Static Sustenance of Power System Stability Using FLC Based UPFC in SMIB Power System

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Abstract: *The unified power flow controller is the most versatile and complex power electronic equipment that has emerged as the indispensable equipment used to control the power flow ,to boost the transmission capacity and to optimize stability of the power system. Low frequency power system oscillations are inevitable characteristics of power systems and they greatly affect the transmission line transfer capability and power system stability. This paper present a control method for damping low frequency system oscillations using fuzzy logic controller installed in a single- machine infinite-bus power system. The UPFC uses two converters coupled through a common DC link to improve the dynamic performance of the system. System response with proportional UPFC controller and proportional fuzzy logic(using mamdani-type inference) based UPFC controller are compared at variable loading conditions through software simulation. The results of the simulation shows that the UPFC with fuzzy-based controller is effectively damping the Low frequency oscillations.*

Keywords: *Unified Power Flow Controller (UPFC), Fuzzy Logic Control (FLC), Transient stability, Flexible AC Transmission Systems (FACTS), Low frequency oscillations (LFO), Damping controller.*

I. INTRODUCTION

FACTS is an acronym which stands for Flexible AC Transmission System. FACTS is an evolving technology-based solution envisioned to help the utility industry to deal with changes in the power delivery business. These devices are used to control power flow and increase the stability of the system. They play a prominent role in the operation and control of power system. Among all the FACTS devices UPFC is more flexible and potent device which is widely in use [3]. The power flow through the transmission line is a function of line impedance, magnitude of sending and receiving end voltages, the phase angle between these voltages. By proper implementation of controllable components for these variables, it is possible to regulate the power flow through the transmission line [16]. Real and Reactive power can be controlled independently by using this. UPFC can also be used for voltage support and electromechanical oscillation damping [1]. For secure system maneuver damping of electromechanical oscillations due to sudden change in input mechanical power, faults is essential [17]. In this paper, the researches are based on single-machine infinite-bus system with UPFC. UPFC controller has the capacity not only to increase the transmission but also to improve the power system stability.

Flexible AC Transmission System (FACTS) involves the application of high power electronics to AC power transmission to achieve fast, reliable control of power transmission, reactive power control and enhancement of stability margins. The Unified Power Flow Controller (UPFC) was proposed for real-time control and dynamic compensation of AC transmission systems, providing the necessary functional flexibility required to solve the many problems facing the utility industry. The UPFC from the view point of conventional transmission compensation and control is an apparatus that can provide simultaneous, real time control of all or any combination of the basic power system parameters (Transmission voltage, Line impedance and Phase angle) which determine the transmission power. UPFC can control each parameter either selectively or simultaneously in appropriate combinations (control of real power and reactive power independently).

The main objective of this paper is to develop a fuzzy based power oscillation damping controller for the UPFC. For a better understanding of the performance of the controller, it is considered that the UPFC is connected with a Single Machine Infinite Bus (SMIB) system. A Simulink Model for Fuzzy logic controller based UPFC has been developed in MATLAB/SimPowerSystems environment in order to test the transient behavior of the system when it is connected with the fuzzy logic controller and proportional fuzzy logic controller.

II. UPFC SYSTEM

The basic block diagram of UPFC system used in the investigation of this paper is as shown in below figure 1.

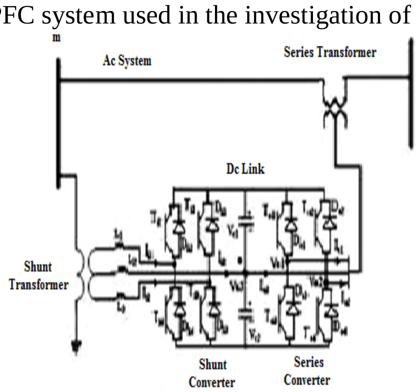


Fig. 1: Block Diagram of UPFC installed in a single-machine infinite-bus

It consists of two Voltage Source Converters (VSCs) coupled through a common dc link terminal. One VSC (series converter) is connected is shunt with the line through a coupling transformer and the other VSC (Shunt converter) is in series with the line through an interface transformer. DC voltage required for both the converters is provided by a common capacitor bank.

