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Small Signal Stability Enhancement Of Power System Using Adaptive Control Based Power System Stabilizer

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Abstract
Power systems are subjected to low frequency disturbances that might cause loss of synchronism and an eventual breakdown of entire system. The oscillations, which are typically in the frequency range of 0.2 to 3.0 Hz, might be excited by the disturbances in the system or, in some cases, might even build up spontaneously. These oscillations limit the power transmission capability of a network and, sometimes, even cause a loss of synchronism and an eventual breakdown of the entire system. For this purpose, Power system stabilizers (PSS) are used to generate supplementary control signals for the excitation system in order to damp these low frequency power system oscillations.
The use of power system stabilizers has become very common in operation of large electric power systems. The conventional PSS which uses lead-lag compensation, where gain settings designed for specific operating conditions, is giving poor performance under different loading conditions. The constantly changing nature of power system makes the design of CPSS a difficult task. Therefore, it is very difficult to design a stabilizer that could present good performance in all operating points of electric power systems. To overcome the drawback of conventional power system stabilizer (CPSS).In an attempt to cover a wide range of operating conditions, adaptive control based technique has been suggested as a possible solution to overcome the above problem, thereby using this technique complex system mathematical model can be avoided, while giving good performance under different operating conditions.
Keywords: *small signal stability, power system stabilizer, adaptive control and Matlab /Simulink*

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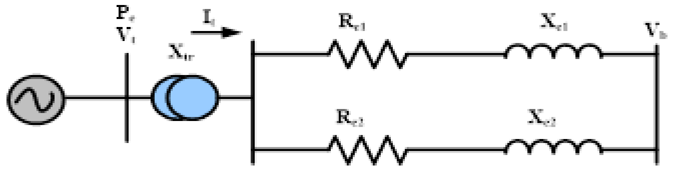
I. Introduction

Low-frequency oscillations in the range of (0.2 – 3) Hz are inherent to systems, when the power exchanges between two areas of interconnected power systems or when power is transferred over long distances under varies operation conditions. The fast acting high gain Automatic Voltage Regulator (AVR),is uses to improves the transient stability, it has a detrimental effect on the small-signal stability (DeMello et al 1969),but oscillations arising from the lack of sufficient damping in the system. The recent introduction of the deregulation and the unbundling of generation, transmission and distribution as well as a number of Distributed Generation connected to the power system have exacerbated the problem of low-frequency oscillations. the Power System Stabilizers (PSSs) is add signal to excitation for damping electromechanical oscillations. Conventional Power System Stabilizers (CPSSs) is accept by the power utilities due to their simplicity. Moreover they have some drawbacks such as the time- consuming tuning and its non-optimal damping in the entire operating range (Larsen et al 1981). Owing to which the CPSS determined in the nominal operating point does not assure optimal damping in the operating range, the synchronous generator dynamic characteristics also vary when the load is increase or decrease. To overcome this drawback, numerous advance techniques have been proposed to design PSSs. (Klein et al 1991,1992) present effects of stabilizers on inter-area and local modes of oscillations in interconnected power systems. It shows that the PSS location , the voltage characteristics and the loads it has a significant factors in the ability of a PSS increase the damping of inter-area oscillations. Also (TsE et al 1993) and (HSU et al 1986,1987) propose conventional lead-lag power system stabilizer (CPSS) based on proportional-integral power system stabilizer (PI-PSS) and proportional-integral derivative power system stabilizer (PID-PSS). (HSU et al 1986,1987) proposed Fuzzy logic controllers (FLCs) are very useful in the case a good mathematical model for the plant is not available, however, experienced human operators are available for providing qualitative rules to control the system (HSU et al 1986,1987) .Also, (Hashen et al 2002, Menniti D et al 2002) presented Hybrid PSSs using fuzzy logic , neural networks and Genetic Algorithms.

This work deals with a design PSS based on model reference adaptive control to damp out low-frequency oscillation when disturbance subjected to a single machine infinite bus and Use Matlab/Simulink to evaluate performance of a controller by time domain simulation for different cases of operation condition.

II. Mathematical Model Of Plant

The mathematical model of a single machine connect to transmission line (infinite bus) presents in this section to analyze the local mode of oscillations in the range of frequency (1-3) Hz. A schematic representation of this model is shows in Figure (1) (K.Sobel, 1997). Linearization the system equipped with Static Excitation System and PSS .



