Multiobjective Control Based Robust PSS Design

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1. Abstract

This paper addresses an LMI (linear matrix inequalities) based robust control methodology for designing of power system stabilizers (PSS) using mixed H_2/H_∞ control technique. A single-machine infinite-bus (SMIB) system example is given to illustrate the developed approach. The robust PSS is shown to maintain the robust performance and minimize the effect of disturbance and specified uncertainties.

2. Introduction

Power systems continuously experience changes in operating conditions due to variations in generation/load and a wide range of disturbances. The power system stabilizer (PSS) design objectives (i.e. holding the power system stability and performance in the presence of various disturbances and uncertainties) determine the PSS synthesis as a multi-objective control problem. Therefore, it is expected that an appropriate multi-objective control strategy could be able to give a better solution for this problem. However, in the most of reported robust PSS approaches only one single norm is used to capture design specifications. It is clear that meeting all the PSS design objectives by a single norm-based control approach is difficult. Furthermore each robust method is mainly useful to capture a set of special specifications.

An application of mixed H_2/H_∞ control technique for tuning of PSS under pole region constraints is given in Ref. (1). In continuation, the present paper provides a more general H_2/H_∞-based control framework for decentralized designing of power system stabilizers. In this paper, first the robust stability and performance objectives are formulated via a multi-objective control problem and then the desired PSS will be obtained using a mixed H_2/H_∞ control approach. The model uncertainty in power system is covered by an unstructured multiplicative uncertainty block.

3. Proposed control methodology

The main control framework to formulate the PSS design problem via a mixed H_2/H_∞ control design for a given power system "*i*" is shown in Fig. 1. $G_i(s)$ and $K_i(s)$ correspond to the nominal dynamical model of the given power system and PSS, respectively. Also y_i is the measured output, u_i is the control input and w_i includes the perturbed and disturbance signals in the control area.

The model uncertainties in power system are considered as multiplicative and/or additive uncertainties. Δ_i models the structured uncertainty set in the form of multiplicative type and W_i includes the associated weighting function. The output channel $z_{\infty i}$ is associated with the H_∞ performance while the fictitious output z_{2i} is associated with LQG aspects or H_2 performance.

The η_{1i}, η_{2i} and η_{3i} are constant performance weighting coefficients. The PSS design problem as a multi-objective control problem can be transfered to design a controller that minimizes the 2-norm of the fictitious output signal z_{2i} under the constraints that the ∞-norm of the transfer function from w_{1i} to $z_{\infty i}$ is less than one. On the other hand, the PSS design is reduced to find an internally stabilizing controller $K_i(s)$ such that,

$$\textit{minimize } \gamma_2 = \left\| T_{z_{2i} w_{2i}} \right\|_2 \ \textit{subject to } \gamma_\infty = \left\| T_{z_{\infty i} w_{1i}} \right\|_\infty < 1 \qquad (1)$$

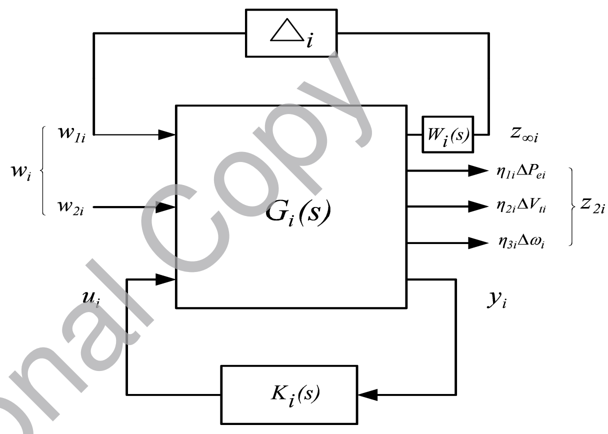

Fig. 1. Mixed H_2/H_∞-based PSS synthesis framework.

This problem can be solved by convex optimization techniques using LMI. Using conventional linear models for the given power system "*i*", it will be easy to find the state-space realization in the following form.

$$\begin{aligned} \dot{x}_i &= A_i x_i + B_{1i} w_i + B_{2i} u_i \\ z_{\infty i} &= C_{\infty i} x_i + D_{\infty 1i} w_i + D_{\infty 2i} u_i \\ z_{2i} &= C_{2i} x_i + D_{21i} w_i + D_{22i} u_i \\ y_i &= C_{yi} x_i + D_{y1i} w_i \end{aligned} \qquad (2)$$

Here, disturbance input and output vector z_{2i} are considered as follows:

$$w_i^T = [w_{1i} \quad w_{2i}],\ w_{2i} = \Delta V_{tdi}$$
$$z_{2i}^T = [\eta_{1i}\Delta P_{ei} \quad \eta_{2i}\Delta V_{ti} \quad \eta_{3i}\Delta\omega_i]$$

where, w_{1i}, ΔV_{td}, ΔP_e, ΔV_t and $\Delta\omega$ are the perturbed input, voltage disturbance, electrical power, terminal voltage and the machine speed, respectively.

The H_2 performance is used to minimize the effects of disturbances on controlled output signals. The H_∞ performance is used to meat the robustness against specified uncertainties and reduction of its impact on closed-loop system performance.

