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Using Teaching Learning Based Optimization to Efficacious and Tuning of UPFC-PODs of Interconnected Systems

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Using Teaching Learning Based Optimization to Efficacious and Tuning of UPFC-PODs of Interconnected Systems

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Abstract. This paper offers a systematic procedure for modelling and simulating a teaching-learning-based optimization (TLBO) technique that exercised with styling power system stabilizer (PSS) and UPFC-controller for 6-bus test system. TLBO is used to find an effective and powerful solution for power system stabilizers (PSS) and the power oscillation damping (POD) controller in power systems. The results show the fast damping oscillations and rapidly reaching the steady state with TLBO compared to other methods such as PI-POD and UPFC individually. The parameters of traditional PI are adjusted using try and error method.

1. Introduction

The increasing need for electricity has led to a continuous work in difficult and tiring conditions. These conditions do not generate much electricity due to the resources and the environment. The need for large and increasing demands has inclined due to the large number of nonutility generators and competition [1]. PSS is one of the solutions for the damping oscillation [2]. The PSS is connected to the generation in order to cancel negative torque oscillations that are produced by AVR action and to improve the overall performance of the power system, however, it was not efficient for large disturbance such as three-phase faults [3].

Therefore, flexible alternative current transmission systems (FACTS) devices can be applied to avoid voltage breakdown and stabilizing fluctuations. These controllers have unique compensation features when connected to the power systems. One compensatory controller (series or shunt) such as the SVC control shunt, STATCOM shunt control and series shunt, UPFC should be analysed for transient stability and reactive energy control (voltage injection) because FACTS are very expensive, although they are versatile. In interconnected energy systems, these networks improve energy networks through reactive, active and voltage control, allowing the system better transient stability and enhancing the load capacity of transmission lines over their short and long-term thermal capabilities [4]. Recently, several FACTS devices have been implemented and installed in practical power systems [5-7].

There are many researchers have been working on FACTS devices in power systems. The work in [8,9] involved the TCPAR, UPFC and TCSC to improve the strength system. The researchers in [10] have presented the transient stability assessment of two series (CSC-STATCOM) where it was improved transients due to faults while enhancing the available transfer capacity (ATC).

A research in [11], has offered a study to optimally solve the clustering problem through artificial bee technique. While in [12], the optimal location of FACTS has been calculated using (simulated steel, genetic algorithm and Tabu search,). In [13], a 45-bus system has been introduced using the particle sprain improvement (PSO) with STATCOM and the results have shown that PSO gives the best results. In [14], the system stability in a transmission line has been improved using P & Fuzzy controllers utilizing MATLAB and UPFC. The researchers in [15] have offered different types of FACTS (SVC, STATCOM, SSSC, TCSC, TCPS and UPFC) showing the utility of using FACTS to enhance stability and damping oscillations.

In this study, the UPFC is used for fast hindering power transient system. The results show that the TLBO-controlled damping control unit performed well under different operating conditions.

2. Teaching learning-based optimization

Figure 1 shows a flowchart for the TLBO algorithm, the idea of the TLBO was developed from the teaching and learning process, where it works to find the optimal solution through improving learners' knowledge and improving the parameters [16]. This algorithm can be divided into:

2.1 Teacher phase:

To locate a solution for the teacher by choosing the best learner, the teacher works to get the preferable mean, $M_{j,i}$ [17]. TLBO is calculating the mean difference (Difference_$M_{j,i}$) as:

$$\text{Difference\_}M_{j,i} = r_i \, (X_{j,kBest,i} - T_F M_{j,i}) \tag{1}$$

Where r_i is a random number between 0 and 1, $X_{j,kBest,i}$ is the result of the teacher in subject j, T_F is the teaching factor. The value of T_F can be either 1 or 2 and can be calculated using:

$$T_F = \text{round}[1+\text{rand }(0,1) \{2-1\}] \tag{2}$$

Based on the Difference_$M_{j,i}$ in the teacher phase ready the updated solution becomes as follows:

$$X'_{j,k,i} = X_{j,k,i} + \text{Difference\_}M_{j,i} \tag{3}$$

Where $X'_{j,k,i}$ is the updated value of $X_{j,k,i}$, and $X'_{j,k,i}$ is accepted if it gives the best solution for the function value. These values are the input to the learner phase, and all the accepted function values at the end of the teacher phase are preserved.

