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A NEW EVALUTIONARY ALGORITHMS USED FOR OPTIMAL LOCATION OF UPFC ON POWER SYSTEM

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ABSTRACT

Recent trends in power systems are mostly undergoing research in the area of widespread failures. With the increase in power demand, operation and planning of large interconnected power system are becoming more complex, so power system will become less secure and stable. Operating environment, conventional planning and operating methods can leave power system exposed to instabilities. Voltage stability is one of the phenomena which have result in a major blackout. Moreover, with the fast development of restructuring, the problem of voltage stability has become a major concern in deregulated power systems. FACTS controllers narrow the gap between the no controlled and the controlled power system mode of operation, by providing additional degrees of freedom to control power flows and voltages at key locations of the network because of their flexibility and fast control characteristics. Placement of these devices in suitable location can lead to control in line flow and maintain bus voltages in desired level and so improve voltage stability margins. This paper presents a GA and PSO analysis based allocation algorithm for Unified Power Flow Controller (UPFC) considering Cost function of UPFC device, Voltage stability indices(VSI) for optimal placement, Improvement of voltage profile and Reduction of power system losses. Proposed algorithm is tested on a IEEE- 5 bus and IEEE-30 bus test power system for optimal allocation of UPFC device and results are presented.

Keywords: *Voltage stability index(VSI), Unified Power Flow Controller (UPFC), Genetic Algorithm (GA), Particle Swarm Optimization (PSO)*

1.0 INTRODUCTION

The FLEXIBLE AC transmission systems (FACTS) initiative was originally launched to solve the emerging problems in the late 1980s due to restrictions on the transmission line construction and to facilitate the growing power export/import and wheeling transactions among the utilities. FACTS devices can enhance transmission system control and increase line loading in some cases all the way up to thermal limits thereby without compromising reliability. These devices can be an alternative to reduce the flows in heavily loaded lines, resulting in an increased loadability, low system loss, improved stability of the network, reduced cost of production and fulfilled contracture requirement by controlling the power flows in the network, reduce cost of production and fulfilled contracture requirement by controlling the power flows in the network. These capabilities allow transmission system owners and operators to maximize asset utilization and execute additional bulk transfer with immediate bottom-line benefits. FACTS devices provide new control facilities, both in steady state power control and dynamic stability control [1].

Unified power flow controller (UPFC) is the most comprehensive multivariable flexible ac transmission system (FACTS) controller. Simultaneous control of multiple power system variables with UPFC posses enormous difficulties. In addition, the complexity of the UPFC control increases due to the fact that the controlled and the control variables interact with each other. UPFC which consists of a series and a shunt converter connected by a common dc link capacitor can simultaneously perform the function of flow control in addition to UPFC bus voltage/shunt reactive power control [2] - [5].

Effect of FACTS devices on power system security, reliability and loadability has been studied according to proper control objectives. Some of papers have been tried to find suitable location for FACTS devices to improve power security and loadability. Voltage stability index has been to find the suitable location of UPFC to improve power system security after evaluating the degree of severity of considered contingencies [6] and [7]. This paper present a novel heuristic method based on GA and PSO to find optimal location of UPFC to enhance voltage stability level considering investment cost these device and power system losses.

Genetic Algorithms (GA) and Particle Swarm Optimization (PSO) is previously used for many optimization problems like optimal power flow, economic dispatch and controller optimization, congestion management and etc in power systems [8] - [11] . Proposed method is tested on a IEEE-5 bus and IEEE-30 bus test system and results are presented.

2.0 UNIFIED POWER FLOW CONTROLLER

A schematic representation of a UPFC is shown in fig.(1). The output voltage of the series converter is added to the AC terminal voltage V_0 *via* the series connected coupling transformer. The injected voltage V_{cR} acts as an AC series voltage source, changing the effective sending-end voltage as seen from node m. The product of the transmission line current I_m and the series voltage source V_{cR}, determines the active and reactive power exchanged between the series converter and the AC system.

The real power demanded by the series converter is supplied from the AC power system by the shunt converter *via* the common DC link. The shunt converter is able to generate or absorb controllable reactive power in both operating modes (i.e. rectifier and inverter). The independently controlled shunt reactive transmission line real/reactive power compensation can be used to maintain the shunt converter terminal AC voltage magnitude at a specified value.

2.1 UPFC Equivalent Circuit

The UPFC equivalent circuit shown in Fig. 2 is used to device the steady-state model. The equivalent circuit consists of two ideal voltage sources representing the fundamental Fourier series component of the switched voltage waveforms at the AC converter terminals. The ideal voltage sources are:

$$V_{vR} = V_{vR}\ (cos\theta_{vR} + sin\theta_{vR}) \qquad (1)$$

$$V_{cR} = V_{cR}\ (cos\theta_{cR} + sin\theta_{cR}) \qquad (2)$$

Where V_{vR} and θ_{vR} are the controllable magnitude ($V_{vRmin} \leq V_{vR} \leq V_{vRmax}$) and angle ($0 \leq \theta_{vR}\ 2\pi$) of the voltage source representing the shunt converter. The magnitude V_{cR} and angle θ_{cR} of the voltage sources of the series converter are controlled between limits ($V_{cRmin} \leq V_{cR} \leq V_{cRmax}$) and ($0 \leq \theta_{cR} \leq 2\pi$), respectively.

