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Determination of Optimal Location of Upfc Controller Devices in Electric Transmission System by Using Pso Method

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Abstract : *This paper aims to determine the optimal location for the installation of UPFC controller using Particle Swarm Optimization (PSO) method to minimize small signal oscillations in a multi machine power system and we get reduction in power losses. The UPFC is required to regulate bus voltages and control power flows through the line. This way proper capacitor switching strategy is established to reduce daily and seasonal voltage fluctuations to within acceptable limits. The steady-state transmittable power of network can be increased and the voltage profile along the transmission line controlled by reactive shunt compensation. Here, the performance of UPFC mainly depends upon its parameters which are set for providing economical operation..PSO method is an efficient and general solution to solve most non linear optimization problems with nonlinear inequality constraints. In PSO Particle swarm optimization (PSO), the potential solution, called particles. All particles selected in this controller depends on only its parameter, which will keep there feasible solutions in their memory. The FACTS devices provides effective damping capability. In power transmission oscillations are reduced and the voltage profile is also improved. Based on this methodology, by considering time delay, an innovative approach is presented and by varying the power angle and making wide area damping control feasible. Only with such a control scheme, UPFC controller can be applied beneficially for economical operation i.e. with reduced generation cost and fuel cost. So by performing sensitivity analysis on the UPFC controller, we are able to find the optimal location on buses to place the UPFC controller in the network.*

Keywords: *GUPFC(generalized unified power flow controller), PSO(particles swarm optimization), SSSC(static series compensator), STATCOM(static synchronous compensator), UPFC(unified power flow controller)*

I. Introduction

The main objective to introduce FACTS Technology is to increase the power transfer capability of a transmission network in a power system, giving the direct control of power flow over designated transmission routes and to provide secure loading of a transmission line near the thermal limits. For improve the damping of oscillations as this can threaten the security or limit the usage line capacity. FACTS devices can control the parameters depending on electric transmission systems and there by improving the characteristics of electric transmission systems. Power flow control is the main role of series FACTS devices.

In this paper this fact has been taken into consideration as well as PSO based technique has been proposed to place FACTS controller in a multi machine system in order to reduce load uncertainty damp small signal oscillations. Under various system conditions and thereby improve the power system transmission and distribution stability a effectively operating unified power flow controller (UPFC) are provided continuously the reactive power required to control dynamic voltage oscillations. By Installation for increasing transfer capability and reduce losses while maintaining a smooth voltage profile under different network conditions UPFC is placed at one or more suitable points in the network. Also UPFC can mitigate active power oscillations through voltage amplitude modulation. In this paper we are using PSO method for obtaining the best location of UPFC controller in transmission system where we get effective power flow control and with economical operation for the given power injected.

II. Design Procedure

In most of cases, linearly-decreasing inertia weight PSO is used. This variant focuses more on exploration of search space in initial iterations while at later iterations, the exploitation is mainly conducted, thus, an appropriate trade-off between exploration and exploitation is established. However, in some cases, other PSO variants are adopted for tackling FACTS allocation problem.

In PSO applications on FACTS allocation problem, in most cases, no parameter tuning has been conducted, but the parameters are adopted from PSO literature (normally ωi = 0:9, ωf =0:4, C1 = C2 ¼=2). Since PSO parameters are problem-dependent, for extract- ing its best computational behaviour, all its parameters should be tuned for the particular FACTS allocation problem to be solved. In PSO literature, there are different methods for tackling constraints. These methods include Penalty approaches (with static/dynamic penalty factors),multi- objective-based approaches, death-penalty approach, flyback approach, co-evolutionary-based approaches, Deb'srules-based approach, stochastic ranking-based approach and ϵ-constrained approach have been demonstrated by numerous installations in the world. Transmission line segmentation can be expanded for the use of multiple compensators, which are located at equal segments of the transmission line in power system network. Theoretically, we know that the transmittable power would double as the segments are doubles for the same overall line length. As we are increasing the number of segments the variation of voltage along the line would rapidly decrease, and approaching the ideal case of constant voltage profile. Such a distributed compensation depends on the instantaneous response and unlimited var generation and absorption capability of the shunt compensators employed, which would have to stay in synchronism with the prevailing phase of the segment voltages and maintain the predefined amplitude of the transmission voltage, independently of load variation. Such a system, however, would tend to be too complex and probably too expensive, to be practical, particularly if stability and reliability requirements under appropriate contingency conditions are also considered. However, the practicability of limited line segmentation, using thyristor-controlled. The transmission benefits of voltage support by controlled shunt compensation at strategic locations of the transmission system.

