IJIREEICE ISSN (O) 2321-2004, ISSN (P) 2321-5526

International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering

Impact Factor 8.021 ⁂ Peer-reviewed & Refereed journal ⁂ Vol. 13, Issue 3, March 2025

DOI: 10.17148/IJIREEICE.2025.13369

Dynamic Stability Enhancement using PSS and UPFC

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Abstract: This research proposes a new PSO-based PSS for the UPFC to dampen power system low frequency oscillations. A power system stabilizer is developed for UPFC to efficiently damp the oscillations of the power system. The parameters of PSS are tuned using the PSO algorithm. The effectiveness of the proposed control technique is tested under various fault scenarios and compared to the GA-based PSS to demonstrate its robust performance using time simulation studies and certain performance indices.

Keywords: UPFC, GA, PSO, FACTS devices, Power System Stability.

I. INTRODUCTION

In the recent years, the fast progress in the field of power electronics had opened new opportunities for the application of the FACTS devices as one of the most effective ways to improve power system operation controllability and power transfer limits [1–2]. The Unified Power Flow Controller (UPFC) is regarded as one of the most versatile devices in the FACTS device family [3-4] which has the ability to control 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 [1,4]. Investigations on the UPFC main control effects show that the UPFC can improve system transient stability and enhance the system transfer limit as well. The application of the UPFC to the modern power system can therefore lead to the more flexible, secure and economic operation [10]. When the UPFC is applied to the interconnected power systems, it can also provide significant damping effect on tie line power oscillation through its supplementary control. The modern power system tends to be interconnected to yield the most economic benefits. However, low frequency oscillation will occur on the heavily loaded tie lines especially after a large or small disturbances. Sometimes the Power System Stabilizer (PSS) installed on a specific generator cannot provide effective damping for that kind of oscillations. In [5, 6], it is shown that the addition of a conventional supplementary controller to the UPFC is an effective solution to the problem. However, an industrial process, such as a power system, contains different kinds of uncertainties due to continuous load changes or parameters drift due to power systems highly nonlinear and stochastic operating nature. As a result, a fixed parameter controller based on the classical control theory such as PI or lead-lag controller [5-8] is not certainly suitable for the UPFC damping control methods. Thus, it is required that a flexible controller be developed. Some authors suggested neural networks method [9] and robust control methodologies [10-12] to cope with system uncertainties to enhance the system damping performance using the UPFC. However, the parameters adjustments of these controllers need some trial and error. Also, although using the robust control methods, the uncertainties are directly introduced to the synthesis, but due to the large model order of power systems the order resulting controller will be very large in general, which is not feasible because of the computational economical difficulties in implementing.

Recently, applications of the Fuzzy Logic (FL) theory to the engineering issues have drawn tremendous attention from researchers [13-14]. The fuzzy controller has a number of distinguish advantages over the conventional one. It is not so sensitive to the variation of system structure, parameters and operation points and can be easily implemented in a large-scale nonlinear system. The most attractive feature is its capability of incorporating human knowledge to the controller with ease. This approach provides the FL systems better functionality, performance, adaptability, reliability and robustness. The most dynamic area of fuzzy systems research in the power systems has been the stability enhancement and assessment. Some authors used FL-based damping control strategy for TCSC, UPFC and SVC in a multi-machine power system [15, 16]. The damping control strategy employs non-optimal FL controllers that is why the system's response settling time is unbearable. Dash et al. presented a fuzzy damping control system for series connected FACTS devices, e.g. TCSC, UPFC and TCPST to enhance power system stability[17]. The FL-based damping controller may exhibit lack of robustness due to its simplicity and the system's response for a wide incursion in the operating condition is anticipated to deteriorate.

