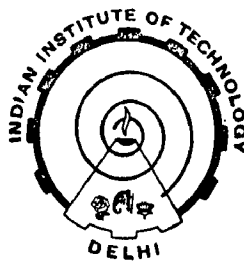


SWITCHING TRANSIENTS IN TRANSMISSION SYSTEMS

by

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**DEPARTMENT OF ELECTRICAL ENGINEERING
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C E R T I F I C A T E

Certified that the thesis entitled, "Switching Transients in Transmission Systems", which is being submitted by Shri K.K. Patel in partial fulfilment for the award of the degree of Doctor of Philosophy in Electrical Engineering of the Indian Institute of Technology, Delhi is a record of the student's own work carried out by him under our supervision and guidance. The matter embodied in this thesis has not been submitted for the award of any other Degree or Diploma.

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ABSTRACT

The insulation level of an EHV transmission system is mainly decided by the switching overvoltages to which it is subjected. A transmission system may consist of ac and/ or dc overhead lines, homogeneous or crossbonded cables, and cascades of UG cables and OH lines. Very few results are at present available in the literature regarding the switching transients in cables and cascade systems. To fill this gap in the literature a detailed study of switching transients in crossbonded cables and cascaded systems has been undertaken and pertinent digital computer results have been presented. For the study the powerful Fourier transform technique, which takes into account the frequency dependence of system parameters, has been used in conjunction with the theory of natural modes. The effects of sequential pole closure, source inductance and preinsertion resistors have also been investigated.

The thesis also deals with the fault transients in EHV dc overhead line due to single line-to-ground faults. To evaluate these transients a new algorithm suitable for linear and nonlinear elements incorporating the frequency dependence of line parameters has been developed in conjunction with the method of characteristics. Multiterminal EHV dc lines are also studied.

SUMMARY

SWITCHING TRANSIENTS IN TRANSMISSION SYSTEMS

A transmission system is subjected to overvoltage transients due to lightning, switching operations and faults. The overvoltage due to switching operations and faults are directly related to the system voltage and their magnitudes increase as the system voltage increases. As a result the insulation level of an EHV ac system is mainly decided by the switching overvoltages to which it is subjected. The cause of switching transients in a transmission system is the sudden change in the circuit conditions. Thus the study of transients under single pole closure, simultaneous and sequential pole closure of circuit breakers and fault initiation and fault clearing conditions is very important.

The transmission system may consist of ac and/or dc overhead lines, homogeneous or crossbonded underground cables and cascades of underground cables and overhead lines.

Numerous studies of switching transients in overhead lines have been conducted and reported in the literature and the same have been summarised comprehensively in an IEE monograph. But concerning switching surges in cable systems only a few results are at present available. The studies on cables have been confined to the case of single pole and simultaneous pole closure. The cascade of underground cables and overhead lines is also a common feature

of any power system. In published literature, except for some Transient Network Analyser studies, the transients in a cascaded system have not been studied. In order to fill this gap in the literature a detailed study of switching transients in crossbonded cables and cascaded system has been undertaken. For this study the powerful Fourier transform technique, which takes into account the frequency dependence of system parameters, has been used to predict the transient performance of the system. The solution of the multiconductor wave equation has been obtained through the theory of natural modes of propagation. The digital computer results of the fault and energisation transients on crossbonded cables and cascaded systems have been presented in this thesis. The effect of sequential pole closure, source inductance and preinsertion resistors have also been investigated.

The thesis also deals with the fault transients in EHV dc overhead lines. In EHV dc systems switching overvoltages are negligible because an EHV dc line is energized by raising the input voltage smoothly by appropriate control of the converter valves. The source of transient overvoltage in the case of dc lines is the voltage induced in the healthy pole due to pole-to-ground faults. To evaluate these fault transients a new algorithm has been presented. Instead of using the principle of superposition to simulate the fault initiation and fault clearing, the

new algorithm uses appropriate boundary conditions at the fault point and hence is suitable for dealing with both linear and nonlinear elements in the system. The method of characteristics is used for reducing the partial differential equations for lossless lines to difference equations. These difference equations of transmission lines are then substituted in the differential equations of the lumped inductors and capacitors. The resultant differential equations are then solved by the modified Euler's method. The frequency dependence of system parameters in HVDC line has also been taken into account considering the ground mode only. The method has been applied to various line terminations including the non-linear smoothing reactor and lightning arresters.

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