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Comparison of Facts Devices to Reduce Power System Losses and Improvement in Voltage Stability by Using Optimization Technique

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Abstract: ***The research work described in this paper concentrates on the application of Flexible Alternative Current Transmission System (FACTS) controllers as a solution to the power system problems like voltage stability and losses. Electrical power generation in our country has been a bigger challenge to meet the growing demands for more power. Because of this, the power trading and grid maintenance becomes complex issues, and power system is becoming less secure. In power system, voltage instability is one of the most important problems. The problem voltage stability plays a major role in fast development of restructuring in deregulated power system. Placing of FACTS devices in a suitable location is important to improves the voltage stability and reduce power system losses. This paper proposes a Bacterial Foraging Optimization (BFO) technique to determine optimal location for FACTS devices like Thyristor Controlled Series Capacitor (TCSC) & Unified-Power-Flow Controller (UPFC) to reduce power system losses and improve voltage stability. Among these two FACTS devices UPFC is better to reduce power system losses and improve voltage stability than TCSC. The method has been successfully demonstrated on IEEE30-bus system.***

Keywords: Flexible Alternative Current Transmission System (FACTS), Voltage Stability, Thyristor Controlled Series Capacitor (TCSC), Unified-Power-Flow Controller (UPFC), Bacterial Foraging Optimization Algorithm (BFOA).

1. Introduction

Electrical power generation in our country has been a bigger challenge to meet the growing demands for more power. The demand is increasing due to rapid industrialization, urbanization and increase in population of the developing countries. As a measure to meet the increasing demand ensuring adequate availability and reliability, private participation is being encouraged. Because of this, the power trading and grid maintenance becomes complex issues. And power system is becoming less secure.

So the problem of instabilities in entire system working environment, regular planning and method of operation. In power industry, voltage instability is one of the most important problem. Voltage collapse is the main reason for network blackouts.

When the generation and consumption of electric power causes the transmission system to operate beyond transfer limits, the system is said to be under congestion. Congestion management is the process to avoid or relieve the congestion. In a broader sense, congestion management is considered as a systematic approach for scheduling and matching generation and loads in order to reduce congestion.

Besides, with the electricity market deregulation, increasesthe number of unplanned power exchanges due to the competition among utilities and direct contracts concluded between generation companies and consumers. So the problem of overloading is takes place in some transmission lines. Because many of the existing transmission lines could not deal with increasing power demand, the problem of voltage stability and voltage collapse has also become a major concern. Transmission system operator (TSO) is in interest with the control of power flow to have more reliable, secure and efficient. To overcome this problem, FACTS devices are introduced.

FACTS devices can regulate the active and reactive-power control as well as adaptive to voltage magnitude control simultaneously by their fast control characteristics and their continuous compensating capability and so reduce flow of heavily loaded lines and maintain voltages in desired level.

Besides, FACTS devices can improve both transient and small signal stability margins. Controlling the power flows in the network, under normal and abnormal conditions of the network, can help to reduce flows in heavily loaded lines, reduce system power loss, and so improve the stability and performance of the system without generation rescheduling or topological changes in the network. Because of the considerable costs of the FACTS devices, it is so mementos to find out the optimal location for placement of these devices to improve voltage stability margins and enhance network security.

Some of papers use heuristic approaches and intelligent algorithms to find suitable location of FACTS devices. Voltage stability index has been used to find the suitable location of UPFC to improve power system security/stability after evaluating the degree of severity of considered contingencies. This paper presents a novel heuristic method based on GA to find optimal location of multi-type FACTS devices to enhance voltage stability level considering investment cost these devices and power system losses.

Previously used technique for many optimization problems like economic dispatch, optimal power flow, and congestion management, controller optimization and etc. in power system is Genetic Algorithm. Proposed method is tested on IEEE 30 bus system and results are presented.

2. Modeling of TCSC & UPFC

2.1 Modeling of TCSC

For static application like congestion management FACTS devices can be modeled as Power Injection Model [1]. The injection model describes the FACTS devices as a device that injects a certain amount of active and reactive power to a node, so that the FACTS devices are presented as PQ elements. The advantage of power injection model is that it does not destroy the symmetrical characteristic of the admittance matrix and allows efficient and convenient integration of FACTS devices into existing power system analytical tools. During steady state operation, TCSC can be considered as an additional reactance –jxc. The value of xc is adjusted according to control scheme specified. Fig. 1(a) shows a model of transmission line with one TCSC which is connected between bus-i and bus-j.

