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Abstract: Power system oscillations are a characteristic of the system and they are inevitable. Power System Stabilizer (PSS) can help the damping of power system oscillations. This controller has become an accepted solution for oscillatory instability problems and thus improves system stability. Small signal stability is the system ability to maintain synchronism when a small disturbance occurs. This study provides an analysis of the small signal stability of the power system under different system conditions and operating loads. Several simulations have been done to show the effect of the line parameters on the power system oscillations stability.

Key words: Small signal stability, transmission line model, power system stabilizer, dynamic analysis

INTRODUCTION

Power systems are capital intensive big complex systems. In general in a modern interconnected power system, transmission lines are under-utilized and uncontrolled. That are more heavily loaded then ever before to meet the growing demand. The dynamic stability categorized two sub-classes: small signal stability and transient stability. Small signal stability analysis using linear techniques provides valuable information about the inherent dynamic characteristics of the power system and assists in its design. Among the various methods of damping of power system oscillations, excitation control is one of the most common and economical method. PSS is added to excitation systems to enhance the damping of electric power systems during low frequency oscillations (Gupta et al., 2003).

The PSS is a control device to improve the stability of the system by introducing a supplementary signal to an Automatic Voltage Regulator (AVR). The AVR is an exciter control device which maintains the terminal voltage of the generator at a constant level. A dynamical model of PSS is included to investigate the effect in providing positive damping to overcome the undamped electromechanical modes. In some cases, PSSs are used as an additional control feature so that excitation system with a high response may be used without compromising the small signal instability of the generators.

Power system stabilizers have been shown to be effective in stabilizing the modes where there are different oscillation frequencies. PSS have been used for many years to add damping to electromechanical oscillations. To design a PSS with better performance, several approaches have been applied to PSS design problem and many useful results have been published. These include pole placement, H∞ optimal control, adaptive control, variable structure control and different optimization and artificial intelligence techniques (Abdel-Magid et al., 1999; Shoulai et al., 2009; Gibbard et al., 2004; Hasanovic et al., 2004).

According to Lee and Park (1998), to tackle the problem of the unmeasurable state variables in the conventional SMC, three kinds of controllers have been developed and the PSS has been applied for a small-signal stability study. In (Mrad et al., 2000) an adaptive fuzzy synchronous machine PSS that behaves like a PID controller for faster stabilization of the frequency error signal and less dependency on expert knowledge is proposed. In (Shamsololahi and Malik, 1999) an indirect adaptive PSS is designed using two input signals, the speed deviation and the power deviation to a neural network controller. In (Nambu and Ohsawa, 1996) a similar linearization method without having to explicitly identify internal rotor angle and resort to a single machine setting is described. In (Jiang, 2009) the dynamic characteristics of the proposed PSS based on synergetic control theory are studied in a typical single-machine infinite-bus power system and compared with the cases with a conventional PSS and without a PSS. Two techniques for the tuning of PSS parameters based on the integral of squared error criterion and the phase compensation criterion are studied by Bhattacharya et al. (1997).

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Modern power systems are highly complex and strong non-linearity and their operating conditions can vary over a wide range. Operating conditions of a power system are continually changing due to load patterns, electric generation variations, disturbances, transmission topology and line switching.

For small signal stability, the linearized system model is acceptable. The dynamic equations governing the performance of the single machine infinite-bus are non-linear. They are linearized about an operating point for small signal stability studies.

This study presents a newly developed linearized block diagram of a power system with a PSS which represents the dynamics of power system. The analysis of the performance of PSS under different system conditions and operating loads was described.

The simulation results show the effects of the transmission line parameters and line model on small signal stability.

**MATERIALS AND METHODS**

**Transmission line model:** A transmission line is a crucial link between power generation units and distribution units in consumption areas. In this study, it is considered that the transmission line parameters are uniformly distributed and the line can be modeled by a two-port, four-terminal networks as shown in Fig. 1.

