Vague Set Base Power System Stabilizer for Multi-Machine Power System

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Abstract

In this paper, a Vague Set Based Power System Stabilizer (VCPSS) has been evaluated on multi machine power system. In order to accomplish the stability enhancement, speed deviation and acceleration of the rotor of synchronous generator of multi machine power system were taken as the inputs to the vague set based controller. This VCPSS is capable of providing appropriate stabilization signals over a broad range of operating conditions to damping of the generator shaft mechanical oscillations. The stabilizing signals were computed using the vague set membership functions depending on these variables. Simulation results show the eminent efficiency of the proposed vague set based power system stabilizer .

Keywords: *Multi-Machine System, Vague Set Based Controller Power System Stabilizer (VCPSS)*

1.Introduction

Power system stability analysis and control are among the most significant issues being dealt with by the sophisticated power systems of today. The ability of a power system to maintain stability and to provide high quality power supply depends to a large extent on the controls available within the system. Analysis and design of power system controls are indeed important and essential for modern power systems. The application of power system stabilizers for improving dynamic stability of power systems and damping out the low frequency oscillations due to disturbances has received much attention [3-5].
Traditional PSS rely on robust liner design methods .In an attempt to cover a wide range of operating conditions, expert or rule based controllers have also been proposed. Fuzzy knowledge acquisition is considered as a key problem in the field of expert system, decision analysis, machine learning etc. Recently, the vague set theory introduced by W.L. Gau and D.J. Buehrer [1] has been conceived as a new efficient tool to deal with ambiguous data and it has been applied successfully in different field.

Recently, the vague set theory introduced by W.L. Gau and D.J. Buehrer has been conceived as a new efficient tool to deal with ambiguous data and it has been applied successfully in different fields. The vague set theory is a new concept and extended form for fuzzy sets and synonyms of the interval type fuzzy set [2]. It adopts truth and false membership function to express for and against evidence .Vague logic makes complex and non-linear problems much easier to solve by allowing a more natural representation of the situations being dealt with.

Stabilization of the multi-machine power systems has been one of the vital problems in the research area for several years. This paper presented the controller in multi machine power system to damp the oscillations. The performance of the proposed method is simulated over a wide range of operating conditions and disturbances and its robustness is proved and settling will be less.

This paper proposes vague set based power system stabilizer for multi machine system .Simulations have been performed taking four machine connected with 11 bus (The Kundur test) power systems. The brief outline of the paper is as follows: Section II presents concept of vague set whereas Section III contains vague set based controller(VC). Section IV presents structure of vague set based controller power system stabilizer (VCPSS). Section V contains the modeling of multi-machine system. Section VI contains the simulations of multi-machine power system with the proposed controller followed by the concluding section.

2.Vague Set

A vague set (or in short VS) A in the universe of discourse U is characterized by two membership functions given by :

1) A truth membership function

$t_A : U \rightarrow [0; 1]$ and

2) A false membership function

$f_A : U \rightarrow [0; 1]$;

where $t_A(u)$ is a lower bound of the grade of membership of u derived from the 'evidence for u', and is a lower bound on the negation of u derived from the 'evidence against u', and $t_A(u) + f_A(u) \leq 1$.The vague set A is bounded by a subinterval $\left[t_A(u), 1 - f_A(u)\right]$ of [0,1]. This indicates that if the actual grade of membership is $\mu_A(u)$, then $t_A(u) \leq \mu_A(u) \leq 1 - f_A(u)$. The vague set A is written as

$$A = \{ < u; \left[t_A(u); 1 - f_A(u)\right] >: u \quad \} \qquad (1)$$

where the interval $[t_A(u), 1 - f_A(u)]$ is called the 'vague value' of u in A and is denoted by $V_A(u)$ [1] .A vague set in the universe of discourse U is illustrated in Fig. 1.

3.Vague set based controller (VC)

Vague set controllers are rule-based controllers. The structure of the VC resembles that of a knowledge based controller except that VC utilizes the principles of vague set theory in its data representation and its logic. The basic configuration of the VC can be simply represented in four parts, as shown in the Fig. 2. [8,9,10].