III. Static Modeling Of Facts Devices

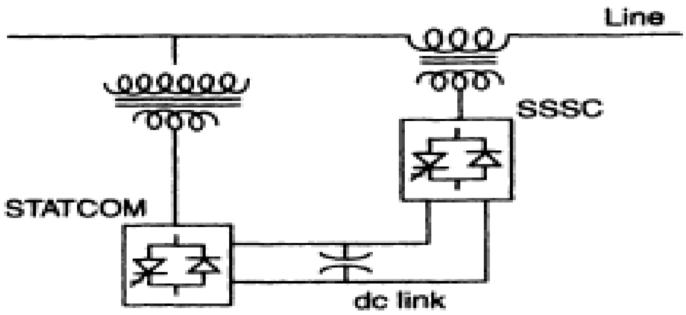


Fig:2 Unified power flow controller (UPFC)

A combination of static synchronous compensator (STATCOM) and a static series compensator (SSSC) which are coupled via a common dc link, to allow bidirectional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM.

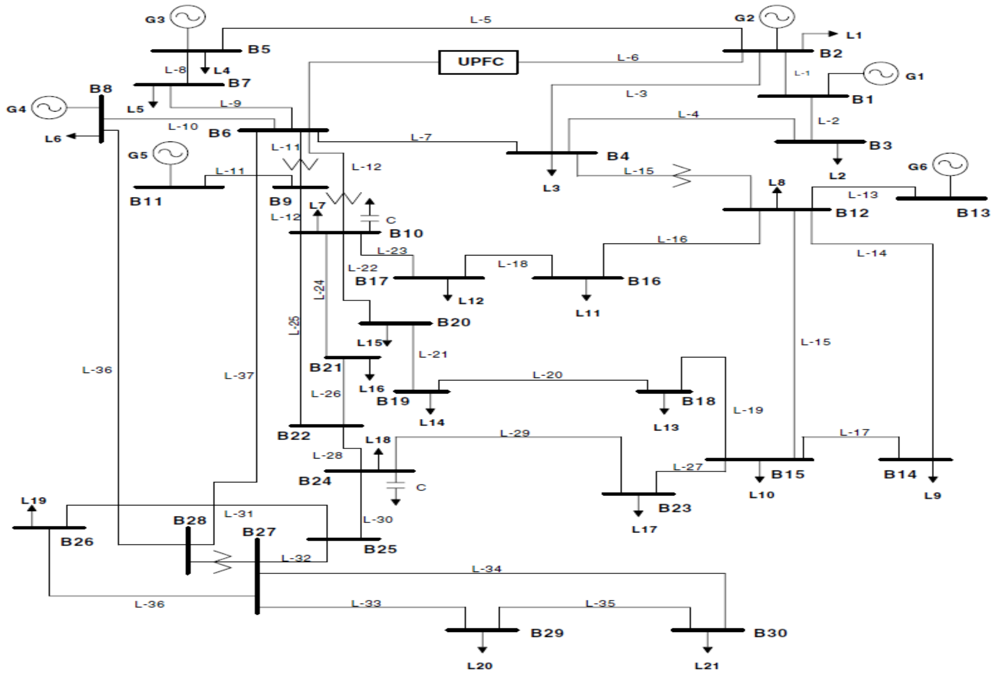


Fig:1 IEEE-30 Bus test system including UPFC

A combination of static synchronous compensator (STATCOM) and a static series compensator (SSSC) which are coupled via a common dc link, to allow bidirectional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM.

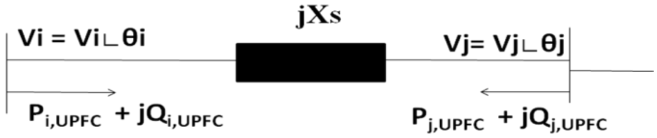


Fig :3 Power injection model of UPFC

Inverter 2 provides the main function of the UPFC by injecting an ac voltage Vpq with controllable magnitude Vpq ($0 < Vpq < Vpq$ max) and phase angle $\alpha(0< \alpha< 360)$, at the power frequency, in series with line via an insertion transformer. The transmission line current flows through this voltage source resulting in real and reactive power exchange between it and the ac system. The real power exchanged at the ac terminal (i.e. at the terminal of the injection transformer) is converted by the inverter into dc power, which appears at the dc link as positive or negative real power demand. The basic function of Inverter 1 is to supply or absorb the real power demanded by Inverter 2 at the common dc link. Inverter 1 can also generate or absorb controllable reactive power, if it is desired, and thereby it can provide independent shunt reactive compensation for the line. The effect of UPFC on network can be incorporated into load flows by power injection model shown in figure. The injected power at buses i and j due to UPFC can be given as:

$P_{i,UPFC} = rb_s V_i V_j Sin(\theta_i - \theta_{j+}\gamma)$ (1)

$Q_{i,UPFC} = rb_s (V_i)^2 Cos(\gamma)$ (2)

$P_{j,UPFC} = -rb_s V_i V_j Sin(\theta_i - \theta_{j+}\gamma)$ (3)

$Q_{j,UPFC} = - rb_s V_i V_j Cos(\theta_i - \theta_{j+}\gamma)$ (4)

The UPFC power injection model can be easily incorporated to Newton Raphson load flow programme as follows. If UPFC is connected between i and j in a power system network, then bus admittance matrix is modified by adding a reactance equivalent to X_S; between node i and j. so that the elements of jacobian matrix are modified by adding appropriate derivatives of power injection at the nodes where UPFC is located. General nodal power flow equations and linearized power system model can be expressed in rectangular form by the following equations:

$P = f_1(V,\theta,G,B)$ (5)

$Q = f_2(V,\theta,G,B)$ (6)

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix}^n = \begin{bmatrix} H & N \\ J & L \end{bmatrix}^n \begin{bmatrix} \Delta\theta \\ \Delta V/V \end{bmatrix}^n$$

where P and Q are vectors of real and reactive nodal power injections, which are function of nodal voltages, (V∟θ), and network conductances and susceptances, (G and B), respectively. (ΔP = Pspe _ Pcal) is the real power mismatch vector and (ΔQ = Qspe _ Qcal) is the reactive power mismatch vector. (ΔV and $\Delta\theta$) are vectors of incremental changes in nodal voltages. H, N, J, and L denote the basic elements in the Jacobian matrix. They corresponds to partial derivatives of the real and the reactive powers with respect to the phase angles and the magnitudes of the nodal voltages, n is iteration number. Derived injected power model can be incorporated into a general NR power flow algorithm by modifying the related elements in the normal Jacobian matrix and the corresponding power mismatch equations as well. Since injected powers vary with busbar voltage amplitudes and phases, the relevant elements of Jacobian matrix will be modified at each iteration. Based on the following additional elements of Jacobian matrix ((H = Horg + Hupfc) and for N, J and L elements) owing to the injections of the UPFC at the buses i and j can be derived.

For bus i; when i = j;

$H_{jj} = \partial P_{ijupfc} / \partial\theta_j$; $N_{jj} = V_j(\partial P_{j,upfc} / \partial V_j)$ (7)

$J_{jj} = \partial Q_{j\,upfc} / \partial\theta_j$; $L_{jj} = V_j(\partial Q_{j,upfc} / \partial V_j)$ (8)

When $i \neq j$

$H_{ij} = \partial P_{i,upfc} / \partial\theta_j$; $N_{ij} = V_j(\partial P_{i,upfc} / \partial V_j)$ (9)

$J_{ij} = \partial Q_{i,upfc} / \partial\theta_j$; $L_{ij} = V_j(\partial Q_{j,upfc} / \partial V_j)$ (10)

For bus j; when i=j;

$H_{ii} = \partial P_{i,upfc} / \partial\theta_i$; $N_{ii} = V_i(\partial P_{i,upfc} / \partial V_i)$ (11)

$J_{ii} = \partial Q_{i,upfc} / \partial\theta_i$; $L_{ii} = V_i(\partial Q_{i,upfc} / \partial V_i)$ (12)

When $i \neq j$

$H_{ij} = \partial P_{i,upfc} / \partial\theta_j$; $N_{ij} = V_j(\partial P_{i,upfc} / \partial V_j)$ (13)

$J_{ij} = \partial Q_{i,upfc} / \partial\theta_j$; $L_{ii} = V_i(\partial Q_{j,upfc} / \partial V_j)$ (14)

