Table 2:
Fully Transposed Line Parameters (50 Hz)

Zero Sequence Impedance (Z_0)	0.30859 + J0.9528	Ohm/Km
positive Sequence Impedance (Z_1)	0.029364 + J0.32075	Ohm/Km
Zero Sequence Suceptance(Y_0)	0.22933E – 5	mho/Km
positive Sequence Suceptance (Y_1)	0.35775E– 5	mho/Km
Earth Resistivity	100	Ohm–m

Table 3:
Fully Transposed Line Parameters (50 Hz)

Sequence	Surge Impedance Magnitude ohm	Angle degree	Attenuation (DB/Km)	Velocity (Km/Sec)	Wave Length (Km)
Zero	0.66084E3	–0.8973E1	0.20532E- 2	0.2098E6	0.4197E4
positive	0.30006E3	–0.26154E1	0.42546E- 3	0.2929E6	0.58594E4

Table 4:
Source Data

V_a = 343000 cos wt
V_b= 343000 cos (wt– 120)
V_c= 343000 cos (wt– 240)
Z_0 = 32 Ohm
Z_1 = 64 Ohm
1pu = 400000 X 1. 41/1. 73 = 326000
for phase to phase and phase to ground

References:

1. A. Clerici, G. Ruckstuhl, A. Vian " Influence of shunt Reactors on Switching Surge" IEEE, PAS– 89, No. 8, Nov/Dec 1970, pp 1727-1736
2; J.P. Bickford" Transient overvoltages in power system" Ms.c Notes. UMIST, 1982
3. EMTP Newsletter, Vol 1, No. 5, Feb. 1981
4. EMTP– RULE Book, BPA- Co, U.S. A 1984

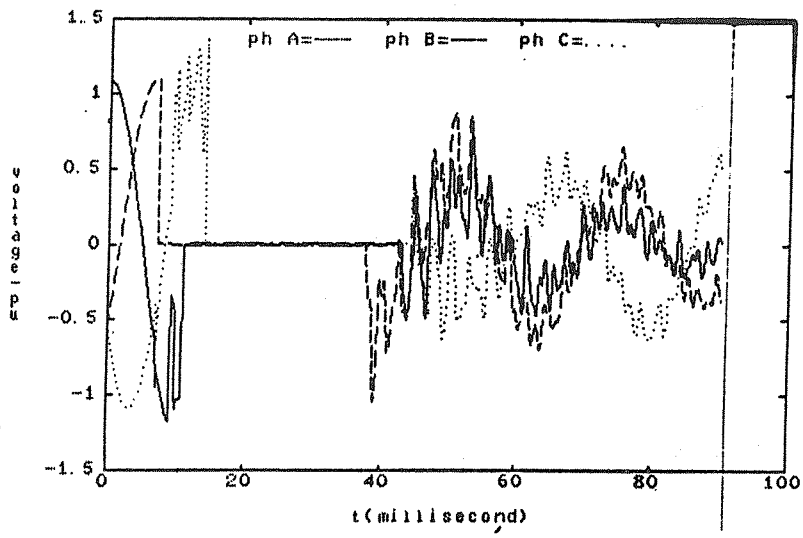

Fig17: Trapped charge voltage variations at sending end of compensated transposed line (Rg = 0)

