Design of Robust Power System Stabilizer for Interconnected System

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Abstract— Electrical Power System is one of the most complex real time operating systems. It is probably one of the best examples of a large interconnected non-linear system of varying nature. This system changes it's state time to time with change in load, transmission and generation conditions. Such changes in the system causes small signal oscillations, the frequency range of such oscillations is about 0.2 to 3 Hz, if they are persist for long duration they may limiting the power transfer capability of the system. For the stable and secure operation of the system adequate damping for small signal oscillations is required. A auxiliary controller can provide adequate damping for the system called power system stabilizer (PSS).

Fixed parameter controllers are most commonly used controller for this applications. This is a conventional method of designing power system stabilizer. It gives the better performance for single operating condition only. In this paper a technique for designing a robust power system stabilizer using H_∞ control theory has been discussed. These stabilizers gives the comparable performance for a wide range of operating condition. In case of interconnected system conventional method of designing power system stabilizer is extremely complex, and there is need of system information external to the plant. Modified Heffron-Phillip's model provide solution for this problem, it allow designing power system stabilizers without using system information external to the plant. In this paper modified Heffron-phillip's model has used for designing stabilizer for multi-machine system. PSS at each machine can be synthesized using information available at local buses only.**.**

Index Terms— Power system stabilizer (PSS) , small-signal stability, Heffron-Phillip's model (HP) , Single Machine Infinite Bus (SMIB).

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1 INTRODUCTION

One of the major problems in electrical power system operation is related to the small-signal oscillatory instability caused by insufficient natural damping in the system. The most effective way of countering this instability is to use auxiliary controllers called power system stabilizers (PSS), to produce additional damping in the system [1], [2]. The concept of PSS and their tuning procedures are well explored in [1]–[4]. The fixed gain stabilizers perform reasonably well if they have been tuned properly [5]. Though these stabilizers have simple robust structures, tuning them either by computer simulation modeling [2], [4] or by actual field tests [3] is an involved process which requires considerable expertise and also a knowledge of system parameters external to the generating station. These parameters may not be readily available and may vary during normal operation of the power system. Even in the case of single machine infinite bus model, estimates of equivalent line impedance and the voltage at the external bus are required. The PSS design also requires information of the rotor angle δ measured with respect to an external bus. These parameters cannot be measured directly and need to be estimated based on reduced order models of the rest of the system connected to the generator. If the available information for the rest of the system is inaccurate, the conventionally designed PSS results in poor system performance.

A coordinated PSS design methodology based on damping torques approach for a wide range of operating conditions has been described in [6]–[8]. This method uses P-Vr characteristics obtained by disabling the shaft dynamics of all the machines. However, this formulation is not suitable for very large systems. In [9] a thorough analysis of the frequency responses of generator electrical torques is performed. It is shown that the frequency responses between AVR input and the resultant electrical torque at the rotor shaft has two components. One component is dependent on the associated generator as well as on the network admittance matrix augmented with the generator admittances and the other component depends only on the associated generator. The diagonal dominance property of the admittance matrix makes the first component less affected by the generators external to the generator under consideration. It means that the required dynamic information for the PSS design may be contained mostly within the generating plant. The tuning guidelines of [2] recommend the PSS tuning for a strongest system possible with full loading for speed and power input signals due to the occurrence of maximum phase lag under these conditions. From the above discussions it follows that even if the dynamics of the external generators are ignored as a first approximation and the stabilizer is designed to provide maximum phase lead around the local mode of oscillations, the PSS will still have sufficient lead at the inter area modes which are largely influenced by the dynamics of the external generators. Such PSS will be able to damp out both local mode and inter area modes of oscillation. The present design is based on this presumption.

The method proposed for the PSS design in the present paper is also based on the conventional design

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technique as described in [2] and [4]. However, as opposed to a conventional stabilizer design, the system dynamics are linearized by taking the secondary bus voltage of the step-up transformer (high voltage bus) [10] as reference instead of the infinite bus [11]. The GEP(s) phase characteristics obtained from this model can be treated as that of a strong system having virtually transformer reactance as external reactance with full loading. This model is almost similar to the Heffron-Phillip's (HP) model; however the model parameters are independent of the external system information. This facilitates one to use this model for any machine in the multi-machine environment. Following conventional compensator design techniques based on root-locus and bode plots [12], PSSs are designed independently for each machine. All PSS design parameters are thus calculated from local measurements,

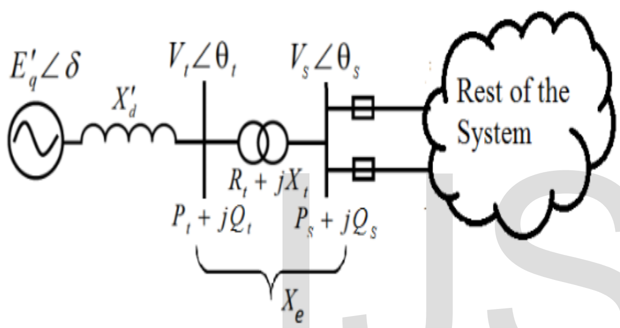

Fig. 1: Single Machine Connected to External Network

i.e., voltage and power measurements at the high voltage bus and there is no need to estimate or compute the values of equivalent external impedance, bus voltage and rotor angle.

