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POTENTIALS OF THE TRANSMISSION TOWERS DURING GROUND FAULTS

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Abstract – *A phase-to-ground fault occurring on a transmission line divides the line into two sections, each extending from the fault towards one end of the line. These two sections of the line may be considered infinite if some certain conditions are met; otherwise, they must be regarded as finite. In this paper are studied these two sections of the line and then the analysis of full-lines can be accomplished by regarding them as a composite of the two sections.*
Keywords – *overhead transmission lines, ground fault, tower potential*

1. INTRODUCTION

A phase-to-ground fault occurring on a transmission line divides the line into two sections, each extending from the fault towards one end of the line. In this paper are studied these two sections of the line and then the analysis of full-lines can be accomplished by regarding them as a composite of the two sections. These two sections of the line may be considered infinite if some certain conditions are met; otherwise, they must be regarded as finite.
During ground faults on transmission lines, a number of towers near the fault are likely to acquire high potentials to ground. These tower voltages, if excessive, may present a hazard to humans and animals.
Since during a ground fault the maximum voltage will appear at the tower nearest to the fault, attention in this study will be focused on that tower.
The voltage rise of the faulted tower depends of a number of factors. Some of the most important factors are: magnitudes of fault currents on both sides of the fault location, fault location with respect to the line terminals, conductor arrangement on the tower and the location of the faulted phase, the ground resistance of the faulted tower, soil resistivity, number, material and size of ground wires.
In exploring the effects of these factors, an important assumption will be that the magnitudes of the fault currents, as supplied by the line on both sides of the fault location, are known from system studies; no attempt will be made, therefore, to determine these quantities.
The calculation method introduced is based on the following assumptions: impedances are considered as lumped parameters in each span of the transmission line, capacitances of the line are neglected, the contact resistance between the tower and the ground wire, and respectively the tower resistance between the ground wire and the faulty phase conductor, are neglected.

2. FAULTS ON OVERHEAD LINES

When a ground fault occurs on an overhead transmission line in a power network with grounded neutral, the fault current returns to the grounded neutral through the tower structure, ground return path and ground wires. In this case, an infinite half-line can be represented by the ladder network presented in figure 1. It is assumed that all the transmission towers have the same ground impedance Z_{st} and the distance between towers is long enough to avoid the influence between there grounding electrodes. The impedance of the ground wire connected between two grounded towers, called the self-impedance per span, it is noted with Z_{cp_d}. Considering the same distance l_d between two consecutive towers and that Z_{cp_d} is the same for every span, then $Z_{cp_d} = Z_{cp} l_d$, where Z_{cp} represents the impedance of the ground wire in Ω / km. Z_{cp_m} represents the mutual impedance between the ground wire and the faulted phase conductor, per span.
In order to determine the equivalent impedance of the circuit presented in figure 1, it is applied the continuous fractions theory [5].

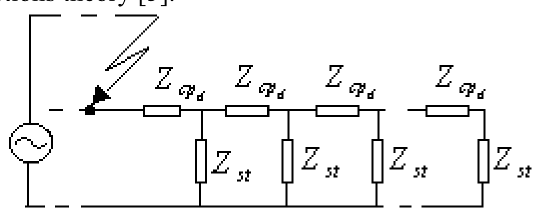

Fig. 1- Equivalent ladder network for an infinite half-line

Applying this theory, the expression for the equivalent impedance seen from the fault location will be [5]:

$$Z_{\infty} = \frac{Z_{cp_d}}{2} + \sqrt{Z_{cp_d} Z_{st} + \frac{Z_{cp_d}^2}{4}} \tag{1}$$

For an infinite line in both directions (the two sections of the line between the fault and the terminals could be considered long), the equivalent impedance is given by the next expression:

$$\frac{1}{Z_{\infty\infty}} = \frac{1}{Z_{\infty}} + \frac{1}{Z_{st}} + \frac{1}{Z_{\infty}} \tag{2}$$

respectivelly:

$$Z_{\infty\infty} = \frac{1}{\dfrac{2}{Z_\infty} + \dfrac{1}{Z_{st}}} \tag{3}$$

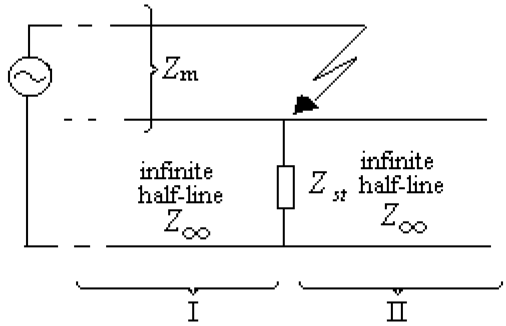

Fig. 2 - Full-line, infinite on both directions

The voltage rise of the faulted tower U_0 is given by the next expression [6]:

$$U_0 = (1-\nu) I_d Z_{\infty\infty} \tag{4}$$

In expression (4), the coupling between the faulted phase conductor and the ground conductor is taken into account by Z_{cp_m}, the mutual impedance per unit length of line and $\nu = \dfrac{Z_{cp_m}}{Z_{cp_d}}$ represents the coupling factor.