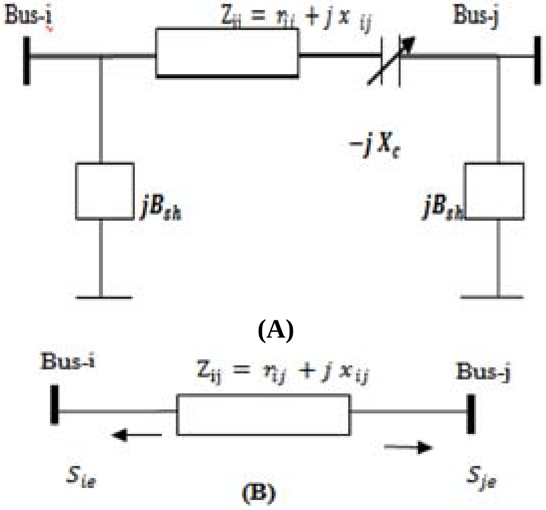

Figure1: (A) TCSC Model; (B) Injection Model of TCSC

The real power injections at bus- i (p_{ic}) and bus- j (p_{jc}) are given in the below equations are given by [2].

$$P_{ic} = V_i^2\Delta G_{ij} - V_iV_j[\Delta G_{ij}\cos\delta_{ij} + \Delta B_{ij}\sin\delta_{ij}] \tag{1}$$

$$P_{jc} = V_j^2\Delta G_{ij} - V_iV_j[\Delta G_{ij}\cos\delta_{ij} - \Delta B_{ij}\sin\delta_{ij}] \tag{2}$$

Similarly, the reactive power injections at bus- i (Qic) and bus- j (Qjc) are given by below equations.

$$Q_{ic} = -V_i^2\Delta B_{ij} - V_iV_j[\Delta G_{ij}\sin\delta_{ij} - \Delta B_{ij}\cos\delta_{ij}] \tag{3}$$

$$Q_{jc} = -V_j^2\Delta B_{ij} - V_iV_j[\Delta G_{ij}\sin\delta_{ij} + \Delta B_{ij}\cos\delta_{ij}] \tag{4}$$

Where: $$\Delta G_{ij} = \frac{x_c r_{ij}(x_c - 2x_{ij})}{(r_{ij}^2 + x_{ij}^2)(r_{ij}^2 + (x_{ij} - x_c)^2)} \tag{5}$$

$$\Delta B_{ij} = \frac{-x_c(r_{ij}^2 - x_{ij}^2 + x_c x_{ij})}{(r_{ij}^2 + x_{ij}^2)(r_{ij}^2 + (x_{ij} - x_c)^2)} \tag{6}$$

Where ΔG_{ij} and ΔB_{ij} are the change in conductance and change in susceptance of the line i-j.

2.2 Modeling of UPFC

The UPFC, which was first proposed by Gyugiin1991[3], consists of shunt (exciting) and series (boosting) transformers as shown in Fig2. Both transformers are connected by two-gate turn off (GTO) converters and a DC circuit represented by the capacitor. Converter 1 is primarily used to provide the real power demand of converter 2 at the common DC link terminal from the AC power system.

Converter 1 can also generate or absorb reactive power at its AC terminal, which is independent of the active power transfer to (or from) the DC terminal. Therefore with proper control, it can also fulfill the function of an independent advanced static VAR compensator providing reactive power compensation for the transmission line and thus executing indirect voltage regulation at the input terminal of the UPFC. Converter 2 is used to generate a voltage source at the fundamental frequency with variable amplitude ($0 \le VT \le VT$max) and phase angle ($0 \le \phi_T \le 2\pi$), which is added to the AC transmission line by the series connected boosting transformer. The inverter output Voltage injected in series with line can be used for direct voltage control, series compensation, phase shifter and their combinations. This voltage source can internally generate or absorb all the reactive power required by the different type of controls applied and transfers active power at its DC terminal.

