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Power Oscillation Damping Control Scheme with SSSC using Lead-Lag and Fuzzy Based Controllers

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Abstract*: *In our power systems every time we get frequency oscillations because of nonappereance of the damping torque so as to pervasiveness to control framework aggravations changes as in the mechanical information control. As our power system is getting to next level, Low power oscillations are controlled by Power System Stabilizer (PSS), and very good transient stability can be done by Unified Power Factor Control(UPFC) and by comparision of this and a new development is done in power system to get transient stability and damping out Low frequency oscillation which was done byStatic Synchronous Series -Compensator (SS-SC) SSSC has a speciality with a direct control of voltage and power to damp frequency oscillations. Here in this Heffron Philips model of synchronous machine with infinite bus with SSSC is used to wet out the Less Frequency Oscillations. The Fuzzy damping controller is used with (SMIB) single machine infinite bus system to SSSC to damp out oscillations quickly . Simulations are performed at different conditions of different loads and for various upsetting Fuzzt damping controller had got a best results of damping out oscillations when compared with the examinations of Lead-Lack strucures

Index Terms*: *Power Oscillation Dmping (POD), Static Synchronous Series Compensator(SSSC) ,Unified Power Flow Controller (UPFC), Single Machine-Infinite Bus (SMIB) power system , FUZZY controller

I. INTRODUCTION

There are Flexible Ac Transmission Systems which we have many benefits and need to improve the control structures in power sytems with quality and accurate results [1],[2].

The progress of the vitality for electrical criticalness prompts stacking the transmission structure close past what many would think about possible. In that aspects, the subject of Lower Frequency Oscillations has prolonged. Power controllers is capable of sorting out damping conditions with less time and this FACTs devices has capacity to improve control strategy which was suffering from power quality. The SSSC is a FACTS contraption that can be used to the LFO. It is a basic measurement of power measurments in power structures and is used to control power stream .This SSSC is constructed with the two voltage source converters (VSC) which are connected in align with the transmission power lines having the two input control parameters each me, δe, mb , δb which are unequivocal [3]. The SSSC is mainly used for voltage stability enhancement, reactive power compensation for transient stability , structural and voltage rule improvements [3]. A watchful and proficient technique for numerical showing up of SSSC for strong state and negligible flag (linearized) active examinations has been showed in [4]and [7]. Heffron Philips model is another model to showed with SSSC in [8]and [9]. There are some systems which are not having any compensators or without stabilizers , marvelous cleaning out of oscillations can be done by solid control loop structures of SSSc parameters. By arranging sensible SSSC controller, a shocking damping can be created. It is customary that Heffron-Philips show is used in power structure to consider negligible banner soundness. This model has been used for quite a while giving trustworthy results [10].

In this examination, Applying counterfeit neural structures has diverse focal centers, for instance, the most remote purpose of adjusting to changes, acclimation to inside disappointment limit, recovery limit, High-speed getting ready by honesty of shunt overseeing and able to develop a DSP chip with VLSI Technology. By the help of Mat-lab Simulink compartment is used to deal with instrument for run the FUZZY. To demonstrate this executions the versatile adaptive fuzzy network and lead-slack or pi controller which is showed in [11] is taken. The results of both the controllers are held and examinate them and results are isolated for comparison[17-18] .

II. SSSC INSTALLED WITH SINGLE - MACHINE INFINITE BUS SYSTEM

SSSC is meant for the most stable device which having a full direct control of voltage and power. It is sounds in the control structure of power system. In below showed a single machine with infinite bus is connected with SSSC. "The SSSC starts working when it gets signals from our controllers .The control signals from our controller are me, mb and δe, δb sended to the convertors as shown in Fig1. These control signals are for change in degree and stage edge of the reference voltage. me, mb and δe, δb these are govening parameters of the SSSC

