Chapter 7
Reactive Power Loss Index for Identification of Weak Nodes and Reactive Compensation Analysis to Improve Steady State Voltage Stability

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ABSTRACT

This chapter presents a new reactive power loss index for identification of weak buses in the system. This index can be used for identification of weak buses in the systems. The new reactive power loss index is illustrated on sample 5-bus system, and tested on sample 10-bus equivalent system and 72-bus equivalent system of Indian southern region power grid. The validation of the weak buses identification from the reactive power loss index with that from other existing methods in the literature is carried out to demonstrate the effectiveness of the index. Simulation results show that the identification of weak buses in the system from the new reactive power loss index is completely non-iterative, and thus requires minimal computational efforts as compared with other existing methods in the literature.

INTRODUCTION

The present day power system is being operated under stressed conditions due to rapidly growing power demand, and lacks of upgradation/augmentation of the existing infrastructure such as generation and transmission capacity in the system because of various operational, economical and environmental con-

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straints. In addition, the situation becomes more worst if the system is perturbed by critical/severe network contingencies such as tripping of heavily loaded transmission lines or outage of large generating units. Under such situations, power system may result in voltage instability and susceptible to voltage collapse due to insufficient amount of reactive power reserve available in the system to support the voltage. Not only is reactive power necessary to operate the transmission system reliably, but it can also substantially improve the efficiency with which real power is delivered to customers/end users. Hence, the secure and reliable operation of power system has always been concern to the system operator.

In recent years, it has been observed that the voltage instability problem is the root cause for several major network blackouts in different countries such as France, Belgium, Sweden, Germany, Iran, Japan, USA and India (FERC, 2005; Srivastava, Velayutham, Agrawal, & Bakshi, 2012.). A system may be voltage unstable if it includes at least one voltage unstable bus (Ca˜nizares, De Souza, & Quintana, 1996). Therefore, the system operator must make sure that there are enough reactive reserve capacities available for the system to maintain voltage profiles. Properly planned reactive power reserve minimizes the risk of voltage collapse or low voltages as well as reduces transmission loss by keeping appropriate voltage profiles. For the above reason, the identification of critical/weak buses in the system is very much useful for installing additional voltage support devices to prevent possible voltage instability problem.

BACKGROUND

Voltage Stability Analysis

In the literature many voltage stability and voltage collapse prediction methods have been proposed (Ajjarapu & Lee, 1998). Some of these methods are P-V and Q-V curve analysis (Taylor, 1994), determination of how far the system is operating from the point of collapse from continuation power flow (CPF) method (Ajjarapu & Christy, 1992), multiple load flow solutions (Tamura, Mori, & Iwamoto,1983), modal analysis (Gao, Morison, & Kundur, 1992), voltage instability proximity indicator (CIGRE Task Force 38.02.11 Report, 1994), minimum singular value of power flow Jacobian (Lof, Andersson, & Hill, 1993), voltage stability index based on load flow solution (Kessel & Glavitsch, 1986), sensitivity analysis (Begovi´c & Phadke, 1992), energy function (Overbye & DeMarco, 1991), reactive power optimization based methods (J. Singh, S. Singh, & Srivastava, 2007), artificial neural networks (El-Keib & Ma, 1995), and other methods (Moger, 2015). The indices derived from these methods can be used to identify the weakest bus or area in the power system and also provide reliable information about the closeness of the system to voltage collapse.

Traditionally, utilities depended on conventional power flow programs for the static analysis of voltage stability by computing P-V curves (Kundur et al., 2004) and QV curves (Taylor, 1994; Ajjarapu & Christy, 1992) at selected load buses. P-V curves are generated by obtaining power flow solutions for the different loading conditions. The MW load at the buses is increased in small steps while maintaining the power factor of the load and the pattern of generation. The shape of the P-V curve is similar to that of a parabola. The knee point of this parabola gives the critical loading of the bus. The distance between the operating point and the knee point gives the MW and the voltage magnitude stability margins for the given load power factor. Similarly, Q-V curves are used in conjunction with P-V curve. A disadvantage of using the conventional power flow or Newton-Raphson method is that power flow simulation will fail to converge near the nose or maximum power point on the curve. Ajjarapu and Christy (1992) proposed