2.2 UPFC power and Jacobin equations

The general transfer admittance matrix for the UPFC is obtained by applying Kirchhoff current and voltage laws to the electric circuit shown in Fig. 2 and given by

$$\begin{bmatrix} I_k \\ I_m \end{bmatrix} = \begin{bmatrix} Y_{kk} & Y_{km} & Y_{km} & Y_{vR} \\ Y_{mk} & Y_{mm} & Y_{mm} & 0 \end{bmatrix} \begin{bmatrix} V_k \\ V_m \\ V_{cR} \\ V_{vR} \end{bmatrix} \qquad (3)$$

Where

$$y_{cR} = \frac{1}{z_{cR}} = \frac{1}{R_{cR} + j\,X_{cR}} \qquad (4)$$

$$y_{vR} = \frac{1}{z_{vR}} = \frac{1}{R_{vR} + j\,X_{vR}} \qquad (5)$$

$$Y_{kk} = G_{kk} + j\,B_{kk} = y_{cR} + y_{vR} \qquad (6)$$

$$Y_{mm} = G_{mm} + jB_{mm} = y_{cR} \tag{7}$$

$$Y_{km} = Y_{mk} = G_{km} + jB_{km} = -y_{cR} \tag{8}$$

$$Y_{vR} = G_{vR} + jB_{vR} = -y_{vR} \tag{9}$$

Assuming a loss-free converter operation, the UPFC neither absorbs nor injects active power with respect to the AC system. The active power demanded by the series converter is supplied from the AC power system by the shunt converter via the common DC link. The dc link voltage, V_{dc}, remains constant. Hence, the active power supplied to the shunt converter P_{vR}, must satisfy the active power demanded by the series converter, $P_{cR,}$ i.e.

$$P_{cR} + P_{vR} = 0 \tag{10}$$

Where

$$\begin{aligned} P_{cR} &= V_{cR}^2 G_{mm} \\ &+ V_{cR}V_k\left(G_{km}\cos\begin{pmatrix}\theta_{cR}\\ -\theta_k\end{pmatrix} B_{km}\sin(\theta_{cR} - \theta_k)\right) V_m(G_{mm}\cos(\theta_{cR} - \theta_m) \\ &+ B_{mm}\sin(\theta_{cR}-\theta_{vR})) \end{aligned} \tag{11}$$

$$\begin{aligned} P_{vR} = -V_{vR}^2 G_{vR} + V_{vR}V_k(G_{vR}\cos(\theta_{vR} - \theta_k) \\ + B_{vR}\sin(\theta_{vR} - \theta_k)) \end{aligned} \tag{12}$$

Also, by assuming a loss-free coupling transformer operation, the active power at node k, P_k, should match the active power at node m, P_m. Then, an alternative equation which satisfies the constant V_{dc} , constant is

$$P_k + P_m = 0 \tag{13}$$

The UPFC linearized power equation are combined with the linearized system of equation corresponding to the rest of the network,

$$[g(X)] = [J][\Delta X] \tag{14}$$

Where

$$[g(X)] = [\Delta P_k \ \ \Delta P_m \ \ \Delta Q_k \ \ \Delta Q_m \ \Delta P_{mk} \ \ \Delta Q_{mk} \ \ P_{cR} + P_{vR}]^T \tag{15}$$

The superscript T indicates transposition. $[\Delta X]$ is the solution vector and $[J]$ is the Jacobian matrix. If both nodes, *k and m*, are PQ-type and the UPFC is controlling active power, flowing from *m to k*, and reactive power injected at node *m*, the solution vector and the Jacobin matrix are defined as shown in (16) and (17) . Assuming the power control mentioned above and that the UPFC controls voltage magnitude at the AC system shunt converter terminal *(node k)*, the solution vector and the Jacobian matrix are shown in (18) and (19).

$$[\Delta X] = \left[\Delta\theta_k \ \ \theta_m \ \frac{\Delta V_k}{V_k} \ \frac{\Delta V_m}{V_m} \ \ \Delta\theta_{cR} \ \frac{\Delta V_{cR}}{V_{cR}} \quad \Delta\theta_{vR}\right]^T \tag{16}$$

$$[J] = \begin{bmatrix} H_{kk} & H_{km} & N_{kk} & N_{km} & H_{kcR} & N_{kcR} & H_{cvR} \\ H_{mk} & H_{mm} & N_{mk} & N_{mm} & H_{mvR} & N_{mvR} & 0 \\ J_{kk} & J_{km} & L_{kk} & L_{km} & J_{kcR} & L_{kcR} & J_{kvR} \\ J_{mk} & J_{mm} & L_{mk} & L_{mm} & J_{mcR} & L_{mcR} & 0 \\ H_{mk} & H_{mm} & N_{mk} & N_{mm} & H_{mcR} & N_{mcR} & 0 \\ J_{mk} & J_{mm} & L_{mk} & L_{mm} & J_{mcR} & L_{mcR} & 0 \\ H_{cRk} + H_{vRk} & H_{cRm} & H_{cRk} + N_{vRk} & N_{cRm} & H_{cRcR} & N_{cRcR} & H_{vRvR} \end{bmatrix} \tag{17}$$

$$[\Delta X] = \left[\Delta\theta_k \ \ \Delta\theta_m \ \frac{\Delta V_{vR}}{V_{vR}} \ \frac{\Delta V_m}{V_m} \ \ \Delta\theta_{cR} \ \frac{\Delta V_{cR}}{V_{cR}} \ \ \Delta\theta_{vR}\right]^T \tag{18}$$

