SIMULATION OF METAL OXIDE VARISTOR DYNAMIC BEHAVIOR UNDER FAST TRANSIENTS

MOHAMMAD FIRDAUS BIN MAT DIN

NOVEMBER 2005

“I hereby declare that I have read through this report and found that it is sufficient in terms of scope and quality to be awarded of the Degree of Bachelor in Electrical Engineering (Industrial Power).”

Signature : ……………………………………..

Name of Supervisor : Encik Zikri Abadi Bin Baharudin

Date : 18/11/2005

SIMULATION OF METAL OXIDE VARISTOR DYNAMIC BEHAVIOR UNDER FAST TRANSIENTS

MOHAMMAD FIRDAUS BIN MAT DIN

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

Fakulti Kejuruteraan Elektrik
Kolej Universiti Teknikal Kebangsaan Malaysia

November 2005

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

Signature : ……………………………………
Name : Mohammad Firdaus bin Mat Din
Date : ……18. 11. 05……………………

DEDICATION

To my parents Mat Din b Mat and Halijah bt Long, to my brothers Fauzi and Fadzli, my sister Fazilah, for all their support and unconditional love throughout my college studies. To Bebe Sabrina bt Abdullah, my inspiration that encourages and motivate me to work harder into achieving my goals.

ACKNOWLEDGMENTS

Bismillahirahmanirahim.

Alhamdulillah, thanks to the Almighty Allah with his permission finally I have finished my Project Sarjana Muda II. This project has been accomplished within the given time.

I would like to express my sincerest gratitude to my supervisor, En Zikri Abadi bin Baharudin, for his patient guidance, advice and encouragement. His knowledge of lightning protection and insulation coordination was indispensable toward the successful completion of my project.

I am very thankful to Bebe Sabrina bt Abdullah for all the useful discussions we had on surge protective devices (SPD). Her extensive study of SPDs during her thesis research was very helpful during the simulation phase of my work.

I also would like to thank all lecturers and staffs of Kolej Universiti Teknikal Kebangsaan Malaysia for their guidance, assistance and provide facilities for my project.

To my beloved parents, brothers and sister for their motivation and generous financial support.

Last but not least, I am sincerly thankful to all my friends who had offered their assistance and suggestions for this project.

ABSTRACT

Transient voltage surges that occur in power systems have caused problems to industrial and residential systems. Therefore, surge protection model was designed to represent the transient surge phenomenon. The protection of electrical equipment in low voltage system using metal oxide varistor (MOV) is commonly used. MOV have dynamic characteristics that are significant for overvoltage coordination studies involving fast transient. Data on characteristic of MOV indicates that for fast front surges, those with rise time less than 8μs, the peak of the voltage wave occurs before the peak of the current wave and the residual voltage across the varistor increases as the time to crest of the varistor discharge current. This project concentrates on low voltage systems. Two models of MOV's have been simulated that is based on a well-known frequency dependent behavior. The simulations were performed with the Alternative Transient Program (ATP) version of the Electromagnetic Transients Program (EMTP). The results of the simulation were compared with both the experimental data.

ABSTRAK

Voltan fana pusuan yang berlaku dalam sistem kuasa telah menimbulkan masalah kepada sektor industri dan kawasan kediaman. Oleh yang demikian, model perlindungan telah direkabentuk untuk mewakili fenomena voltan pusuan di dalam persekitaran yang sebenar. Kebiasaanya, penangkap voltan fana pusuan jenis logam oksida (MOV) digunakan bagi peranti perlindungan dalam sistem voltan rendah. MOV mempunyai ciri tipikal bagi menganalisa koordinasi dari segi voltan lampau yang disebabkan oleh voltan fana pusuan. Data ciri tipikal MOV menunjukkan bahawa, bagi arus fana pusuan yang masanya kurang dari 8μs untuk pusuan fana hadapan, voltan puncak residual akan berlaku sebelum arus puncak fana pusuan dan voltan residual yang melintangi MOV akan meningkat selaras dengan kenaikkan arus fana pusuan. Projek ini menumpukan kepada sistem elektrik voltan rendah. Dua model MOV telah disimulasikan dengan menggunakan Program Alternatif Fana Pusuan (ATP) versi kepada Program Fana Pusuan Elektromagnetik (EMTP). Keputusan simulasi dibandingkan dengan data eksperimen bagi mengesahkan model yang dipersembahkan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Motivation

