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Particle swarm optimization tuned unified power flow controller for power oscillation reduction

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ABSTRACT

One of the best flexible AC transmission system (FACTS) is unified power flow controller (UPFC). As it gets more benefit from both real and reactive power transfer, it is used in power system for controlling the transmitted power. The UPFC controls the power on the transmission side of the power system. When the real as well as reactive power is set the UPFC tries to follow the command by using the proportional and integral (PI) controller. But in some power systems the PI controllers cannot produce the proper power due to the power oscillations. These oscillations are created due to PI controller properties. In this paper the PI controller is replaced with the particle swarm optimization tuned PI controller (PSO-PI). It minimizes the power oscillations by using the objective function. The MATLAB 2017b is used to demonstrate the power transfer curves and the voltages. The IEEE 9 bus system is being used as a reference system.

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1. INTRODUCTION

FACTS devices are used for improvement of the power transfer in the power system. In that type UPFC produces both real and reactive power control through the transmission line [1]. There are many types of UPFC compensation like line sending end/ receiving end and mid-point compensations [2]. These devices are used to damp the torque oscillations in the generator a new control is introduced in [3]. Then the voltage stability is done by [4] with radial basis neural network. With same solution reducing the inputs used are used in [5]. As well as the researches to improve the artificial intelligence are also done like direct adaptive network for training it with backpropagation is carried out in [6] and with feed forward neural network [7], [8] are carried out. And in the power system the improvement in transient stability by using the neural network is proposed in [9]. An automatic regulation of the reactive power in a hybrid power system has also been proposed in [10]. The digital signal peripheral interface controller (DSPIC) processor is used for reactive power compensation is depicted in [11] and it is implemented with neural network. Reactive power control with ANN in hybrid power grid is discussed in [12] and based on fuzzy is discussed in [13]. The fault location identification is done with ANN in [14]. There are many researches available in UPFC [15]-[24]. The multiverse optimization is presented in [25] for power sytem oscillation stability. In this paper the PI is tuned to minimize the steady state error of the power in the UPFC control is implemented. This reduces the oscillations with in the power system as the settling time is reduced.

2. UPFC MODELING

The UPFC consist of two converters, which is shown in Figure 1. One is connected in parallel and another one is connected in series to the bus system. So, it can able to handle the real and reactive power in decoupled way by using the control techniques shown in Figure 2. The converter is connected using the series and parallel connected isolated transformers.

