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Comparative Stability Enhancement of Micro-Grid Interconnected Power system with ANFIS and Integer-order Power System Stabilizer

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ABSTRACT

This paper proposes integer order power system stabilizer for the enhancement of inter-area stability. The parameters of this controller are optimizing using grey wolf optimization algorithm. The proposed controller is tested on modified three machine nine bus system and is implemented in MATLAB/Simulink environment. The performance of this controller is compared with ANFIS based power system stabilizer and the results demonstrated that proposed controller improving the inter-area stability effectively.

Key words: Integer order power system stabilizer (IOPSS), Artificial Neuro fuzzy Inference system (ANFIS), Grey wolf optimizer (GWO).

1. INTRODUCTION

PSS is an economical way of removing LFO [1]. A variety of intelligent optimization algorithms have been implemented for the tuning of parameters of PSS in order to enhance the PSS 's efficiency and adaptability, such as genetically modifying algorithms[2], grey wolf optimizations[3].
However, in some conditions, PSS may have limits on the suppression of LFO [5, 6]. PSSs may not provide adequate damping in inter-area modes, particularly in large-scale transmission systems even if they are properly tuned according to China's "Stabilizing System Test Guide" [4]. A bigger benefit for the PSSs is important for PSS to provide adequate damping for the oscillations concerned. Unfortunately, the additional increase in the PSS gain can reduce the damping of additional modes and lead to divergent oscillations [7].
This paper is organized into five sections: first section deals with Introduction, second section focusing on ANFIS based PSS, third section deals with GWO-IOPSS, fourth section is simulation & discussion on results and fifth section is conclusion[11],[12].

2. ANFIS BASED PSS

This Artificial Neuro fuzzy Inference system is basically Mamdani fuzzy inference system and this is mapping input and output characteristics [7]. First input characteristics will be mapped into input Member functions, then input Member functions mapped into rules and rules will be mapped into output characteristics and then output characteristics mapped

Into output membership functions, and finally output membership functions will be mapped to a single valuable output [8].The structure of ANFIS model for PSS of Machine 1 & 2 and flow chart of ANFIS controller and model structures are shown in figures 2, 3, & 4 respectively.

3. INTEGER ORDER CONTROLLER

In this paper, GWO based Integer order power system stabilizer (IOPSS) was proposed for enhancing the stability of power system [4]. IOPSS is a combination of gain block, lead lag blocks and washout block. The number lead lag blocks decided based on the leading angle required [5]. The structure of IOPSS is shown in fig.1.

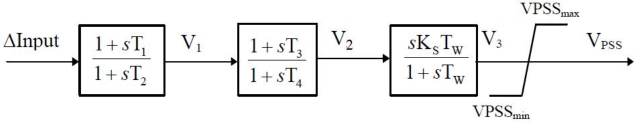

Figure 1: Structure of Integer Order Power System Stabilizer

A typical PSS is given for each generator. Three power stabilizers must be installed for three area power system. For integer controllers, a total of 12 parameters are available out of three generators two are identical so total 10 parameters need to be tuned here.

$$K_{PSS1}, T_{1(1)}, T_{2(1)}, T_{3(1)}, T_{4(1)}, K_{PSS(2)}, T_{1(2)}, T_{2(2)}, T_{3(2)}, \& T_{4(2)} \qquad (1)$$

The Gain parameters (KPSS) and time constants for the integer order PSS controller are adjustable and these parameters affect the system response. Consequently we need an efficient optimization algorithm that ensures the optimal global values for these parameters. This paper uses the GWO algorithm to optimize parameters of IOPSS by minimizing

Integral of Time multiply Absolute Error (ITAE) is shown in fig.5.

Integral of Time multiply Absolute Error of change in speed of all areas was defended as objective function is shown in Fig.5.

$$J = \int_{0}^{\infty} t[(\Delta\omega_1)+(\Delta\omega_2)+(\Delta\omega_3)]dt \tag{2}$$

The objective function J can be minimized by considering by the following system constraints for integer controller.