I_d in expression (4) represents the fault current.

Figure 3 presents the connection of a ground wire connected to earth through transmission towers, each transmission tower having its own grounding electrode or grid, Z_{st}. When a fault appears, part of the ground fault current will get to the ground through the faulted tower, and the rest of the fault current will get diverted to the ground wire and other towers.

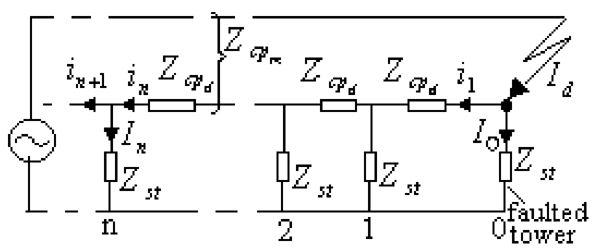

Fig. 3 - Fault current distribution

For the voltage rise of the terminal tower in this case the next expression is obtained [11], [12]:

$$U_0 = I_0 Z_{st} == (1-\nu) I_d Z_N \tag{5}$$

With impedance Z_N was noted the equivalent impedance of the network looking back from the fault in this case:

$$Z_N = Z_{st} \left(\begin{array}{l} \dfrac{B_2 - B_1}{A_1 B_2 - B_1 A_2}(1 - e^{\alpha}) + \\ \dfrac{A_1 - A_2}{A_1 B_2 - B_1 A_2}(1 - e^{-\alpha}) \end{array} \right) \tag{6}$$

where A_1, B_1, A_2, B_2 are:

$$A_1 = \frac{1}{1 - e^{\alpha}} + \frac{Z_{st}}{Z'_p}$$

$$B_1 = \frac{1}{1 - e^{-\alpha}} + \frac{Z_{st}}{Z'_p}$$

$$A_2 = e^{\alpha N} \left[\frac{e^{\alpha}}{1 - e^{\alpha}} \left(1 + \frac{Z'_{cp_d}}{R_p}\right) - \frac{Z_{st}}{R_p} \right]$$

$$B_2 = e^{-\alpha N} \left[\frac{e^{-\alpha}}{1 - e^{-\alpha}} \left(1 + \frac{Z'_{cp_d}}{R_p}\right) - \frac{Z_{st}}{R_p} \right]$$

3. RESULTS

In order to illustrate the theoretical approach outlined in section above, we are considering that the line who connects two stations is a 110kV transmission line with aluminium-steel 185/32mm^2 and one aluminium-steel ground wire 95/55mm^2 (figure 4). Line impedances per one span are determined on the bases of the following assumptions: average length of the span is 250m; the resistances per unit length of ground wire is $0{,}3\,\Omega / km$ and it's diametere is 16mm. Ground wire impedance per one span Z_{cp_d} and the mutual impedance Z_m between the ground wire and the faulted phase are calculated for different values of the soil resistivity ρ with formulas based on Carson's theory of the ground return path [4]. Impedance Z_m is calculated only in relation to the faulted phase conductor, because it could not be assumed that a line section of a few spans is transposed. The fault was assumed to occur on the phase which is the furthest from the ground conductors, because the lowest coupling between the phase and ground wire will produce the highest tower voltage.