2.2 Learner phase:

Through interacting and discussing together with other students, the students can gain their knowledge [17]. To improve this knowledge, the learners interact with each other. The learning process for this phase is demonstrated explicitly as shown below. Randomly choose two learners, P and Q, such that $X'_{totalP,i} \neq X'_{totalQ,i}$ where, $X'_{totalP,i}$ and $X'_{totalQ,i}$ are the modern values of $X_{totalP,i}$ and $X_{totalQ,i}$, sequentially. At the end of the teacher phase,

$$X''_{j,P,i} = X'_{j,P,i} + r_i \, (X'_{j,P,i} - X'_{j,Q,i}), \text{ If } X'_{total-P,i} > X'_{totalQ,i} \tag{4}$$

$$X''_{j,P,i} = X'_{j,P,i} + r_i \, (X'_{j,Q,i} - X'_{j,P,i}), \text{ If } X'_{totalQ,i} > X'_{totalP,i} \tag{5}$$
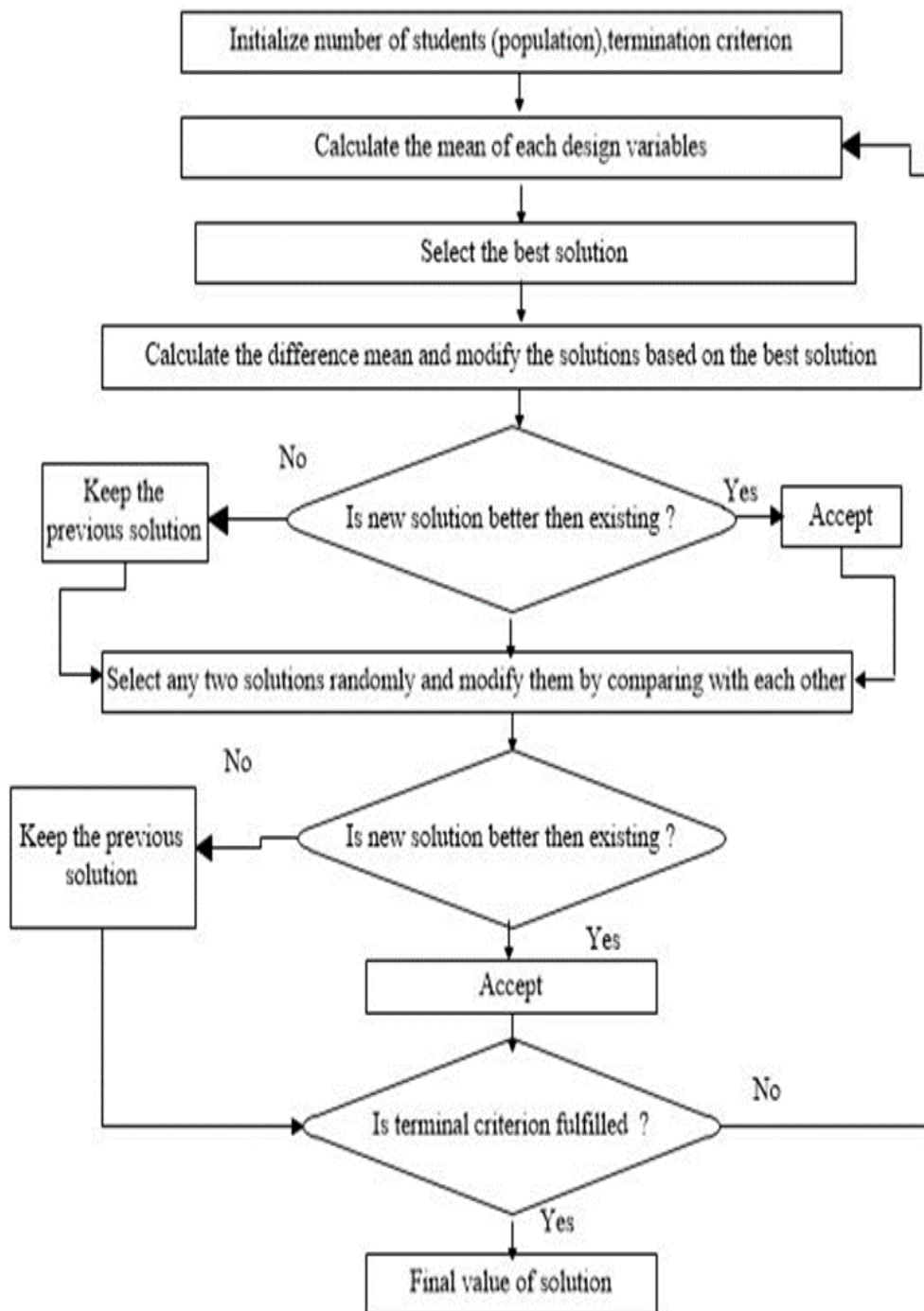
Figure 1. Flowchart for the TLBO algorithm.