Fig(1) schematic diagram of single machine connected infinite bus

$$\Delta\dot{\delta} = \omega_s \Delta\omega \quad (1)$$
$$\Delta\dot{\omega} = -\frac{K_2}{2H}\Delta\acute{E}_q - \frac{K_1}{2H}\Delta\delta - \frac{D\omega_s}{2H}\Delta\omega + \frac{1}{2H}\Delta T_M \quad (2)$$
$$\Delta\dot{\acute{E}}_q = \frac{-1}{K_3\acute{T}_{do}}\Delta\acute{E}_q - \frac{K_4}{\acute{T}_{do}}\Delta\delta + \frac{1}{\acute{T}_{do}}\Delta E_{fd} \quad (3)$$
$$\Delta\dot{E}_{fd} = -\frac{K_A K_6}{T_A}\Delta\acute{E}_q - \frac{K_A K_5}{T_A}\Delta\delta - \frac{1}{T_A}\Delta E_{fd} + \frac{K_A}{T_A}\Delta V_{ref} \quad (4)$$

III. Power System Stabilizer Structure

The objective of power system stabilizer is to modulate the generator's excitation system to produce an electrical torque at the generator it is proportional to the rotor speed (Padiyaar ,K.R 1997,Larsen,E.V et al 1981).To do that, the PSS uses a simple lead-lag compensator circuit to adjust the input signal and correct the phase lag between the exciter input and the electrical torque. The speed deviation of the generator shaft, change in electrical power , accelerating power and even the terminal bus frequency uses as input signal for PSS. Figure (2) illustrates the block diagram of power system stabilizer, it has consists of a washout, lead-lag networks, a gain and a limiter stages.

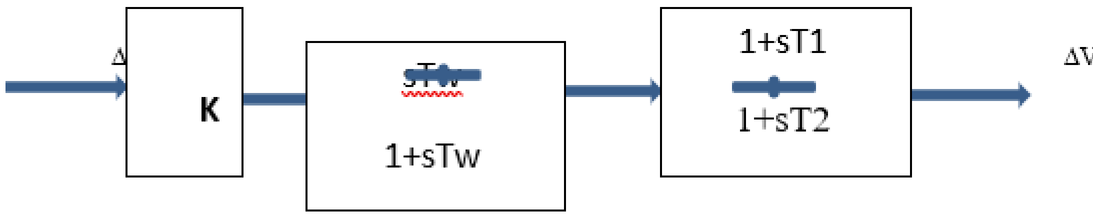


Figure (2) illustrates the block diagram of PSS

$$\frac{dV_1}{dt} = K_{PSS}\frac{d\Delta\dot{\omega}}{dt} - \frac{1}{T_W}V_1 \quad (5)$$
$$\frac{dV_2}{dt} = \frac{T_1}{T_2}\frac{dV_1}{dt} + \frac{1}{T_2}V_1 - \frac{1}{T_2}V_2 \quad (6)$$

IV. Model Reference Adaptive System

output of the reference The model reference adaptive system (MRAS) is a control method that define desired performance as a reference model. Then, the system with MRAS controller tracks the reference model following any command in input (Astron et al 2008). In fact, the idea behind MRAS is to create a closed loop controller with parameters that can be updated to change the response of the system to follow the desired model. Fig.(3) shows a general block diagram of MRAS method. Two ordinary feedback loop (inner loop) is compose the process and the controller and another feedback loop (outer loop) are used to adjust the controller parameters. The parameters' adjustment is carried out based on the tracking error which is defined as the difference between the output of the system and the model. The methodology of parameters' adjustment in MRAS is obtained by different methods such as gradient method or Lyapunov stability theory (Popv,1973).