Figure 1 shows the actual line model where \( U_{SE} \) and \( I_{SE} \) are the sending-end voltage and current and \( U_{RE} \) and \( I_{RE} \) are the receiving-end voltage and current. The relation between the Sending End (SE) and Receiving End (RE) quantities can be written as (Chen et al., 2006):

\[
\begin{bmatrix}
U_{SE} \\
I_{SE}
\end{bmatrix} =
\begin{bmatrix}
A & B \\
C & D
\end{bmatrix}
\begin{bmatrix}
U_{RE} \\
I_{RE}
\end{bmatrix}
\]

(1)

Where generalized circuit constants (ABCD) of a line of length \( a \) are parameters that depend on the transmission line constants and given by:

\[
\begin{align*}
A &= D = \cosh(\gamma a) \\
B &= Z_c \sinh(\gamma a) \\
C &= \frac{1}{Z_c} \sinh(\gamma a)
\end{align*}
\]

(2)

Where:
- \( Z_c \) = Characteristic impedance of the line
- \( \gamma \) = The line propagation constant

\[
\begin{align*}
\overline{Z}_c &= \sqrt{Z} \\
\overline{Y} &= \sqrt{Z/Y}
\end{align*}
\]

(3)

Where \( z \) is series impedance per unit length/phase and \( y \) is shunt admittance of per unit length/phase. The maximum power transferred by a line can be increased by decreasing either the characteristic impedance or electrical length or both. If \( A_D = B_C = 1 \) and \( A = D \), the currents at the SE and RE of the line can be written as:

\[
\begin{align*}
I_{SE} &= \frac{\overline{A}}{B} U_{SE} \frac{1}{B} U_{RE} \\
I_{RE} &= \frac{1}{B} U_{SE} \frac{\overline{A}}{B} U_{RE}
\end{align*}
\]

(4)

Where, \( A = A/\alpha \) and \( B = B/\beta \). The total series inductance determines primarily the maximum transmissible power at a given voltage. The shunt capacitance influences the voltage profile and thereby the power transmission along the line. Reactive power cannot be transmitted over long distance; therefore reactive compensation has to be effected by using various devices. The parameter and variable of the transmission line such as line impedance, terminal voltage and voltage angle can be controlled by FACTS devices in a fast and effective way.

**Study system and mathematical model:** A simplified dynamic model of power system is considered in this study. As shown in Fig. 2, this model is consisted a single synchronous generator including the voltage regulator and exciter connected through a transmission line to very large network approximated by an infinite bus. Synchronous generators are normally equipped with AVR which continually adjust the excitation so as to control the armature voltage. The excitation voltage \( E_E \) is supplied the exciter and is controlled by the AVR. The torque angle \( \delta \) is defined as the angle between the infinite bus voltage, \( U_B \) and the internal voltage of quadrature axis, \( E' \). The equal parameters between bus T and bus B are A, B, C and D, so that:
Fig. 2: A single machine infinite bus power system with phasors diagram (a) Power system configuration (b) Voltage phasor diagram

\[
\begin{bmatrix}
A & B \\
C & D
\end{bmatrix} = 
\begin{bmatrix}
1 & 0 & \bar{A}_{12} & \bar{B}_{12} \\
0 & 1 & \bar{C}_{12} & \bar{D}_{12}
\end{bmatrix}
\]

(5)

\[
U_t = \frac{1}{A} \bar{U}_a + \frac{\bar{B}}{A} \bar{I}_x
\]

(8)

Where \( Y_L \) is admittance of shunt load in generator bus, \( Y_L \) is admittance of shunt load in bus M and \( A_{12}, B_{12}, C_{12}, D_{12} \) are line parameters in section 1 and 2. The stator algebraic equations are expressed as:

\[
\begin{align}
U_q &= U_t \sin \delta = X_q i_q - R_A i_q \\
U_d &= U_t \cos \delta = E' - X_d i_d - R_A i_d
\end{align}
\]

(6)

Resolving into \( d \) and \( q \) components gives:

\[
u_q = \frac{U_t}{A} \sin(\delta + \alpha) + B i_q \cos(\beta - \alpha) - \frac{B}{A} i_q \sin(\beta - \alpha)
\]

(9)

\[
u_d = \frac{U_t}{A} \cos(\delta + \alpha) + B i_q \sin(\beta - \alpha) + \frac{B}{A} i_q \cos(\beta - \alpha)
\]

(10)

The armature current components are:

\[
i_q = \frac{U_t}{Z_q} - \frac{1}{Z_q} \left( \frac{U_t}{A} \sin(\delta + \beta) + X_q \cos(\delta + \alpha) \right)
\]

(11)

\[
i_d = \frac{1}{Z_q} \left( \frac{U_t}{A} \sin(\delta + \alpha) + X_q \cos(\beta + \delta) \right) + Y_q E_t
\]

