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Incomplete information based multi-port two-layer active network equivalent for electromagnetic transient states studies in large power systems

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ABSTRACT

In this study, an approach is presented for external network modeling of power systems in the absence of required data involving all of transmission lines and equipment in all of the substations. In the proposed approach which is based on multi-port networks, the studied power system is divided into two parts of surface layer and deep region. The surface layer should be modeled high accuracy, thorough details and frequency dependent. The deep region should be modeled by a multi-port equivalent network. This multi-port equivalent network is achievable using a steady state model of the power system which is under the study. In order to investigate the performance of the proposed approach, numerical studies are performed for a typical network. Results show the high precision of the modeled network in comparison to the complete network. Effectiveness of the presented approach in electromagnetic transient studies of large-scale power systems has been indicated in this paper.

1. Introduction

Normally, electromagnetic transient state studies of large scale power systems need detailed transmission network modeling. However, modeling all of transmission lines with details may increase the time of simulation execution enormously. Therefore, in order to study the electromagnetic transient states, a part of the network which is needed for consideration of transient studies should be modeled accurately and equivalent networks can be utilized for consideration effects of the remaining parts of the network [1–2]. In general, presented methods for external networks modeling can be divided into two categories including, frequency dependent network equivalent (FDNE) [3–4] and two-layer network equivalent (TLNE) [5–9].

Generally, it should be noted that the reasons for external network modeling in electromagnetic transient state studies are divided into two categories:

1- To reduce the required data of the network to perform studies.
2- To reduce the execution time of calculations.

Reduction of required data to perform transient studies is the main objective of the proposed model in this paper.

Relatively huge amount of literature is available regarding external network modeling by using the frequency dependent network equivalent (FDNE). In [3], a method to produce the equivalent circuit of the external network is developed from the admittance frequency response. The method in this reference is developed from simple RLC modules. In this model, a RC branch is used to model the dominant behavior of the external network at substantially high frequencies and a RL branch is used to model the dominant behavior at low frequencies. Furthermore a RLC branch is used to model the dominant behavior of the external network at resonance frequencies. The proposed method of [3] has been enhanced in [4] by improvement of fitting technique.

Considering the fact that even one transmission line causes an infinite number of peaks in the frequency domain, to estimate this line with simple RLC branches, a huge number of R, L, C and G resonance groups are required. Since the main characteristic of the external network is due to transmission lines, the authors of [5] recommended that the external network should be modeled as two-layer. In the proposed model of this reference, the surface layer includes simple line models and the deep region is modeled by transfer functions. In this approach, the deep region is set to correct the error of using simple line models in the surface layer and also accounts for the effects of the external network. Modifications of this model are also performed in [6–8]. In [6], surface layer has been focused and simplifications are done on TLNE. Furthermore, the characteristic impedance of transmission lines in the

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Nomenclature

z_{ii}	self impedance of the ith port
z_{ij}	mutual impedance of the ith port with the jth port
V_i	terminal voltage of the ith port
I_i	terminal current of the ith port
$V_{i,si}$	terminal voltage of the ith port when other ports are open circuit
$V_{i,si}^a$	terminal voltage of the phase an of the ith port when other ports are open circuit
Z	impedance matrix
N_p	the number of external network connection points with the surface layer
V_i^a	terminal voltage of phase an of the ith port
I_i^a	terminal current of phase b of the ith port
α	a vector which its magnitude is equal to 1 and its angle is equal to 120 degrees
$Z_{c,i}$	surge impedance of the ith line connected between surface layer and deep region

surface layer is modeled by a constant resistance instead of low-order rational function. In [7–8], a deep region modeling improvement by using optimization algorithms has been performed.

Ref. [10] focuses on real time simulation of electromagnetic transients. In this paper a two channels scheme is proposed for network equivalent. A low-frequency channel with longest time step reproduces the low-frequency response and a high-frequency channel with shortest time step reproduces the high-frequency response. Ref. [11] improves the presented implicitly-coupled electromechanical and electromagnetic transient analysis model in [12]. In order to achieve this improvement, rational function approximation was used to develop frequency dependent network equivalent. In the presented approach of this paper, impedance matrix of external network is needed within a specified frequency range.