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Limyingcharone et al. [18] applied fuzzy logic based UPFC for the transient stability improvement. Khon and Lo [19] used a fuzzy damping controller designed by micro Genetic Algorithm (GA) for TCSC and UPFC to improve powers system low frequency oscillations. The proposed method may have not enough robustness due to its simplicity against the different kinds of uncertainties and disturbances. Mak et al. [20] applied a GA-based Power system stabilizer (PSS) and UPFC combination is used to enhance power. system damping. The GA based PSS and UPFC damping the oscillations but takes more settling time. In order to overcome the above drawbacks, PSO based PSS and UPFC is used to damp the oscillations effectively. In this paper the parameters of PSS are obtained using PSO optimized algorithm.

II. POWER SYSTEM MODEL WITH UPFC

Fig.1 shows a SMIB system equipped with a UPFC. The UPFC consists of an Excitation Transformer, a Boosting Transformer, two three-phase GTO based Voltage Source Converters (VSCs), and a DC link capacitors. The four input control signals to the UPFC are m_E , m_B , δ_E ,and δ_B. Where, m_E is the excitation amplitude modulation ratio, m_B is the boosting amplitude modulation ratio, δ_E is the excitation phase angle and δ_B is the boosting phase angle. By applying Park's transformation and neglecting the resistance and transients of the ET and BT transformers, the UPFC can be modeled as [22-23]:

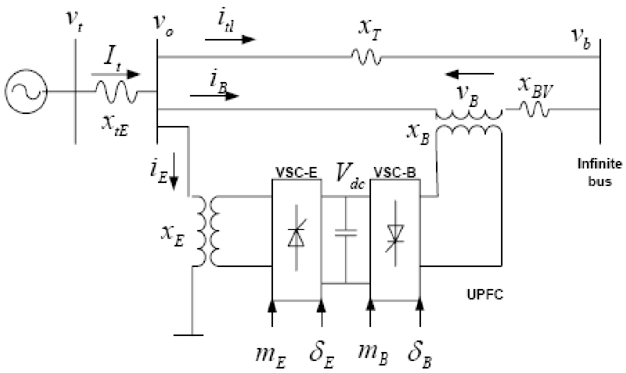

Fig.1. SMIB power system equipped with UPFC

$$\begin{bmatrix} V_{Etd} \\ V_{Etq} \end{bmatrix} = \begin{bmatrix} 0 & -X_E \\ X_E & 0 \end{bmatrix} \begin{bmatrix} i_{Ed} \\ i_{Eq} \end{bmatrix} + \begin{bmatrix} \dfrac{m_E \cos(\delta_E) V_{dc}}{2} \\ \dfrac{m_E \sin(\delta_E) V_{dc}}{2} \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} V_{Btd} \\ V_{Btq} \end{bmatrix} = \begin{bmatrix} 0 & -X_B \\ X_B & 0 \end{bmatrix} \begin{bmatrix} i_{Bd} \\ i_{Bq} \end{bmatrix} + \begin{bmatrix} \dfrac{m_B \cos(\delta_B) V_{dc}}{2} \\ \dfrac{m_B \sin(\delta_B) V_{dc}}{2} \end{bmatrix} \tag{2}$$

$$\frac{dV_{dc}}{dt} = \frac{3m_E}{4c_{dc}} \begin{bmatrix} \cos\delta_E & \sin\delta_E \end{bmatrix} \begin{bmatrix} i_{Ed} \\ i_{Eq} \end{bmatrix} + \frac{3m_B}{4c_{dc}} \begin{bmatrix} \cos\delta_B & \sin\delta_B \end{bmatrix} \begin{bmatrix} i_{Bd} \\ i_{Bq} \end{bmatrix} \tag{3}$$

