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# Design of Robust Power System Stabilizer in an interconnected Power System with Wind Power Penetrations

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## 1. Introduction

In the recent years, renewable electrical energy such as wind power generations, have achieved a significant level of penetration in the power systems due to infinite availability and low impact to environment. However, wind power generation is intermittent in nature. Matching the supply and the demand is often a problem. The power output fluctuations from wind power generations cause a problem of low frequency oscillation, deteriorate the system stability and make the power system operation more difficult. The power frequency and the tie-line power deviations persist for a long duration. In these situations, the governor system may no longer be able to absorb the frequency fluctuations due to its slow response (Elgerd & Fosha, 1970). To stabilize power oscillation, PSS is often used as an effective device to enhance the damping of electromechanical oscillations in power systems. The power system stabilizer is a supplementary control system, which is often applied as part of excitation control system. The basic function of the PSS is to apply a signal to the excitation system, creating electrical torques to the rotor, in phase with speed variation, that damp out power oscillations.

In the past decades, the utilization of supplementary excitation control signals for improving the dynamic stability of power systems has received much attention. Extensive research has been conducted in many fields such as the effect of PSS on power system stability, PSS input signals, PSS optimum locations, and PSS tuning techniques. In (deMello & Concordia, 1969), the concept of synchronous machine stability as affected by excitation control has been examined. This work developed insights into effects of excitation systems and requirement of supplementary stabilizing action for such systems based on the concept of damping and synchronizing torques. These stabilizing requirements included the adjustment of voltage regulator gain parameters as well as the PSS parameters.

Since the primary function of the PSS is to add damping to the power oscillations, basic control theories have been applied to select the most suitable input signal of PSS. Some readily available signals are generator rotor speed, calculated bus frequency, and electrical power. In

(Larsen & Swann, 1981), the application of PSS utilizing either of speed, frequency or power input signals has been presented. Guidelines were presented for tuning PSS that enable the user to achieve desired dynamic performance with limited effort. The need for torsional filters in the PSS path for speed input PSS was also discussed. The most PSS controls today use the generator rotor speed as the feedback input signal. They would provide robust damping over a wide range of operating conditions with minimum interaction (Murdoh et al, 2000).

Simulation studies of PSS effects on inter-area and local modes of oscillations in interconnected power systems have been presented by (Klein et al, 1991) and (Klein et al, 1992). It was shown that the PSS location and the voltage characteristics of the system loads are significant factor in the ability of a PSS to increase the damping of inter-area oscillations. The procedures for the selection of the most effective machines for stabilization have been proposed. In (Abdalla et al, 1984), an eigenvalue-based measurement of relative improvement in the damping of oscillatory modes has been implemented and used as a criterion to find the best candidate machine for stabilizer application. On the other hand, an eigenvector analysis to identify the most effective generating units to be equipped with PSSs in multi-machine systems that exhibit dynamic instability and poor damping of several inter-area modes of oscillations, has been presented in (DeMello et al, 1980).

Nowadays, the conventional lead/lag compensator PSS is widely used by the power system utility (Tse & Tso, 1993). Other types of PSS such as proportional-integral PSS (PI-PSS) and proportional-integral-derivative PSS (PID-PSS) have also been proposed by (Hsu & Hsu, 1986) and (Hsu & Liou, 1987). Several approaches based on modern control theories have been successfully applied to design PSSs. In (Yu & Siggers, 1971), the application of state-feedback optimal PSS has been presented, while an eigenvalue shifting technique for determining the weighing matrix in the performance index has been proposed by (Moussa & Yu, 1972). In (Fleming et al, 1981), a sequential eigenvalue assignment algorithm for selecting the parameters of stabilizers in a multi-machine power system has been presented. In sequential tuning, the stabilizer parameters are computed using repeated application of single-input/single-output (SISO) analysis. In (Zhou et al, 1992), the eigenvalue assignment has been proposed to design the optimal PSS. Besides, the new optimal linear quadratic regulator (LQR) based design has been presented by (Aldeen & Crusca, 1995). It is superior to previously reported LQR approaches. Moreover, PSS designs based on self tuning control (Cheng et al, 1986) and (Lim, 1989), fuzzy-logic system (Hsu & Cheng, 1990) and (Hoang & Tomsovic, 1996), artificial neural network (ANN) (Zhang et al, 1993), (Segal et al, 2000) and (Abido & Abdel_Magid, 1998) have been presented. However, since these techniques do not take the presence of system uncertainties such as system nonlinear characteristics, variations of system configuration due to unpredictable disturbances, loading conditions etc. into consideration in the system modeling, the robustness of these PSSs against uncertainties cannot be guaranteed.

To overcome these problems, $H_\infty$ control has been applied to design of robust PSS configuration by (Chen & Malik, 1995) and (Yan, 1997). In these works, the designed $H_\infty$ PSS via mixed sensitivity approach have confirmed the significant performance and high robustness. In this approach, however, due to the trade-off relation between sensitivity function and complementary sensitivity function, the weighting functions in $H_\infty$ control design cannot be selected easily. Moreover, the order of $H_\infty$ controller depends on that of the plant which is different from the conventional lead/lag PSS. Despite the significant potential of control techniques mentioned above, power system utilities still prefer the conventional lead/lag PSS structure. This is due to the ease of implementation, the long-term reliability, etc.

On the other hand, much research on a conventional lead/lag PSS design has paid attentions to tuning of PSS parameters. The parameters of a lead/lag PSS are optimized under various operating conditions by heuristic methods such as tabu search (Abdel-Magid et al, 2001), genetic algorithm (Abdel-Magid et al, 1999), and simulated annealing (Abido, 2000). Using these approaches, the PSS parameters are obtained so that all of the electro-mechanical mode eigenvalues may be placed at the prescribed locations in the s-plane. In these designs, however, the uncertainty model is not embedded in the mathematical model of the power system. Furthermore, the robust stability against system uncertainties is not taken into consideration in the optimization process. Therefore, the robust stability margin of the system in these works may not be guaranteed in the face of several uncertainties.

