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Improvement of Single and Multimachine Power System Stabili TY Using Fuzzy State Feedback PSS

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Abstract: This study deals with the design and evaluation of a robust controller for generator excitation system to improve the steady state and transient stability. The design is based on fuzzy state feedback controller, applying for the single machine systems and extended to multi-machine systems. The effectiveness of the proposed PSS is demonstrated under different operating regimes. A comparative study of the proposed PSS (FSFPSS: Fuzzy state feedback power system stabiliser) with a conventional PSS such as optimal controllers has been performed and the superiority of the FSFPSS in improving the transient stability of the power generator is demonstrated in a simulation environment.

Key words: Fuzzy logic, power system stabilizer

INTRODUCTION

One of the most important problems arising from large-scale power systems is the low frequency oscillation. Excitation control or Automatic Voltage Regulator (AVR) is well known as an effective means to improve the overall stability of the power system. Power System Stabilisers (PSS) are introduced in order to provide additional damping to enhance the stability and the performance of the electric generating system. The output of the PSS as supplementary control signal is applied to the machine voltage regulator terminal.

Conventional PSS have been widely used in power systems. Such PSS ensures optimal performance only at a nominal operating point and does not guarantee good performance over an entire range of the system operating conditions. Several techniques have been proposed for the design of more robust PSS structures.

To guarantee the desired performance, this paper describes the control design models of a PSS based on fuzzy logic, which is returned when the system configuration changes. The control law is presented in both frequency domain and time domain.

SYSTEM DESCRIPTION

The power system considered in this study is modelled as a synchronous generator connected to a constant voltage bus through a double transmission line. In Fig.1 is represented the system structure including the PSS unit.

A simplified model describing the system dynamics used in this study is given by the following state space Equations (Anderson and Foud, 1993; Feliachi *et al.*, 1988).

$$x\,(t) = Ax\,(t)\;Bu\,(t) + Ld\,(t)$$
$$y\,(t) = Cx\,(t) + Du\,(t)$$

Where u represents the system input and d is an external disturbance

$$d = [\Delta V_{ref}\;\; \Delta GSC]^T$$

Where ΔGSC is governor speed changer (produces a change in the mechanical torque T_m)

The state variables and the system output are, respectively

$$x = \left[\Delta\delta \quad \Delta\omega \quad \Delta e_q^{'} \quad \Delta e_{FD} \quad \Delta V_r \quad \Delta V_E \Delta T_m\right]^T$$
$$y = \left[\Delta\omega \;\; \Delta\delta\right]^T$$

The transfer function form of the nominal model is given by

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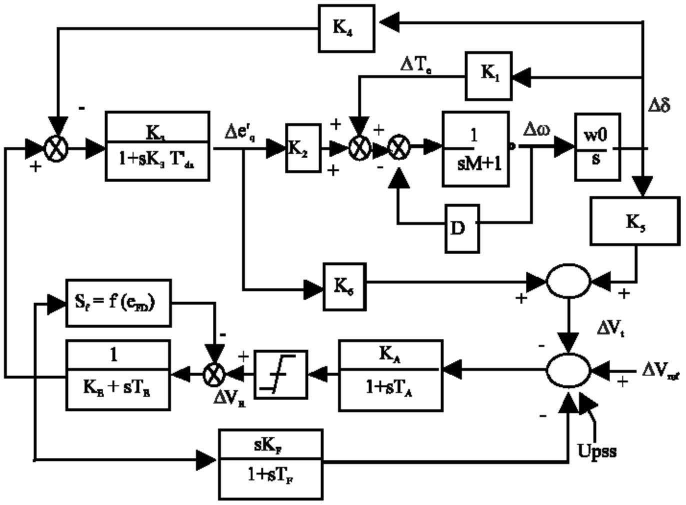

Fig. 1: Combined block diagram of linear synchronous machines and exciter

$$G_{nom}(s) = C_0 (sI - A_0)^{-1}.\ B_0.\ D_0$$

Where

$$Y(S) = G_{nom}(S).\ U(S)$$

Let the generator operating point is defined by

$$\xi = [P \quad x_e]$$

These operating points are associated with a set models (A_i, B_i, C_i, D_i, L_i). For these models, uncertainties may be defined and taken into account in the controller design stage.

