TRANSMISSION LINE MODELS FOR COORDINATION OF SURGE PROTECTIVE DEVICES

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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)."

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

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This dedicated to my beloved father and mother

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ABSTRACT

Transient voltage surges occur in power systems have caused problem to industrial and residential systems. Therefore, surge protection model was designed to represent the transient surge phenomenon. This project describes the distribution of surge voltage at 3 location categories that are separated by a transmission line. Seven different models of transmission lines are used in the simulations were; (1) the line is modeled as a single inductor, (2) the line is modeled as a single resistor (3) an ideal transmission line, (4) a cascade of lumped RLC elements where the R value accounts only for the dc resistance of the line, (5) a model with transmission line equations for a continuous line including only the dc resistance, (6) a model with transmission line equations for a continuous line including both dc resistance and the skin effect resistance and (7) a model proposed by Michael F. Stringfellow. The aim of this project is to develop a complete transmission line model and make a comparison that is based on seven different models for low-voltage systems. The simulations were performed with the Alternative Transient Program (ATP). The results of the simulation were compared with both the experimental data. From the simulations, Stringfellow's model produced a satisfactory waveshape of voltage that gives a good representation of the transmission line in low voltage systems.

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. Projek ini menerangkan pengagihan voltan fana pusuan di 3 kategori yang dipisahkan oleh talian penghantaran. Tujuh model talian penghantaran yang digunakan dalam simulasi ialah; (1) model talian sebagai satu induktor, (2) model talian sebagai satu resistor, (3) model talian ideal, (4) model talian sebagai elemen RLC lata dengan R terdiri dari rintangan dc talian penghantaran, (5) model dengan persamaan talian penghantaran selanjar terdiri hanya rintangan dc, (6) model dengan persamaan talian penghantaran selanjar terdiri rintangan dc dan rintangan kesan kulit dan (7) model talian penghantaran yang dipersembahkan oleh Michael F. Stringfellow. Matlamat projek ini ialah untuk mempersembahkan model talian penghantaran dan membuat perbandingan bagi sistem voltan rendah berdasarkan model yang dipersembahkan sebelumnya. Program simulasi yang digunakan ialah Program Alternatif Fana Pusuan (ATP), yang merupakan aplikasi piawai untuk menaksir koordinasi penebatan bagi peranti perlindungan voltan fana pusuan di dalam sistem kuasa elektrik. Daripada keputusan simulasi, didapati model yang dipersembahkan oleh Michael F. Stringfellow memberikan keputusan yang memuaskan dari segi gelombang voltan membolehkan model ini dapat mewakilkan sebagai talian penghantaran untuk sistem elektrik voltan rendah.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The sensitivity of semiconductor due to transient voltage surges have caused problem to industrial and residential systems and equipment. These problems have received increased attention in recent years because of the widespread application of complex semiconductor devices that are more sensitive to voltage surges. For that reason a protection of power systems from transient surge related damage and faults is crucial to maintaining adequate power quality, reliability and controlling damage costs to the utility system. Surge voltages occurring in low-voltage ac power circuits have two origins, external surges and internal surges. External surges produced by lightning or power system switching operation and internal surges produced by switching of loads within the local low voltage system.

In low voltage systems the earth wire protection is generally not very effective. A lightning would hit not only one wire (the earth wire) but all, including the phase wires and induced and transferred over voltages could not be avoided. The most effective protection against over voltages in low voltages networks is therefore the use of surge protective devices (SPD) in the vicinity of the equipment.

Therefore, the protection model was designed to represent the transient surge voltage phenomenon for analysis study. In this project, a model of transmission line will be creating through simulation with coordination of surge-protective devices.

The model performance will be compare between the simulation results with the experimental data using.