3. Unified Power Flow Controller (UPFC)

There are many-sided controllers in the FACTS concept and it contains both the shunt and series converters that work by a common DC link. The shunt converter is providing active power to the series converter through the DC link capacitor. The series converter acts as a voltage source, and it improves the power system stability. Figure 2 shows the general planner of UPFC [18,19].
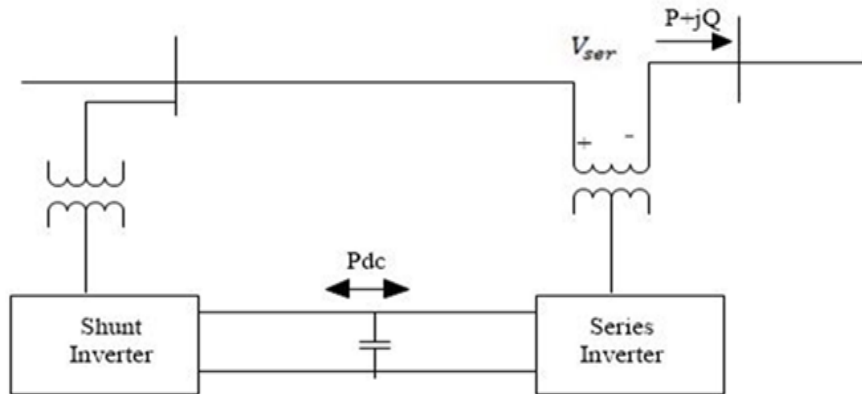
Figure 2. General planner of UPFC.

4. Modelling of PSS and UPFC-POD

The chassis of PSS and POD is presented in Figure 3, the input signal to the PSS is ($\Delta\omega_i$ or P) and (V_{PSS} or V_{pod}) is the output signal. It comprises of a wash out block acting as high pass filter, with time constant T_W (10 sec), $T_1 - T_4$ are to be determined, and K is the gain, and $\Delta\omega_i$ is the angular speed deviation of the corresponding synchronous machine i [20]. The suggested control of POD for UPFC is presented in Figure 4, while Table 1 shows the parameters obtained through the proposed methodology considering the one case of contingencies.
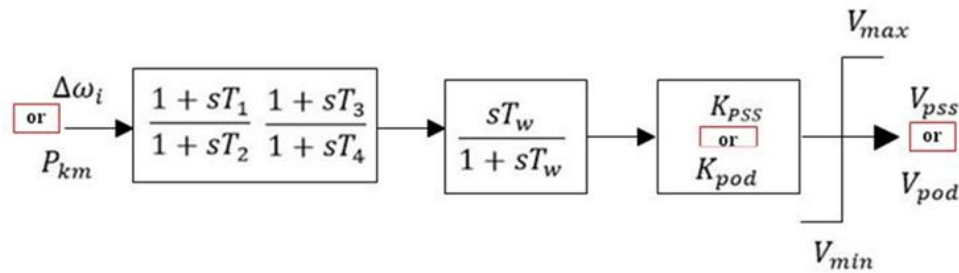

Figure 3. Chassis of PSS and POD.

Table 1. Parameters of PSS and POD for 6-bus test system.

