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Simple and efficient method for steady-state voltage stability assessment of radial distribution systems

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ABSTRACT

A new static voltage stability index of a radial distribution system is proposed to faithfully evaluate the severity of the loading situation, thereby predicting for voltage instability at definite load value. The proposed index includes different parameters which affect the steady-state voltage stability of distribution systems, therefore it gives accurate results. The maximum value of 1 of that index denotes the point where the system reaches the point of collapse whereas a minimum value of 0 shows the state of no load. The performance of the new index was tested on two radial distribution systems consisting of 33 and 85 buses. Comparison between the results of the new index and those of previous indices showed that the new index yielded reliable results in predicting voltage stability condition of the system. The new index overcomes the problem which faces many previous indices especially as the load approaches the critical point. Analysis of the two-bus equivalents of the test systems under different scenarios is also presented. A new *P*–*Q* plane of stability is introduced based on the equation of the proposed index. The active, reactive and apparent power margins are then directly determined from the voltage stability boundary.

1. Introduction

Voltage stability is considered to be one of the keen interests of industry and research sectors around the world since the power system is being operated closer to the limit whereas the network expansion is restricted due to many reasons such as lack of investment or serious concerns on environmental problems [1]. Distribution systems experience distinct change from a low to high load levels every day. In certain industrial areas, it was observed that under certain critical loading conditions, the distribution systems may experience voltage collapse [2]. Radial distribution systems have low reactance to resistance ratio (X/R). This causes considerable IR and IX voltage drops in these systems which may lead to voltage collapse. Therefore, they are categorized as ill conditioned systems [3]. The voltage stability problem has been investigated for some years but most of the investigations analyzed the problem for high voltage transmission systems. The influence of loads at distribution level might therefore not to be fully taken care by these investigations. So far, the researchers and the industries have paid very little attention to analyze the voltage stability problem for a distribution system [4].

Refs. [3,5] introduced different steady-state voltage stability indices for indicating the state of radial distribution systems while the load is increased at a certain bus. These indices can be used by reducing the actual radial system into a two-bus equivalent system using the method derived in [6]. Whereas Ref. [2] introduced a voltage stability index which can be evaluated at each bus of the radial distribution system. The index is derived from load flow equations given in [7]. Computing the value of this index needs a load flow solution and determining of the line losses for each line in the system. Ref. [8] presented a criteria for voltage stability analysis in radial distribution systems by a geometrically form using the load flow equations. The feasibility and uniqueness properties of load flow (using Newton–Raphson method) were tested by the circle diagram of synchronous generator and Jacobian matrix. Reducing the system into a two-bus equivalent system is used for testing these properties. In [4] a voltage stability margin of radial distribution systems was presented. This method was used to determine the distance to voltage collapse point.

An analytical approach to voltage collapse proximity determination based on voltage phasors was presented in [9]. The actual system is reduced into a two-bus equivalent system then the maximum active and reactive powers were computed.

Voltage stability problem is mainly a load stability aspect; the load bus voltage relations attribute a special importance. Two-bus power system can represent satisfactory the load bus performance in all its situations encountered in practice [10,11].

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