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Small Signal Stability Enhancement Using GWO Algorithm in SMIB System

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***Abstract*: Power system is a very complex and problem of low frequency oscillation. In this paper FACTs based Static VAR Compensator (SVC) has been used. Here, a structure has been designed in cooperating PSS and SVC for the purpose of damping out low frequency oscillations. The system further enhanced by the use of Grey Wolf optimization algorithm by optimizing its parameters. This developed optimized structure is then implemented in the Single Machine Infinite Bus System (SMIB) to analyze its performance. To realize the whole model the platform was provided by the MATLAB/SMIULINK. The system tested without and with PSS and SVC controller tuned by PS & GWO technique to show its vitality and robustness. The various graph obtains of speed deviation at nominal, light and heavy loading conditions. The results obtained have been tabulated and compared in different fault conditions without & with PS & GWO technique.**

***Keywords*: SMIB, GWO Algorithm, SVC, PSS Controller, FACTS.**

1. Introduction

Power system having three major networks which are generation, transmission and distribution. The different fault occur in power system and many time system goes on instability so this is necessary when any fault occur to system that time system is ready to accurate. In this paper various types of faults in presented in single phase infinite bus system and in this condition

So, it is essential to keep the stability parameters within permissible limit. So, to reduce such issues proper damping of these oscillations is required. But for large interconnected network it is too much critical task to eliminate these issues [1]. Presently various power electronics-based semiconductor devices are used to resolve these issues and maintain stability [2]. In this paper the system is used GWO tuned PSS structured SVC controller is applied on SMIB system [3]. The system is tested on various types of loading conditions as nominal, light and heavy. When various loading is applied to the system shows high oscillatory response but when system is tuned with GWO algorithm PSS structure SVC controller shows superior result [4]. The oscillation is damp out very fast and improves stability of the system [5].

A. *Objective Function*

To minimize such oscillations and improve stability SVC-PSS based controller is designed. In this thesis, objective function J is chosen as an integral time absolute error (ITAE) of speed deviation Δω [6].

ITAE is taken as objective function J which is formulated as follows:

Where,

$\Delta\omega(t)$ = Absolute value of speed deviation which follows a disturbance,

t_{sim} = Range of simulation time

To improve system response objective function parameters are minimize by controlling SVC parameters

$$J = \int_0^{tsim} t|\Delta\omega(t)|dt \tag{1}$$

For SVC controller:

$$K_S^{min} \le K_S \le K_S^{max} \tag{2}$$

$$T_{1S}^{min} \le T_{IS} \le T_{IS}^{max}$$

$$T_{2S}^{min} \le T_{2S} \le T_{2S}^{max}$$

$$T_{3S}^{min} \le T_{3S} \le T_{3S}^{max}$$

$$T_{4S}^{min} \le T_{4S} \le T_{4S}^{max}$$

For PSS Controller

$$K_{PS}^{min} \le K_{PS} \le K_{PS}^{max} \tag{3}$$

$$T_{1P}^{min} \le T_{1P} \le T_{1P}^{max}$$

$$T_{2P}^{min} \le T_{2P} \le T_{2P}^{max}$$

$$T_{3P}^{min} \le T_{3P} \le T_{3P}^{max}$$

$$T_{4P}^{min} \le T_{4P} \le T_{4P}^{max}$$

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2. System Model

A. SMIB System with PSS Structured SVC Controller

Fig. 1 shows Simulink model of PSS structured SVC controller. The various blocks are connected together and then apply a proper input parameter and join a design manner. The various blocks are as SVC, exciter, three phase fault, transformer, motors and circuit breakers PSS structure with SVC, load blocks etc. The given scheme dealt with the low frequency oscillations disturbing the operation of SMIB. These disturbances are suppressed the by installing PSS structured SVC controller [7]. To further improvise its performance, its parameters are optimized using GWO technique. To realize the model, it is developed in SIMULINK where it is performance is evaluated while comparison with system without controller, with GWO.

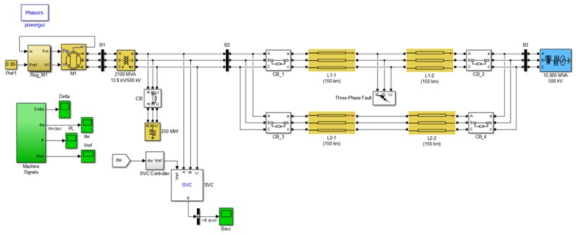

Fig. 1. SMIB using SVC controller in MATLAB

3. GWO Tuned PSS Controller

A. Grey Wolf Optimizer (GWO)

The Grey Wolf Optimisation (GWO) method is an optimisation algorithm inspired by nature that simulates the social structure and hunting habits of grey wolves in the wild. It is mostly employed in data science, engineering, and other computational domains to solve optimisation challenges [15].

