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Optimal Placement of STATCOM using Two Stage Algorithm for Enhancing Power System Static Security

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Abstract

In recent years, there has been a consistent increase in power demand which has resulted in heavy line flows, greater losses, and may threaten system security and stability. The power system consists of diversified loads with rapid variations in its reactive power requirement. STATCOM is a shunt compensator used for fast response when the reactive power of the load is changing rapidly. This paper presents STATCOM modeled as synchronous voltage source. In this work, optimum location and optimal parameters of STATCOM have been determined. The objective is to minimize system power loss by controlling device parameters. In this work, a two-stage approach is proposed for optimal placement of STATCOM. In the first stage, optimal location of STATCOM is obtained by generalized approach which is based on sensitivity analysis and in the second stage STATCOM parameter setting is done using Newton- Raphson (N-R) power flow technique. This approach is implemented on 14-bus test system. Voltages in the network, power flows and power loss before and after placing the STATCOM have been compared. It is observed that, after placement of STATCOM voltage profile is improved and power loss is minimized in the system. Proposed algorithm is implemented in MATLAB.

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Keywords: *STATCOM; optimal location; optimal sizing; sensitivity analysis; real power loss.*

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1. Introduction

In transmission network majority of the interruptions take place due to voltage instability. Voltage instability is one of the reasons for blackout in North American power system on August 14^{th}, 2003. With the help of modern technology voltage stability margin can be enhanced [1]. To meet the load demand, the stability and reliability of the power system can be enhanced by the efficient use of existing power system. The transmission network expansion constraint, curbs the operation of electrical power systems close to their stability limits. The transmission network supplies the load at a required reliable and optimum efficiency at a reasonable cost. Hence, emerges the necessity for optimizing power system capacities effectively by installing Flexible AC transmission systems (FACTS) devices. The maximum capability of power systems can be exploited by means of FACTS devices.

The detailed description of different FACTS devices including their operating principles were explained by Hingorani et al [2, 3]. The power flow control, voltage profile, stability enhancement and minimal loss can be anticipated by FACTS devices. The economical considerations limit the installation of FACTS controllers in all the buses or the lines.

There are diverse methods proposed in literature for optimizing location and parameter setting of FACTS devices in power system [4, 5, 6]. Sensitivity indices based on line loss have been developed for placement of series capacitors by Preedavichit et al [7]. The economic dispatch problem resolves the optimal positioning of FACTS devices by Tran Bach et al [8]. The FACTS devices are also considered for transmission congestion management purposes [9, 10, 11].The best converter based FACTS devices are Static Synchronous Compensator (STATCOM) and Unified Power Flow Controller (UPFC). The STATCOM and UPFC were applied for power system steady state operation in [12]. The damping of STATCOM was enhanced by an adaptive fuzzy controller in [13]. The optimum gain setting of STATCOM to enhance the dynamic response of the hybrid power system is presented in [14]. In a multi-machine environment, cuckoo Search (CS) algorithm based on the life of a bird family has been developed for optimal design of static synchronous compensator (STATCOM) by Abd-Elazim et al [15].

The purpose of this paper is to investigate on placement of STATCOM for improvement of voltage profile of power system. In this work, two stage algorithm has been proposed to determine the optimal location and optimal parameter setting of STATCOM. In the first stage optimal location of STATCOM is obtained based on partial derivative of objective function with respect to reactive power injection according to generalized approach for placement of FACTS devices [16] and in the second stage optimal parameter setting of STATCOM is obtained using N-R polar technique. The objective considered is, minimization of sum of active power loss in the transmission network. The static model of STATCOM has been used. The two stage approach has been demonstrated on 14 bus test system.

The remaining paper is structured as follows. Section 2 consists of a static modeling of STATCOM. In section 3, method for optimal placement of STATCOM is described. Section 4 consists of simulation results. Finally conclusions are presented in Section 5.

2. Static Synchronous Compensator (STATCOM) model

The mathematical model of the controller can be derived by the STATCOM equivalent shown in Fig.1. It is reasonable to represent the STATCOM with a synchronous voltage source having maximum and minimum voltage magnitude limits. In the STATCOM at the AC converter terminal the synchronous voltage source represents the primary Fourier series component of the switched voltage waveform. In the event of limits being violated the bus connected to STATCOM is reassigned to PQ bus from PV bus. In such a case, the generated or absorbed reactive power would correspond to the violated limit.

In this work, the STATCOM is represented as a voltage source for the complete range of operation, permitting rigid voltage support mechanism. Using Fig.1 of STATCOM the nonlinear power equations are obtained.