The performance of the designed stabilizers is analyzed for two widely used IEEE test systems, 3 generator 9 bus system and 10 generator 39 bus system. The performance is evaluated under various operating conditions and compared with the performance of PSS designed by PVr characteristics and the method of residues [13]. The stabilizers based on the proposed design technique have shown better damping characteristics under heavy and nominal loading conditions and more or less similar performance under light loading conditions, when compared to the other two methods which are based on the complete system information.

2 MODELING OF POWER SYSTEM

For small-signal stability analysis, dynamic modeling is required for the major components of the power system. It includes the synchronous generator, excitation system, automatic voltage regulator (AVR), etc. Different types of models have been reported in the literature depending upon their specific application. The model shown in Fig. 1 is used to obtain the linearized dynamic model [14] (Heffron-Phillip's or K-constant model). IEEE Model 1.0 is used to model the synchronous generator [12] with a high gain, low time constant static exciter.

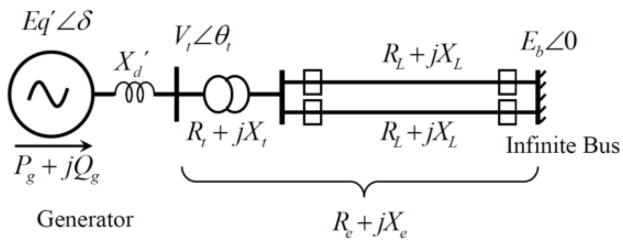

Fig. 2: Single Machine Infinite Bus System

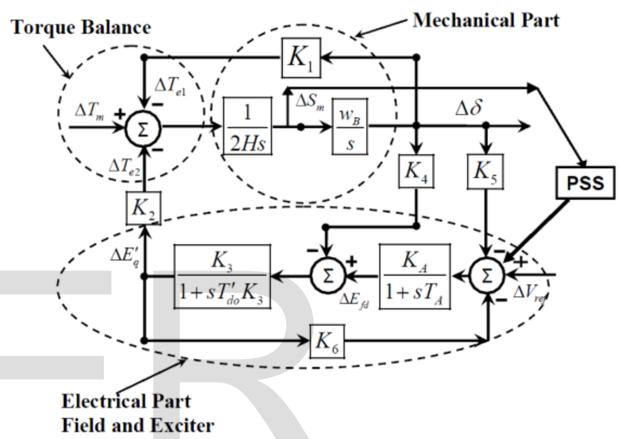

Fig. 3: linearized Model of Single Machine Infinite Bus System

Generator Mechanical and Electrical Torque Equations:

$$\dot{\delta}_s = w_B S_m \quad (1)$$

$$\dot{S}_m = \frac{1}{2H}\left[\Delta T_m - \Delta T_e - DS_m\right] \quad (2)$$

$$\Delta T_e = K_1\Delta\delta + K_2\Delta E'_q \quad (3)$$

Expression for Heffron -Phillip's constant K_1 and K_2 is given

$$K_1 = \frac{E_b E_{q0}\cos\delta_0}{X_q + X_t} + \frac{X_q - X'_d}{X_e + X'_d} E_b \sin\delta_0 \quad (4)$$

$$K_2 = \frac{X_q + X_e}{X_e + X'_d} i_{q0} \quad (5)$$

q-axis Flux Linkage:

$$\Delta E'_q = \frac{1}{K_3 T'_{do}}\left[K_3(\Delta E_{fd} - K_4\Delta\delta) - E'_q\right] \quad (6)$$

Expression for Heffron-Phillip's constant K_3 and K_4 is given

$$K_3 = \frac{X_e + X'_d}{X_d + X_e} \quad (7)$$

$$K_4 = \frac{X_d - X'_d}{X_e + X'_d} E_b \sin\delta_o \quad (8)$$

Excitation System:

Representation of Linearized equations for the excitation system can be expressed as

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$$\Delta V_t = K_5 \Delta\delta + K_6 \Delta E'_q \quad (9)$$

$$\Delta E_f d = \frac{1}{T_A}\left[K_A\left(\Delta V_{ref} + \Delta V_{pss} - \Delta V_t\right) - E_f d \right] \quad (10)$$