(12)

Where:

\[
Y_t = \frac{X_t \cos \alpha - R_t \sin \alpha}{Z_k^2}
\]

(13)

\[
Y_t = \frac{X_t \sin \alpha + R_t \cos \alpha}{Z_k^2}
\]

(14)

\[
Z_k^2 = R_k^2 + X_k^2 + X_{eq} X_{2q}
\]

(15)

The electric power is:

\[
P_e = (X_q - X_d) i_d i_q + E_d i_q
\]

(7)

The network constraint equation for the system is:
The initial torque angle, currents and voltages of the system in the steady state are $\delta_0$, $i_{tq}$, $i_{qs}$, $U_{tq}$, $U_{qs}$ and $U_{qr}$. The variation of the $d$ and $q$ armature windings is:

$$\Delta i_d = Y_d \Delta E_q + F_q \Delta \delta$$

$$\Delta i_q = Y_q \Delta E_d + F_d \Delta \delta$$

Where:

$$F_d = -\frac{U_q}{Z_t} (R_E + X_E + X_{et} \sin \delta)$$

$$F_q = \frac{U_d}{Z_t} (R_E + X_E + X_{et} \cos \delta)$$

The non-linear differential equations of the single machine infinite bus power system are:

$$\frac{d}{dt} \delta = \omega_0 \Delta \delta$$

$$\frac{d}{dt} \omega = \frac{1}{2H} (P_t - P_g - K_0 \Delta \omega)$$

$$\frac{d}{dt} E_t = \frac{1}{T_{dt}} [E_r - E_q + (X_d - X_q) i_d]$$

$$\frac{d}{dt} E_q = \frac{1}{T_{dq}} [-E_r + K_E (U_q - U_d)]$$

In the design of power system stabilizer for improving the dynamic stability of power system, linearized incremental models are usually employed. Basic linear differential equations describing dynamics of the single machine infinite bus power system are:
Power system stabilizer: Power system oscillations are a characteristic of the system and they are inevitable. Power system oscillations are initiated by normal small changes in system loads and they become much worse following a large disturbance. The AVR can inject negative damping into the system at high power leading, leading power factors and large tie-line reactance (Rajkumar and Mohler, 1995). This so-called negative damping may be eliminated by introducing a supplementary control loop known as the power system stabilizer. The basic function of a PSS is to extend the stability limits by modulating the generator excitation to provide damping for the rotor oscillations of synchronous machines. The PSS can enhance the damping of power system, increase the static stability and improve the transmission capability. Two distinct types of oscillations are already identified: local mode oscillation and inter-area mode oscillation (Jiang, 2007). Local mode are largely determined and influenced by local area states. Usually, PSS is designed for damping local electromechanical oscillations. The PSS output is added to the difference between reference and actual value of the terminal voltage.

The design goal of PSS is to improve the damping torque coefficient with the least influence on the synchronizing torque coefficient by adding the PSS signal to AVR. A diagram illustrating the principle mode of operation of a PSS is shown in Fig. 4, where the generator speed deviation (Δω) from that synchronous frequency is input signal. A PSS is directly connected to the AVR of power system synchronous generator. The block diagram of the SMIB system with PSS and voltage control loop shown in Fig. 5.

The task of the PSS is to add an additional signal U₅ (output from the PSS) into the control loop which
compensates for the voltage oscillations and provides a damping component that is in phase. The washout block is a high-pass filter with a time constant high enough to allow signals associated with the speed oscillations to pass through unchanged (Machowski et al., 1998). The signal washout block serves as a high-pass filter. By choosing a large \( T_w \) value, the washout block will not have any effect on gain phase shift at the oscillating frequency.

The lead-lag network provides the appropriate phase-lead characteristic to compensate the phase lag between the exciter input and the generator electrical torque (Abdel et al., 2000).

The goal is to eliminate phase lag as best as possible throughout a wide range of frequencies of interest, then adjust gain as outlined below. The stabilizer gain \( K_p \) determines the size of that contribution. A gain high as practicable is required for best contribution to system damping.

The gain \( K_p \) is adjusted to obtain the desired damping for unstable or poorly damped modes. The time constants \( T_w, T_2 \) are usually pre-specified. The remaining parameters, namely time constant \( T_1 \) and stabilizer gain \( K_p \) are assumed to be adjustable parameters. The PSS frequency characteristic is adjusted by varying the time constant of system.