To solve this problem, the robust PSS design by a fixed structure with a conventional lead/lag PSS have been proposed [Cuk supriyadi et al, 2008]. In this work, the fixed structure robust PSS design by the $H_\infty$ loop shaping technique is proposed. The normalized coprime factor is used to model system uncertainties. To optimize the control parameters, the performance and robust stability conditions in the $H_\infty$ loop shaping technique are formulated as the objective function. As a result, the proposed PSSs are very robust against various uncertainties. With lower order, the stabilizing effect and robustness of the proposed PSS are almost the same as those of the PSS with high-order designed by $H_\infty$ loop shaping technique. In this works, however, the weighting functions in $H_\infty$ control design cannot be selected easily.

To tackle this problem, a new parameters optimization of robust PSS is proposed. The inverse additive perturbation is applied to represent unstructured system uncertainties. The configuration of PSS is a conventional second-order lead-lag compensator. To tune the PSS parameters, the concept of enhancement of system robust stability margin is formulated as the optimization problem. The genetic algorithm (GA) is applied to solve the problem and achieve the PSS parameters. Simulation studies in the two-area four-machine system with wind farms confirm that the damping effect and robustness of the proposed PSS are superior to those of the compared PSS.

## 2. System modelling

### 2.1 Power system model

A two-area four-machine interconnected power system with wind farms in Fig. 1 is used to design PSS. Each generator is represented by a 5th-state transient model. It is equipped with a simplified exciter and PSS with the speed deviation input. L1 and PW1 are load and wind farms in area 1, respectively. L2 and PW2 are load and wind farms in area 2, respectively.
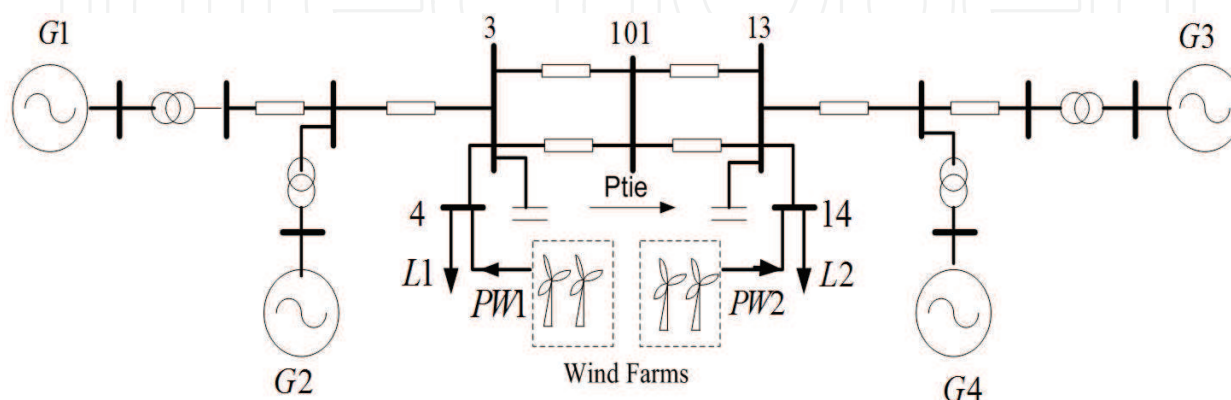


Fig. 1. Two areas four machines power system with wind farms

The linearized state equation of system in Fig. 1 can be expressed as

$$\Delta \dot{X} = A\Delta X + B\Delta u_{pss,i} \tag{1}$$

$$\Delta Y = C\Delta X + D\Delta u_{pss,i} \tag{2}$$

$$\Delta u_{pss,i} = K_{pss,i}(s)\Delta \omega_i \tag{3}$$

Where the state vector $\Delta X = \begin{bmatrix} \Delta\delta & \Delta\omega & \Delta e_d^{'} & \Delta e_q^{'} & \Delta E_{fd} \end{bmatrix}^T$, the output vector $\Delta Y = \begin{bmatrix} \Delta\omega \end{bmatrix}$, $\Delta u_{pss,i}$ is the control output signal of the PSS no. $i$ ( $K_{pss,i}(s)$ ), which uses only the angular velocity deviation ( $\Delta\omega$ ) as a feedback input signal and $i$ is the number of PSS. Note that the system in (1) is a Multi-input Multi-output (MIMO) system. The proposed method is applied to design a robust PSS $K(s)$. The system of (1) is referred to as the nominal plant $G$.

## 2.2 Wind power model
### 2.2.1 Wind velocity model
The output power of wind generator depends on wind velocity. The wind speed model chosen in this study consists of four-component model (Dong-Jiang & Li Wang, 2008), and is defined by

$$V_W = V_{WB} + V_{WG} + V_{WR} + V_{WN} \tag{4}$$

where:

$V_{WB}$ = Base wind velocity

$V_{WG}$ = Gust wind component

$V_{WR}$ = Ramp wind component

$V_{WN}$ = Noise wind component

The base wind velocity component is represented by

$$V_{WB} = K_B \tag{5}$$

Where $K_B$ is a constant, this component is always assumed to be presented in a wind power. The gust wind velocity can be expressed by

$$V_{WG} = \begin{cases} 0 & t < T_{1G} \\ V_{\cos} & T_{1G} < t < T_{1G} + T_G \\ 0 & t > T_{1G} + T_G \end{cases} \tag{6}$$

where:

$V_{\cos}$ = $(MAXG / 2)\{1 - \cos 2\pi[(t / T_G) - (T_{1G} / T_G)]\}$

MAXG = the gust peak

$T_G$ = the gust period

$T_{1G}$ = the gust starting time

(1-cosine) gust is an essential component of wind velocity for dynamic studies.

The ramp wind velocity component is described by

$$V_{WR} = \begin{cases} 0 & t < T_{1R} \\ V_{ramp} & T_{1R} < t < T_{2R} \\ 0 & t > T_{2R} \end{cases} \qquad (7)$$

where:

$V_{ramp}$ = $MAXR[1-(t-T_{2R})/(T_{1R}-T_{2R})]$

MAXR = the ramp peak

$T_{1R}$ = the ramp start time

$T_{2R}$ = the ramp maximum time

This component may be used to approximate a step change with $T_{2R} > T_{1R}$.

