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Power System Damping Oscillations in Smib with Pss-Fuzzy Upfc Controller

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***Abstract*—**Low frequency electromechanical oscillations are inevitable characteristics of power systems and they greatly affect the transmission line transfer capability and power system stability. Traditionally, power system stabilizers (PSS) are being used to damp these oscillations. Unified Power Flow Controller (UPFC) is a well-known FACTS device that can control power flow in transmission lines. It can also replace PSS to damp low frequency oscillations effectively through direct control of voltage and power. In this paper a liberalized Philips-Heffron model of a (Single Machine–Infinite Bus) power system with a unified power flow controller is considered. The designed fuzzy-based UPFC controller adjusts four UPFC inputs by appropriately processing of the input error signal, and provides an efficient damping. The results of the simulation show that the UPFC with fuzzy-based controllers is effectively damping the LFO.

***Keywords*—**Low frequency Oscillations (LFO), Unified Power Flow Controller (UPFC), Fuzzy logic, Damping controller, Flexiable AC transmission System (FACTS)

I. INTRODUCTION

The growth in the demand for electric power is ever increasing. Simultaneous growing demand of power and environment concern necessitated a review of the traditional power system concepts and practices to achieve greater operating flexibility and better utilization of existing transmission system. Rapid development of power electronics technology provides exciting opportunities to develop new power system equipments for better utilization of the exciting system.flexible AC transmission systems (FACTS) devices, which provides the needed correction of transmission functionality in order to fully utilize the existing transmission systems. FACTS technology based on use of reliable high speed power electronics, advanced control been demonstrated successfully and continues to be implemented at transmission locations in various parts of the world . The installed FACTS controllers have provided new possibilities and unprecedented flexibility aiming at maximizing the utilization of transmission assets efficiently and reliably.

Now adays, the electric power system is in transition to a fully competitive deregulated scenario. Under this circumstance, any power system controls such as frequency and voltage controls will be served an ancillary services. Especially, in the case that the proliferation of non-utility generations, i.e., Independent Power Producers (IPPs) that do not possess sufficient frequency control capabilities, tends to increase considerable. Furthermore, various kinds of apparatus with large capacity and fast power consumption such as magnetic levitation transportation, a testing plant for nuclear fusion, or even an ordinary scale factory like a steel manufacturer, etc., increase significantly. In future when these loads are concentrated in a power system, they may cause a serious problem of frequency oscillations. The conventional frequency control, i.e., governor, may no longer able to absorb these oscillations and this becomes challenging and is highly expected in the future competitive environment.

The problem of poorly damped low frequency oscillations associated with generator rotor swings has been a matter of concern to Power System Stabilizer (PSS). In addition, HVDC, SVC controllers have also been used to damp these low frequency oscillations. The advent of high power electronic equipments to improve the utilization of transmission capacity provides system planners with additional leverage to improve stability of the system. Traditionally, power system stabilizers (PSS) are being used to damp these oscillations. Unified Power Flow Controller (UPFC) is a well-known FACTS device that can control power flow in transmission lines. It can also replace PSS to damp low frequency oscillations effectively through direct control of voltage and power.

This paper presents a new approach to the implementation of the UPFC based on a multiple input single output fuzzy logic controller in a single Machine infinite bus power system.

II. DYNAMIC MODELING OF POWER SYSTEM WITH UPFC

Fig. 1 shows a single-machine-infinite-bus (SMIB) system with UPFC. In Fig. 1 me, mb and δe, δb are the amplitude modulation ratio and phase angle of the reference voltage of each voltage source converter respectively. These values are the input control signals of the UPFC

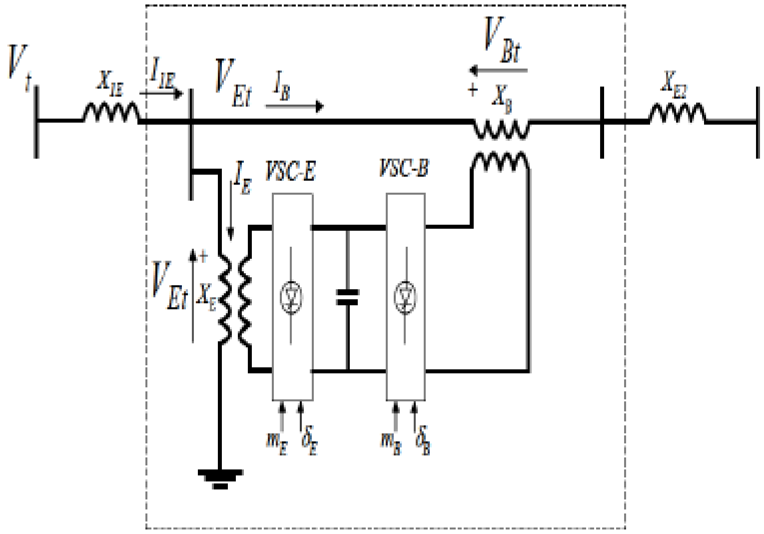

Fig. 1. UPFC installed in a single-machine infinite-bus power system.