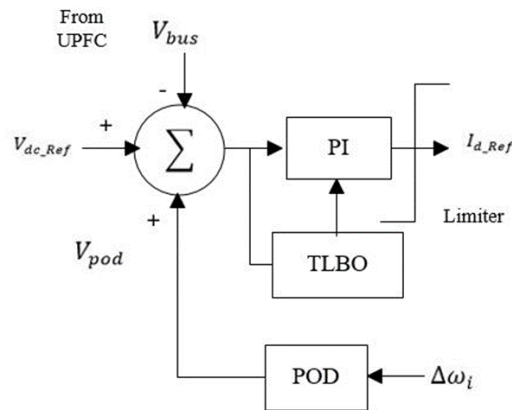| T_1	T_2	T_3	T_4	T_w	K	V_{max}	V_{min}
0.3663	0.0235	0.3924	0.0445	10	8.86	1	-1

Figure 4. Suggested control of POD for UPFC.

5. Case study of a four machine six-bus test system

The test system is a study of two-areas, the six-bus and the four-machine systems have been implemented. In Figure 5, the system has 2 areas that are connected by a transmission line between bus 2 and bus 3. The generators G1 and G2 have 1000MVA, while G3 and G4 have 3000MVA. Appendix A contains the data of 6-bus test system from [21].
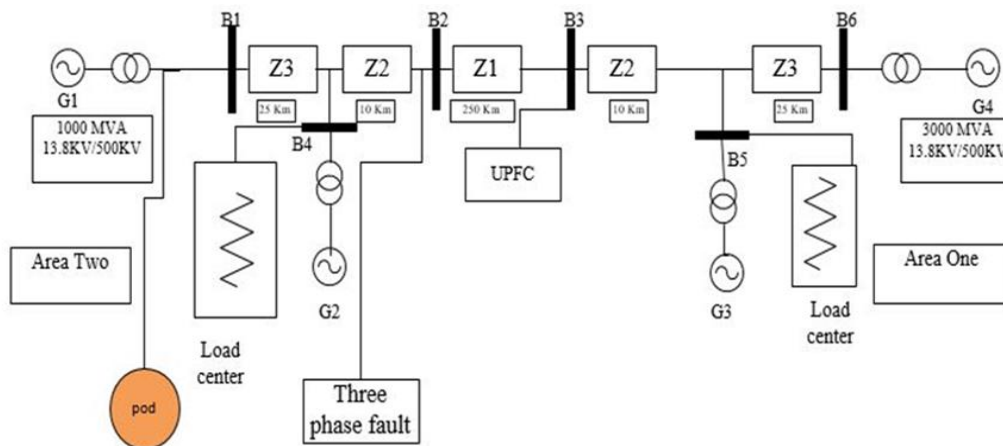

Figure 5. 4- machine and 6-bus system with UPFC and POD.

6. Simulations and Results

The simulations have performed on a 6-bus test system as shown in Figure 5. The system experienced a three-phase fault near bus B2 that starts at time 0.6 sec while the clearing time was at 0.7 sec after initiating the fault.

Figures 6-9 presented the relative variations in the rotor angle of the generators G1-4, G2-4 and G3-4 during the fault. In Figure 9, the relative variation in rotor angle was better than the other methods. Figure 10 shows the terminal voltage at bus B2 has improved for the damping oscillation and a fast-steady state with TLBO has achieved. Figure 11 shows the terminal voltage at bus B3.

