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Design of Power System Stabilizer using Fuzzy based Sliding Mode Control Technique

[1]Kanthalakshmi Srinivasan, [1]Latha Ramasamy, [2]Kanagaraj Jeganathan

[1]*Department of Instrumentation and Control Systems Engineering, PSG College of Technology, Coimbatore - 641004, India.*
[2]*Department of Electrical and Electronics Engineering, PSG College of Technology, Coimbatore - 641004, India.*

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ABSTRACT

Background: Power systems are usually large non-linear systems, which are often subjected to low frequency electromechanical oscillations. Power System Stabilizers (PSSs) are often used as effective and economic means for damping the generators' electromechanical oscillations and enhance the overall stability of power systems. Power system stabilizers have been applied for several decades in utilities and they can extend power transfer stability limits by adding modulation signal through excitation control system. **Objective:** Sliding mode control is one of the main methods employed to overcome the uncertainty of the system. This controller can be applied very well in presence of both parameter uncertainties and unknown nonlinear function such as disturbance. To enhance stability and improve dynamic response of the system operating in faulty conditions a Fuzzy based Sliding Mode Control PSS is developed for a multimachine system with two generators. **Results:** A Fuzzy based Sliding Mode Control PSS is compared with the Conventional PSS, Fuzzy based PSS and Sliding Mode based PSS. **Conclusion:** According to non-linear simulation results of a multi-machine power system, it is found that the Fuzzy based Sliding Mode Controller work well and is robust to change in parameters of the system and to disturbance acting on the system.

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INTRODUCTION

Electrical power systems play a vital role in modern human life and any disturbances in their normal functioning cause interruptions to both the component and system level. A large power system is very complex and consists of various components such as power generating units which are connected to each other and with distributed loads through very long transmission lines, transformers and capacitors. The power system is a highly non linear in nature. One of the most important aspects in electric system operation is the stability of power systems. Low frequency oscillations persists in power system for longer time duration and at times affects the overall power transfer capability of the power system. Hence suppressing this low frequency oscillation is one major issue that has to be addressed.

Dynamic stability of the power system have been in focus during recent years. Supplementary signals are added to increase the damping of the power system and thereby to improve the dynamic performance. Power System Stabiliser was developed as an control equipment that would be attached to the Automatic Voltage Regulator to damp its rotor oscillations caused by small signal disturbances(Vitthal Bandal *et al.*, 2005, Hossein Shahinzadeh *et al*., 2012).

Continuous research related to design of Power System Stabiliser and its tuning is in progress in the recent times. Though many utility companies adopt conventional PSS owing its design simplicity and easy implementation, it may lead to power system instability due to negative damping effects of conventional PSS on the rotor. The reason behind this is that conventional PSS are tuned around steady state operating point and their damping effects are valid only around that operating point. During large disturbances, conventional PSS may make the generator lose synchronism. Since power systems are highly nonlinear, conventional fixed-parameter PSSs cannot cope with great changes in the operating conditions (Vitthal Bandal *et al*., 2005).

MATERIALS AND METHODS

Modelling of the plant:

The modelling of a simple 500 KV transmission system containing two hydraulic power plants is shown in Fig. 1. PSSs are used to improve transient stability and power system oscillations damping. Despite the simple

Corresponding Author: Kanthalakshmi Srinivasan, Department of Instrumentation and Control Systems Engineering, PSG College of Technology, Coimbatore - 641004, India.
E-mail: klakshmiramesh@yahoo.co.in, lathasivak@yahoo.co.in

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structure of the illustrated power system in the figure, the phasor simulation method can be used to simulate more complex power grids.

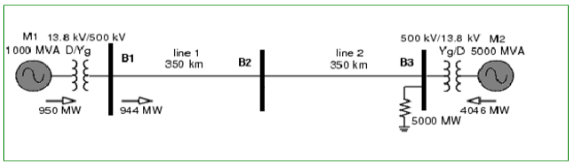

Fig. 1: Single line diagram of power system.

A 1000 MW hydraulic generation plant (M1) is connected to a load centre through a long 500 KV, 700 km transmission line. A 5000 MW of resistive load is modelled as the load centre. The remote 1000 MVA plant and a local generation of 5000 MVA (plant M2) feed the load.

A load flow has been performed on this system with plant M1 generating 950 MW so that plant M2 produces 4096 MW. The line carries 944 MW which is close to its surge impedance loading (SIL = 977 MW). The two machines are equipped with a hydraulic turbine and governor (HTG), excitation system, and power system stabilizer (PSS). (D.Jovcic and G.N.Pillai, 2005)

Power System Stabiliser:

The Power System Stabilizer (PSS) is a device that can be added to the power system to improve the system stability. Compared to system reconstruction or other enhancement techniques, PSS would serve as cost effective stability enhancement device. Power System Stabilizers reduces damping by controlling the generator rotor angle swings. Since the main objective of Power System Stabilizer is to control the rotor oscillations, the input to the PSS is taken as the deviation in the rotor speed. The main demerit of using speed input PSS is that it leads to volt/VAR swing. Washout filter with suitable time constant is used to reduce the demerit of speed input PSS. As PSS must produce component of electrical torque in phase with the speed deviation, lead-lag blocks are used to compensate for the phase difference between PSS output and the control action(K. David Young *et al*., 1999, P.K. Dash *et al*., 1998). The number of lead-lag blocks needed depends upon the power system where it is employed. Fig.2. shows Generic PSS. (D.Jovcic and G.N.Pillai, 2005)

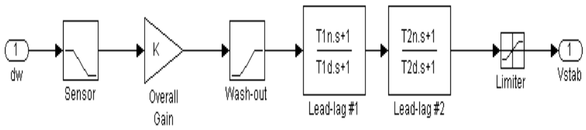

Fig. 2: Generic power system stabilizer.

During the loading/un-loading or loss of generation, when large fluctuations in the frequency and speed may act through the PSS and drive the system towards instability a suitable control has to be exercised. A modified limit logic will allow these limits to be minimized while ensuring the damping action of PSS for all other system events. The limiter given in the above block diagram does this function.

Fuzzy Logic Control:

FLCs are very useful when an exact mathematical model of the plant is not available however; experienced human operators are available for providing qualitative rules to control. The essential part of the fuzzy logic controller (FLC) is a set of linguistic control rules related by dual concepts of fuzzy implication and the compositional rule of inference. The Fuzzy Logic Controller (FLC) is simpler and fastest methodology. It does not need any exact system mathematical model and it can handle nonlinearity of arbitrary complexity. It is based on the linguistic rules with an IF-THEN general structure, which is the basis of human logic. The structure of fuzzy controller is shown in Fig 3. It consists of fuzzification inference engine and defuzzification blocks. (Hadi Saadat, 2007)

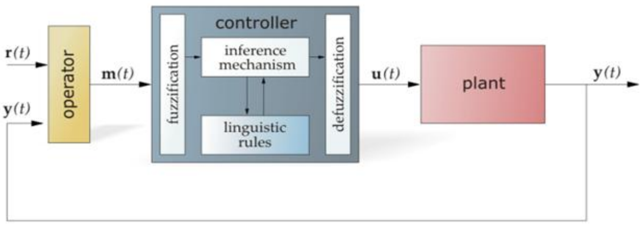

Fig. 3: Structure of fuzzy controller.

Here the, input variables are change in speed deviation (dω) and change in acceleration(da) and the output variable is stabilizing voltage (V_{stab}). The membership functions for dω, da, and Vstab are as shown below in Fig.5, Fig.6, and Fig.7 respectively. Table I. shows the rule base for fuzzy controller.

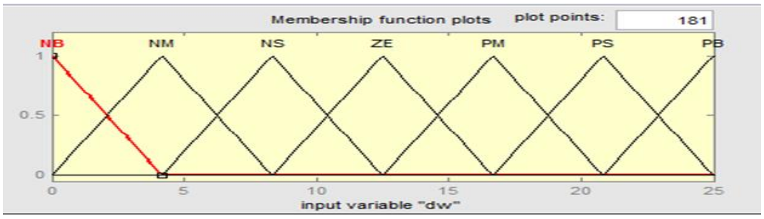

Fig. 4: Membership function plot of speed deviation (dω).

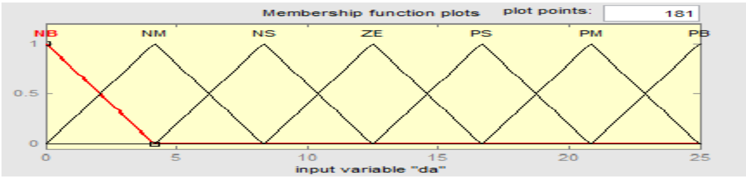

Fig. 5: Membership function plot of acceleration (da).

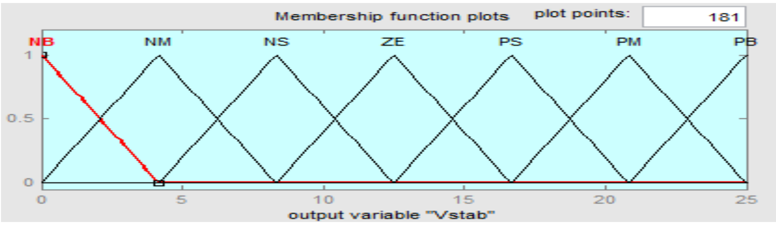

Fig. 6: Membership function plot of stabilizing voltage (V_{stab}).

Table I: Rule base for fuzzy controller.

Speed deviation	Acceleration						
	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NM	NS
NM	NB	NM	NM	NM	NS	NS	ZE
NS	NM	NM	NS	NS	ZE	ZE	PS
ZE	NM	NS	NS	ZE	PS	PS	PM
PS	NS	ZE	ZE	PS	PS	PM	PM
PM	ZE	PS	PS	PM	PM	PM	PB
PB	PS	PM	PM	PB	PB	PB	PB

Sliding Mode Control:

Sliding Mode Control (SMC) one of the main methods employed to overcome the uncertainty of the system. This controller can be applied very well in presence of both parameters uncertainties and unknown nonlinear function such as disturbance. Sliding mode control technique has been used to control robots, motors, mechanical systems, etc. and assure the desired behavior of closed loop system. (P.Kundur, 1994).

