Optimal allocation of multi-type FACTS devices and its effect in enhancing system security using BBO, WIPSO & PSO

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Received 19 August 2015; received in revised form 13 December 2016; accepted 10 January 2017

Abstract

FACTS devices play a vital role in improving the static as well as dynamic performance of the power systems. However the type, location and rating of the FACTS devices play a major role in deciding the extent to which the objective of improving the system performance is achieved in a cost effective manner. In this work an objective function comprising of cost, line loadings and load voltage deviations is proposed to tap maximum benefits out of their installation and the weights assigned to them decide their relative importance. The impact of installing TCSC, SVC, TCSC-SVC and UPFC in minimizing the formulated objective has been analyzed in enhancing security, under increased system loading conditions.

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Keywords: FACTS devices; PSO; WIPSO; BBO; Enhance system security; Optimal placement

1. Introduction

Due to the dynamic load pattern and ever increasing load demand, power flows in some of the transmission lines are well above their normal limits while some of the lines are not loaded up to their full capacity. As a result of this uneven load distribution the voltage profile of the system gets deteriorated which poses a threat for the security of the system. Considering economical and technical constraints involved in setting up new generation resources and limitations faced in purchasing right of ways to realize new transmission corridors, it becomes essential to utilize the existing transmission lines in an efficient manner. FACTS controllers are found to be an effective alternative for the complex task of building up new transmission corridors (Manoj and Puttaswamy, 2011).

Modulating and reversing the power flow through the transmission lines a fast, accurate and precise manner was made possible through the FACTS (Flexible Alternating Current Transmission System) concept introduced by Hingorani

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Peer review under the responsibility of Electronics Research Institute (ERI).

http://dx.doi.org/10.1016/j.jesit.2017.01.008

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and Gyugyi (1999). FACTS devices are very effective in improving the voltage profile, reducing the line loadings and line losses, providing reactive power support over a wide range of operating voltages and enhancing the stability of the system. They can as well be used with the existing lines in order to enhance their power transfer capability. The power flow through the network can be controlled without modifying the generation and carrying out any switching operations in the network (Singh and David, 2001). In order to achieve maximum benefits through the installation of the FACTS devices, devices of suitable ratings need to be installed at optimal locations (Benabid et al., 2009).

Optimal placement of FACTS devices is vital to tap the maximum advantages in terms of system performance and cost effectiveness (Aghaei et al., 2012). There are several strategies and approaches in the literature, to solve the issue of FACTS optimization problem. Commonly employed approaches to solve the installation of FACTS devices are sensitivity based analysis (Mandala and Gupta, 2010) and optimization and index calculation method (Hamid et al., 2012a,b). Various techniques adopted to solve the FACTS placement problem are categorized into analytical, linear programming and heuristic based procedures (Sirjani et al., 2012). The optimal location of a given number of FACTS devices is an issue of combinatorial investigation and to solve such sort of issues, heuristic based techniques are observed to be powerful (Gerbex et al., 2001) since they are robust and result in acceptable solutions to real problems within a limited computation time (Radu and Besanger, 2006).

Some common heuristic search techniques to decide the optimal location of FACTS devices in the power system, reported in literature are Genetic Algorithm, Simulated Annealing, Immune Algorithm, Particle Swarm Optimization, Differential Evolution, Harmony search algorithm, and Ant Colony algorithm. The work focuses on a new type of heuristic search algorithm, based on the species behavior – BBO (Biogeography Based Optimization). It is a population based algorithm, which uses the immigration and emigration behavior of the species based on various natural factors (Simon, 2008). Application of BBO to solve the economic dispatch problem is described in Bhattacharya et al. (2010) where it has been proved that BBO gives a solution which is comparable with evolutionary programming and differential evolution techniques. In this paper, BBO is applied to solve the optimization problem of finding the optimal placement and capacity of multi-type FACTS devices under varying the system load up to 30% from base case. The results obtained using BBO are compared with PSO and WIPSO (Weight Improved PSO) techniques.

2. Problem formulation

2.1. Objective of the optimization

As the cost of the FACTS devices is high, in order to achieve the maximum benefit, the devices are to be installed at the optimal locations. The objective function has three terms; the first term represents the installation cost of the devices, the second and third terms representing the load bus voltage deviations and line loadings respectively. The minimization of the proposed objective function has to lead to a cost effective security oriented device placement.

The objective function is formulated as

$$\text{Min } F = W_1 [(C_{FACTS} \times S)] + W_2 \{LVD\} + W_3 \{LL\}$$

(1)

where $F$ is the objective function, $C_{FACTS}$ is the cost of FACTS device in US $/\text{KVar}$, $S$ is the operating range of the FACTS device, $LVD$ is the Load voltage deviation, $LL$ is the Line loading, $W_1$, $W_2$ & $W_3$ are the weight factors.

2.1.1. Cost ($C_{FACTS}$)

The first term of the objective function $C_{FACTS}$, presents the installation cost of FACTS devices considered and are given by the following equations.

$$C_{TCSC} = 0.0015s^2 - 0.7130s + 153.75$$

(2)

$$C_{SVC} = 0.0003s^2 - 0.3051s + 127.38$$

(3)

$$C_{UPFC} = 0.0003s^2 - 0.2691s + 188.22$$

(4)

$C_{TCSC}$ is the cost of TCSC device in US $/\text{KVar}$, $C_{SVC}$ is the cost of SVC device in US $/\text{KVar}$, $C_{UPFC}$ is the cost of UPFC device in US $/\text{KVar}$.  

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