Typical range of the optimized parameters are 0.06-1 for \( T_1 \) and 0.001-50 for \( K_w \). The time constants \( T_w, T_2 \) are set as 5 and 0.05 sec, respectively (Abido, 2002). For the system with PSS, the new state variable vector becomes (Shahgholian et al., 2007):

\[
X = [\Delta \delta \quad \Delta \omega \quad \Delta E_q \quad \Delta E_r \quad \Delta U_w \quad \Delta U_d]^T \tag{40}
\]

In this case, the equation describing the AVR can be written as:

\[
\frac{d}{dt} \Delta E_r = \frac{1}{T_E} [K_E \Delta U_k - K_E K_p \Delta \delta - K_E K_p \Delta E_q - \Delta E_r + K_p \Delta U_d] \tag{41}
\]

The dynamic of the PSS can be expressed by the following differential equations:

\[
\frac{d}{dt} \Delta U_w = -\frac{K_u K_r T_e}{J T_2} \Delta \delta - \frac{K_u K_r T_e}{J T_2} \Delta \omega - \frac{K_u K_r T_e}{J} \Delta E_q - \frac{1}{T_w} \Delta U_w + \frac{K_p}{J} \Delta P_m \tag{42}
\]

\[
\frac{d}{dt} \Delta U_d = -\frac{K_u K_r T_e}{J T_2} \Delta \delta - \frac{K_u K_r T_e}{J T_2} \Delta \omega - \frac{K_u K_r T_e}{J} \Delta E_q - \frac{1}{T_d} \Delta U_d + \frac{K_p}{J} \Delta P_m \tag{43}
\]

The characteristic equation system without PSS is given by:

\[
\Delta(s) = s^5 + a_5 s^4 + a_4 s^3 + a_3 s^2 + a_2 s + a_1 \tag{44}
\]

Where:

\[
a_i = \frac{K_E}{T_1} + \frac{1}{T_E} + \frac{1}{T_w} + \frac{1}{T_2} \tag{45}
\]

\[
a_i = \frac{K_2}{T_1} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + \frac{1}{T_E} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + \frac{1}{T_2} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) \tag{46}
\]

\[
a_i = \frac{K_2}{T_1} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + \frac{1}{T_E} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + \frac{1}{T_2} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) \tag{47}
\]

\[
a_i = \frac{K_2}{T_1} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + \frac{1}{T_E} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + \frac{1}{T_2} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) \tag{48}
\]

The characteristic equation system with PSS is given by:

\[
\Delta(s) = s^5 + a_s s^4 + a_{s-1} s^3 + a_{s-2} s^2 + a_{s-3} s + a_s \tag{49}
\]

Where:

\[
a_i = \frac{K_E}{T_1} + \frac{1}{T_E} + \frac{1}{T_w} + \frac{1}{T_2} \tag{45}
\]

\[
a_i = \frac{K_2}{T_1} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + \frac{1}{T_E} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + \frac{1}{T_2} \left( \frac{1}{T_2} + \frac{1}{T_w} \right) \tag{46}
\]

\[
K_s \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + K_s \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + K_s \left( \frac{1}{T_2} + \frac{1}{T_w} \right) \tag{47}
\]

\[
K_s \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + K_s \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + K_s \left( \frac{1}{T_2} + \frac{1}{T_w} \right) \tag{48}
\]

\[
K_s \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + K_s \left( \frac{1}{T_2} + \frac{1}{T_w} \right) + K_s \left( \frac{1}{T_2} + \frac{1}{T_w} \right) \tag{49}
\]
\[ a_0 = \frac{\omega_0 K_x}{J \left[ K_{t_1} + K_{t_1} K_{t_2} + K_{t_2} K_{t_1} \right]} \]

A necessary condition for stability of the system is that all the roots in equation characteristic have a negative real part which in turn requires that all coefficients \((a_0, \ldots, a_4)\) are positive.

The natural modes of system response are related to the eigenvalues. The real component of the eigenvalues gives the damping and the imaginary component gives the frequency of oscillation.