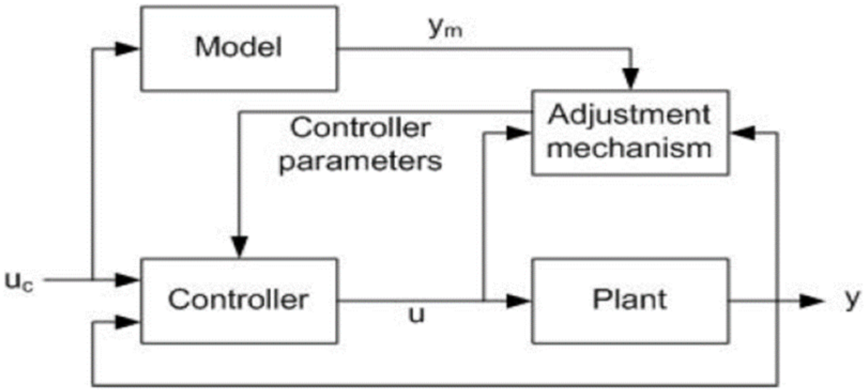


Fig. (3) shows a general block diagram

V. MRAC Design Using Lyapunov Method

The model reference adaptive controller designed using the Gradient method/MIT rule has does not guarantee stability to the resulting closed-loop system. However, MRAC can also be designed such that the globally asymptotic stability of the equilibrium point of the error difference equation is guaranteed. To do this, we use the Lyapunov method (Popov, 1973). The first method of Lyapunov is difficult to choose function, whereas the second method is more systematic. This work looks at the MRAC system designed using the Lyapunov method. In designing an MRAC using Lyapunov Method, the following steps should be Followed

i) Make a differential equation for error, e = y − gym (i.e. $e^{\bullet}, e^{\bullet\bullet}, ect$) that contains the adjustable parameter θ.

II) Find a suitable Lyapunov function, V(e,θ) - usually in a quadratic form (to ensure positive definiteness).

III) Make an adaptation mechanism based on e,θ such that e goes to zero.

Consider an adaptive control system with the following plant as describe in (6), reference model and controller Plant

$$\frac{dy}{dt} = -ay(t) + bu(t) \quad (7)$$

Reference model:

$$\frac{dy_m}{dt} = -ay(t) + b_m r(t) \quad (8)$$

Controller:

$$u(t) = \theta_1 r(t) - \theta_2 y(t) \quad (9)$$

It follows from equation (7) and (9), that

$$y = \frac{b}{s + a + b\theta_2}\theta_1 r \quad (10)$$

$$y_m = \frac{b_m}{s + a_m} r$$

(11)

Step 1: Derive differential equation for e that contains

$$e^{\bullet} = y^{\bullet} - y^{\bullet} \quad (12)$$

$$y^{\bullet} + (a + b\theta_2)y = b\theta_1 r \quad (13)$$

$$y^{\bullet} = -(a + b\theta_2)y + b\theta_1 r \quad (14)$$

$$y_m^{\bullet} + a_m y_m = b_1 r \quad (15)$$

$$y_m^{\bullet} = -a_m y_m + b_1 r \tag{16}$$

$$e^{\bullet} = y^{\bullet} - y^{\bullet}$$

$$e^{\bullet} = -(a + b\theta_2)y + b\theta_1 r + a_m y_m - b_1 r \tag{17}$$

$$e^{\bullet} = -ay - b\theta_2 y + b\theta_1 r + a_m y_m - bmr \tag{18}$$

$$e^{\bullet} = -ay - b\theta_2 y + b\theta_1 r + a_m (y - e) - bmr \tag{19}$$

$$e^{\bullet} = -a_m e - (a + b\theta_2 - a_m)y + (b\theta_1 - b_m)r \tag{20}$$

$$e^{\bullet} = -a_m e - [\frac{a - a_m}{b} + \theta_2]by + [\theta_1 - \frac{b_m}{b}]br \tag{21}$$

$$e^{\bullet} = -a_m e - [X_1]by + [X_2]br \tag{22}$$

Step 2: Find the suitable Lyapunov function (usually in quadratic form) ,The Lyapunov function, $V(e, X_1, X_2)$ is chosen based on (22). Let

$$V(e, X_1, X_2) = [e \quad X_1 \quad X_2]\begin{vmatrix} a_m & 0 & 0 \\ 0 & \lambda_1 & 0 \\ 0 & 0 & \lambda_2 \end{vmatrix}\begin{vmatrix} e \\ X_1 \\ X_2 \end{vmatrix} \tag{23}$$