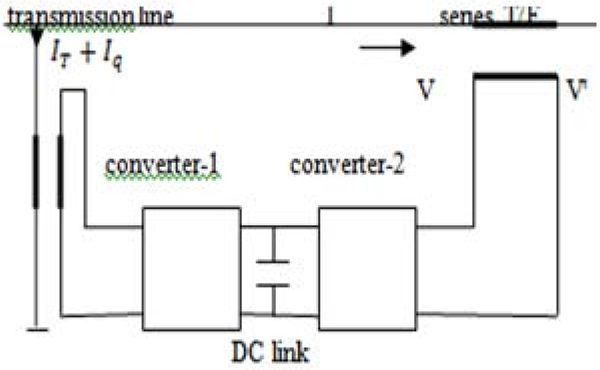

Figure 2: The UPFC basic Circuit Arrangement [3]

With these features, UPFC is probably the most powerful and versatile FACTS device which combines the properties of TCSC, TCPAR and SVC. It is only FACTS device having the unique ability to simultaneously control all three parameters of power flow, voltage, line impedance and phase angle. Therefore, when the UPFC concept was developed in 1991, it was recognized as the most suitable and innovative FACTS device.

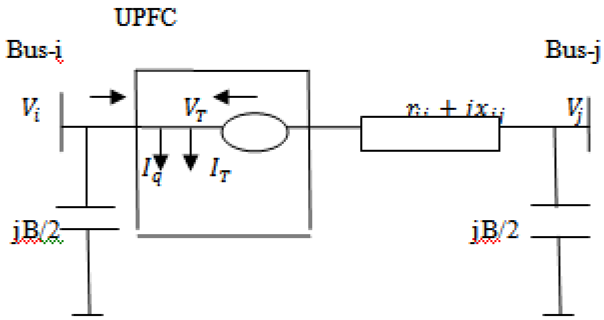

Figure3: The UPFC Placed Between Bus-i and Bus-j

3. Methodology

3.1 Voltage Stability Index

$$L_j = \left| 1 - \sum_{i=1}^{g} F_{ji} \frac{V_i}{V_j} \right| \qquad (7)$$

Where $j = g+1$, n and…,all the terms inside the sigma on the right-hand side of (7) are complex quantities. The complex values of *Fij* are obtained from the *Y*-bus matrix of power system. For a given operating condition:

$$\begin{bmatrix} I_G \\ I_L \end{bmatrix} = \begin{bmatrix} Y_{GG} & Y_{GL} \\ Y_{LG} & Y_{LL} \end{bmatrix} \begin{bmatrix} V_G \\ V_L \end{bmatrix} \qquad (8)$$

Where *IG*, *IL*, and *VG*, *VL*, represent complex current and voltage vectors at the generator nodes and load nodes. [*YGG*], [*YGL*], *YLL*…], and [*YlG*] are corresponding partitioned portions of the *Y*-bus matrix. Rearranging (8),

For stability, the index *Lj* must not be more than one for any of the nodes *j*. Hence, the global index *L* demon-strating the stability of the complete sub-system is given by *L*= maximum of *Lj* for all *j* (load buses). An *L*-index value far away from 1 and close to 0 indicates improved voltage stability. For an unloaded system with genera-tor/load buses voltages, the *L* for load buses are close to zero, indicating that the system has maximum voltage stability margin. For a given network, with the increase in load/generation, the voltage magnitude and angles change near maximum-power-transfer condition and the propensity of voltage-stability is to be close to unity, indicating that the system is close to voltage collapse.