The random noise component can be defined by

$$V_{WN} = 2 \sum_{i=1}^{N} [S_V(\omega_i)\Delta\omega]^{1/2} \cos(\omega_i t + \phi_i) t < 0 \qquad (8)$$

where:

$\omega_i = (i-1/2)\Delta\omega$

$\phi_i$ = a random variable with uniform probability density on the interval 0 to $2\pi$

and the spectral density function is defined by

$$S_V(\omega_i) = \frac{2K_N F^2[\omega_i]}{\pi^2[1+(F_{\omega_i}/\mu\pi)^2]^{4/3}} \qquad (9)$$

Where $K_N$ (=0.004) is the surface drag coefficient, F(=2000) is turbulence scale, and $\mu$ is the mean speed of wind at reference height. Various study have shown that values of N=50, and $\Delta\omega$ = 0.5-2.0 rad/s provide results of excellent accuracy.

### 2.2.2 Characteristic of wind generator output power

The output power of studied wind generator is expressed by a nonlinear function of the power coefficient $Cp$ as function of blade pitch angle, $\beta$, and tip speed ratio, $\gamma$.

The tip speed ratio can be described by

$$\lambda = \frac{R_{blade}\omega_{Blade}}{V_W} \qquad (10)$$

The power coefficient can be expressed by

$$C_P = (0.44 - 0.0167\beta)\sin\left[\frac{\pi(\lambda-3)}{15-0.3\beta}\right] - 0.0184(\lambda-3)\beta \qquad (11)$$

Finally, the output mechanical power of wind generator is

$$P_W = \frac{1}{2}\rho A_r C_P V_W^3 \qquad (12)$$

where $\rho$ (=1.25 kg/m$^3$) is the air density and $A_r$(=1735 m$^2$) is the swept area of blade.

## 3. Proposed method

### 3.1 System uncertainties

System nonlinear characteristics, variations of system configuration due to unpredictable disturbances, loading conditions etc., cause various uncertainties in the power system. A controller which is designed without considering system uncertainties in the system modeling, the robustness of the controller against system uncertainties can not be guaranteed. As a result, the controller may fail to operate and lose stabilizing effect under various operating conditions. To enhance the robustness of power system damping controller against system uncertainties, the inverse additive perturbation (Gu et al, 2005) is applied to represent all possible unstructured system uncertainties. The concept of enhancement of robust stability margin is used to formulate the optimization problem of controller parameters.
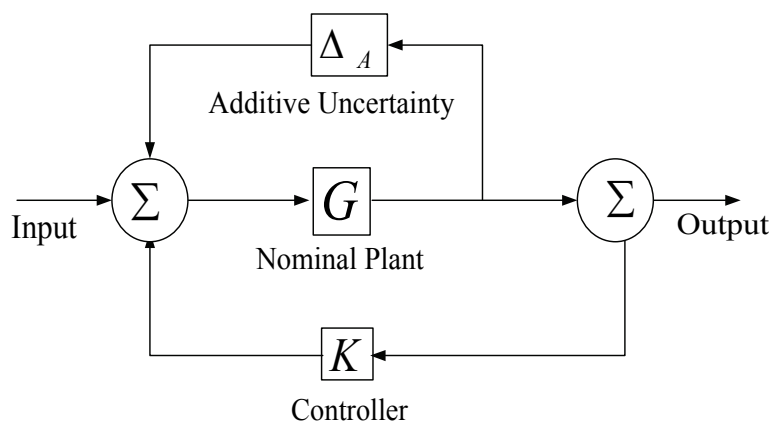


Fig. 2. Feedback system with inverse additive perturbation.

The feedback control system with inverse additive perturbation is shown in Fig.2. $G$ is the nominal plant. $K$ is the designed controller. For unstructured system uncertainties such as various generating and loading conditions, variation of system parameters and nonlinearities etc., they are represented by $\Delta_A$ which is the additive uncertainty model. Based on the small gain theorem, for a stable additive uncertainty $\Delta_A$, the system is stable if

$$\left\| \Delta_A G / (1 - GK) \right\|_\infty < 1 \tag{13}$$

then,

$$\left\| \Delta_A \right\|_\infty < 1 / \left\| G / (1 - GK) \right\|_\infty \tag{14}$$

The right hand side of (14) implies the size of system uncertainties or the robust stability margin against system uncertainties. By minimizing $\left\| G/(1-GK) \right\|_\infty$, the robust stability margin of the closed-loop system is a maximum.

### 3.2 Implementation
### 3.2.1 Objective function

To optimize the stabilizer parameters, an inverse additive perturbation based-objective function is considered. The objective function is formulated to minimize the infinite norm of $\left\| G/(1-GK) \right\|_\infty$. Therefore, the robust stability margin of the closed-loop system will increase

to achieve near optimum and the robust stability of the power system will be improved. As a result, the objective function can be defined as

$$\text{Minimize} \quad \left\| G/(1 - GK) \right\|_\infty \tag{15}$$

It is clear that the objective function will identify the minimum value of $\left\| G/(1 - GK) \right\|_\infty$ for nominal operating conditions considered in the design process.

### 3.2.2 Optimization problem
In this study, the problem constraints are the controller parameters bounds. In addition to enhance the robust stability, another objective is to increase the damping ratio and place the closed-loop eigenvalues of the electromechanical mode in a D-shape region. The D-shape region can be established to achieve the following objectives.
1.  To have some degree of relative stability (Abdel-Magid et al, 1999). The parameters of the controller may be selected to place the electromechanical mode eigenvalue in the left-side of the s-plane by the following function,

$$J_1 = \sigma \leq \sigma_{spec} \tag{16}$$

where $\sigma$ is the actual real part of eigenvalue and $\sigma_{spec}$ is desired real part of the dominant inter-area oscillation mode, respectively. The relative stability is determined by the value of $\sigma_{spec}$. This will place the closed-loop eigenvalues in a region as shown in Fig. 3.
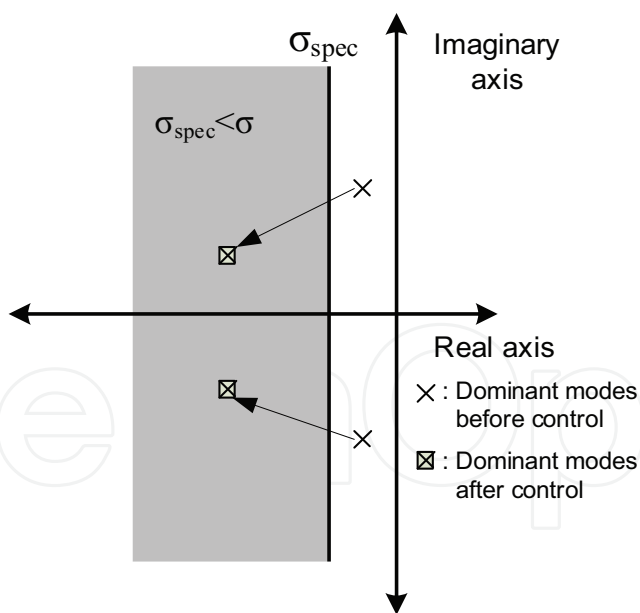