$$[J] = \begin{bmatrix} H_{kk} & H_{km} & N_{kvR} & N_{km} & H_{kcR} & N_{kcR} & H_{cvR} \\ H_{mk} & H_{mm} & 0 & N_{mm} & H_{mvR} & N_{mvR} & 0 \\ J_{kk} & J_{km} & L_{kvR} & L_{km} & J_{kcR} & L_{kcR} & J_{kvR} \\ J_{mk} & J_{mm} & 0 & L_{mm} & J_{mcR} & L_{mcR} & 0 \\ H_{mk} & H_{mm} & 0 & N_{mm} & H_{mcR} & N_{mcR} & 0 \\ J_{mk} & J_{mm} & 0 & L_{mm} & J_{mcR} & L_{mcR} & 0 \\ H_{cRk} + H_{vRk} & H_{cRm} & N_{cRk} + N_{vRk} & N_{cRm} & H_{cRcR} & N_{cRcR} & H_{vRvR} \end{bmatrix} \tag{19}$$

2.3 UPFC Initial Conditions

Good starting conditions are mandatory in any iterative process. The solution of the load flow equation does not differ in this respect. Engineering judgment indicates that for the simple case in which no controlled buses or branches are respect, 1 p.u. voltage magnitude for all PQ buses and 0 voltage angle for all buses provide suitable starting conditions.

2.3.1. Series source initial Conditions

For specified nodal powers at node m, P_{mref} and Q_{mref}, the solutions of the active and reactive power equations at this node give,

$$\theta_{cR}^0 = arctan\left({P_{mref}}/{C_1}\right) \tag{20}$$

$$V_{cR}^0 = \left({X_{cR}}/{V_m^0}\right)\sqrt{(P_{mref}^2 + C_1^2)} \tag{21}$$

Where

$$C_1 = Q_{mref} - \frac{V_m^0}{X_{cR}}\left(V_m^0 - V_k^0\right) \;\; if \;\; V_m^0 \neq V_k^0 \tag{22}$$

$$C_1 = Q_{mref} \quad if \; V_m^0 = V_k^0 \tag{23}$$

X_{cR} is the inductive reactance of the series source and superscript 0 indicates initial value.

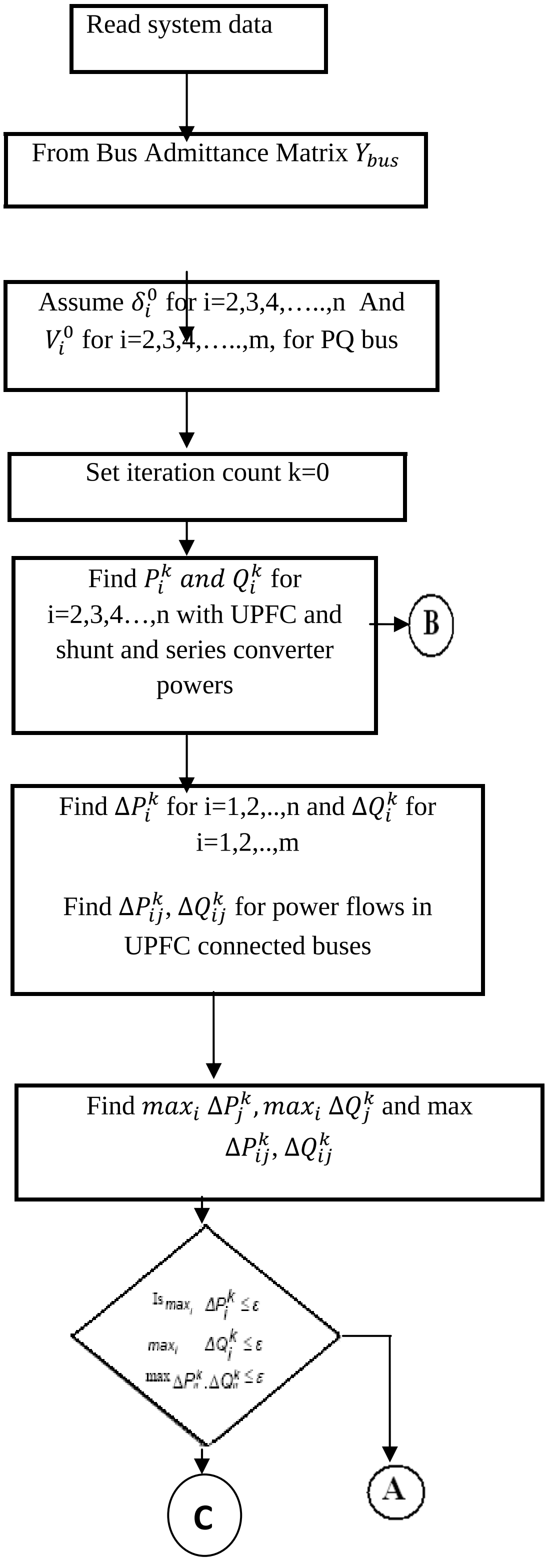
2.3.2. Shunt source initial Conditions

An equation for initializing the shunt source angle can be obtained by solving (11) and it is given by,

$$\theta_{vR} = -arcsin\left(\frac{(V_k^0 - V_m^0)V_{cR}^0 X_{cR} \sin(\theta_{cR}^0)}{V_{vR}^0 V_k^0 X_{cR}}\right) \tag{24}$$

Where X_{cR} is the inductive reactance of the shunt source. When the shunt converter is acting as a voltage regulator, the voltage magnitude of the shunt source is initialized at the target voltage value and then it is updated at each iteration. Otherwise, if the shunt converter is not acting as a voltage regulator, the voltage magnitude of the shunt source is kept at a fixed value within prescribed limits, ($V_{vRmin} \leq V_{vR} \leq V_{vRmax}$), for the whole iterative process.