Expression for Heffron-Phillip's constant K_5 and K_6 is given

$$K_5 = -\frac{X_q V_{do} E_b \cos\delta_0}{(X_q+X_e)V_{to}} - \frac{X'_d V_{q0} E_b \sin\delta_0}{(X_e+X'_d)V_{to}} \quad (11)$$

$$K_6 = \frac{X_e}{X_e+X'_d}\frac{V_{q0}}{V_{to}} \quad (12)$$

Consider a single generator connected to the external system through a power transformer as shown in Fig. 4 The rotor angle with respect to the voltage $V_s \angle \theta_s$ of the high voltage bus is defined as $\delta_s = \delta - \theta_s$. The expressions for δ_s , E'_q , i'_d and i'_q can be derived from the phaser diagram.

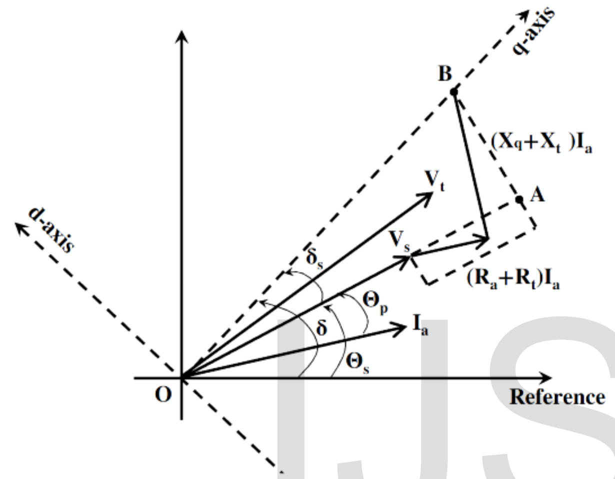

Fig. 4: Phaser diagram of the system shown in Fig. 1

From the ΔOAB in Fig. 4 we get

$$AB = I_a (X_q + X_t)\cos\theta_p - I_a (R_a + R_t)\sin\theta_p \quad (13)$$

$$OA = V_s\, I_a (R_a + R_t)\cos\theta_p + I_a (X_q + X_t)\sin\theta_p \quad (14)$$

$$\delta_s = \tan^{-1}\frac{AB}{OA} \quad (15)$$

$$\delta_s = \tan^{-1}\frac{P_s (X_t+X_q) - Q_s (R_a+R_t)}{P_s (R_a+R_t) + Q_s (X_t+X_q) + V_s^2} \quad (16)$$

Where

P_s and Q_s can be given by

$P_s = V_s I_a \cos\theta_p$ and $Q_s = V_s I_a \sin\theta_p$

In rare cases, under leading power factor operations

$$P_s (R_a + R_t) + Q_s \left(X_t + X_q\right) + V_s^2 < 0 \quad (17)$$

And δ_s is given by

$$\delta_s = \pi - |\delta_s \text{obtained in (eq 16)}| \quad (18)$$

The stator algebraic equations are given by

$$E'_q + X'_d i_d - R_a i_q = V_q$$

$$-X_q i_q - R_a i_d = V_d \quad (19)$$

From stator algebraic (19) one can get the following equation for E'_q

$$E'_q = \frac{(X_t+X'_d)}{X_t}\sqrt{V_t^2 - \left(\frac{X_q}{(X_t+X_q)} V_s \sin\delta_s\right)^2} - \frac{X'_d}{X_t} V_s \cos\delta_s \quad (20)$$

The expressions for i_d and i_q and are as follows

$$i_d = BE'_q - YV_s \cos(\delta_s + \alpha) \quad (21)$$

$$i_q = GE'_q - YV_s \sin(\delta_s + \alpha) \quad (22)$$

Where

$\alpha = \frac{\pi}{2} - \tan^{-1}\frac{B}{G}$ with $Y = |Y_{eq}|$

$$Y_{eq} = \frac{1}{\left((R_a+R_t) + j\,(X_t+X_q)\right)} = G + j\,B$$

3 Modified Heffron-Phillip's Model

Modified Heffron-Phillip's model is suggested in [7]. The standard linear model of SMIB known as Heffron-Phillip's model (also called as K-constant model) can be obtained by linearizing the system equations around an operating condition. The synchronous machine can be interfaced with the external network by converting machine equations in Park's reference frame to synchronously rotating Kron's reference frame. The equations are given below for a SMIB system.

$$V_Q + jV_D = \left(V_q + jV_d\right)e^{j\delta}$$

$$= \left(i_q + j\, i_d\right)(R_e + j\,X_e)\, e^{j\delta} + E_b\angle 0 \quad (23)$$

