ZnO LIGHTNING ARRESTER EARTHING IMPEDANCE CHARACTERISTICS UNDER TRANSIENT OVERVOLTAGES

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To my wife Sepideh, to my daughter, Bahar, and to my parents

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ABSTRACT

Lightning arrester in a power system is categorized as a device, which operates in transient conditions. Therefore, the performance of the arrester must be analyzed in transient circumstances. Some particular considerations such as physical (grounding installation) and electrical (impulse current) aspects must be taken. Hence, this research aims to take into account the effect of nonlinear characteristics of the grounding impedance on the residual voltage of the lightning protection system in different discharge conditions. In this issue, the lightning protection system consisting of ZnO and grounding model was adjusted to yield the accurate results in EMTP. For this purpose, IEEE dynamic model of ZnO arrester was adjusted such that the manufacturer's performance test results are achieved. The arrester was connected to the improved circuit model of the grounding electrode system. To analyze the performance of the lightning protection system with different grounding configurations, the system was subjected to the three groups of lightning impulse currents. For this purpose, CIGRE standard, Berger, and 8/20 (µs/µs) standard lightning currents were applied as impulse currents. The results shown that the lightning protection system cannot completely protect the power system equipment during the high amplitude and very fast front times of discharge currents, which were experienced under CIGRE and Berger current. In addition, residual voltages of the lightning protection system under standard performance tests for discharge currents less than 5kA do not exceed the protection level, but compare to the manufacturer’s results, the residual voltages are considerably increased.

ABSTRAK

Penangkap kilat dalam sistem kuasa dikategorikan sebagai alat yang beroperasi dalam keadaan fana (sementara). Oleh itu, prestasi penangkap kilat mesti dianalisis dalam keadaan fana. Beberapa pertimbangan tertentu seperti aspek fizikal (asas pemasangan pembumian) dan elektrik (arus dorongan) perlu diambil kira. Oleh itu, penyelidikan ini bertujuan untuk mengambil kira kesan ciri-ciri linear rintangan pembumian pada sisa voltan sistem perlindungan kilat dalam keadaan pelepasan yang berbeza. Dalam isu ini, sistem perlindungan kilat terdiri daripada ZnO dan sistem pembumian yang telah diselaraskan untuk menghasilkan keputusan yang tepat dalam EMTP. Bagi tujuan ini, model dinamik IEEE penangkap ZnO telah diselaraskan untuk mencapai keputusan ujian prestasi pengilang. Penangkap kilat ini telah disambungkan kepada model litar baik sistem elektrod pembumian. Untuk menganalisis prestasi sistem perlindungan kilat dengan konfigurasi asas yang berbeza, sistem adalah tertakluk kepada tiga kumpulan arus dorongan kilat. Bagi tujuan ini, kelas CIGRE, Berger dan 8/20 (μs / μs) arus kilat piawai digunakan sebagai arus dorongan. Keputusan menunjukkan bahawa sistem perlindungan kilat tidak dapat melindungi peralatan sistem kuasa semasa amplitud tinggi dan masa depan arus pelepasan yang sangat cepat, di mana ia telah berpengalaman di bawah arus CIGRE dan Berger. Di samping itu, sisa voltan sistem perlindungan kilat di bawah ujian prestasi piawai bagi pelepasan arus kurang dari 5kA tidak melebihi tahap perlindungan, tetapi sisa voltan ini meningkat dengan ketara berbanding dengan keputusan pengeluar.

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LIST OF SYMBOLS

a	-	Diameter
d	-	Depth
C	-	Capacitance
E_0	-	Critical electric field
Ig	-	Ionization current
I_{max}	-	Maximum impulse current
L	-	Inductance
l	-	Length
R	-	Resistance
S_{max}	-	Maximum slope of impulse current
T_f	-	Front time of impulse current
T_h	-	Tail time of impulse current
ε	-	Permittivity
μ	-	Permeability
π	-	Pi number = 3.14
ρ	-	Soil resistivity