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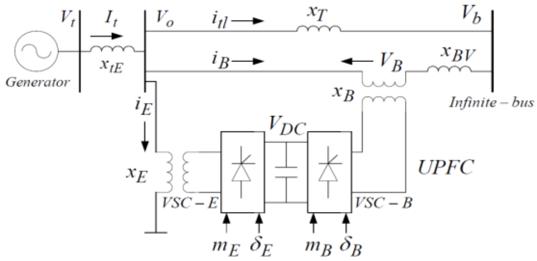

Fig 1: Model of power system installed with SSSC

As it referenced beginning at now, a power system of linearized model is used in novel examinations of intensity structure. To account the SSSC effect in damping of LFO, the SSSC dynamic model is used; In this model the impediment and transient of the transformers of the SSSC can be expelled.

The dynamic expression and their relations are conveyed as :-

$$\bar{\delta} = \omega_o \Delta\omega$$

$$\bar{\omega} = (P_m - P_e - D\omega)/M$$

$$\bar{E}'q = (-E_q + E_{fd})/T'_{do}$$

$$\bar{E}_{fd} = -\frac{1}{T_A} E_{fd} + \frac{K_A}{T_A}(v_{to} - v_t) \qquad (1)$$

Here we get different models on different case study for SSSC .The following equation describe the dynamic behavior of

$$\text{SSSC}: \begin{bmatrix} v_{Etd} \\ v_{Etq} \end{bmatrix} = \begin{bmatrix} 0 & -x_E \\ x_E & 0 \end{bmatrix} \begin{bmatrix} i_{Ed} \\ i_{Eq} \end{bmatrix} + \begin{bmatrix} \frac{m_E v_{dc} \cos\delta_E}{2} \\ \frac{m_E v_{dc} \sin\delta_E}{2} \end{bmatrix} \qquad (2)$$

$$\begin{bmatrix} v_{Btd} \\ v_{Btq} \end{bmatrix} = \begin{bmatrix} 0 & -x_B \\ x_B & 0 \end{bmatrix} \begin{bmatrix} i_{Bd} \\ i_{Bq} \end{bmatrix} + \begin{bmatrix} \frac{m_B v_{dc} \cos\delta_B}{2} \\ \frac{m_B v_{dc} \sin\delta_B}{2} \end{bmatrix} \qquad (3)$$

$$\frac{dv_{dc}}{dt} = \frac{3m_E}{4C_{dc}}[\cos\delta_E \quad \sin\delta_E] \begin{bmatrix} i_{Ed} \\ i_{Eq} \end{bmatrix} + \frac{3m_B}{4C_{dc}}[\cos\delta_B \quad \sin\delta_B] \begin{bmatrix} i_{Bd} \\ i_{Bq} \end{bmatrix} \qquad (4)$$

By combining the all above linear dynamic equations ,The state equations expressed as follows:

$$\dot{X} = AX + BU \qquad (5)$$

Where the matrixces

$$X = \begin{bmatrix} \Delta\delta \\ \Delta\omega \\ \Delta E'_Q \\ \Delta E_{fd} \\ \Delta v_{dc} \end{bmatrix} \qquad (6) \qquad U = \begin{bmatrix} \Delta m_E \\ \Delta\delta_E \\ \Delta m_B \\ \Delta\delta_B \end{bmatrix}$$

(7)

Where Δm_E, $\Delta\delta_E$, Δm_B and, $\Delta\delta_B$ *are* the variations of SSSC control parameters considered as the inputs of state space model

$$A = \begin{bmatrix} 0 & \omega_o & 0 & 0 & 0 \\ -\frac{k_1}{M} & -\frac{D}{M} & -\frac{k_2}{M} & 0 & -\frac{k_{pd}}{M} \\ -\frac{k_4}{T'_{d0}} & 0 & -\frac{k_3}{T'_{d0}} & \frac{1}{T'_{d0}} & -\frac{k_{qd}}{T'_{d0}} \\ -\frac{k_A k_5}{T_A} & 0 & -\frac{k_A k_6}{T_A} & -\frac{1}{T_A} & -\frac{k_A k_{vd}}{T_A} \\ k_7 & 0 & k_8 & 0 & -k_9 \end{bmatrix} \qquad (8)$$

