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Application Of Power System Stabilizer At Serir Power Plant

***T. Hussein, **A. Shamekh**
Electrical and Electronics Dept
University of Benghazi
Benghazi- Libya
*Tawfiq.elmenfy@uob.edu.ly
**Awad.shamekh@uob.edu.ly

***Salh ABDALLA, **Salah Bohliqa**
General Electricity Company of Libya
Benghazi, Libya
*salih.abbar@yahoo.com
**Zwuitina@yahoo.com

***Abstract*—Power system instability as a result of Serir power plant of one of the largest power plants of the general electricity company of Libya (GECOL) prevented the plant to be fully utilized specially at base load. Power system stabilizers (PSSs) were installed on the generating units of the power station at 2008, to improve its small and large signals stability, and enhance the stable generation limit. Particle Swarm Optimization (PSO) is used to determine the parameters of (PSS2A) off-line. A bench mark simulation problem of a single machine infinite bus power system equipment with gas turbine model is exploited to demonstrate the performance of the static excitation (ST1A) and PSS2A. The simulation results clearly indicate the effectiveness and validity of the studied PSS2A with updated parameters.**

Keywords—power system stabilizer, static excitation system, swarm optimization technique.

I. INTRODUCTION

The power system is a complex nonlinear due to wide range of operating conditions, unpredictable fault locations and the loading conditions changing from time to time.

The power system stability can be defines as that property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance.

Rotor angle stability is the ability of the interconnected generators of the power system to remain in synchronism. The stability problem involves the study of the electromechanical oscillations inherent in power systems.

The common factor in this problem in the manner in which the electrical power of generators vary as their rotor oscillate [1].

To solve this problem supplementary control signal adds to the automatic voltage regulator called Power System Stabilizer (PSS) which adding phase lead to compensate for phase lag which coming from automatic voltage regulator (AVR) time constant.

The basic function of the PSS is to add damping to the generator rotor oscillations by controlling its field current and voltage using excitation system by auxiliary stabilizing signal. To add damping, the PSS must produce a component of electrical torque in phase with speed variations.

When system runs under AVR mode, the generator is the control plant. The PSS function is disabled and the output is zero. When PSS is enabled, the control plant becomes AVR and PSS controls which closed control loops in excitation system [2].

The mathematic model of the generator, AVR and PSS are analyzed and the system transfer function in presence of the PSS is derived in [2], base on the transfer function, a new tuning method is introduced which does not require all the system parameters. It is an experiment based tuning method. Frequency response tests are at the core of the method [2]. An analysis of the phenomena of stability of synchronous machines under small perturbations by examining the case of a single machine connected to a large system through external impedance, and studies the effect of conventional stabilizers and automatic voltage regulator gain (K_A) on electrical torques components at different loading conditions introduced in [3], that system after adding stabilizers model that taken under study be more stable especially at light, normal, and at heavy loads, but about the effect of AVR gain (K_A), it is concluded that the (K_A) hasn't any effect to change the response of the system. Study shunt compensation in power system to improve steady-state stability and security performance introduced in [4]. The optimization problem of tuning of lead-lag Power System Stabilizer (PSS) to damping the oscillations in single machine infinite bus power system with multiple design requirements were considered in [4], the design requirements are considered as both time domain and frequency domain specifications which are initially specified before designing the PSS, the optimization based linear control design technique is used to determine the optimal controller parameters and tested

for various disturbance conditions for damping of oscillations while satisfying the design requirements. Deals with a design technique for the stability enhancement of a multi-machine power system using PSS in each machine which their parameters are tuned using particle swarm optimization technique PSO (PSO-PSS) introduced in [5]. Simulation results show that the (PSO-PSS) method guarantees robust performance under a multi of operating points.
This paper introduces simulation problem of a single machine infinite bus power system to demonstrate the performance of the static excitation (ST1A) and re-tuned power system stabilizer PSS2A.

II. STA1 FAST STATIC EXCITATION SYSTEM

The static excitation equipment converts a 3-phase alternating current into a direct current which is used to generate the magnetic field in the synchronous machine. The excitation current can influence the machine voltage, the reactive power and the cos φ. Furthermore, the active power and/or the rotor displacement angle can be dynamically influenced (not stationary).
All components in these system are static or stationary, static rectifiers, controlled or uncontrolled, supply the excitation current directly to the field of the main synchronous generator through slip rings [1].
Type ST excitation systems in Fig. (1), in which excitation power is supplied through transformers or auxiliary generator windings and rectifiers.
In this type of system, the inherent exciter time constants are very small, and exciter stabilization not required.
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The PI controller has to be converted to lead-lag filter.