2.2. FLOW CHART FOR LOADFLOW NR-WITH UPFC:



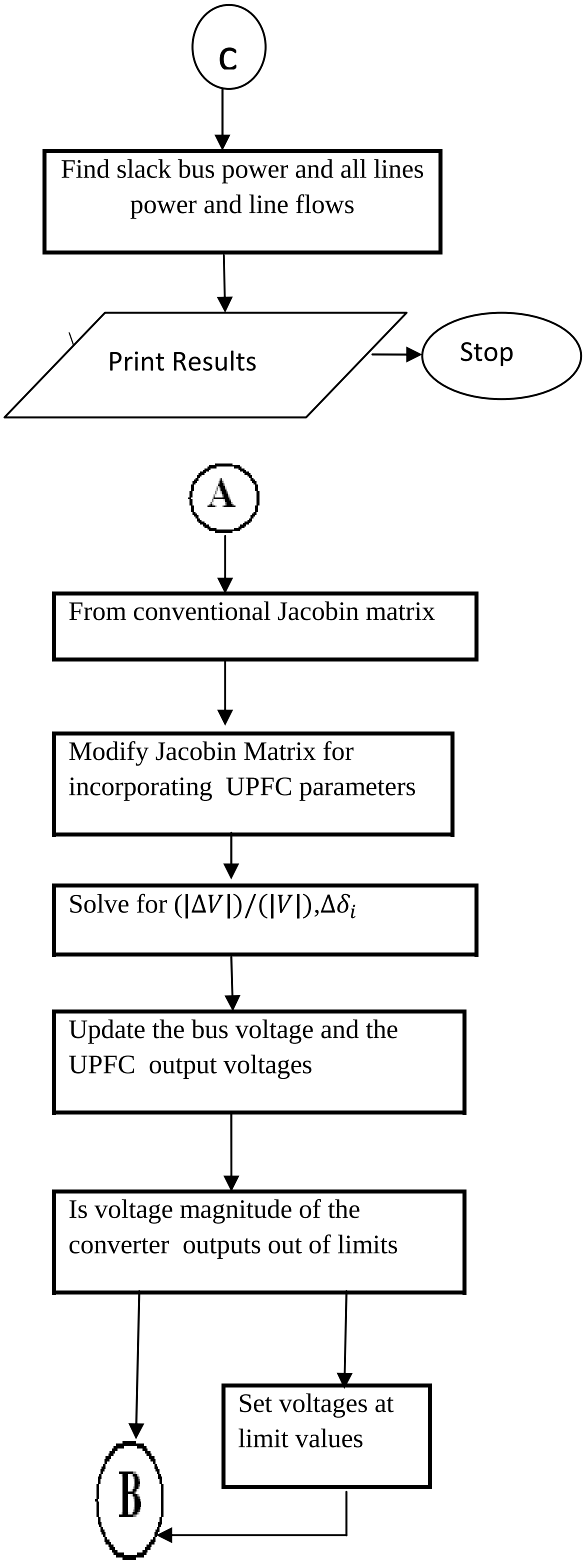


Fig.3 Flow chart for load flow NR-method with UPFC

3.0 VOLTAGE STABILITY INDEX COMPUTATION

Consider the power network where n is the total number of buses with 1,2,………g generator buses, and g+1,……….,n remaining (n-g) buses. In this paper we have tested on the IEEE 5 bus system for a given operating condition, using the load flow results, the Voltage stability index ‘**L**’ can be calculated as

$$L_j = \left|1 - \sum_{i=1}^{g} F_{ji} \frac{V_i}{V_j}\right| \qquad (25)$$

where j=g+1… n and all the terms inside the sigma on the right hand side of (1) are complex quantities. The complex values of F_{ij} are obtained from the Y_{bus} matrix of power system. For a given operating condition:

$$\begin{bmatrix} V_L \\ I_G \end{bmatrix} = \begin{bmatrix} Z_{LL} & F_{LG} \\ K_{GL} & Y_{GG} \end{bmatrix} \begin{bmatrix} I_L \\ V_G \end{bmatrix} \qquad (26)$$

where I_G ,I_L , and V_G , V_L , represent complex current and voltage vectors at the generator nodes and load nodes.

$$[I_G] = [I_1, \ldots \ldots \ldots \ldots \ldots \ldots \ldots . I_n]^t$$

$$\textit{injected voltage of generator buses}$$

$$[I_L] = [I_{g+1}, \ldots \ldots \ldots \ldots \ldots \ldots . I_n]^t$$

$$\textit{injected currents of load buses}$$

$$[V_G] = [V_1, \ldots \ldots \ldots \ldots \ldots \ldots \ldots V_g]^t$$

$$\textit{complex generator bus voltages}$$

$$[V_N] = [V_{g+1}, \ldots \ldots \ldots \ldots \ldots V_n]^t$$

$$\textit{complex load bus voltages}$$

$[Y_{GG}], \ldots \ldots \ldots [Y_{GL}], \ldots \ldots, [Y_{LL}] \ldots \ldots and. [Y_{LG}]$ are corresponding partitioned portions of the Y_{bus} matrix

$$\begin{bmatrix} I_G \\ I_L \end{bmatrix} = \begin{bmatrix} Y_{GG} & Y_{GL} \\ Y_{LG} & Y_{LL} \end{bmatrix} \begin{bmatrix} V_G \\ V_L \end{bmatrix} \qquad (27)$$

This analysis will be carried out only for the load buses; hence the index that to be obtained for load buses only. For stability the index L must not be more than one for any of the nodes j. The global index for stability of the given power system is defined to be

L= maximum of L_j for all j (load buses).