Where V_{Et}, i_E, V_{Bt}, and i_B are the excitation voltage, excitation current, boosting voltage, and boosting current, respectively; C_{dc} and V_{dc} are the DC link capacitance and voltage, respectively. The nonlinear model of the SMIB system as shown in Fig. 1 is described by:

$$\dot{\omega} = (P_m - P_e - D\Delta\omega) / M \tag{4}$$

$$\dot{\delta} = \omega_o(\omega - 1) \tag{5}$$

$$\dot{E}_q' = (-E_q + E_{fd}) / T'_{do} \tag{6}$$

$$\dot{E}_{fd} = (-E_{fd} + K_a(V_{ref} - V_t)) / T_a \tag{7}$$

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Impact Factor 8.021 ⁙ Peer-reviewed & Refereed journal ⁙ Vol. 13, Issue 3, March 2025
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Where

$$P_e = V_{td} I_{td} + V_{tq} I_{tq} \; ; \; E_q = E'_{qe} + (X_d - X_d') I_{td}$$

$$V_t = V_{td} + jV_{tq} \; ; \; V_{td} = X_q I_{tq} \; ; \; V_{tq} = E_q' - X_d' I_{td}$$

III.PSO BASED POWER SYSTEM STABILIZER

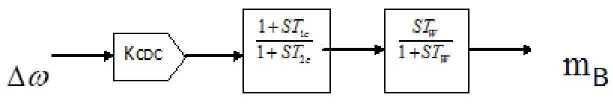

Fig.2. Block diagram of PSS controller.

The structure of the PSS based is shown in Fig.2. It consists of gain, signal washout and phase compensator blocks. The parameters of the PSS are obtained using Partical swarm optimization method.

The parameters of PSS are gain, Time constants for lead blocks. These parameters are obtained using an one of the best optimized algorithm PSO.The performance of the proposed PSOPSS controller are shown in Figs.9 to 12 for different fault conditions. The flow chart used for this optimization is shown in Fig.3

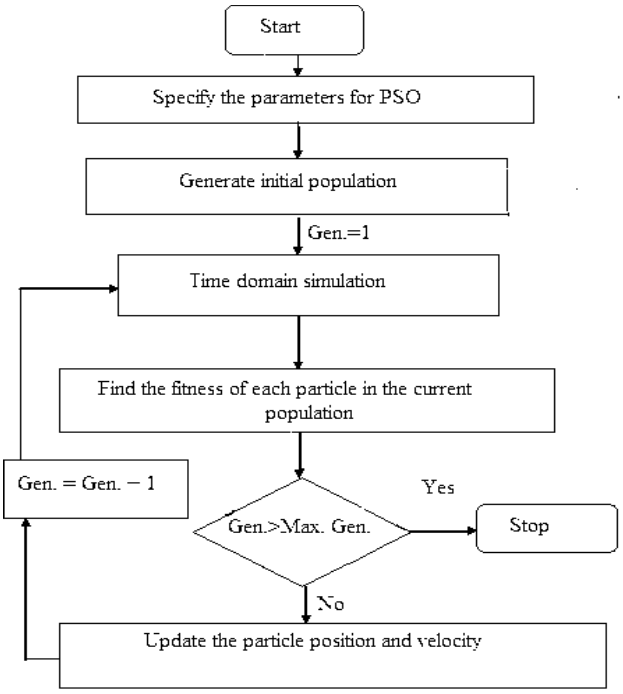

Fig.3. PSO algorithm Flowchart

IV. SIMULATION RESULTS

The simulation diagrams are shown in Fig.4.The performance of GA based PSS and UPFC is shown in Fig.5 to Fig.8 and performance of PSO based PSS and UPFC is shown in Fig.9 to Fig.12. Fig.5 shows change in delta with respect to time with single line to ground fault with GA based PSS and UPFC. Fig.6 shows power system stabilizer output with single to ground fault with GA based PSS and UPFC. Fig.7 shows change in delta with respect to time with double line to ground fault with GA based PSS and UPFC. Fig.8 shows power system stabilizer output with double line to ground fault with GA based PSS and UPFC. Fig.9 shows change in delta with respect to time with single line to ground fault with PSO based PSS and UPFC. Fig.10 shows power system stabilizer output with single to ground fault with PSO based PSS and UPFC.