The common deficiency of all aforementioned models in both FDNE and TLNE categories, is that the frequency response of the network is required and the presented methods in these studies just reduce the required time of electromagnetic transient state simulations. In other words, the accurate value for external network impedance viewed from the connection point should be determined. Previous papers tried to

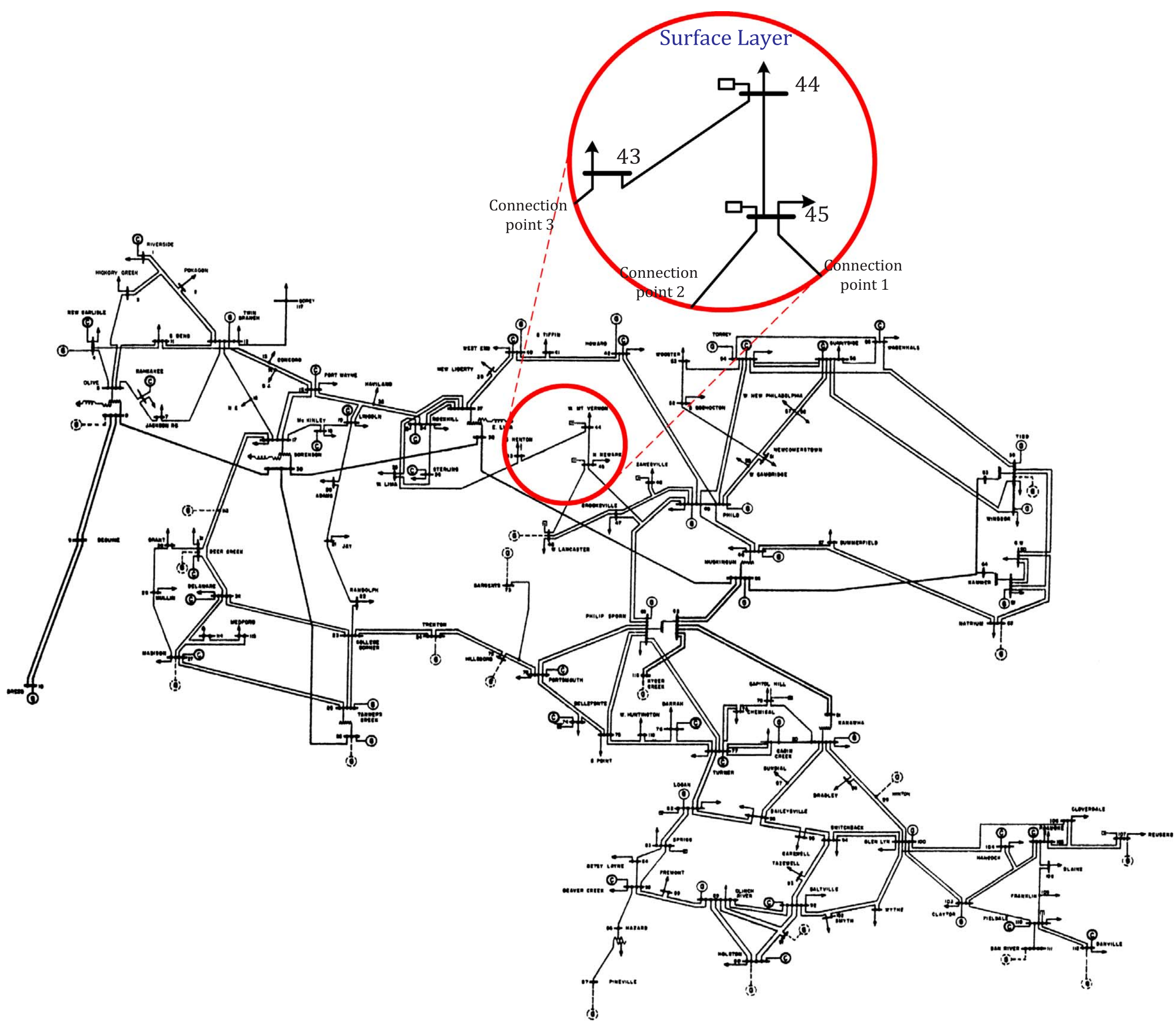

Fig. 1. A typical power system (IEEE 118 bus power system [13]).