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Optimal Design of Power System Stabilizer Based on Imperialist Competitive Algorithm

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Abstract- In interconnected power systems, a low frequency oscillation (LFO) is one the most important. These oscillations may cause system instability. Power system stabilizer (PSS) is the effective solution. PSS is an extra controller system of a generator's excitation system. In this paper optimal deign of PSS by using Imperialist Competitive Algorithm (ICA) is addressed. The single machine connected infinite bus (SMIB) is the base of designing the PSS and to this purpose Heffron-Phillip's model is simulated.

Keywords- *Heffron -Phillip's model, ICS, LFOs, PSS.*

I. INTRODUCTION

In interconnected power systems, a low frequency oscillation (LFO) is one the most important. These low frequency oscillations (LFOs) are related to the small signal stability of a power system [1-3]. These oscillations may keep growing in magnitude until loss of synchronism results. Heavy power transmitted over weak tie line and high gain automatic voltage regulator (AVRs) is some of factors to create the small signal disturbances [4]. Thus it I necessary control (LFO). For these kinds of studies Heffron-Phillip's Model that showed in figure 1, is used; because this model gives credible results, so that it used to designing the classical power system stabilizers (PSS) [5,6]. PSS is an extra control system for excitation system and it is used in power systems since 1960 and considered by many researchers. Its output signal injected into the summing junction of the exciter block in the generator. In other word, PSS is a help to excitation system to damp out low frequency oscillations of the power system and it can be defined as the ability of synchronous generator to remain in synchronism with each other in the event of possible disturbances.

As figure shows, this model contains two loops; the above loop is mechanical loop and bottom loop is electrical loop.

II. SYSTEM MODELING

Equivalent circuit of synchronous generator connected to grid as a SMIB is presented in figure 2.

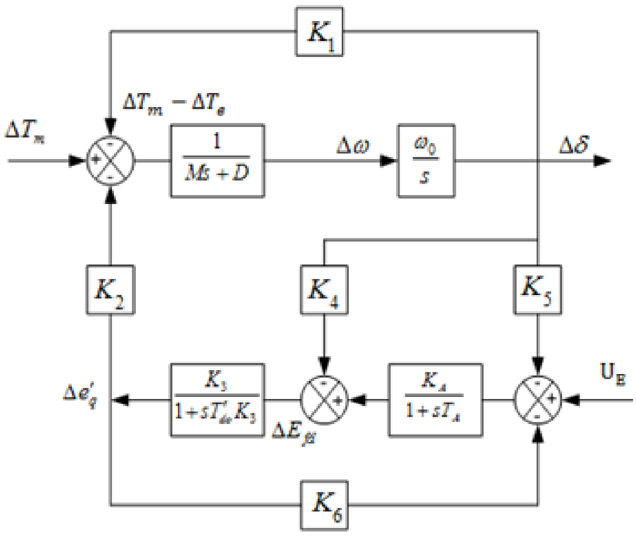

Figure 1. Block diagram of Heffron-Phillip's Model

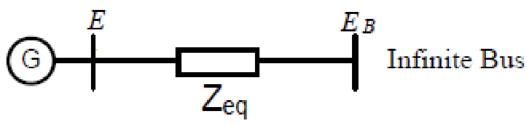

Figure 2. SMIB model

Its mathematical equation is as follow:

$$Ms\Delta\omega = -\Delta T_e = -(K_1\Delta\delta + K_2\Delta e'_q) \quad (1)$$

$$s\Delta\delta = \omega_b\Delta\omega \quad (2)$$

$$(1 + sT'_{do}K_3)\Delta e'_q = K_3(-K_4\Delta\delta + \Delta E_{FD}) \quad (3)$$

$$(1 + sT_A)\Delta E_{FD} = K_A(U_E - K_5\Delta\delta - K_6\Delta e'_q) \quad (4)$$

Value of these constant $(K_1 - K_6)$ are depended on the machine parameters and the system operation.

A. Power system stabilizer configuration

One of the most widely used techniques to deal with low frequency oscillations is the use of power system stabilizers. It is used to increase the damping of synchronous machine [7, 8].