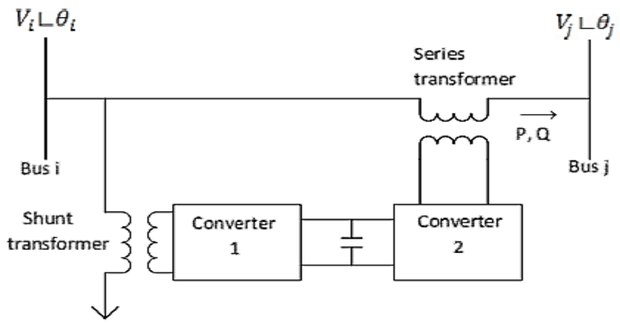

Figure 1. UPFC model

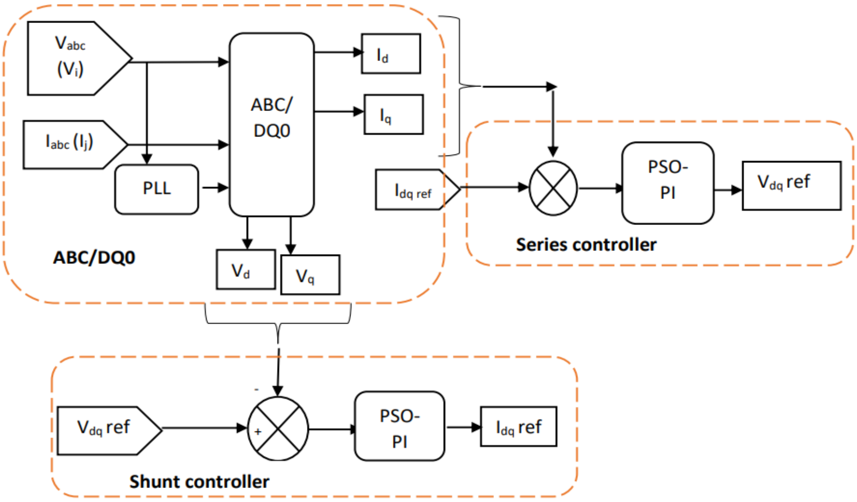

Figure 2. UPFC controller with PSO-PI

In control techniques the control is divided by three. They are ABC to DQ0 conversion, series controller and shunt controller. The ABC to DQ0 transformation is used for converting decoupling the real and reactive component from the ABC. The series controller compares the Idqref with the measured Idqmeasured. This compared error is given to PI controller or as proposed PSO-PI controller. It is converted to Vdqref. Then shunt controller takes the action and it compares this voltage with reference voltage then it converts it as current. So, series and shunt converters are controlling the voltage and current respectively. Here the PSO-PI is the proposed converter which work optimum compared to PI controller.

3. OBJECTIVE FUNCTION

Minimization of Settling time of real power,

$$\sum_{i=1}^{n} Ts \tag{1}$$

With respect to constraints,

$$Kp\ min \leq Kp \leq Kp\ max \tag{2}$$

$$Ki\ min \leq\ Ki\ \leq\ Ki\ max \tag{3}$$

where Ts is the settling time, Kp min and Kp max are indeed the minimum and the maximum proportional gains, while Ki min and Ki max are also the minimum and maximum Integral gains procured by expertise while using a PI controller.

Particle swarm optimization technique is based on the swarm's food-seeking behaviour [26]. The large group of birds or fishes (particle) actively looking for food and the best particle sharing its position to its neighbourhood particle (whole populace is considered as neighbourhood particle) and the data is shared to whole swarm with best area in the pursuit space. Here, food is the goal work, the particles are the populace and swarm are the absolute populace in each emphasis. As PSO depends on the conduct of the food search in a gathering of fish or bees or birds. The scheme of the algorithm as flow chart is given as Figure 3.

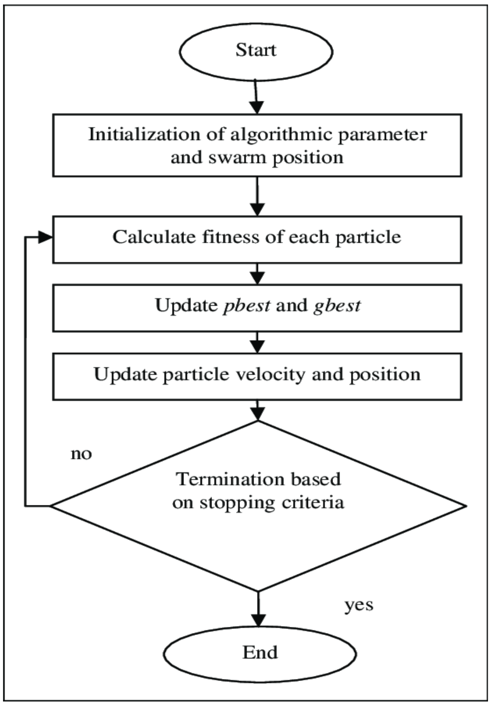

Figure 3. Flow chart of PSO algorithm used for PI controller

4. RESULTS AND DISCUSSIONS

The Figure 4 is the proposed standard IEEE 9 bus system for test power system problem. The IEEE 9 bus system is connected with UPFC device. The UPFC is connected at the bus number 4. The series converter is connected in series with the transmission line between bus 4 to bus 6. The controls for both the converter is implemented as shown in the Figure 2.