The parameters are listed in Appendix A.

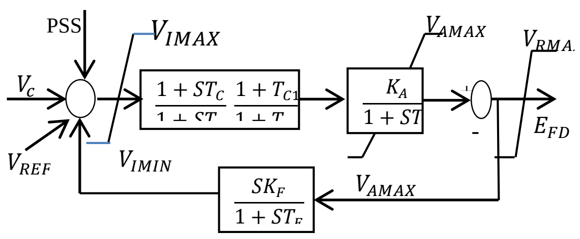

Fig. 1, Type ST1A Excitation Model System

III. POWER SYSTERM STABILIZER (PSS2A)

Nowadays, Integral-of-Accelerating Power Stabilizer is widely used in power system stable control. The typical PSS is IEEE standard PSS2A(B) model as shown in Fig. (2).The input signals are the angular frequency of the rotor (ω) and the electrical power (P_e), the two wash-out filters (T_{W1}, T_{W2}) eliminate the steady state components of the inputs signals [6]. (T_6& T_7) represented the input filters. K_{S2} is used to adapt the scaling of the two inputs and should be equal to ($T_7/2H$), where H is the inertia constant of the generator and turbine. The ramp tracking filter (T_8, T_9 ,M and N) is a low pass filter that eliminate any high frequency components. K_{S1} determine the gain of the stabilizer and the lead-lag stages with non-windup limiter (T_1, T_2, T_3, T_4) provide phase compensation [7]. Fig. of PSS2A is shown in Appendix (A). The setting of PSS2A are listed in Appendix B

IV. OVERVIEW OF PARTICLE SWARM OPTIMIZATION (PSO)

The PSO concept [8] is to change the velocity of each particle toward its global ($gbest$) and local ($pbest$) locations at each iteration [6]. The modified velocity of each agent can be calculated using the current velocity and the distance from pbest and gbest as shown below :

$$v_i^{k+1} = w_i v_i^k + c_1 r \times (pbest - s_i^k) + c_2 r \times (gbest - s_i^k) \quad (1)$$

where,

v_i^k : velocity of particle i at instant k,

v_i^{k+1} : velocity of particle at instant $(k+1)$,

$rand()$: random number between 0 and 1,

s_i^k : position of particle i at instant k ,

$pbest$: pbest of particle i ,

$gbest$: gbest of group,

w_i : inertia weight factor,

c_i : acceleration constant

The current position (searching point in the solution space) can be modified by the following equation.

$$s_i^{k+1} = s_i^k + v_i^{k+1} \quad (2)$$

The PSO algorithm

The proposed algorithm to search for the optimal value of the power system stabilizer (PSS1A) parameters using PSO can be summarized as follows:

1. Initialize the swarm with initial positions and velocities.

2. Calculate the fitness function of each particle by Integral of the Square of the Error (ISE):

$$ISE = \int_0^t e^2 dt \, . \qquad (3)$$

Where,

$e = \omega - \omega_d$

ω : actual speed

ω_d : desired speed

3. Determine $pbest$ and $gbest$ positions.
4. Update the particle velocity using Eq. (1).
5. Update the particle position using Eq. (2).
6. If the evaluation value of each particle is better than the previous $pbest$, the value is set to $pbest$. If the best $pbest$ is better than $gbest$, the value is set to $gbest$.
7. If the iterations are exhausted, then go to step 8. Otherwise, go to step 2.
8. Plot $pbest$, $gbest$.

we select the best one which have small error Eq. (3), sometimes we used the controller's gains which got by the PSO as reference values and decreasing the error by changing these gains by trial and error.
The objectives of the designer is to obtain the minimum value of ISE by proper search of PSS2A parameters by PSO.

V. POWER SYSTEM DESCRIPTION

A three-phase generator rated 282 MVA, 20 kV, 3000 rpm is connected to a 230 kV, 10,000 MVA network through a Delta-star 210 MVA transformer.
At t = 1 s, a three-phase to ground fault occurs on the 230 kV bus. The fault is cleared after 3 cycles (t = 1.08 s).
During this system, we will initialize the system in order to start in steady-state with the generator supplying active power and observe the dynamic response of the machine speed deviation and of its active power.