Most flash over faults occurring in low voltage systems are attributed to lightning. A momentary reduction of voltage due to lightning stroke has been a subject of issues, since it frequently gives rise to adverse influence of information processing and control equipment. Under such circumstances, studies have positively been advanced to protect low voltage system against lightning surge, through the application of metal oxide varistor (MOV).

While a circuit breaker provides protection against abnormally high currents, a metal oxide varistor guards equipment against excessively high surge voltages which can be impressed on the system by direct (or even near miss) lightning strokes or by switching operations. Transient surge voltage occurring in AC power circuit can be caused by operational upset or product failure in industrial and residential systems and equipment. Therefore, the introduction of metal oxide varistor is necessary to discharge the high current impulse which accompanies over voltages.

The MOVs have a variable resistance that is dependent on voltage. When voltage is below a certain level, the electrons in the varistors flow in such a way as to create a very high resistance. When the voltage exceeds that level, the electrons behave differently, creating a much lower resistance. When the voltage is correct, an MOV does nothing. When voltage is too high, an MOV can conduct a lot of current to eliminate the extra voltage. That is, the voltage-current characteristic or frequency dependent behavior of the device is non-linear.

For the simulation over voltage coordination studies involving fast transient, a model is required to represent MOVs in simulation work. Several models have been proposed to simulate this frequency dependent behavior characteristic. But, this models concentrate for metal oxide surge arrester (MOSA) which to be installed at high voltage system. For that reason, the goal of this simulation is to present a model for MOV based on the well known frequency dependent behavior model for low voltage system. The difficulties in this simulation are to determine the parameters, where the iterative-trial and error procedures are required, in others the necessary data are not reported on manufacturers' datasheets.

1.2 Objectives of Project

1. To study and understand the concept of surge voltages and surge currents occurring in low-voltage ac power circuits.
2. To study and understand the recommended practice for analyzing surge protective devices based on IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuit -ANSI/IEEE C62.41-1997.
3. To study and understand the well-known frequency dependent behavior model.
4. To develop a complete metal oxide varistor model that is based on well-known frequency dependent behavior.
5. To compare simulation data and experimental results.
6. To make comparison of the performance between Pinceti's and Naylor's model.
7. To get the best model to represent simulation work.

1.3 Scope of Project

1. The simulations are performed with Alternative Transient Program (ATP) version of Electromagnetic Transient Program (EMTP).
2. In order to verify the validity of the simulation, the results of the simulation were compared with both the experimental data.
3. The stroke model that will be used is lightning stroke model-combination wave 8/20μs. (Referred to ANSI/IEEE C62.41-1997 Location Standards).
    a. Location Category : C2
    b. System Exposure : Medium
    c. Voltage : 4000V
    d. Current : 5000A
4. For the study case, the metal oxide varistor will develop into low voltage ac power system protection for the rated 110V (based on experimental data).

1.4 Problem Statement

Data on characteristics of metal-oxide varistor indicates that these devices have dynamic characteristics that are significant for overvoltage coordination studies involving fast front surges and for their location. For fast front surges, those with rise times less than 8μs, the peak of the voltage wave occurs before the peak of the current wave and the residual voltage across the arrester increases as the time to crest of the arrester discharge current decreases. This increase of the residual voltage could reach approximately 6% when the front time of the discharge current is reduced from 8 to 1.3 μs. Indeed, the voltage across the arrester is not only a function of the discharge current, but also of the rate of its rise. This will not be the case if the metal-oxide performed strictly as a non-linear resistance. Therefore, this frequency dependent frequency dependent behavior, require a more sophisticated model than the simple static non-linear resistance [1].