Fig. 3. Region in the left-side of the s-plane where $\sigma \leq \sigma_{spec}$

2.  To limit the maximum overshoot, the parameters of the controller may be selected by the following function

$$J_2 = \zeta \geq \zeta_{spec} \tag{17}$$

$\zeta$ and $\zeta_{spec}$ are the actual and desired damping ratio of the dominant inter-area oscillation mode, respectively. This will place the closed-loop eigenvalues in a wedge-shape region in which as shown in Fig. 4.
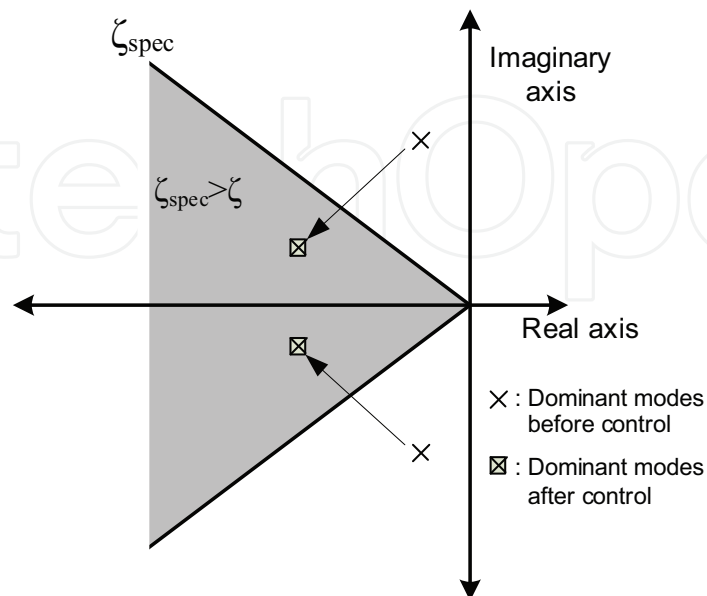


Fig. 4. Wedge-shape region in the s-plane where $\zeta \geq \zeta_{spec}$

Next, the conditions $J_1$ and $J_2$ are imposed simultaneously and will place the system closed-loop eigenvalues in the D-shape region characterized by $\zeta \geq \zeta_{spec}$ and $\sigma \leq \sigma_{spec}$ as shown in Fig. 5. It is necessary to mention here that only the unstable or lightly damped electromechanical modes of oscillations are relocated.
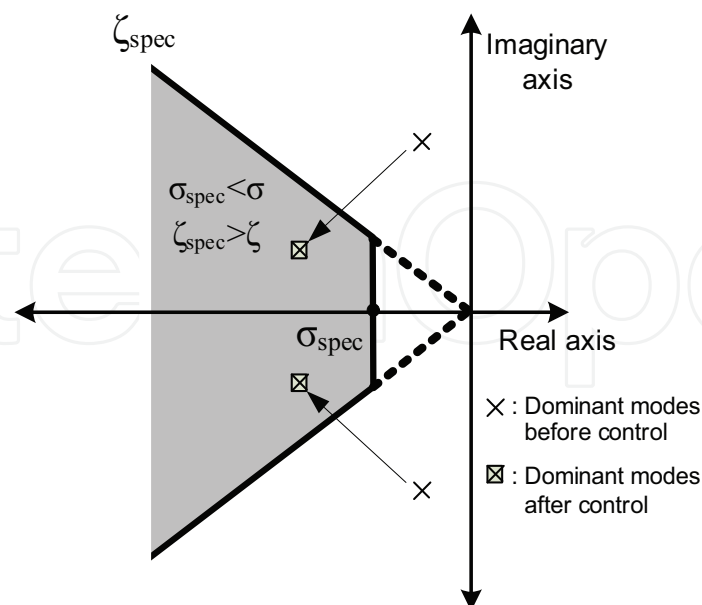


Fig. 5. D-shape region in the s-plane where $\sigma \leq \sigma_{spec}$ and $\zeta \geq \zeta_{spec}$

Therefore, the design problem can be formulated as the following optimization problem.

$$\text{Minimize} \quad \left\| G/(1 - GK) \right\|_\infty \tag{18}$$

$$\text{Subject to} \quad \zeta \geq \zeta_{spec}, \sigma \leq \sigma_{spec} \tag{19}$$

$$K_{\min} \leq K \leq K_{\max}$$

$$T_{\min} \leq T \leq T_{\max}$$

where $\zeta$ and $\zeta_{spec}$ are the actual and desired damping ratio of the dominant inter-area oscillation mode, respectively; $\sigma$ and $\sigma_{spec}$ are the actual and desired real part, respectively; $K_{\max}$ and $K_{\min}$ are the maximum and minimum controller gains, respectively; $T_{\max}$ and $T_{\min}$ are the maximum and minimum time constants, respectively. This optimization problem is solved by GA (GAOT, 2005) to search the controller parameters.