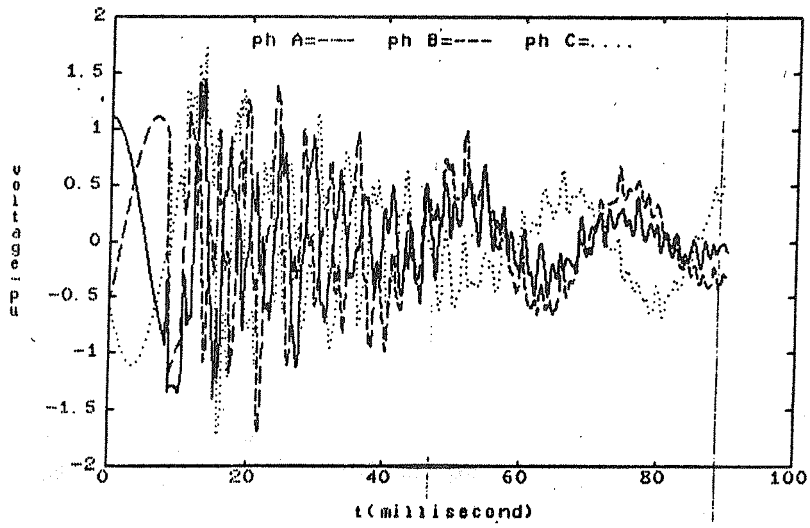

Fig18: Trapped charge voltage variations at receiving end of compensated transposed line (Rg = 0)

Appendix A

In this appendix, the numerical data for 400KV sample system is given:

Table 1:
Numerical Data for 400KV Tower (Fig3)

Nominal Voltage: 400KV, rms, Line to Line	
A = 10.1m	B= 45.6cm
C=20 m	D= 8.875 m
E= 30m	

Table 1: Contd

Number of phases: 3 Number of Bundles: 2
Conductor: CURLEW- ACSR- 1033 KMIL
Number of Sheild Wire: 2
Sheild Wire: Alumweld— 7No. 8-115.6 KCMIL

Figs 15, 16 show the trapped charge voltage on different phases at both ends of uncompensated transposed system. In recent cases Top is assumed be 1.5 cycle. It is clear that in solidly grounded scheme(Rg=o) voltages on different phases reach 1. 5 P.U., so this scheme is not recommended. It is also clear that after removal of solidly grounded scheme(t 〉Top),voltages still oscillate at both ends of transmission system. Fig 17, 18 depict the same results as above, however, the compensated transposed system is considered. In recent case, voltages on different phases reach 1. 7 P. U and voltage oscilations continue after solidly grounded scheme removal, which is discouraging as far as trapped charge voltage reduction is concerned.

Conclusions

In this paper the role of grounding resistons (Rg) in trapped charge voltage reduction is considered through digital computer simulation by EMTP. It is concluded that this scheme is quite reasonable, however, the solidly grounded system (Rg = 0) is not encouraging and would not be recommended. The discharge can be controlled through varying Rg and Top for different systems.

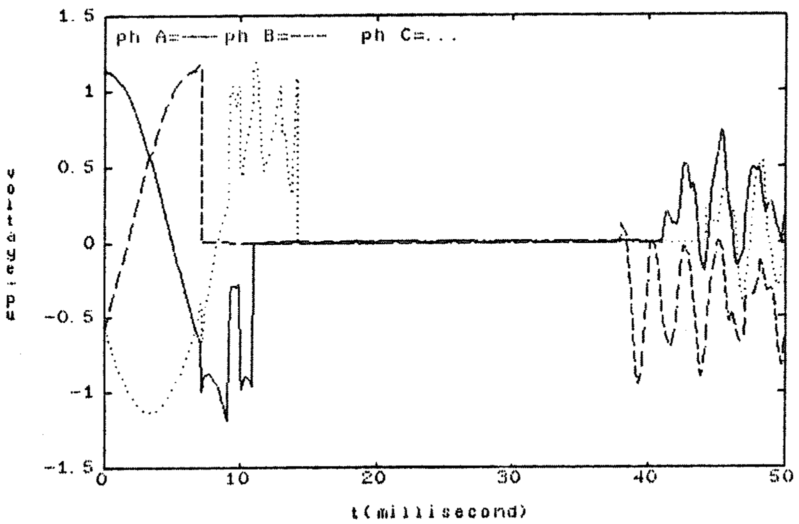

Fig15: Trapped charge voltage variations at sending end of uncompensated transposed line (Rg = 0)