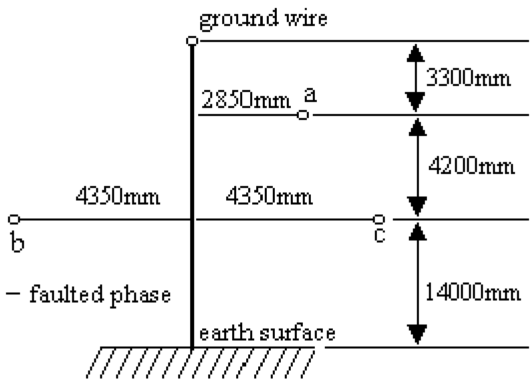

Fig. 4 - Disposition of line conductors

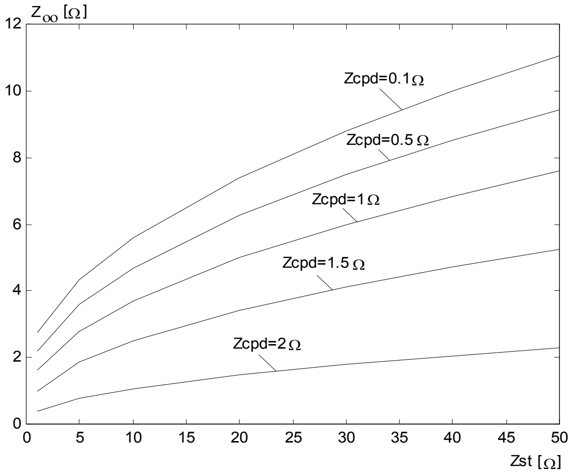

Fig. 5 - The infinite line impedance as a function of the towers impedances

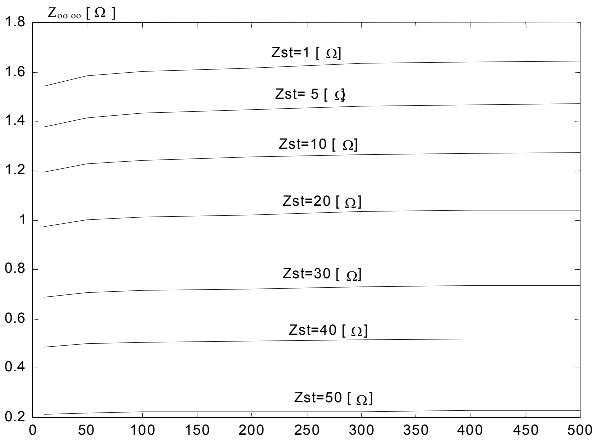

Fig. 6 - The equivalent impedance of the line infinite in both directions

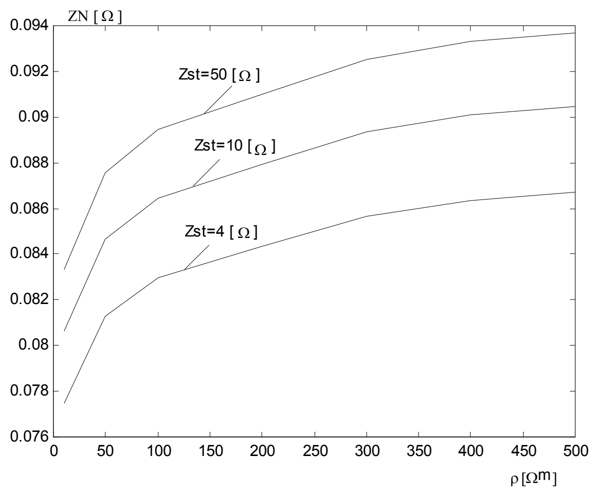

Fig. 7- Finite line impedance

Figure 5 presents the values of the impedance of the infinite half-line, as a function of the towers impedances, for different values of the ground wire.

Figure 6 presents the values of the equivalent impedance of the line, composed by two infinite half-line, for different values of the towers impedances.

Figure 7 shows the values for the impedance of finite line, in case of a fault at the last tower of the line. The values are calculated with the expression (6).

4. CONCLUSIONS

A phase-to-ground fault occurring on a transmission line divides the line into two sections, each extending from the fault towards one end of the line. This paper describes an analytical method in order to determine the equivalent impedaces and the voltage rise of the faulted tower for those sections of the line.

REFERENCES

[1] A. Buta, *Transmission and Distribution of Electricity*, Publishing House of Technical University of Timisoara, 1991 (in Romanian)

[2] Buta A., Milea L., Pană A., *Power Systems Harmonic Impedance*, Publishing Technical House, Bucharest, 2000 (in Romanian)

[3] Buta A., Pană A., Milea L., *Electric Power Quality*, Publishing AGIR House, Bucharest, 2001 (in Romanian)

[4] Clarke E., *Circuit Analysis of A-C Power Systems,* Publishing Technical House, Bucharest, 1979 (Translated into Romanian)

[5] Edelmann H., *Electrical Calculus of Interconnected Networks*, Publishing Technical House, Bucharest, 1966 (in Romanian)

[6] Endrenyi J., *Analysis of Transmission Tower Potentials during Ground Faults*, IEEE Transactions on Power Apparatus and Systems, Vol.PAS-86, No.10, October 1967

[7] Goci H. B., Sebo S. A., *Distribution of Ground Fault Currents along Transmission Lines - an Improved Algorithm*, IEEE Transactions on Power Apparatus and Systems, Vol.PAS-104, No.3, March 1985

[8] *** *Methodology of Current Fault Calculus in Electrical Networks - PE 134/1984*, Electrical Research and Development - ICEMENERG, Bucharest 1993 (in Romanian)

[9] Rudenberg R., T*ransient Performance of Electric Power Systems*, Publishing Technical House, 1959, (Translated into Romanian)

[10] Verma R., Mukhedkar D., *Ground Fault Current Distribution in Sub-Station, Towers and Ground Wire*, IEEE Transactions on Power Apparatus and Systems, Vol.PAS-98, No.3, May/June 1979

[11] Vintan M., *Fault Current Distribution in High Voltage Electrical Networks,* PhD Thesis, Timisoara 2003 (in Romanian)

[12] Vintan M., Bogdan M., *A Practical Method for Evaluating Ground Fault Current Distribution on Overhead Transmission Lines*, Scientific Bulletin of the "Politehnica" University of Timisoara, Transaction on Power Engineering, Tom 48(62) pg. 563 - 568, ISSN 1582-7194, November 2003