2.1 VSC AS SHUNT COMPENSATOR (STATCOM)

A STATCOM or Static Synchronous Compensator is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. A STATCOM works by rebuilding the incoming voltage waveforms by switching back and forth from reactive to capacitive load. If it is reactive, it will supply reactive AC power. If it is capacitive, it will absorb reactive AC power.

2.2 VSC AS SERIES COMPENSATOR (SSSC)

A series connected VSC injects a voltage in series with the line. Real and Reactive power exchange is controlled by the phase exchange is controlled by the phase displacement of the injected voltage w.r.t the line current. When it is in phase, only real power is exchanged and if it is in quadrature, reactive power is exchanged.

The series connected VSC is an extremely powerful tool for power flow control, as it is able to control both the transmission line impedance and phase angle. When restricted to fundamental frequency, it will not produce undesirable electrical resonance with transmission network. Also by suitable control it can damp SSR due to existing capacitive compensation by injecting non-fundamental voltage components of appropriate amplitude, frequencies and phase angles.

A static synchronous generator operated without an external electric energy source as a series compensator whose output voltage is in quadrature with, and controllable independently of, the line current for the purpose of increasing or decreasing the overall reactive voltage drop across the line and thereby controlling the transmitted electric power. The SSSC may include transiently rated energy storage or energy absorbing devices to enhance the dynamic behavior of the power system by additional temporary real power compensation, to increase or decrease momentarily, the overall real(resistive) voltage drop across the line.

III. PROPOSED UPFC WITH FUZZY CONTROLLER WITH MAT LAB MODELS.

The primary reason for choosing the fuzzy logic controller in this study is that the flexibility offered by it. In which the control strategy is represented by a set of rules and it doesn't require the exact set of equations to represent the system. This allows the design to change the basic characteristics of the controller with a minimal effort i.e., simply by redefining the rules. The block diagram of the fuzzy logic controller is shown in Fig. 2 and Fig. 3.

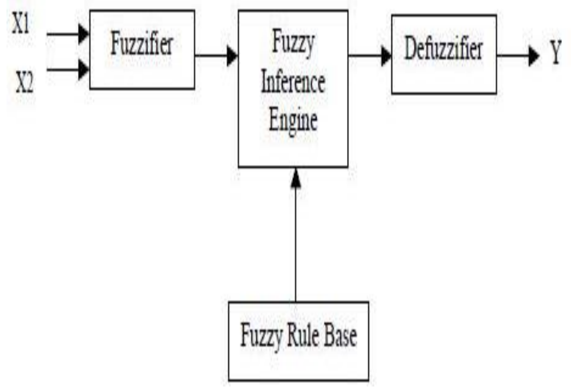


Fig. 2: Schematic diagram of Fuzzy Logic Controller

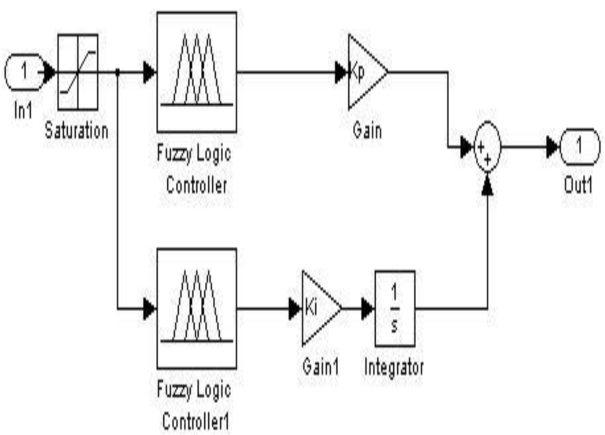


Fig. 3: Fuzzy Logic PI Controller in UPFC

As mentioned in the control strategy the stability and damping of the system is dependent on the electrical output power (Pe). In order to maintain the stability electrical output power (Pe) must be equal to that of the mechanical input power (Pm). Thus the two input variables chosen for the fuzzy logic controller are the deviation of Pe from Pm and its rate of change with respect to time. The rule base for the generic Fuzzy logic controller for UPFC is designated from the knowledge base of the system.

3.1. Membership Functions

The present design utilizes three types of membership functions (Γ, Ί ,&Δ). The input variables are partitioned into seven linguistic variables while the output variables are assigned form the any of the linguistic variables. The input and output membership functions with associated linguistic variables are shown in Fig. 3.