A. Dynamic Model of Synchronous Generator:

A multi-machine power system consisting of two synchronous generators with load as shown in Fig.7. This system is a two area power system, the two areas are identical and each include a generator equipped with fast acting excitation systems.

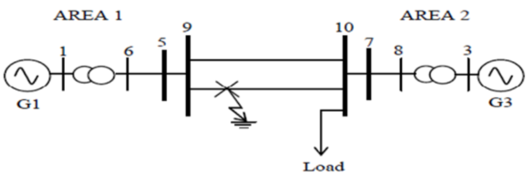

Fig. 7: Multimachine system with two generators.

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The equations describing a third order model of a synchronous generator (for jth generator) is written as:

$$\dot{\delta}_j = w_j(t) - w_{oj}$$
$$\dot{w}_j(t) = \frac{K_{Dj}}{2H_j}(w_j(t)-w_{oj}) + \frac{w_{oj}}{2\,H_j}(P_{mj}-P_{ej}(t)) \quad (1)$$
$$\dot{E}'_{qj}(t) = \frac{1}{T'_{doj}}(E_{Fj}(t) - E_{qj}(t))$$

Where:

$$E_q(t) = \frac{X_{dj}}{X'_{dj}} E'_{qj}(t) - \frac{x_{dj} - x'_{dj}}{X'_d} V_s \cos\left(\delta_j(t)\right)$$
$$E_{Fj(t)} = k_{cj} u_{Fj}(t) \quad (2)$$
$$P_{ej}(t) = \frac{V_s\ E_{qj}(t)}{X_d} \sin(\delta_j(t))$$

and $\delta_j(t)$ is the rotor angle of the jth generator (radians),
$w_j(t)$ is the speed of the rotor of the jth generator (radian/sec),
w_{oj} is the synchronous machine speed of the jth generator (radian/sec),
K_{Dj} is the damping constant of the jth generator (pu),
H_j is the inertia constant of the jth generator (sec),
P_{mj} is the mechanical input power of the jth generator (pu),
$P_{ej}(t)$is the active electrical power delivered by the jth generator (pu),
$E_{qj}(t)$ is the EMF of the q-axis of the jth generator (pu),
$E'_{qj}(t)$ is the transient EMF in the q-axis of the jth generator (pu),
$E_{Fj}(t)$ is the equivalent EMF in the excitation winding of the jth generator (pu),
T'_{doj} is the d-axis transient short circuit time constant of the jth generator (sec),
k_{Cj} is the gain of the excitation amplifier of the jth generator,
$u_{fj}(t)$ is the control input of the excitation amplifier with gain k_{Cj},
x'_{dj} is the d-axis transient reactance of the jth generator (pu),
X_{dj} is the total direct reactance of the system (pu),
X'_{dj} is the total transient reactance of the system (pu),
V_s is the infinite bus voltage (pu) and j denotes the no. of generator.
The states of the system for jth generator choice as follows:

$$x_{1j}(t) = \delta_j(t)$$
$$x_{2j}(t) = w_j(t)-w_{oj} \quad (3)$$
$$x_{3j}(t) = E'_{qj}(t)$$

Hence state vector for each generator will be:

$$x_{1j}(t) = (x_{1j}(t)\ \ x_{2j}(t)\ x_{3j}(t))^T \quad (4)$$

Also the control input $u_j(t)$ is taken to be:

$$u_j(t) = \frac{k_c(j)}{T'_{doj}} u_{fj}(t) \quad (5)$$

The nonlinear equations of the system, define the following constants for each generator:

$$\alpha_{1j} = \frac{k_{cj}}{2\,H_j}$$
$$\alpha_{2j} = \frac{w_{oj}}{2\,H_j\ X'_{dj}} V_s$$
$$\alpha_{3j} = \frac{w_{oj}\ (x_{dj} - x'_{dj})}{4\,H_j\ X_{dj} X'_{dj}} V_s^{\,2}$$
$$\alpha_{4j} = \frac{w_{oj}}{2H_j} P_{mj}$$
$$\alpha_{5j} = \frac{-1}{T'_{doj}} \frac{X_{dj}}{X'_{dj}}$$
$$\alpha_{6j} = \frac{x_{dj} - x'_{dj}}{T'_{doj} X'_{dj}} V_s \quad (6)$$

Substituting (6) in (1) and (2), we get set of equations describing jth generator as below.

$$\dot{x_1} = x_{2j}(t)$$
$$\dot{x_2} = \alpha_{1j} x_{21}(t) + \alpha_{2j} x_{3j}(t) \sin\left(\alpha_{1j} x_{21}(t)\right) + \alpha_{3j} \sin\left(2x_{1j}(t)\right) + \alpha_{4j}$$
$$\dot{x}_3 = \alpha_{5j} x_{3j}(t) + \alpha_{6j} \cos\left(x_{1j}(t)\right) + u_j(t) \quad (7)$$

The desired values of the system state vector for the jth generator is

$$x_{Dj} = (x_{1dj}\ \ x_{2dj}\ \ x_{3dj}) \qquad (8)$$

Where $x_{1dj}\ \ x_{2dj}\ \ x_{3dj}$ desired value of state.
The control input which enables the system to achieve the desired states is denoted by u_{dj}.