By using Kirchhoff's Voltage law between the generator terminal and the infinite bus. The subscripts q and d refers to the q and d-axis, respectively, in Park's reference frame Q and D refers to the q and d-axis, respectively, in Kron's reference frame. Similar equation can be written between transformer bus and the generator terminal voltage and is given below. This is the only modification suggested in this paper to make the PSS design independent of the external system parameters

$$\left(V_q + jV_d\right) = \left(i_q + j\, i_d\right)(R_t + j\,X_t) + V_s\angle\theta_s\, e^{-j\delta} \quad (24)$$

Replacing δ by $(\delta_s + \theta_s)$ in the above equation gives

$$\left(V_q + jV_d\right) = \left(i_q + j\, i_d\right)(R_t + j\,X_t) + V_s\angle -\delta_s \quad (25)$$

We can get the modified stator algebraic equations referred to the transformer bus by equating the real and imaginary parts of the above equation . These equations are valid even for the multi-machine system.

$$V_q = R_t i_q - X_t i_d + V_s \cos\delta_s$$
$$V_d = R_t i_d - X_t i_q + V_s \sin\delta_s \quad (26)$$

Equating stator algebraic equation (19) and modified stator algebraic equation (26) and rearranging we can get

$$(X'_d + X_t)\, i_d - R_t i_q = V_s \cos\delta_s - E'_q \quad (27)$$
$$-\left(X_q + X_t\right) i_q - R_t i_d = -V_s \sin\delta_s \quad (28)$$

These equations can be written as

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \frac{-1}{X}\begin{bmatrix} -\left(X_q + X_t\right) & R_t \\ R_t & (X'_d + X_t) \end{bmatrix} \begin{bmatrix} V_s \cos\delta_s - E'_q \\ -V_s \sin\delta_s \end{bmatrix} \quad (29)$$

Where

$$X = \left(X_q + X_t\right)(X'_d + X_t) + R_t^2$$

The terminal voltage of the machine is given by

$$V_t = \sqrt{\left(V_d^2 + V_q^2\right)} \quad (30)$$

Linearizing (29) around an operating condition using first order Taylor series approximation and upon simplification one can obtain

$$\Delta i_d = C_1 \Delta\delta_s + C_2 \Delta E'_q + C_{V1} \Delta V_s$$
$$\Delta i_q = C_3 \Delta\delta_s + C_4 \Delta E'_q + C_{V2} \Delta V_s \quad (31)$$

Where

$$C_1 = \frac{1}{X}\left[R_t V_{s0} \cos\delta_{s0} - \left(X'_q + X_t\right) V_{s0} \sin\delta_{s0}\right]$$
$$C_2 = -\frac{1}{X}\left(X'_q + X_t\right)$$
$$C_3 = \frac{1}{X}\left[(X'_d + X_t) V_{s0} \cos\delta_{s0} + R_t V_{s0} \sin\delta_{s0}\right]$$
$$C_4 = R_t \frac{1}{X}$$
$$C_{V1} = \frac{1}{X}\left[\left(X'_q + X_t\right) \cos\delta_{s0} + R_t \sin\delta_{s0}\right]$$
$$C_{V2} = \frac{1}{X}\left[-R_t \cos\delta_{s0} + (X'_d + X_t) \sin\delta_{s0}\right]$$

δ_{s0}, S_{m0}, E'_{q0}, E_{fd0} and V_{s0} denote the values at the initial operating condition. The linearized versions of the equations (1) (2) (6) (10) and (30) are as follows

$$\Delta T_e = K_1 \Delta\delta_s + K_2 \Delta E'_q + K_{v1} \Delta V_s \quad (32)$$
$$\Delta\delta_s = w_B S_m - \Delta\theta_s \quad (33)$$
$$\Delta S_m = \frac{1}{2H}\left[\Delta T_m - \Delta T_e - D\Delta S_m\right] \quad (34)$$
$$\Delta E'_q = \frac{K_3}{1 + sK_3 T'_{do}}\left[\Delta E_{fd} - K_4 \Delta\delta_s - K_{v2} \Delta V_s\right] \quad (35)$$
$$\Delta V_t = K_5 \Delta\delta_s + K_6 \Delta E'_q + K_{v3} \Delta V_s \quad (36)$$
$$\Delta E_{fd} = \frac{K_A}{1 + sT_A}\left[\Delta V_{ref} - \left(K_5 \Delta\delta_s + K_6 \Delta E'_q + K_{v3} \Delta V_s\right)\right] \quad (37)$$