Its configuration is presented in figure 3:

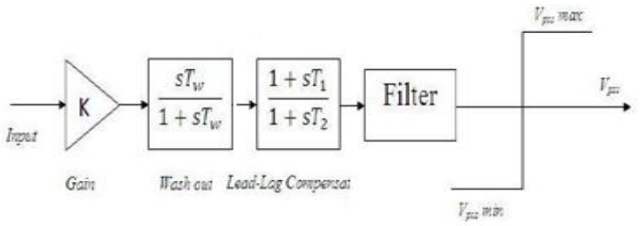

Figure 3. Block diagram of PSS

Gain: amount of damping is showed by PSS gain. In other word, by increasing the gain, the act of damping will be better. its formula is as follow:

$$K_{pss} = \frac{2\xi_n \omega_n}{K_2 |G_c(j\omega_n)||G_E(j\omega_n)|} \quad (5)$$

Washout: The washout circuit works as high pass filter and T_w can be chosen from 1 to 20 second [9].

Pahse compansator: This block has maximum three lead – lag compensators and it is depended on the amount of phase lag of AVR and field circuit of the generator.

Filter: The role of this filter in PSS is attenuating the torsional dynamics of the generator. Because, may result in damage to shaft.

III. IMPERIALIST COMPETITIVE ALGORITHM (ICA)

The Imperialist Competitive Algorithm (ICA) was proposed by Esmaeil and Caro [10], this method is a new socio-politically motivated global search strategy that has recently been introduced for dealing with different optimization tasks. Its flowchart is shown in figure 4 [11].

IV. SIMULATION RESULTS

In this the simulation results is presented. First the behavior of system without PSS and after that with conventional PSS is presented. At end the performance of system by using ICA is presented.

A. Without PSS

The results of system without PSS are presented in figure 5 and 6.

It is clear system is not stable. So PSS is added in next part.

B. With conventional PSS

In this model, PSS is added to previous model as a supplement device. The effect of adding PSS is showed in figure 7 and 8.

Fig 7 and Fig 8 shows the speed and angle response of the system operating respectively. From these responses, it is clear that the system with PSS is stable.