PSS DESIGN BASED ON FUZZY STATE FEEDBACK (FSFPSS)

Assuming that a family of linear state space models may be obtained for different operating points of generator system.

A related global fuzzy model may be formulated by the following rules (Denia and Attia, 2002; Hassaon *et al.*, 1991; Cao *et al.*, 1999; Takagi and Sugeno, 1985).

$$R^i\text{: IF } x_1 \text{ AND } x_2 \text{ is } F_2^{\,i} \ldots \text{ AND } x_n \text{ is } F_n^{\,i}$$

$$\text{then} \begin{cases} \dot{x} = A_i x + B_i u & i = 1,\ldots,L \\ y = Cx \end{cases}$$

$$R^i\text{: IF } x_1 \text{ AND } x_2 \text{ is } F_2^i \ldots \text{ AND } x_n \text{ is } F_n^i$$

R^i rule related to the ith operating point

$$\text{then} \begin{cases} \dot{x} = A_i x + B_i u & i = 1,\ldots,L \\ y = Cx \end{cases}$$

L number of operating points
F^i_J are fuzzy sets for the state variables

The nominal model my be described analytically by

$$\dot{x} = A_0 x + B_0 u$$

With

$$A_0 = \sum_{i=1}^{L} \mu_i A_i \quad \text{and} \quad B_0 = \sum_{i=1}^{L} \mu_i B_i$$

μ_i being the membership factor for the i^{th} rule based on the Sum-prod inference method.

The basic idea is to develop for each rule a state feedback control law using the classical pole placement topology.

The state feedback is formulated as:

$$R^i\text{: IF } x_1 \text{ AND } x_2 \text{ is } F_2^{\,i} \ldots \text{ AND } x_n \text{ is } F_n^{\,i}$$

$$\text{then} \begin{cases} \dot{x} = A_i x + B_i u & i = 1,\ldots,L \\ y = -K_i x \end{cases}$$

Where K_i is the gain vector related to the (A_i, B_i) state space model.

These local controllers are inferred into one global fuzzy state feedback controller for the overall operating regimes of the generator system,

$$K = \sum_{i=1}^{L} \mu_i K_i$$

Problem formulation: In this study, we present a fuzzy direct approach of the control multi-models for linear systems at parameter variables, our method breaks up in fact in two stages: training of the fuzzy local controllers of type Takagi and Sugeno (1985) around points of operation which is the power active (Pe = 0.2' 0.4' 0.6' 0.8' 1), Then the synthesis of a fuzzy switch by serving fuzzy controllers previously determined. The control applied to proceeds is thus weighting of the controls worked out by the fuzzy local controllers.

Our objectives are to ensure the stability and the robustness of our system when it is uncertainty (error of modelling, disturbance influences, change of point of operating).

To obtain a structure of complete control homogeneous turned towards the fuzzy formalism, we chose local controllers linear fuzzy rather than of the local controllers linear traditional.

One defines the functions of membership, these last allowing to convert into fuzzy values the variables of inputs in their affecting a weight which one names degree of membership μ Functions of membership of Pe.

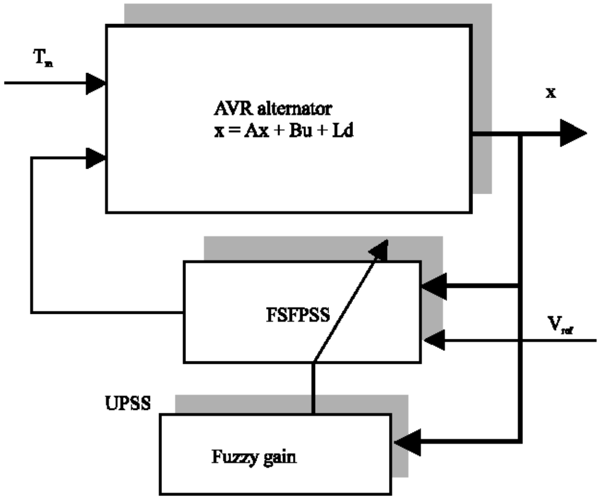

Fig. 2: Block diagram of the control device with gain on of fuzzy state feedback

Figure 2 presents the block diagram of the system exciter alternator with PSS has commutation of fuzzy gain. Block PSS comprises a state feedback or the gain is committed by fuzzy logic. This approach used exploits the rules of the theory of fuzzy logic, for the assignment of the gain of the return of state to a zone of point of operation given ζ.