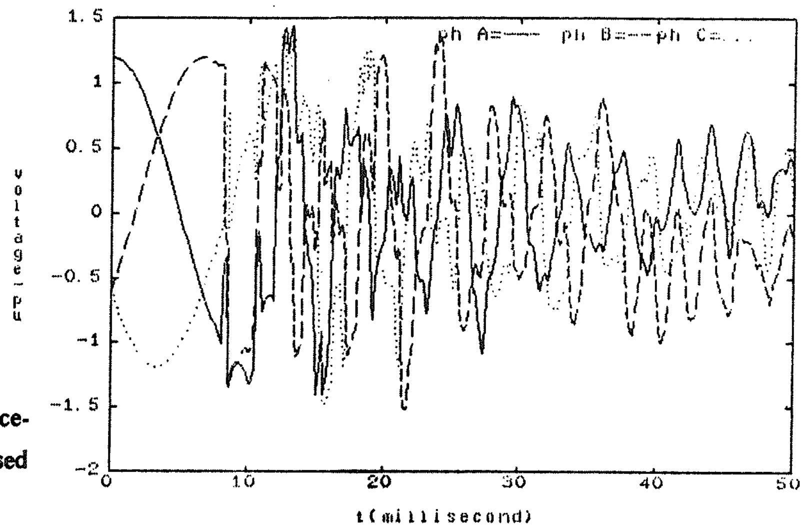

Fig16: Trapped charge voltage variations at receiving end of uncompensated transposed line (Rg = 0)

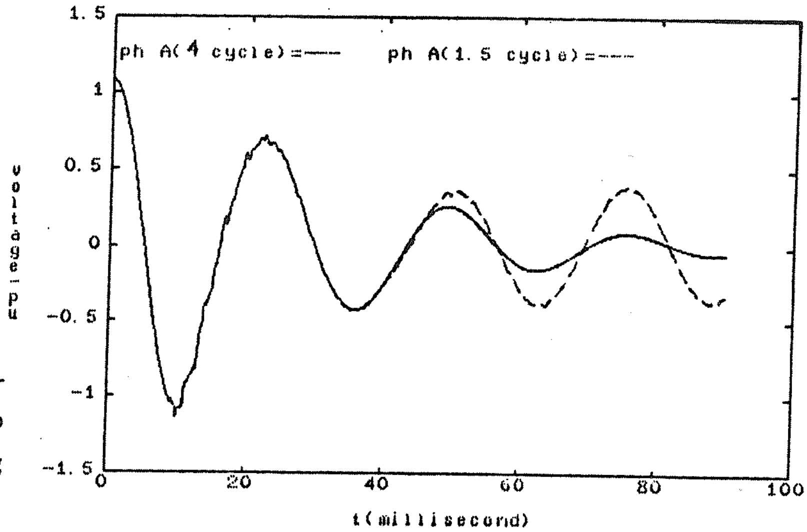

Fig12: comparison between trapped charge voltage reduction at phase A for two Top (compensated Transposed line, sending end)

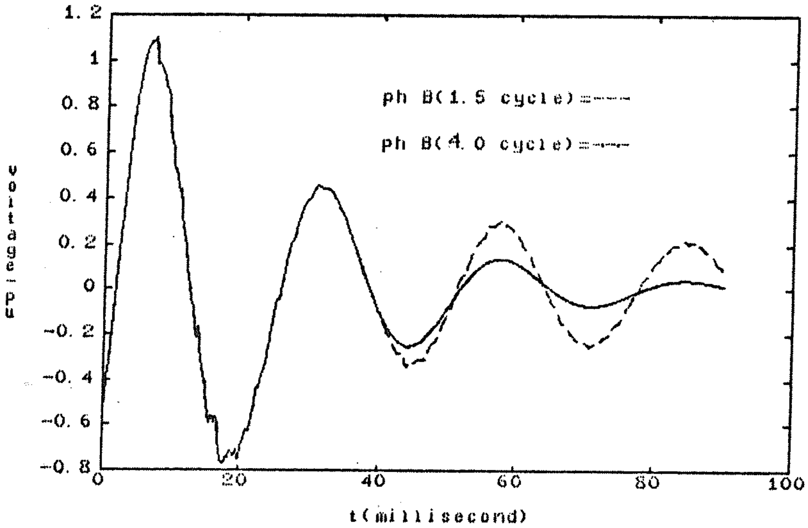

Fig13: comparison between trapped charge voltage reduction at phase B for two Top (compensated transposed line, sending end)

