Electric Power Systems Research 113 (2014) 88–94

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

A study of human safety against lightning considering the grounding system and the evaluation of the associated parameters

Daniel S. Gazzana [a,*], Arturo S. Bretas [a], Guilherme A.D. Dias [a], Marcos Telló [b], Dave W.P. Thomas [c], Christos Christopoulos [c]

[a] Department of Electrical Engineering, Federal University of Rio Grande do Sul, Av. Osvaldo Aranha, 103, 90035-190 Porto Alegre, RS, Brazil
[b] Companhia Estadual de Energia Elétrica – CEEE-D, Av. Ipiranga 8500, E2A, 91530-000 Porto Alegre, RS, Brazil
[c] George Green Institute for Electromagnetics Research, University of Nottingham, Nottingham NG7 2RD, UK

ARTICLE INFO

Article history:
Received 30 July 2013
Received in revised form 28 February 2014
Accepted 11 March 2014
Available online 1 April 2014

Keywords:
Grounding
Human safety
Lightning
Transmission line modeling method

ABSTRACT

This paper presents a study about the influence of different types of soils and surge wave characteristics in terms of human safety. The study is focused on the step, contact and transferred potentials generated by a lightning striking a grounding system and the produced potential gradients that a person could be exposed to. Initially, an introduction about the subject is made. After that, some important aspects about the grounding systems and human body representation are presented followed by a discussion regarding to the survivability threshold and the model parameterization. A Transmission Line Modeling Method and a circuit based model are used to represent the grounding system and the human body. Several simulations were performed in order to analyze the behavior of the current passing through the heart. It was found that soils with different properties do not affect the possible harmful currents considering the step potential mechanism. On the other hand, in the case of contact and transferred potentials, the soil characteristics have significant influence in the survivability threshold.

© 2014 Elsevier B.V. All rights reserved.

1. Introduction

Since the dawn of humanity, thousands of injuries caused by lightning have been observed, causing fatalities and damage to humans with short and long term effects [1]. It is known that the effects of a given electrical current passing through the human body are primarily related to its duration, frequency and magnitude [2].

There are several efforts, over the past decades, dedicated to the establishment of reference limits and development of studies related to the effects of electric current on human beings and animals. However, most of these studies consider only low frequencies and are focused primarily on the analysis of sinusoidal current with frequency in the order of 15–100 Hz, which culminated in the elaboration of international norms currently in use [3]. It is not usual to evaluate the electric current tolerable by human being from a lightning, as well as for frequencies higher than the industrial (60 Hz), since today there are not defined criteria for such purpose. Nowadays, the main standard that provides procedures for the determination of step and touch potentials and current tolerable by humans is the IEEE Std 80 [4], but it is important to note that this standard is based on the industrial frequency and steady state analysis, which is not appropriate for transient studies. Moreover, a more reliable approach must be centered in energy evaluation, which is not the main goal of the referred standard. Also, in the existing literature there is little information about the current pathway through the human body, in the case of submission to a touch potential, step potential and other lightning mechanisms.

Unlike the studies related to the effect of alternating current for low frequencies and low magnitudes, research with focus on the lightning and its iteration with humans are very difficult to be carried out due to the tests that have to be performed. It is a tricky task to verify the effects caused by atmospheric discharges in humans. It is obviously unacceptable to submit people to contact with electric shocks. This may be the reason for the rare studies found in the state-of-art literature. Also, there is little consideration of the grounding systems and the influence of the soil and variation of lightning parameters. Thus, the use of computational models that represent the human body is a viable alternative to learn about the behavior of the lightning passing through it, contributing to the development of new research and serving as a basis to the identification and understanding of the effects and potential damages caused by a lightning [5].

* Corresponding author. Tel.: +55 51 3308 4291; fax: +55 51 3308 3293.
E-mail addresses: dgazzana@ece.ufrgs.br, dsgazzana@gmail.com (D.S. Gazzana), abretas@ece.ufrgs.br (A.S. Bretas), gaddias@terra.com.br (G.A.D. Dias), marcost@ceee.com.br (M. Telló), dave.thomas@nottingham.ac.uk (D.W.P. Thomas), christos.christopoulos@nottingham.ac.uk (C. Christopoulos).

http://dx.doi.org/10.1016/j.epsr.2014.03.015
0378-7796/© 2014 Elsevier B.V. All rights reserved.

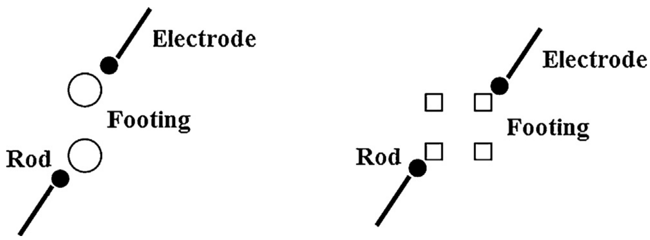

Fig. 1. Basic grounding in power system networks: left – wood poles; right – metallic towers.

Usually, in the design of grounding systems both for transmission and distribution systems as well as for the protection of installations in a general manner, the main performance criterion is related to obtaining low values of grounding static impedance. This design requirement ensures only that high currents from a given disturbance follow the path of low impedance. However, this procedure does not provide personal safety.

