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Transmission Line Lightning Performance Characterization

A Thesis

Submitted in Partial Fulfillment for the Requirements of the
Degree of Master of Science in Electrical Engineering

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STATEMENT

This thesis is submitted to Ain Shams University in fulfillment of the requirements for master degree in Electrical Engineering.

The work included in the thesis was carried out by the author during the period of October 2007 to February 2013 at Power Engineering Department of the Ain Shams University.

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Abstract:

This Thesis studies the transmission line lightning performance characterization, which is one of the most important research plans over the past few years because of the amount of energy loss caused by lightning.

The Thesis aims to introduce a developed and more accurate algorithm to evaluate the effect of lightning multi stroke on the transmission line, Moreover, it helps the transmission line designer to evaluate the line performance and change some parameters in order to improve the line performance.

It also contains the sensitivity analysis based on changing some parameters like footing resistance, phase spacing and OHGW (Over Head Ground Wire) spacing, which affects the transmission line performance.

.

The designer should consider certain limiting factors such as voltage level, the sending and receiving points of the transmission line and the desired voltage of the line which can't be changed.

Other parameters that the designer can choose among them to improve the lightning performance like the structural details, the geometry of the structure, the structural height, the exact placement of the over head ground wires, the amount and the type of insulation, the type of the grounding and some other design feature of the tower.

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List of Abbreviations

T.L	:	Transmission Line
O.H.G.W	:	Over head ground wire.
GFD	:	Ground flash density.
SFR	:	Shielding failure rate.
SFFOR	:	Shielding failure flash over rate.
HV	:	High voltage.
HVDC	:	High- voltage direct current.
BF	:	Back Flashover
BFR	:	Back Flashover Rate

Definitions

1 **Back flashover (lightning):** A flashover of insulation resulting from a lightning stroke to part of network or electric installation which is normally at ground potential.

2 **Back flashover rate**: the annual outage rate on a circuit or tower-line length basis cause by back flashover on a transmission line.

3 **Critical current**: The first stroke lightning current to a phase conductor which produces a critical impulse flashover voltage wave.

Chapter 1
Introduction

1.1 Background

Lightning strokes cause a lot of power losses in the transmission lines as they are responsible for around 65 % of unscheduled line outage as per many technical publications. This high percentage of outage affects on the electrical utility power delivery.

Power supply utilities have verified the load losses due to voltage sags on their systems from transient outages caused by lightning activity and in some regions they have found serious permanent damage caused to the system itself due to these transient disturbances occurring on important lines. The effect of these transitory disturbances on transmission lines is more critical in areas with high ground resistivity when associated with high lightning activity.

Although, it is a fact that most of the non-scheduled outages are transient in nature, with a fault time shorter than 1 minute, in many cases this is still deemed, by power supply utilities and their customers, to be unacceptable.

This loss of supply is critical for all modern industries now, so reliant on sophisticated electronic equipment and especially production processes sensitive to momentary disturbances on the system.

In order to reduce the number of non-scheduled outages in electrical systems, some improvements need to be done on the transmission line design to protect it from lightning strokes after a good understand the lightning phenomena and that one lightning strike may contains more the one stroke.

1.2 Thesis Objectives

The objective of this thesis is to study the effect of the multi stroke on the transmission line and to provide a tool for determining the line outage probability due to lightning strikes, choice among different tower shapes and other variables to study and reduce the outage of the transmission line and in return increase the performance of the power supply utilities.

The thesis include sensitivity studies which show different types of footing resistance, spacing between phases, spacing between O.H.G.W. and different tower shapes and their effect on the transmission line lightning performance characterization, which will clearly show that changing one parameter will affect the whole system performance either improve or worsen the system performance.

1.3 Disposition

A good understanding for the lightning cause and effect and the transmission line with its components is required in order to explain the idea of the developed program, how it works and how it help the designer to make the calculations. Consequently, the thesis consists of seven chapters which will be shown in the below thesis outlines.