The deviations of the rotor angle of each generator from its desired value are taken as output of each system.

$$y_j(t) = x_{1j}(t) - x_{1dj} \qquad (9)$$

The desired values are calculated by equating $\dot{x}_1$,$\dot{x}_2$,$\dot{x}_3$ to zero. The values of x_{1dj} x_{2dj} and x_{3dj} are derived as follows:

$$\left(-\frac{\alpha_{1j}\alpha_{6j}}{2\alpha_{5j}} + \alpha_{3j}\right)\sin(2x_{1dj}) - \frac{\alpha_{2j}}{\alpha_{5j}}u_{dj}\sin(x_{1dj}) + \alpha_{4j} = 0$$

$$x_{2dj} = 0$$

$$x_{3dj} = -\frac{\alpha_{6j}}{\alpha_{5j}}\cos(x_{1dj}) - \frac{1}{\alpha_{5j}}u_{dj} \qquad (10)$$

B. Controller Design:

The objective of this section is to design a controller based on sliding mode theory for synchronous generator so that it regulates the states of the system to their desired values and maintain the stability of the system in operation point and uncertainty and also increase the rate of oscillation damping. The (7) and (9) describing the synchronous generator are highly nonlinear.(Hossein Shahinzadeh *et al*., 2012)

Therefore, in first step, to facilitation design of nonlinear controller for each generator, a change of variable $z_j(t)$ is considered, such that:

$$z_{1j}(t) = x_{1j}(t) - x_{1dj}$$

$$z_{2j}(t) = x_{2j}(t)$$

$$z_{3j}(t) = \alpha_{1j}x_{21}(t) + \alpha_{2j}x_{3j}(t)\sin\left(\alpha_{1j}x_{21}(t)\right) + \alpha_{3j}\sin\left(2x_{1j}(t)\right) + \alpha_{4j} \qquad (11)$$

From (10) and (11) it is obvious that if $z_j(t)$ converges to zero as t →α , then $x_j(t)$ converges to as t→α. The inverse of the transmission given in (11) is

$$x_{1j}(t) = z_{1j}(t) - x_{1dj}$$

$$x_{2j}(t) = z_{2j}(t)$$

$$x_{3j}(t) = \frac{-\alpha_{1j}x_{21}(t) - \alpha_{3j}\sin\left(2x_{1j}(t)\right) - \alpha_{4j}}{\alpha_{2j}\sin\left(\alpha_{1j}x_{21}(t)\right)} \qquad (12)$$

Substituting (7) in (11), the equations of the synchronous generator can be written as function of the new variable such that

$$\dot{z}_{1j}(t) = z_{2j}(t)$$

$$\dot{z}_{2j}(t) = z_{3j}(t)$$

$$\dot{z}_{3j}(t) = f_j(z) + G_j(z)\,u_j$$

$$y_j(t) = z_{1j}(t) \qquad (13)$$

Where:

$$f_j(z) = \left((\alpha_{1j} + \alpha_{5j})\,z_{3j} - \alpha_{1j}\alpha_{5j}z_{2j} + \left(\frac{1}{2}\alpha_{1j}\alpha_{6j} - \alpha_{3j}\alpha_{5j}\right)\sin(2\,(z_{1j} + x_{1dj}))\right) + 2\alpha_{3j}z_{2j}\cos\left(2\,(z_{1j} + x_{1dj})\right) + z_{2j}\cot(z_{1j} + x_{1dj})\left(z_{3j} - \alpha_{1j}z_{2j} - \alpha_{3j}\sin\left(2\,(z_{1j} + x_{1dj})\right) - \alpha_{4j}\right) - \alpha_{4j}\alpha_{5j} \qquad (14)$$

and $G_j(z) = \alpha_{2j}\sin(z_{1j} + x_{1dj})$ (15)

In the original coordinate, the functions $f_j(z) = f_{j1}(x)$ and $G_j(z) = G_{j1}(x)$ are :

$$f_{j1}(x) = \alpha_{1j}\left(\alpha_{1j}x_{2j} + \alpha_{2j}x_{3j}\sin(x_1) + \alpha_{3j}\sin(2x_1) + \alpha_{4j}\right) + \alpha_{2j}(\alpha_{5j}x_{3j} + \alpha_{6j}\cos(x_1))\sin(x_{1j}) + \alpha_{2j}x_{2j}x_{3j}\cos(x_{1j}) + 2\alpha_{3j}x_{3j}\cos(2x_{1j}) \qquad (16)$$

and $G_{1j}(x) = \alpha_{2j}\sin(x_{1j})$ (17)

The model of the synchronous generator given by (14) will be used for designing the sliding mode controller. Then the designed controller will be transformed into the original coordinate is given in (12).