### 3.3 Parameters optimization by GA

In this section, GA is applied to search the controller parameters of PSS with off line tuning. The flow chart of the proposed method is illustrated in Fig. 6. Each step is explained as follows.
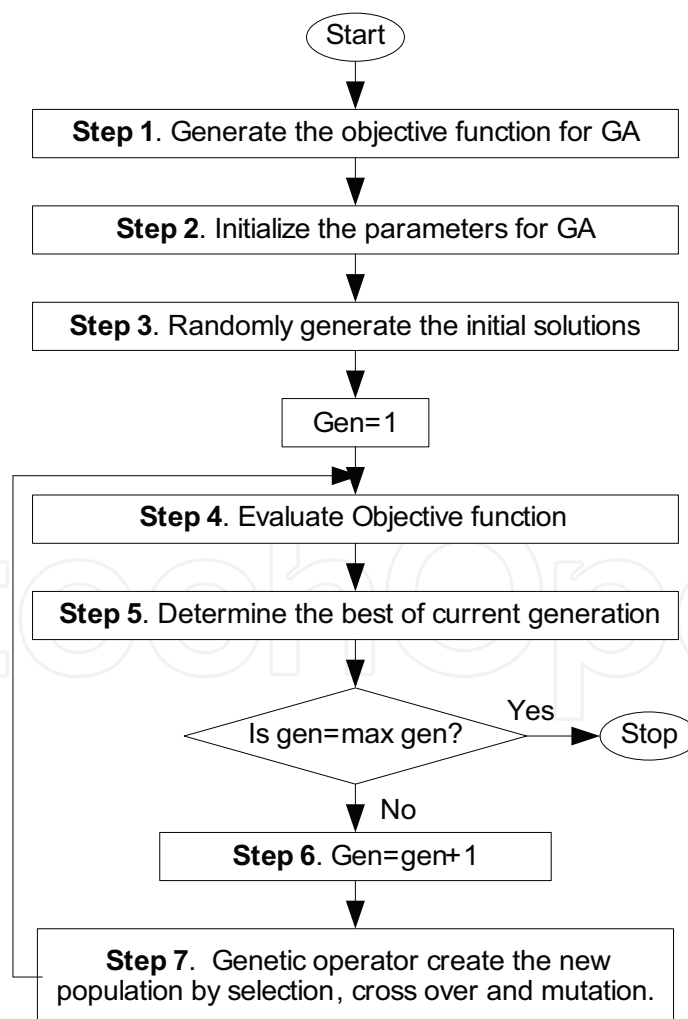


Fig. 6. Flow chart of the proposed design

**Step 1.** Generate the objective function for GA optimization.

In this study, the performance and robust stability conditions in inverse additive perturbation design approach is adopted to design a robust PSS. The conventional PSS with a 2nd-order lead-lag controller is represented by

$$\Delta u_{pss,i} = K_i \left( \frac{sT_W}{sT_W + 1} \right) \left( \frac{sT_{1,i} + 1}{sT_{2,i} + 1} \right) \left( \frac{sT_{3,i} + 1}{sT_{4,i} + 1} \right) \Delta \omega_i \qquad (20)$$

where, $\Delta u_{pss,i}$ and $\Delta \omega_i$ are the control output signal and the rotor speed deviation at the *i-th* machine, respectively; $K_i$ is a controller gain; $T_W$ is a wash-out time constant (s): and $T_{1,i}$, $T_{2,i}$, $T_{3,i}$, and $T_{4,i}$ are time constants (s).

**Step 2.** Initialize the search parameters for GA. Define genetic parameters such as population size, crossover, mutation rate, and maximum generation.

**Step 3.** Randomly generate the initial solution.

**Step 4.** Evaluate objective function of each individual in (18) and (19).

**Step 5.** Select the best individual in the current generation. Check the maximum generation.

**Step 6.** Increase the generation.

**Step 7.** While the current generation is less than the maximum generation, create new population using genetic operators and go to step 4. If the current generation is the maximum generation, then stop.

## 4. Performance simulation and results

In the optimization, the ranges of search parameters and GA parameters are set as follows: $\zeta$ and $\zeta_{spec}$ are actual and desired damping ratio is set as 0.1, respectively, $\sigma$ and $\sigma_{spec}$ are actual and desired real part of the inter-area oscillation mode is set as -0.1, $K_{i,\min}$ and $K_{i,\max}$ are minimum and maximum gains of PSS are set as 1 and 30, $T_{ji,\min}$ and $T_{ji,\max}$ are minimum and maximum time constants of PSS are set as 0.01 and 1. $T_w$ is set to 10 s. The optimization problem is solved by genetic algorithm. Under the normal operating condition case 1 in Table 1, the robust control parameters (RPSS) are obtained as follows.

$$K_{PSS1} = 25.05 \left( \frac{0.8638s + 1}{0.7425s + 1} \right) \left( \frac{0.8538s + 1}{0.7227s + 1} \right)$$

$$K_{PSS2} = 25.58 \left( \frac{0.5395s + 1}{0.3324s + 1} \right) \left( \frac{0.5124s + 1}{0.3175s + 1} \right)$$

$$K_{PSS3} = 12.79 \left( \frac{0.4940s + 1}{0.2545s + 1} \right) \left( \frac{0.4748s + 1}{0.2675s + 1} \right) \qquad (21)$$

$$K_{PSS4} = 12.50 \left( \frac{0.6235s + 1}{0.1806s + 1} \right) \left( \frac{0.6133s + 1}{0.1350s + 1} \right)$$

Table 2 shows the eigenvalue and damping ratio of the dominant inter-area oscillation mode. Clearly, the damping ratio of the oscillation mode of RPSS is improved as designed in comparison with No PSS case.

| CASE | 1. NOC (Ptie =3.0) | 2. HL (Ptie =4.5) | 3. HL (Ptie =4.5) with fault | 4. HL (Ptie =4.5) and WL with fault |
|------|------|------|------|------|
| G1 | PG=7 | PG=9 | PG=9 | PG=9 |
| G2 | PG=6 | PG=7.5 | PG=7.5 | PG=7.5 |
| G3 | PG=3.25 | PG=5 | PG=5 | PG=5 |
| G4 | PG=3.75 | PG=4 | PG=4 | PG=4 |
| Load | L1=10 , L2=10 | L1=12 , L2=13 | L1=12 , L2=13 | L1=12 , L2=13 |
| Line condition | Two lines of 3-101 | Two lines of 3-101 | one line of 3-101 is openned at 10 s. | one line of 3-101, 3ø fault at line 3-101 |

Note: NOC=normal operating condition, HL=heavy load, WL=weak line,
G = Generation (pu), L = Load (pu), Base = 900 MVA

Table 1. Operating conditions

| Cases | Eigenvalue and damping ratio |
|-------|------------------------------|
| No PSS | $-0.0829 \pm j\,3.6759$, $\zeta = 0.023$ |
| With RPSS | $-0.3407 \pm j\,2.4603$, $\zeta = 0.137$ |

Table 2. Dominant inter-area modes

In the study, the performance and robustness of RPSS are compared with Conventional PSS (CPSS) (Klein et al, 1992). The eigenvalue analysis and nonlinear simulations are carried under four case studies as given in Table 1.