A linearized model of the power system is used in studying dynamic studies of power system. In order to consider the effect of UPFC in damping of LFO, the dynamic model of the UPFC is employed. The Dynamic model of the SMIB with UPFC can be represented as

$$\begin{bmatrix} \Delta\delta \\ \Delta\dot{\omega} \\ \Delta E'q \\ \Delta Efd \\ \Delta vdc \end{bmatrix} = \begin{pmatrix} 0 & \omega o & 0 & 0 \\ -K1/M & -D/M & -K2/M & 0 \\ -K4/T'do & 0 & -K3/T'do & 1/T'do \\ -KAK5/TA & 0 & -KAK6/TA & -1/TA \\ K7 & 0 & K8 & 0 \end{pmatrix} \begin{bmatrix} \Delta\delta \\ \Delta\omega \\ \Delta E'q \\ \Delta Eqe \end{bmatrix}$$

$$+ \begin{bmatrix} 0 \\ -Kpd/M \\ -Kqd/T'do \\ KAKvd/TA \\ -K9 \end{bmatrix} \Delta vdc + \begin{pmatrix} 0 & 0 & 0 & 0 \\ -Kqe/M & -Kp\delta e/M & -Kpb/M & -Kpb/M \\ -Kpe/T'de & Kq\delta e/T'do & -Kqb/T'do & -Kqb/T'do \\ -KAKve/TA & -KAKv\delta e/TA & -KAKvb/TA & -KAKv\delta b/TA \\ Kce & Kc\delta e & Kcb & Kc\delta e \end{pmatrix} \begin{bmatrix} \Delta mE \\ \Delta\delta E \\ \Delta mB \\ \Delta\delta B \end{bmatrix}$$

where mE, mB, E and B are the deviations of the input control signals of the UPFC.

III. DESIGN OF FUZZY LOGIC CONTROLLER

There are two major types of fuzzy controllers, namely Mamdani type and Takagi- Sugeno (TS) type. The classification depends on the type of fuzzy rules used. If a fuzzy controller uses the TS type of fuzzy rules, it is called a TS fuzzy controller. Otherwise, the controller is named a Mamdani fuzzy controller. Throughout this paper, attention is focused on the Mamdani type fuzzy controller in order to damp the low frequency oscillations of the power system.

Angular velocity deviation $\Delta\omega$ and load angle deviation $\Delta\delta$ is used as the fuzzy controllers inputs. One of the upfc inputs has been controlled via fuzzy controller output as shown in Fig. 2.

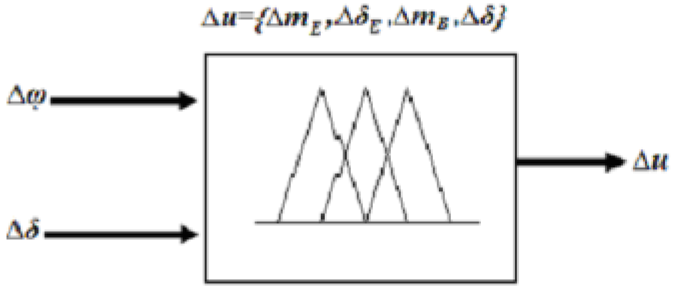

Fig. 2. Fuzzy Logic Controller

Seven membership functions are used in this work are triangular and trapezoidal in shape. The inputs and ouputs are fuzzified using seven fuzzy sets: LN (large negative), MN (medium negative), SN (small negative), Z (zero), SP (small positive), MP (medium positve), and LP(large positive).The membership functions of the input and output signals are shown in Fig. 3, Fig. 4 and Fig. 5.