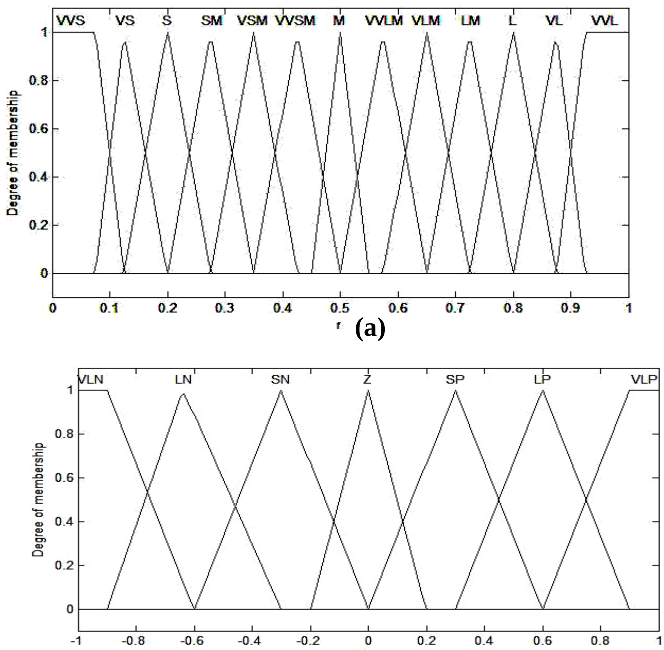


Fig 4: Input and output Membership function and linguistic Variables

3.2. Fuzzification

Fuzzification process convents the physical variables to fuzzy set variables. The crisp variables of the inputs are mapped into the fuzzy plane with the associated membership functions. It gives each input variable a membership function relating to the fuzzy set.

3.3. Fuzzy Rule Base

Each input variables are assigned to seven linguistics variables, therefore 49 rules are formulated. These rules are formulated with a simple IF-THEN structure. They map the inputs states into 49 output conditions. The fuzzy rules will take up the general form. The rule base can be represented by the fuzzy associative memory (FAM) table shown in Table 1.

Table 1: FAM table for UPFC Fuzzy Logic Controller

Pe/dPe	VLN	LN	SN	Z	SP	LP	VLP
VLN	VVS	VS	S	SM	VSM	VVSM	M
LN	VS	S	SM	VSM	VVSM	M	VVLM
SN	S	SM	VSM	VVSM	M	VVLM	VLM
Z	SM	VSM	VVSM	M	VVLM	VLM	LM
SP	VSM	VVSM	M	VVLM	VLM	LM	L
LP	VVSM	M	VVLM	VLM	LM	L	VL
VLP	M	VVLM	VLM	LM	L	VL	VVL

3.4. Fuzzy Inference Engine

The Fuzzy logic controller discussed in this paper incorporates Mamdani's implication method of inference. This implication has a simple min-max structure. It involves two phase of operations. In the first phase the two input variables are involved with min-operation, hence the antecedent pair in the rule structure are constructed by logical AND. Then all the rules are aggregated by using max operation.

3.5. Defuzzification

Defuzzification is the process by which fuzzy linguistic variables are converted to real control variables. Different defuzzification techniques have been introduced depending on the complexity of the system. The weighted average method is adopted in this study.

IV. MATLAB/Sim Power Systems Model

A Unified Power Flow Controller (UPFC) is used to control the power flow in a 230 kV transmission system. The UPFC located at the left end of the 50-km line L2, is used to control the active and reactive powers flowing through bus . It consists of two 100-MVA, three-level, thyristor based converters, one is connected in shunt with line and one connected in series with line. The shunt and series converters can exchange power through a DC bus. The series converter can inject a maximum of 10% of nominal line-to-ground voltage (28.87 kV) in series with line L2.

