TRANSIENT ANALYSIS OF SHORT-CIRCUIT FAULTS OCCURING IN CASCADE CONNECTED OVERHEAD LINE/CABLE SYSTEMS: EFFECT OF FAULT TYPE

Siyami HIDIROĞLU [1]　　**M.Uğur ÜNVER** [2]

[1]e-mail: siyami_hidiroglu@yahoo.com　　[2] e-mail: u_unver@yahoo.com

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ABSTRACT

In this paper, transient analysis with reference to short-circuit faults taking place in cascade-connected overhead line/cable systems is studied. Particularly, the effect of fault type is given the emphasis. In the analysis, modified Fourier Transform Method and Matlab software are used.

I. INTRODUCTION

It is well known fact that transient currents and voltages may appear in power transmission systems during any types of short circuit. It is important and desirable to be able to predict the possible occurrences of such overvoltages and overcurrents at the design stage so that the consequent damage to the power-system equipment can be avoided and optimum economical design can be met.

In this paper, different types of faults i.e. single line-to-ground fault, line-to-line fault, double line-to-ground fault and three phase-to-ground faults are considered while the transmission system is fed at both ends. The magnitudes and waveforms of the transients are determined at three different locations of the transmission system i.e. at the sending-end buses and at the junction bus of the overhead line/ cable system. when the short-circuit fault occur at the junction point.

Transient analysis is carried out using Modified Fourier Transform Method and Matlab Program [1-2-3-4-5]. Desired accuracy is provided benefiting from strong advantage of this method incorporating frequency dependent characteristics of the transmission system parameters in the solution. In the technique, the response is first determined in frequency domain. That is, steady-state solution is firstly obtained in frequency domain. Afterwards, transient response in time domain is obtained using the inverse Fourier transform technique, which makes use of the steady-state response functions to a wide range of frequency harmonics.

Series impedance and shunt admittance matrices of the line and cable, which are highly frequency dependent, are formed as described in the literature [6-7]. The single line diagram illustrating the transmission system studied is shown in Fig. 1

In the transmission system, the short-circuit fault occurs at point F, as shown in Figure 1. It is assumed that there is no load in the system and hence the pre-fault currents are ignored.

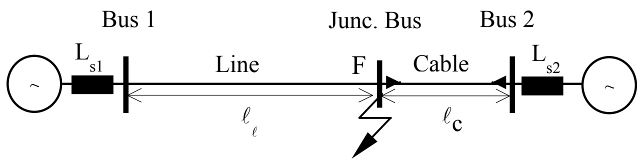

Fig. 1 Single line diagram of the transmission system

II. FAULT SIMULATION

Faults occurring on transmission systems are simulated making use of the Superposition Method [8]. The steps to be followed are as follows:

1) The pre-fault voltages at the fault point as well as at any point along the transmission system are determined ignoring the occurrence of the fault.

2) Fictitious voltage source(s) depending on the type of fault is applied at the fault point at the instant of fault inception, while other voltage sources of the system being shorted. The voltage of the fictitious source is equal in magnitude but opposite in polarity to the pre-fault voltage at the fault location. The transient response is computed starting from the instant of fault inception which is taken as t=0.

3) Making use of the principle of superposition, the resultant fault responses are obtained, i.e., summing up the two responses determined above by steps (1) and (2)

Since the fault occurs at the junction point of the overhead line/cable system, the transmission system is split into two different sections at the fault point. That is, the former is the typical overheadline system while the latter is the cross-bonded cable system. For similar transmission systems, voltage–current relations have been derived and already given in references (9-10).

It should be noted here that the transient fault currents are obtained just due to the contribution of fictitious source(s), since pre-fault currents are ignored.

III. SYSTEM STUDIES

In this section, computer results of the transient voltages and transient currents due to the occurrence of the short-circuit fault are presented. The effects of various faults on the magnitudes and the waveforms of transient voltages and transient currents are investigated.

The transmission system considered is of 380 kV. The line has bundled conductors, i.e., four sub-conductors per phase, and it has one earth wire as shown in Fig. 2. The cross-bonded underground cable system consists of single core power cables, which are laid as shown in Fig. 3. The total lengths of the line and the cable are 50 km and 20 km, respectively. Line and cable parameters are given in Tables 1 and 2.

the cross-bonded cable consists of several major sections. The sheaths of the phase cables are inter-connected and earthed solidly at each cross-bonding point. The length of every major section is 1 km for the cable.