C. Design of Sliding Surface:

The second step of the SMC design process is the design of the sliding surface. The sliding surface for each generator is as follows:

$$S = \ddot{y}_j + \rho_{1j}\dot{y}_j + \rho_{1j}y_j = z_{3j} + \rho_{1j}z_{2j} + \rho_{2j}z_{1j} \qquad (18)$$

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Where coefficients ρ_{1j} and ρ_{2j} are positive scalars and are chosen to obtain the desired transient response of the output of the system. The switching surface can be written as a function of $x_{1j}(t), x_{2j}(t)$, and $x_{3j}(t)$ such that:

$$S_j = \alpha_{1j}x_{2j} + \alpha_{2j}x_{3j}\sin x_{1j} + \alpha_{3j}\sin 2x_{1j} + \alpha_{4j} + \rho_{1j}x_{2j} + \rho_{2j}(x_{1j} - x1_{dj}) \tag{19}$$

The choice of the switching surface guarantees that the output of the system converges to zero as $t \to \infty$ on the sliding surface $S_j(x) = 0$.

D. Design of Sliding Surface:

The third step of the proposed sliding mode controller process is to design the control function that provides the motion on the sliding surface, such that:

$$u_j(t) = \frac{-1}{G_j(z)}\left(f_j(z) + \rho_{1j}z_{3j} + \rho_{2j}z_{2j} + \eta_j \operatorname{sign}(z_{3j} + \rho_{1j}z_{2j} + \rho_{2j}z_{1j})\right) \tag{20}$$

Where η_j is a positive scalar and is determined by designer.

On differentiating equation (19) with respect to the time, $\dot{S}$ is obtained as follows

$$\begin{aligned}\dot{S} &= \dddot{y}_j + \rho_{1j}\ddot{y}_j + \rho_{2j}\dot{y}_j \\ &= f_j(z) + G_j(z)u_j + \rho_{1j}z_{3j} + \rho_{2j}z_{2j}\end{aligned} \tag{21}$$

Substituting (20) in (21)

$$\begin{aligned}\dot{S} &= f_j(z) + \rho_{1j}z_{3j} + \rho_{2j}z_{2j} + (-f_{1j}(z) - \rho_{1j}z_{3j} + \rho_{2j}z_{2j} - \eta_j \operatorname{sign}(z_{3j} + \rho_{1j}z_{2j} + \rho_{2j}z_{1j})) \\ &= -\eta_j \operatorname{sign}\left(z_{3j} + \rho_{1j}z_{2j} + \rho_{2j}z_{1j}\right) = -\eta_j \operatorname{sign}(S)\end{aligned} \tag{22}$$

Hence

$$S_j\dot{S}_j = -S_j\eta_j \operatorname{sign}(S_j) = -\eta_j|\dot{S}| \tag{23}$$

Therefore the dynamics of S_j in (23) guarantees that $S_j\dot{S}_j < 0$. The proposed sliding mode controller guarantees the asymptotic convergence of $z_j(t)$ to zero as $t \to \infty$.

Substituting (16), the controller function given in (20) can be written in the original coordinate as follow:

$$u_j = \frac{1}{\alpha_{2j}\sin x_{1j}}\begin{bmatrix}\left(-\alpha_{1j} - \rho_{1j}\right)\left(-\alpha_{1j}x_{2j} + \alpha_{2j}x_{3j}\sin x_{1j} + \alpha_{3j}\sin 2x_{1j} + \alpha_{4j}\right) + \\ \left(-\alpha_{2j}(\alpha_{5j}x_{3j} + \alpha_{6j}\cos x_{1j}\sin x_{1j} - \alpha_{2j}x_{2j}x_{3j}\cos x_{1j} - 2\alpha_{3j}x_{2j}\cos 2x_{1j}\right) + \\ \left(-\rho_{2j}x_{2j} - \eta_j \operatorname{sign}(S_j)\right)\end{bmatrix} \tag{24}$$

Where

$$S_j = \alpha_{1j}x_{2j} + \alpha_{2j}x_{3j}\sin x_{1j} + \alpha_{3j}\sin 2x_{1j} + \alpha_{4j} + \rho_{1j}x_{2j} + \rho_{2j}(x_{1j} - x1_{dj}) \tag{25}$$

The control signal u_j is stabilizing voltage.

Fuzzy based Sliding Mode Control:

The Fuzzy Sliding Mode Control (FSMC) technique, is an integration of variable structure control and FLC, provides a simple way to design FLC systematically. The main advantage of FSMC is that the control method achieves asymptotic stability of the system. Another feature is that the method can minimize the set of FLC and provide robustness against model uncertainties and external disturbances. In addition, the method is capable of handling the chattering problem that is arisen in traditional SMC. (Vitthal Bandal *et al*., 2005).

