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Optimal location and parameter setting of UPFC for enhancing power system security based on Differential Evolution algorithm

Husam I. Shaheen *, Ghamgeen I. Rashed, S.J. Cheng

Electric Power Security and High Efficiency Lab, Department of Electrical Engineering, Huazhong University of Science and Technology, Wuhan 430074, Hubei, China

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ABSTRACT

This paper presents a new approach based on Differential Evolution (DE) technique to find out the optimal placement and parameter setting of Unified Power Flow Controller (UPFC) for enhancing power system security under single line contingencies. Firstly, we perform a contingency analysis and ranking process to determine the most severe line outage contingencies considering line overloads and bus voltage limit violations as a Performance Index. Secondly, we apply DE technique to find out the optimal location and parameter setting of UPFC under the determined contingency scenarios. To verify our proposed approach, we perform simulations on an IEEE 14-bus and an IEEE 30-bus power systems. The results we have obtained indicate that installing UPFC in the location optimized by DE can significantly enhance the security of power system by eliminating or minimizing the overloaded lines and the bus voltage limit violations.

1. Introduction

The secure operation of power system has become an important and critical issue in today's large, complex, and load-increasing systems. Security constraints such as thermal limits of transmission lines and bus voltage limits must be satisfied under all system operation conditions. Commonly, power systems are planned and operated based on the $N-1$ security criterion, which implies that the system should remain secure under all important first contingencies. One solution to cope with this problem is to design the system to meet the $N-1$ security criterion which is somewhat conservative and costly. An alternative solution to improve the security of power system is the Flexible AC Transmission Systems (FACTS) devices which is a concept proposed by Hingorani [1].

FACTS devices can reduce the flows of heavily loaded lines, maintain the bus voltages at desired levels, and improve the stability of the power network. Consequently, they can improve the power system security under contingency situations. Unified Power Flow Controller (UPFC) is a versatile FACTS's device which can independently or simultaneously control the active power, the reactive power, and the bus voltage to which it is connected [2]. However, to achieve such functionality of UPFC, it is highly important to determine the optimal location of this device in the power system with the appropriate parameter setting. Since UPFC can be installed in different locations, its effectiveness will be different. Therefore, we will face the problem of where we should install UPFC. For this reason, some performance indices must be satisfied. The following are some factors that can be considered in the selection of the optimal installation and parameter setting of UPFC: the stability margin improvement, the power transmission capacity increasing, and the power blackout prevention, etc. Therefore, conventional power flow algorithm [3] should incorporate with UPFC and the optimization should consider one, two, or all of the above mentioned factors. However, in this paper, we only consider blackout prevention, in other words, enhancing the security of power system under single line contingencies through installing UPFC in an optimal location with optimal parameter setting.

In the last decade, new algorithms have been developed for the optimal power flow incorporating with UPFC device as well as for the optimal placement of UPFC. Some of them are: a sensitivity-based approach which has been developed for finding suitable placement of UPFC [4], an evolutionary-programming-based load flow algorithm for systems containing unified power flow controllers [5], a Genetic Algorithm (GA) which proposed for solving the optimal location problem of UPFC [6], and a Particle Swarm Optimization (PSO) for optimal location of FACTS devices [7].

Also a lot of work has been done in the contingency analysis research area. Different contingency selection methods can be found in [8–10]. Operation scheme of FACTS devices to enhance the power system steady-state security level considering a line contingency analysis is suggested in [11]. A method for contingency selection and security enhancement of power systems by optimal placement of FACTS devices using GA is presented in [12].

* Corresponding author. Address: Department of Electrical Engineering, Faculty of Mechanical and Electrical Engineering, Tishreen University, Lattakia, Syria. Tel.: +86 27 63318505.
E-mail address: shaheen@ieee.org (H.I. Shaheen).

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