$$B = \begin{bmatrix} 0 & 0 & 0 & 0 \\ -\frac{k_{pe}}{M} & -\frac{k_{p\delta e}}{M} & -\frac{k_{pb}}{M} & -\frac{k_{p\delta b}}{M} \\ -\frac{k_{qe}}{T'_{d0}} & -\frac{k_{q\delta e}}{T'_{d0}} & -\frac{k_{qb}}{T'_{d0}} & -\frac{k_{q\delta b}}{T'_{d0}} \\ -\frac{k_A k_{ve}}{T_A} & -\frac{k_A k_{v\delta e}}{T_A} & -\frac{k_A k_{vb}}{T_A} & -\frac{k_A k_{v\delta b}}{T_A} \\ k_{ce} & k_{c\delta e} & k_{cb} & k_{c\delta b} \end{bmatrix} \qquad (9)$$

k is the coefficient which is obtained by linearizing of (1) and (2)at the operating point [6].

III. Design of Damping Controllers

3.1. Lead-Lag Controller Design

As referenced as of now, In the paper two different controllers are considered for damping of LFO. Initial one is Lead Lag controller which is consists of the Gain block , Washout block , Lead Lag block. While the gain block is constant it allows the error signal , Washout block is nothing but a high passfilter which allows the frequency oscillations as it is and Lead-Lag block is used to compensate lag characterstics to lead and vice versa. In this Lead lag structure the time taken is not a fundamental but it is about 1-20 sec. The parameters taken to lead lag structure is from [11].

3.2 Adaptive Fuzzy Adjustor Controller Design

B. Fuzzy Adjustor

This accurate adjustor is for modification of parameters of taking a gander at control expansion and essential control increment subject to the goof e and the refinement in mess up e_c

$$\begin{cases} K_P = K_P^* + \Delta K_P \\ K_I = K_I^* + \Delta K_I \end{cases}$$

Where are reference estimations of the warm summed up integrator PI controller. In this paper, are settled isolated subject to the Ziegler– Nichols methodology. In a warm reason controller, the control improvement is settled from the assessment of an immense measure of clear phonetic principles.

The improvement of the standards requires a mindful perspective on the system to be controlled, yet it doesn't require a numerical model of the structure. A square chart sensitive reason adjustor is showed in Fig 2.

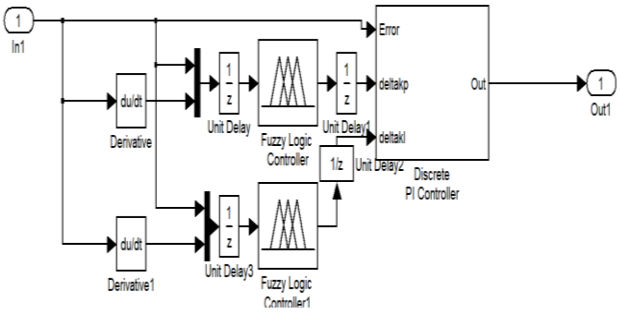

Fig. 2 Block Diagram for Fuzzy Adjustor

Thus, structure steadfast quality and a quick novel response with little overshoot can be created with veritable giving of the agreeable guard adjustor. Fuzzification changes over new data into agreeable sets, making it OK with the warm set depiction of the state variable in the standard. In the fuzzification system, guideline by changing a scale change is required at first, which maps the physical estimations of the state variable into a composed universe of talk . The chaos up e and switch of misconception are used as numerical components from the attested structure. To change over these numerical parts into semantic segments, the running with seven agreeable estimations, these estimations are take from positive to negative via zero and these are named as negative big, middle, small, zero, positive big, middle , small (NB), (NM), (NS), (ZE), (PS), (PM) and (PB). To confirm the affectability and constitution of the fuzzy , interest furthest reaches to the softened values for and in this paper are obtained from the degrees of , which are gotten from undertaking and experience. In like way, beyond what many would consider possible are showed up in Fig 3, unreservedly