The conventional sliding mode control will make the system converge to the sliding surface at a rate proportional to, however on convergence to the surface the chattering present in the system would also be proportional to the . In order to get maximum advantage of the controller structure, η_j should be tuned to be of high magnitude when the state is approaching the sliding surface, thus helping for faster convergence and when the state is in sliding mode, η_j should be tuned to be of low magnitude in order to reduce chattering. This can be tuned by fuzzy controller. (Hossein N. Zadeh and A. Kalam, 1999).

Design of Fuzzy based SMC:

The Fuzzy based SMC-PSS consists of a single - input, a single - output component. The Input variable is considered as Sliding surface 'S' and the Output variable is considered as Tuning parameter $'\eta_j'$.The fuzzy inference mechanism contains seven rules. The membership function for Sliding surface $'S'$ as shown in Fig 8. The membership function for tuning parameter $'\eta_j'$ is as shown in Fig.9. The Table II gives the rule base for the fuzzy controller.

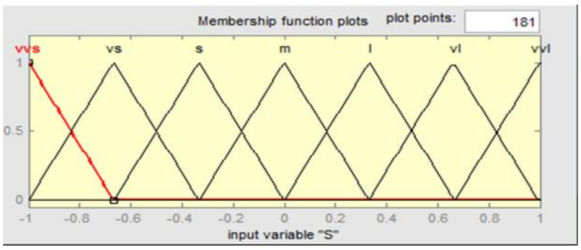

Fig. 8: Membership function plot of sliding surface (S).

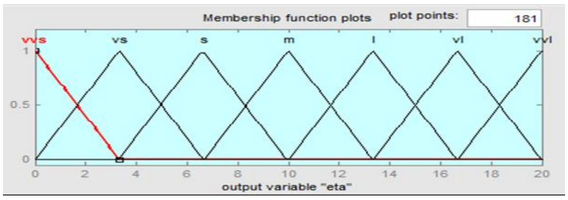

Fig. 9: Membership function plot of tuning parameter (η_j).

Table II: Rule Base Fuzzy Based SMC.

Rule No.	Switching surface $\lvert s \rvert$	Tuning parameter (η_j)
1	VVS	VVS
2	VS	VSS
3	S	S
4	M	M
5	L	L
6	VL	VL
7	VVL	VVL

RESULTS AND DISCUSSION

The proposed Fuzzy based Sliding Mode Control (FSMC) scheme is applied to the multi-machine power system. The controlled system is simulated using Matlab Simulink. The performance of proposed control scheme i.e. Fuzzy based Sliding Mode Control Power System Stabilizer (FSMCPSS) is compared to the performance of a conventional Power System Stabilizer, Fuzzy Power System Stabilizer ,Sliding Mode Control based Power System Stabilizer and with the system without Power System Stabilizer (NOPSS).

The different designs of PSS is compared in terms of Bus voltages (V_{B1}, V_{B2}, V_{B3}), Line Power, Difference between rotor angle deviation of machine 1 and machine 2 ($dtheta_1 - dtheta_2$), Speed of the machines. (ω_1 and ω_2), Terminal voltages of machines (Vt_1 and Vt_2). Fig.10 shows the response of bus voltages (V_{B1}, V_{B2}, V_{B3}) with NOPSS, CPSS, FPSS, SMCPSS, and FSMCPSS.

Response of bus voltages (V_{B1}, V_{B2}, V_{B3}) with FSMCPSS gives better result in terms of settling time and lesser oscillations.Fig.11 shows the response of Line power with NOPSS, CPSS, FPSS, SMCPSS, and FSMCPSS.

Response of Line power with FSMCPSS gives better result in terms of settling time and lesser oscillations. Fig.12 shows the response of difference between rotor angle deviation with NOPSS, CPSS, FPSS, SMCPSS, and FSMCPSS.

Response of difference between rotor angle deviation with FSMCPSS gives better result in terms of settling time and lesser oscillations. Fig.13 shows the response of speed of the machine (ω1 and ω2) with NOPSS, CPSS, FPSS, SMCPSS, and FSMCPSS.

Response of speed of the machine (ω1 and ω2) with FSMCPSS gives better result in terms of settling time and lesser oscillations. Fig.14 shows the response of terminal of the machine with NOPSS, CPSS, FPSS, SMCPSS, and FSMCPSS.

Response of terminal voltages of the machine with FSMCPSS gives better result in terms of settling time and lesser oscillations.

