Chapter 6
Voltage Stability Assessment Techniques for Modern Power Systems

Mahiraj Singh Rawat
National Institute of Technology Uttarakhand, India

Shelly Vadhera
National Institute of Technology Kurukshetra, India

ABSTRACT

In recent times, most of the power systems are made to operate close to their operating limits owing to various reasons like slow pace of transmission line expansion, environmental constraints, deregulated electricity market, etc. Therefore, the issue of maintaining the system stability has become the primary objective of the utility companies. The recent development and integration of renewable energy sources have further pushed the modern power systems to system security risks. The voltage instability had been the major cause of recent blackouts around the world. The timely assessment of voltage stability can prevent the blackouts in the power systems. This chapter explores the classical as well as newly developed static voltage stability assessment techniques proposed by various researchers in recent years. Also, the chapter cater to the needs of undergraduate as well as graduate students, professional engineers, and researchers who all are working in the domain of power system voltage stability.

INTRODUCTION

The phenomena of power system voltage stability is being continuously studied through various offline and online computer simulation programs at energy control centers. In literature, the authors have proposed and implemented various static and dynamic techniques for the assessment of voltage stability. The static voltage assessment techniques utilize the Newton-Raphson (N-R) based power flow programs, whereas the dynamic techniques requires the time domain simulation with mathematical modeling of various power system components such as automatic voltage regulators (AVRs), generators, governors,

DOI: 10.4018/978-1-5225-8551-0.ch006

and under load tap changing transformers (ULTC) etc. (Kundur et al., 2004). Plotting the P-V/ Q-V curves for the particular load buses selected are the most widely used methods for assessment of voltage stability (Ajjarapu, 2009). Traditionally, when P-V/Q-V curves are to be plotted, the power flow solutions are executed repeatedly with increasing the loads in steps until solution diverges. The system load at which the Jacobian of N-R method becomes singular is considered as maximum loading/critical point. The problem of divergence in the power flow results are mostly due to mathematical error or if the system states reach to a critical point. Therefore, the main drawback of this method is the recognition of the critical point. The problem of divergence in power flow solutions is resolved by the continuation power flow (CPF) technique. In CPF, the power flow equations are reformulated and locally parameterized continuation technique is applied (Ajjarapu & Cristy 1992).

The voltage stability is not only about the identification of critical point, but also it is necessary to find the factors that influence it. The bus voltage sensitivity with respect to change in reactive load demand (dV/dQ) is used as a tool for assessment of voltage stability by Faltabo, Ognedal, & Carlson (1990). The modal analysis technique which is an indirect method for calculating dV/dQ sensitivities is proposed by Gao, Morison, & Kundur (1992). In order to determine the stability margin between current operating point to the critical point, several voltage stability indices (VSIs) are proposed in the literature. Recently, a comprehensive review on VSIs had been presented by Modarresi et al. (2016). Other voltage stability methods such as bifurcation analysis (Ajjarapu 1992; Dobson 1993; Alvarado, 1994), direct methods and energy function (Overbye & DeMarco, 1991) methods can be found in literature. In recent years, wide deployment of phasor measurement units (PMUs) in power systems had opened a new perspective for developing voltage stability assessment techniques. The PMUs based voltage assessment techniques can be classified into local (Corsi & Tarantu, 2008) and wide area monitoring (Glavic 2009; Beiraghi 2013). Since, PMUs capture large amount of data, therefore for large power systems, Mohammadi & Behghani (2015), Diao et al., (2009) have proposed computational intelligence based techniques such as decision trees for online voltage stability assessment. The chapter reflects the major assessment techniques that are useful for the voltage stability of power system.

BACKGROUND

According to IEEE/CIGRE joint task force report, power system stability is defined as "*Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most system variables bounded so that practically the entire system remains intact*" (Kundur et al., 2004, p. 1388). Power system instability may be evident in various ways depending upon the power system configuration and operating mode. Different phenomenon that lead to instability are presented in Kundur, (1994), Kundur (2006). These phenomenon are referred to as: 1) rotor angle stability, 2) voltage stability and 3) frequency stability. The broad classification of power system stability is shown in Figure1. Rotor angle stability is related to the ability of the synchronous generators in an interconnected power network to maintain synchronism after large disturbances such as sudden loss of large loads, line tripping due to faults etc. The frequency instability arises due to imbalance between total generation and load demand. In recent years, the voltage instability was identified as the primary cause of many blackouts around the world.

Related Content