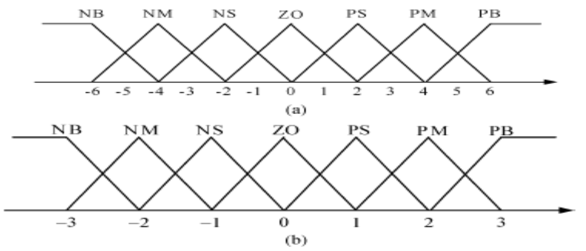

Fig.3 (a) Membership fuctions of e(k) andec(k)
(b) Membership functions of delKp and delKi

The purpose of assembly of cushy control is the cushioned control rule, which is gotten all around from the ordinary affinity for and experience of the logic. The cushy control rule setup solidifies depicting picks that relate the data parts to the yield show properties. For sorting out the control rule base for tuning , the running with fundamental sections have been considered. Conditions for adjusting of Kp and Ki values in Fuzzy:

1) For broad estimations of e , a wide del Kp is essential, and for little estimations of e , a little del Kp is essential.

2) If e*ec is greater than 0 , a broad del Kp is needed, and for e*ec is less than 0 a little del Kp is needed.

3)Far reaching estimations of mod e and ec ,del Ki is becomes zero, which can avoid control splashing.

4) For little estimations of |e, del Ki is incredible, and del Ki is progressively conspicuous when e| is humbler, which is progressively astute to decrease the foreseen state mess up. Then the modification principles of del Kp , del Ki is shown in below fig 4 and fig 5

ΔK_p		e_c						
		NB	NM	NS	0	PS	PM	PB
e	NB	PB	PB	NB	PM	PS	PS	0
	NM	PB	PB	NM	PM	PS	0	0
	NS	PM	PM	NS	PS	0	NS	NM
	0	PM	PS	0	0	NS	NM	NM
	PS	PS	PS	0	NS	NS	NM	NM
	PM	0	0	NS	NM	NM	NM	NB
	PB	0	NS	NS	NM	NM	NB	NB

Fig.4 Rule parameter for del Kp (ΔK_P)

ΔK_I		e_c						
		NB	NM	NS	0	PS	PM	PB
e	NB	0	0	NB	NM	NM	0	0
	NM	0	0	NM	NM	NS	0	0
	NS	0	0	NS	NS	0	0	0
	0	0	0	NS	NM	PS	0	0
	PS	0	0	0	PS	PS	0	0
	PM	0	0	PS	PM	PM	0	0
	PB	0	0	NS	PM	PB	0	0

Fig.5 Rule parameter for delKi (ΔK_I)

The impelling procedure uses the MAX-MIN framework. The unsure warm control action produced using the end must be changed to an accurate control action in affirmed applications. The reason for association of gravity system is used to defuzzify the cushioned variable into physical space

$$\begin{cases} K_P = K_P^* + \dfrac{\sum_{j=1}^{n} \mu_j(e,e_c)\Delta K_{Pj}}{\sum_{j=1}^{n} \mu_j(e,e_c)} \\ K_I = K_I^* + \dfrac{\sum_{j=1}^{n} \mu_j(e,e_c)\Delta K_{Ij}}{\sum_{j=1}^{n} \mu_j(e,e_c)} \end{cases}$$

IV. SIMULATION RESULTS

In this system generally we have two cases to see power oscillations damping out by creating deviations of angular velocity deviation by change in mechanical power and by step change in reference voltage then by any of these we can see the deviation of angular velocity ω and its angle δ .The change in angular velocities denoted by Δω and its deviation of angle by Δδ .In this paper mechanical input power case is represented simulations are performed for change in mechanical input power to 0.1pu at time 1 sec when it has 10% extension . The (ΔmE, ΔδE, ΔmB, ΔδB) are the input pulses comes out from Fuzzy based adaptive controllers which are given to the series convertors connected with transformers which are in series with the transition lines in SSSC . The simulation system is shown in fig6.