1.2 Objective

The objectives of this project are as follows:

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 analyze surge protective device 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 several of transmission line models in low-voltage systems.
4. To simulate a complete typical L-V transmission line model and obtained results of simulation.
5. To make comparison of the performance transmission line models.
6. To determine the best transmission line models which are more representative for low-voltage systems

1.3 Scope of Work

The simulations are performed with Alternative Transient Program (ATP) version of Electromagnetic Transient Program (EMTP). In order to verify the validity of the simulation, a series of experiments have been conducted using 8/20μs current wave. This project has been undertaken in the following five developmental stages:

1. Choose an appropriate surge type model with Alternative Transient Program (ATP).
2. The stroke model that will be used is lightning stroke model-combination wave 8/20μs. (Referred to ANSI/IEEE C62.41-1997 Location Standards).

Location Category	: C2
System Exposure	: Medium
Voltage	: 4000V
Current	: 5000A

3. Use Pinceti, type model of Metal Oxide Varistor (MOV).
4. Compare simulation with data experimental results.
5. Development of transmission line model for L-V systems which consist of 110 V two wire power line 30m length equipped with phase and neutral conductors. MOV will be applying at three points of the system. These will be at service entrance, at a distribution panel and at the load end.

1.4 Problem Statement

The problem in this project is to determine the best transmission line models of low voltage ac systems. It is very important to validate the accuracy and effectiveness of the models to obtain a coordination of all the appliances in a home or all the equipment in an industrial environment.

1.5 Methodology

Achieving the objective of this project and answering the problematic as mentioned in the previous chapter, the following methodology are going to be carried out in this project:

1. Literature Study
2. Simulation study using ATP-EMTP
3. Metal Oxide Varistor (MOV) model

4. Transmission line models
5. Comparison simulation with data experimental result

1.6 Literature Study

Literature study is done for the purpose of learning as much as possible, in terms of this project application, about transmission line models of low voltage power system and surge-protective devices. The main references for this study are:

M.F.Stringfellow, (1991) [1] reports on a theoretical and experimental study on the coordination of surge suppressors on an indoor low-voltage power system. The system studied was a 120-volt three-wire power line, equipped with phase, neutral and ground conductors. Metal oxide varistor surge suppressors were applied at three points on the systems. These were at the service entrance, at a distribution panel and at the load. Total line length studied 30 meters (100feet), with the distribution panel and its suppressors being located at the central point. When unidirectional surges typical of lightning were applied at the service entrance, both experimental and theoretical studies showed similar results. Namely, removal of a suppressor at either load or distribution panel resulted in unacceptably large oscillatory voltages. Best load protection was achieved with suppressors in all three locations.

Ronald B.Standler, (1992) [2] has made a comparison with six different models of transmission line. The models are:

1. The line modeled as single inductor
2. The line modeled as single resistors
3. An ideal (i.e,lossless) transmission line
4. A cascade of lumped RLC elements including only the dc resistance
5. A model with transmission line equations for continuous line including only the dc resistance

6. A model with transmission line equations for continuous line including both the resistance and skin effect resistance is to be ignored.

Ronald B.Standler, (1992) [2] described the distribution of surge currents inside a building during a direct lightning strike, on the basic of numerical simulations of building wiring, various load, and five different combination of metal oxide varistors connected inside the building as surge arresters and suppressors. The network inside a building is modeled as eight branch circuits, each with a different resistive, capacitive or inductive load and each with a different length. The results of this modeling is compared with the 8/20 and 10/1000µs standard surge test waveforms ANSI/IEEE C62.41.

The University of Algeria groups (Bayadi et al., 2003) [3] have made a comparison between well known frequency-dependent models. The frequency-dependent models are:

1.) The IEEE Recommended model
2.) Model proposed by Pinceti
3.) Model proposed by Fernandez

The group studies also make comparison using conventional model ($I=kV^{\alpha}$). The frequency-dependent models proposed in Pinceti and Fernandez reproduces acceptably the peak voltage from manufacturer while the IEEE and conventional model perform high error.

Dev Paul, (2000) [4] provides a fundamental overview of transient surge and associated noise in the low voltage power distribution system. Electrical noise generated within the facility by the transient surges corrupts low voltage power supplies. In discussing the characteristics of transient surges and associated noise it is helpful to understand other related terms. Working groups of IEEE and IEC Standards have developed different standard surge waves for testing transient voltage surge suppressors devices meant for outdoor and indoor application locations to the low voltage power distribution system.