TRANSIENT ANALYSIS DUE TO SHORT CURRENT IN ONE END FEED UNDERGROUND POWER CABLES: EFFECT OF FAULT LOCATION

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ABSTRACT

In this study, transient analysis due to short current fault conditions on underground power cables are investigated. The method of solution developed is based on the modified Fourier Transform technique. Mathematical formulations of the transient responses are first obtained in frequency domain. Then the solutions are found in time domain using inverse Fourier Transform Technique. The effect of fault location are investigated. This investigations are based on computer simulation.

1.INTRODUCTION

In this study, transient analysis due to short current fault conditions when cables have no loading on underground power cables are investigated.

The modified Fourier Transform Technique have been used for the analysis. Cable system are crossbonded and solidly earthed at major section joints.

2. EMPEDANCES AND ADMITTANCES MATRICES OF A UNDERGROUND CABLE SYSTEM

Cable empedance and admittance matrices have been obtained as represented in ref.1 [1].

If we consider distributed cable parameters of a cable system, containing n conductors for x distance in frequency domain following equations can be obtained;

$$d^2\tilde{V} / dx^2 = Z.Y.\ \tilde{V} = P.\ \tilde{V} \qquad (2.1)$$

$$d^2\ \tilde{I}\ / dx^2 = Y.Z.\ \tilde{I}\ = P^T.\ \tilde{I} \qquad (2.2)$$

Making some necessary arrangements, these equations can be written in terms of sending end and receiving end with matrix form as follows;

$$\begin{bmatrix} \tilde{I}_S \\ \tilde{I}_R \end{bmatrix} = \begin{bmatrix} Y_0.\coth(\psi) & -Y_0.\mathrm{cosech}(\psi) \\ -Y_0.\mathrm{cosech}(\psi) & Y_0.\coth(Bl) \end{bmatrix} \begin{bmatrix} \tilde{V}_S \\ \tilde{V}_R \end{bmatrix} \qquad (2.3)$$

Equation (2.3) shows, admittance matrix of a homojen system. Sending end voltages and receiving end voltages are obtained from equation (2.3).

After this, the simulation of cable system is made and necessary relations are obtained [2]. Then the equations of fault condition is obtained from fig.2.1. The matrices equations which expressed voltages and currents which belong to right hand side and left hand side of fault point are as follows.

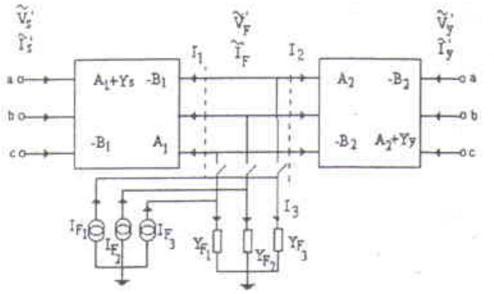


Figure 2.1 Reduces form of single – line diagrams of the faulted system

$$\begin{bmatrix}\tilde{I}'_s\\ \tilde{I}_1\end{bmatrix}=\begin{bmatrix}A_1+Y_S & -B_1\\ -B_1 & A_1\end{bmatrix}\begin{bmatrix}\tilde{V}'_s\\ \tilde{V}'_F\end{bmatrix} \quad (2.4)$$

$$\begin{bmatrix}\tilde{I}_2\\ \tilde{I}'_y\end{bmatrix}=\begin{bmatrix}A_2 & -B_2\\ -B_2 & A_2+Y_y\end{bmatrix}\begin{bmatrix}\tilde{V}'_F\\ \tilde{V}'_y\end{bmatrix} \quad (2.5)$$

where A_1 and B_1 are submatrices of left hand side and A_2 and B_2 are submatrices of right hand side. That is;

$A_1 = Y_0.\coth(\psi x)$, $B_1 = Y_0.\text{cosech}(\psi x)$,
$A_2 = Y_0.\coth(\psi (l - x))$, $B_2 = Y_0.\text{cosech}(\psi (l - x))$
ψ = propagation coefficient matrices of the cable
l = total cable lenght
x = distance from fault point to sending end busbar
Y_S is admittance matrix of source and Y_y is admittance matrix of load. Applying Kirchoff's current law to fault point from figure (2.1) following equals is written;

$$\tilde{I}_1+\tilde{I}_2+\tilde{I}_3-\tilde{I}'_F=0 \quad (2.6)$$

where;

$$\tilde{I}_3 = Y_F.\tilde{V}'_F\,;\ \tilde{I}'_F = -Y_F.\tilde{V}_F \quad (2.7)$$

and Y_F is fault admittance matrix. $\tilde{V}_F$ is voltage vector of pre-fault voltage in fault point. $\tilde{V}'_F$ is voltage vector of fictituous source which is applied to fault point.