The setpoint power is given as 0.75 pu. of real power for UPFC. It is increased to 0.8 pu at 5.5 secs. The total run time is 10secs. The reactive power reference taken is 0.3 pu.The comparative results of the PI controller and PSO-PI are presented in the Table 1. The PI controller takes only 2.2539e-5 secs to rise. And the PSO-PI takes only 2.245e-5 secs. According to the objective set the settling time is 0.9806 secs for PI controller but using PSO-PI it takes only 0.8723 secs. The other parameters are as tabulated in the Table 1, and it is evident that PSO-PI performance is better. The Figure 5, depicts the Power curves using PI controller in UPFC system. The Figure 6, depicts the Power curves using PSO-PI controller in UPFC device. Figure 7, shows the Comparison of PI and PSO-PI controller in IEEE 9 bus system placed with UPFC. The set point is reached in the output as expected.

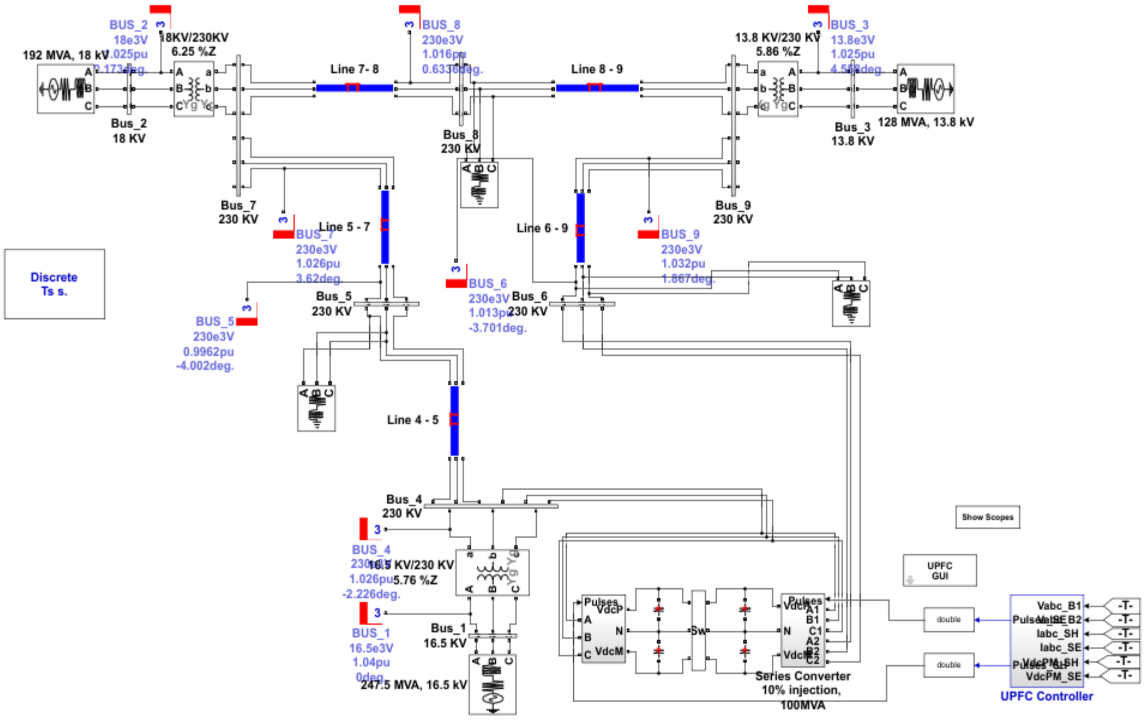

Figure 4. Proposed block diagram (IEEE-9 bus system)

Table 1. Comparison of methods

Parameter	PI	PSO-PI
Rise Time (sec)	2.2539e-05	2.2450e-05
Settling Time (sec)	0.9806	0.8723
Settling Min%	0.0763	0.0765
Settling Max %	0.0763	0.8549
Peak (MW)	8.6979	8.6979
Peak Time (sec)	0	0.2938