For machine 1 and machine 2

$$\begin{gathered} K_{PSS(1)}^{Min} < K_{PSS(1)} < K_{PSS(1)}^{MAX}\ ,\ T_{1(1)}^{Min} < T_{1(1)} < T_{1(1)}^{MAX}\ , \\ T_{2(1)}^{Min} < T_{2(1)} < T_{2(1)}^{MAX}\quad T_{3(1)}^{Min} < T_{3(1)} < T_{3(1)}^{MAX}\ , \\ T_{4(1)}^{Min} < T_{4(1)} < T_{4(1)}^{MAX}\ ,\ K_{PSS(2)}^{Min} < K_{PSS(2)} < K_{PSS(2)}^{MAX}\ , \\ T_{1(2)}^{Min} < T_{1(2)} < T_{1(2)}^{MAX}\ ,T_{2(2)}^{Min} < T_{2(2)} < T_{2(2)}^{MAX} \\ T_{3(2)}^{Min} < T_{3(2)} < T_{3(2)}^{MAX}\ ,\ T_{4(2)}^{Min} < T_{4(2)} < T_{4(2)}^{MAX} \end{gathered} \tag{3}$$

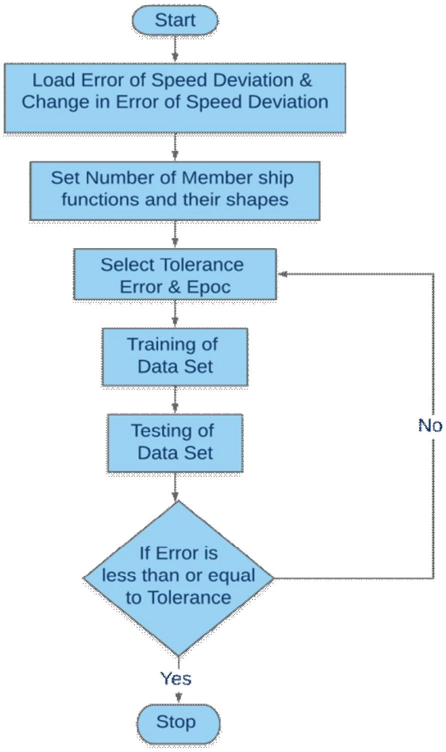

Figure 2: Flow chart of ANFIS controller

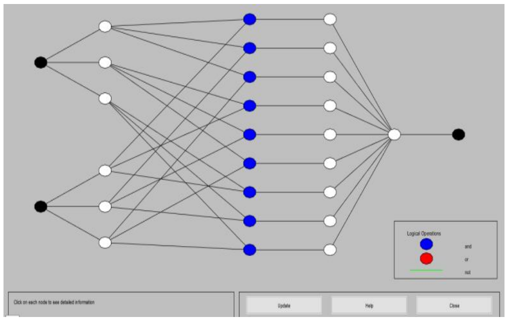

Figure 3: ANFIS Model structure of PSS of M-1

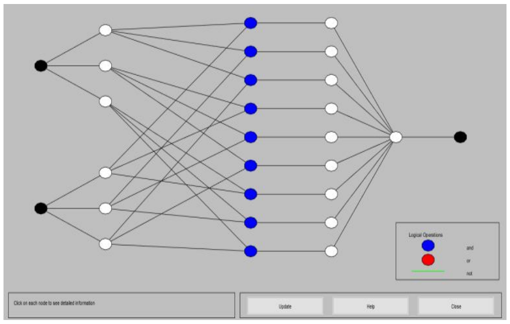

Figure 4: ANFIS Model structure of PSS of M-2

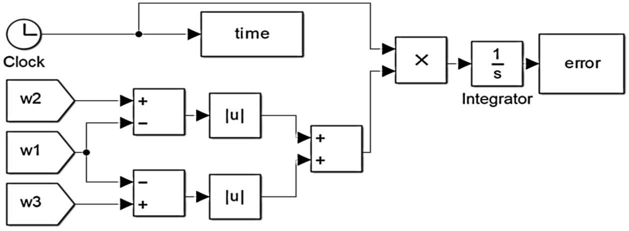

Figure 5: Objective function Simulink diagram

3.1 Grey Wolf Algorithm (GWO)

Grey wolf algorithm has been developed by Mirjalili, a population dependent metaheuristic algorithm [10]. It is inspired by grey wolves and imitates the structure of wolves' leadership and frame. GWO takes three crucial steps; the first step includes searching, searching at the quarry and going on to it. The second stage consists in tracking, circling and disrupting the quarry. The third move is to hitting the quarry. The entire Process is given in flow chart given in Fig-7[9], [10].