B. Key Features of GWO

1) Inspired by Gray Wolf Hierarchy

1) *Alpha (α):* The leader, who stands for the greatest answer thus far.
2) *Beta (β):* The second-best solution, helping the alpha.
3) *Delta (δ):* The third-best solution, helping the alpha and beta.
4) *Omega (ω):* The rest of the pack, standing in for the remaining candidate solutions.

2) Hunting Practices

The algorithm mimics the following steps in the hunting process:

- *Encircling victim:* Using mathematical formulae, wolves encircle the victim.
- *Attacking Prey:* The position updates concentrate on convergently reaching the best solution as the wolves get closer to the prey.
- *Finding Prey:* To ensure diversity, wolves spread out to investigate the search area.

Fig. 2 shows the grey wolf social hierarchy of GWO algorithm.

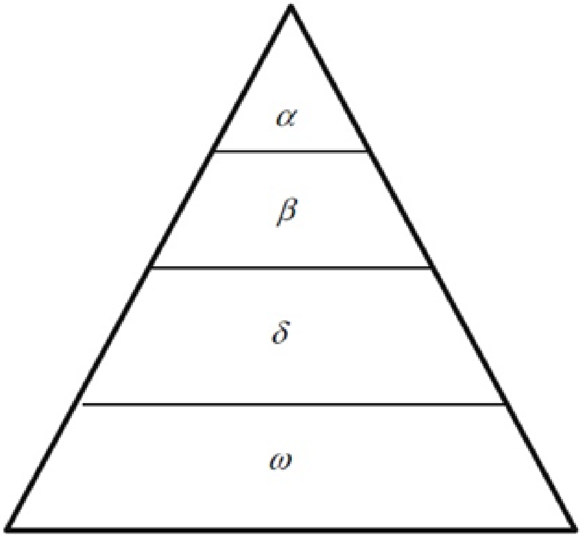

Fig. 2. Grey wolf social hierarchy

3) GWO Flow Chart Steps

Fig. 3 shows flow chart of GWO different steps perform by different agent and find out by best solution of the system [14].

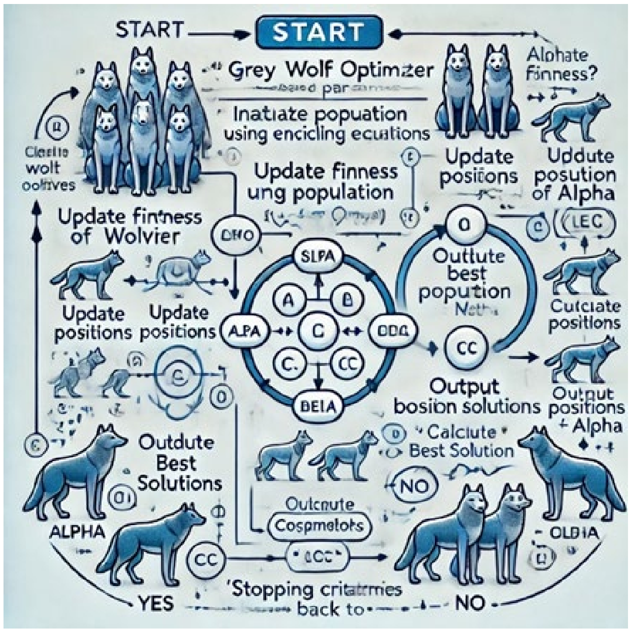

Fig. 3. GWO Flow Chart Diagram

C. PSS Controller Tuned by GWO

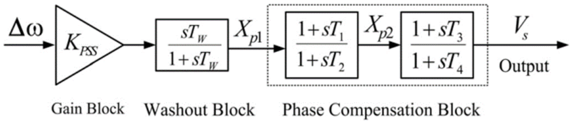

Fig. 4. Block diagram of two stage power system stabilizer

By modifying the controller parameters for optimum performance, a PSS (Power System Stabilizer) controller optimised by the Grey Wolf Optimiser (GWO) is used to improve the stability of power systems [7].

A PSS is employed for: Reduce low-frequency power system oscillations and boost system stability across a range of

Table 1
Various parameters of GWO

S.No.	Parameter	Value
1	Number of Search Agent	30
2	Name of the objective function	ITAE
3.	Max Number of Iteration	50
4	Lower Bound	[1e1 1e-4 1e-4 1e-4 1e-4 1e1 1e-4 1e-4 1e-4 1e-4]
5	Upper Bound	[1e2 1e1 1e1 1e1 1e1 1e2 1e1 1e1 1e1 1e1]
6	Dimensions	10

operational scenarios. Optimising the PSS's parameters is the aim of the process we got Faster settling times, lower overshoot, reduced oscillations.

