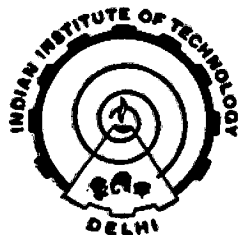


# **SOME STUDIES ON MULTICONDUCTOR TRANSMISSION LINES AND MULTIWINDING TRANSFORMERS**

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TO THE



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INDIA**

**October, 1990**

DEDICATED

TO

my daughter

SHOBHA

the prettiest and the best three year old  
child in the world.

and my husband

SHAJI

whose love and affection sustained me during  
these three and a half years.

## CERTIFICATE

Certified that the thesis entitled, "Some Studies on Multiconductor Transmission Lines and Multiwinding Transformers", which is being submitted by Mrs. Mini Shaji Thomas in fulfilment of the requirements 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 her 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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(Mini S. Thomas)

## ABSTRACT

The sensitivity analysis of a system function to parameter variations is of considerable importance in the optimal design and operation of a power system. With this end in view, the sensitivity analysis of modal propagation quantities at carrier frequencies for underground cables, and the sensitivity analysis of peak switching overvoltages to parameter variations in underground cables and overhead lines, have been carried out in this thesis.

A carrier communication network is essential for the reliable operation of a power system. For the design of a proper communication channel, a complete information regarding the attenuation and velocity characteristics of polyphase lossy cables at carrier frequencies is of importance. At high a.c. voltages, the cable design is greatly influenced by the dielectric loss which assumes a considerable proportion of the total losses. Therefore, the basic shunt admittance matrix of the cable system is reformulated in the present work to take into account the dielectric loss, and the sensitivity analysis of the modal attenuation and velocities carried out at carrier frequencies for various system parameters. It is found that the attenuation of the coaxial mode is sensitive to the dielectric loss part of the complex permittivity. When the cable is loaded, certain parameters of the cable change due

to temperature changes. Hence, the temperature dependence of the modal propagation quantities is also investigated. It has been found that there could be a substantial change in the propagation characteristics of the cable depending on whether it is on-load or off-load.

The reliable operation of a power system requires a knowledge of the conditions under which transient overvoltages may be developed within the system and the means by which these may be estimated. The transient overvoltages may be caused by lightning, switching operations or faults. The overvoltages due to switching and faults are dependent on the system voltage. As the system voltage increases, these overvoltages become more and more important. Hence, the insulation level of a transmission system in the EHV/UHV range is based mainly on the study of switching overvoltages to which it is subjected.

Many system parameters contribute to the peak overvoltages occurring in the power system. Since the system characteristics may vary with changes in certain parameters, the sensitivity analysis of multiconductor lines is of great importance to system designers. Sensitivity studies have been carried out in diverse areas of power systems like the sensitivity of charging currents to line configurations, the sensitivity of voltage and power to system parameters at the

receiving end of a transmission line, the sensitivity of lightning induced voltages to system parameters etc. All the above studies are based on the steady-state operation of the system. In the present work, the emphasis is on the variation of the peak overvoltages to parameter changes under switching transients. The sensitivity analysis of the peak switching overvoltages to parameter variations is carried out for a multiconductor overhead line and an underground cable system. The studies are conducted for both loaded and unloaded lines and cables.

Apart from switching transients in overhead lines and cables, the thesis also deals with the switching transients in transformers, and in cascades of line-transformer and cable-transformer transmission systems.

Transformers are one of the most expensive items in the bulk transmission system and are increasing in size and complexity and are no longer the simple two-winding units which can be represented in a transient study as a simple capacitor, or as a  $\pi$ -section and an ideal transformer. Considerable attention has been paid to the transient voltage distribution along the winding turns of a high-voltage transformer, but in all these studies, the transformer is modelled by lumped parameters for representing the magnetic and capacitive couplings. But, for a complete picture of the high frequencies that a

transformer might be exposed to, a complete model employing a number of sections to represent the transformer windings is necessary so that the switching surges on all its phases can be investigated for any type of transformer winding connection.

When one primary winding of the 3-phase transformer is energized, transient voltages are produced in the other primary and secondary windings of the transformer. These are studied in detail in the thesis. The transformer model considered is a complex 3-phase model with 'n' sections per phase, taking into account the various inductive and capacitive couplings. The method proposed is in phase coordinates and this model can handle all varieties of primary, secondary and neutral connections.

Using the new transformer model, the transient analysis has been carried out for a variety of transformer connections like, star/star, delta/delta, star-grounded/delta, delta/star-grounded, star-grounded/star-grounded and open delta. The study is repeated with only the transformer primary and the influence of the secondary and the secondary connections on the primary transients is clearly brought out.

Transformers are also subjected to oscillatory voltage waveforms at the terminals by many events in the power system like energization of the line or cable

connected to the transformer. Hence, the study of a line-transformer or cable-transformer cascade on a multiconductor basis with detailed models for all the elements becomes pertinent. Such a study for the transient analysis of the line-transformer and cable-transformer cascades is carried out in this thesis for a variety of transformer connections using the detailed multiconductor model for the line, and the multiwinding model for the transformer. The analysis brings out the fact that the transients are very sensitive to the type of neutral connection and that the presence of a line or cable at the transformer terminals reduces the switching transients at the transformer terminals.

The method of transient analysis in all the above studies uses the Fourier transform pair to derive the time response of the system from its frequency response and thus can handle the frequency dependence of the system parameters.

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