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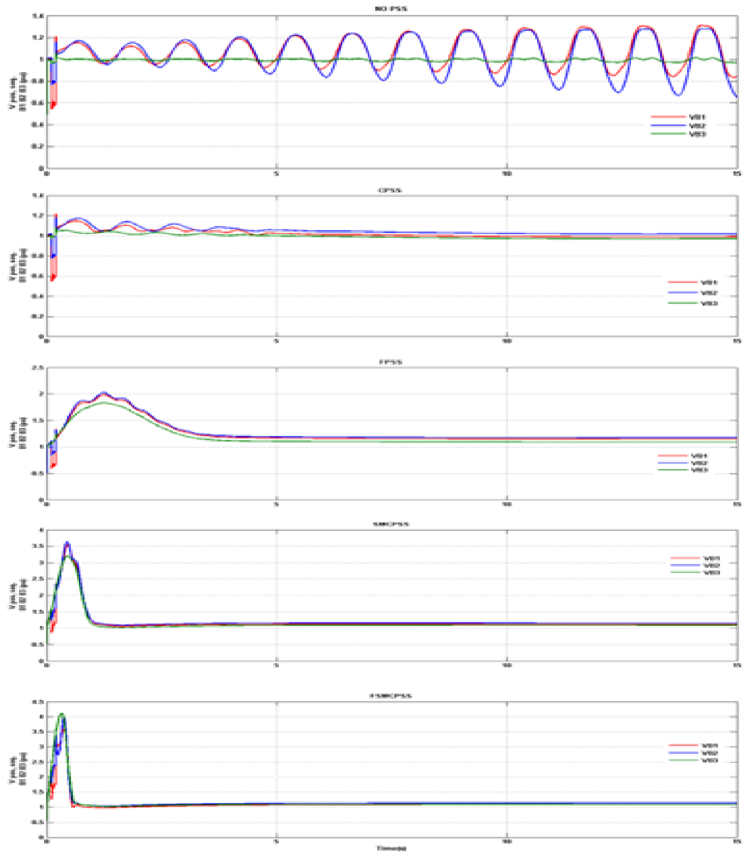

Fig. 10: Response of bus voltages (V_{B1} , V_{B2} , V_{B3}).

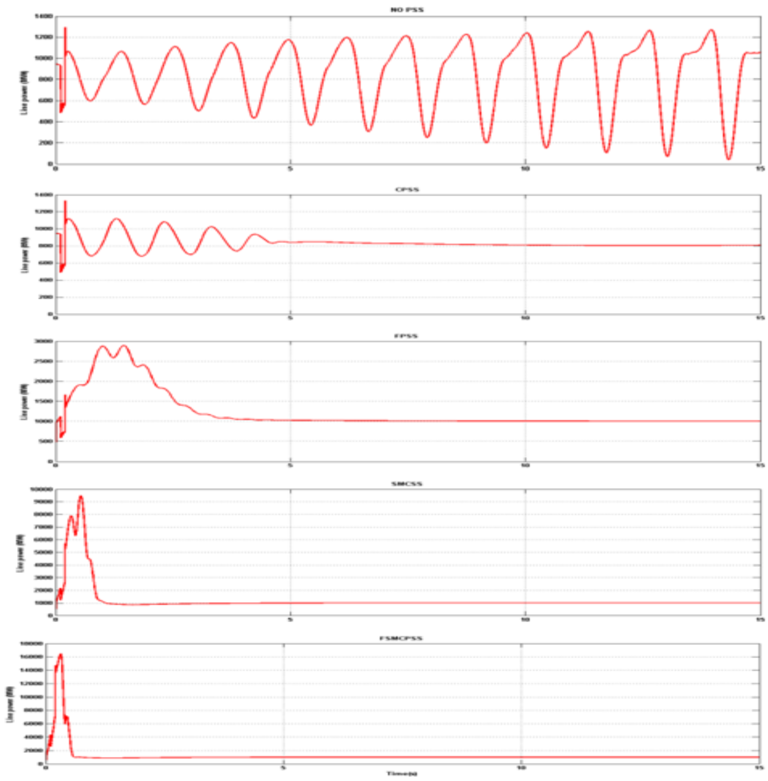

Fig. 11: Response of Line Power.

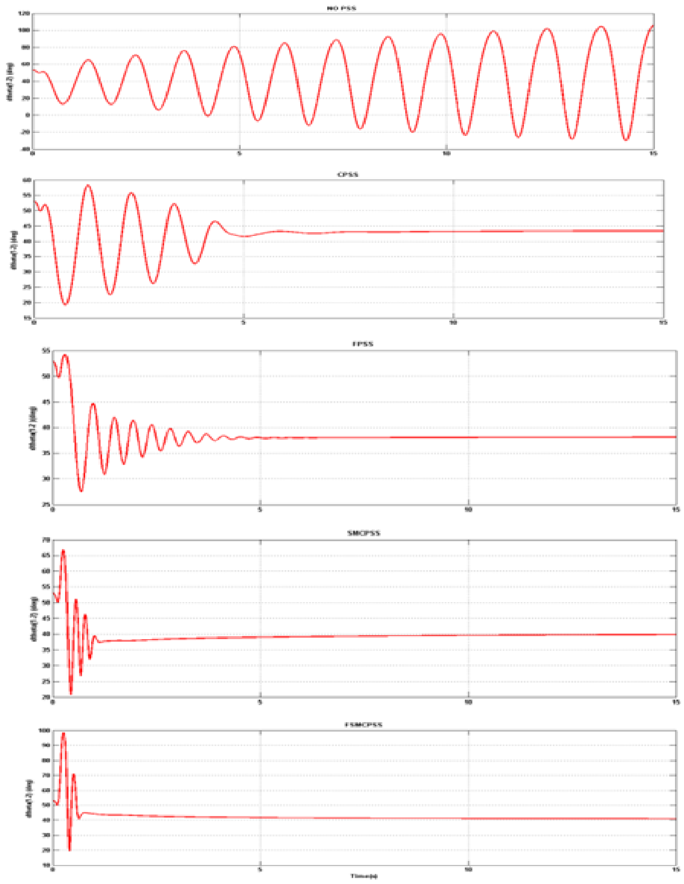

Fig. 12: Response of difference between rotor angle deviations.