PERFORMANCE ET EVALUATION

The objective is to order the alternator group having the characteristics in annex, for variations of the power

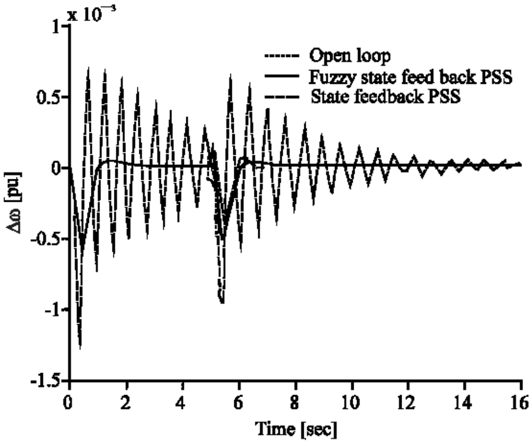

Fig. 3a: Transient Responses following a 5% -10% change in the reference at voltage operating condition Pe = 0.9 pu 0.1 pu

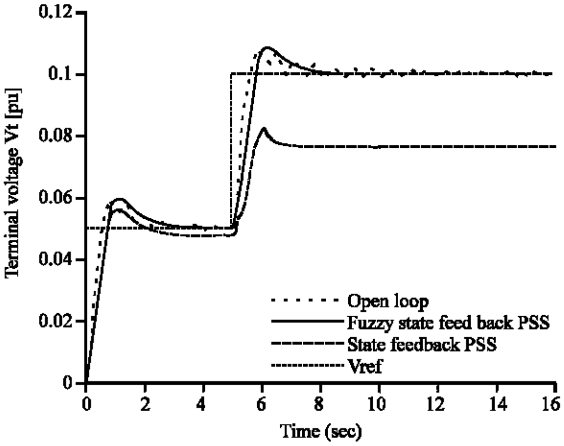

Fig. 3b: Transient Responses following a 5-10% change in the reference at voltage operating condition Pe = 0.9 pu-0.1 pu

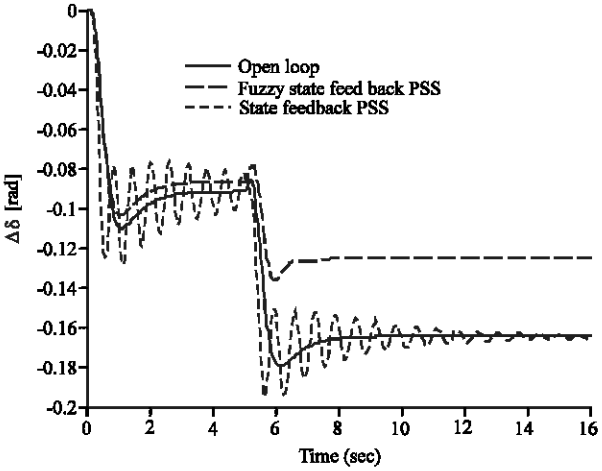

Fig. 3c: Transient responses following a 5-10% change in the reference at voltage operating condition Pe = 0.9 pu -0.1 pu

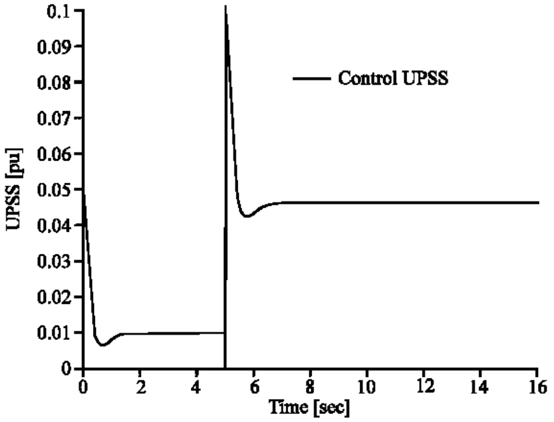

Fig. 3d: Transient responses following a 5-10% change in the reference at voltage operating condition Pe = 0.9 pu-0.1 pu

active of 0.1 pu up to 1 pu activates been able and thereafter a variation of the reactance of the line of network x_e

The designed PSS must achieve the following requirements:

- Ensure sufficient closed loop stability margins to allow for changes in closed loop transfer such as those which might arise from unmodeled low-damped high frequency modes of oscillations.
- Satisfactory performance over a wide range operating conditions.