3.2 Modeling of IOPSS

In Figure 2 the lead lag PSS structure was used. The control equations are given for this PSS

$$V_{PSS(i)} = \begin{Bmatrix} V_{PSS(\max)} & if\ \dot{V}_3 \geq V_{PSS(\max)} \\ V_3 & if\ V_{PSS(\max)} \succ V_3 \succ V_{PSS(\max)} \\ V_{PSS(\min)} & if\ V_3 \leq V_{PSS(\min)} \end{Bmatrix} \tag{4}$$

$$V_3 = K_{sw}V_2 - \frac{V_3}{T_W} \tag{5}$$

$$V_2 \frac{T_3}{T_4}V_1 + \frac{V_1 - V_2}{T_4} \tag{6}$$

$$V_1 = \frac{T_1}{T_2}\Delta\omega + \frac{\Delta\omega - V_1}{T_2} \tag{7}$$

4. SIMULATION DIAGRAM & RESULTS

Fig.6 is implemented on modified 3-machine 9 bus system with the inclusion of DFIG through MATLAB/Simulink. The simulation results are explained in three cases depends on the type of fault created. Between buses 5 and 7, a three phase fault is created.

A fault occurs in t=5 and has been resolved in 5.1s. Figures 5 to 10 display the load angle change, the speed difference of the Rotor, electric power of each machine, the frequency change of every machine, deviation of the rotor angle are shown in figures 8 t0 19.

The performance comparison is shown in table.1 and from this it is concluded that the proposed controller effectively reducing the settling time, steady state error and peak over shoot.