The transmission system is fed at both-end by the identical sources. Source inductance is taken as 0.12 Henry for both sending-ends. Earth is assumed to be homogenous with a resistivity of 30 ohm-meters.

In the studies, at the instant of fault occurrence, the second phase voltage is assumed to be at the peak value and the other phases at half of the voltage peaks, since the angular displacements of the supply voltages are 120° between phases. So, at the instant of fault occurrence, the angular displacements of the phase voltages are taken to be θ_1=240°, θ_2=0° and θ_3=120°, respectively. The short-circuit faults is simulated by a fault impedance of $10^{-6}\Omega$ in the computer.

Transient responses are obtained at the sending-end buses, which are of main interest for protective devices as well as at the fault location. In the following figures, i.e., from Figure 4 to Figure 7, the waveforms of transient fault voltages and currents are given for different types of fault types.

Phases which are denoted by black, red, blue colours are respectively conform to 1, 2 and 3 in the waveforms presented in the following sections.

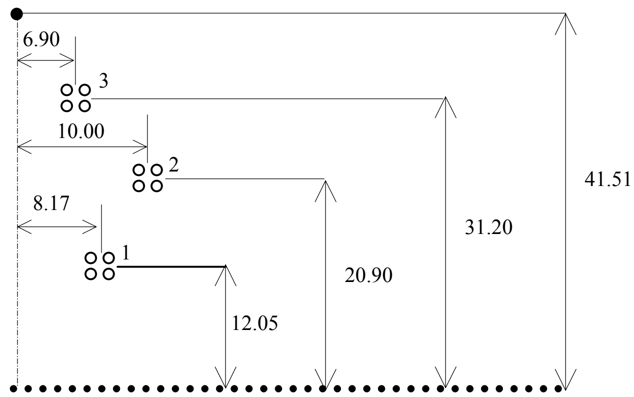

Fig 2 Configuration of the overhead line (Distances are in meters)

Table 1 Overhead line data

Parameters	Phase conductors	Earth wire
Diameter (cm)	30.902	2.858
Strand diameter (cm)	0.318	0.318
Resistivity (ohm-m)	$3.21.10^{-8}$	$3.21.10^{-8}$
Number of outer strands	24	24
No.of effective strands	54	54
Inductance correction factor	0.21088	0.21088
Number of sub-conductors per phase	4	-
Number of earth wire	1	-

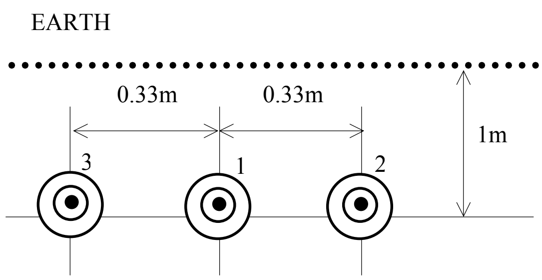

Fig 3 Configuration of the underground cable (Distances are in meters)

Table 2 Cable data

Parameters	
Core radius	2.44 cm
Sheath inner radius	4.20 cm
Sheath outer radius	4.60 cm
Cable outer radius	5.10 cm
Resistivity of core	1.72e-8Ωm
Resistivity of sheath	3.58e-8Ωm
Relative permittivity of core insulation	3.55
Relative permittivity of sheath insulation	8
Relative permeability of core	1
Relative permeability of sheath	1