The desired poles are:

$$p = [-3.51+j *12,\ -3.51-j *12, -2.73+j *5.33\ -2.73-j *5.33, -7.28,\ -1.6]$$

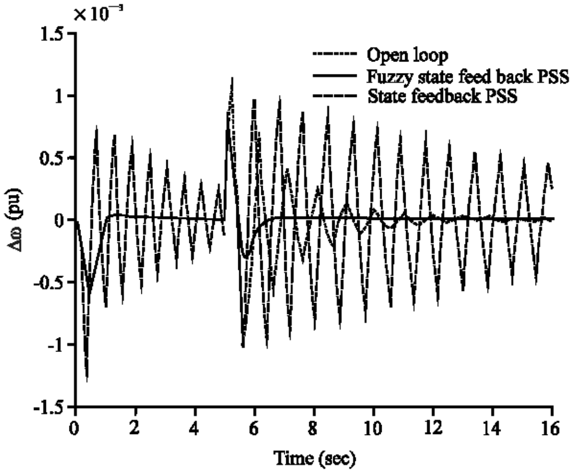

Fig. 4a: Transient responses following a 5-10% change in the reference at voltage operating condition Pe = 0.1 pu-0.9 pu

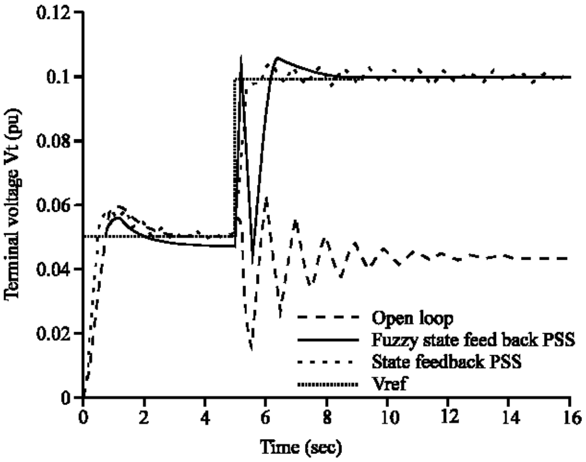

Fig. 4b: Transient responses following a 5-10% change in the reference at voltage operating condition Pe = 0.1 pu-0.9 pu

The control with placement of pole on of state feedback gives us the matrix gain K.

Let us introduce the values of point of nominal operation and the change of the points of operation in a block of fuzification and one adapts the gain of the return of state.

For an active power fixes of 0.5 been able, the FSFPSS is compared in simulation with a control optimal with state feedback. The results are illustrated by the Fig. 3a-d which, respectively represent machine speed of the system, the angle of load in radian and the terminal voltage.

For a variable power (change of point of operating at the time t = 5 sec dryness the answers temporal are presented in the Fig. 4a-d.

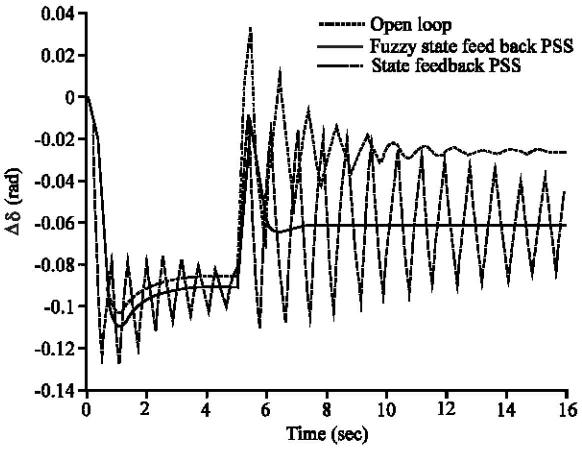

Fig. 4c: Transient responses following a 5-10% change in the reference at voltage operating condition Pe = 0.1 pu-0.9 pu

