Electrical Power and Energy Systems 33 (2011) 1462–1469

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

journal homepage: www.elsevier.com/locate/ijepes

Fault calculations using three terminal Thevenin's equivalent circuit

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ARTICLE INFO

Article history:
Received 2 September 2009
Received in revised form 20 March 2011
Accepted 3 June 2011
Available online 5 July 2011

Keywords:
Fault calculations
Three terminal Thevenin's equivalent circuit
Bus impedance matrix

ABSTRACT

The aim of this paper is to present a systematic approach of calculating fault currents due to the switching of elements or fault impedances that involve two buses and ground. Traditionally, Thevenin's equivalent circuits are made up of two terminals suitable for calculating the current into an element connected between both terminals of the equivalent circuit. In such cases, the current entering the element is equal to the current leaving the element. So many practical cases involve elements that have a third terminal connected to ground. Tee and pi models of transmission lines are examples of such cases. Traditionally, the two terminals Thevenin's equivalent circuit is used to tackle such problems by decomposing the three terminal element into its basic elements. The problem is then transferred to a multi element application where each element is processed once a time. This approach is cumbersome and time consuming. In this paper, a systematic approach to applying the three terminal Thevenin's equivalent circuit to three terminal elements is proposed.

1. Introduction

Electric power system networks are vulnerable to faults. The calculation of bus voltages and branch currents due to faults is an inevitable tool for power system analysis. Faults are either symmetrical or unsymmetrical. Symmetrical faults involve faults on the three phases through equal fault impedances yielding balanced post-fault bus voltages and branch currents. Unsymmetrical faults involve unbalanced fault impedances yielding unbalanced post-fault bus voltages and branch currents. It is easier to analyze symmetrical faults than unsymmetrical faults. Several researches have been done in the area of fault analysis of power systems involving symmetrical and unsymmetrical faults. Most of the work tackled simple and single faults. Very few tackled complex and multiple faults. Single faults occur at a single location in the network while multiple faults occur at multiple locations simultaneously. Simple faults involve only a single type of faults such as line to ground, line to line and double line to ground faults. Complex faults involve a combination of the simple faults that may occur simultaneously in the network. Gross [1] considered fault calculations due to multiple faults at different locations in power systems. Strezoski and Bekut [2] presented a canonical model for the study of faults in power systems. Gill [3] applied the generalized Thevenin's theorem to solve asymmetrical series faults on power systems. Tanaka [4,5] presented a method to calculating the effects of mutual coupling in multi faults and the incorporation of the zero sequence mutual coupling effects among multi parallel routes. Abouelenin [6] investigated the calculation of simultaneous faults on power systems. Teng [7] presented a systematic short circuit analysis method for unbalanced distribution systems based on exact three phase models and two relationship matrices of distribution systems. Gajbhiye et al. [8] described a generic approach to the analysis of faulted power systems in three phase coordinates. El-Tamaly and Ziedan [9] investigated the influence of mutual coupling between parallel transmission lines on single line-to-ground and double line-to-ground faults. Bhalja and Maheshwari [10] presented detailed analysis of the apparent impedance as seen from the relaying point due to faults on parallel transmission lines. Kalantari and Kouhsari [11] presented a piecewise solution procedure for fault studies using large change sensitivity concept. Song et al. [12] presented a fault location algorithm for parallel transmission lines using post-fault voltage and current measured at one terminal. Eisa and Ramar [13] presented a one-end fault location method for overhead transmission lines of interconnected power systems using a distributed parameters model for the faulted transmission line and a two-bus Thevenin equivalent network model for the power system. Most of the cited researches in this area involve the application of Thevenin's theorem applied to two terminal elements. The two terminals involved in such cases are two buses or a bus and the ground. However, faults may occur at locations on transmission lines at distances from the buses connecting the line. There is no information in the bus impedance matrix regarding this location. One has to create an extra bus in the bus impedance matrix to obtain such information, which may be cumbersome and time consuming. In this paper, a systematic approach to applying the three terminal Thevenin's equivalent circuit to fault analysis is presented. Several numerical examples of case

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doi:10.1016/j.ijepes.2011.06.027