In this context, the aim of the paper is to evaluate the influence of soil parameters and variation of surge characteristics (wave shape and wave magnitude) in terms of potential generated in a person submitted to a lightning mediated by a grounding system. To reach these goals, a Transmission Line Modeling Method (TLM) algorithm combined with a human body model representation was implemented. The step, contact and transferred potentials mechanisms were considered in order to estimate the current and the energy flowing to the chest of a person, contributing to the study of human safety as well as to the development of more reliable lightning protection systems (LPS).

2. Grounding system representation

The grounding system is one of the main resources responsible for dissipating the current proceeding from a lightning to the earth, being an important component for the population's safety [6]. Although it is known that the performance of a LPS can be improved considering the use of elaborated grounding meshes, the implementation of simple structures composed of horizontal or vertical electrodes is a common practice adopted by the power utilities both in distribution and transmission networks. Fig. 1 shows some of the basic grounding schemes used in power utilities.

Usually, the practical implementation of these basic grounding components is justified either by the physical constraints, especially in urban areas, or by means of financial resources, taking into account only the minimum material necessary to obtain low values of grounding impedance. However, as mentioned above, this approach does not guarantee personal safety and low potentials generated in the soil surface. This problem has a significant relevance particularly in populated sites, where the people are more susceptible to be injured by contact, transferred and step potential or other lightning mechanisms [7].

In order to evaluate the current scattered along a horizontal or vertical electrode and consequently the potentials generated, a numerical technique can be considered. This will ensure knowledge of the grounding behavior before its physical implementation along with the estimation of the possible harmful electrical quantities that a person can be exposed to [8].

Thus, the Transmission Line Modeling Method in one dimension (TLM-1D) can be a powerful tool to analyze the transients generated by a lightning surge reaching a LPS [9]. In this technique, the impulsive response and the behavior in the time domain at any point (node) along the electrode can be explicitly determined and there are no problems with convergence, stability or spurious solutions. Additionally, nonlinearities such as the soil ionization phenomenon can be incorporated to the model [10,11]. Fig. 2 shows a horizontal electrode represented in TLM-1D.

Based on the TLM-1D algorithm, the calculated electrical quantities can be used as input sources to the human body model. The step and touch potentials can be determined, allowing the evaluation of the current flowing through the body. The variations of the soil parameters, lightning wave shape and electrode characteristics can be simulated with this technique. Therefore, the influence of the related parameters in terms of possible harmful energy, currents and potentials can be evaluated.

3. Human body representation

According to [3], the resistance of the human body depends on the moisture, temperature and other physical properties. It is further considered that the human body has two impedances (external and internal). The body inside has lower impedance compared to the impedance of the skin. This quantity may be represented by a combination of resistive and capacitive components. The impedance of the body is dependent on the voltage, frequency and contact area, considering the current pathway through it.

More simplified models where the body is represented by equivalent impedances [12,13,14] can be found in the literature. To summarize, in the referred works the human body is molded by a single resistance ranging from 500 Ω to 1 kΩ. Another approach is the representation of the human body by an association of electrical components, where a group of elements is associated with a

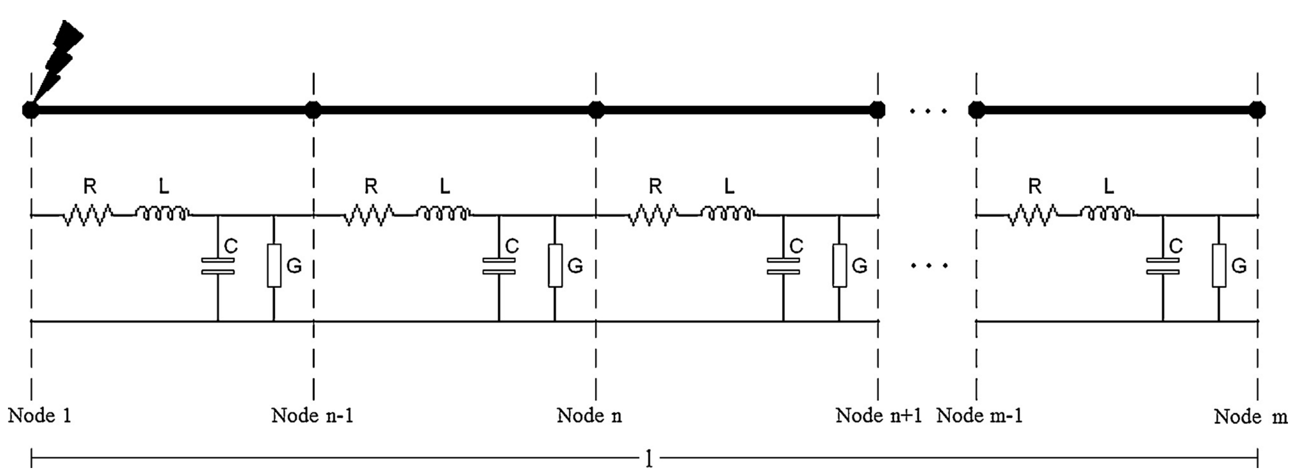

Fig. 2. Grounding electrode representation: top – horizontal conductor; bottom – equivalent circuit using TLM-1D.

Download English Version:

https://daneshyari.com/en/article/703550

Download Persian Version:

https://daneshyari.com/article/703550

Daneshyari.com