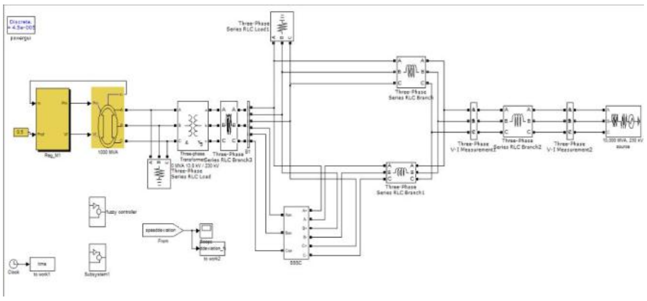

Fig6. Simulink digaram of SSSC based pod using with FUZZY controller

The figures below represents the power oscillation damping of angular velocity deviation of machine by Fuzzy controller and lead lag structure controller .Here observed the Fuzzy damped out oscillations with low peak and less time period

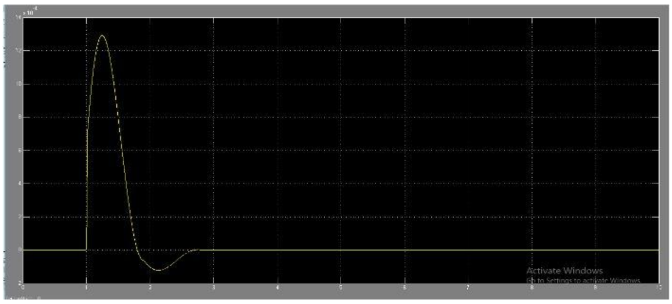

Fig 7. Fuzzy based angular velocity deviation by change in mechanical input

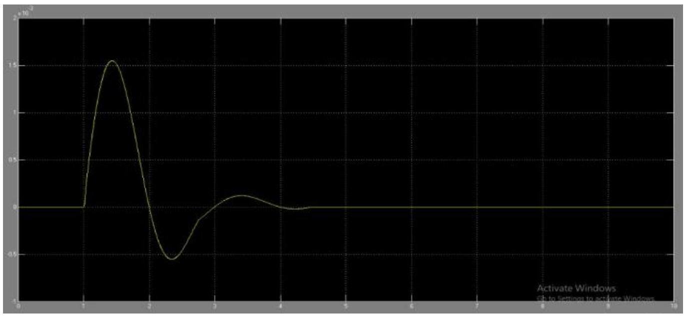

Fig 8. LEAD-LAG based angular velocity deviation by change in mechanical input

The paper intension is to show the speed deviation of machine with respect to time by change in mechanical inputs. As from the results of FUZZY based damping controller using with SSSC made very fast removal of oscillations with low magnitude. After the comparision results of lead lag structure and Fuzzy it says that the Fuzzy based damping controller with SSSC gives effective results of desired low magnitude with speed settling of oscillation or damping of oscillations are happened.

V. CONCLUSIONS

As from studies of compensation SSSC is very important compensator which is highly used in transient stability enhancement because of having a character of injection of stable voltage of desired magnitude. Lowe frequency oscillations are occurred by many reasons .In this paper the comparision of machines speed oscillation damping by lead lag structure and Fuzzy is seen , by changing of mechanical input power. Examination of results showed that a very effective outputs are aquired from Fuzzy damping controller with lower magnitude and speed settling time .

Appendix

Generator: M = 2H = 8.0MJ/MVA, D=0.0,
T 'do = 5.044s, X d = 1.0 pu, Xq = 0.6pu , X'd = 0.3pu
Exciter (IEEE Type ST1): KA=100, TA=0.01s
Reactance's: Xl E = 0.1pu, XE = XB = 0.1pu XBv= 0.3pu, X e = 0.5pu
Task Condition: Pe = 0.8pu, Vt = 1pu, Vb = 1pu
SSSC parameters: mE = 0.4013, mB = .0789,
δE = - 85.3478 0 δB = - 78.2174 0
DC interface: Vdc = 2pu, Cdc=1pu

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