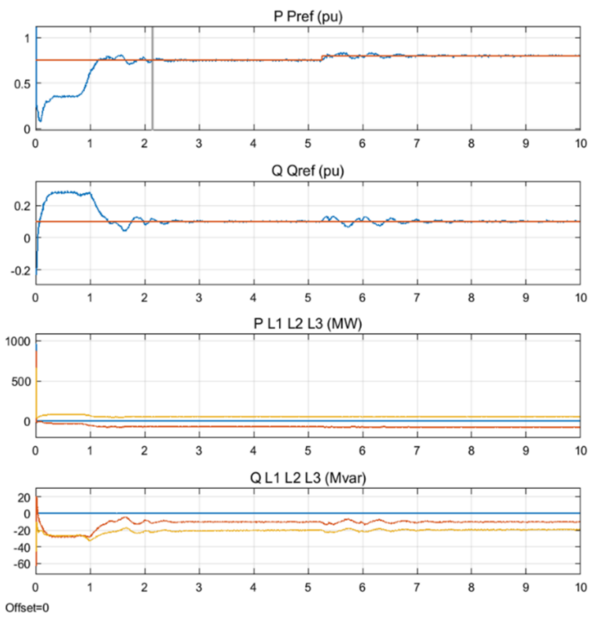

Figure 5. Power curves of PI controller in IEEE-9 bus system

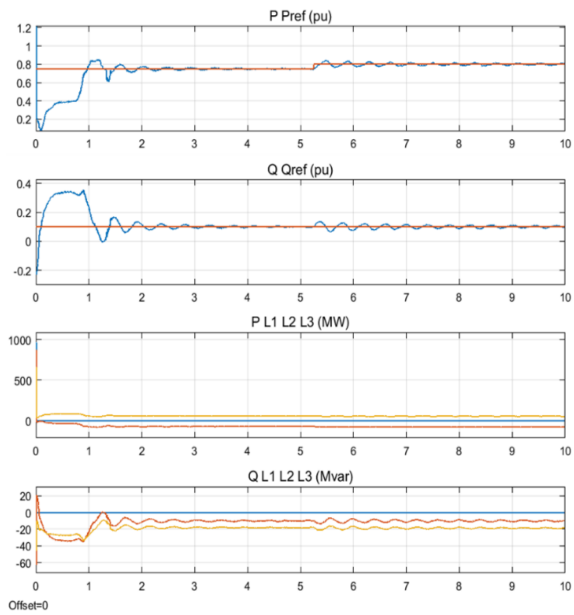

Figure 6. Power curves of PSO-PI controller in UPFC in IEEE 9 bus system

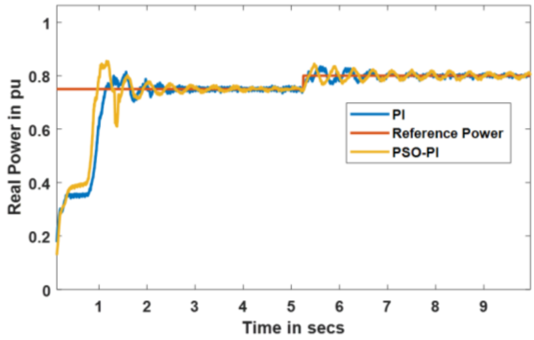

Figure 7. Comparison of PI and PSO-PI controller in IEEE 9 bus system placed with UPFC

5. CONCLUSION

The UPFC is placed in dynamic IEEE 9 simulation model. The settling time is minimized by using the PSO algorithm. The comparative analysis of PI and PSO-PI control in UPFC is implemented in this paper. The settling time is minimized in PSO-PI controller. IEEE 9 bus system shows the test results and the time data are tabulated. The particle swarm optimization tuned PI controller (PSO-PI) helps to reduce the power oscillations much better and faster.

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