The constants K_1 to K_6 are same as the original Heffron-phillips constants (Equations (4)(5) (7)(8) (11)(12)). However, they are no longer referenced to δ and E_b and independent of the equivalent reactance X_e. They are functions of V_s, δ_s, V_t and machine currents. In this model, as V_s is not a constant, during linearization, three additional constants K_{v1} to K_{v3} are introduced at the torque, field voltage and terminal voltage junction points, that is the major difference between this model and original Heffron-phillips model.
K_{v1} to K_{v3} can be written as

$$K_{v1} = \frac{E_{q0} \sin\delta_{s0}}{(X_t + X_q)} - \frac{(X_q - X'_d)\, I_{q0} \cos\delta_{s0}}{(X'_d + X_t)} \quad (38)$$
$$K_{v2} = -\frac{(X_d - X'_d) \cos\delta_{s0}}{(X'_d + X_t)} \quad (39)$$
$$K_{v3} = -\frac{X_q V_{d0} \sin\delta_{s0}}{(X_q + X_t) V_{t0}} + \frac{X'_d V_{q0} \cos\delta_{s0}}{(X_t + X'_d) V_{t0}} \quad (40)$$

The modified Heffron Phillip's model is shown in the fig 5. If the deviations in the transformer voltage are neglected then this model exactly represents a system with the external reactance X_e equal to the transformer reactance X_t. The modified constants can be obtained in real time by load flow information at the transformer and at the generator terminals. So for any PSS design based on this model, the parameters can be easily ,

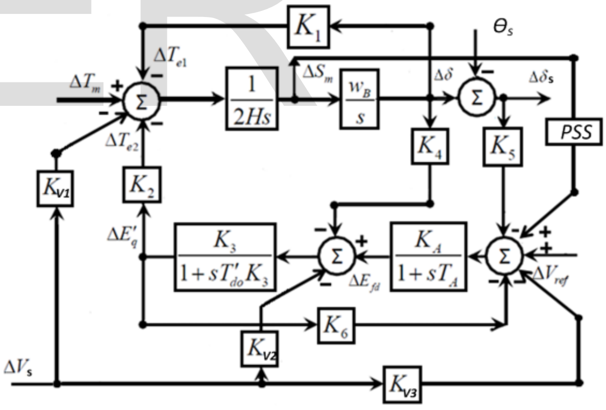

Fig. 5: Linearized model of a single machine in a connected network

Modified to accommodate major structural changes in the system from time to time by local measurements.

4 H_∞ Control Theory power system stabilizer design

A method for designing robust power system stabilizer for a Single Machine Infinite Bus (SMIB) power system is described in this paper. A robust control approach based on H_∞ control theory is implemented to provide desired damping to the lightly damped or unstable mechanical modes. The implemented method provides adequate damping for the system dynamics over a range of operating condition. Performance of the designed controller is simulated over wide range of operating conditions and compared with conventional PSS.

Here P(s) is the plant and C is the controller.The signal w contains all external inputs, including disturbances, sensor noise, and commands; the output z is an error signal; y is the measured variables; and u is the control input. The resulting closed-loop transfer function from w to z is denoted by T_{ZW}.

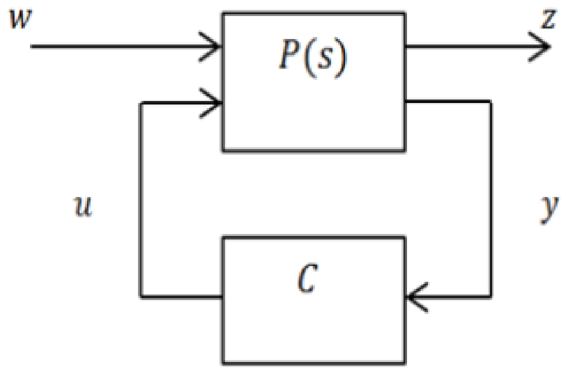

Fig. 6: Basic Block Diagram of H_∞ Optimal Control

The state-space representation of the above system is given by

$$\dot{x} = Ax + B_1 w + B_2 u \quad (41)$$
$$z = C_1 x + D_{12} w \quad (42)$$
$$y = C_2 x + D_{21} w \quad (43)$$

There exist a compensator C(s) such that

$$\|T_{zw}\|_\infty < \gamma \quad (44)$$

Compensator C(s) exist if and only if

$$X_\infty = Ric(H_\infty) \geq 0 \quad (45)$$
$$Y_\infty = Ric(J_\infty) \geq 0 \quad (46)$$
$$\rho(X_\infty Y_\infty) < \gamma^2 \quad (47)$$

Here H_∞ and J_∞ given by

$$H_\infty = \begin{bmatrix} A & \frac{B_1 B_1^T}{\gamma^2} - B_2 B_2^T \\ -C_1^T C_1 & -A^T \end{bmatrix} \quad (48)$$

$$J_\infty = \begin{bmatrix} A^T & \frac{C_1^T C_1}{\gamma^2} - C_2^T C_2 \\ -B_1 B_1^T & -A \end{bmatrix} \quad (49)$$