Composing equations (2.4), (2.5) and (2.6), expression of all system is obtained:

$$\begin{bmatrix}\tilde{I}'_s\\ \tilde{I}'_F\\ \tilde{I}'_y\end{bmatrix}=\begin{bmatrix}A_1+Y_s & -B_1 & 0\\ -B_1 & (A_1+A_2+Y_F) & -B_2\\ 0 & -B_2 & A_2+Y_y\end{bmatrix}\begin{bmatrix}\tilde{V}_s\\ \tilde{V}_F\\ \tilde{V}_y\end{bmatrix} \quad (2.8)$$

If equation (2.8) is solved considering boundary conditions follwing expression is found;

$$\tilde{V}'_F=\begin{bmatrix}-B_1(A_1+Y_s)^{-1}B_1+(A_1+A_2+Y_F)\\ -B_2(A_2+Y_y)^{-1}B_2\end{bmatrix}^{-1}\tilde{I}'_F \quad (2.9)$$

Substituting $\tilde{I}'_F$ in equation (2.7), following equations can be written;

$$\tilde{V}'_s=(A_1+Y_s)^{-1}B_1.\tilde{V}'_F \quad (2.10)$$

$$\tilde{V}'_y=(A_{2+}Y_y)^{-1}B_2.\tilde{V}'_F \quad (2.11)$$

where V'_F is given by equation (2.9). The currents due to application of fictituous source can be determined as;

$$\tilde{I}'_s=-Y_{S1}\tilde{V}'_s$$
$$\tilde{I}'_y=-Y_{S2}\tilde{V}'_y \quad (2.12)$$

As it can be seen from figure (2.1);

$\tilde{V}_s=\tilde{V}'_s$ and $\tilde{V}_y=\tilde{V}'_y$. Thus substituting $\tilde{V}_s$ and $\tilde{V}_y$ to $\tilde{V}'_s$ and $\tilde{V}'_y$ in equation (2.12), $\tilde{I}_s$ and $\tilde{I}_y$ are obtained. $\tilde{V}'_s$ and $\tilde{V}'_y$ are given by equation (2.10) and (2.11) respectively.

The resultant sending end currents and receiving end currents can be obtained by adding steady-state load currents to currents obtained due to the application of the fictituous source at the fault point. The resultant voltages can also be determined in the some way i.e. by adding steady-state voltages to voltages obtained due to the application of fictituous source.

$$\tilde{V}_s = (\tilde{V}_s)_{ss} + \tilde{V}'_s \quad (2.13)$$

$$\tilde{V}_y = (\tilde{V}_y)_{ss} + \tilde{V}'_y \quad (2.14)$$

$$\tilde{V}_F = (\tilde{V}_F)_{ss} + \tilde{V}'_F \quad (2.15)$$

$\tilde{V}_F$ is the resultant fault point voltage vector, $(\tilde{V}_F)_{SS}$ is steady-state voltage vektor and $\tilde{V}'_F$ is the fault point voltage vector due to the application of the fictituous source at the fault point.

These values obtained frequency domain is transformed to time domain by fourier transform technique. [3].

3. Application Studies and Results

The basic system studies is a one-end fed, cable system is 154 kV and cable type is 2XS(FL)2YX1X1000 RMF 89/154 Kv . Cable lenght is 30 km. Load current is zero at the fault moment. Characteristic values of used cable is given in Table 1.

