FORMULATION OF GRAPH THEORETIC STRUCTURE-SENSITIVE Z_{Bus} MODELS FOR POWER SYSTEM ANALYSIS

by

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C E R T I F I C A T E

Certified that the research work "Formulation of Graph Theoretic Structure - Sensitive Z_{Bus} Models for Power System Analysis" by D.Anand Rao, has been carried out under our joint supervision at the Indian Institute of Technology, Delhi, and that this work has not been submitted elsewhere for the award of a Degree.

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A B S T R A C T

Power System Analysis usually entails the computation of system network voltages and currents under a given set of conditions. Under abnormal fault conditions, Short Circuit Studies determine the voltages and currents at the system buses. Bus Impedance Matrix, Z_{Bus}, is the preferred model for Short Circuit Analyses of Large Interconnected Power Systems using Digital Computers.

The main thrust of the present work is to explore and demonstrate the practical applicability and effectiveness of the Physical Systems Modelling Methodology based upon the Linear Graph Theory. Investigations made in the course of this thesis highlight the prudent application of a Physical Systems Modelling Construct in advantageously exploiting the structure of the system network for the purpose of the Z_{Bus} model and thereby, exhibiting features of orderliness and generality that go far beyond the mere manipulation of the Z-matrix driving point and transfer impedances.

The research presentation is organised in six chapters as given below.

Chapter-I presents the literature survey of existing techniques for short circuit studies and associated algorithms for Z_{Bus} modelling.

Chapter-II presents the Symbolic formulation pertaining to the application of the Graph Theoretic Chord Formulation Technique using a component-to-sub-system-to-system construct for obtaining the Z_{Bus} model at the $(i+1)^{th}$ level of interconnection from a basis of the i^{th} level configuration. Simple relations in the form of equations have been derived for modifying the Z_{Bus} matrix corresponding to the addition of a tree branch or a chord of cotree. Ability of the graph theoretic approach - (i) to interconnect one or more elements at any desired level of interconnection and (ii) to identify and model appropriate sub-assemblies compositely in isolation - has been highlighted.

Chapter-III presents an algorithm for efficient modelling of mutually coupled lines. Representation of mutual coupling by appropriate current dependent voltage driver(s) is suggested. Mutually coupled groups of lines are identified as a distinct type of sub-assemblies and are modelled compositely in isolation. The sub-system representation of a coupled group of elements such that the mutual coupling effect is represented by appropriate network elements (current dependent voltage drivers) permits the modelling of the coupled group after the pattern of an uncoupled sub-system which, any way, can be easily modelled according to relevant formulae developed in Chapter-II. Computationally efficient methods have been proposed for simulating minor changes in the structure of the system.

Chapter-IV identifies two distinctive structural features of the system network configuration which have been considered for effective and efficient modelling. One aspect relates to the identification of a cantilever type of sub-structure and exploitation of its associated attributes. The other aspect relates to the optimal structuring and ordering of f-circuits for an efficient formulation of the Z_{Bus} model. Exploitation of these structural features of the system network configuration has resulted in substantial reduction of computer processing time which is highlighted in terms of reduction in arithmetic operations required for the Z_{Bus} formation.

Chapter-V presents algorithms for - (i) developing an inter area Z_{Bus} model corresponding to interconnection of two or more areas to power grids through tie-lines and (ii) identifying study sub-systems in large power systems from a basis of Technical and rational criteria for such sub-divisions in the absence of apriori specifications of study system boundaries.

Chapter-VI presents the overall conclusions arising from the research investigations carried out in this thesis and suggests further avenues of research leading therefrom.

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CHAPTER-VI CONCLUSIONS