ANALYSIS OF BACK-FLASHOVER RATE FOR 132KV OVERHEAD TRANSMISSION LINES

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“I hereby declare that I have read through this report entitle “Analysis Of Back-Flashover Rate For 132kv Overhead Transmission Lines” and found that has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)”

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A report submitted in partial fulfillment of the requirements for the degree ofElectrical Engineering (Industrial Power)

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JULY 2012

I declare that this report entitle “Analysis Of Back-Flashover Rate For 132kv Overhead Transmission Lines” 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 in candidature of any other degree.

Signature : ………………………..

Name : Muhammad Sadiq bin Suhaimi

Date : 02 JULY 2012

Specially dedicated to my beloved mother and father, my brother, my sister and all my friend. Thank you for all of the support and encouragement during my journey to gain knowledge.

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ABSTRACT

Transmission line is a transmission system that delivers electric power supply from one place to another. In Malaysia, there are two types of transmission line which are single circuit line and double circuit line. Whenever lightning strikes the transmission line, there are possibilities of flashover to occur. The reason is, once lightning strike, the voltage that carried is forced down towards the insulator. The insulator prevents the overvoltage to flowing from the tower to the phase line. However, if this overvoltage equal or exceed the line Critical flashover (CFO) rate, flashover occurs. This phenomenon is known as backflash or back-flashover. During the phenomenon, the back flashover rate (BFR) had been calculated to do the analysis in improving the transmission line performance. The lowest value of BFR indicates that the line is well shielded and can sustain from the surge overvoltage and vice versa. There are several factors that influence the back-flashover rate such as ground flash density, surge impedances, coupling factors, heights of the tower, horizontal separation of ground wires and CFO. Basically, BFR can be calculated by using 3 different methods; simplified, CIGRE and IEEE method. For this project, both simplified and CIGRE methods are used to determine the BFR. Programs are created based on these two methods using GUI, MATLAB software for user-friendly purpose. In the completion of this dissertation, several steps had been taken which are doing research and find information that related to the project through out resources of internet and books, analyze and compare the method of BFR calculation, design and build program by MATLAB (GUI), compare result from program with the result from book and do the conclusion & suggest future recommendation. For the result of this dissertation, it show that the programs that had been built are approved to be used.

ABSTRAK

Talian penghantaran adalah suatu sistem penghantaran yang menyalurkan bekalan kuasa elektrik dari satu tempat ke tempat lain. Di Malaysia, terdapat dua jenis kelaziman talian penghantaran iaitu litar tunggal dan talian litar berkembar. Setiap kali kilat menyambar talian penghantaran, terdapat kemungkinan ‘flashover’ berlaku. Hal ini kerana, apabila panahan kilat berlaku, voltan yang terhasil terpaksa turun ke penebat. Penebat menghalang voltan lebihan dari mengalir daripada menara ke talian fasa. Walau bagaimanapun, jika voltan ini sama atau melebihi kadar voltan ‘Flashover Kritikal’ (CFO), ‘flashover’ akan berlaku. Fenomena ini dipanggil ‘backflash’atau ‘back-flashover’. Semasa fenomena, kadar ‘back-flashover’ (BFR) perlu dikira untuk dilakukan analisis dalam meningkatkan prestasi talian penghantaran. Nilai terendah bagi BFR menunjukkan bahawa talian tersebut akan dilindungi dan boleh bertahan dari lonjakan voltan lampau dan sebaliknya. Terdapat beberapa faktor yang mempengaruhi kadar ‘backflashover’ seperti ketumpatan bumi, galangan lonjakan, gandingan faktor, ketinggian menara, pemisahan mendatar wayar bumi dan nilai CFO. Pada asasnya, BFR boleh dikira dengan menggunakan 3 kaedah yang berbeza iaitu kaedah ‘Simplified’, kaedah CIGRE dan kaedah IEEE. Untuk projek ini, dua kaedah telah digunakan iaitu kaedah ‘Simplified’ dan kaedah CIGRE bagi menentukan atau mengira nilai BFR. Program dicipta berdasarkan kedua-dua kaedah ini dengan menggunakan perisian GUI, MATLAB bagi tujuan yang mesra pengguna. Dalam penyiapan disertasi ini, beberapa langkah telah diambil seperti membuat penyelidikan dan mencari maklumat berkaitan dengan projek melalui sumber-sumber daripada internet dan buku-buku, menganalisis dan membandingkan kaedah yang digunakan dalam mengira BFR, mereka bentuk dan membina program oleh MATLAB (GUI), membandingkan hasil program dengan hasil dari buku dan melakukan kesimpulan & cadangkan untuk masa hadapan.Untuk hasil disertasi ini, ia menunjukkan bahawa program-program yang telah dibina telah diluluskan untuk digunakan.