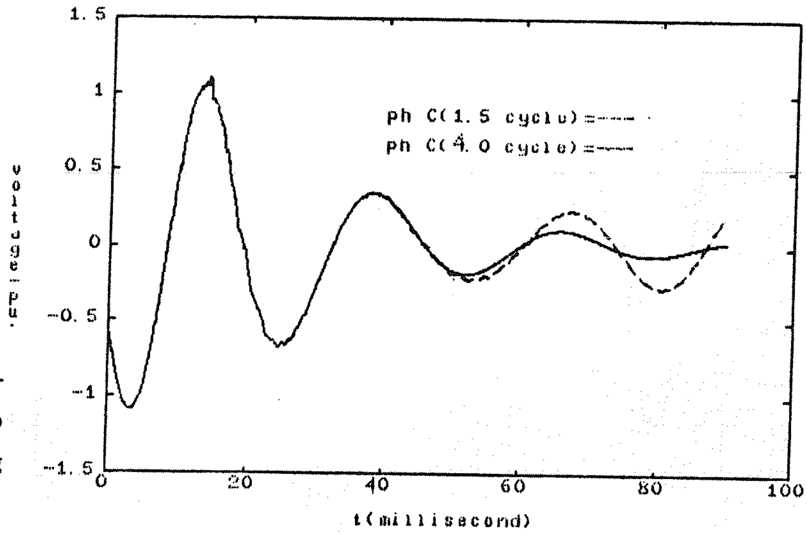

Fig14: comparisan between trapped charge voltage reduction at phase C for two Top (compensated transposed line, sending end)

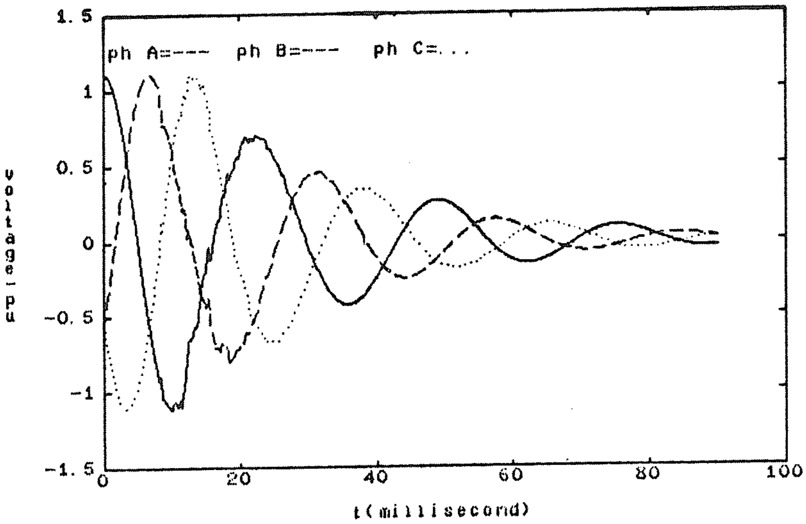

Fig 9: Trapped charge voltage reduction at receiving end of compensated transposed line (Top= 4 cycle)