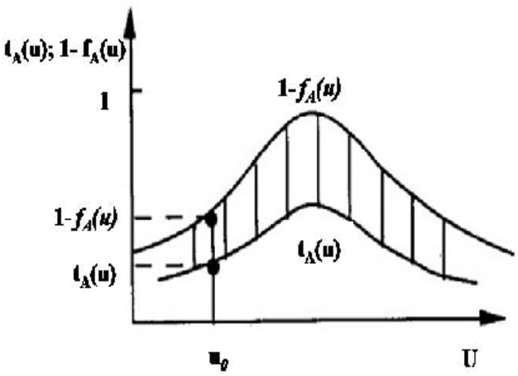

Fig. 1. Vague Set

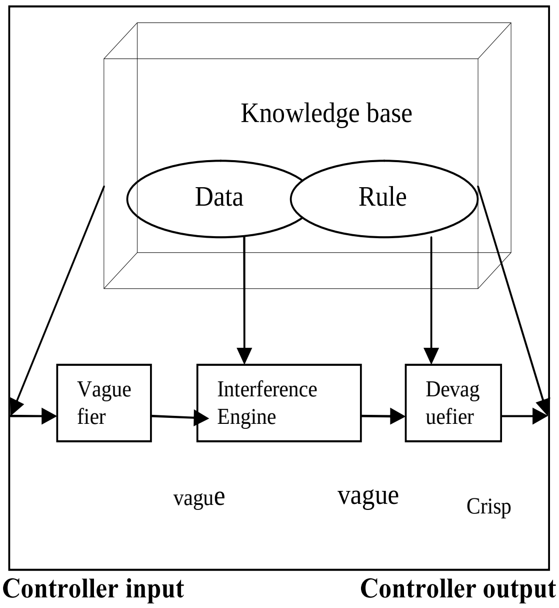

Fig. 2. Schematic Diagrams of the VS Building Blocks

4.Vague Set Based Controller Power System Stabilizer (VCPSS) Structure

The design structure of VCPSS involves the following steps[10]:

1. Designing a vague set based controller is to decide which state variables represent of system dynamic performance and must be taken as the input signal to controller. In the present work generator speed deviation ($\Delta\omega$) and acceleration ($\Delta\dot{\omega}$) are chosen to be the input signals of vague set based PSS. In practice, only shaft speed deviation is readily available. Hence, the acceleration signal can be derived from speed signal.
2. In the present work five linguistic variables for each of the input and output variables are used which transform the numerical values of the input of the vague controllers to vague quantities.
3. Then formulating the vague rules are very important factors in the performance of the vague control system. The two inputs; speed deviation and acceleration, result in 25 rules. For example If speed deviation is NS (negative small) AND acceleration is PB (positive big) then voltage (output of VCPSS) is PS (positive small). Each of the 25 control rules represents the output of vague controller (as voltage) response to a particular situation.

4. The sugeno inference engine is used.
5. A crisp signal is needed for the excitation system hence by knowing the membership function of the vague controller its numerical value should be determined. The devaguefy method used in this VCPSS is sugeno type.

5.Modeling of a Multi -Machine System

Analysis of practical power system involves the simultaneous solution of equations consisting of synchronous machines and the associated excitation system and prime movers, interconnecting transmission network, static and dynamic load (motor) loads and other devices such as HVDC converters, static var compensators. The dynamics of the machine rotor circuits, excitation systems, prime mover and other devices are represented by differential equations. The result is that the complete system model consists of large number of ordinary differential and algebraic equations [5].

Model 1.0 is assumed for synchronous machines by neglecting damper windings. In addition, the following assumptions are made for simplicity [6].

1. The loads are represented by constant impedances.

2. Transients saliency is ignored by considering $x_q = x'_d$.

3. Mechanical power is assumed to be constant.

5.1Generator equations

The machine equations (for k^{th} machine) are

$$pE'_{qk} = \frac{1}{T'_{d0k}}[-E'_{qk} + (x_{dk} - x'_{dk})i_{dk} + E_{fdk}] \quad (2)$$

$$p\delta_k = \omega_0 \Delta\omega_{rk} \quad (3)$$

$$p\Delta\omega_{rk} = \frac{1}{2H}[-K_{Dk}\Delta\omega_{rk} + T_{mk} - T_{ek}] \quad (4)$$

5.2State space model of multi machine system

The state space model of a 4-machine 11 bus system as shown in Fig.7.1 can be obtained using machine data, line data and load flow data as given in [6] as

$$\dot{\mathbf{x}} = [\bar{\mathbf{A}}]\mathbf{x} + [\bar{\mathbf{B}}](\Delta\bar{\mathbf{V}}_{ref} + \Delta\bar{\mathbf{V}}_S) \quad (5)$$

$$\mathbf{y} = [\bar{\mathbf{C}}]\mathbf{x} \quad (6)$$

where $\mathbf{x} = [x_1, x_2, x_3, x_4]^T$ and $\mathbf{y} = [y_1, y_2, y_3, y_4]^T$

x_k (k=1,4) denotes the states of k^{th} machine, and y_k (k=1,4) denotes the output of the k^{th} machine.