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

In normal operation, lightning arresters according to the micro characteristics (micro varistor) are in a block position until the system is exposed to transient overvoltages. Then in these circumstances, the lightning arrester is short-circuited and it instantly discharges the impulse current and mitigates the overvoltage to less than the desired value (80-85% BIL). In power frequency, a pure resistor characterizes the grounding system of the power system equipment, however, under transient overvoltage circumstances the nonlinear behavior of the grounding system, in relation to the high discharge frequency, requires a complex model of earthing system, which includes resistor, inductor, and capacitor [1]**.** In these conditions, the residual voltages of the lightning protection system is different when compared to the simple grounding model or power frequency cases. Therefore, the effect of grounding nonlinear characteristics in transient condition should be taken into account [2], [3]. Although many studies that have been conducted in the field of lightning protection systems include gapless ZnO lightning arresters, none of them shows the effect of non-linearity characteristics of the ground impedance under transient conditions on the residual voltage of the system. In the IEEE standard, only the inductive behavior is considered with a length of more than 300m. However, many studies were done to analyze the soil and impedance behavior [4], [5]. Therefore, it needs more investigations to determine the effects of nonlinearity behavior of the grounding system on the protective performance of the lightning protection system, which includes the surge arrester and grounding system.

1.2 Statement of Problem

To damp the effects of the surge impulses in power system equipment such as transformers, reactors, or cables, use of lightning surge arresters are necessary. Surge arresters are connected between line conductors and earthing system by means of leads and connectors. In a simple configuration, ground electrode is modeled as a resistor and in some surveys, it is neglected. However, in transient conditions, two phenomena affect the ground impedance, which are soil breakdown and electromagnetic effects. Many parameters such as the length of the electrode, soil resistivity, discharge current magnitude, and current front time affect the ground impedance characteristics. In some cases, according to the previously mentioned parameters, the so-called impulse coefficient can be less than one or greater than one, which represents more or less the grounding system efficiency. Therefore, the voltage drop across the ground impedance varies with the effect of these parameters and behavior of the ground system. This voltage drop is represented by $V(t)=R(t).I(t)+X(t)$, where $R(t)$ is the soil breakdown nonlinear resistance, $I(t)$ is the discharge current, and $X(t)$ is the voltage drop related to the frequency dependent phenomena. According to the impulse coefficient of the earthing system (the impulse coefficient defined as $A=Z/R$), the voltage drop in earthing systems can be more or less than the measured value in the simple resistive model. This voltage is to be added to the residual voltage of the ZnO lightning arrester. Therefore, the effects of the grounding impedance characteristics and effective parameters in transient conditions, on the total residual voltage of the lightning protection system should be taken into account.

1.3 Purpose of Study

The aim of this research is to survey the effect of dynamic ground impedance characteristics under transient overvoltage conditions and lightning current parameters on the value of the voltage drop across the whole lightning protection system, which includes the ZnO lightning surge arrester and the ground proper.

1.4 Objectives of Study

The objectives of the study are as follows:

1) To improve the model of the grounding system to cope with the various impulse conditions.

2) To evaluate the protective performance of the ZnO lightning arrester based on simple and complex grounding models.

3) To survey the effects of lightning current amplitude and front time on the protective performance of the lightning protection system.

1.5 Significance of Study

By determining the voltage drop value in different conditions according to the effective parameters of the impulse current for simple and complex models of the grounding systems, accurate data can be used in protection formulas.these data can be taken into account to determine the residual voltage across the lightning protection system during the insulation coordination considerations.

1.6 Scope of Study

The scope of the research is 33kV AC transmission overhead lines, which are protected by gapless ZnO lightning surge arrester grounded by simple and complex earthing system.

1.7 Methodology

This study was conducted to evaluate the effect of grounding system on residual voltage of the lightning protection system. Therefore, three main components of the lightning protection system, which are zinc oxide gapless lightning arrester, grounding system, and the lightning current source were taken into account. In this regard, IEEE-C62.22 was used to set the dynamic model of ZnO lightning arrester in transient conditions for ABB commercial lightning arresters (MVK type) in 33kV overhead transmission lines. A linear resistor was used as an equivalent circuit of the horizontal and vertical rod representing a simple earthing model. While, for the modeling of complex grounding system the improved grounding system based on the electromagnetic approaches was used as grounding system. The validity of the improved model was checked by the computational, simulation and experimental cases. Three types of current sources based on incidence probability, CIGRE impulse current, Berger findings, and ZnO standard performance test (8/20 (µs/µs) in different magnitudes) were used as current sources.

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