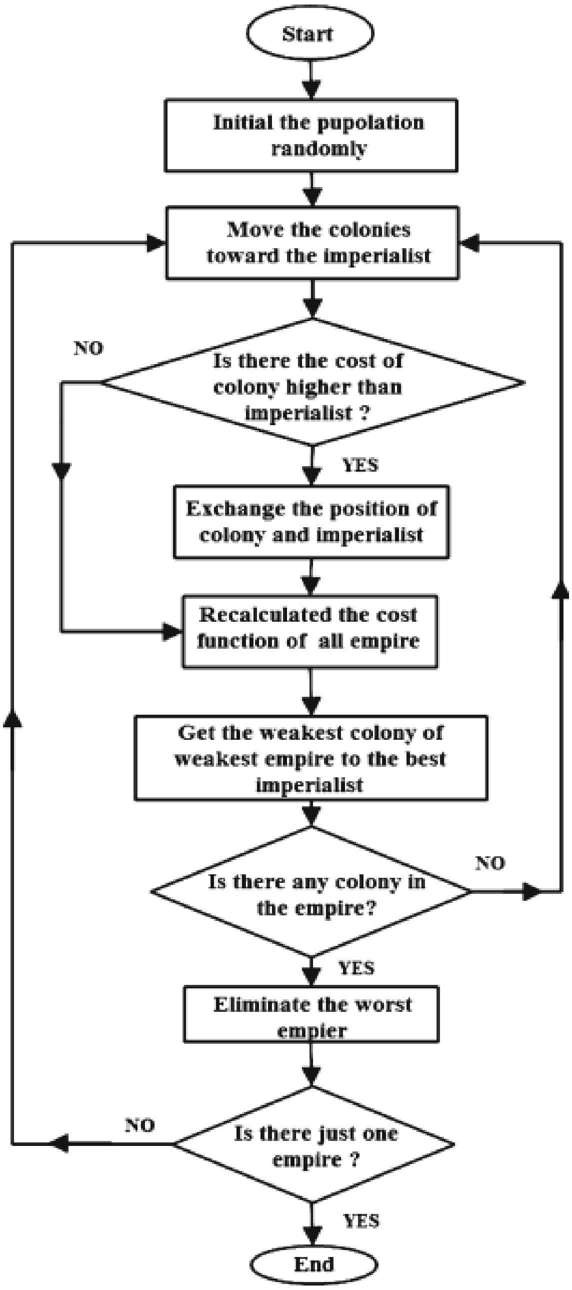

Figure 4. Imperialist competitive algorithm (ICA) flowchart

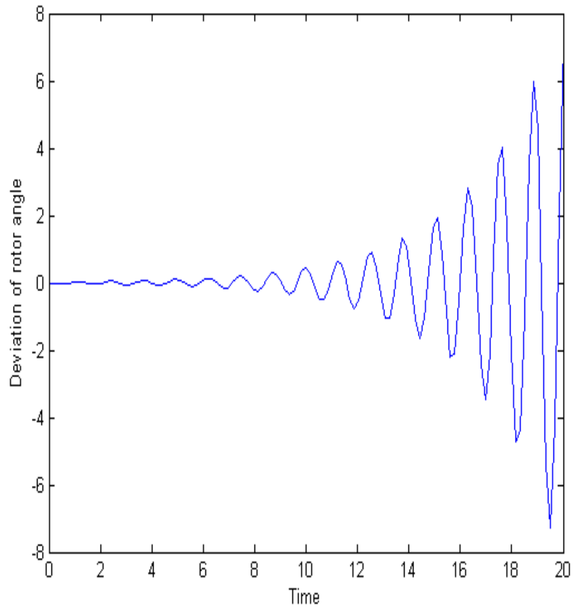

Figure 5. Deviation of rotor angle

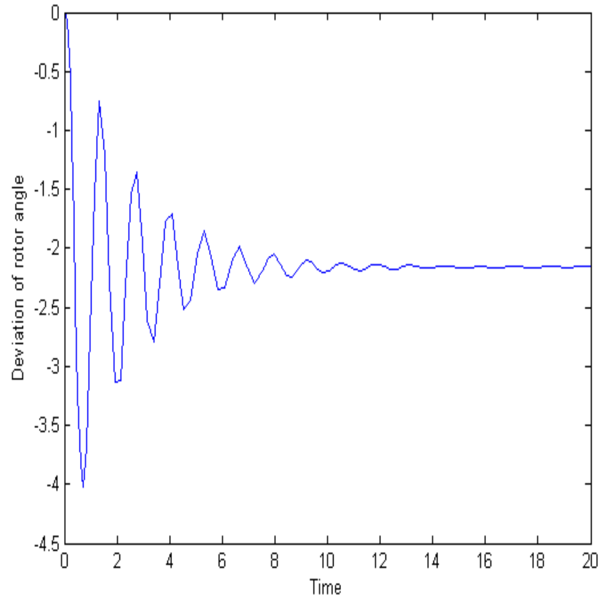

Figure 7. Deviation of rotor angle

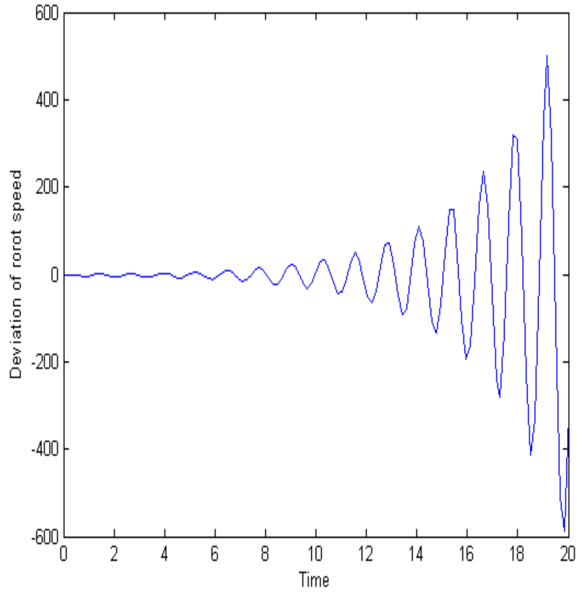

Figure 6. Deviation of rotor speed

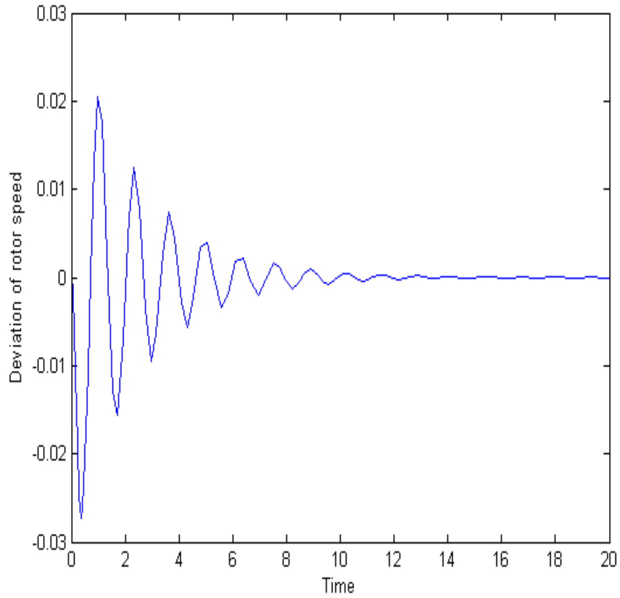

Figure 8. Deviation of rotor speed

C. ICA PSS

In this section the results of the simulation system with ICA is presented Figures 9 and 10 showed the rotor angle deviation ($\Delta\delta$) and the rotor speed deviation ($\Delta\omega$) respectively.

It is clear that the system with ICAPSS provide better damping to the oscillations compared to the system conventional PSS. Figure 10 shows that by using ICA, rotor speed overshoot is reduced to compare with conventional design. Effect of optimization is showed in tables 1 and 2.

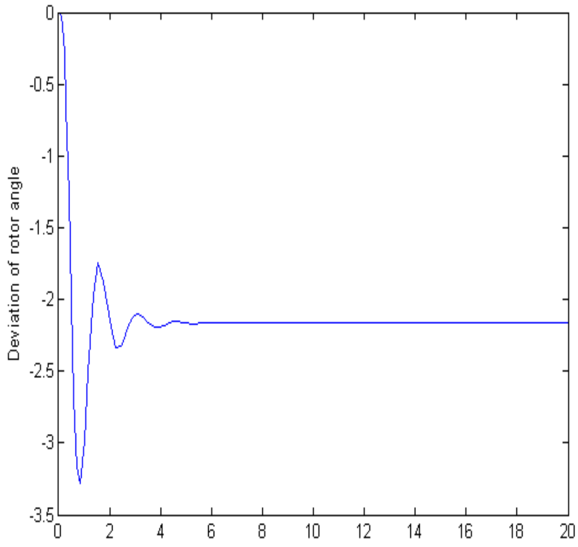