4. Result and Discussions

They so far discussed proposed system is designed without PSS structured SVC controller a with GWO algorithm. The system is tested on various types of loading conditions as nominal, light and heavy loading. The different loading conditions are tested with various types of faults applied on the proposed system. The various result tested with various graph as speed deviation, in SMIB, PSS stabilizing signal at without controller, with PSS and SVC controller tuned by PS technique and PSS and SVC controller tuned by GWO algorithm. Proposed Model of SMIB system tuned by GWO technique. The various comparisons table presented in tabulation form in the system and its shows superiority of the system.

Table 2
Different loading condition values

S.No.	Cases	Description
1	Case – 1	Nominal Loading (Pe = 0.85, δ = 52.51˚)
2	Case – 2	Light Loading (Pe = 0.5, δ = 29.33˚)
3	Case – 3	Heavy Loading (Pe = 1.0, δ = 60˚)

Table 3
Types of different faults

Types of Faults	Conditions
ftype-1	Single Line to Ground Fault
ftype-2	Three Phase Fault

The various table shows in this system table 1 shows various parameters of GWO and table 2 shows different loading condition values and table 3 shows different types of fault applied to system. These parameters applied to the system and obtain the graph of the system. The GWO parameters optimized the system.

A. Speed Deviation at Single Line to Ground Fault & Three Phase Fault at Nominal Loading Condition

The system applies a nominal loading at with single line to ground fault and three phase faults for speed deviation response with time are shown in fig. 5 and 6. The performance of the proposed controllers is compared without and with controller. The legend 'NC' represents the response no controller which is shown in blue lines, the response with PSS and SVC controller tuned by PS technique and GWO technique are shown black & red lines. So GWO tuned PSS & SVC controller shows better response and the system shows with less overshoot and settling time. Finally, uncontrolled response is poorly damped and controlled response settle down very quickly.

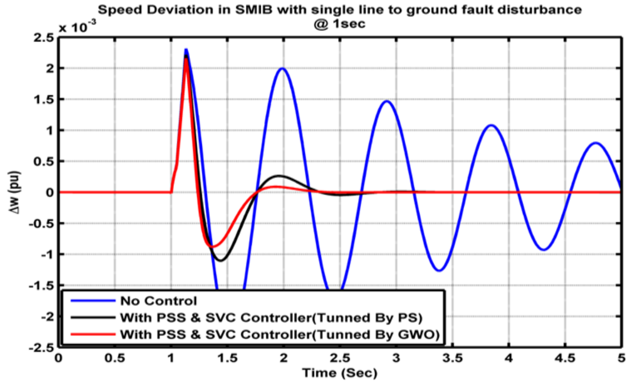

Fig. 5. Speed deviation response for fault type-1 at nominal loading

B. Speed Deviation at Single Line to Ground Fault & Three Phase Fault at Light Loading Condition

The GWO Tuned PSS Structured SVC Controller result is tabulated with their settling time is shown in table 4. The comparison results shows that the same system when optimized without controller & with PS & GWO algorithm. We conclude that when GWO tuned PSS structure SVC controller shows good response. The stability of system is increase and all response shown by fig. 7 and 8. This condition we apply contingency. This contingency effect negligible then we applying tuned controller. The system shows superiority result.

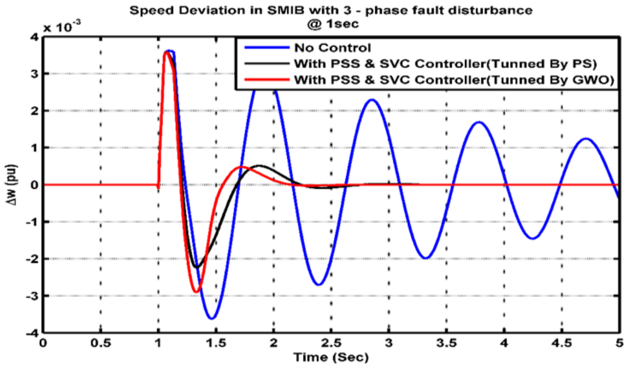

Fig. 6. Speed deviation response for fault type-2 at nominal loading

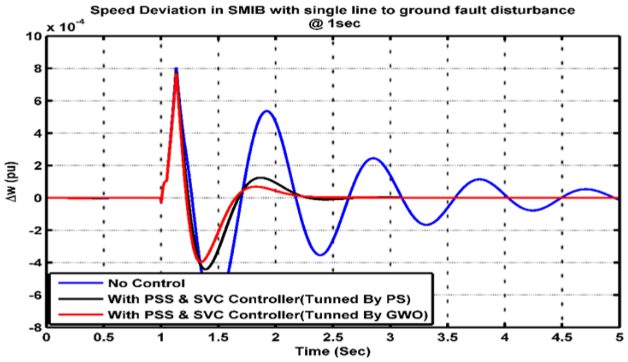

Fig. 7. Speed deviation response for fault type-1 at light loading

Table 4
SMIB System at without controller and with PSS & SVC controller tuned by PS and GWO algorithm at ftype