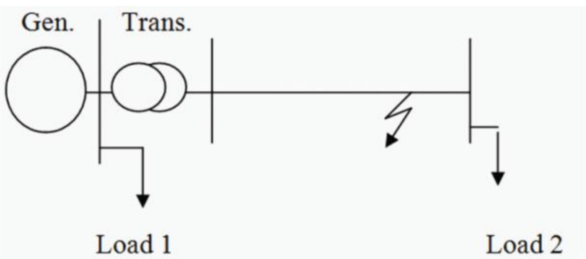

Fig. 2, single machine infinite bus power system

VI. SIMULATION STUDY

The power system stabilizer (PSS2A) Serir Power Plant (SPP) is implemented as shown in Fig. 4. Its parameters are tuned off-lines using the particle swarm optimization (PSO) algorithm, assuming the number of particles to ten and the weighting coefficients $C_1 = 2, C_2 = 2.5$.

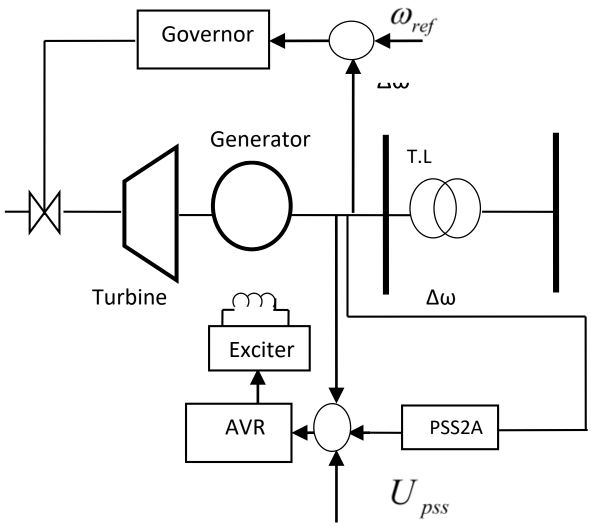

Fig. 3, Power system model used in study

The performance of the PSS2A in SPP is evaluated by applying a large disturbance in the form of a three-phase fault of the transmission line. The fault occurs at 1 sec. and cleared at 0.08 sec.

Three different operating points (cases) are shown here to measure the performance of the power system stabilizer (PSS2A) in SEMIPOL .

Case (1)
Active Power P_e=0.9 pu
Reactive Power Q_e=0.114 pu

Case (2)
Active Power P_e=0.6 pu
Reactive Power Q_e=0.048 pu

Case (3)
Active Power P_e=0.37 pu
Reactive Power Q_e=0.0175 pu

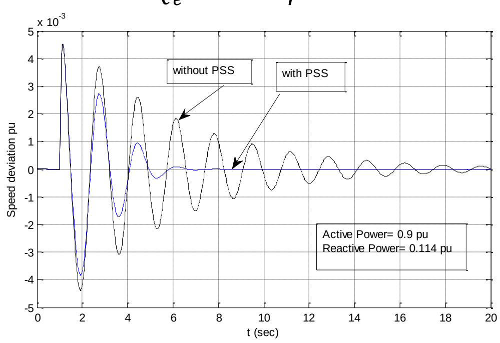

Fig.4 :speed deviation case (1)

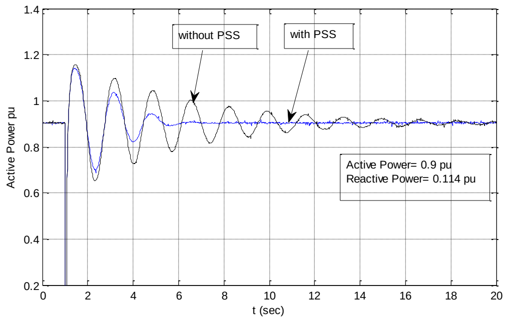

Fig.5 :Active Power case (1)

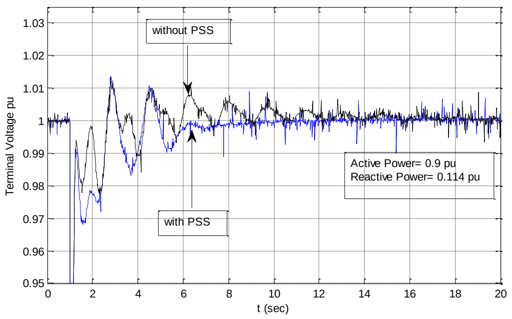

Fig.6 :Terminal Voltage case (1)

