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An innovative technique to evaluate network equivalent for voltage stability assessment in a widespread sub-grid system

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ABSTRACT

The equivalent two-bus network models currently available are obtained by lumping all the series impedances and shunt admittances of transmission lines within a series equivalent impedance, to assess voltage stability of multi-bus power system. This paper reports the development of an equivalent pi-network model using a new methodology considering series and shunt parts of line loss *separately* obtained from the operational parameters of optimal power flow solution of the original multi-bus power network, which can be applied to assess the overall voltage stability status of the system accurately by developing the concept of a generalized global voltage stability margin (GVSM). Simulation results for a typical longitudinal power supply (LPS) system and a robust practical (Indian Eastern Grid) system establish that the pi-equivalent model obtained by the proposed method is highly promising for assessing voltage stability of any power system at any operating point in global scenario in a better way as compared to available series equivalent model. Continuation power flow (CPF) method has also been adopted here to verify the potential of the proposed method for voltage stability assessment. In the proposed equivalent network the generators have been modeled more accurately considering optimal operating criteria.

1. Introduction

The voltage stability is increasingly becoming a limiting factor in the modern power systems due to the numerous changes that are continuously introduced to meet ever-increasing load demand without sufficient transmission and generation enhancement. This has necessitated the employment of techniques for analyzing and determining the critical point of voltage stability. Voltage stability is concerned with the ability of the power system to maintain acceptable voltages at all buses in the system under normal conditions and after being subjected to a disturbance [1]. A system is said to enter a state of voltage instability when a disturbance causes a progressive and uncontrollable decline in voltage, which can occur because of the inability of the network to meet the increasing demand for reactive power. The continuous sequences of voltage instability lead to voltage collapse and end in total blackout of the power system. Many recent large-scale power system breakdowns over different parts of the globe have been the consequences of instabilities characterized by voltage collapse phenomena [2,3]. Therefore, voltage stability analysis is important in order to identify critical buses in a power system i.e., buses which are closed to their voltage stability limits [4] and to enable the planning engineers and operators to take appropriate actions in order to avoid any incidents of voltage collapse.

A review of literature reveals the common techniques [5–8] available for the assessment of voltage stable states of any power system as well as for identifying the point of critical voltage stability are based on the load flow solution feasibility, singularity of Jacobian, bifurcation technique, optimal power flow, etc. Most of the researchers used the conventional *P–V*, *Q–V* curves and *P–Q* plane for assessing the voltage stability of critical bus in a power system [1,9]. Efforts also have been made to assess the voltage stability in terms of network equivalencing [10–18] to obtain a global picture of voltage stability. Here, the actual system is reduced into an equivalent two-bus system and then the global voltage stability indices for indicating the state of the actual system are computed. In [14,15], a technique for reducing the given power system to its equivalent two-bus model is described. The parameters of the equivalent system are obtained from the results of load flow solution of the original system. This equivalent system is simply a power line having series equivalent impedance with a load at the receiving end, while the sending end voltage is kept at the reference voltage. Refs. [16–18] report the voltage collapse proximity determination, based on the concept of single line equivalent. Accurate determination of the global voltage stability indices is possible if the power system is faithfully represented by an equivalent two-bus system. So far the equivalent models [13–20] used to assess voltage stability of power system are obtained by

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