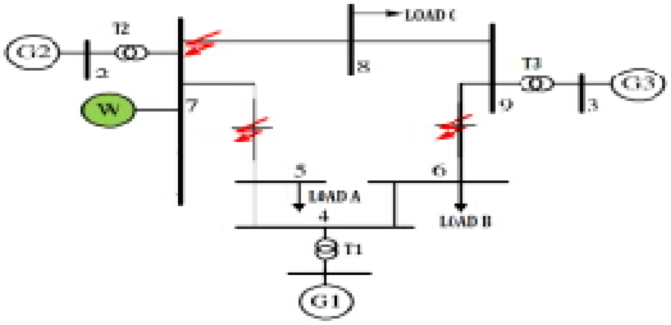

Figure 6: Three machine test system

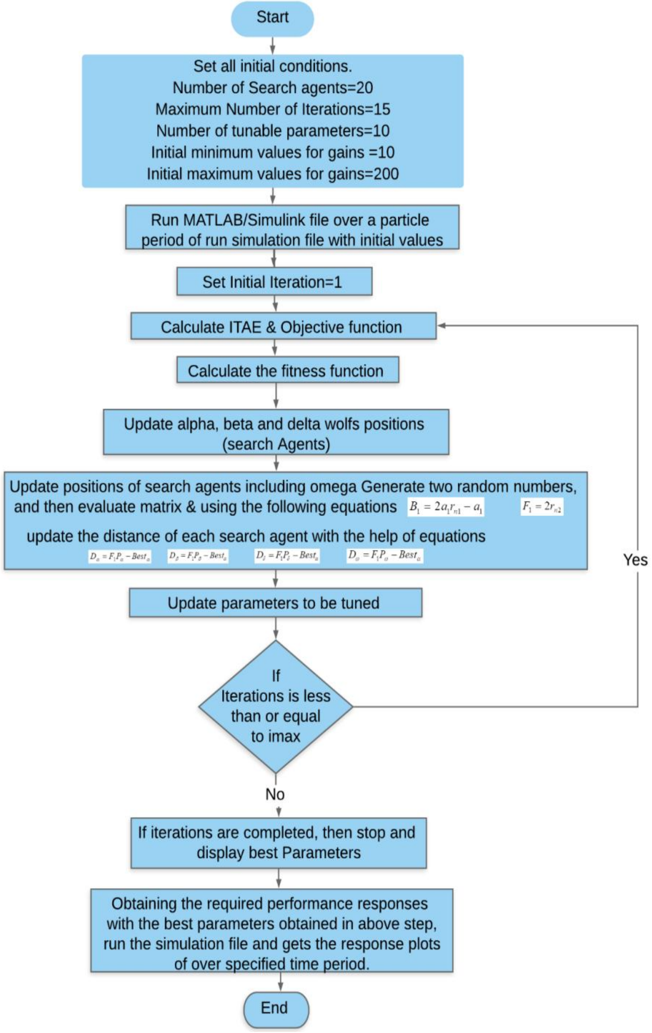

Figure 7: Implementation of GWO algorithm for FOPSS parameter optimization

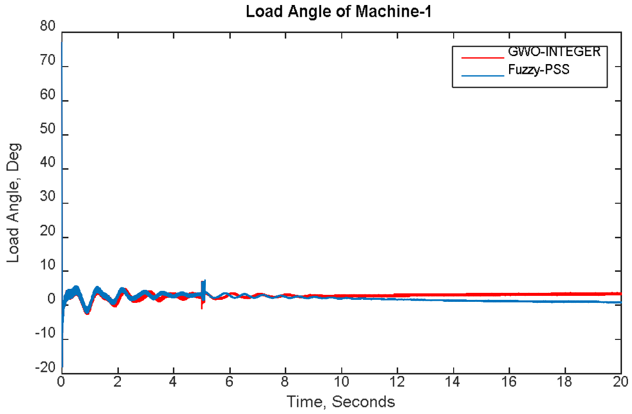

Figure 8: Change in Load Angle Delta of M-1

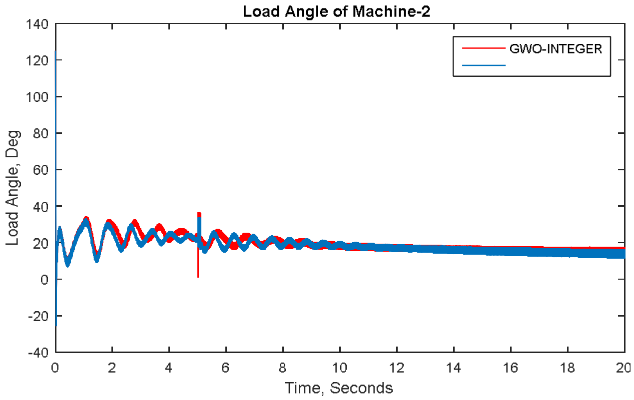

Figure 9: Change in Load Angle Delta of M-2

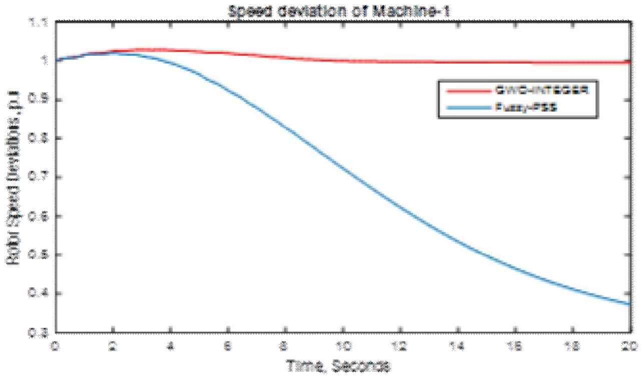

Figure 10: Rotor Speed of M-1

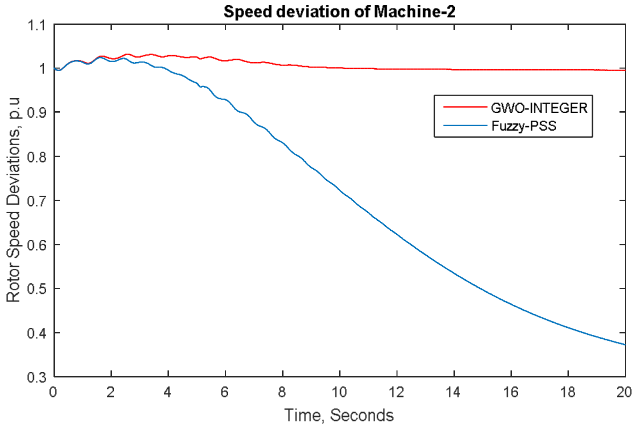

Figure 11: Rotor Speed of M-2

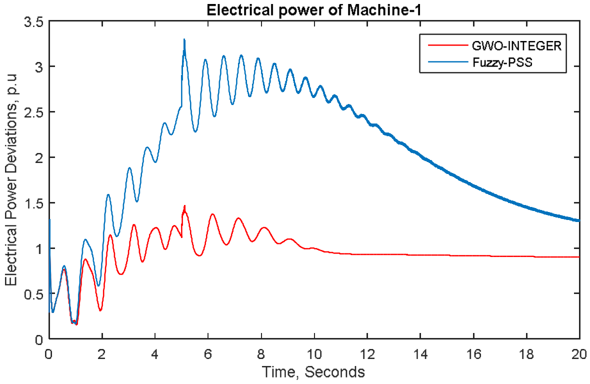

Figure 12: Electrical Power Output of M-1

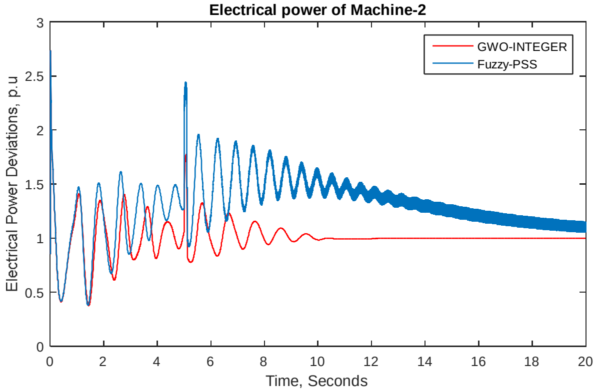

Figure 13: Electrical Power Output of M-2

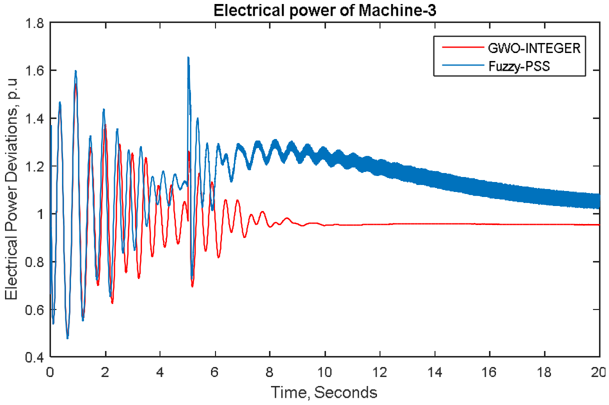

Figure 14: Electrical Power Output of M-3

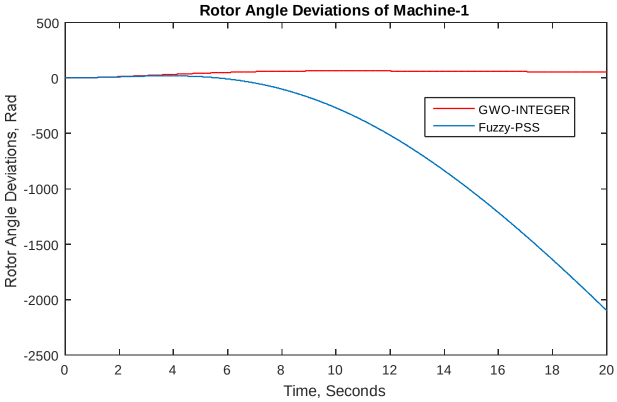

Figure 15: Rotor angle deviation of M-1

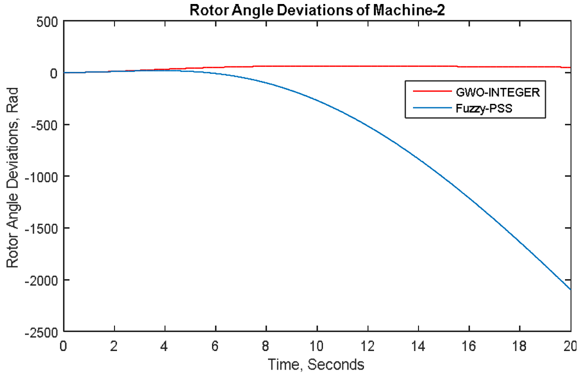

Figure 16: Rotor angle deviation of M-2

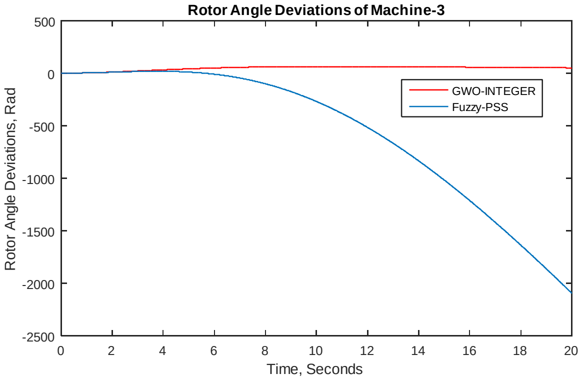

Figure 17: Rotor angle deviation of M-3

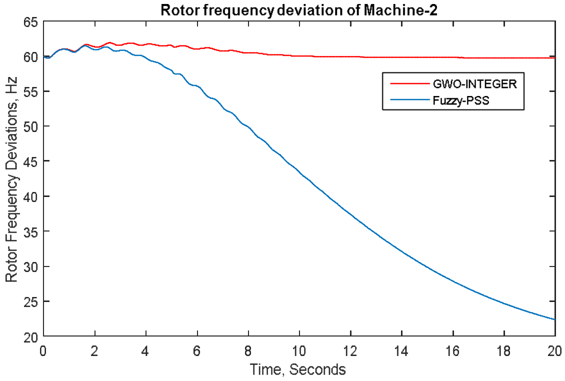

Figure 18: Change of frequency of M-2