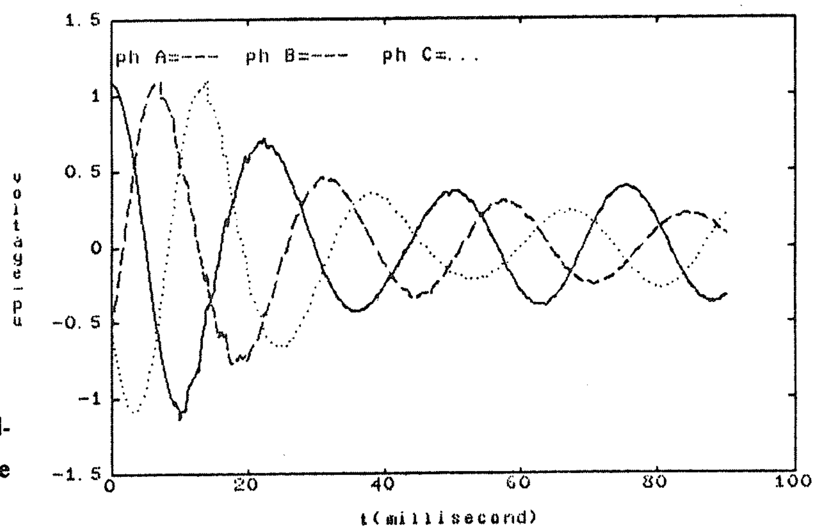

Fig10: Trapped charge voltage reduction at sending end of compensated transposed line (Top = 1.5 cycle)

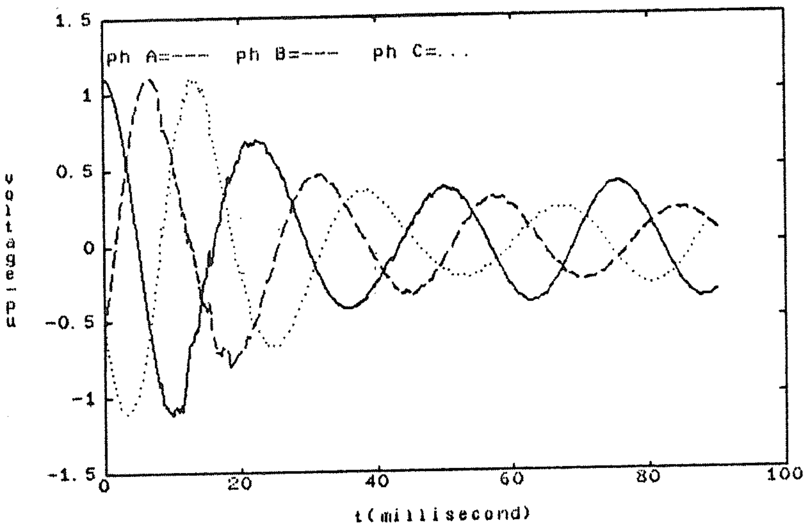

Fig11: Trapped charge voltage reduction at receiving end of compensated transposed line (Top= 1.5 cycle)

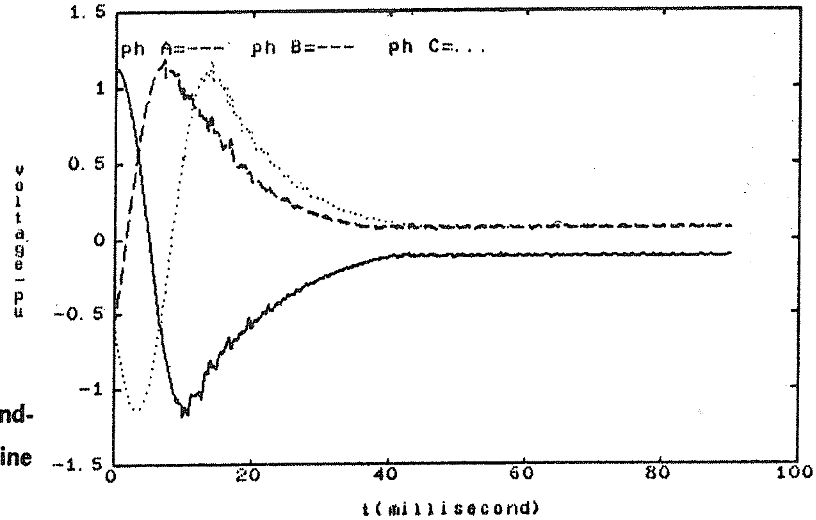

Fig 6: Trapped charge voltage reduction at sending end of uncompensated transposed line (Top = 1.5 cycle)