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Fig.11 shows change in delta with respect to time with double line to ground fault with PSO based PSS and UPFC. Fig.12 shows power system stabilizer output with double line to ground fault with GA based PSS and UPFC.
It can be seen that the proposed PSOPSS controller is very effective, achieve good robust performance, compared to GA based PSS and UPFC have the best ability to reduce power system low frequency oscillations.

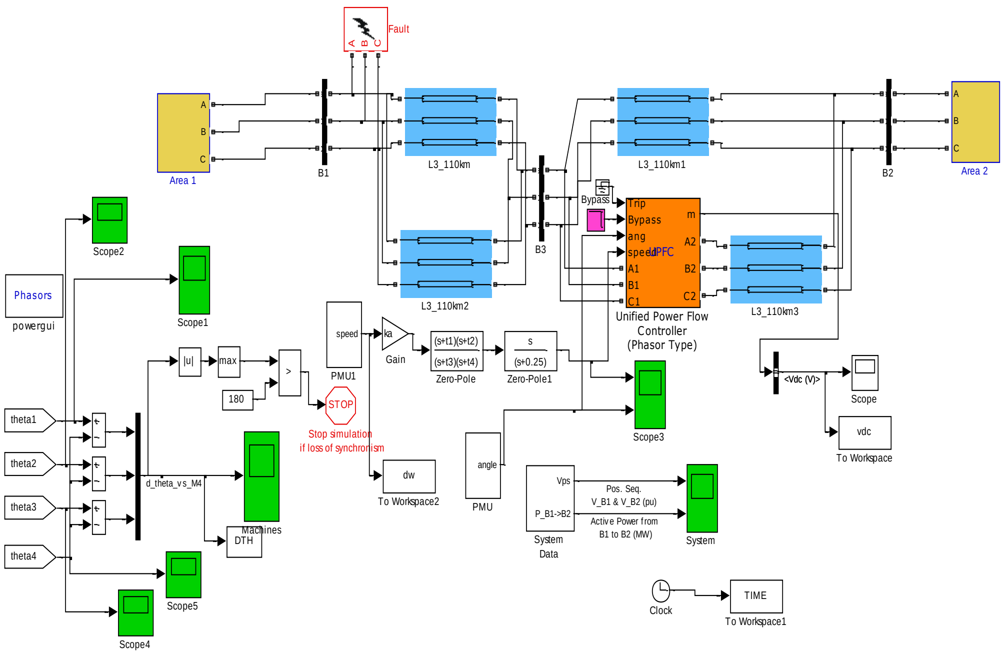

Fig.4. Simulation diagram for both GA based PSS and PSO based PSS with UPFC.

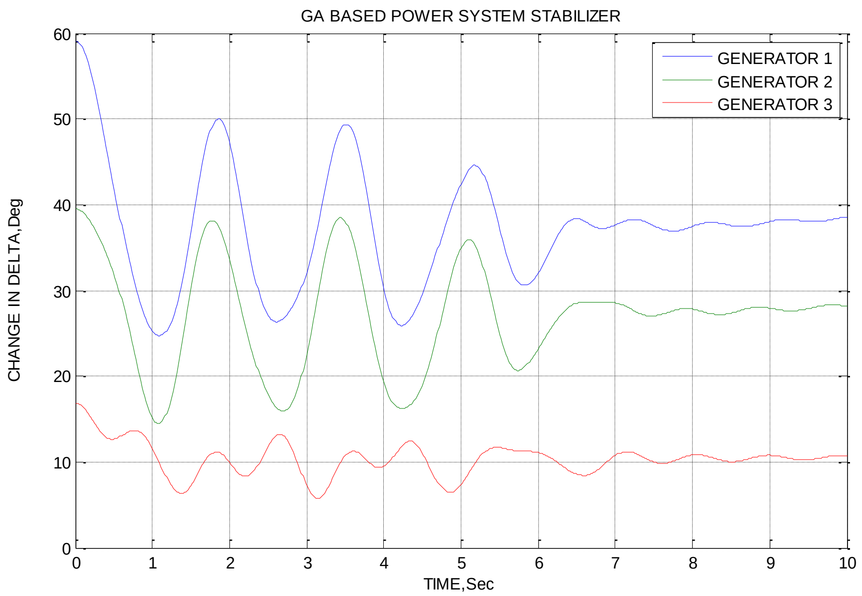

Fig.5. Power system response for single line to ground fault (Line a to ground) using GA based PSS and UPFC.

