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Population based evolutionary optimization techniques for optimal allocation and sizing of Thyristor Controlled Series Capacitor

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Abstract

During the last decade, the application of Flexible AC Transmission System (FACTS) devices in electrical power system increased due to their numerous advantages such as power transfer capability enhancement, reliability and security improvement and reactive power compensation. Although to obtain maximum advantage, their size and location should be optimal. Optimal position and size of Thyristor Controlled Series Capacitor (TCSC) in power system using evolutionary optimization techniques such as, Teaching Learning Based Optimization (TLBO), Artificial Bee Colony (ABC) and Particle Swarm Optimization (PSO) are presented in this paper. The minimization of transmission loss, the installation cost of TCSC and voltage deviation is considered as an objective function. To demonstrate the viability of the algorithms, it is validated on the IEEE 14 bus, IEEE 30 bus and Indian 75 bus systems. The results accomplish from TLBO are compared with the ABC and PSO to show the capability of the TLBO and its superiority over ABC and PSO.

Keywords: ABC; FACTS; PSO; TCSC; TLBO; Transmission loss

1. Introduction

In recent years, the size and complexity of electric power system are increased enormously due to exponential rise in demand of electricity. Therefore, a stable, reliable and the uninterrupted power quality with the minimum transmission loss is a Herculean task and demand stern constraints to be satisfied. To accomplish the above objectives, the most

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reliable and feasible alternative is the application of Flexible AC Transmission System (FACTS) devices, which provide better power flow control, voltage control, flexibility of operation and superior quality of the existing transmission line capacity (Hingorani and Gyugyi, 2000; Mathur and Varma, 2002). In this process the size and location of the FACTS devices in the wide electricity transmission network play a pivotal role. FACTS controller can be classified into three types, Series Controllers, Shunt Controllers and Combined Series and Shunt Controllers, based on the type of connection in the transmission line (Hingorani and Gyugyi, 2000). Static Synchronous Compensator (STATCOM) and Static VAR Compensator (SVC) are classified as shunt controllers whereas Static Synchronous Series Compensator, Interphase Power Controller (IPC) and Thyristor Controlled Series Capacitor are classified as series controllers. Unified Power Flow Control (UPFC), Interline Power Flow Control (IPFC) and Thyristor Controlled Phase Shifting Transformer (TCPST) are examples of combined series-shunt controllers. FACTS devices can also be categorized as, thyristor based FACTS controller and VSC based FACTS controller, based on the power electronics switch used.

The Thyristor Controlled Series Capacitor (TCSC) is a series connected FACTS device, used for the control of power transfer between the lines by varying the impedance of the line. The principal applications of TCSC are mentioned in the literatures as to improve power system stability, to enhance power and to damp oscillations presented in the power system. The purpose of the present work is to minimize the transmission loss and voltage deviation of power systems. In conceiving the suggested objectives, the location and ratings of the TCSC must be brought off. The optimization methods, namely Teaching Learning Based Optimization (TLBO), Artificial Bee Colony (ABC) and Particle Swarm Optimization (PSO) are used for the same and discussed briefly in the section 4 of the paper. The location and degree of compensation of TCSC are considered as the optimization variables.

The size and location of the FACTS devices in the wide electricity transmission network play a pivot role. As FACTS devices are expensive and need to be utilized effectively to get the maximum benefit, these devices must be placed optimally. Also, it should be ensured that there will be no negative impact in the deregulated environment. The optimal location and size of FACTS devices are helpful to enhances loadability, available transfer capability, total transfer capability, voltage stability, transient stability, damping, security, etc. besides reduction of losses, minimization of generation cost and removal of congestion. The Optimal location and size of the FACTS devices in a power system will be helpful for utilities in the decision making of investment costs and further expansion plans. This research work proposes the optimal location and value of FACTS devices in power system using the evolutionary optimization techniques.

To find the suitable location of TCSC to enhance security and minimize the generation cost of the IEEE 30, IEEE 57 and IEEE 118 bus systems using fuzzy logic with Harmony search algorithm were examined by Pandiarajan and Babulal (2016). The optimal power flow with TCSC to minimize transmission loss, fuel cost and emission cost using Symbiotic Organism Search (SOS) algorithm are witnessed in (Prasad and Mukherjee, 2016). It was simulated on the MATLAB and tested on the standard IEEE 57 bus and IEEE 30 bus systems. The position and range of TCSC devices to mitigate system losses and investment cost using Genetic Algorithm and Particle Swarm Optimization is presented in (Rashed et al., 2007, 2011). Duong et al. (2014) proposed a Min cut algorithm, to find the best location of TCSC for enhancing loadability and minimization of transmission losses. Nagalakshmi and Kamaraj (2012) proposed the Particle Swarm Optimization (PSO), Differential Evolution (DE) and Composite Differential Evolution (CoDE) to determine the location and control of FACTS devices to improve the loadability of the power system. It is shown that the computational time required for CoDE is less than Differential Evolution and Genetic Algorithm. To minimize the generation, emission and real power transmission loss of IEEE 30 bus and IEEE 57 bus systems using TCSC with Non-dominated Sorting Genetic Algorithm-II (NSGA-2) is reported in (Basu, 2011). It is revealing that the outcome obtained from Differential Evolution is improved compared to Genetic Algorithm. Naresh et al. (2016) has used the Harmony Search Algorithm (HSA) to damp out the power system oscillation. It is shown that the result obtained from the HSA is better compared to Bacteria Swarm Optimization. In Rezaee Jordehi et al. (2015) Enhanced leader PSO (ELPSO) was used for optimal location of TCSC to minimize the voltage deviation and power losses under contingency. The Real Genetic Algorithm (RGA) to determine the proper location and sizing of TCSC to enhance the voltage profile and Available Transfer Capability (ATC) has been proposed by Rashidinejad et al. (2008).

Going through the research survey, we observed that a numerous evolutionary optimization technique has been developed to investigate the transmission loss, voltage profile, security, ATC, loadability and installation cost of TCSC. The examination of literature review also reveals that the solution of the above problem along with TCSC cannot be solved without optimization technique. The outcome also shows that the multi-objective problem consisting transmission loss minimization, installation cost minimization and voltage profile improvement is not presented in

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