The elements of $\bar{\mathbf{A}}$ matrix depend on the machine and network parameters.

5.3Two area system (kundur test system)

The Kundur test system is shown in Fig. 3. The system contains eleven buses and two areas, connected by a weak tie between bus 7 and 9. Totally two loads are applied to the system at bus 7 and 9. Two shunt capacitors are also connected to bus 7 and 9 as shown in the figure below. The system has the fundamental frequency 60 Hz.

The system comprises two similar areas connected by a weak tie. The left half of the system is identified as area 1 and the right half is identified as area 2. Each area consists of two fully symmetrical areas linked together by two 230 kV lines of 220 km length. Each area is equipped with two identical round rotor synchronous acts as thermal plant generators rated 20kV/900MVA connected to transformer (T1, T2, T3, and T4).

The synchronous machines (G1, G2, G3, and G4) in all area have identical parameters, except for inertia which is H=6.5s for all generators in Area 1 and H=6.175s for all generators in Area 2. Thermal generating plants having identical speed regulators and fast static exciters with a 200 gain at all locations. Each generator produces 700 MW.

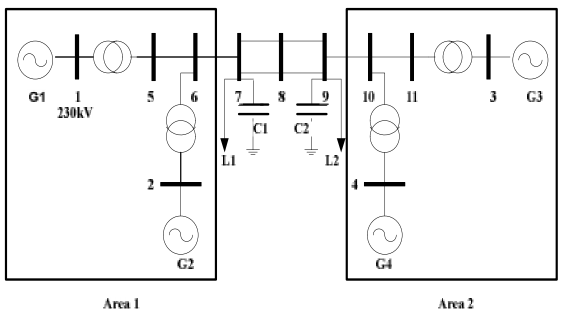

Fig. 3. The Kundur test system

The loads are assumed everywhere as constant impedance load. The Area 1 and Area 2 loads are 967 MW (L1) and 1767 MW (L2), respectively. The load voltage profile was improved by installing 187 MVAr capacitors (C1 and C2) in each area to make closer to unity. Area 1 is exporting to Area 2 through two tie-lines and a single tie-line with power transfer level 413 MW and 353 MW, respectively [5, 7].

6.Simulation Result And Analysis

A simulink based block diagram including all the nonlinear block is generated. Comparison of three Power System Stabilizer (PSS) as Conventional PSS (CPSS), Fuzzy logic based Power System Stabilizer (FPSS) and Vague set based controller Power System Stabilizer (VCPSS) using Kundur's Four-Machine Two-Area Test System are shown in Fig. 4 to Fig. 10 for small-signal performance assessment at change in 5% magnitude on the voltage reference (Vref) of M1(turbine and regulator at generator 1) . These three PSS are compared using the same settings for all machines of turbine and regulators (M1,M2,M3,M4) for damping inter-area mode of oscillation are observed in response to disturbances .

It is clear from the Fig.4,5,6 of dynamic responses for speed deviation at small perturbation results that the damping to the system oscillations improves with the proposed VCPSS as compare to CPSS and FPSS. It is clear from the results that without CPSS in the system, the system oscillations are sustained, where as with vague set based PSS oscillations are damped very quickly. The VCPSS has a lower peak offshoot and smaller oscillations.

Similar pattern of responses can be observed in terminal voltage of generators as shown in Figs. 7. to Fig.9.

Fig. 10. shows active power transfer from area 1 to area 2 of generator for all three cases, namely with CPSS, FLPSS and VCPSS. As can be clearly seen from the response, the time taken for damping oscillation is lesser and amplitude of oscillation is lower than CPSS and FPSS case.

All PSSs do a good job stabilizing the naturally unstable system. However, it is clear that the VCPSS is superior to the other two PSSs, providing significantly more damping in inter-area mode of oscillation , especially with respect to the conventional PSS.

7.Conclusion

A comparison between the VCPSS, the FLPSS and the CPSS shows that the VCPSS provides better performance than others two for damping inter-area mode of oscillation are observed in response to disturbances. The results show that the proposed VCPSS provides good damping and improves the dynamics.

The simulation results indicate that the proposed stabilization technique results in better stabilization than the existing techniques. The future scope of this technique would be to use better optimization techniques which can provide a better stabilization results. Results of simulation studies look promising. The developed control strategy is not only simple, reliable, and may be easy to implement in real time applications.