Where γ is spectral radius of the matrix, expression for the controller is

$$C(s) = \begin{bmatrix} \hat{A}_\infty & -Z_\infty L_\infty \\ -F_\infty & 0 \end{bmatrix} \quad (50)$$

Where

$$\hat{A}_\infty = A + \frac{B_1 B_1^T X_\infty}{\gamma^2} + B_2 F_\infty + Z_\infty L_\infty C_2 \quad (52)$$
$$L_\infty = -Y_\infty C_2^T \quad (53)$$
$$F_\infty = -B_2^T X_\infty \quad (54)$$
$$Z_\infty = \left(I - \frac{Y_\infty X_\infty}{\gamma^2}\right)^{-1} \quad (55)$$

Theory explained in power system stabilizer design has been used with modified heffron-phillip's model. Designed stabilizer is tested with widely used standard IEEE systems one is 3 generator 9 bus system. The performance of the designed stabilizer is compared with conventional stabilizer.

5 Robust Power System Stabilizer

The combination of H_∞ control technique and the modified Heffron-philip's model describe to design a stabilizer. Designed stabilizer is tested with widely used standard IEEE systems one is 3 generator 9 bus system. The performance of the designed stabilizer is compared with conventional stabilizer.

Fig 7 shows single line diagram of 3 generator 9 bus test system. Generator data, network data and load flow data for the same sytem is given in the appendix B.

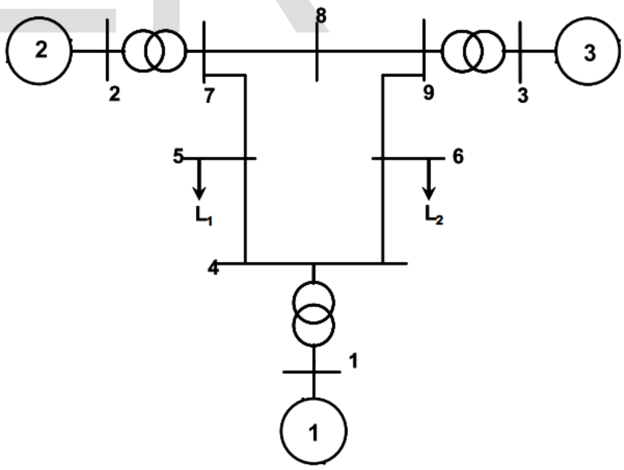

Fig. 7: 3 Generator 9 Bus System

By using H_∞ control theory PSS has been designed for all three generator For given test system and their performance has been compared with conventional PSS. For performance analysis simulation has been carried out for nominal operating condition with creating some disturbances.

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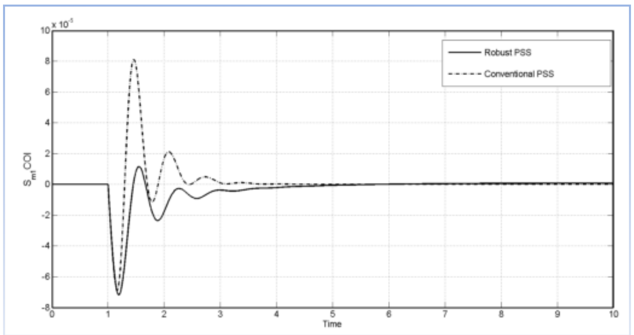

Fig. 8: Sm1COI for 0.1 pu Change in Tm of Generator 1

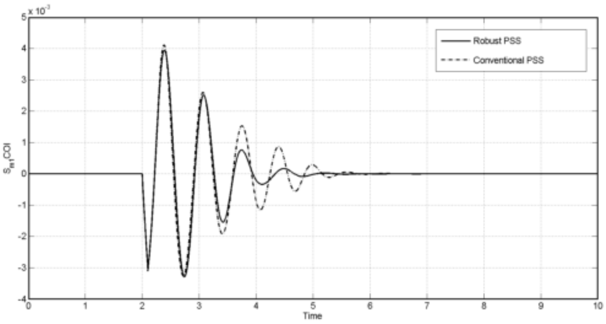

Fig. 8: Sm1COI for 3∅ Fault on the Bus no. 7 for the duration of 100 msec.

