Control Of Unified Power Flow Controller For Power System Oscillations Using Lead Lag Controller Tuned Of PSO

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Abstract : This system proposes an application of Unified Power Flow Controller (UPFC) in order to voltage support and also enhancement of stability in system. Lead lag controller is considered for UPFC control and the parameters of lead lag controller are tuned using Particle Swarm Optimization (PSO). The optimal design problem is formulated as an optimization problem, and particle swarm optimization (PSO) is used to search for the lead lag controller parameters. To show the ability of UPFC in voltage control and also stability enhancement, the results of the system are compared with and without UPFC.

IndexTerms – **UPFC, Lead lag controller, Particle Swarm Optimization (PSO).**

I. INTRODUCTION

Power demand is increasing dramatically. Because of lack of availability of resources and environmental aspect, power transmission and generation is limited which causes the power system to be operated near to the stability constraints. Low frequency oscillations arise due to the interconnected power system which is in the range of 0.2-3 Hz. Power system stabilizers are used to overcome this problem but in case of large disturbance [1], it is unable to damp out oscillations. Hence FACTS devices are introduced to overcome these oscillations which control the power system fast and reliably. These FACTS devices are electronics based equipment used to enhance controllability and to optimize the existing system capacities reliably in place of mechanical controller [2]. The unified power flow controller is regarded as one of the most versatile devices in the FACTS device family [3,4] which has the ability to control of the power flow in the transmission line, improve the transient stability, mitigate system oscillation and provide voltage support. It performs this through the control of the in-phase voltage, quadrate voltage and shunts compensation due to its mains control strategy. The application of the UPFC to the modern power system can therefore lead to the more flexible and economic operation [5]. When the UPFC is applied to the interconnected power systems, it can also provide significant damping effect on the line power oscillation through its supplementary control.

This paper investigates the effect of fault on dynamic stability occurred in the system. The term dynamic stability has been used as a class of speed deviation of rotor stability. The effectiveness of the suggested controller is carried out by the time domain simulation. The effect of efficient control of the UPFC to damp the low-frequency oscillations is Demonstrated and also parameters of UPFC based damping controller are optimize using Particle Swarm Optimization (PSO) algorithm has used to damp out the low frequency oscillations.

II. UNIFIED POWER FLOW CONTROLLER

UPFC is a device placed between two buses referred to as the UPFC sending bus and the UPFC receiving bus. It consists of two voltage-source converters, as illustrated in Figure 1. The back-to-back converters, labelled “shunt converter” and “series converter” in the Figure, are operated from a common DC link provided by a DC storage capacitor. The shunt converter is primarily used to provide active power demand of the series converter through the common DC link. Shunt converter can also generate or absorb reactive power, if it is desired, and thereby it provides independent shunt reactive compensation for the line. Series converter provides the main function of the UPFC by injecting a voltage with controllable magnitude and phase angle in series with the line. For the fundamental frequency model, the VSCs are replaced by two controlled voltage sources.

Series voltage magnitude V and its phase angle ρ with respect to the sending bus are controllable in the range of V($0 \leq V \leq V$) and ρ ($0 \leq \rho \leq 360°$) respectively. The shunt converter injects controllable shunt voltage such that the real component of the current in the shunt branch balance the real power demanded by the series converter. The real power can flow freely in either direction between the AC terminals. On the other hand, the reactive power cannot flow through the DC link. It is absorbed or generated locally by each converter. The shunt converter operated to exchange the reactive power with the AC system provides the possibility of independent shunt compensation for the line. If the shunt injected voltage is regulated to produce a shunt reactive current component that will keep the sending bus voltage at its pre specified value, then the shunt converter is operated in the Automatic Voltage Control Mode.