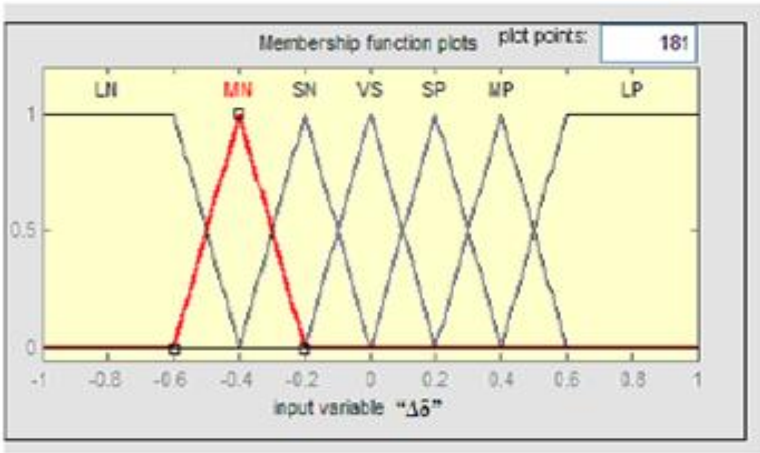

Fig. 3. Membership functions for input $\Delta\delta$

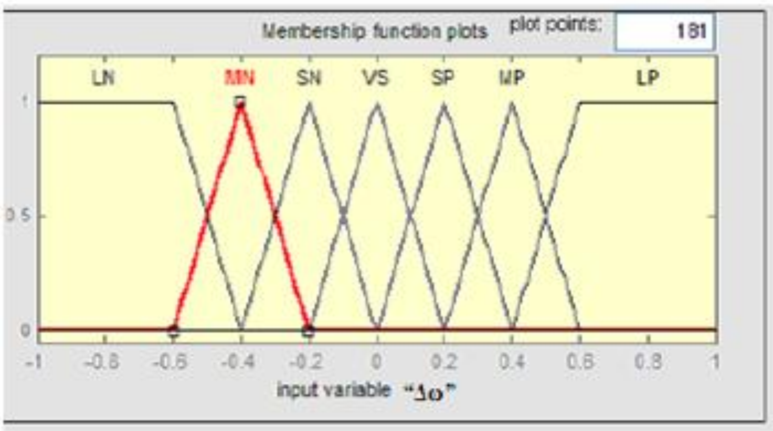

Fig. 4. Membership functions for input $\Delta\omega$

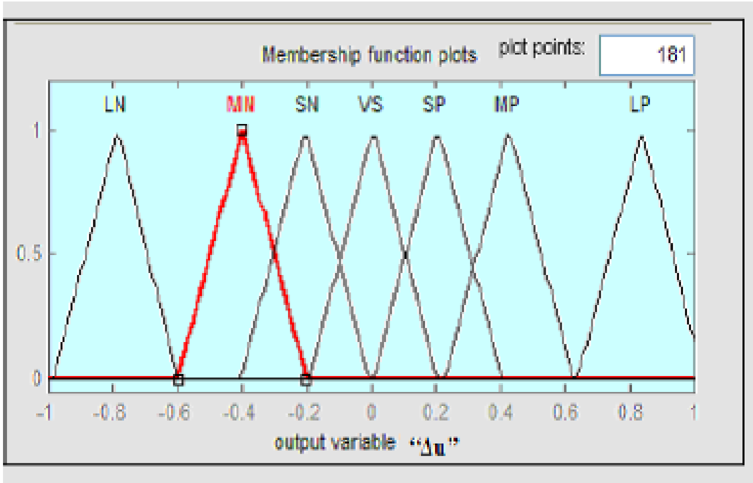

Fig. 5. Membership functions for output Δu

The rules used in this controller are chosen as follows:

1. If δ is LP and Δw is LP then ΔΔu is LP.
2. If δ is LP and is Δw MP then Δu is LP.
3. If δ is LP and is Δw SP then Δu is LP.
4. If δ is LP and is Δw VS then Δu is MP.
5. If δ is LP and is Δw SN then Δu is MP.
6. If δ is LP and is Δw MN then Δu is SP.
7. If δ is LP and is Δw LN then Δu is VS.
8. If δ is MP and is Δw LP then Δu is LP.
9. If δ is MP and is Δw MP then Δu is LP.
10. If δ is MP and is Δw SP then Δu is MP.
11. If δ is MP and is Δw VS then Δu is MP.
12. If δ is MP and is Δw SN then Δu is SP.
13. If δ is MP and is Δw MN then Δu is VS.
14. If δ is MP and is Δw LN hen Δu is SN.
15. If δ is SP and is Δw LP then Δu is LP.
16. If δ is SP and is Δw MP then Δu is MP.
17. If δ is SP and is Δw SP then Δu is MP.
18. If δ is SP and is Δw VS then Δu is SP.
19. If δ is SP and is Δw SN then Δu is VS.
20. If δ is SP and is Δw MN then Δu is SN.
21. If δ is SP and is Δw LN then Δu is MN.
22. If δ is VS and is Δw LP then Δu is LP.
23. If δ is VS and is Δw MP then Δu is LP.
24. If δ is VS and is Δw SP then Δu is LP.
25. If δ is VS and is Δw VS then Δu is LP.
26. If δ is VS and is Δw SN then Δu is LP.
27. If δ is VS and is Δw MN then Δu is LP.
28. If δ is VS and is Δw LN then Δu is LP.
29. If δ is SN and is Δw LP then Δu is LP.
30. If δ is SN and is Δw MP then Δu is LP.
31. If δ is SN and is Δw SP then Δu is LP.
32. If δ is SN and is Δw VS then Δu is LP.
33. If δ is SN and is Δw SN then Δu is LP.
34. If δ is SN and is Δw MN then Δu is LP.
35. If δ is SN and is Δw LN then Δu is LP.
36. If δ is MN and is Δw LP then Δu is LP.
37. If δ is MNand is Δw MP then Δu is LP.
38. If δ is MN and is Δw SP then Δu is LP.
39. If δ is MN and is Δw VS then Δu is LP.
40. If δ is MN and is Δw SN then Δu is LP.
41. If δ is MN and is Δw MN then Δu is LP.
42. If δ is MN and is Δw LN then Δu is LP.
43. If δ is LN and is Δw LP then Δu is LP.

44. If δ is LN and is Δw MP then Δu is LP.
45. If δ is LN and is Δw SP then Δu is LP.
46. If δ is LN and is Δw VS then Δu is LP.
47. If δ is LN and is Δw SN then Δu is LP.
48. If δ is LN and is Δw MN then Δu is LP.
49. If δ is LN and is Δw LN then Δu is LP.

The membership functions of the inputs, output and rule base for all the controllers can be the same. The only difference is the range of these values.

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IV. SIMULATION RESULTS

Firstly Simulation is done with the help of MATLAB software for the model of SMIB with UPFC as shown in the section 2. taking step change in mechanical input power (Pm = 0.01 pu.). In This simulation UPFC has no controller. The results obtained shows that the system is having oscillations and the system is poorly damped as shown in Fig. 6.

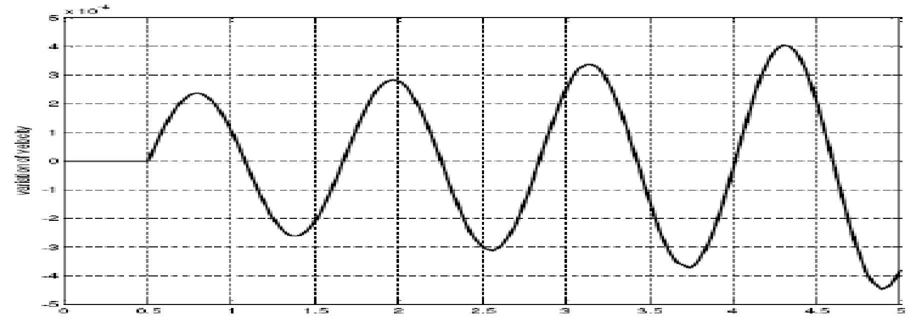

Fig. 6 Response of system without any damping controller

Next, the simulation is performed with the same step change in mechanical input power but the UPFC is controlled by different fuzzy controllers namely mE controller, mB controller, δE controller and δB controller. The performance of the system with mE controller, mB controller, δE controller and δB controller is shown in Figs. 7, 8, 9 and 10 respectively