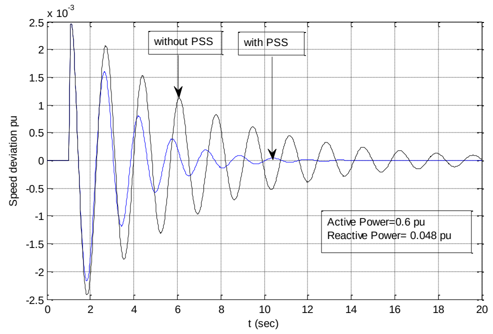

Fig.7 :speed deviation case (2)

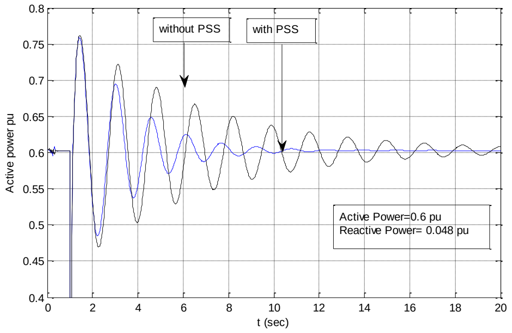

Fig.8 :Active Power case (2)

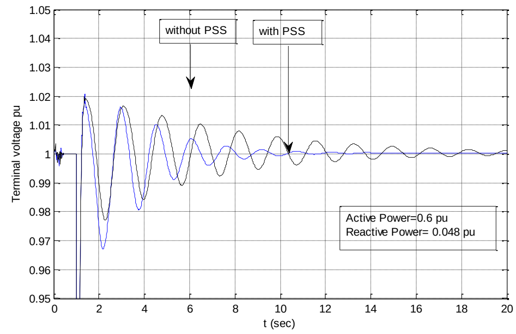

Fig.9 :Terminal Voltage case (2)

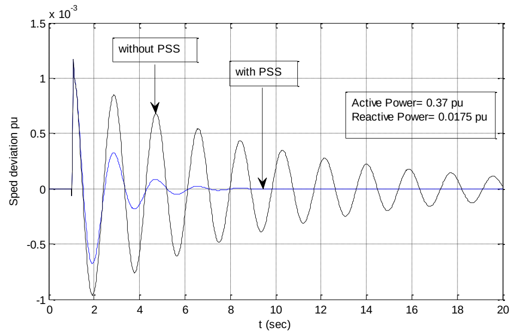

Fig.10 :speed deviation case (3)

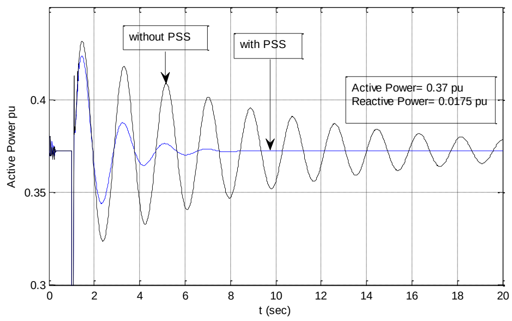

Fig.11 :Active Power case (3)

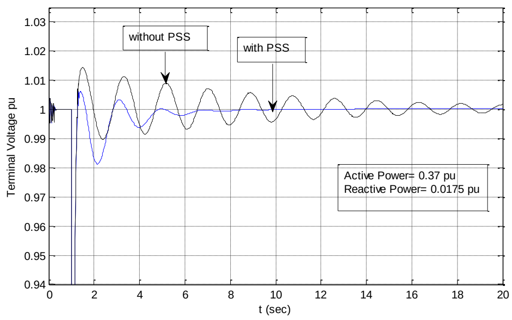

Fig.12 :Terminal Voltage case (3)

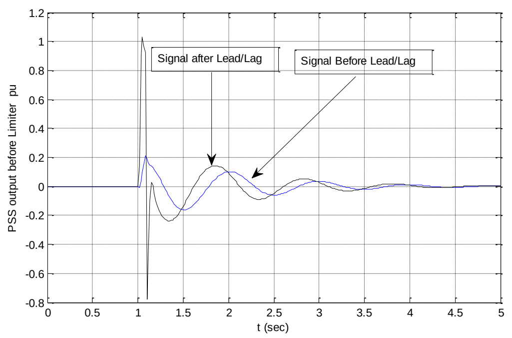

Fig.13 : Signals Before & After Lead/Lag PSS2A

Table I, The performance index of with and without PSS2A for Case (1):.

Controller	*Speed Deviation*
With PSS2A	*0.0015*
Wthout PSS2A	*0.018*

From Fig . 5 to Fig. 13 demonstrate the superiority of the of machine with PSS2A with proposed tuning PSS over the machine without PSS2A both in the transient as well as the steady state periods. This superiority in performance is preserved under change in operating conditions (three cases).