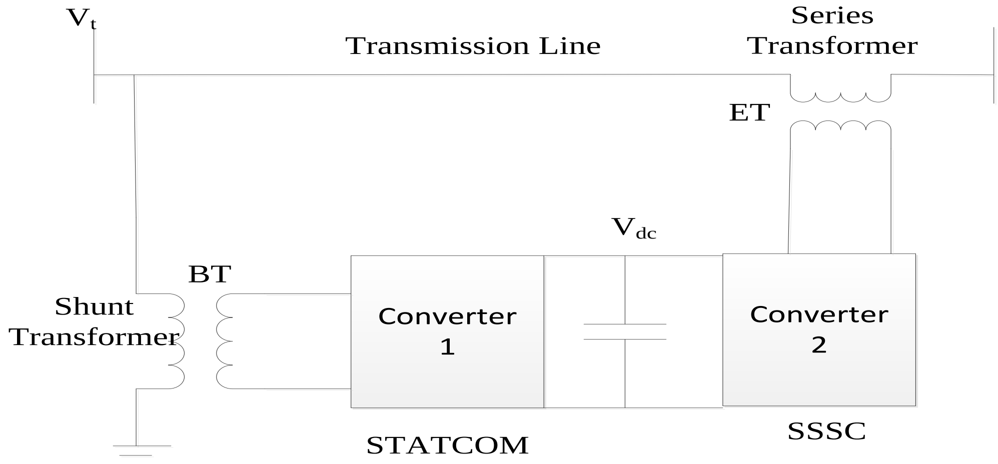

Figure.1 The Schematic diagram of UPFC

III. Designing of Lead Lag Controller Using PSO

PSO is a fast, simple and efficient population-based optimization method which was proposed by Eberhart and Kennedy. Each particle updates its position based upon its own best position, global best position among particles and its previous velocity vector according to the following equations:

With minimum control effort the designed controller with PSO based controller is tuned to damp low frequency oscillations. Here ITAE (Integral of Time multiplexed Absolute value of Error) is used as the fitness function. The objective function is defined as[5].

$$J = \int_0^{t_{sim}} t.\left(\Delta w_i\right)dt \qquad \textbf{(1)}$$

$$F = \sum_{i=1}^{N_P} J_i \qquad \textbf{(2)}$$

In Eq. (1) t_{sim} is the simulation time. In Eq. (2) N_p is the total number of operating points. Damping controller with PSO technique is tune damp power system oscillations. The optimization of controller parameters is carried out by evaluating the objective function. The design problem is converted into optimization problem which is solved by the PSO, where the controller parameter bounds.

The structure of the UPFC with lead- lag damping controller is show Figure 2 Results of the controller parameter set values using the PSO method is given below

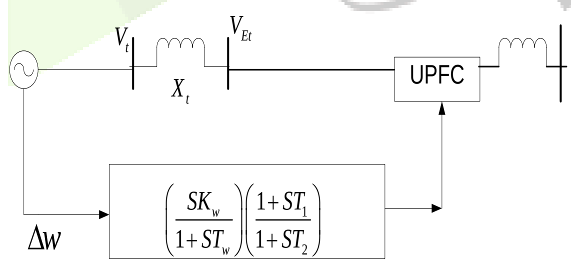

Figure.2 UPFC with lead-lag controller

In order to acquire the particle size, number of particle, number of iteration, C1 and C2 are chosen as 30, 1.2, and 0.12 respectively.

$$V_i^{k+1} = W * V_i^K + c_1 * r_1 * (P_{best} - X_i^K) + c_2 * 2 * (g_{best} - X_i^K) \qquad (3)$$

$$x_i^{k+1} = X_i^k + X * v_i^{k+1} \qquad (4)$$

Where, V_i^{k+1}: The velocity of i^{th} particle at $(k+1)^{th}$ iteration

W : Inertia weight of the particle

V_i^K: The velocity of i^{th} particle at k^{th} iteration
c_1, c_2: Positive constants having values.
r_1, r_2: Randomly generated numbers
P_{best}: The best position of the i^{th} particle obtained based upon its own experience
g_{best}: Global best position of the particle in the population
x_i^{k+1}: The position of i^{th} particle at $(k+1)^{th}$ iteration
X_i^k: The position of i^{th} particle at k^{th} iteration
χ : Constriction factor. It may help insure convergence.

Suitable selection of inertia weight w provides good balance between global and local explorations.

$$w = w_{\max} - \frac{w_{\max} - w_{\min}}{iter_{\max}} \times iter$$

Where, $w_{\max}$ is the value of inertia weight at the beginning of iterations, $w_{\min}$ is the value of inertia weight at the end of iterations, $iter$ is the current iteration number and $iter_{\max}$ is the maximum number of iterations.