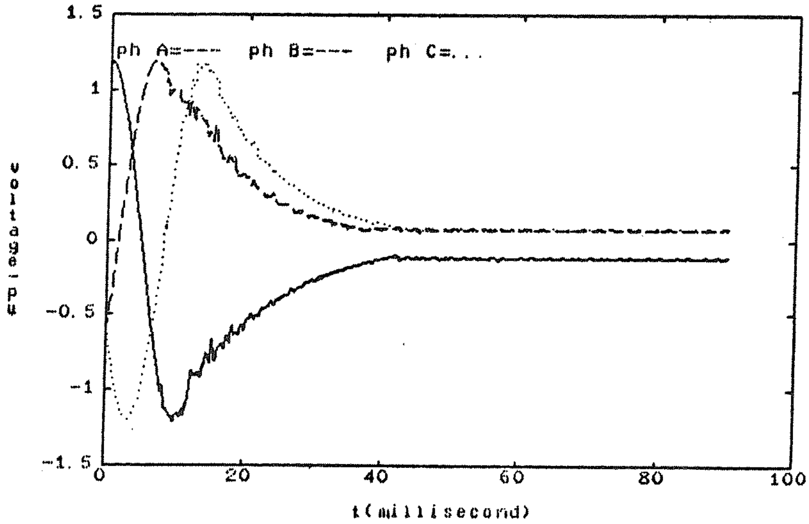

Fig 7: Trapped charge voltage reduction at receiving end of uncompensated transposed line (Top = 1.5 cycle)

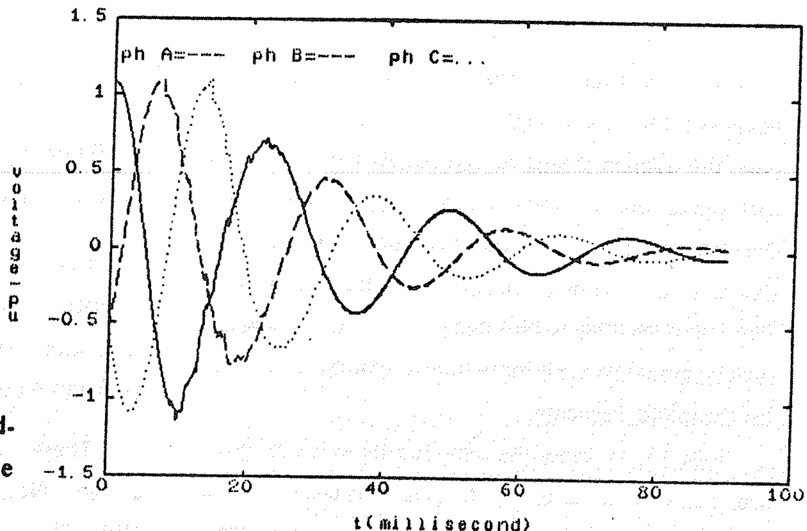

Fig 8: Trapped charge voltage reduction at sending end of compensated transposed line (Top = 4 cycle)