4. Bacterial Foraging Optimization

In the bacterial foraging process, four motile behaviors (chemotaxis, swarming, reproduction, and elimination and dispersal) are mimicked.

i) **Chemotaxis**:
This process simulates the movement of an *E.coli* cell through swimming and tumbling via flagella. Biologically an *E.coli* bacterium can move in two different ways. It can swimfor a period of time in the same direction or it may tumble, and alternate between these two modes of operation for the entire lifetime. Suppose (*j*, *k*, *l*) *i* q represents *i*-th bacterium at *j*th chemotactic, *k*-th reproductive and *l*-th elimination-dispersal step. *C*(*i*) is the size of the step taken in the random direction specified by the tumble (run length unit). Then in computational chemotaxis the movement of the bacterium may be represented by whereD indicates a vector in the random direction whose elements lie in [-1, 1].

ii) Swarming
An interesting group behavior has been observed for several motile species of bacteria including *E.coli* and *S.typhimurium*, where intricate and stable spatio-temporal patterns(swarms) are formed in semisolid nutrient medium. A group of *E.coli* cells arrange themselves in a traveling ring by moving up the nutrient gradient when placed amidst a semisolid matrix with a single nutrient chemo-effecter. The cells when stimulated by a high level of *succinate*, release an attractant *aspertate*, which helps them to aggregate into groups and thus move as concentric patterns of swarms with high bacterial density. The cell-to-cell signaling in *E. coli* swarm may be represented by the following function.

$$J_{cc}(\theta, P(j,k,l)) = \sum_{i=1}^{S} J_{cc}(\theta, \theta^i(j,k,l))$$

$$= \sum_{i=1}^{S}[-d_{\text{attractant}} \exp(-w_{\text{attractant}} \sum_{m=1}^{p} (\theta_m - \theta_m^i)^2)] + \sum_{i=1}^{S}[h_{\text{repellant}} \exp(-w_{\text{repellant}} \sum_{m=1}^{p} (\theta_m - \theta_m^i)^2)]$$

where *J* (, *P*(*j*, *k*, *l*)) *cc* q is the objective function value to be added to the actual objective function (to be minimized) to present a time varying objective function, *S* is the total number of bacteria, *p* is the number of variables to be optimized, which are present in each bacterium.

iii) Reproduction
The least healthy bacteria eventually die while each of the healthier bacteria (those yielding lower value of the objective function) asexually split into two bacteria, which are then placed in the same location. This keeps the swarm size constant.

iv) Elimination and Dispersal
Gradual or sudden changes in the local environment where a bacterium population lives may occur due to various reasons e.g. a significant local rise of temperature may kill a group of bacteria that are currently in a region with a high concentration

of nutrient gradients. Events can take place in such a fashion that all the bacteria in a region are killed or a group is dispersed into a new location. To simulate this phenomenon in BFOA some bacteria are liquidated at random with a very small probability while the new replacements are randomly initialized over the search space.

v) FACTS devices Cost Function

Using Siemens AG Database [33], cost function for SVC, TCSC and UPFC are developed as follows:

$$\text{TCSC: } C_{TCSC} = 0.0015s^2 - 0.713s + 153.75 \quad (12)$$

$$\text{SVC: } C_{SVC} = 0.0003s^2 - 0.3051s + 127.38 \quad (13)$$

$$\text{UPFC: } C_{UPFC} = 0.0003s^2 - 0.2691s + 188.22 \quad (14)$$

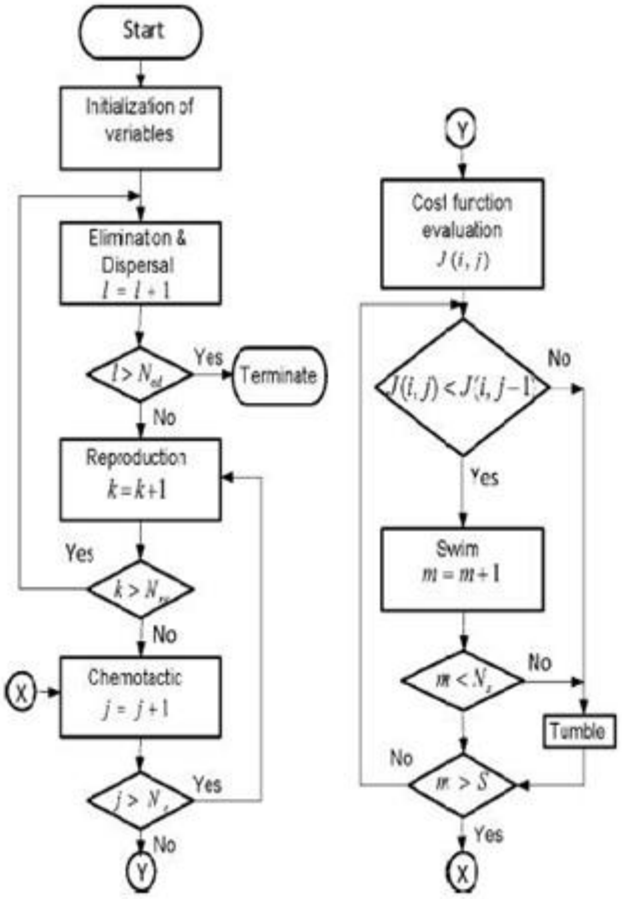

Figure 4: Flowchart of the Bacterial Foraging Algorithm

5. Simulation Results

Simulation studies were done for different cases in IEEE 30 bus power system. Five different scenarios are considered
Case1: power system normal operation (without FACTS devices installation).
Case 2: one TCSC is installed
Case 3: one UPFC is installed

The first Case is normal operation of network without installing any device. In second, third and fourthCase just installation of one device is considered. Each device is placed an optimal location obtained by BFO introduced in Chapter IV.

Table 1: Simulation Results of Different Cases for IEEE 30-Bus System

Case	Losses	Location	Voltage Stability
1	7.56	-	9.5
2	7.24	4-12	5.1
3	7.12	6-28	4.32

Table 2: Comparison of TCSC and UPFC:

S. No	TCSC		UPFC	
	Losses	Voltage stability	Losses	Voltage stability
1	**7.24**	5.1	**7.12**	4.32

6. Conclusion

In this paper a novel approach for optimal placement of FACTS devices based on Bacterial Foraging Optimization (BFO) algorithm is presented. The simulations are carried out successfully on the IEEE 30-bus system. The optimization technique results of TCSC are compared with the results of UPFC. The comparison confirmed that the UPFC results reduces power system losses and improve voltage stability than TCSC. IEEE 30 bus test system for different Cases shows that the placement of FACTS devices leads to improve in voltage stability margin of power system and reduce losses.

References

[1] Nabivi SMHO, Nazanin AH, Somayeh H (2010).“Social Welfare Maximization by optimal locating and sizing of TCSC for Congestion Management in Deregulated Power market”.IJCA, 6(6).
[2] Rajalakshmi L, Suganyadevi MV, Parameswari S (2011).” Congestion Management in Deregulated Power system by Locating Series FACTS devices”. IJCA 13(8)
[3] K.S. Verma, S.N. Singh, H.O. Gupta (2001). “Location Of unifed power flow controller for congestion management”. ELSEVIER Electrical Power System Research 58 (2001) 89-96
[4] Vijay KK (2011). “Optimal Location of FACTS Devices for Congestion Management in Deregulated Power System”. IJCA, 16(6).
[5] F.D. Galiana, K. Almeida, M. Toussaint, J. Griffin, and D.Atanackovic:AssessmImpact of FACTS Devices on Power SystemPerformance‖,*IEEETrans.Power Systems*, Vol. 11, No. 4, Nov 1996.
[6] M. Noroozian, L. Angquist, M. Ghandhari, G. Anderson, "Improv-ing Power System Dynamics by Series-connected FACTS De-vices," *IEEE Trans. onPower Delivery*, Vol. 12, No.4, October 1997.
[7] R. Billinton, M. Fotuhi-Firuzabad, O.S. Faried, S. Aboreshaid, "Impact of Unified Power Flow Controllers on Power System Reliability," *IEEE Trans.on Power* Systems, Vo1.15, No.1, February 2000.
[8] Smt.Ushasurendra andS.S.Parathasarthy(2012). “Congestion management in deregulated power sector

using fuzzy based optimal location technique for series flexible alternative current transmission system (FACTS) device". Research vol.4(1),JEEER

[9] Acharya N, Nadarajah M (2007). "A Proposal for investment recovery of FACTS devices in deregulated Electricity Markets". Electrical Power System. Res. 77;695-703.

[10] Nabivi SMH, Kamran K, Aidin S, Saeid N (2011). "Optimal Locating and Sizing of SSSC using GA in Deregulated power market". IJCA, 22(4).

[11] www.ee.washington.edu