Several models have been proposed to simulate this frequency-dependent characteristic. Difficulties arise in the calculation and adjustment of their parameters, in some cases iterative procedures are required, in others the necessary data are not reported on manufacturers' datasheets. These models differ in the calculation and adjustment of their parameters but they have an acceptable accuracy as reported in the literature [1]. Compared to the model that has been proposed before such as Pinceti's model, Naylor's model and Fernandez's model, the model concentrate on high voltage systems. In this project, the model concentrates on low voltage systems.

At the end of this project, it is expected the simulation data will be validated with experimental data and the best model for metal oxide varistor will be obtained.

1.5 Overview of this Thesis

Chapter 1: Introduction
This chapter briefly explains the needs of surge protective device in low voltage systems. It then describes the objectives, scope of work, problem statement and expected result of the project.

Chapter 2: Literature Review
This chapter describes how the surge voltages and surge currents occurring in low-voltage ac power circuits, basic operation and characteristics of metal oxide varistor. This chapter also introduces the simulation used in this project-Alternative Transient Program. At the end of this chapter tells standard of surge testing waveforms and several of well-known frequency dependent behavior models.

Chapter 3: Surges and metal oxide varistor model.
This chapter introduces the construction of lightning stroke model and metal oxide varistor model based on Pinceti's and Naylor's model. At the end of this chapter the simulation results are compared.

Chapter 4: Discussions

This chapter discuss further simulation of the metal oxide varistor model by applying other rated surge voltages in order to validate the performance of the model. This chapter then discusses on how to minimize the error of the simulation.

Chapter 5: Conclusion

Summing up the characteristics of metal oxide varistor, analyze performance of the models and comparison of the simulation result.

CHAPTER 2

LITERATURE REVIEW

2.1 Alternative Transient Program (ATP)

ATPDraw is a graphical, mouse-driven preprocessor to the ATP version of the Electromagnetic Transients Program (EMTP) on the MS-Windows platform. The program is written in Borland Delphi 2.0 and runs under Windows 9x/NT/2000/XP. In ATPDraw the user can construct an electrical circuit using the mouse and selecting components from menus, and then ATPDraw generates the ATP input file in the appropriate format based on "what you see is what you get". The simulation program ATP and plotting programs can be integrated with ATPDraw [2].

ATPDraw supports hierarchical modeling to replace a selected group of objects with a single icon in unlimited numbers of layers. PARAMETER feature of ATP is also implemented, allowing the user to specify a text string as input in a components' data field, then assign numerical values to these texts strings later. The circuit is stored on disk in a single project file, which includes all the simulation objects and options needed to run the case. The project file is in zip-compressed format that makes the file sharing with others very simple. ATPDraw is most valuable to new users of ATP-EMTP and is an excellent tool for educational purposes. However, the possibility of multi-layer modeling makes ATPDraw a powerful front-end processor for professionals in analysis of electric power system transients, as well.

2.1.1 Main characteristics of plotting programs for ATP

These post-processors are interfaced with ATP via disk files and their main function is to display the results of a time- or frequency domain simulation. ATP simulation data are stored in a file having extension .pl4, and it can be processed either off-line, or on-line. The latter (i.e. to display results while the simulation proceeds) is available only if the operating system provides concurrent PL4-file access for ATP and the postprocessor program [2]. Figure 2.1 shows plotting programs for ATP.

