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ORIGINAL ARTICLE

Performance of two modified optimization techniques for power system voltage stability problems

S. Harish Kiran *, Subhransu Sekhar Dash, C. Subramani

Dept., EEE, SRM University, Kattankulathur 603203, India

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Voltage Stability Artificial Bee Colony (VS-ABC);
Hybrid-Genetic Algorithm (H-GA)

Abstract The development of optimization techniques in power system is to determine the sizing of Flexible AC Transmission System (FACTS) devices such as Unified Power Flow Series Compensator (UPFC) controller in improving the voltage stability and bus voltage margin. An attempt is made to modify the Particle Swarm Optimization (PSO) and Artificial Bee Colony (ABC) with Hybrid-Genetic Algorithm (H-GA) for determination of sizing of the device. Fast Voltage Stability Index (FVSI) is used to identify the location of the device to be connected. The proposed methods are implemented in IEEE 30 Bus system and its results are tabulated for each technique.

1. Introduction

The development in infrastructure leads to a non-linear increase in load demand, which in turn leads to maximum utilization of power system equipments. Economic and environment are the two main factors for construction of new transmission lines. As the systems are more heavily loaded, maintenance of stability in the power system becomes a major problem with system operating very close to its instability point. There are many methods for determining the system stability, but, still research is in progress for predetermining a solution for the stability problem that could prevail in the network [1,2]. Evaluation of system stability is based on the voltage profile of each bus. The stability of the system was analyzed initially by PV curve and QV curve [3] by P. Kunder et al. Then, many other methods emerged such as L-Index [4], Modal analysis [5], Line Stability Index (Lmn) [6], Line Stability Index (LQP) [7], Bus Power Index [8], Power Transfer Stability Index (PTSI) [9], New Voltage Stability Index (NVSI) [10], Fast Voltage Stability Index (FVSI) [11,12], Global Voltage Stability Index (GVSI) [13] and other methods. Each index has its own merits and demerits in identification of the stability index of the power system network. The stability problem has provoked the use of FACTS device to improve the power system stability by injection or absorption of real and reactive power in the power system network depending upon the power

* Corresponding author.
E-mail address: harish99kiran@gmail.com (S. Harish Kiran).
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system loading conditions. Various advantages of FACTS devices in the power system network are improvement in steady state stability, dynamic behavior of the system and system reliability.

The recent developing methods to improve the stability of power system network are to implement Optimization Technique in determining the rating for FACTS devices to be connected based on system loading pattern. In this paper, two Swarm Intelligence (SI) [14] optimization techniques are implemented to identify the FACTS device rating to be connected in the power system network based on line stability index value. The device rating is taken as optimization problem and index value of the line to which the device is connected as the fitness value. Particle Swarm Optimization (PSO) algorithm and Artificial Bee Colony (ABC) Algorithm are coded on the bases of electrical parameters and modified as Voltage Stability Particle Swarm Optimization (VS-PSO) algorithm and Voltage Stability Artificial Bee Colony algorithm (VS-ABC) is used to identify the FACTS device rating. Enhanced Genetic Algorithm (EGA) is incorporated with optimization techniques to have a higher rate of convergence and accuracy in determination of the device rating. The change in system stability, loadability and critical line is analyzed and compared with optimization techniques for FVSI index.

2. Voltage stability indices

FVSI index is formed based on two bus system for simplicity purpose and implementation in the actual system. The line diagram of two bus system model is shown in Fig. 1.

The system stability will be within the stable operating state, when the indices are from '0.0000' to '0.9999', above which the system is said to be in unstable state.

2.1. Fast Voltage Stability Index (FVSI)

The FVSI index was first framed by Dr. Ismail Musirin et el. in 2002 [12]. It is based on the line voltage and the reactive power of the receiving end bus of the system. The general current equation for the two bus system is shown in Fig. 1.

The current flow in the two bus system is

$$I = \frac{V_i\angle 0 - V_j\angle\delta}{R_{ij} + jX_{ij}} \quad (1)$$

The apparent power at the receiving end bus j can be written as

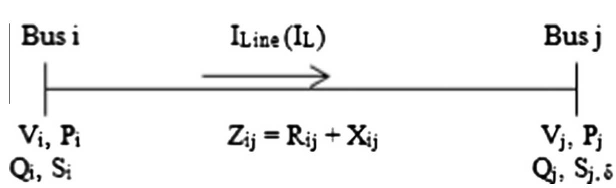

Figure 1 Line diagram of two bus system.
Where V_i, V_j – Voltage at the sending and receiving end buses. P_i, Q_i – Active and reactive power at the sending end bus. P_j, Q_j – Active and reactive power at the receiving end bus. δ – Angular difference between the sending and the receiving end power. $Z_{ij} = R_{ij} + X_{ij}$. R_{ij} is the line resistance and X_{ij} is the line reactance.

$$S_j = V_j I^* \quad (2)$$

Rearranging Eq. (2) we get

$$I = \left(\frac{S_j}{V_j}\right)^* \quad (3)$$

$$I = \frac{P_j - jQ_j}{V_j\angle -\delta} \quad (4)$$

Equating Eqs. (1) and (4) we get

$$V_iV_j\angle -\delta - V_j^2\angle 0 = (R + jX_{ij})(P_j - jQ_j) \quad (5)$$

The real part of Eq. (5) is

$$V_iV_j cos\delta - V_j^2 = RP_j + X_{ij}Q_j \quad (6)$$

And the imaginary of Eq. (5) is

$$-V_iV_j sin\delta = X_{ij}P_j - RQ_j \quad (7)$$

Rearrange Eq. (7) with respect to P_j

$$P_j = \frac{RQ_j - V_iV_j sin\delta}{X_{ij}} \quad (8)$$

Substituting Eq. (8) in (6) and rearrange it with respect to V_j, we get

$$V_j^2 - \left(\frac{R}{X_{ij}} sin\delta + cos\delta\right)V_iV_j + \left(X_{ij} + \frac{R^2}{X_{ij}}\right)Q_j = 0 \quad (9)$$

To get the real roots for V_j the discriminant must be greater than or equal to "0"; Eq. (9) is in the form of $Ax^2 + Bx + C = 0$; hence, $B^2 - 4AC \geqslant 0$

$$\left[\left(\frac{R}{X_{ij}} sin\delta + cos\delta\right)V_i\right] - 4\left(X_{ij} + \frac{R^2}{X_{ij}}\right)Q_j \geqslant 0 \quad (10)$$

$$\frac{4Z^2Q_j}{(V_i)^2(Rsin\delta + X_{ij}cos\delta)} \leqslant 1 \quad (11)$$

Since δ is normally very small we can assume $\delta \approx 0$. Hence, $R\sin\delta \approx 0$, $X\cos\delta \approx X$, then Eq. (11) can be rewritten as

$$\text{FVSI}_{ij} = \frac{4Z_{ij}^2Q_j}{V_i^2X_{ij}} \quad (12)$$

3. FACTS devices sizing

UPFC controller is selected as it has the property of both shunt and series compensation. The rating of FACTS devices [15] for UPFC controller is given in Eq. (13), to improve the power system stability and voltage profile.

$$R_{UPFC} = rf * 180\ (\text{MVAR}) \quad (13)$$

where rf is the rating factor of the devices in the range of 0.1–1.8 for UPFC.

4. Optimization techniques

In 1940, George Dantzig was the first person to introduce the use of Optimization techniques. It is a process of finding the maxima and the minimum value of the concerned function. Initially George Dantzig used this optimization method for military application only and for further development and it