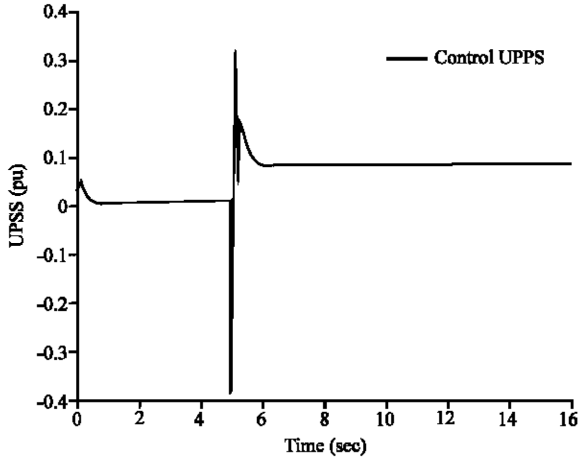

Fig. 4d: Transient responses following a 5-10% change in the reference at voltage operating condition Pe = 0.1 pu-0.9 pu

Performance and evaluation: The FSFPSS approach is evaluated in simulation on different conditions of work (change of point of working, profile of the line, variation of reference voltage, as well as the mechanical torque). The results are illustrated by Fig. 3 and 5 for the operating points defined by $\xi = [\,P \quad X_e]$.

Using FSFPSS, it is possible to find a controller that stabilizes the power systems with the appearance of the system uncertainty and also realize the robust performance.

One notes an improvement of response time of the loop system closed compared to optimal controller.

In the final article one goes presented the extension of this method at the system multimachines illustrated by Fig. 5.

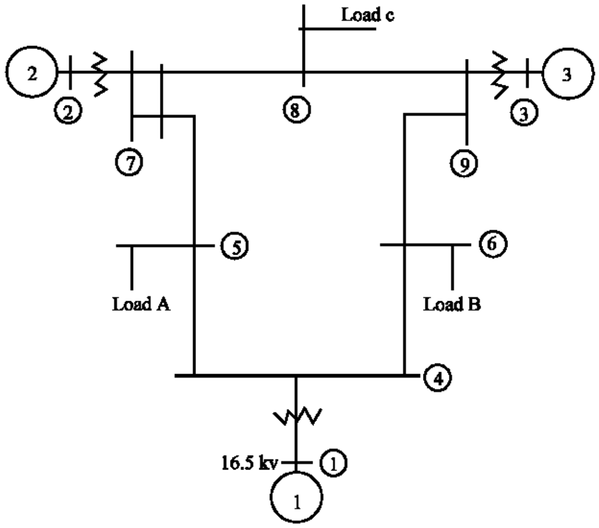

Fig. 5: Multimachine system

CONCLUSIONS

The robustness of the controller has been evaluated with respect to model uncertainties of the power generator. A comparative study of the proposed PSS with a conventional optimal controller has been conducted.

The results relating to the system multimachine are the subject of the final research.

REFERENCES

Anderson, P.M. and A.A. Fouad, 1993. Power System Control and Stability, IEE Press, Piscatawa, NJ 08855-1331.

Denai, M.A. and S.A. Attia, 2002. Intelligent control of an induction motor. Electric power components and Syst., 30: 409-427.

Feliachi, A., X. Zhang and C.S. Sims, 1988. Power System Stabilizers Design Using Optimal Reduced Order Models, Part II: Design, IEEE Trans. On Power Syst., 3: 1676-1681.

Hassaon, M.A.M., O.P. Malek and G.S. Hope, 1991. A fuzzy logic based stabiliser for synchronous machines, IEEE Trans. Energy Conversion, 6: 407-413.

Cao, S.G., N.W. Rees and G. Feng, 1999. Analysis and design of fuzzy control system using dynamic fuzzy state space methods. IEEE Trans. on Fuzzy Syst., 7: 192-199.

Takagi, T. and M. Sugeno, 1985. Fuzzy identification of systems and its application to modelling and control. IEEE Trans. Syst. Man. Cybern., 15: 116-132.