The index far away from 1 and close to 0 indicates voltage stability. The L index will give the scalar number to each load bus. Among the various indices for voltage stability and voltage collapse prediction (i.e. far away from 1 and close to 1 or >1 respectively), the L index will give more accurate results. The L indices for given loads conditions are calculated for all load buses and the maximum of the L indices gives the proximity of the system to voltage collapse.

4.0 PROPOSED GENETIC ALGORITHM (GA) AND PARTICLE SWARM OPTIMIZATION (PSO)

4.1 Overview of GA

Genetic Algorithm (GA) is one of the most famous meta-heuristic optimization algorithms which is based on natural evolution and population. Genetics which is usually used to reach to near global optimum solution. In each iteration of GA (referred as generation), a new set of string (i.e. chromosomes) with improved fitness is produced using genetic operators (i.e. selection, crossover and mutation).

4.1.1 Selection Operator

Key idea: give preference to better individuals, allowing them to pass on their genes to the next generation. The goodness of each individual depends on its fitness. Fitness may be determined by an objective function or by a subjective judgement.

4.1.2 Crossover Operator

Prime distinguished factor of GA from other optimization techniques. Two individuals are chosen from the population using the selection operator .A crossover site along the bit strings is randomly chosen. The values of the two strings are exchanged up to this point. If S1=000000 and S2=111111 and the crossover point is 2 then S1'=110000 and S2'=001111. The two new offspring created from this mating are put into the next generation of the population .By recombining portions of good individuals, this process is likely to create even better individuals

4.1.3 Mutation Operator

With some low probability, a portion of the new individuals will have some of their bits flipped. Its purpose is to maintain diversity within the population and inhibit premature convergence. Mutation alone induces a random walk through the search space; Mutation and selection (without crossover) create a parallel, noise-tolerant, hill-climbing algorithm.

4.2 Overview of PSO

PSO is initialized with a group of random particles and the searches for optima by updating generations. In every iteration each particle is updated by following “two best” values. The first one is the best solution (fitness value) it has achieved so far. This is called Pbest. Another value that is tracked by the particle swarm optimizer is the best value obtained so far by any particle in the population. This best value is the global best called Gbest. After finding the best values the particles updated its velocity and position with the following equation:

$$V_i^{k+1} = WV_i^k + C_1 * rand1 * \left(P_{besti} - S_i^k\right)$$
$$+ C_2 * rand2 * \left(G_{besti} - S_i^k\right) \quad (28)$$

$$S_i^{k+1} = S_i^k + V_i^{k+1} \quad (29)$$

$$W = W_{max} - \left(\frac{W_{max} - W_{min}}{iter_{max}}\right) * iter \quad (30)$$

Where

V_i^k =Velocity of agent *i* at k^{th} iteration

V_i^{k+1} = Velocity of agent i at $(k+1)^{th}$ iteration

W = The inertia weight

$C_1 = C_2$ = Weighting factor (0 to 4)

S_i^k = Current position of agent at k^{th} iteration

S_i^{k+1} =Current position of agent at $(k+1)^{th}$ iteration

$iter_{max}$ = Maximum iteration number

$iter$ = Current iteration number

P_{besti} = P_{best} of agent i

G_{besti} = G_{best} of the group

W_{max} = Initial value of inertia weight = 0.9

W_{min} = Initial value of inertia weight = 0.2

The velocity of the particle is modified by using (28) and position is modified by using (29). The inertia weight factor is modified according to (30) to enable quick convergence.

4.3 UPFC Cost and Fitness Function

Using Siemens AG Database [12] and [13], cost function for UPFC is developed as follows:

$$C_{UPFC} = 0.0003S^2 - 0.2691S + 188.22\ US\$/kVAR \quad (31)$$

Where, S is operating range of UPFC in MVAR

$$S = |Q_2 - Q_1|$$

Q_1 −MVAR flow through the branch before placing FACTS device.

Q_2 −MVAR flow through the branch after placing FACTS device.

The goal of optimization algorithm is to place FACTS devices in order to enhance voltage stability margin of power system considering cost function FACTS devices. So these devices should be place to prevent congestion in transmission lines and transformer and matain bus voltages close to their reference. Voltage stability index introduced in 3^{rd} chapter, were used in objective function considering cost function of UPFC and power system losses. Fitness function is expressed as below:

$$f(x) = a_1\, max(L_j) + a_2\,(Total\ Invesment\ Cost) + a_3(Losses) \quad (32)$$

$$Fitness\ function = \frac{1}{f(x)} \quad (33)$$

The coefficient a_1 to a_3 are optimized by trial and error to 2.78, 0.1 and 2.05 respectively.

5.0 RESULTS AND DISCUSSION

5.1 IEEE 5-bus test system

The solution for optimal location of FACTS devices to minimize the installation cost of FACTS devices and overloads for IEEE 5-bus test system were obtained and discussed in this section.

Voltage stability indices are calculated for the IEEE 5 bus system without any FACTS devices. By considering the Voltage stability index (Lj) value, it is observed that bus Elm is more sensitive towards system security. Therefore bus Elm is more sutiable location for UPFC to improve power system security/stability. An additional node is termed as node Elmfa, is used to connect the UPFC. The modified original network to include a UPFC between nodes Elm and Elmfa as shown in fig.5.