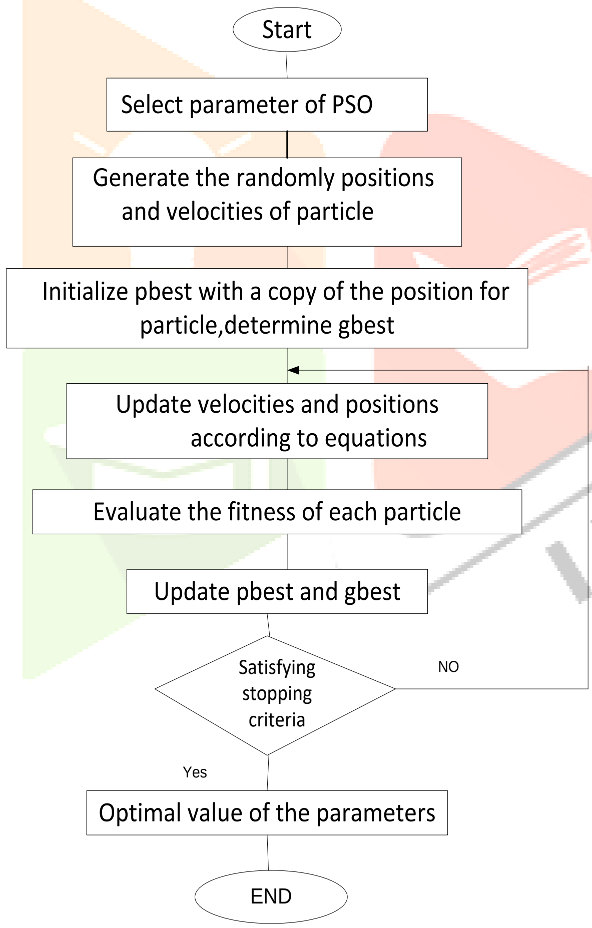

Figure.3 Flowchart of the PSO technique

IV. STUDY OF WSCC 9 BUS SYSTEM

In this study, three machines, 9-buses system Western Science Coordinated Council (WSCC) with 6 transmission lines, 3 generators, 3 loads are considered. Here assuming fault time is at 1.5 second and the fault has been applied between bus 6 and bus 9 of 9-buses system as shown in Figure 4. UPFC is connected between bus 5 and bus 4.The simulation is implemented using the matlab/simulink software. The excitation phase angle (δ_E), which is the efficient input control signal of the UPFC control [7].

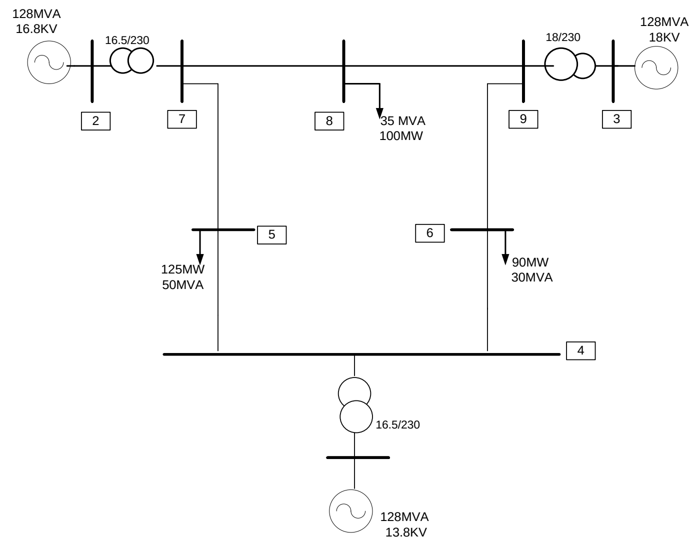

Figure.4 WSCC 9-buses System

V. SIMULATION RESULTS

UPFC based damping controllers are described in above section. This controller may be considered as lead–lag compensator. There are various parameters of controller which are to be optimized. Optimization algorithms are used to get optimized value of damping controllers parameters. Optimized values of lead leg controller parameters are listed in Table 1.

Table 1 Optimized Controller Parameters

Controller Parameters	UPFC based Controller
K	22.1
T_w	0.03
T_1	0.82
T_1	0.78

Figure 5 shows the generator 1 speed deviation with small fluctuation during the fault condition using UPFC. The speed deviation of generator 1, 2, 3 due to designed lead lag controller shown in Figures 5, 6 and 7 shows the speed deviations of UPFC using lead lag controller tuned PSO and with UPFC controller.