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LIST OF ABBREVIATIONS

UTeM	-	Universiti Teknikal Malaysia Melaka
BFR	-	Back Flashover Rate
CIGRE	-	International Council on Large Electric Systems
IEEE	-	Institute of Electric and Electronic Engineers
CFO	-	Critical Flashover voltage
CFO_{NS}	-	Non-Standard Critical Flashover voltage

LIST OF SYMBOL

N_L	-	the number of strokes
P(Ic)	-	the probability of a flashover
I_c	-	critical current above which flashover occurs.
N_g	-	The ground flash density (flashes / km^2 –year)
h	-	The tower height, meter.
S_g	-	The horizontal distance between the ground wires, meter.
C	-	Coupling factor.
V_{PF}	-	Operating voltage, peak value.
R_e	-	Combination of shield-wire surge impedance and R.
Z_g	-	Surge impedance of the ground wires, ohms.
CFO_{NS}	-	Non-standard critical flashover voltage.
CFO	-	Critical flashover voltage.
τ	-	Time constant of tail, µs.
T_s	-	Travel time of a span, µs.
I_R	-	Current through footing resistance, kA.
R_i	-	Tower footing resistance (ohm).
R_o	-	Tower footing resistance at low current (non-ionized soil).
I_g	-	Current required to cause soil breakdown gradient.
ρ_o	-	soil resistivity (ohm-meter)
E_o	-	soil ionization gradient (about 300 kV/m)
C_A	-	coupling factor per phase A.
t_f	-	time to crest of the stroke current, µs.
K_{TT}	-	Tower-top voltage in p.u stroke current.
T_T	-	Travel time of a tower, µs.
K_{TA}	-	Voltage at point A pu stroke current.
T_A	-	Travel time to point A on tower, µs.
K_{SP}	-	Span factor, reduces crest voltage at tower.
α_T , α_R	-	Reflection coefficient at tower / adjacent towers

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Project Background

Lightning strike is the one of the natural event. Normally, lightning will strike to the highest of things from ground such as a tower. From the electrical view, this event will be focus on the overhead transmission lines with their tower. This is because when the lightning strikes to the transmission line, it will interfere the efficiency of transferring energy from one site to the others. In terms of electrical, lightning strike on overhead transmission line can be divided into three categories such as lightning strike on the tower, shield wire and phase wire of the transmission line.

When lightning strike on the tower or shield wire, the overvoltage and current are produced on the transmission line and will be fully grounded. During this situation, the overvoltage and current will drop into the phase line and will interfere it. Hence, this phenomenon is known as a backflash or back-flashover. During this phenomenon, the back flashover rate (BFR) had been calculated to do the analysis in improving the transmission line performance. The lowest value of BFR is refer to the effectiveness of an energy transmission that is sent through a transmission line during the lightning strike occur. There are several factors that influence the back-flashover rate such as ground flash density, surge impedances, coupling factors, heights of the tower, horizontal separation of ground wires and CFO. Basically, BFR can be calculated by using 3 different methods; simplified, CIGRE and IEEE method. For this project, both simplified and CIGRE methods are used to determine the BFR.

1.2 Problem Statement

The back-flashover rate (BFR) is the probability of a flashover, P(Ic) times the number of strokes, $N_{L.}$ However, it is not easy to calculate the value of BFR. Hence, the problem faced is there are difficulties to calculate the BFR value manually. This project just focuses on simplified method and CIGRE method only. The simplified method cannot precisely calculated BFR value for a tower that exceeded 70 meter of height. However, the CIGRE method can accurately calculate BFR value, but it is not appropriate to be done manually due to long of iteration calculation. Hence, computer are required to calculate the BFR value.

1.3 Project Objective

There are three objectives that needs to be achieved during this project :

i. To calculate the BFR value.
ii. To study and analyze the 'Simplified' and CIGRE method to calculate the BFR value.
iii. To create programs that can calculate the BFR value using MATLAB (GUI).

1.4 Project Scope

This project focus on following requirement :

- Type of transmission lines :
  - Single circuit line (132kV)
- Method to calculate the BFR value :
  - Simplified method.
  - CIGRE method.
- Software to create a program to calculate the BFR value :
  - MATLAB with GUI application.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter highlights the past studies that related to this project and bring as the background theory.

2.2 Insulation Coordination

The term insulation coordination is the process to determine the proper insulation level of several components in the transmission line as well as their placement on the system where it would result in the least damage [1]. It is the selection of an insulation structure that will withstand voltage stresses to which the system or equipment will be subjected to together with the proper surge arrester to reduce frequency of supply interruptions and component failure. The process is determined from the known characteristics of voltage surges and the characteristics of surge arresters.

According to the IEEE Standard (1996), the definition of Insulation coordination is the "selection of insulation strength consistent with the expected overvoltage to obtain an acceptable risk of failure" [2].

Insulation coordination study is determined by the following [3]:

- System over voltages, wave shapes, peak voltage values and probabilities of occurrence.
- Withstand levels of equipment are coordinated with the protective levels of surge arrester with safe protective margin to achieve reliable performance.

- The insulation levels of various equipments in a substation are coordinated to protect the equipment such as transformer.

2.2.1 System Overvoltage

There are 3 types of overvoltage extracted from IEC60071-1(2004) which are lightning overvoltage, switching overvoltage, temporary overvoltage in Figure 2.1 shows graph $p.u.$ voltage versus duration of overvoltage occurs [1].