The UPFC is used to maintain active and reactive powers leaving the UPFC, towards Main at 65.6 MW and 5.17 MVARs, respectively. Moreover, the UPFC's shunt converter is set to regulate Elm's nodal voltage magnitude at 1p.u. The initial conditions of the UPFC voltage sources are computed by using equation given in section 2.3, V_{cR} =0.008352 p.u, $\theta_{cR} = -51.758^0$, $V_{vR} = 1$ p.u and $\theta_{vR} = 0^0$. The source impedances have values of $X_{cR} = X_{vR} = 0.1$p.u. The UPFC upheld its target values. The final nodal complex voltages are given in Table A.

Table A: Conventional NR-method without and With UPFC Voltage magnitudes, Phase Angles for IEEE 5-bus test system

Conventional NR-method					
Without UPFC			Without UPFC		
Bus No.	VM (p.u)	VA (p.u)	Bus No.	VM (p.u)	VA (p.u)
1	**1.060**	**0.000**	**1**	**1.060**	**0.000**
2	**1.000**	**-2.061**	**2**	**1.000**	**-2..177**
3	**0.987**	**-4.637**	**3**	**0.997**	**-4.367**
4	**0.984**	**-4.957**	**4**	**0.996**	**-4.590**
5	**0 .972**	**-5.765**	**5**	**1.000**	**-7.346**
--	--	--	6	**1.020**	**-4.053**

5.2 IEEE 30-bus test system

By considering the Voltage stability index (Lj) value, it is observed that 24- bus is more sensitive towards system security. Therefore 24-bus is more sutiable location for UPFC to improve power system security/stability. The orginal network is shown in [12]. Simulation results for Voltage magnitudes and phase angles without UPFC and With UPFC are shown in Table. B, respectively.

Table B: Conventional NR-method without and With UPFC Voltage magnitudes, Phase Angles for IEEE 30-bus test system

Conventional NR-method					
Without UPFC			With UPFC		
Bus No.	VM (p.u)	VA (p.u)	Bus No.	VM (p.u)	VA(p.u)
1	**1.060**	**0.000**	**1**	**1.060**	**0.000**
2	**1.043**	**-5.522**	**2**	**1.043**	**-5.509**
3	**1.024**	**-8.041**	**3**	**1.026**	**-8.060**
4	**1.017**	**-9.173**	**4**	**1.019**	**-9.734**
5	**1.010**	**-14.459**	**5**	**1.010**	**-14.423**
6	**1.008**	**-11.420**	**6**	**1.010**	**-11.418**
7	**1.000**	**-13.188**	**7**	**1.002**	**-13.170**
8	**1.010**	**-12.217**	**8**	**1.010**	**-12.155**
9	**1.011**	**-14.592**	**9**	**1.021**	**-14.751**
10	**0.977**	**-16.322**	**10**	**0.996**	**-16.537**
11	**1.082**	**-14.592**	**11**	**1.082**	**-14.751**
12	**1.019**	**-16.156**	**12**	**1.029**	**-16.189**
13	**1.071**	**-16.156**	**13**	**1.071**	**-16.189**
14	**0.999**	**-17.069**	**14**	**1.013**	**-17.178**
15	**0.990**	**-17.013**	**15**	**1.007**	**-17.308**
16	**0.994**	**-16.510**	**16**	**1.007**	**-16.617**
17	**0.976**	**-16.606**	**17**	**0.994**	**-16.783**
18	**0.973**	**-17.546**	**18**	**0.991**	**-17.786**
19	**0.966**	**-17.651**	**19**	**0.984**	**-17.865**
20	**0.968**	**-17.381**	**20**	**0.986**	**-17.593**

21	**0.963**	**-16.801**	**21**	**0.989**	**-17.220**
22	**0.964**	**-16.775**	**22**	**0.991**	**-17.270**
23	**0.970**	**-17.201**	**23**	**1.000**	**-18.047**
24	**0.951**	**-17.065**	**24**	**1.000**	**-18.668**
25	**0.958**	**-16.842**	**25**	**0.983**	**-15.568**
26	**0.940**	**-17.316**	**26**	**0.964**	**-16.018**
27	**0.972**	**-16.401**	**27**	**0.987**	**-15.423**
28	**1.004**	**-12.056**	**28**	**1.008**	**-11.970**
29	**0.951**	**-17.766**	**29**	**0.967**	**-16.746**
30	**0.939**	**-18.750**	**30**	**0.955**	**-17.698**
-	**-**	**-**	**31**	**0.990**	**-15.360**

The proposed algorithms were implemented to find out the proper setting and installation cost of the UPFC in IEEE-5 bus & IEEE-30 bus test system. Comparisons of two proposed algorithms are shown in Table C and Table D, From Fig. 6-9; it is observed that fitness function is minimized in PSO compare to GA.

Table.C and Table.D shows that PSO is faster than GA from the perspective of time and this is due to the purpose that GA has selection, crossover and mutation operations while PSO doesn't such operations. The simulation studies were carried out on Pentium IV, 1.60 GHz, 1GB RAM in MATLAB 7.1 environment.