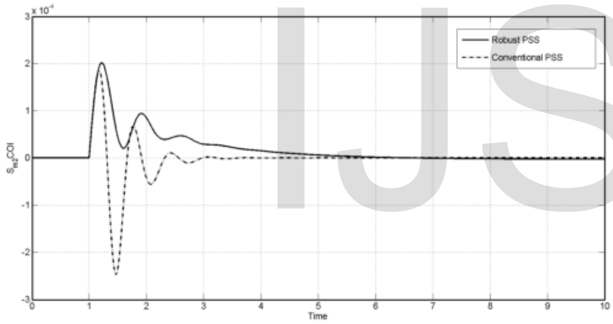

Fig. 9: Sm2COI for 0.1 pu Change in Tm of Generator1

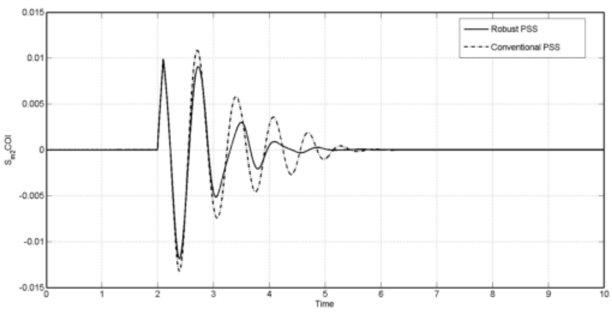

Fig.10: Sm2COI for 3∅ Fault on the Bus no. 7 for the duration of 100 msec.

The linearized fourth order transfer functions of all three generators under nominal operating condition using modified Heffron-phillips's model described in previous section can be written as

$$P_{ni}(s) = \frac{n_{1i}\, s}{s^4 + d_{3i}s^3 + d_{2i}s^2 + d_{1i}\, s + d_{0i}} \qquad (56)$$

where i is the Generator Number

Table 2 gives the undamped or lightly damped rotor modes of 3 generator 9 bus test system for nominal operating condition.

Table 1: 3 Generator 9 Bus System : Generator Transfer Function

Gen. No.(i)	n_1	d_0	d_1	d_2	d_3
1	-384	11990	3713	309.8	20.94
2	-246.9	13490	2579	286.3	20.88
3	-8.245	12510	1126	279.4	20.19

Table 2: 3 Generator 9 Bus System : Undamped or Lightly damped Rotor Modes

Gen. No	Undamped/ Lightly Damped rotor mode
1	$0.007 \pm j7.47$
2	$-1.485 \pm j11.14$
3	$-1.461 \pm j13.91$

6 Appendix A

δ: : Rotor angle
δ_s : Rotor angle with respect to the secondary voltage of transformer.
S_m : Slip speed.
D : Damping coefficient.
E'_q , E'_d : Transient induced voltages due to field flux-linkages.
E_{fd} : Field voltage.
E'_{dc} : Induced voltage of dummy coil used to account for transient saliency.
H : Inertia Constant of machine.
i_d : d-axis component of stator current.
i_q : q-axis component of stator current.
K_e , K_A : Exciter gain.
M : angular momentum.
P_t : Real power injected at the machine terminals.
Q_t : Reactive power injected at the machine terminals.
R_a : Armature resistance.
T_e , T_A : Exciter time constant.
T_m : Mechanical torque.
T_e : Electrical torque.
T'_{do} , T''_{do} : d-axis time constants.
T'_{qo} , T''_{qo} : q-axis time constants.
θ_p : power factor at the transformer bus.
T'_c : Time constant of dummy coil used to account for transient saliency.
$V_s \angle \theta_s$: Voltage measured at the secondary of the transformer.
$V_t \angle \theta$: Voltage measured at the generator terminal.
V_{ref} : Reference voltage.

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V_{pss} : PSS Input.
V_d , V_q : d and q-axis components of terminal voltage.
ω : angular speed.
ω_B : Base Speed
X_t , X_L : Transformer and transmission line reactances.
X_d , X'_d , X''_d : d-axis reactances.
X_q , X'_q , X''_q : q-axis reactances.

Appendix B

This Single Machine Infinite Bus (SMIB) system data is taken from [2].

Generator Data:
$x_d = 1.6; x_q = 1.55; x'_d = 0.32; T'_{do} = 6; H = 5;$
$D = 0; f_B = 60\ HZ; E_B = 1.0\ p.u; x_t = 0.1\ p.u$

Static Excitation System Data:
$K_e = 200\ ; T_e = 0.05s;\ E_{fdmax} = 6; E_{fdmin} = -6.$

PSS Data:
$T_1 = 0.076; T_1 = 0.028; K_{pss} = 16; T_W = 2;$
PSS output limits $= \pm 0.1$

Single line diagram for IEEE 3 generator 9 bus test system is shown in the Fig 7. Base MVA for the system is 100 MVA and system frequency is 60Hz

Table 1: 3 Generator 9 Bus System - Machine Data

Bus no	x_d	x_q	x'_d	x'_q	T'_{do}	T'_{qo}	H	D	R_a
1	0.146	0.096	0.060	0.096	8.96	0.31	23.64	0.012	0
2	0.895	0.864	0.119	0.196	6	0.535	6.4	0.006	0
3	1.312	1.257	0.181	0.25	5.89	0.6	3.01	0.004	0