In regarding to Figure 12, the damping oscillation in the speed deviation of UPFC with TLBO-pod has a superior controller compared to UPFC with PI-pod, UPFC and without control in oscillations problem at time 2.75 sec at steady state. As shown in Figures 13 and 14, an active power at buses B2 and B3 during the fault at B2 has been observed. From the results, the damping to the steady-state operating condition of the fault oscillations has significantly enhanced by UPFC device with TLBO technique. Table 2 shows a parametric value obtained for PI controller of the 6-bus test system.
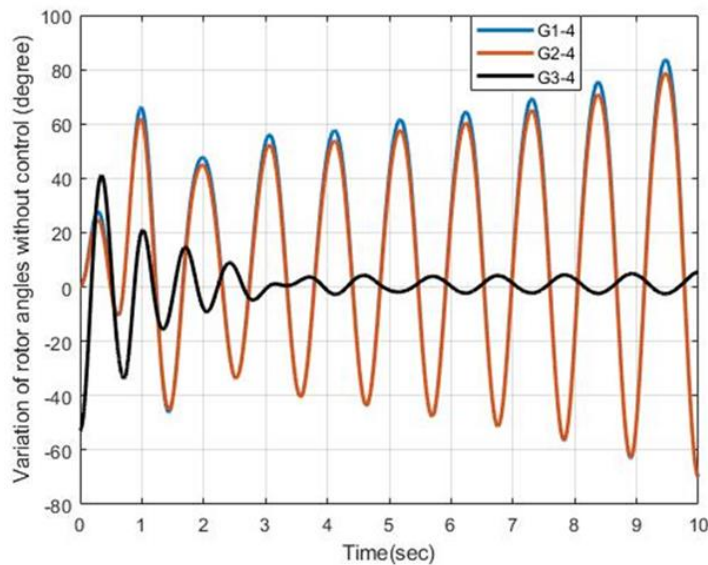

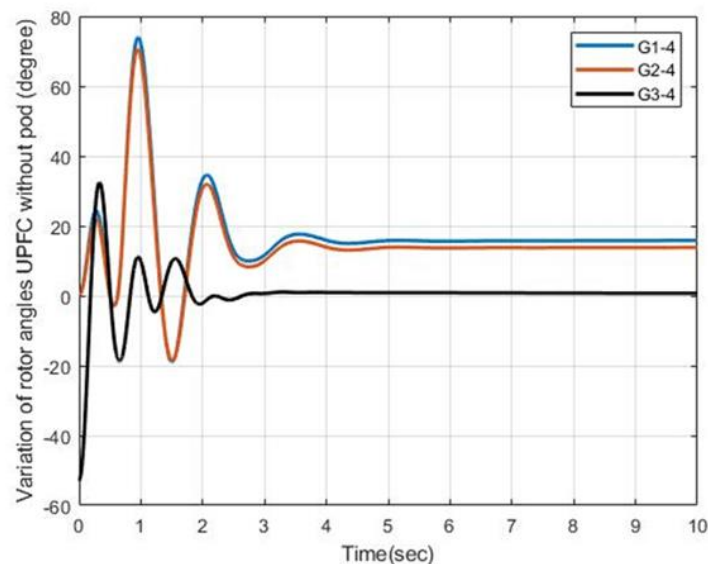**Figure 6.** Relative change in rotor angles between machines without control.