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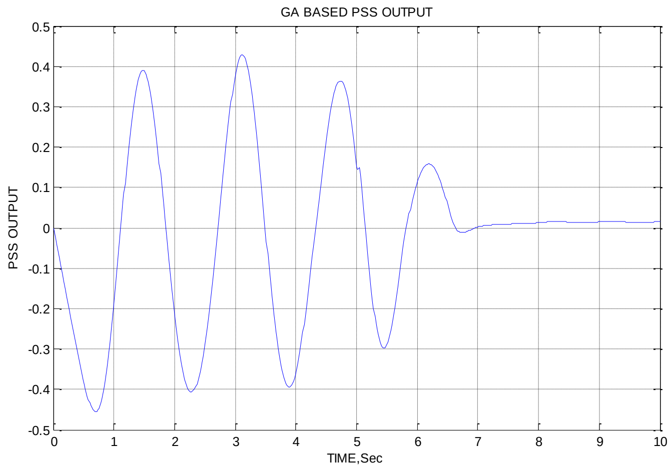

Fig.6. Power system stabilizer output for single line to ground fault (Line a to ground) using GA based PSS and UPFC.

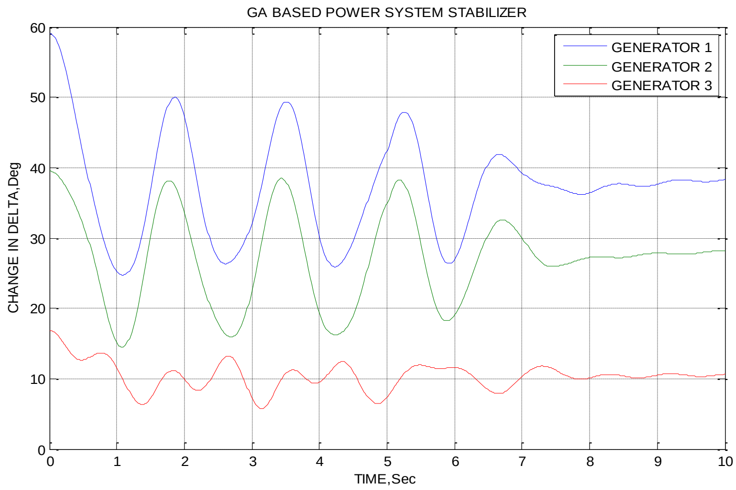

Fig.7. Power system response for double line to ground fault (Lines a,b to ground) using GA based PSS and UPFC.

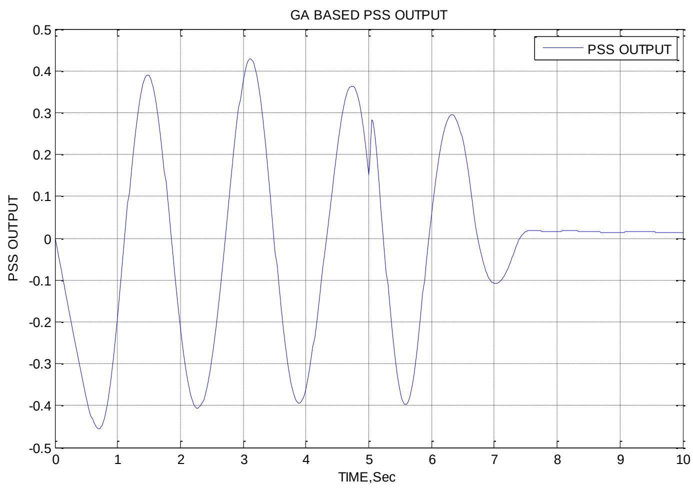

Fig.8. Power system stabilizer output for double line to ground fault (Line a,b to ground) using GA based PSS and UPFC.