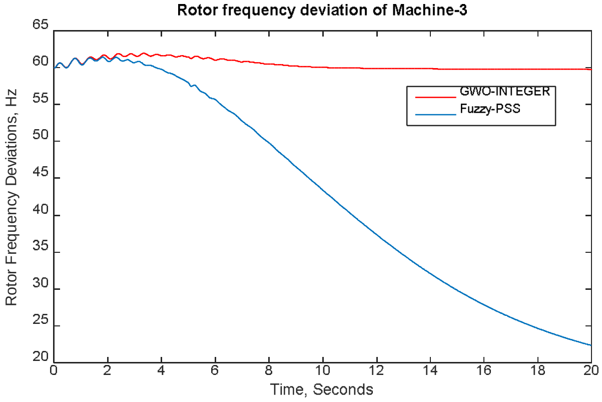

Figure 19: Change of frequency of M-3

Table 1: Various time responses to disturbances of a) Integer PSS & ANFIS PSS

Controller	Performance parameter	Rise Time	Settling Time	Settling Min	Settling Max	Over Shoot	Under shoot	Peak	Peak Time
Fuzzy Logic	**Load Angle Deviations of M- 1**	0.0013	9.0564	-18.1050	7.6244	6.4610e+03	1.5400e+03	77.1337	0
GWO-PSS		0.0013	8.6731	-18.1054	8.9720	1.9687e+03	485.5736	77.1337	0
Fuzzy Logic	**Load Angle Deviations of M- 2**	5.7157e-4	19.997	-25.5449	33.9042	676.1744	158.3779	125.190	0
GWO-PSS		5.6995e-4	19.996	-25.5453	36.7468	633.9629	149.7668	125.190	0
Fuzzy Logic	**Load Angle Deviations of M- 3**	4.2761e-4	19.996	-25.2978	62.6131	464.8615	113.8934	125.466	0
GWO-PSS		4.2627e-4	18.036	-25.2983	62.8108	446.7624	110.2461	125.466	0
Fuzzy Logic	**Speed Deviations of M-1**	11.2770	19.255	0.3724	0.4352	173.9934	0	1.0204	2.0245
GWO-PSS		7.0714	16.554	0.9956	0.9960	3.3828	0	1.0292	3.0162
Fuzzy Logic	**Speed Deviations of M-2**	11.3838	19.256	0.3724	0.4352	175.0434	0	1.0242	1.6187
GWO-PSS		0.0886	16.352	0.9951	1.0315	3.6116	0	1.0315	2.5800
