figure 2.6 shows the I-V characteristic curve for metal oxide varistor and Zener diode. MOV basically a highly non-linear resistor. It is symmetrical, so it works well AC and DC. In operation, it functions as similar with two Zener diodes placed head to foot. The major difference is that the breakdown has a much softer knee than the Zener combination, so its voltage breakdown limit is not precise.

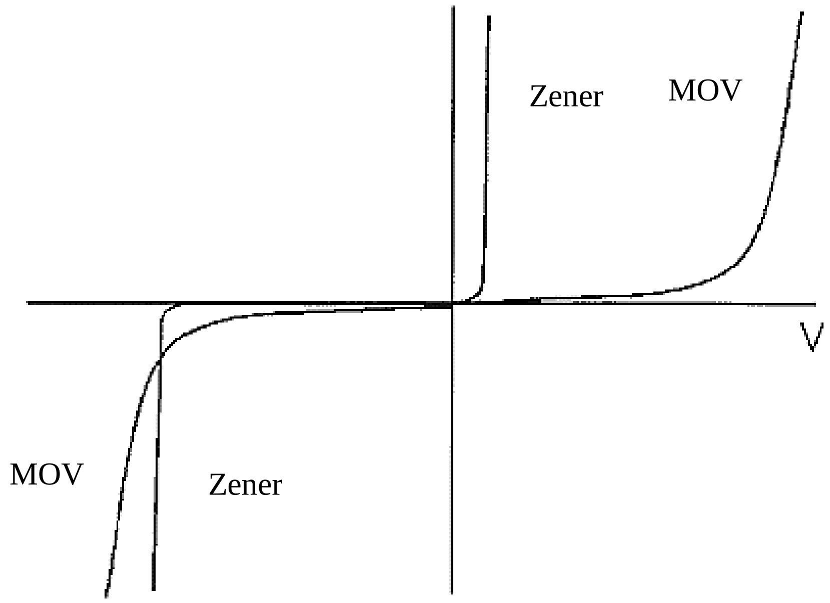


Figure 2.6: Metal Oxide Varistor I-V Characteristic[6]

2.1.3 Class Test of SPD

According to the IEC 61643-12[2], SPD has three types of classes test. The three types of class test are Types 1, 2 and 3 SPDs. The Type 1 SPD usually are installed in the specific sector and industrial building to protect from direct lightning surge. Next, the Type 2 SPD is the main protection for electrical low-voltage systems. Type 2 frequently install at the main electrical switchboard to prevent overvoltage at the electrical appliance. Lastly, Type 3 SPD must install with combination Type 2 SPD to protect the sensitive electrical appliance. Table 2-1 shows the types and classes test of the SPD.

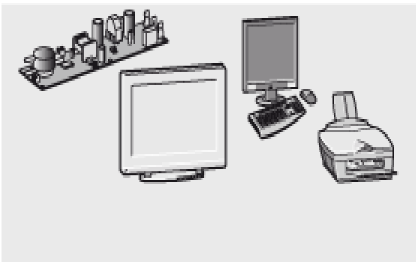
Table 2-1: Type and Class Of The SPD[2]

Item	Direct lightning strike	Indirect lightning strike	
Type SPD	Type 1	Type 2	Type 3
Class Test	Class I	Class II	Class III
Current test wave	10/350µs	8/20µs	8/20µs + 1.2/50µs

2.1.4 Category Installation SPD

Choosing the category installation SPD requires to protect the equipment and to match the SPD rated impulse voltage. Category installation SPD are importance because the suitable installation can protect the load and can save the budget installation. This is relating to the category of overvoltage installation. In the standard IEC 60664-1, the installation overvoltage categories are described which is for a 200/400V installation. There have 4 type of installation overvoltage categories. Table 2-2 are shows about installation overvoltage category.

Table 2-2: Installation Category[7]

category	Equipment	Description
Installation category I		• Installation categories 1 is 1.5 kV only suitable for particularly sensitive equipment. • Example for this category is electronic devices like computer, television, etc
Installation category II		• Installation categories 2 is 2.5 kV for normal impulse voltage equipment user. • Example for this category is a household electrical appliance and similar loads.