Due to time lag produced by automatic voltage regulator time constant, the function of PSS is to compensate the phase lag by adding appropriate phase lead as shown in Fig. 14. To add damping, and produce a component of electrical torque in phase with speed variations [9]. Hence Fig. 14 shows the phase lead by (0.2 sec.) from phase lag,

VII. CONCLUSION

Power systems could loose synchronism and experience system separation if the low-frequency inter-area modes of oscillations are not damped efficiently. A conventional power system stabilizer can provide adequate damping for a limited range around its tuning point. To enhance the performance of power system stabilizer in Serir power plant, the power system stabilizer PSS2A out of service. Hence when the turbine subject to disturbance the generator oscillate and this oscillate not damped will. In this paper the authors put the PSS2A in service and sereach for optimal parameters . The use of a particle swarm optimization based algorithm has made it possible to tune the PSS2A parameters such that the summation of the square of the error (speed deviations) is minimized as in eq.(3).

Simulation results of the bench-mark problem of a single machine infinite bus system have confirmed the superiority of the machine with PSS2A stabilizer compared to the without PSS2A..

Appendix (A)

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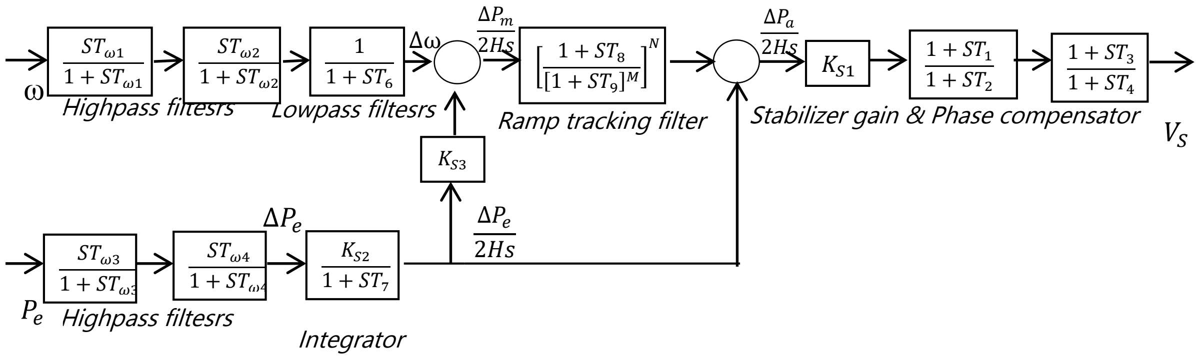

Fig. (2):Power System Stabilizer (PSS2A

Appendix (B)

PSS (PSS2A) parameters

Parameters		Units	Setting
T_{W1}:T_{W4}	Washout filter time constant	Sec.	2.0
T_6	Input filter time constant	Sec.	0.01
T_7	Input filter time constant	Sec.	2.0
K_{S1}	PSS gain	pu	15
K_{S2}	Signal scaling factor	pu	1
K_{S3}	Signal matching factor	pu	0.133
T_1	Lead/Lag Time constant		0.344
T_2	Lead/Lag Time constant		0.182
T_3	Lead/Lag Time constant		0.344
T_4	Lead/Lag Time constant		0.182
T_8	Filter Time constant		0
T_9	Filter Time constant		0.01
M		5	
N		1	
V_{STMAX}	Upper limit of PSS	pu	0.1
V_{STMIN}	Lower limit of PSS	pu	-0.1

Appendix(C)

Static Excitation (ST1A) parameters

Parameters		Units	Setting
V_{IMAX}	Maximum input of regulator	pu	1.0
V_{IMIN}	Minmum input of regulator	pu	-1.0
T_B	Time constant for AVR transient gain	Sec.	2.0
T_C	Time constant for AVR transient gain	pu	25
T_{B1}	Time constant for AVR transient gain	pu	1
T_{C1}	Time constant for AVR transient gain	pu	0.133
K_A	AVR gain	pu	20
T_A	AVR time constant	mSec.	1.8
V_{AMAX}	Maximum internal signal	pu	7.90
V_{AMIN}	Minmum internal signal	pu	-6.95
V_{RMAX}	Maximum output	pu	7.90
V_{RMIN}	Minimum output	pu	-6.95
K_F	Exciter stabilizition gain	pu	0
T_F	Exciter stabilization time constant	pu	1