Table 3 shows the eigenvalues and damping ratios of the dominant inter-area oscillation mode. Clearly, the CPSS loses control effect in case 4 (heavy load and weak line). The damping ratio is negative and the system becomes unstable. On the other hand, the damping ratio of the oscillation mode of RPSS is still positive. The damping effect of RPSS is very robust under any operating condition.

| Case | NOC | HL & WL |
|------|-----|---------|
| CPSS | $-0.1186 \pm j3.6845$ | $0.0452 \pm j2.5707$ |
|      | 0.0322 | -0.0176 |
| RPSS | $-0.3407 \pm j2.4603$ | $-0.2095 \pm j2.0705$ |
|      | 0.137 | 0.101 |

Table 3. Dominant inter-area modes and damping ratio

Fig. 7 depicts wind velocity [Vw1] and [Vw2] of wind farms based on (4). Using (12), wind power generations [PW1] and [PW2] can be shown in Fig. 8. In simulation studies of all cases, wind power generations are injected to buses 4 and 14, respectively. Fig.9 shows tie-line power deviation in case 1 at the normal condition. CPSS and RPSS are able to damp power oscillations due to wind power fluctuations.

Under heavy load condition in case 2, No PSS loses stabilizing effect. It is not able to damp out power fluctuation. The system stability can not be maintained. On the other hand, the PSS is capable of stabilizing power fluctuation. It still retains system stability successfully. Nevertheless, the RPSS provides more damping effects than CPSS as shown in Fig.10. These results signify that the stabilizing effect of RPSS against wind power fluctuations is superior to that of CPSS.
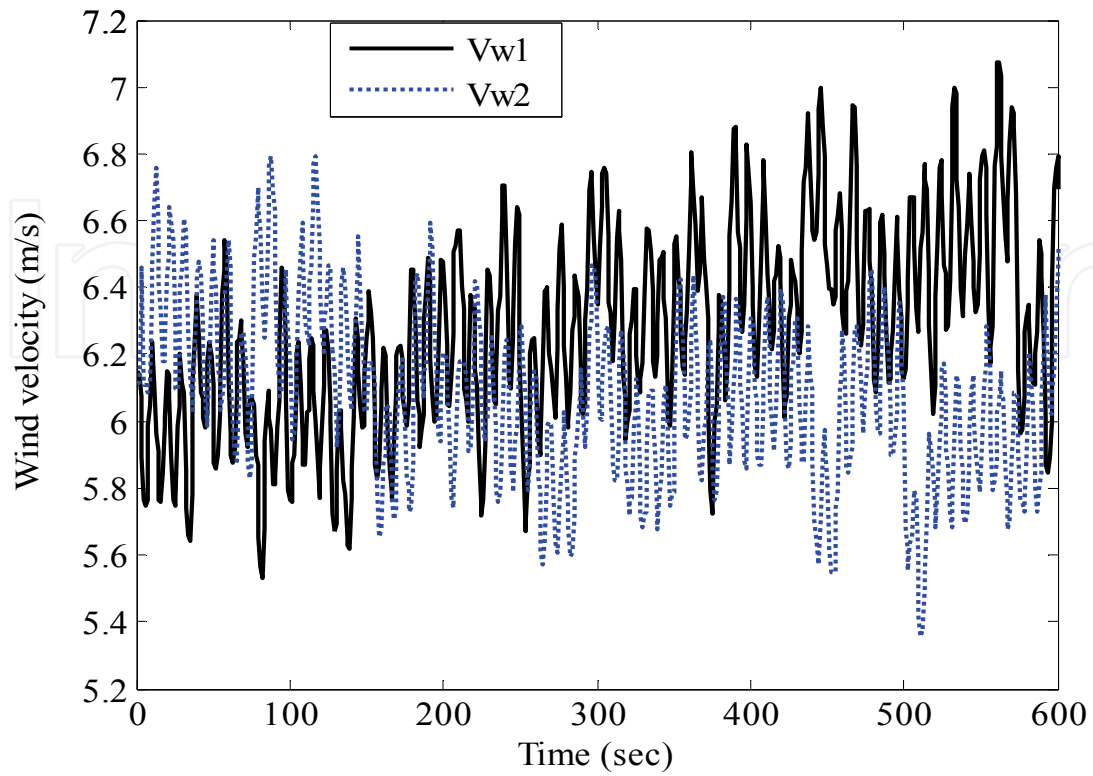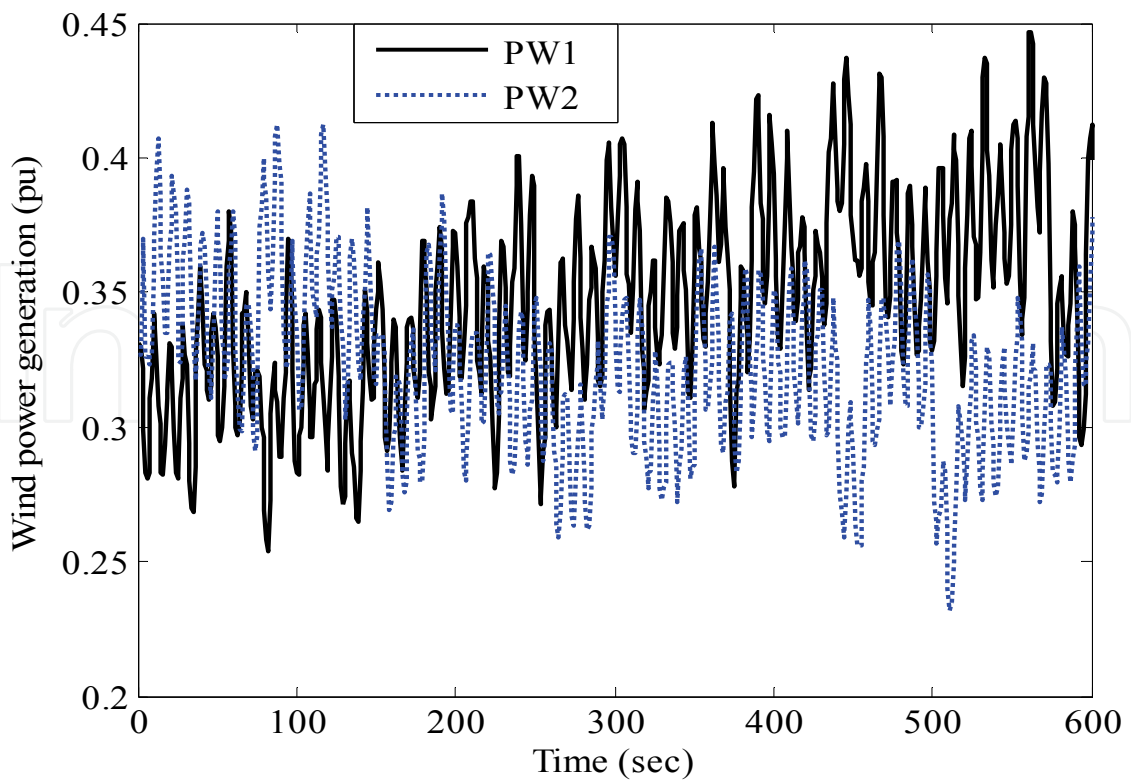
Fig. 7. Wind velocity.