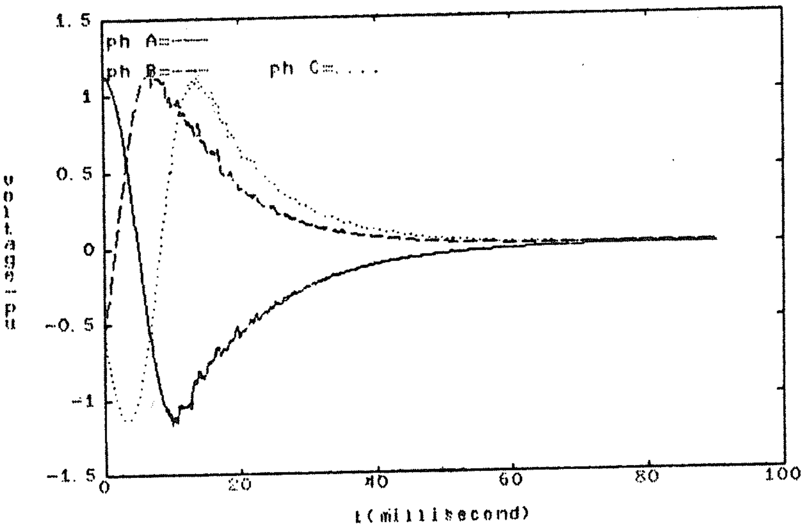

Fig 4: Trapped charge voltage reduction at sending end of uncompensated transposed line (Top = 4 cycle)

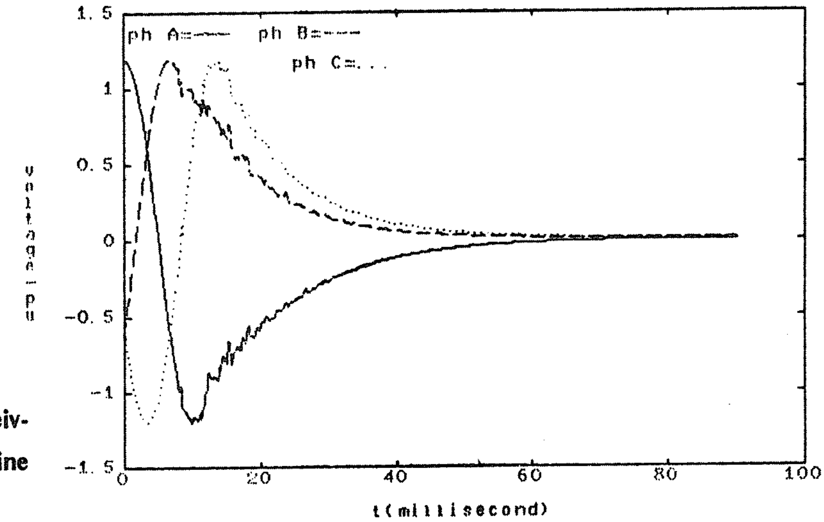

Fig 5: Trapped charge voltage reduction at receiving end of uncompensated transposed line (Top = 4cycle).

Thus the complete disccharge requires total time of 59.8 msec, Figs 6, 7 show the same tests as above, however, Top is assumed to be 1.5 cycle. In recent case, the trapped charge voltage reduced to 0.1 pu for each phase (uncomplete discharge). Figs 8, 9 illustrate the trapped charge voltage reduction for different phases at both ends of compensated transposed line. The Top is assumed to be 4 cycle. Top in compensated system should be made more than uncompensated line, for complete discharge.

Figs 10, 11 show the same results as above, however Top is assumed to be 1.5 cycle. It is clear that the decay of trapped charge voltage is more slower compare with uncompensated case, for example in uncompensated system, the trapped charge voltage would be reduced to 0.1 pu, but in compensated case voltage oscilation with the peak of 0.35 pu results. (comparison between Fig 6 and Fig 10).

Figs 12, 13 , 14 show the comparative study for trapped charge voltage reduction for different phases of compensated transposed line, for two different Top (1.5 and 4 cysle).

These results belong to sending end of transmission system. Now suppose the solidly grounded scheme (Rg = 0).

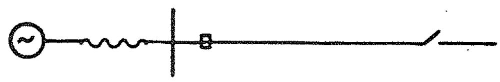

Fig1: No load 400KV uncompensated transmission line

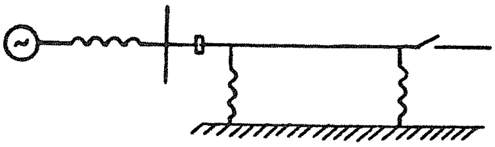

Fig2: No load 400KV compensated transmission line

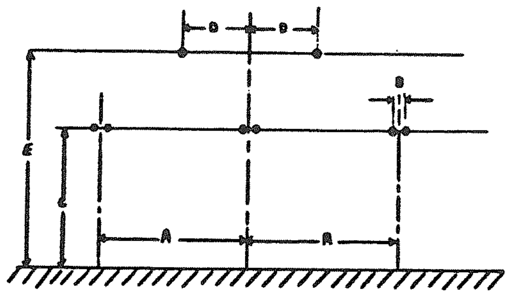

Fig3: Conductor arrangements on 400KVtower

Numerical data for sample system is given in Appendix 1. In whole study the 300 Km, 400 KV line in no load condition is considered in digital computer simulation, because the no load case is more severs as far as switching surge analysis is concerned.