Figure 7. Relative change in rotor angles between machines with UPFC.
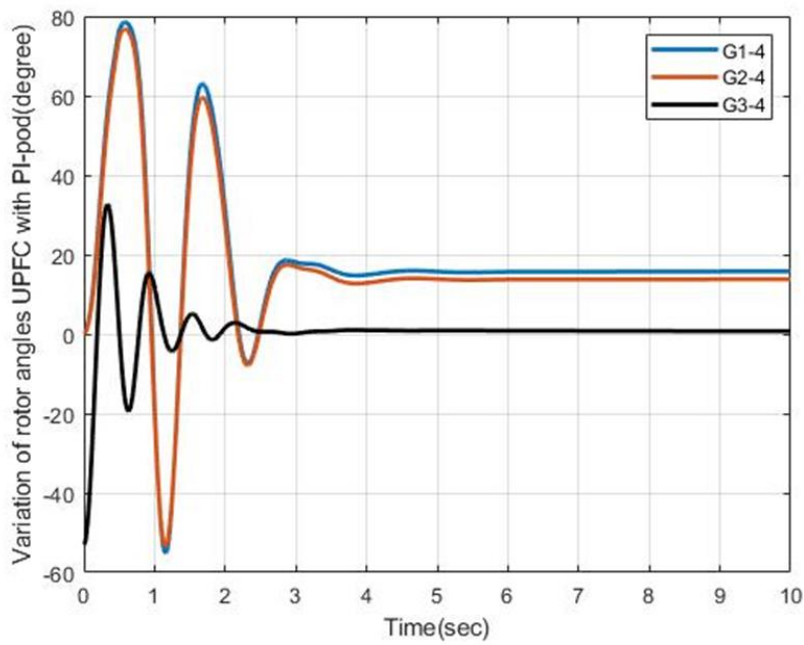
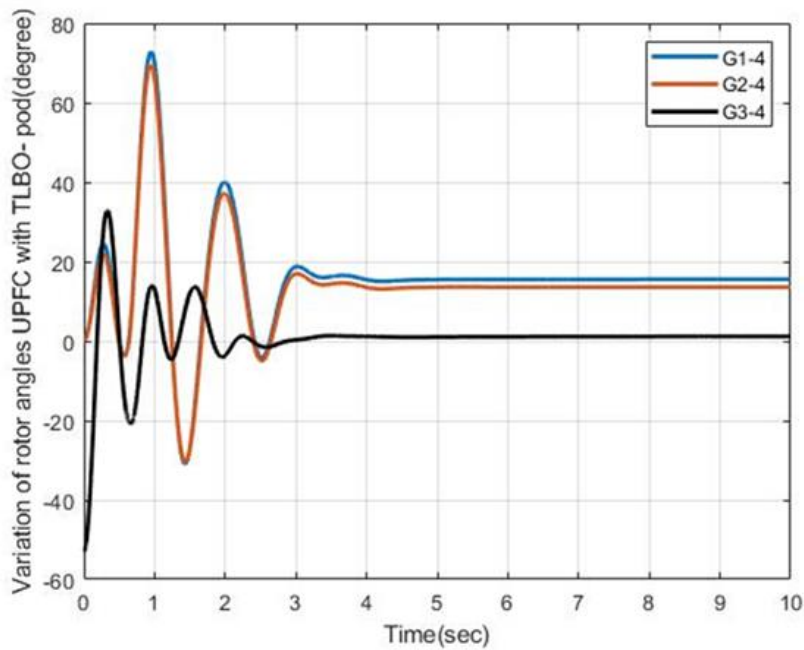**Figure 8:** Relative change in rotor angles between machines using UPFC with PI-pod.

Figure 9: Relative change in rotor angles between machines using UPFC with TLBO-pod.
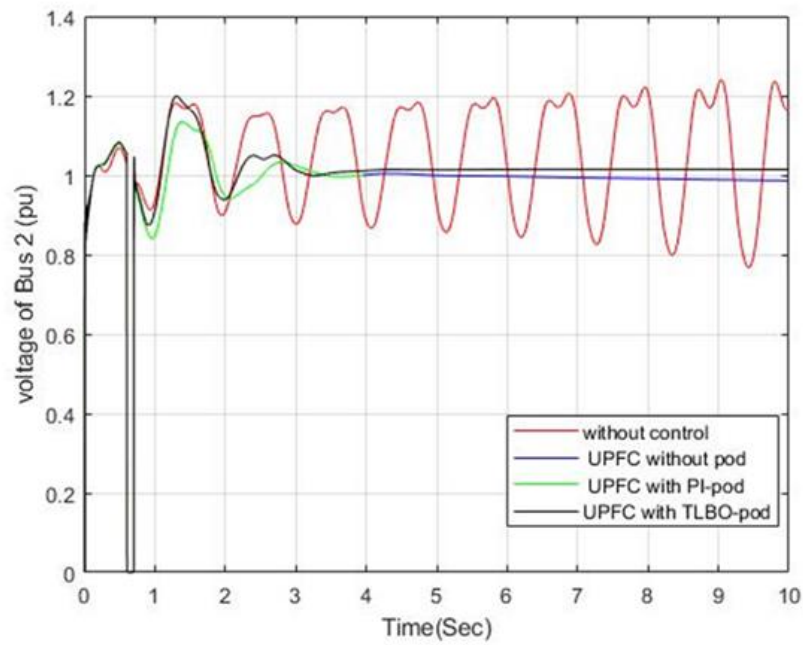
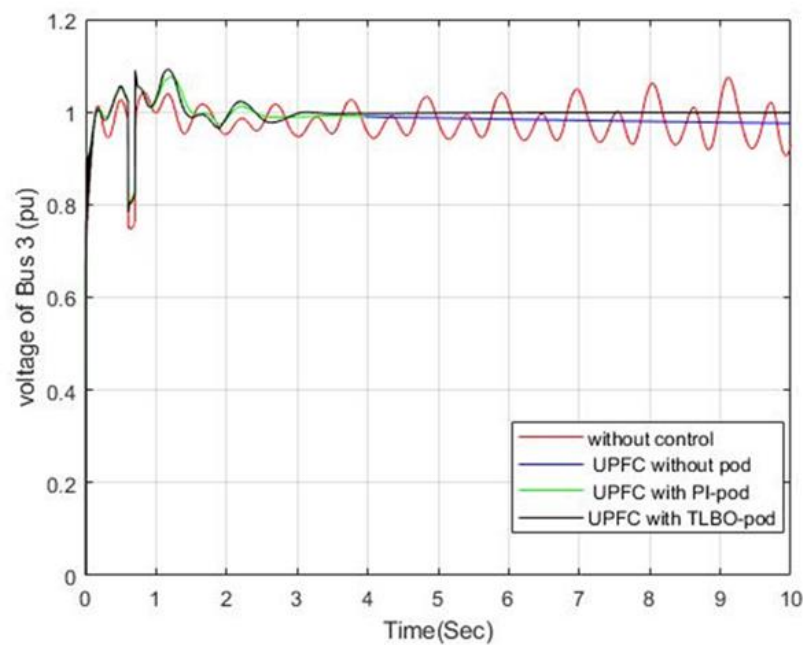**Figure 10:** Voltages of bus 2 with different control methods.