$$V(e, X_1, X_2) = a_m e^2 + \lambda_1 X_1^{\ 2} + \lambda_2 X^{\ 2} \tag{24}$$

Where λ1,λ2 > 0 so that V is positive definite

$$V^{\bullet} = \frac{\partial V}{\partial e}\frac{\partial e}{dt} + \frac{\partial V}{\partial X_1}\frac{\partial X_1}{dt} + \frac{\partial V}{\partial X_2}\frac{\partial X_2}{dt} \tag{25}$$

$$V^{\bullet} = a_m 2ee^{\bullet} + 2\lambda_1 X_1 X_1^{\bullet} + 2\lambda_2 X_2 X_2^{\bullet} \tag{26}$$

$$V^{\bullet} = a_m 2e[-a_m e - X_1 by + X_2 br] + 2\lambda_1 X_1 X_1^{\bullet} + 2\lambda_2 X_2 X_2^{\bullet} \tag{27}$$

$$V^{\bullet} = 2e^2 a_m^{\ 2} - 2a_m X_1 bye + 2a_m X_2 bre + 2\lambda_1 X_1 X_1^{\bullet} + 2\lambda_2 X_2 X_2^{\bullet} \tag{28}$$

For stability $V^{\bullet} \prec 0$

$-Y + Z \prec 0 \Rightarrow Z \prec Y$,Therefore we can take Z=0

$$-2a_m X_1 bye + 2a_m X_2 bre + 2\lambda_1 X_1 X_1^{\bullet} + 2\lambda_2 X_2 X_2^{\bullet} = 0 \tag{29}$$

For expression

$$X_1 = [\frac{a - a_m}{b} + \theta_2] \Rightarrow X_1^{\bullet} = \theta_1^{\bullet}, X_2 = [\theta_1 - \frac{b_m}{b}] \Rightarrow X_2^{\bullet} = \theta_2^{\bullet}$$

$$-2a_m X_1 bye + 2a_m X_2 bre + 2\lambda_1 X_1 \theta_1^{\bullet} + 2\lambda_2 X_2 \theta_2^{\bullet} = 0 \tag{30}$$

Derive an adaptation mechanism (for θ_1 and θ_2)

$$-2X_1[-a_m bye + \lambda_1 \theta_2^{\bullet}] + 2X_2[a_m bre + \lambda_2 \theta_1^{\bullet}] = 0 \tag{31}$$

This is possible if

$$-a_m bye + \lambda_1 \theta_2^{\bullet} = 0 \tag{32}$$

$$a_m bre + \lambda_2 \theta_1^{\bullet} = 0 \tag{33}$$

$$\theta_2^{\bullet} = \frac{-a_m bye}{\lambda_1} = \gamma_2 ye \Rightarrow where \gamma_2 = \frac{a_m b}{\lambda_1} \qquad (34)$$

$$\theta_1^{\bullet} = \frac{-a_m bre}{\lambda_2} = \gamma_1 ye \Rightarrow where \gamma_1 = \frac{a_m b}{\lambda_2} \qquad (35)$$

VI. Simulation Results And Discussion

Following the application of proposed adaptive control to tune the PSS, Figures (4) show time response of speed deviation of the generator in case of without any controller, conventional PSS, and adaptive PSS. The adaptive PSS that would give the best damping for the most dominant poles of the system. The figure (5) and (6) shows speed deviation response at operation points (1+j0.015,1.1+j0.4 and 0.8+j0.015), after applied two controller the classic power system stabilizer and adaptive controller. From time response of two controller , the second method is best for damping out power system oscillations in different operation points.