The location of cables are shown in figure 3.1 and distance are in meters

TABLE 1. Characteristic Value of Used Cable

Conductor radius:1.55 cm
Sheath inner radius:4.1 cm
Sheath outer radius:4.55 cm
Cable outer radius:5.00 cm
Resistivity of core:$1.71.10^{-8}$ ohm-m
Resistivity of sheath:$3.58.10^{-8}$ ohm-m
Relative permittivity of main insulation: 4.2
Relative permittivity of cable covering: 2.4
Relative permeability of the core:1.0
Relative permeability of the sheath:1.0

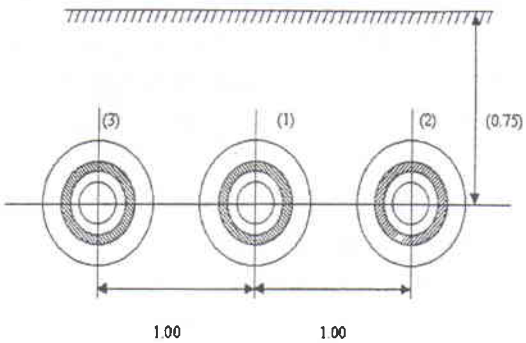


Figure 3.1 Configuration of the cable system

When checking the effect of fault locations, fault is assumed to occur in second phase and single phase to earth fault. In order to see the effect of fault location, first fault point was selected very near to rhe sending end of cable (2 km from sending end) and later fault point was selected very far from the sending end in the case of possibility of fault (29 km from sending end) and calculations were remade.

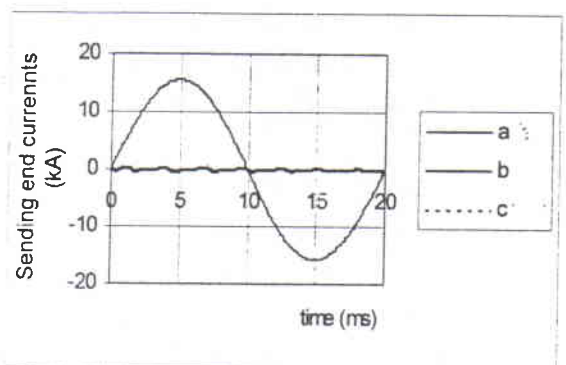
Graphics obtained from the calculation are seen in figure 3.2 and 3.3. As it can be seen from these figures, since fault location is gone away from sending end maximum values of current were decreased. Fault point is 2 km from sending end, the maxsimum current value of sending end is 15.5626 kA while fault point is 29 km far from semding end, this value is 8.9 kA (Figure 3.2 (a) and Figure 3.3 (a))

When investigating the cable sending end voltages, it is seen that the voltage waveform of faulted phase is contained distorsions with higer frequency components while location of faolt approching to sending end (Figure 3.2 (b) and Figure 3.3 (b)).

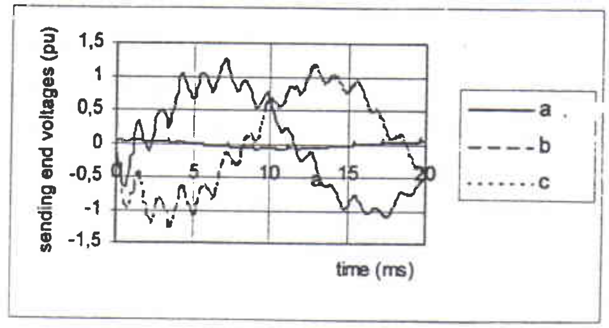
If we look at the cable receiving end voltage, the voltage of faulted phase doesn't suddenly zero, it has been that voltge waveforms has been formed due to imposing reflections and fractions with the effect of empedance for some time. As fault point approaches to the receiving end the voltage of faulted phase suddenly drops to zero.

When checking the voltage waveforms of unfaulted phase, it has been that as it has been gone away from the sending end of cable, the frequency of voltage waveforms has been increased but it's amplitude has been decreased. (Figure 3.2(c) and Figure 3.3(c))

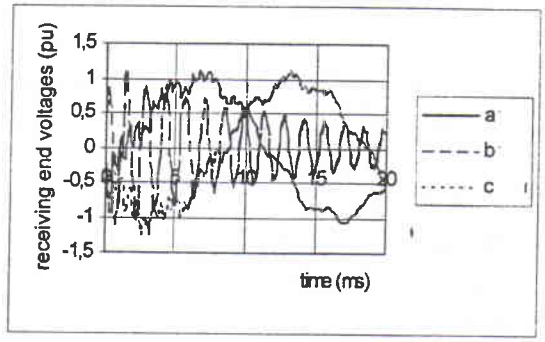
It has been seen that the voltage of the faulted phase being zero, the voltages of unfaulted phases as it has been gone away from sending end of cable oscilations have been increased but amplitude of oscilations have been decreased.(Figure 3.2(d) and Figure 3.3(d)).