Table C: Summary of calculation results by the Proposed Techniques For IEEE-5 bus test system

Aspect	**Conventional NR-method with UPFC**	**Proposed Method**	
		Genetic Algorithm	**Particle Swarm Optimization**
Total loss Without UPFC	**12.395 MVA**	**12.395 MVA**	**12.395 MVA**
Total loss with UPFC	**12.100 MVA**	**12.074 MVA**	**12.070 MVA**
Installation Cost of UPFC	**184.050 US$/ kVAR**	**183.749 US$/ kVAR**	**183.701 US$/ kVAR**
Fitness Value	**44.012**	**43.209**	**43.205**
Elapsed Time		**16.20300 Seconds**	**15.56300 Seconds**

Table D: Summary of calculation results by the Proposed Techniques For IEEE-30 bus test system

Aspect	**Conventional NR-method with UPFC**	**Proposed Method**	
		Genetic Algorithm	**Particle Swarm Optimization**
Total loss Without UPFC	**55.933 MVA**	**55.933 MVA**	**55.933 MVA**
Total loss with UPFC	**53.088 MVA**	**53.081 MVA**	**53.074 MVA**
Installation Cost of UPFC	**188.065 US$/kVAR**	**188.064 US$/kVAR**	**188.058 US$/kVAR**
Fitness Value	**127.817**	**127.803**	**127.790**
Elapsed Time		**134.89100 Seconds**	**62.28200 Seconds**

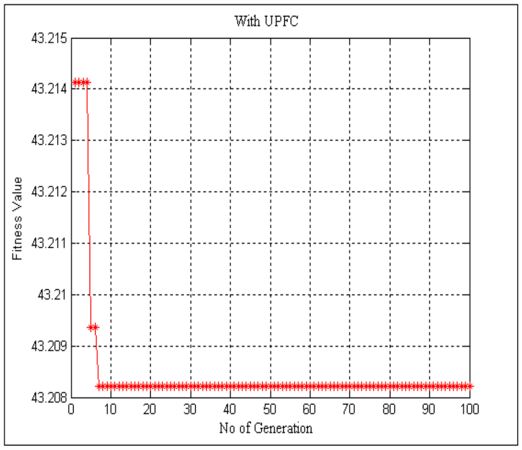


Fig.6 Fitness function minimization by using GA for IEEE-5 bus test system.

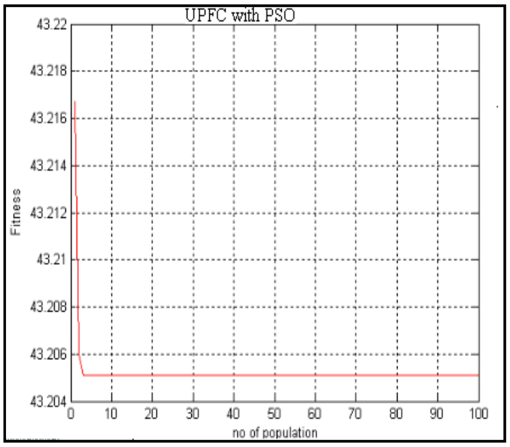


Fig.7 Fitness function minimization by using PSO for IEEE-5 bus test system.

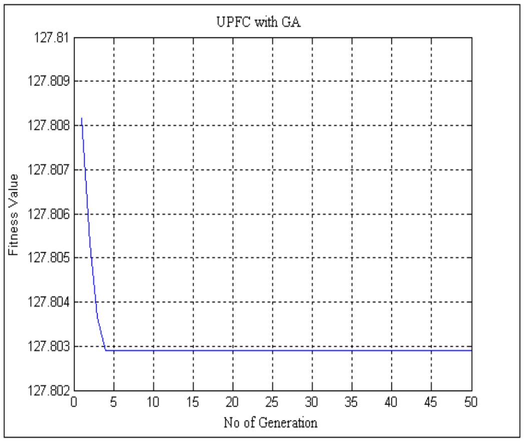


Fig.8 Fitness function minimization by using GA for IEEE-30 bus test system.

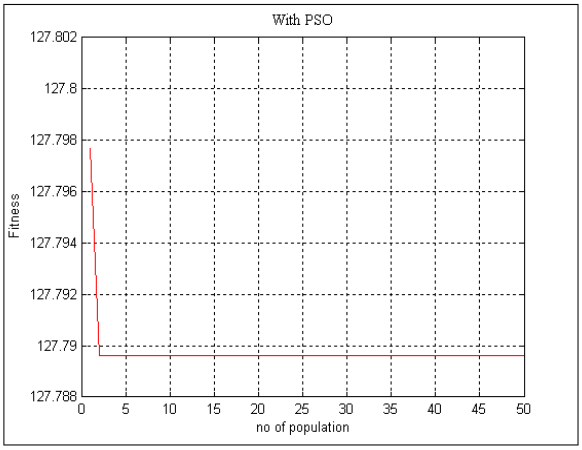


Fig.9 Fitness function minimization by using PSO for IEEE-30 bus test system.

6.0 CONCLUSION

The optimal installation of FACTS devices plays a key role in achieving the proper functionality of these devices. However, this paper made an attempt to find out the optimal location and parameters setting of UPFC device to minimize power loss and improve voltage stability of power system using PSO and GA techniques. With the above proposed algorithm it is possible for utility to place UPFC in transmission line such that proper power planning and operation can be achieved with minimum system losses.

REFERENCES

[1]. L. Gyugyi, C. D. Schauder, S. L. Williams, T. R. Reitman, D. R. Torgerson, and A. Edris, “The unified power flow controller: A new approach to power transmission control,” *IEEETrans. Power Delivery*, vol. 10, pp. 1085–1097, Apr. 1995.

