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Voltage stability enhancement in power systems with automatic facts device allocation

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Abstract

The voltage stability problem in modern power systems is an issue related to the system constraints and voltage collapse. Flexible AC Transmission System (FACTS) is an example of modern device able to control the reactive power flow in a more efficient way. This paper proposes an automatic FACTS device allocation process based on evolutionary algorithm. The model aims to enhance the voltage stability of power systems. The results showed that the proposed method enhanced the voltage stability in IEEE system benchmarks, and the method outperformed other probabilistic and heuristic optimization methods.

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Keywords: Voltage Stability; FACTS devices; Reactive Power

1. Introduction

The power system has become the main driver of the world economy. Nowadays, power systems operate near to their constraints due to the continuous demand increase. The voltage instability is the main cause of constraint violations and voltage collapse. The voltage stability is related to the control of the reactive power. The Flexible AC Transmission System (FACTS) becomes the control of the reactive power flow more dynamic, since the acquired flexibility on the transmission system [1]. The optimum location of FACTS devices is a very important issue in power systems, since the weakest busbar and/or transmission lines need to be identified.

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Several works have used FACTS based models in order to control the reactive power flow and to assess the voltage stability [2-6]. In [7,8], a genetic algorithm is used to determine the parameters and location of SVC, TCSC, and UPFC to improve the voltage stability and to reduce active power losses. In the [9,10], the voltage stability is evaluated according to the L-index indicator and the parameters and location of FACTS devices are obtained with a hybrid genetic algorithms and harmony search. In [11], a modified augmented e-constraint method is used to determine the best location and adjustment of a FACTS device to enhance the voltage stability.

The optimum reactive power flow is important problem in power systems, since the complexity and dimension of the power flow equations. Thus, the use of the evolutionary algorithm is an attractive alternative, since this is a probabilistic, population based, and global search method. Classical optimization methods generally are local search based and require a well-defined analytic functions. Evolutionary algorithm only compares the quality of solutions.

This paper presents an automatic FACTS device allocation method with an evolutionary algorithm. The proposed method also adjusts other decision variables in order to enhance the voltage stability. The method used an adaptive evolutionary algorithm to optimize the following stability indicators: the voltage profile, the reactive power flow losses, and the voltage collapse margin. Several experiments were performed, and the results showed that the proposed method enhanced the voltage stability in IEEE 14 and 57 busbar systems, and the method also outperformed other probabilistic and heuristic optimization methods.

2. Voltage stability

Voltage stability is a problem in power systems which are loaded or have a shortage of reactive power. Voltage stability can be analyzed by examining the production, transmission, and demanding of reactive power [12]. The proposed model uses the L-index method for evaluating the voltage stability in power systems through the voltage collapse margin [13,14].

For a power system with n bus, the index that identifies the proximity to the voltage collapse can be defined as

$$L_j = \left| 1 - \sum_{i=1}^{n_C} C_{\mathrm{ji}} \frac{V_i}{V_j} \right| \tag{1}$$

where nG is the number of generation bus, Vi is the voltage in complex form of i-th generation bus, Vj is the voltage in the complex form of j-th load bus, Cji is the element of the matrix C:

$$[C] = -[Y_{LL}]^{-1}[Y_{LG}] \tag{2}$$

The matrix [YLL] and [YLG] are submatrix of Ybus.

$$\begin{bmatrix} I_L \\ I_G \end{bmatrix} = \begin{bmatrix} Y_{LL} & Y_{LG} \\ Y_{GL} & Y_{GG} \end{bmatrix} \begin{bmatrix} V_L \\ V_G \end{bmatrix} \tag{3}$$

This index Lj ranges from 0, stable system, to 1, voltage collapse.

3. Facts devices

The concept of Flexible AC Transmission system (FACTS) refers to control and adapt the parameters of power systems, reactive power flow, bus voltages, and transmission line impedance [1]. The following subsections present two FACTS devices used by the proposed method.