Acknowledgment

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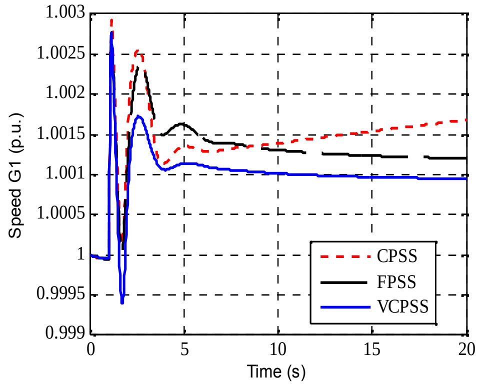

Fig. 4. Dynamic responses for Δw1 at small perturbation

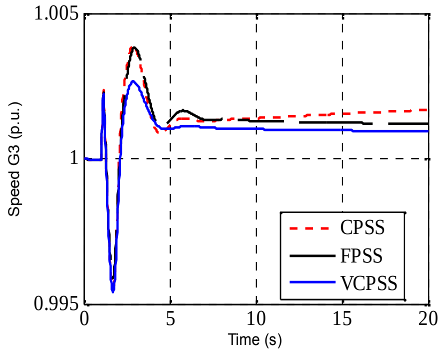

Fig. 5. Dynamic responses for Δw3 at small perturbation

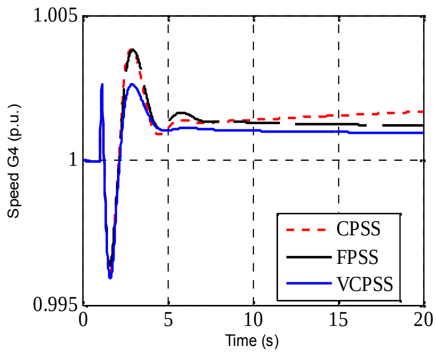

Fig. 6. Dynamic responses for Δw4 at small perturbation

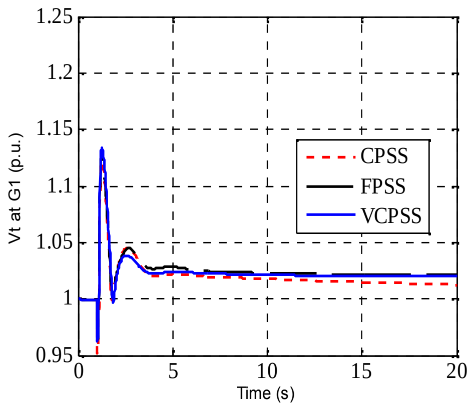

Fig. 7. Terminal voltage(Vt) at generator 1

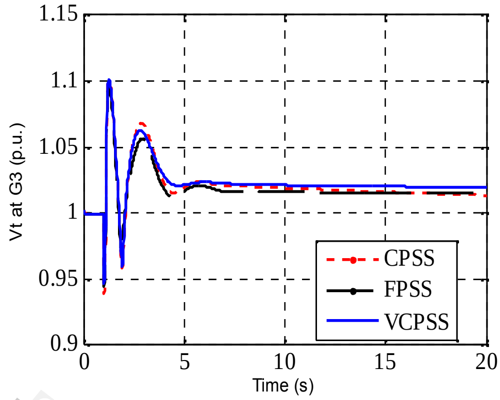

Fig. 8. Terminal voltage(Vt) at generator 3

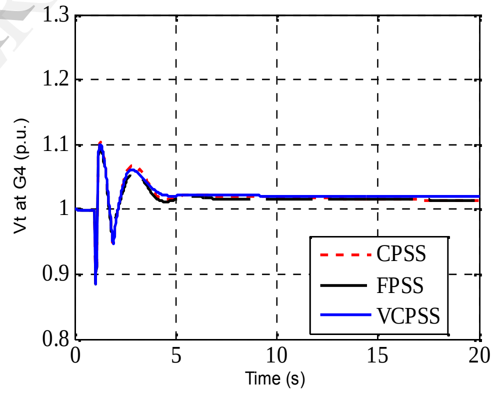

Fig. 9. Terminal voltage(Vt) at generator 4

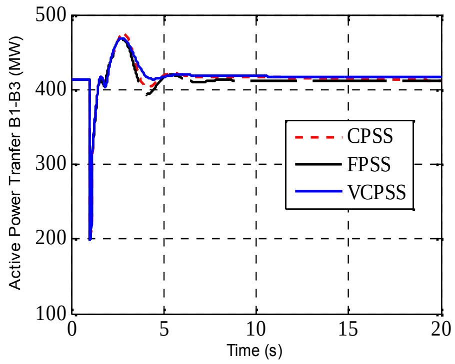

Fig. 10. Active Power transfer from area 1 to area