[2]. S. Kannan, Shesha Jayaram, and M. M. A. Salama, “Real and Reactive power coordination for a Unified power flow controller,” *IEEE Trans. Power system*, vol. 19, No. 3, pp. 1454-1462, Aug. 2004.

[3]. Samina Elyas Mubeen, R. K. Nema, and Gayatri Agnihotri,” Power Flow Control with UPFC in Power Transmission System,” proceedings of world academy of science, engineering and technology vol. 30, july 2008, issn 1307-6884.

[4]. C.R. Fuerte-Esquivel, E. Acha” Unified power flow controller: a critical comparsion of

Newton-Raphson UPFC algorithms in power flow studies," *IEEE Proc.-Gener, Transm.Distrib*, Vol. 144, No. 5, September 1997.

[5]. C.R. Fuerte-Esquivel, E. Acha, and H. Ambriz-Perez "A Comprehensive Newton-Raphson UPFC Model for the Quadratic Power Flow Solution of Practical Power networks," *IEEE Trans. Power System*, vol. 15, No. 1, Feb 2000.

[6]. K. Visakha, D. Thukaram, Lawrence Jenkins," An approach for real power scheduling to improve system stability margins under normal and network contingencies," *Electr. PowerSyst. Res.* 71 (2004) 109-117.

[7]. K. Visakha, D. Thukaram, Lawrence Jenkins, "Application of UPFC for system security improvement under normal and network contingencies," *Electr. Power Syst. Res.* 70 (2004) 46-45.

[8]. S.Sutha, and N. Kamaraj," Optimal location of Multi type facts devices for multiple contingencies using particle swarm optimization," *International Journal of Electrical System Science and Engineering1; www.waset.org winter 2008.*

[9].H. I. Shaheen, G.I Rashed, and S.J.Cheng," Optimal location parameters setting unified power flow controller based on Evolutionary optimization techniques," *proceeding of the IEEE*, 2007.

[11]. H.R baghee, M. jannati, and B.Vahidi,"Improvement of voltage stability and reduce power System losses by optimal GA-based allocation of multi-type FACTS devices," *proceeding of the IEEE*, 2007.

[12]. Lijiun Cai, and Istvan Erlich, "Optimal choice and allocation of FACTS Devices using Genetic Algorithms," ISAP *Intelligent Systems Application to Power Systems, 2003lemnos, Greece*, August 31-September 3, 2003.

[13]. *http://www.siemens/td.com/trancSys/pdf/cost/effectiveReliabTrans.pdf.*

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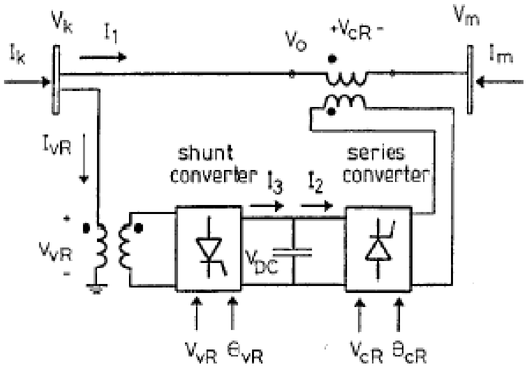

Fig. 1 UPFC schematic diagram

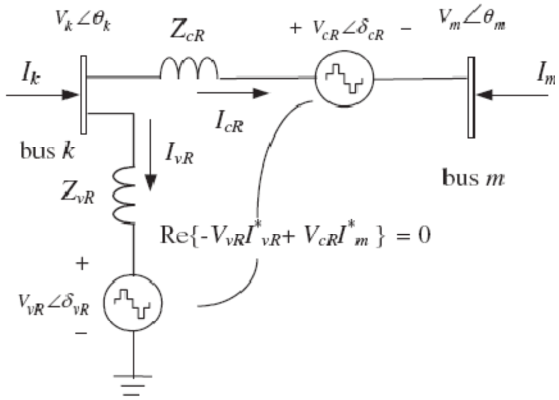

Fig. 2 Unified power flow controller equivalent circuit

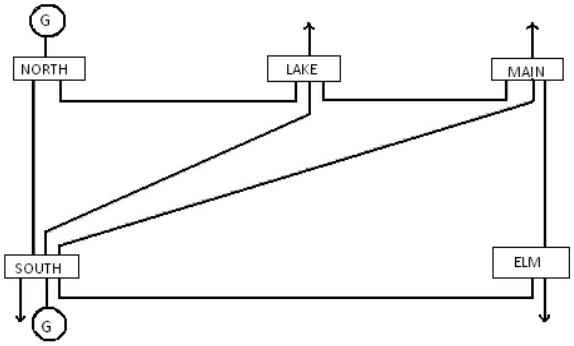

Fig. 4 IEEE 5 Bus Test System

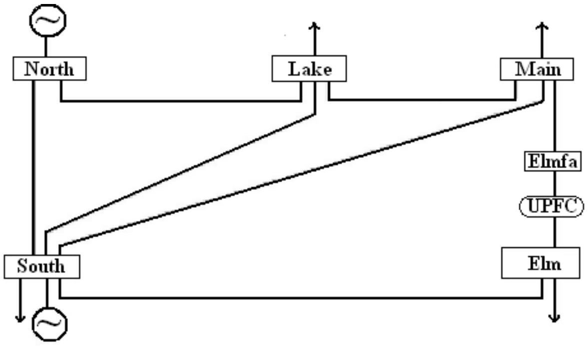

Fig. 5 Modified original Network