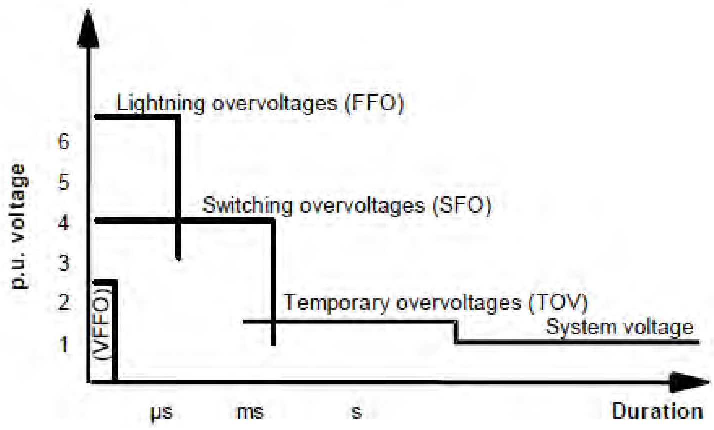
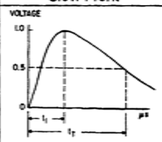
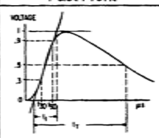
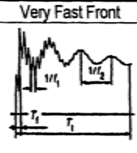


Figure 2.1 Types of overvoltage [4]

Table 2.1 concludes the types and typical shapes of over voltages and its withstanding tests.

Table 2.1Classes and types of overvoltage-Standard voltage shapes and Standard Withstand tests [4]

Class	Low Frequency		Transient		
	Continuous	Temporary	Slow Front	Fast Front	Very Fast Front
	SIN WAVE	SIN WAVE			
Range Of Shapes	f=50/60Hz $T_t \geq 3600s$	$10Hz < f < 500Hz$ $3600s \geq T_t \geq 0.03s$	$5000\mu s \geq T_t \geq 20\mu s$ $T_2 \leq 20ms$	$20\mu s \geq T_1 \geq 0.1\mu s$ $T_2 \leq 300\mu s$	$100ns \geq T_p \geq 3ns$ $0.3MHz < f_1 < 100MHz$ $30kHz < f_2 < 300kHz$ $T_t \leq 3ms$
Standard Shape	f=50/60Hz	$48Hz \leq f \leq 62Hz$ T_t=60s	T_p=250µs T_2=2500µs	T_1=1.2µs T_2=50µs	
Typical Causes	Normal System Operation	Ferroresonance Ferranti Effect Earth Faults On Non-Ideally Earthed Systems	Switching surges	Lightning strokes	Operation of disconnector switches in GIS switchgear
Standard Test		Short duration power frequency test	Switching impulse test	Lightning impulse test	

2.2.2 Insulation Withstand Characteristics

The insulation withstand of an insulation coordination can be determine by two difference characteristic that is the voltage/clearances or the voltage/time characteristics [1].

- Voltage/Clearance Characteristics
  - Withstand voltage as a function of gap spacing for lightning and switching surges.

- Voltage/Time Characteristics
  - Withstand voltage as a function of time to crest of the voltage surge

2.2.3 Standard Basic Insulation Levels (BIL)

In IEC Publication 71(1993), Standard Basic Insulation Levels (BIL) is the electrical strength of insulation expressed in crest of standard in crest of “Standard lightning impulse”[5]

There are two types of BIL [1]:

i. Statistical BIL is crest of standard lightning impulse for which insulation exhibits 90% probability of withstand and the probability of flashover or failure is 10% per impulse application. The BIL is standard deviation below the CFO, the BIL equation (2.1)

$$BIL=CFO[1-1.28(\sigma f/CFO)] \tag{2.1}$$

Where,
σf = Critical flashover voltage, CFO in $p.u.$
CFO = Critical flashover voltage, CFO.

ii. Conventional BIL is crest of standard lightning impulse for which insulation must withstand one to three applications of an impulse whose crest is equal to the BIL. The probability insulation characteristics are unknown.

2.2.4 Characteristic of Insulation Coordination

Table 2.2 stated the characteristics a typical coordination of insulation for some system voltages together with the corresponding line insulation in High engineering-J R Lucas (2001) [6].

Table 2.2 Typical coordination of insulation system voltage

Nominal System Voltage(kV)	Maximum System Voltage(kV)	Transformer BIL, kV (peak)	Line Insulation, kV	Arrestor Rating, kV	Separation Distance, m
11	12	150	500	20	23
33	36	200	600	30	27
66	72.5	350	600	73	29
132	145	550	930	145	35
220	245	900	1440	242	58
400	420	1425/1550		336	Close to transmission

2.3 Lightning

Lightning is an atmospheric electrostatic discharge (spark) accompanied by thunder, which typically occurs during thunderstorms, and sometimes during volcanic eruptions or dust storms which measure in kilometer[7].

IEEE Std. 1410-2004 (2010) state that, the amount of lightning that can occur in a country or continent is based upon the Keraunic level in this case is defined as the number of thunderstorm days time [8]. Figure 2.2 shows the number of days with thunderstorm in Malaysia.