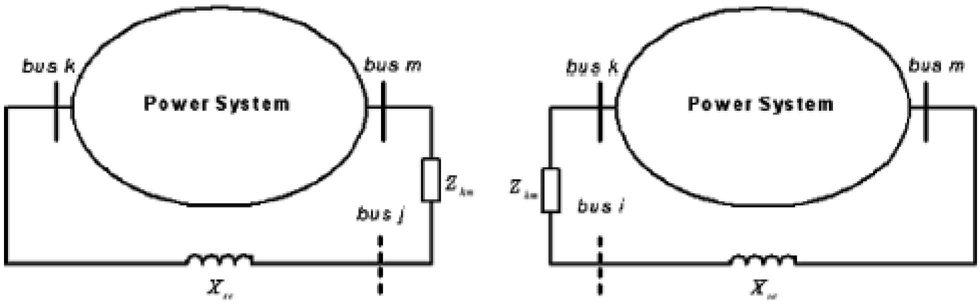
Objective function formulated is based on the optimization parameters. It is worth mentioning that the PID damped SVC controller is designed to minimize the power system oscillations after a disturbance so as to improve steady state stability. These oscillations are reflected in the deviations in the generator rotor speed Δw and deviation in terminal voltage Δvt. In the present study the objective function J is formulated as the minimization of related power mismatches equations at bus i and bus j must also be modified as:

$\Delta P_i = P_{i,G} - P_{i\,L} + P_{i\,upfc} - P_{i\,Cal}$ (15)

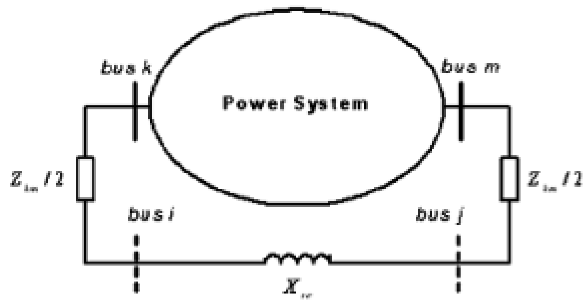
$\Delta P_J = P_{J,G} - P_{J\,L} + P_{J\,upfc} - P_{J\,Cal}$ (16)

$\Delta Q_i = Q_{i,G} - Q_{i\,L} + Q_{i\,upfc} - Q_{i\,Cal}$ (17)

$\Delta Q_J = Q_{J,G} - Q_{J\,L} + Q_{J\,upfc} - Q_{J\,Cal}$ (18)



(a) UPFC location at near bus k (b) UPFC location at near bus m



(b) UPFC location at near bus k and bus m

Fig 4. Possible UPFC locations in a sample line

Related power mismatches equations at bus i and bus j must also be modified as:

$\Delta P_i = P_{i,G} - P_{i\,L} + P_{i\,upfc} - P_{i\,Cal}$ (15)

$\Delta P_J = P_{J,G} - P_{J\,L} + P_{J\,upfc} - P_{J\,Cal}$ (16)

$\Delta Q_i = Q_{i,G} - Q_{i\,L} + Q_{i\,upfc} - Q_{i\,Cal}$ (17)

$\Delta Q_J = Q_{J,G} - Q_{J\,L} + Q_{J\,upfc} - Q_{J\,Cal}$ (18)

The proposed algorithm for solving power flow problem embedded with UPFC is implemented by using Fortran-77 language. The program is referred to as ‘‘unified power flow controller load flow’’ (UPFCLF). Fig.4 depicts the flow diagram of the programming process. Overall procedure of the proposed algorithm can be summarized as follows: The input system data includes the basic system data needed for conventional power flow calculation, i.e., the number and types of buses, transmission line data, generation and load data, the location of UPFC and the values of UPFC control parameters (r and c). System admittance matrix and conventional Jacobian matrix is formed due to incoming of UPFC. At the next step, Jacobian matrix is modified and power equations are mismatched. And then busbar voltages are updated at each iteration. Convergence is checked whether achieved or not; If no, Jacobian matrix is modified and power equations are mismatched until convergence is achieved. If yes, power flow results are displayed.