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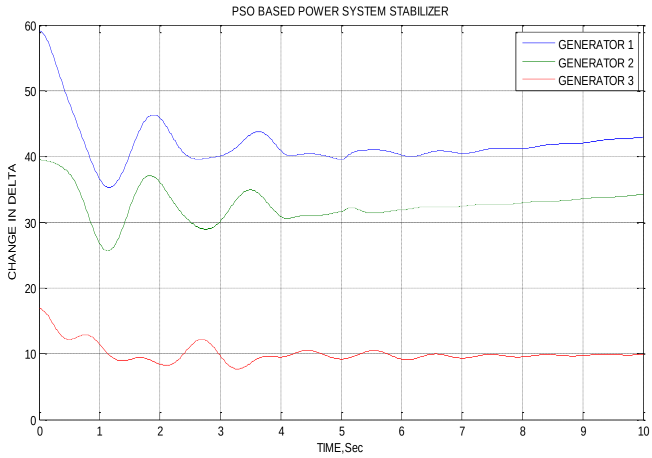

Fig.9. Power system response for single line to ground fault (Lines a to ground) using PSO based PSS and UPFC.

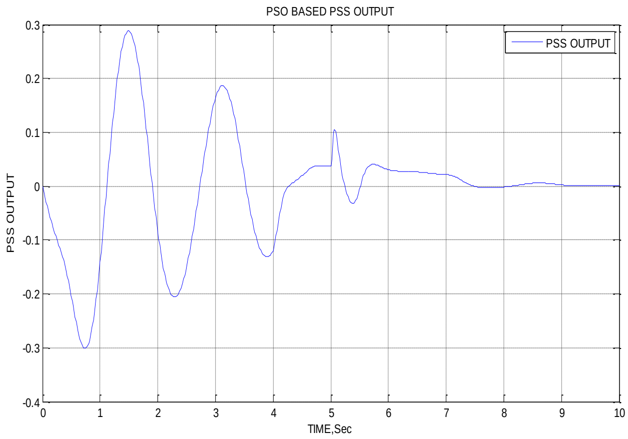

Fig.10. Power system stabilizer output for single line to ground fault (Line a to ground) using PSO based PSS and UPFC.

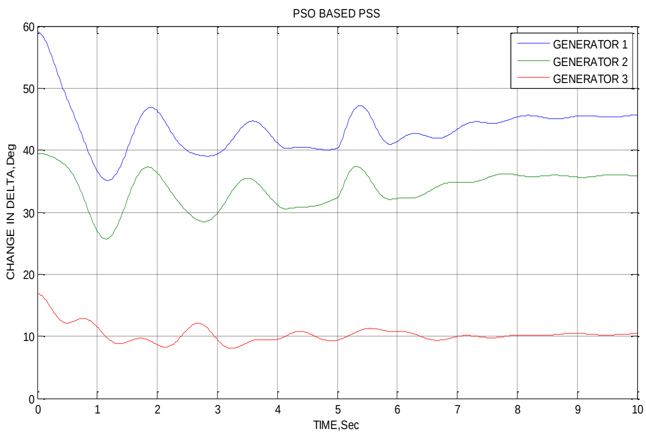

Fig.11. Power system response for double line to ground fault (Lines a,b to ground) using PSO based PSS and UPFC.

V.CONCLUSION

This work proposes a new PSOPSS stabilizer for the UPFC to dampen low frequency oscillations in the power system.The suggested controller can be helpful in real-world power systems and is reasonably simple to construct and apply.In comparison to GA-based PSS controllers, the suggested controller has been tested on a three-machine, nine-bus power system under various fault scenarios.

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