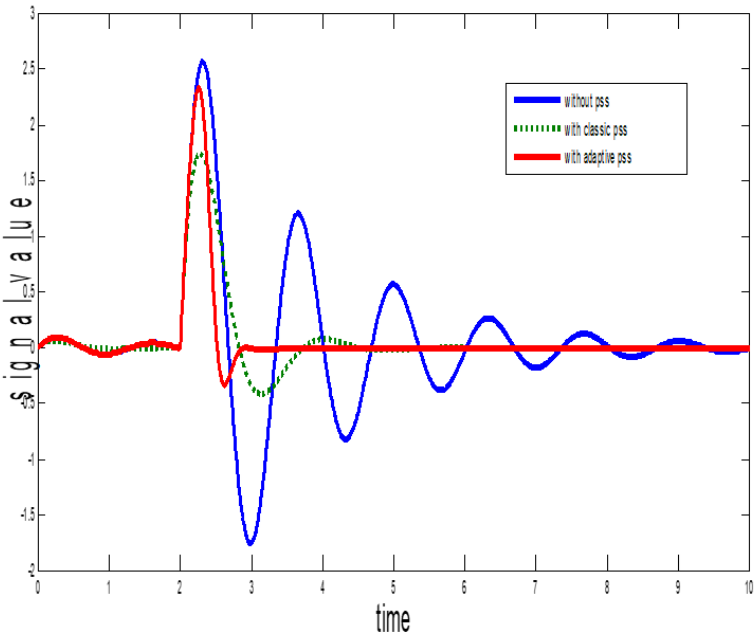
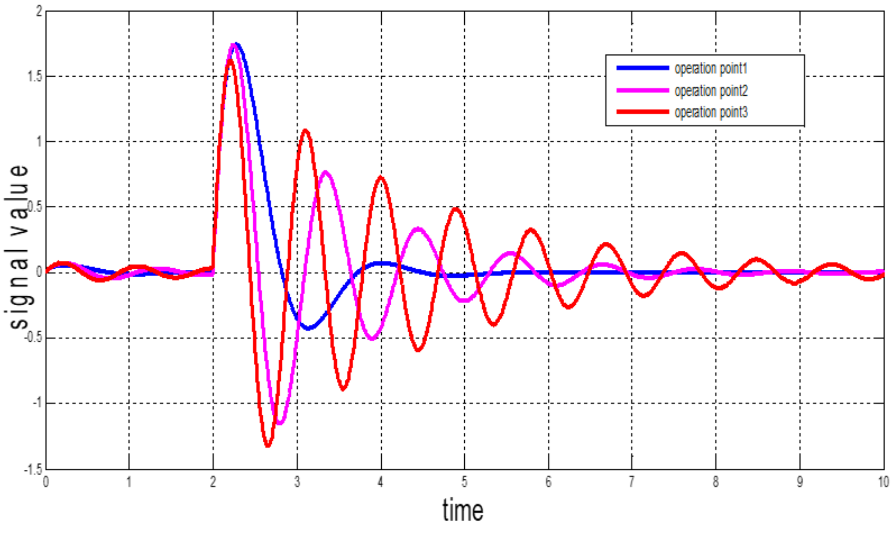
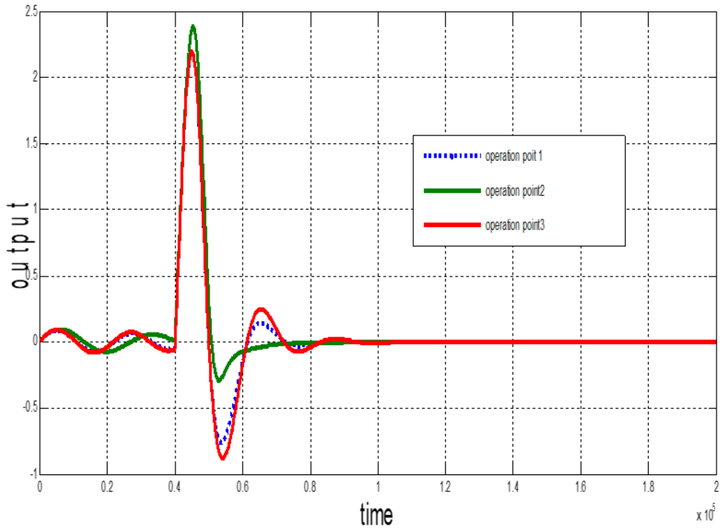


Figure (4) Show Speed Response With Different Type Of Psss



The Figure (5) Shows Speed Deviation Response In Different Operation In Case Of Conventional PSS



The Figure (6) Shows Speed Deviation Response In Case Of Adaptive PSS

VII. Conclusion

This work presents an application of MRAS technique to design PSS as a regulator controller in electric power systems. Also use lyapunov second to design controller then applied to single machine connected infinite bus the, to shows performance under various operating conditions. Furthermore, the proposed MRAS-PSS is evaluated against conventional PSS which is tuned by residue approach. Simulation results emphasize on the viability and robustness of the proposed adaptive method under various operating conditions. also the results indicate that MRAS-PSS is better than CPSS to damp out oscillations and stability enhancement under same conditions.

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