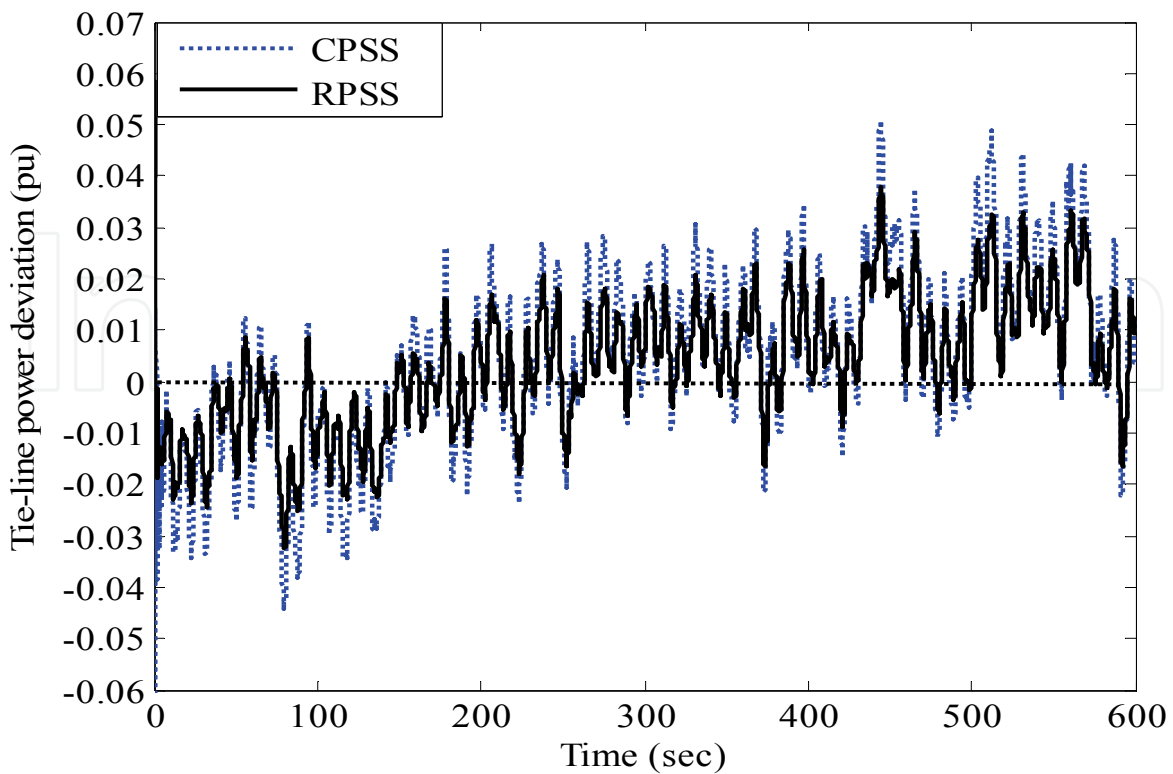Fig. 8. Wind power generations.

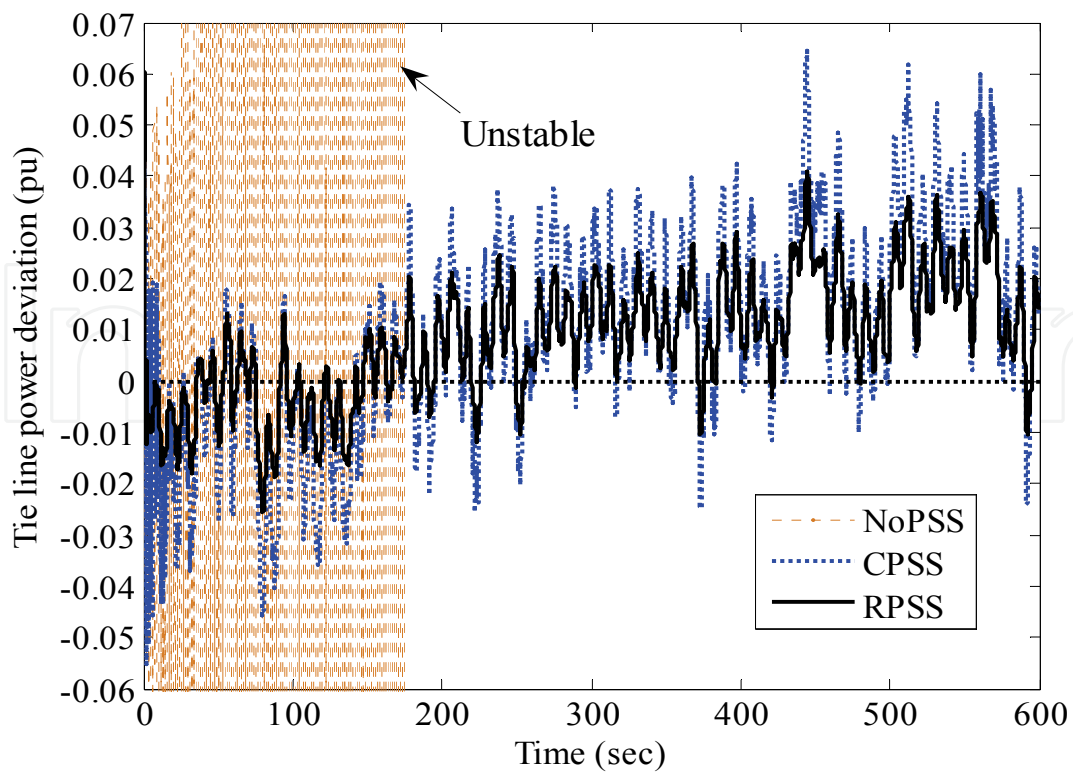Fig. 9. System responses in case 1 (normal condition).