**RESULTS AND DISCUSSION**

Table 1 shows the parameters of the SMIB system used in digital computer simulation to verify the performance of the proposed control scheme. The effects of the line model on sensitivity constant of linear model of power system are shown in Table 2. The steady state operating points of the model power system with normal loading are \(U_{ls} = 0.7234, U_{lg} = 0.6905, I_{ls} = 0.5754, I_{lg} = 0.4110, U_{ls} = 0.7088\) and \(\delta = 64.8799^\circ\).

The effect of line model on system damping with and without PSS for normal loading is shown in Table 3 and 4. Without PSS, the system was slightly damped because its dominant poles were close to the imaginary axis in the complex plane.

The damping ratio determines the rate of decay of the amplitude of oscillation. The damping ratio of the mechanical mode is improved as it changes from 0.0563-0.5972 with short model to 0.5887 with medium model and to 0.5824 with long model.

The selection of the washout time constant \(T_w\) value depends upon the type of modes under study (Awed-Dadeeb, 2006), the \(T_w\) does not have a significant impact on the complex mode correspond. The effect of PSS gain on system damping for normal loading is shown in Table 5.

The damping ratio of the mechanical mode is changes from 0.6274 at \(K_p = 10\) to 0.5934 at \(K_p = 30\). Also, the damping ratio of the electrical mode is changes from 0.4418 at \(K_p = 10\) to 0.2716 at \(K_p = 30\).

Therefore, an increase in the gain \(K_p\) decreases both the natural frequency and the damping ratio of system mechanical mode. Conversely, increasing the gain \(K_p\)...

**Table 1: Data of the SMIB system**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generator</td>
<td></td>
</tr>
<tr>
<td>(X_1)</td>
<td>1.76</td>
</tr>
<tr>
<td>(X_2)</td>
<td>1.81</td>
</tr>
<tr>
<td>(X_3)</td>
<td>0.30</td>
</tr>
<tr>
<td>(J)</td>
<td>7.00</td>
</tr>
<tr>
<td>(K_0)</td>
<td>4.00</td>
</tr>
<tr>
<td>(T_1)</td>
<td>8.00</td>
</tr>
<tr>
<td>(T_2)</td>
<td>60.0</td>
</tr>
<tr>
<td>Power system stabilizer</td>
<td></td>
</tr>
<tr>
<td>(T_1)</td>
<td>0.8</td>
</tr>
<tr>
<td>(T_2)</td>
<td>0.1</td>
</tr>
<tr>
<td>(T_3)</td>
<td>10</td>
</tr>
<tr>
<td>Automatic voltage regulator</td>
<td></td>
</tr>
<tr>
<td>(K_1)</td>
<td>20</td>
</tr>
<tr>
<td>Transmission line</td>
<td></td>
</tr>
<tr>
<td>(R)</td>
<td>0.113Ω/km^-1</td>
</tr>
<tr>
<td>(L)</td>
<td>1.618×10^9 H/km^-1</td>
</tr>
<tr>
<td>(C)</td>
<td>8.488×10^9 F/km^-1</td>
</tr>
<tr>
<td>(V_{bus})</td>
<td>250 KV</td>
</tr>
<tr>
<td>(S_{base})</td>
<td>200 MVA</td>
</tr>
<tr>
<td>Shunt load</td>
<td>300 kV</td>
</tr>
<tr>
<td>G</td>
<td>0.3</td>
</tr>
<tr>
<td>B</td>
<td>0.3</td>
</tr>
<tr>
<td>Loading normal</td>
<td></td>
</tr>
<tr>
<td>(U_{ls})</td>
<td>1.0</td>
</tr>
<tr>
<td>(P_{ls})</td>
<td>0.9</td>
</tr>
<tr>
<td>(Q_{ls})</td>
<td>0.1</td>
</tr>
<tr>
<td>Leading power factor</td>
<td></td>
</tr>
<tr>
<td>(U_{lg})</td>
<td>1.0</td>
</tr>
<tr>
<td>(P_{lg})</td>
<td>0.7</td>
</tr>
<tr>
<td>(Q_{lg})</td>
<td>-0.5</td>
</tr>
<tr>
<td>Line length (km)</td>
<td>300</td>
</tr>
<tr>
<td>Base in line</td>
<td></td>
</tr>
<tr>
<td>(V_{bus})</td>
<td>250 KV</td>
</tr>
<tr>
<td>(S_{base})</td>
<td>200 MVA</td>
</tr>
</tbody>
</table>