Types of Faults	**Without Controller (Settling Time) Seconds**	**With PSS & SVC Controller (Tunned By PS) (Settling Time) Seconds**	**With PSS & SVC Controller (Tunned By GWO) (Settling Time) Seconds**
Nominal Loading Conditions			
Ftype-1	Highly Oscillatory	2.2563	2.1381
Ftype-2	Highly Oscillatory	2.5228	2.0451
Light Loading Conditions			
Ftype-1	Highly Oscillatory	2.2083	2.1731
Ftype-2	Highly Oscillatory	2.3980	2.0044
Heavy Loading Conditions			
Ftype-1	Highly Oscillatory	2.6920	2.1928
Ftype-2	Highly Oscillatory	2.6932	2.1902

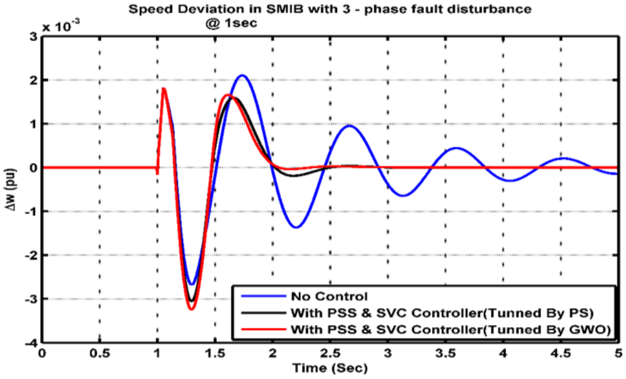

Fig. 8. Speed deviation response for fault type-2 at light loading

C. Speed Deviation at Single Line to Ground Fault & Three Phase Fault at Heavy Loading Condition

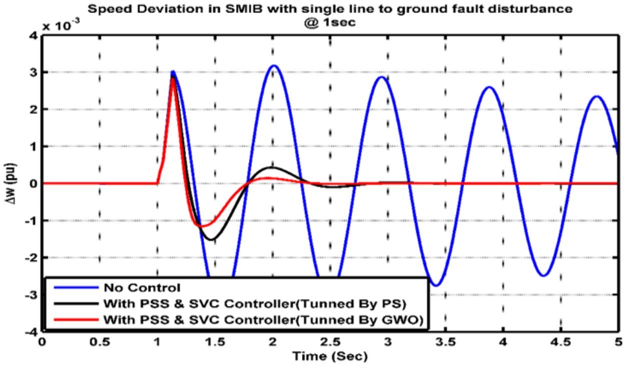

Fig. 9. Speed deviation response for fault type-1 at heavy loading

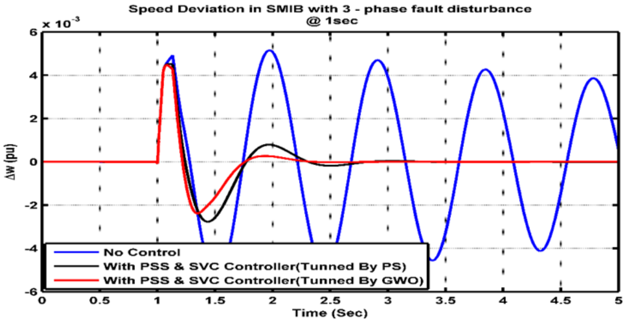

Fig. 10. Speed deviation response for fault type-2 at heavy loading

The system applies a heavy loading at with single line to ground fault for speed deviation response with time are shown in fig. 8 and 9. The performance of the proposed controllers is compared without and with controller. So GWO tuned PSS & SVC controller shows better response and the system shows with less overshoot and settling time. Finally, uncontrolled response is poorly damped and controlled response settle down very quickly. The comparison of different settling time response shows in table 4.

5. Conclusion

Table 4 is tabulated form of various value settling time at different types of deviation at without and with PS and GWO tuned PSS controller at various types of faults at different loading conditions at nominal, light and heavy loading conditions. The various time domain graph plotted with respected time as speed deviation, all condition shows when GWO tuned PSS structure system stability improves and controller control very quickly stabilizes the system. Every condition different contingency applied to system all shows superior response. The system shows superior result both fault conditions.

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