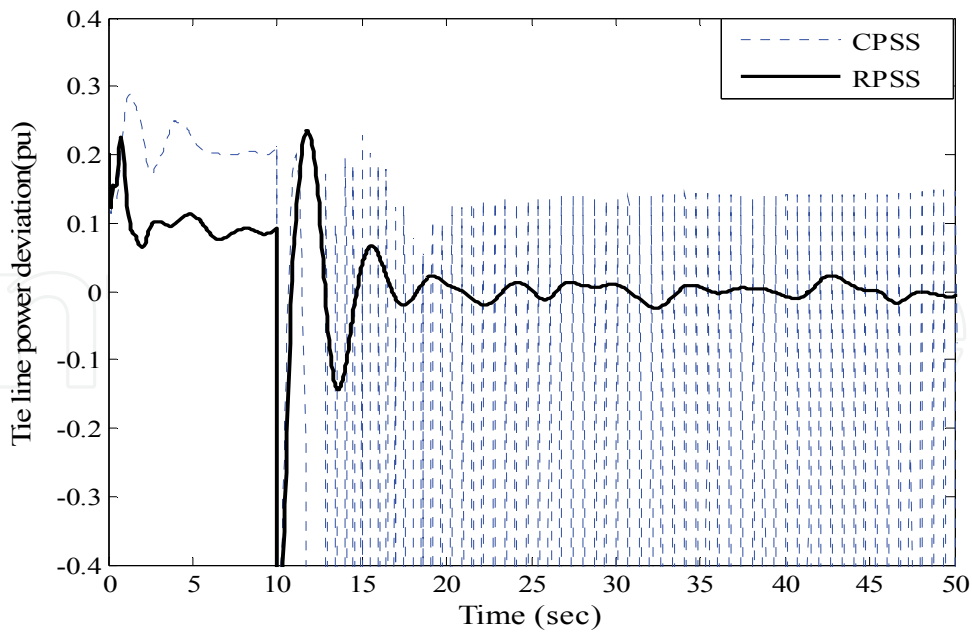Fig. 10. System responses in case 2 (heavy load).

Fig. 11. System responses in case 3 (heavy load).

In case 3, it is assumed that the tie-line power transfers from areas 1 to 2 via two lines of tie-line 3-101, then one line is suddenly opened at 10 s. Simulation result is depicted in Fig. 11. The CPSS is not capable of damping power oscillation and eventually loses stabilizing effect. On the other hand, the RPSS is very robust against this situation. The power oscillation can be stabilized effectively.
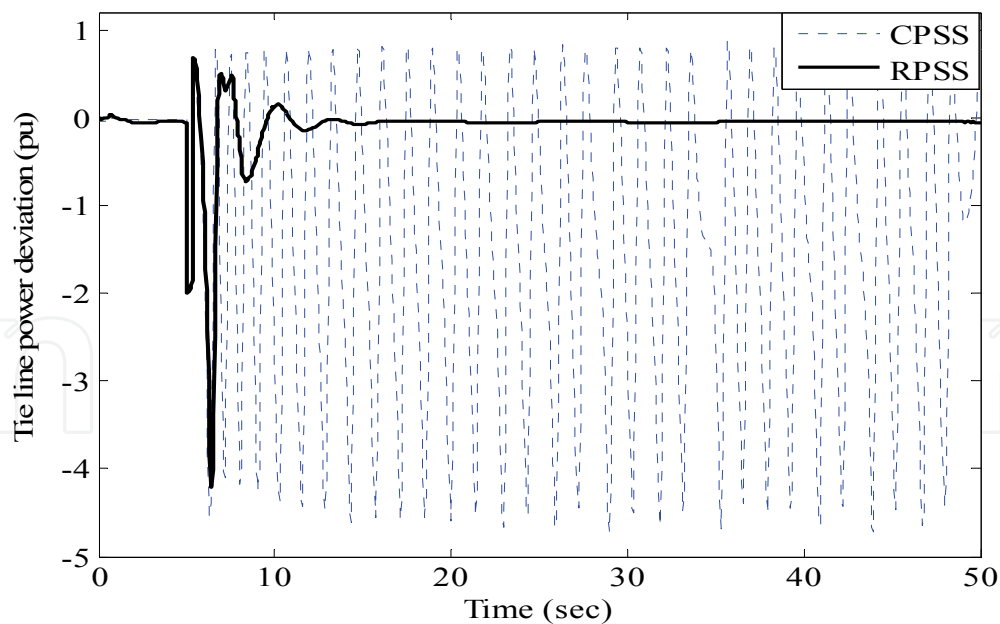


Fig. 12. System responses in case 4 (heavy load & weak line).

Finally, in case 4, it is assumed that one line of 3-101 is in service. A 3ø fault occurs at line 3-101 at 5s and the fault is cleared after 150 ms. Simulation results in Fig. 12 show that CPSS completely loses its control effect. On the other hand, the RPSS still retains system stability successfully. This explicitly shows the superior robustness of RPSS beyond CPSS.

# 7. Conclusion

Robust PSS design based on inverse additive perturbation in a power system with wind farms has been proposed in this work. The parameters optimization of PSS is formulated based on an enhancement of system robust stability margin. Solving the problem by GA, PSS parameters are automatically obtained. The designed PSS is based on the conventional 2nd-order lead-lag compensator. Accordingly, it is easy to implement in real systems. The damping effects and robustness of the proposed PSS have been evaluated in the two areas four machines power system with wind farms. Simulation results confirm that the robustness of the proposed PSS is much superior to that of the CPSS against various uncertainties.

# 8. References

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**Wind Power**

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This book is the result of inspirations and contributions from many researchers of different fields. A wide verity of research results are merged together to make this book useful for students and researchers who will take contribution for further development of the existing technology. I hope you will enjoy the book, so that my effort to bringing it together for you will be successful. In my capacity, as the Editor of this book, I would like to thanks and appreciate the chapter authors, who ensured the quality of the material as well as submitting their best works. Most of the results presented in to the book have already been published on international journals and appreciated in many international conferences.

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