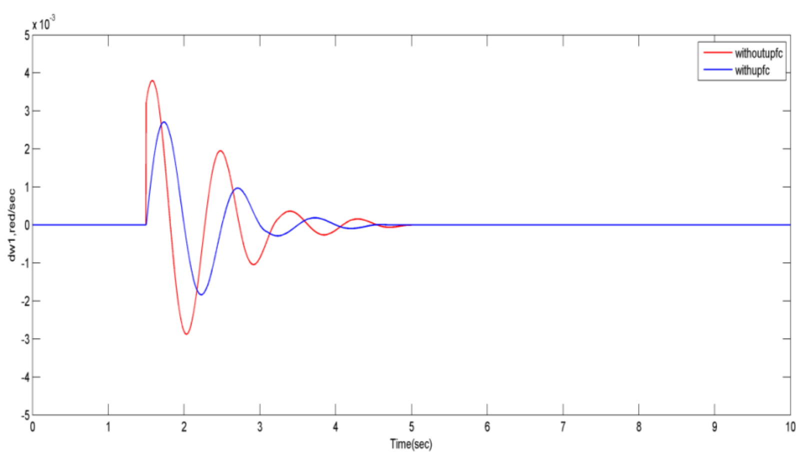

Figure.5 speed deviation of generator G1 with and without UPFC

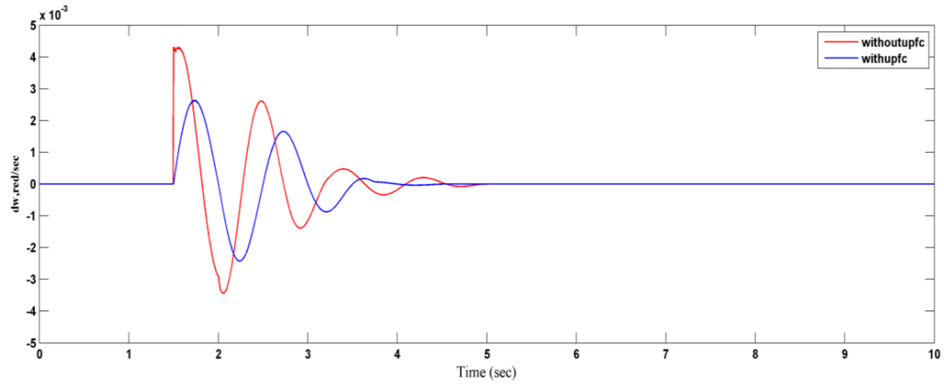

Figure.6 speed deviation of generator G2 with and without UPFC

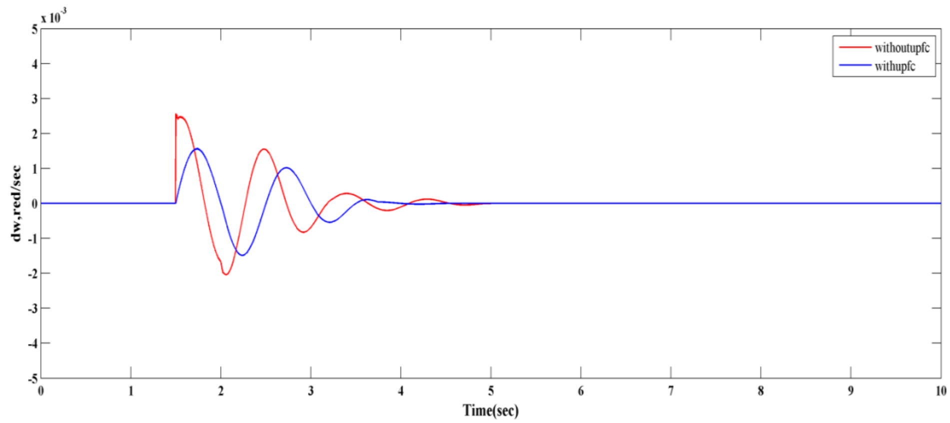

Figure.7 speed deviation of generator G3 with and without UPFC

VI. CONCLUSION

In this paper, the UPFC device that is used to control the line active and reactive power flow of the transmission line using lead lag controller. The proposed model of the UPFC is explained and it can be implemented in MATLAB/SIMULINK software. The design problem of the UPFC lead lag controller parameters is converted into an Optimization problem can solve by using PSO technique that has a strong ability to find the most optimistic results. The results have shown that the proposed UPFC model with lead lag controller optimized with particle swarm optimization Can effectively damp power system oscillations following large disturbances compared to without UPFC.

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