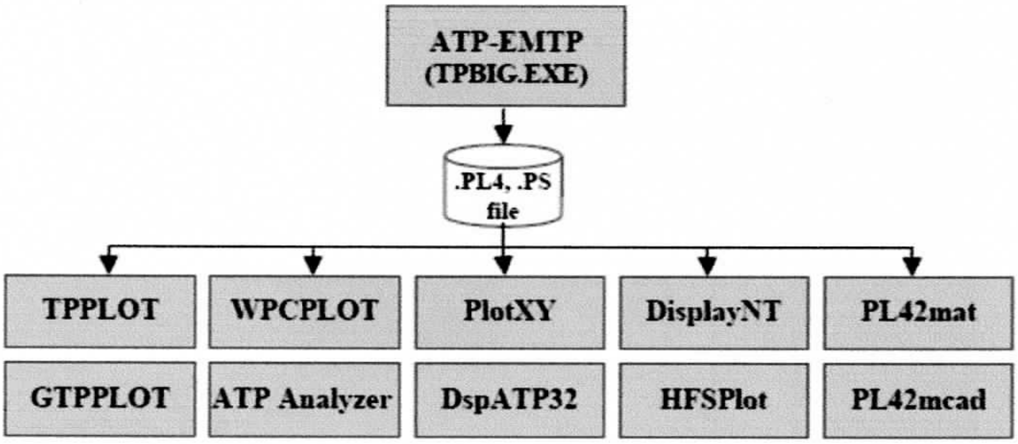

Figure 2.1: Plotting Program for ATP

2.1.2 Interfacing ATPDraw with other programs of the ATP-EMTP package

The ATP-EMTP simulation package consists of various separate programs which are communicating with each other via disk files: i.e. the output of pre-processors are used as input for the main program TPBIG.EXE, while the product of the simulation can be used as input for plotting programs. The main program itself is often used as pre-processor (e.g. for LINE CONSTANTS, CABLE CONSTANTS, BCTRAN or DATA BASE MODULE runs), and the punch-file products in that cases can be re-used as input in a subsequent run via $Include [8]. Taking that the structure of the program components is rather difficult, a user shell to supervise the execution of separate programs and input/output flows has a great advantage. Figure 2.2 shows interaction between ATPDraw and the other ATP programs.

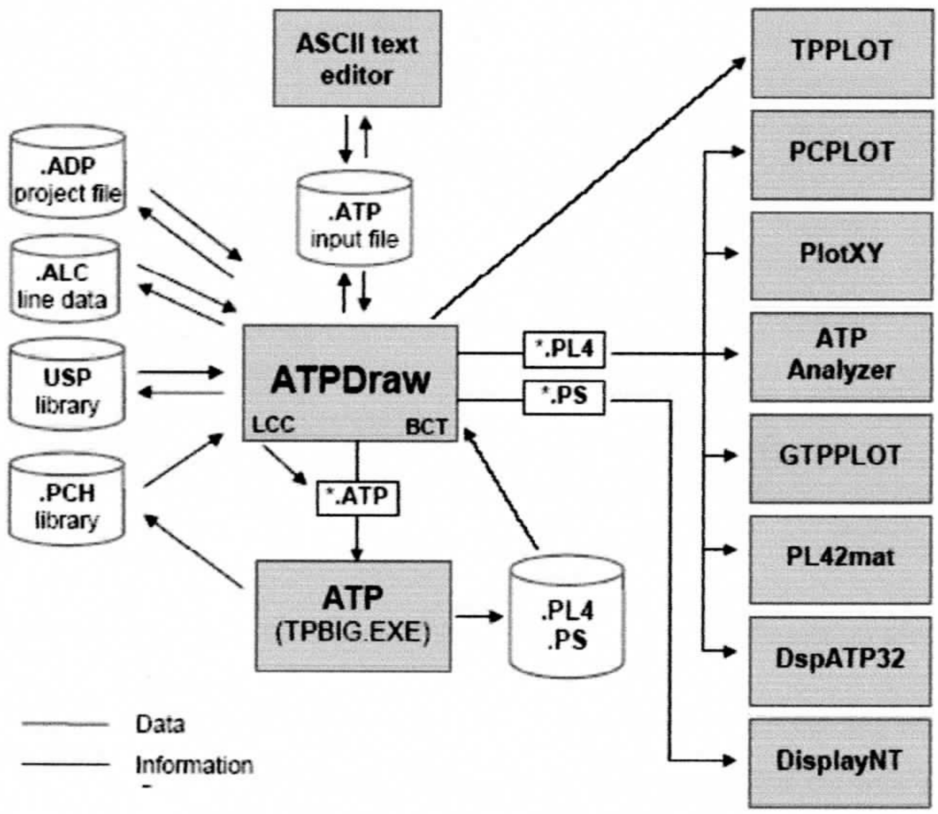

Figure 2.2: Interaction between ATPDraw and the other ATP programs.