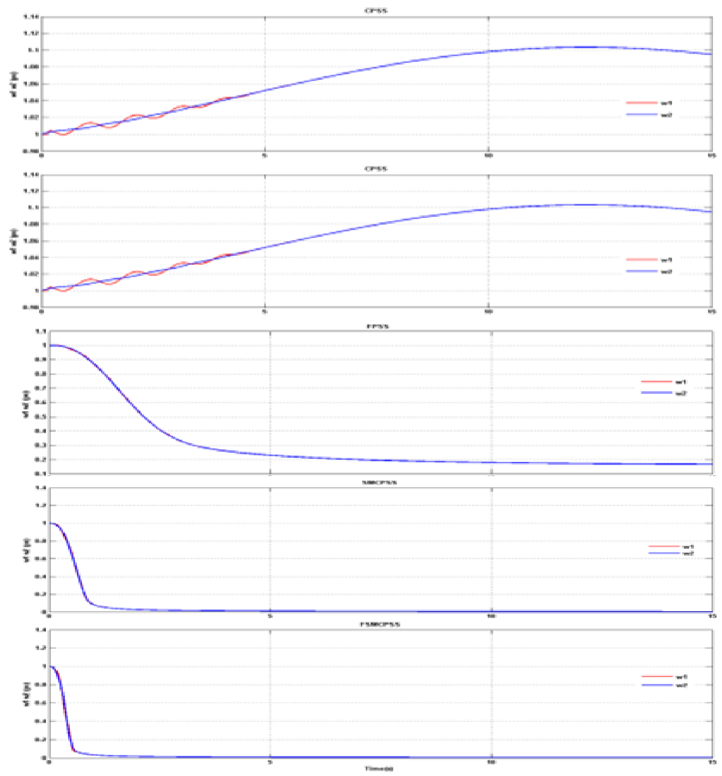

Fig. 13: Response of speed of the machine (ω1 and ω2).

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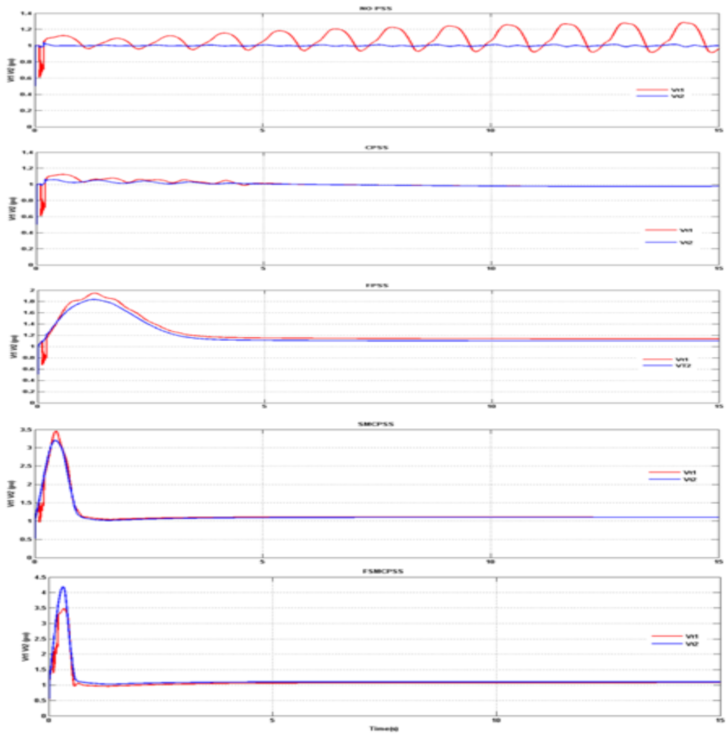

Fig. 14: Response of terminal voltages of the machine.

Conclusion:

As power system is a highly complex system and the system equations are nonlinear as the parameters vary due to noise and load fluctuation, the Fuzzy based Sliding Mode Control based Power System Stabilizer enhances the stability of the system and improves the dynamic response of the system operating in faulty conditions in a better way and it has also effectively enhanced the damping of electromechanical oscillations. According to non-linear simulation results of a multi-machine power system, it is found that the Fuzzy based Sliding Mode Controller work well and is robust to change in parameters of the system and to disturbance acting on the system and also indicate that the proposed controller achieves a better performance than the Sliding Mode Control based Power System Stabilizer (SMCPSS), Fuzzy based Power System Stabilizer (FPSS) and Conventional Power System Stabilizer (CPSS).

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