1.3.1 Thesis Outlines

- **Chapter 1** is the introduction that presents the aim of writing the master thesis and the objectives of this thesis, the abbreviation used within thesis. In addition to a brief description for each chapter with its disposition in the thesis.

- **Chapter 2** presents literature survey and exploration of previous work and efforts exerted regarding the effect of lightning on transmission line.

- **Chapter 3** explains lightning initiation and stages and presents the different kinds of lightning with their cause and effect. Moreover, it describes the upward and the downward lightning strikes and their cause and effect.

- **Chapter 4** is Transmission line which describes the types, requirements, components and the factors that affect the transmission line design.

- **Chapter 5** is Transmission Line outage probability assessment algorithms with the methodology of evaluating the lightning performance characterization on the transmission line taking in consideration all the parameters. In addition to the explanation of the idea of the developed program.

- **Chapter 6** is the sensitivity studies that show the effect of changing the footing resistance, phase spacing, OHGW spacing and changing more than one parameter at the same time with a brief comment in each result.

- **Chapter 7** presents the thesis summery, conclusion and recommendations for Future research area.

Chapter 2
Literature Survey

2.1 Introduction

Lightning strokes to transmission line and tower are classified into two groups which are direct stroke and induced voltage.

Direct stroke is the phenomenon of thunder cloud directly discharges into transmission line and it is considered the major source of disturbance in transmission line system [1].

Induced voltage is introduced when the thunderstorm generates negative charges and the earth objects develop induced positive charges. When cloud discharges to some earthed objects other than the transmission line, the line is left with a huge concentration of charge (positive) which cannot leak instantaneously. The transmission line and the ground will act as a huge capacitor charged with a positive charge and hence overvoltage occurs due to these induced charges [1, 2].

A significant number of the faults on overhead transmission lines are due to lightning. These faults may be single or multiphase.

Te outage rate of a line and the quality of the delivered voltage depend on the lightning performance of the line.

2.2 Lightning Effect on Transmission Line Protection

When a direct lightning strike occurs, lightning current of large amplitude will be injected into the transmission line. Lightning can strike on transmission lines in many ways. However, only the lightning strokes which can cause transients on phase conductors of the transmission line are direct stroke to a phase conductor and strike to the overhead shield wire or tower, which then flashes over to the phase conductor [3].

2.2.1 Back Flashover

When lightning strikes a tower, a traveling voltage is generated which travels back and forth along the tower, being reflected at the tower footing and at the tower top, thus raising the voltage at the cross-arms and stressing the insulators. The insulator will flashover if this transient voltage exceeds it's withstand level (backflash). Back flashover voltages are generated by multiple reflections along the struck tower and also along the shield wire for shield lines at the adjacent towers. The back flashover voltage across insulator for the struck tower is not straight forward. The peak voltage will be directly proportional to the peak current [4].

2.3 Evaluation Methodology

A computer program for predicting the number of lightning faults on a transmission line is an important tool for establishing line design practices and choosing the adequate lightning performance techniques.

Many procedures have been presented over the years with the aim of predicting the lightning performance of transmission lines. In many cases, such procedures have been based on simplifications and assumptions which are proved later to be inaccurate or incomplete, leading to estimations far from the experienced lightning performances.

Modern understanding about lightning phenomena and lightning attraction mechanisms allowed developing methods for estimating the lightning performance of overhead lines which avoid such empiricism. The work by Anderson [5] was the pioneer.

More recently, international pre-normative institutions, such as IEEE [Institute of Electrical and Electronics Engineers and CIGRÉ [Conseil International des Grands Réseaux Électriques] have paid a great interest to the subject, and extensive overview work was developed by working groups where the most knowledgeable experts were present. This work led to guidelines for estimating the lightning performance of transmission lines.

The work done by the IEEE working group is based on the work done by Anderson [5] and includes several versions of a computer program, FLASH. This program estimates the lightning performance of a given line using the procedures exposed in [6] and [7] depending on the version of the program.

The procedures developed by the CIGRÉ working group are exposed in [8].