Figure 9. Deviation of rotor angle

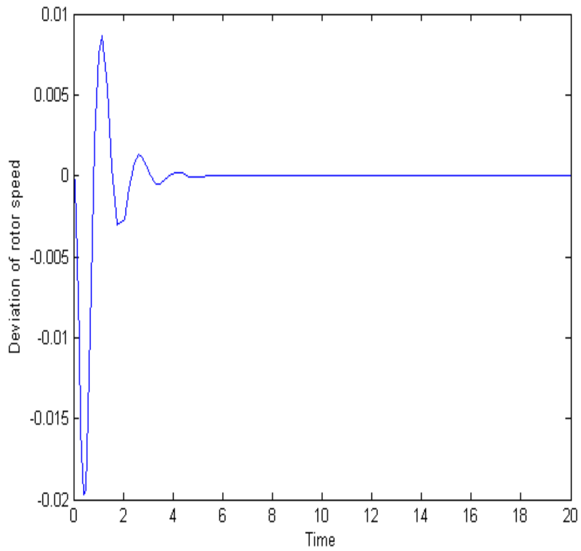

Figure 10. Deviation of rotor speed

TABLE I. OVERSHOOT

	Conventional	ICA
$\Delta\delta$	1.27	0.415
$\Delta\omega$	0.02	0.0086

TABLE II. SETTLING TIME

	Conventional	ICA
$\Delta\delta$	14	5.57
$\Delta\omega$	14.6	5.41

V. APPENDIX

Xd=0.92, X'd=0.296, Xq=0.48, T'do=7.2 sec, Tdo''=0.05, KA=90, TA=0.1, M=8, D=0, Peo=1, Qeo=0.02, Vto=1.05, R=0.034, X=0.997, G=0.249, B=0.262; F=60 Hz.

VI. CONCLUSION

In power systems, Low frequency oscillations (LFOs) are related to the small signal stability of a power system. In this paper Imperialist Competitive Algorithm (ICA) is applied to optimization PSS parameters. To do this work MATLAB/SIMULINK is used. Results show that by using ICA, overshoot and settling time will be reduced. In other words power system performance will be better if we use optimization method to design power system stabilizer.

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