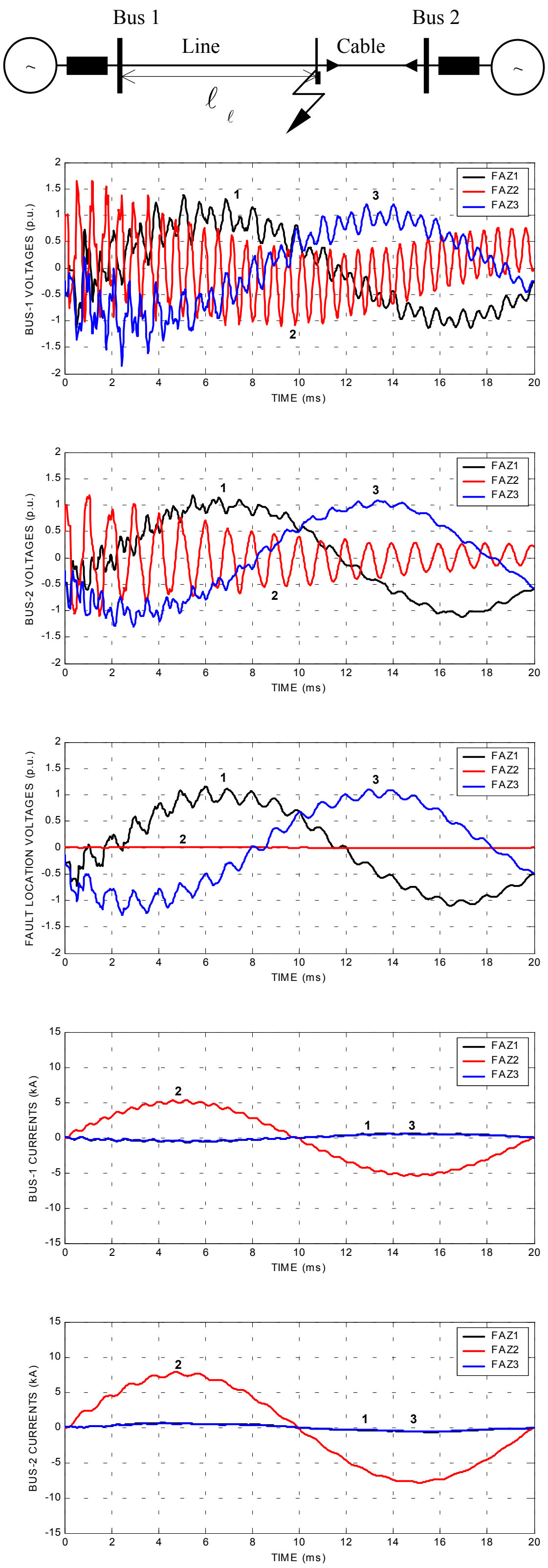

Fig. 4 The waveforms of transient voltages and currents due to single line-to-ground fault on phase 2 at the junction point.

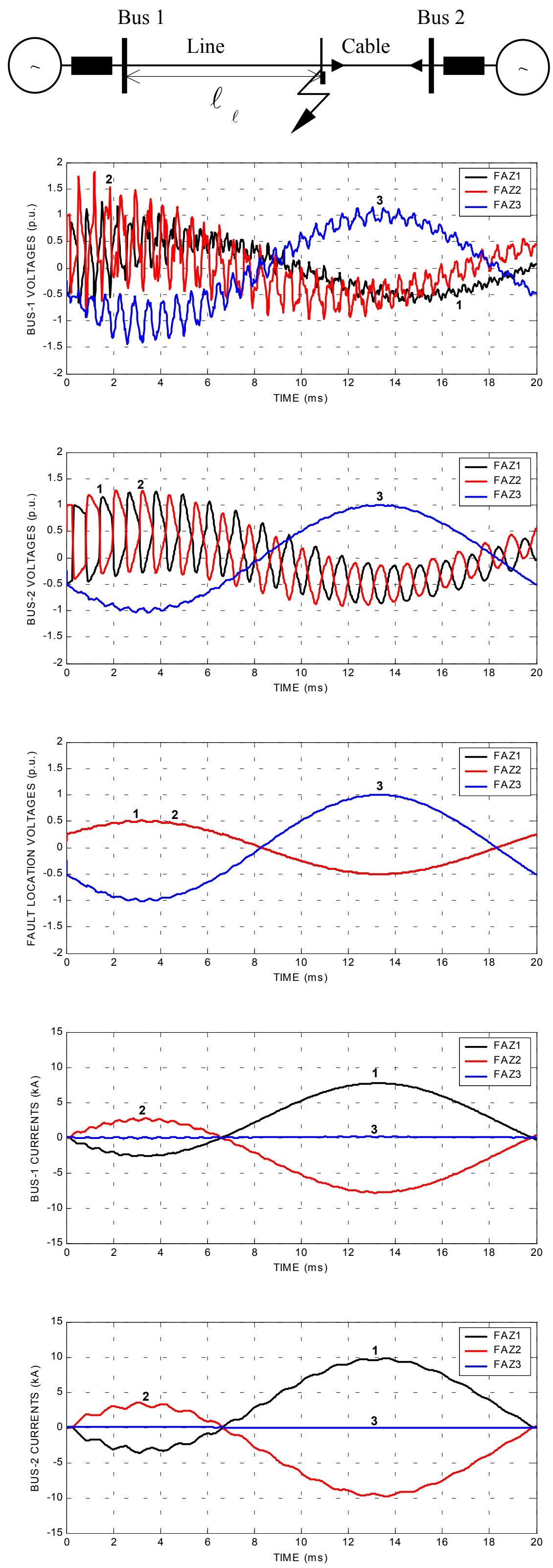

Fig. 5 The waveforms of transient voltages and currents due to the line-to-line short-circuit fault on phases 1 and 2 at the junction point.