2- Mathematical Model for Transmission line

In this article, the distributed parameter model with frequency independent scheme is used for line modeling through whole study, because the frequency of waves after line grounding is closed to nominal frequency [4].

Effect of Rg on Trapped Charge Voltage Reductian

In digital computer simulation, the following assumptions are made:

1: Two 50 MVAR shunt reactors are kept in operation at both ends of transmission lines (compensated case)

2: The circuit breaker of each phase opened when its own phase current passed zero crossing. (deenergization), so the opening time for circuit breakers of different phases are:

ta = 0.0105 Sec

tb = 0.0066 Sec

tc = 0.0133 Sec

3: After each phase opening, the same phase would be grounded through grounding resistor (Rg) imediately. This action could be made by seperate circuit breaker which would be closed, after main breaker openings.

4: Each three phase shunt reactors consists of three single phase reactor with resistance of 8 ohm/phase.

5: Rg is assumed to be 3500 ohm/phase It should be noted that the trapped charge on each phase discharges through Rg to the ground. the amount of Rg and its operating time (Top) depend on followings:

a: Length of transmission line

b: Tower configuration.

c: Autoreclosing time (main breaker).

d: Desired amount for trapped charge voltage reduction.

Figs 4, 5 depict the trapped charge voltage reduction for different phases at both ends of uncompensated transposed line. The Top for Rg is assumed to be 4 cycle (80 msec). It should be noted that in uncompensated transposed line, the time constant for discharge phenomenon could be defined as:

Tc= RgC(ignore line resistance and inductance) [2, 3]

It is obvious that after 5Tc the complete discharge occurs. In our sample system we have:

C = 3.416 μf/phase

Rg= 3500 ohm/phase

Tc= 11.96 msec

Digital Computer Studies of Grounding Resistor Effects on Trapped Charge Voltage Reduction in EHV Transmission Lines

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ABSTRACT

In this paper the well established digital computer program called EMTP (Electro- Magnetic– Transient –Program) is used to analyse grounding resistor (Rg) effects on trapped charge voltage reduction after transmission line deenergization, with special reference to 400KV transmission line in Iran. In our studies transposed line as well as compensated and uncompensated transmission systems are considered in digital simulations.

Introduction

In EHV transmission systems, due to line capacitance, electrical charges (trapped charges) still remain on conductor, even the circiut breakers are opened and supply is disconnected (deenergization). This argument insists that trapped charges provide, voltages for different phases. Trapped charge voltages appear in two different form, namely: [1]

1- D. C form in uncompensated transposed or uncompensated untranspased lines (lines without shunt reactors).

2- Oscillatory form in compensated transposed or compensated untranspased lines (lines with shunt reactors). Trapped charge voltages in both compensated or uncompensated lines could be critical as for as overvoltages caused by next action after deenergization (auto reclosing). In this article attempt has been made to use EMTP to simulate grounding resister (Rg), in order to be able to study its effect on trapped charge voltage reduction in 400KV transmission lines in Iran. Thus the severity of autoreclosing overvaltages can be reduced.

1- Sample System

Fig 1 shows the uncompensated 400 KV sample transmission line in no load condition, in which the supply busbar is represented by eqvivalent Thevenin's Model. Fig 2 illustrates the same system with two shunt reactors installed at both ends (compensated line). Fig 3 depicts conductor arrangement and tower configuration for 400KV transmission line, which is going to be standard system for Iran.