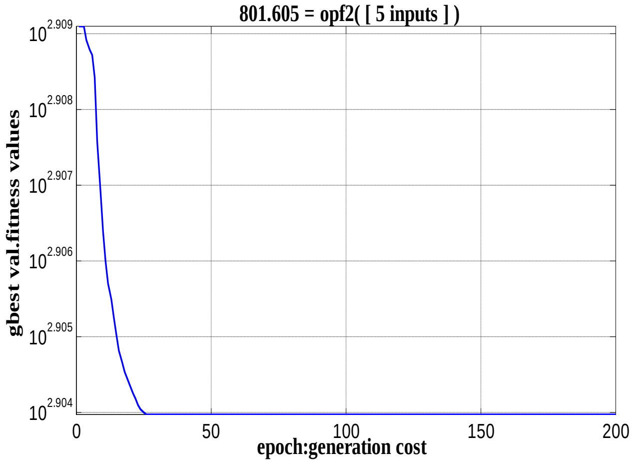


Fig.7 . Output of PSO for economical operation of UPFC

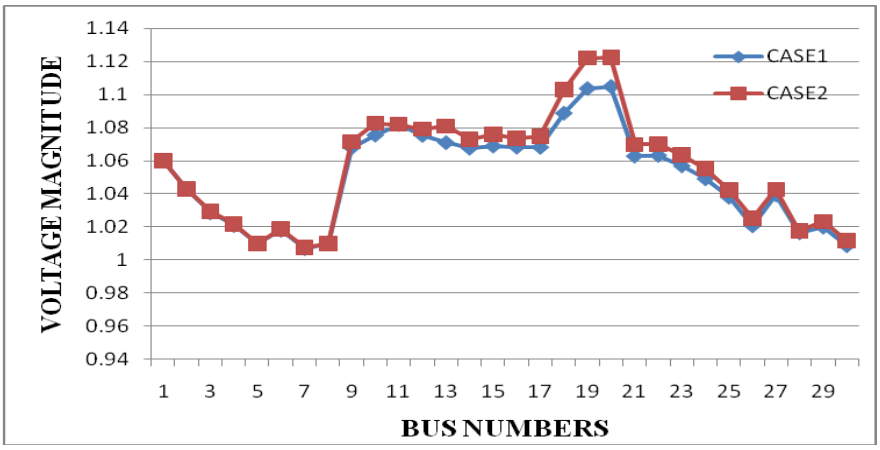


Fig.8: Voltage profile at different busses

IV. Case Study

In order to investigate the feasibility of the proposed techniques, UPFC embedded power flow studies on IEEE 30-bus test system , shown in fig.1. It should be pointed out that the results are taken by the choice of UPFC parameters, i.e., the control parameters of UPFC (r, c) are given and UPFC is operated in an open-loop form. All the results indicate good convergence and high accuracy achieved by the proposed methods.. Flat voltage start and a tolerance of accuracy less than 10^{-5} (pu) of the maximum absolute mismatch of nodal power injection are used in all analyses. First of all and without any compensation, the electrical system is studied in order to determine the power flow in each of the transmission line. This allows having a general idea about system steady-state operation. Then UPFC is allocated on line L-5, close to bus 2, thought to be near power generation sections. Different UPFC parameters are set to activate UPFC, the transmitted active and reactive power of all of the lines has remarkably changed. Comparing power flow solutions of the system without and with UPFC, it can be concluded that the proposed method developed in this study are efficient on analysis of both power flow and control parameters of UPFC.

From the results of power flow study performed on IEEE 30-bus test system without UPFC, uncompensated real and reactive power flows on line L-6 are 0.5895 pu and 0.0155 pu, respectively, while the total real and reactive transmission losses are 0.1560 pu and -0.0164 pu, respectively. With UPFC user-defined model is employed to evaluate the effects of UPFC allocation on steady-state operational characteristics of IEEE 30- bus test system. Allowed iteration tolerance is taken as 1E- 6 in all tasks.

UPFC device is positioned on line L-6 close to bus 6. Line L-6 is the controlled line. Effects of UPFC on system parameters such as; real and reactive power flows on line L- 6, overall total real and reactive transmission losses of the system are investigated.When UPFC parameter is controlled, another is kept constant. Namely, while r is controlled, γ is kept constant, and vice versa. The constant values of r and γ are 0.1 pu and angle 90.0, respectively.