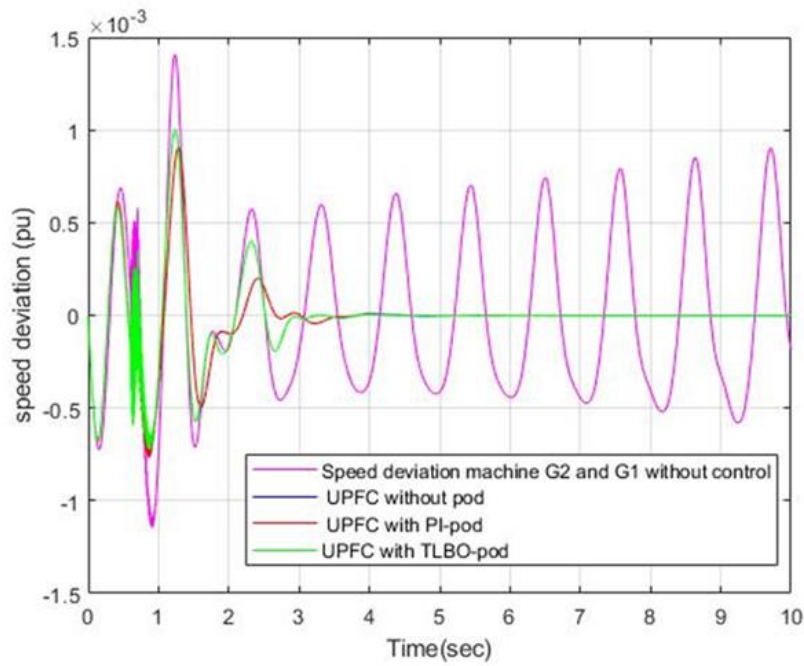**Figure 11:** Voltages of bus 3 with different control methods.