Fuzzy Logic	**Speed Deviations of M-3**	11.3174	19.257	0.3723	0.4352	174.8275	0	1.0233	1.7997
GWO-PSS		17.1276	16.302	0.9955	0.9961	3.6792	0	1.0322	3.3376
Fuzzy Logic	**Deviations of Electrical Power of M-1**	3.9519e-5	19.502	0.1638	3.3055	153.5920	0	3.3055	5.1048
GWO-PSS		2.3744e-5	16.392	0.1531	1.4701	63.4107	0	1.4701	5.1119
Fuzzy Logic	**Deviations of Electrical Power of M-2**	5.3050e-6	19.998	0.3767	2.7334	148.7450	0	2.7334	0.0167
GWO-PSS		3.1749e-6	9.6385	0.3732	2.7334	173.7417	0	2.7334	0.0167
Fuzzy Logic	**Deviations of Electrical Power of M-3**	2.2074e-5	19.999	0.4757	1.6560	57.2411	0	1.6560	5.0172
GWO-PSS		1.6416e-5	8.7756	0.4861	1.5445	61.9932	0	1.5445	0.9177
Fuzzy Logic	**Deviations of Rotor angle of M-1**	9.7109	19.820	-2.0987e+3	-1.8889e+3	0	0.8751	2.0987e+03	20
GWO-PSS		4.2756	19.377	46.4639	62.8517	21.7599	0	62.8517	10.154
Fuzzy Logic	**Deviations of Rotor angle of M-2**	9.7156	19.820	-2.0982e+3	-1.8883e+3	0	0.8884	2.0982e+3	20
GWO-PSS		4.1138	19.384	46.8006	63.2636	21.9379	0	63.2636	10.1548
Fuzzy Logic	**Deviations of Rotor angle of M-3**	9.7137	19.820	-2.0982e+3	-1.8883e+3	0	0.9044	2.0982e+3	20
GWO-PSS		4.2010	19.392	46.8222	63.4699	22.2468	0	63.4699	10.079
Fuzzy Logic	**Rotor Frequency deviations of M-1**	11.2770	19.255	22.3447	26.1102	173.9934	0	61.2231	2.0245
GWO-PSS		7.0714	16.554	59.7336	59.7604	3.3828	0	61.7544	3.0162
Fuzzy Logic	**Rotor Frequency deviations of M-2**	11.3838	19.256	22.3415	26.1106	175.0434	0	61.4533	1.6187
GWO-PSS		0.0886	16.352	59.7042	61.8915	3.6116	0	61.8915	2.5800
Fuzzy Logic	**Rotor Frequency deviations of M-3**	11.3174	19.257	22.3393	26.1106	174.8275	0	61.3992	1.7997
GWO-PSS		17.1276	16.302	59.7283	59.7634	3.6792	0	61.9299	3.3376

5. CONCLUSION

This paper proposes Integer order power system stabilizer for the enhancement of stability and the parameters of this controller are optimized using grey wolf optimization algorithm. The proposed controller is tested on modified three machine nine bus system and the performance is compared with ANFIS based power system stabilizer. The results conclude that the proposed controller effectively improves performance parameters.

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