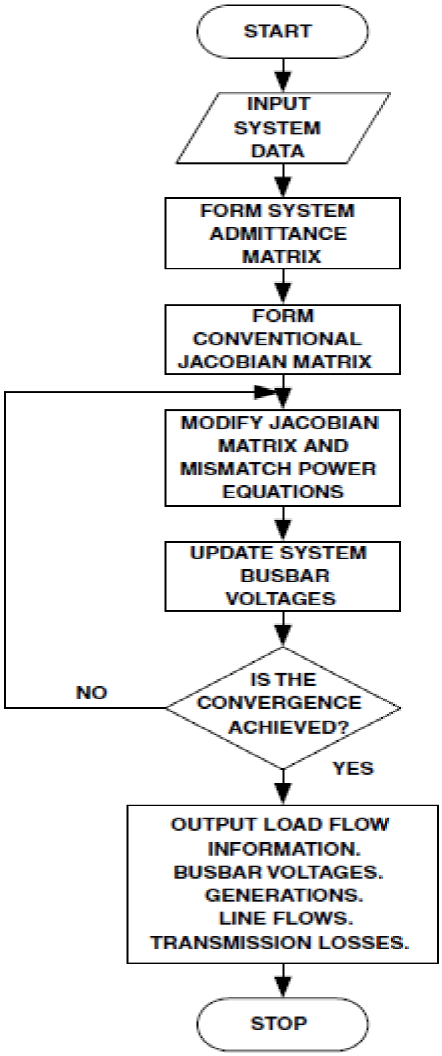


Fig: 5 Flow chart of proposed power flow algorithm

V. Pso Overview

Inspired from the nature social behavior and dynamic movements with communications of insects, birds and fish PSO is a meta heuristic optimisation algorithm which uses a number of agents (**particles**) that constitute a swarm moving around in the search space looking for the best solution. Each particle in search space adjusts its "flying" according to its own flying experience as well as the flying experience of other particles. Collection of flying particles (swarm) - Changing solutions Search area - Possible solutions
Movement towards a promising area to get the global optimum
Each particle keeps track:

- its best solution, personal best, *pbest*
- the best value of any particle, global best, *gbest*

In the basic particle swarm optimization algorithm, particle swarm consists of "n" particles, and the position of each particle stands for the potential solution in D-dimensional space. The particles change its condition according to the following three principles: (1) to keep its inertia (2) to change the condition according to its most optimist position (3) to change the condition according to the swarm's most optimist position. The position of each particle in the swarm is affected both by the most optimist position during its movement (individual experience) and the position of the most optimist particle in its surrounding (near experience). When the whole particle swarm is surrounding the particle, the most optimist position of the surrounding is equal to the one of the whole most optimist particle; this algorithm is called the whole PSO. If the narrow surrounding is used in the algorithm, this algorithm is called the partial PSO. Each particle can be shown by its current speed and position, the most optimist position of each individual and the most optimist position of the surrounding.

Algorithm parameters used in PSO method: **A** : Population of agents; $\mathbf{p_i}$: Position of agent $\mathbf{a_i}$ in the solution space **f** : Objective function ; $\mathbf{v_i}$: Velocity of agent's $\mathbf{a_i}$; $\mathbf{V(a_i)}$: Neighborhood of agent a_i (fixed)
The neighborhood concept in PSO is not the same as the one used in other meta-heuristics search, since in PSO each particle's neighborhood never changes (is fixed).

- Particle update rule

$$p = p + v$$

with

$$v = v + c_1 * rand * (pBest - p) + c_2 * rand * (gBest - p)$$

where
***p*:** particle's position**;** ***v*:** path direction
c_1: weight of local information
c_2**:** weight of global information
***pBest*:** best position of the particle
***gBest*:** best position of the swarm
***rand*:** random variable

- Number of particles usually between 10 and 50
- C_1 is the importance of personal best value
- C_2 is the importance of neighborhood best value
- Usually $C_1 + C_2 = 4$ (empirically chosen value)
- If velocity is too low → algorithm too slow
- If velocity is too high → algorithm too unstable

Advantages of the basic particle swarm optimization algorithm:
(1)PSO is based on the intelligence. It can be applied into both scientific research and engineering use.
(2)PSO have no overlapping and mutation calculation. The search can be carried out by the speed of the particle. During the development of several generations, only the most optimist particle can transmit information onto the other particles, and the speed of the researching is very fast.
(3)The calculation in PSO is very simple. Compared with the other developing calculations, it occupies the bigger optimization ability and it can be completed easily.
(4) PSO adopts the real number code, and it is decided directly by the solution. The number of the dimension is equal to the constant of the solution.
Insensitive to scaling of design variables, Simple implementation, easily parallelized for concurrent processing, derivative free, very few algorithm parameters are required, very efficient global search algorithm but also;
(1)The method easily suffers from the partial optimism, which causes the less exact at the regulation of its speed and the direction.
(2)The method cannot work out the problems of scattering and optimization.
(3)The method cannot work out the problems of non-coordinate system, such as the solution to the energy field and the moving rules of the particles in the energy field