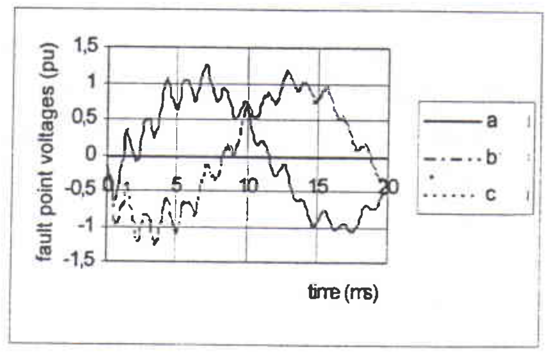
(a)



(b)



(c)



(d)

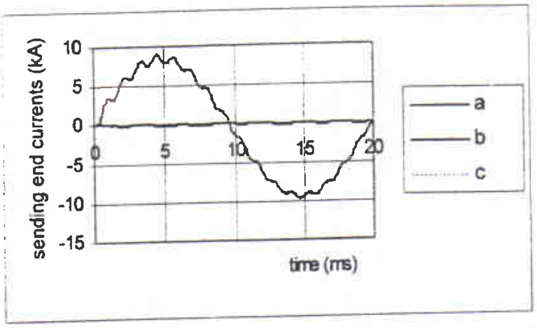
Figure 3.2 Effect of Fault Location L_x =2 km

a- Sending end Currents

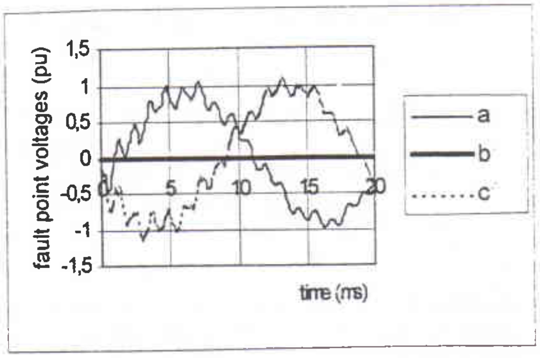
b- Sending end Voltages

c- Receiving end Voltages

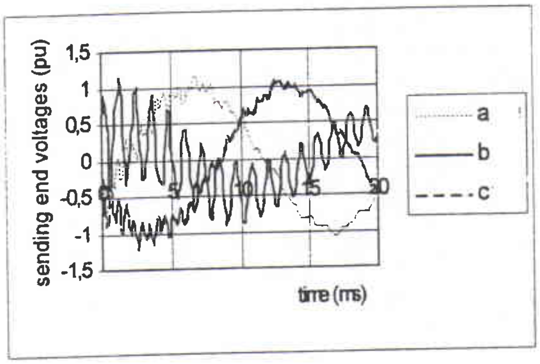
d- Fault Point Voltages



(a)



(d)



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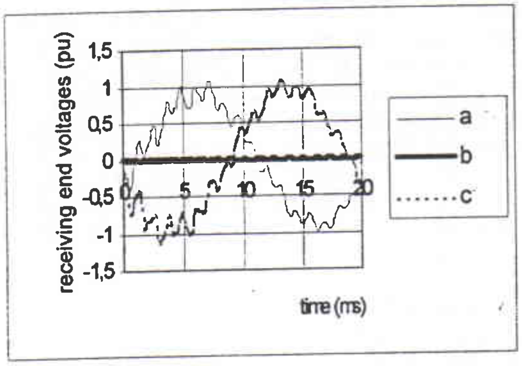

(c)

Figure 3.3 Effect of Fault Location L_x =29 km

a- Sending end Currents

b- Sending end Voltages

c- Receiving end Voltages

d- Fault Point Voltages

4.References

[1] Wedepohl and Wilcox, D.J. "Transient Analysis of Underground Power Transmission Systems. Systam Model and Wavw Propagation Characteristic", Proc.IEE, Vol. 120, 1973, pp.243-257.

[2] Unver, U. "Transient Analysis of Cable Systems Including The Effect of Non-Linear Protective Devices", Ph. D. Thesis, UMIST, Manchester, October, 1979.

[3] Unver U., "Enerji Nakil Hatlarının Kısa Devre Analizi: Çift Taraftan Beslenen Hatlar.", Elektrik Mühendisliği 6. Ncı Ulusal Kongresi, 1995, pp. 180-196.