4. Application to a SMIB system

To illustrate the effectiveness of the proposed control strategy, one-machine infinite-bus (SMIB) system is considered as a test system. A single line representation of the power system is shown in Fig. 2. The electrical power signal is considered as the input of PSS. The power system parameters are given in Ref. (2). The state variables and the measured output signal are chosen as (3), where v_R, E_{fd} and e'_q are AVR voltage, field excitation voltage and the quadratic-axis transient voltage, respectively.

$$x^T = \begin{bmatrix} \Delta\omega & \Delta\delta & \Delta E_{fd} & \Delta e'_q & \Delta v_R \end{bmatrix} \qquad (3)$$
$$y = \Delta P_e$$

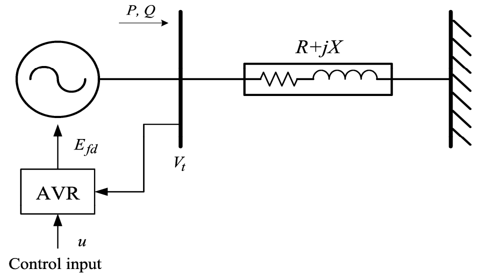

Fig. 2. The single line representation of a SMIB system.

In this example with regards to uncertainty, it is assumed that the parameters of connected line to infinite bus (R_i and X_i) have uncertain parameters. These uncertainties are modeled as an unstructured multiplicative uncertainty block that contains all the information available about R_i and X_i variations. The selection of constant weights η_{1i}, η_{2i} and η_{3i} entails a trade off among several performance requirements. Here, the values of constant weights are fixed in 0.01.

According to the proposed synthesis methodology and using the LMI control toolbox in MATLAB[3], a robust PSS satisfying optimization problem (1) is obtained. The order of resulted controller is 8, but using a model reduction technique, a 2nd order controller with virtually no performance degradation is yielded.

5. Simulation results

The performance of the closed-loop system in comparison of a conventional PSS is tested in the presence of voltage disturbances, short circuit fault and parameter variations. For this purpose, a quite popular structure for the conventional PSS with properly tuned coefficients is considered. In first test case, the performance of two controllers was evaluated in the presence of a 0.1 pu step disturbance injected at the voltage reference input of the AVR at 1 second. Fig. 3 shows the closed-loop response of the power systems fitted with the conventional and proposed PSS.

Fig. 4 shows the electrical power, terminal voltage and machine speed following a fault on the transmission line during 1 to 10 seconds (the fault is removed at 10s). Comparing the simulation results with both types of controllers shows that the robust design achieves robustness against the uncertainties/disturbance and a quite better performance with less control effort.

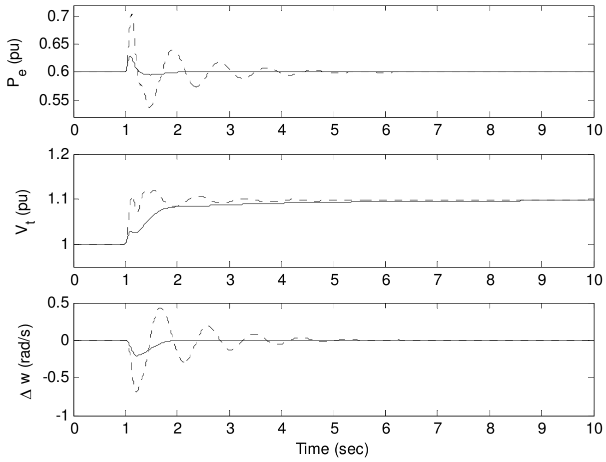

Fig.3. System response to a step disturbance at the voltage reference input; Solid (Robust PSS), dotted (Conventional PSS).

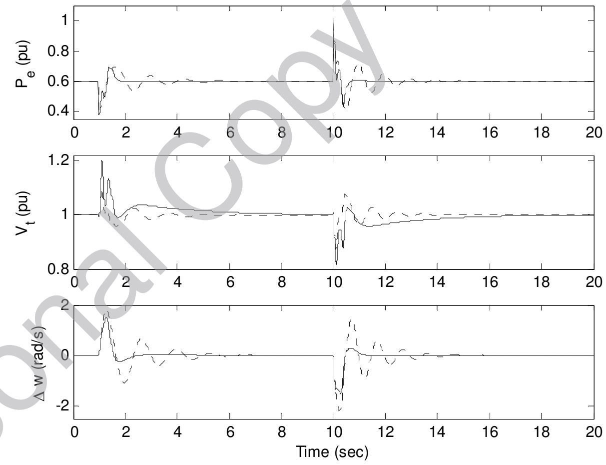

Fig. 4. System response following a fault on transmission line during 1 to 10 seconds; Solid (Robust PSS), dotted (Conventional PSS).

6. Conclusion

The power system stabilizer design problem is formulated as a decentralized multi-objective optimization control problem using the mixed H_2/H_∞ control technique. The proposed method was applied to a single-machine infinite-bus power system, and the results are compared with the conventional PSS design. The performance of the resulting fixed structure robust PSS is shown to be satisfactory over a wide range of operating conditions.

Acknowledgements

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7. Reference

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