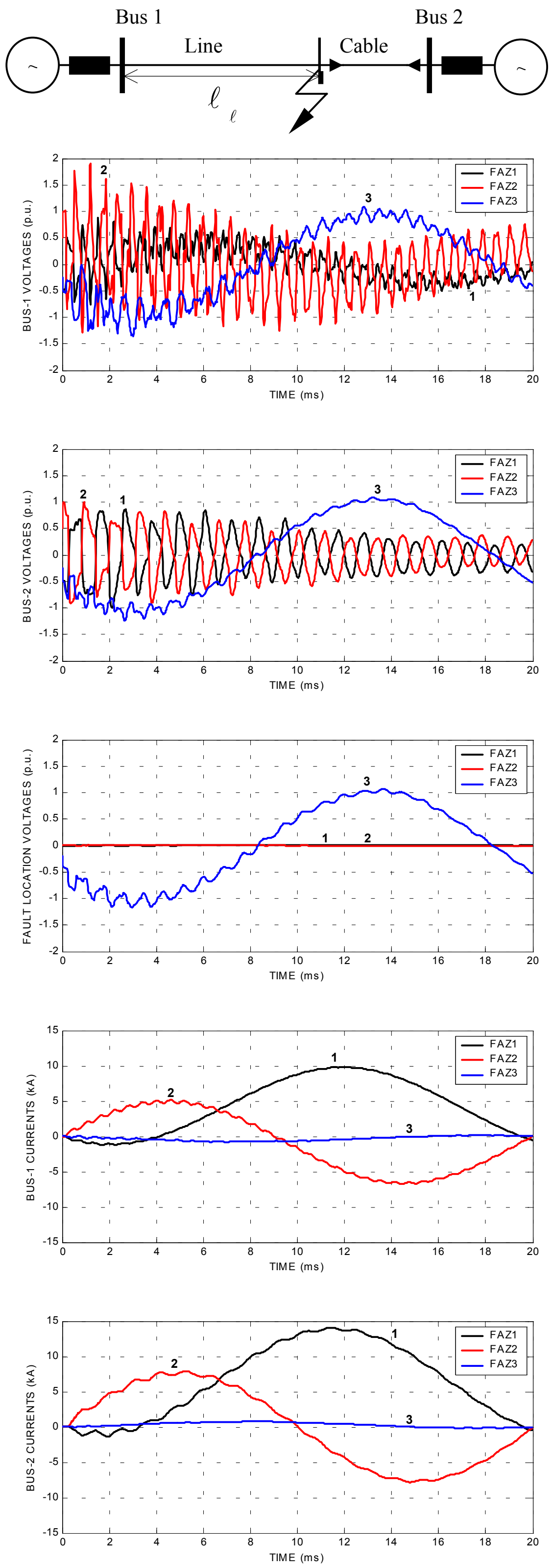

Fig. 6 The waveforms of transient voltages and currents due to double line-to-ground fault on phases 1 and 2 at the junction point.