Particle swarm optimization has become a common heuristic technique in the optimization community, with many researchers exploring the concepts, issues, and applications of the algorithms. The coordinated search for food which lets a swarm of birds land at a certain place where food can be found was modeled with simple rules for information sharing between the individuals of the swarm. A PSO algorithm maintains a population of particles (the swarm), where each particle represents a location in a multidimensional search space (also called problem space). The particles start at random locations and search for the minimum (or maximum) of a given objective function by moving through the search space. The movements of a particle depend only on its velocity and the locations where good solutions have already been found by the particle itself or other (neighbouring) particles in the swarm. PSO algorithm each particle keeps track of the coordinates in the search space which are associated with the best solution it has found so far. The corresponding value of the objective function (fitness value) is also stored. Another "best" value that is tracked by each particle is the best value obtained so far by any particle in its topological neighbourhood. When a particle takes the whole population as its neighbours, the best value is a global best. At each iteration of the PSO algorithm the velocity of each particle is changed towards the Personal and global best (or neighbourhood best) locations. But also some random component is incorporated into the velocity update. Integral time absolute error of the speed deviations is taken as the objective function. The expression of objective function is as follows:

$$J = \int_{t=0}^{t=t_{sim}} |\Delta\omega|.t.dt$$

Where, Δω is the speed deviation and tsim is the time range of simulation. generates the reactive power (capacitive mode), when the system voltage is lower and it absorbs reactive power (inductive mode), when the voltage is higher. reactive shunt compensation can significantly increase the maximum transmittable power.

Thus, it is reasonable to expect that, with suitable and fast controls, shunt compensation will be able to change the power flow in the system during and following dynamic disturbances so as to increase the transient stability limit and provide effective power oscillation damping.The potential effectiveness of shunt (as well as other compensation and flow control techniques) on transient stability improvement can be conveniently evaluated by the *equal area criterion.*

The convergence rate of the objective f□*J*unction *J* towards best solutions with population size 20 and number of generations 200 has been shown in Figure by graphical point view.The results in minimization of the critical damping index (*CDI*) given by: □*J* □ □ (1□ ζ*i*) Hereζ *i* is the damping ratio of the *i*th critical swing mode. The objective of the optimization is to maximize the damping ratio as much as possible. There are four tuning parameters of the SVC controller; the controller gain (*Ksvc*), lead time constant (*T*1), lag time constant (*T*2) and the location number (*Nloc*). These parameters are to be optimized by minimizing the objective function *J* given by. With the change of locations and parameters of the TCSC controller the damping ratio as well as *J* varies. The problem constraints are the bounds on the possible locations and parameters of the SVC controller.

VI. Conclusion

In this paper a meta heuristic method PSO has been implemented for determining the optimal location of UPFC controller in a 30 bus bar transmission system and this multi objective controller in a standard multi-machine power system will mitigate the small signal oscillation problem with improved voltage profile for economic operation. This optimization technique based on PSO seems to have good accuracy, faster convergence rate.The problem of finding optimal location in network and parameters of FACTS devices in electrical power systems is called “FACTS allocation problem” and has widely gained the attention of researchers in electrical and electronic power engineering. In this paper by PSO method a improved voltage profile is obtained for the busses to which UPFC is connected for economical operation i.e., with reduced generation cost and economic size of controller. Also for the same voltage a reactive power is obtained which will again injected to the same bus to which UPFC is connected. By this iteration of injecting different power results in compensated losses in network. Problem of finding the best optimal location of UPFC controller represents a nonlinear and non-convex optimization problem. Because of the existence of multiple local optimal locating near-global solutions in such an optimization problems PSO is used as a powerful and well-established meta heuristic optimization algorithm. It has been frequently utilized to solve UPFC controller allocation problems ,although it suffers from premature convergence problem. In this paper, by the applications of PSO for solving UPFC allocation problem to get the best location on transmission line, where reduced power losses and reduced oscillation is achieved.

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