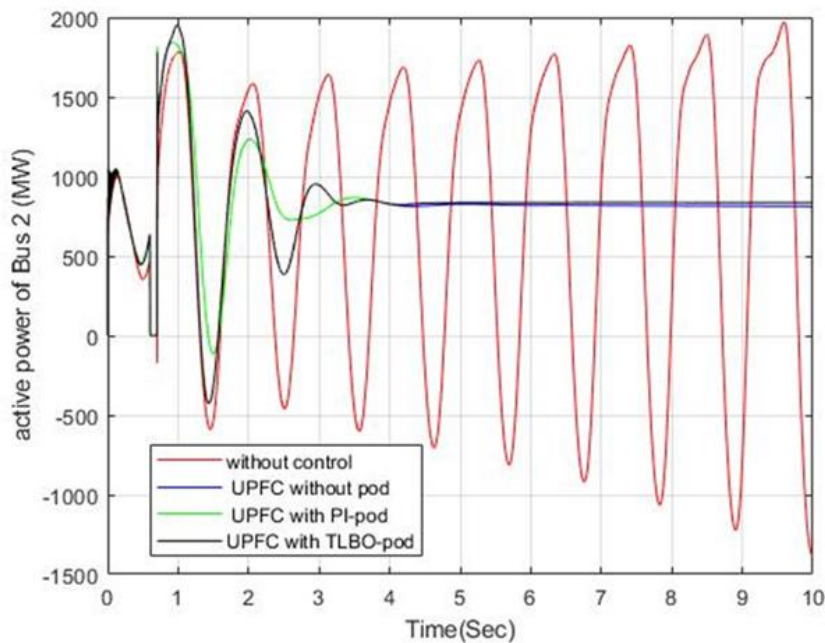**Figure 12:** Speed deviation with different control methods.

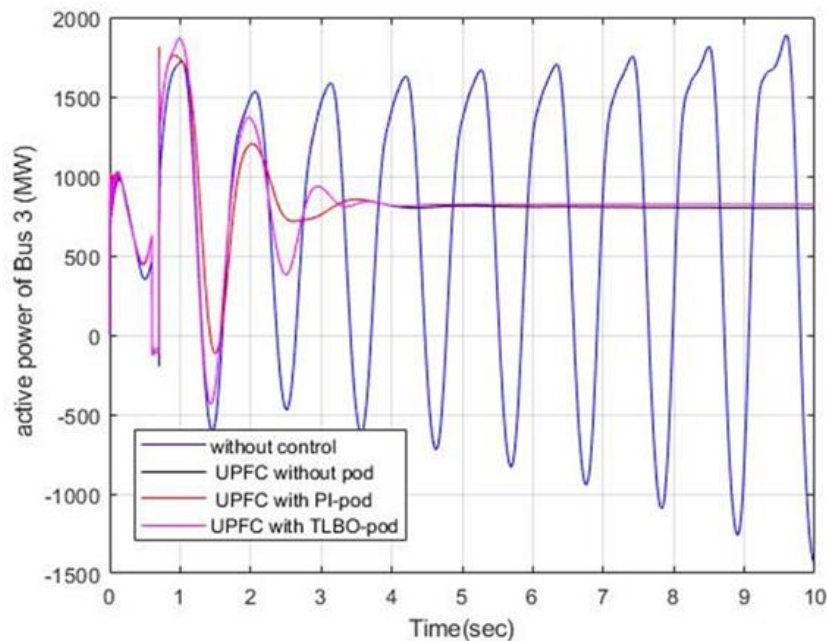**Figure 13:** Power of bus 2 with different control methods.

Figure 14. Power of bus 3 with different control methods.

Table 2. Parametric values obtained for PI controller of the 6-bus test system.

Item	TLBO	Manually
K_P	0.8231	0.8263
K_I	0.5	0.9

7. Conclusion

In conclusion, TLBO technique was used to find an optimization solution and applications of TLBO based UPFC with PSS and POD controller of 6-bus test system of the multi-machine with a three-phase fault as a disturbance to investigate the activeness of the suggested control method. From the results, the system has achieved superior result when the UPFC with TLBO-pod is compared to other methods and the total losses are minimized during the fault. The proposed system with TLBO has better damping characteristics for the interactive energy response.

8. Appendix (A)

The Parameters used in the 6-bus test system in Figure 5.

For all generators of multi-machine power system, consider

V_G= 13.8 KV; R_s= 0.003; f = 60 Hz; X_d= 1.305; X'_d=0.296; X''_d= 0.252; X'_q= 0.50; X''_q= 0.243; T'_d = 1.01; T''_d = 0.053; H = 3.7s. Bus data offer in Table (A.1).

Table (A.1). Bus data.

Bus No.	P_L (MW)	Q_L (MVAR)
1	0	0
2	0	0
3	0	0
4	1000	0
5	6000	0
6	0	0

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