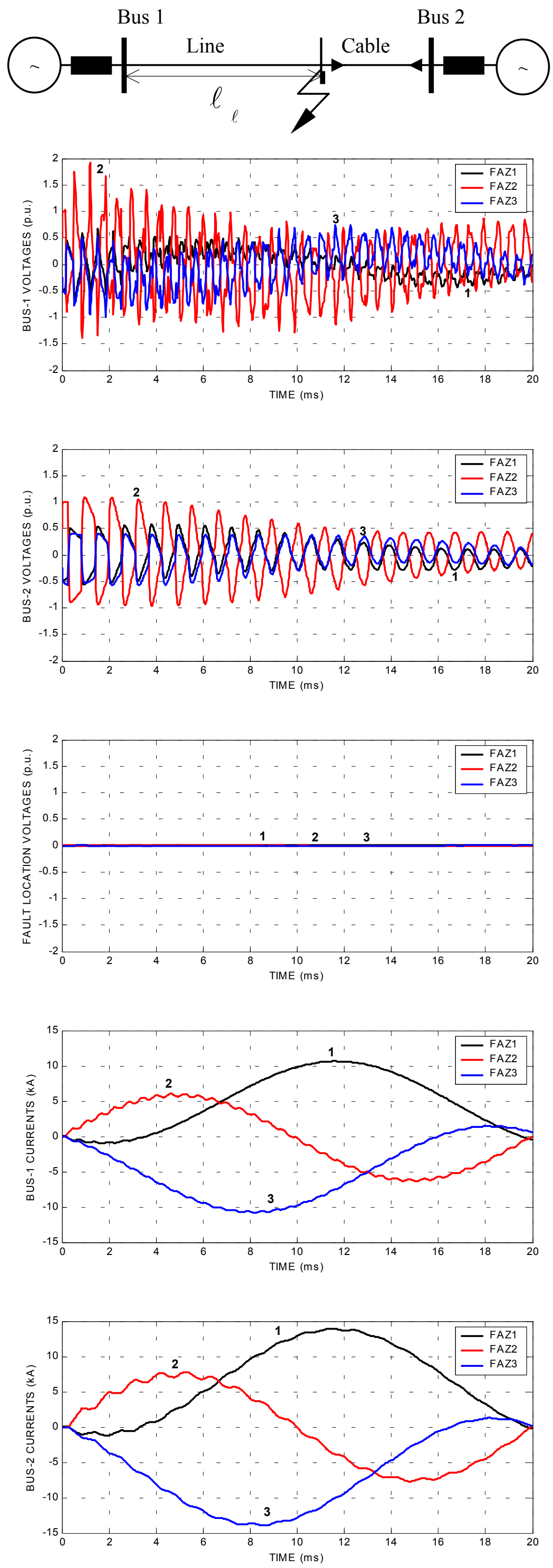

Fig. 7 The waveforms of transient voltages and currents due to three phase-to-ground fault at the junction point.

IV. CONCLUSIONS

In this study, subsequent to short-circuit fault, transient overvoltages and overcurrents have been obtained depending on various fault types. It has been verified from the results that severity of fault transients in transmission systems depends on various factors, namely fault location, fault type, the magnitude of the system voltage at the instant of fault, etc [8-9]. These factors have significant effects on the frequency and damping rate of distortions as well as on the shapes and the maximum magnitudes of the current and voltage waveforms along the transmission system.

From the analysis of transient fault currents and voltages, the following main results can be deduced:

- As expected, faulted phase voltage at the fault location and somewhere close to fault location is approximately zero or negligible because of the zero fault impedance

- The closer the fault point to the source terminal, the higher the magnitude of the current at this terminal exists, or viceversa due to relevant circuit impedance.

- In general, the transient voltage waveforms contain more distortions than the ones in the current waveforms. Higher-frequency and higher-amplitude oscillations are observed on the voltage waveforms compared to those in the current waveforms.

- The waveform of the voltage pertaining to the faulted phase 2 have considerably high-amplitude oscillations compared to the other phase voltages at any point. The current flow is considerable in the faulted phase whilst it is negligible in the unfaulted phases

- For the case of single line-to-ground fault at the peak value of system voltage of phase 2, the highest voltage amplitude is seen to be 1.858 p.u at bus 1 on phase 3. Faulted phase current, i.e phase 2 reaches up to 7.888 kA at bus 2 because of the close distance of the fault location to the sending-end bus.

- For the case of line-to-line fault on phases 1 and 2 at the peak value of system voltage of phase 2 and at the half-peak value of system voltage of phase 1, the highest voltage magnitude, which is encountered under this condition, belongs to phase 2 at bus 1 as 1.822 p.u. Regarding the currents, the current on phase 1 at bus 2 reaches up to 9.842 kA being the highest current magnitude.

- For the case of double line-to-ground fault on phases 1 and 2 at the peak value of system voltage of phase 2 and at the half-peak value of system voltage of phase 1, maximum voltage magnitude of 1.909 p.u. is seen at bus 1 on phase 2. Maximum current magnitude of 14.085 kA is obtained at bus 2 on phase 1

- For the case of three line-to-ground fault at the peak value of system voltage of phase 2 and at the half-peak value of system voltage of the other phases, the highest voltage magnitude of 1.915 p.u. is observed at bus 1 on phase 2. The highest maximum current magnitude of 13.969 kA is obtained at bus 2 on phase 1

V. REFERENCES

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