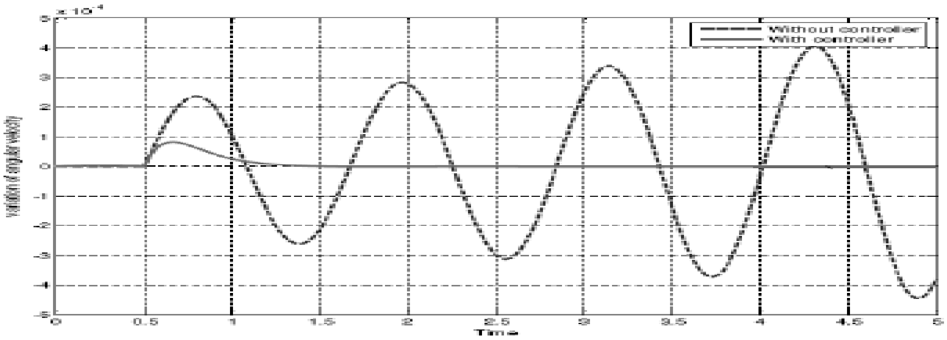

Fig. 7. Response of system with m_E Controller

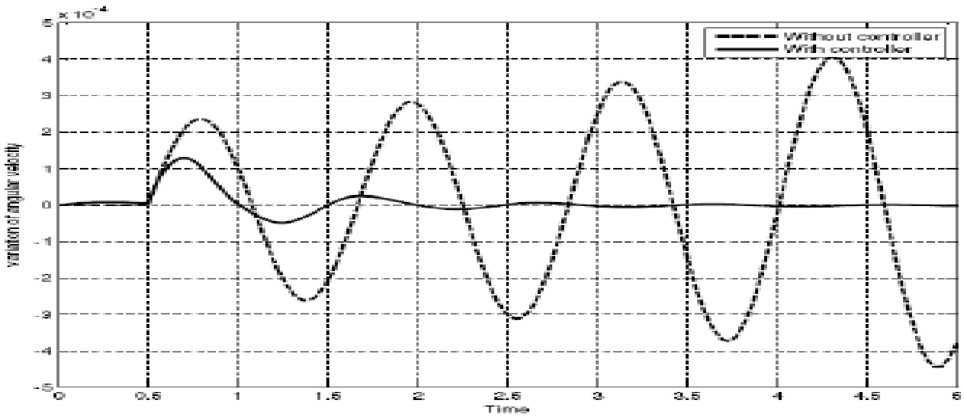

Fig. 8. Response of system with m_B Controller

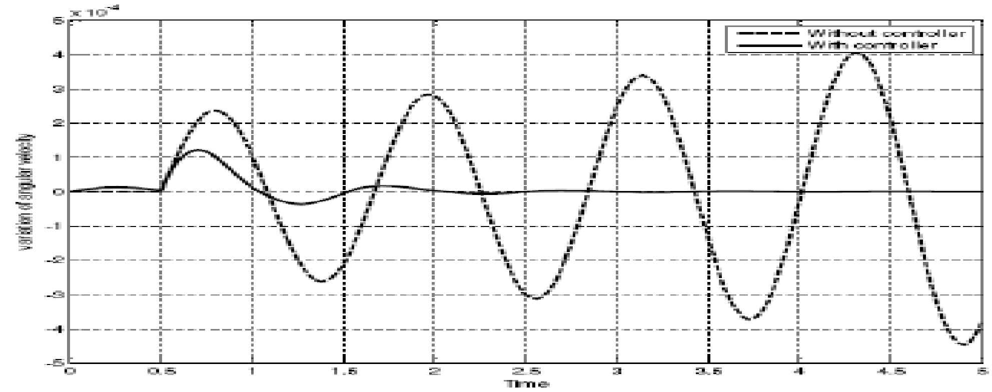

Fig. 9. Response of system with δ_E Controller

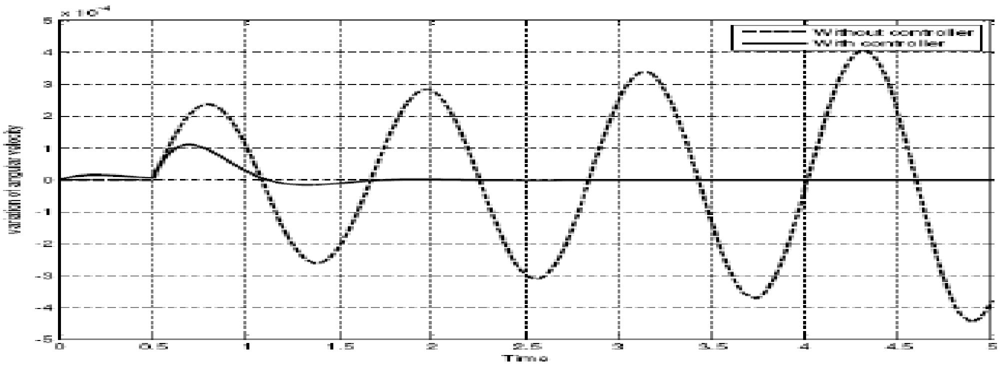

Fig. 10. Response of system with δ_B Controller

V. CONCLUSION

The above simulations shows that the system considered when used without any damping controller is undamped in nature.The fuzzy controller is designed for this UPFC controller. The simulation results shows that when there is a small perturbance in the power system, the proposed UPFC based fuzzy controller is effectively damping the oscillations.

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