**Table 2: Sensitivity constant of model power system for line different models**

<table>
<thead>
<tr>
<th>Constants</th>
<th>Short line model</th>
<th>Medium line model</th>
<th>Long line model</th>
</tr>
</thead>
<tbody>
<tr>
<td>(K_1)</td>
<td>0.7084</td>
<td>0.6773</td>
<td>0.6673</td>
</tr>
<tr>
<td>(K_2)</td>
<td>1.2019</td>
<td>1.1965</td>
<td>0.1948</td>
</tr>
<tr>
<td>(K_3)</td>
<td>2.4005</td>
<td>2.3541</td>
<td>2.3402</td>
</tr>
<tr>
<td>(K_4)</td>
<td>1.1071</td>
<td>1.0595</td>
<td>1.0451</td>
</tr>
<tr>
<td>(K_5)</td>
<td>-0.0495</td>
<td>-0.0462</td>
<td>-0.0450</td>
</tr>
<tr>
<td>(K_6)</td>
<td>0.6735</td>
<td>0.6897</td>
<td>0.6944</td>
</tr>
<tr>
<td>(\delta)</td>
<td>64.8799^\circ</td>
<td>64.9242^\circ</td>
<td>65.2588^\circ</td>
</tr>
<tr>
<td>(U_{ls})</td>
<td>0.7088</td>
<td>0.6335</td>
<td>0.6303</td>
</tr>
</tbody>
</table>

**Table 3: The effect of line model on system eigenvalues without pss for normal loading**

<table>
<thead>
<tr>
<th>Short line model</th>
<th>Medium line model</th>
<th>Long line model</th>
</tr>
</thead>
<tbody>
<tr>
<td>-95.5844</td>
<td>-95.4735</td>
<td>-95.4406</td>
</tr>
<tr>
<td>-4.12630</td>
<td>-4.2660</td>
<td>-4.30250</td>
</tr>
<tr>
<td>-0.5804+i5.9996</td>
<td>-0.5658+i5.8663</td>
<td>-0.5604+i5.8127</td>
</tr>
</tbody>
</table>

**Table 4: The effect of line model on system eigenvalues with pss for normal loading**

<table>
<thead>
<tr>
<th>Short line model</th>
<th>Medium line model</th>
<th>Long line model</th>
</tr>
</thead>
<tbody>
<tr>
<td>-97.6702</td>
<td>-97.5577</td>
<td>-97.5244</td>
</tr>
<tr>
<td>-0.1015</td>
<td>-0.1015</td>
<td>-0.1015</td>
</tr>
<tr>
<td>-1.5009+i2.0640</td>
<td>-1.4631+i2.0241</td>
<td>-1.4516+i2.0262</td>
</tr>
</tbody>
</table>
Table 5: The effect of PSS gain on system eigenvalues for normal loading

<table>
<thead>
<tr>
<th>K_p</th>
<th>Without PSS</th>
<th>10</th>
<th>20</th>
<th>30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical mode</td>
<td>-0.5809+5.0996</td>
<td>-2.1359+2.6551</td>
<td>-1.5009+1.0696</td>
<td>-1.2493+1.6946</td>
</tr>
<tr>
<td>Electrical mode</td>
<td>-4.1263, -95.5844</td>
<td>-4.9709+1.0950</td>
<td>-5.6999+1.2435</td>
<td>-4.8619+1.2304</td>
</tr>
<tr>
<td>Control</td>
<td>-0.1007, -96.0511</td>
<td>-0.1015, -97.6705</td>
<td>-0.1022, -98.6468</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 6: Effect of gain K_p on load angle

Fig. 7: Effect of gain K_p on generator terminal voltage

Fig. 8: Effect of gain K_p on output electrical power

Fig. 9: Effect of gain K_p on rotor speed – load angle

shown in Fig 6-9. From the simulation results of the mathematical model, it is inferred that the damping of the power system is improved with the help of PSS. We can see that with the addition of the PSS, the system has become very stable.

CONCLUSION

Power system stabilizers have been thought to improve power system damping by generator voltage regulation depending on system dynamic response. The PSS is a supplementary control system which is often applied as part of excitation control system. This study proposes a linearized block diagram of a power system with a PSS and the performance of the PSS controller for the damping of oscillations in a SMIB using small signal model.

For power system dynamic researches transmission line is modeled using the parameters of line. The transfer functions are studied using Matlab and the step response verified by time domain simulation.

REFERENCES