Table 2: 3 Generator 9 Bus System - Network Data

Type	From	To	R	X	B/2	Tap	No of Parallel Elements
1	2	7	0	0.062	0	1	0
1	3	9	0	0.058	0	1	0
2	4	5	0.01	0.085	0.088	1	1
2	4	6	0.017	0.092	0.079	1	1
2	5	7	0.032	0.161	0.153	1	1
2	6	9	0.039	0.17	0.179	1	1
2	7	8	0.008	0.072	0.074	1	1
2	8	9	0.011	0.1008	0.104	1	1

Table 3: 3 Generator 9 Bus System - Load flow Data

Bus No.	P	Q	V	Θ
1	0.71641	0.27046	1.04	0
2	1.63	0.066536	1.025	9.28
3	0.85	-0.1086	1.025	4.6648
4	0	0	1.0258	-2.2168
5	-1.25	-0.5	0.99563	-3.9888
6	-0.9	-0.3	1.0127	-3.6874
7	0	0	1.0258	3.7197
8	-1	-0.35	1.0159	0.72754
9	0	0	1.0324	1.9667

7 CONCLUSION

H_∞ Based robust power system stabilizer design for interconnected power system has been presented. The use of modified Heffron-Phillip's model [7] permits the use of H_∞ control technique for PSS design of multi-machine system. PSS at each machine is synthesized using information available at the local buses only. The performance of the proposed stabilizer is reasonably good at all conditions tested.

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REFERENCES

[1] E. V. Larsen and D. Swann, “Applying power system stabilizers, parts I, II and III,”IEEE Trans. Power App. Syst., vol. PAS-100, No.6, pp. 3017-3046, June 1981.
[2] F. P. Demello and C. Concordia, “Concepts of synchronous machine stability as affected by excitation control,” IEEE Trans. Power App. Syst., vol. PAS-88, No.4, pp.316-329, 1969.
[3] K.R.Padiyar, “Power System Dynamics Stability and Control”. John Wiley; Interline Publishing, 1996.
[4] P. S. Kundur, “Power System Stability and Control”. New York: McGraw-Hill, Inc., 1994.
[5] P.M.Anderson and A.A.Foud, “Power System Control and Stability”. The Iowa State University Press, 1977.
[6] Gurunath Gurrala, “Power System Stabilizing Controllers - Multi-machine System”, Ph.D Thesis, Indian Institute of Science Bangalore, January 2010.
[7] G. Gurunath and I. Sen, “A modified Heflron-phil1ip’s model for the design of power system stabilizers,” in Powercon-2008, New Delhi, India, October 12 - 15, 2008.
[8] G. Gurunath and I. Sen, “Power system stabilizers design for interconnected power systems,” IEEE Trans.Power Sys., vol. 25, no.2, pp.1042—1051,May 2010.

[9] P. Srikant Rao and I. Sen, "A QFT Based Robust SVC Controller for Improving the Dynamic Stability of Power System" ,4'" International Conference on Advances in Power System Control, Operation and Management, APSCOM-97, Hong Kong, November 1997.

[10] P. Srikant Rao and Indraneel Sen,"Robust Tuning of Power System Stabilizers Using QFT", IEEE Transactions on Control Systems Technology, Vol. 7, No. 4, pp. 478-486,July 1999.

[11] P. Srikant Rao and Indraneel Sen, "Robust pole placement stabilizer design using linear matrix inequalities ", IEEE Transactions on Power Systems, Vol.15, No. 1, pp. 3003-3008, Feb. 2000

[12] John C. Doyle, Keith Glover, Promod P. Khargonkar and Bruce A. Francis, "State-Space Solutions to Standard H2 and H00 Control Problems," IEEE Trans. Automatic Control, vol. 34, No.8, pp. 831-847, June 1989.

[13] V.L.Khartinov, "Asymptotic stability of an equilibrium position of a family of systems of linear differential equations,"Vol. 14, pp. 1483-1485, 1979

[14] Saikat Bhattacharya, L. H. Keel and S. P. Bhattacharyya, "Robust Stabilizer Synthesis for Interval Plant Using H—infinity Method" , Proceedings of 2"" Conference on Decision and Control, San Antonlo,Texas, December 1993.

[15] A. Hariri and O.P. Malik, "A Fuzzy Logic Based Power System Stabilizer With Learning Abi1ity",IEEE Trans. on Energy Conuersion,vol. 11, No.4,pp.721—727, December 1996.

[16] S. Chen and O.P. Malik, "Power System Stabilizer Design Using it Synthesis",IEEE Trans. on Energy Conversion,vol. 10, No.1,pp.175—181, March 1995.

BIBILOGRAPHY

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