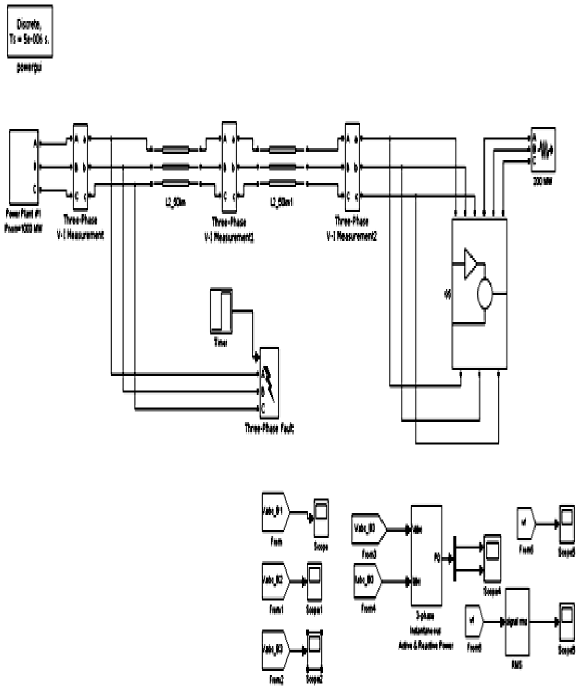


Fig. 5: MATLAB/Sim Power Systems Model of FLC based UPFC

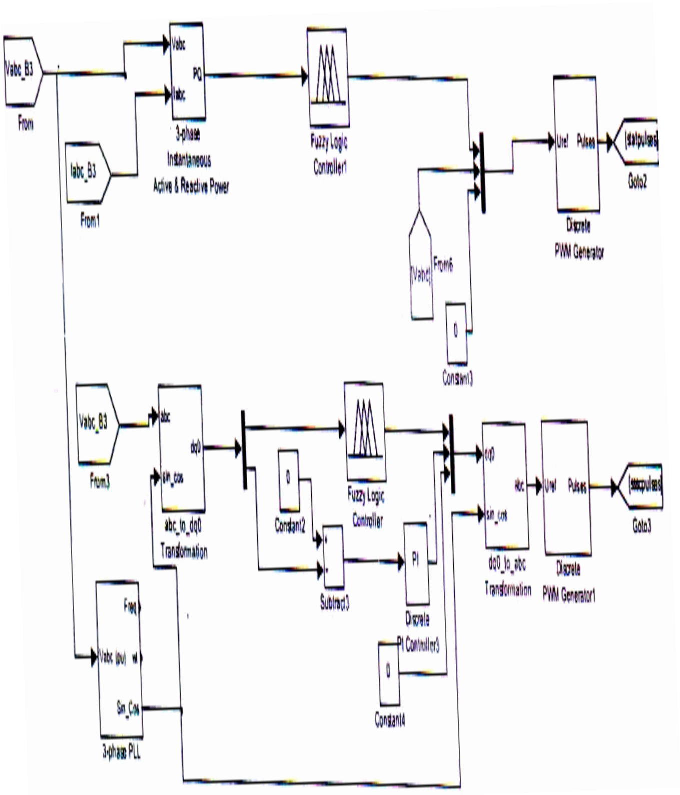
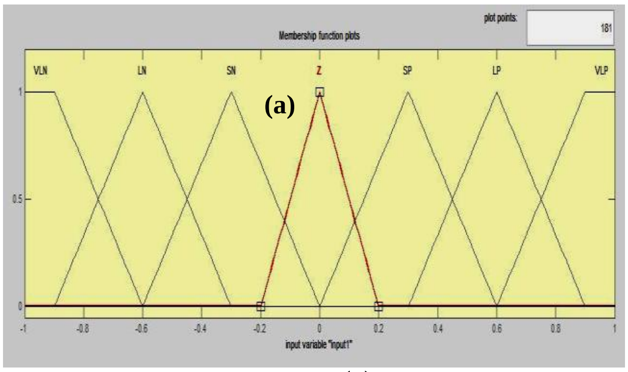
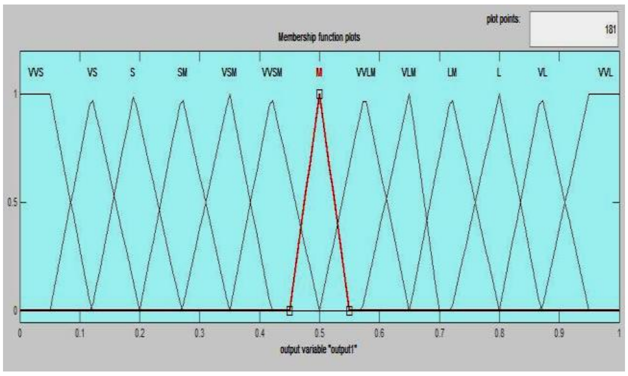


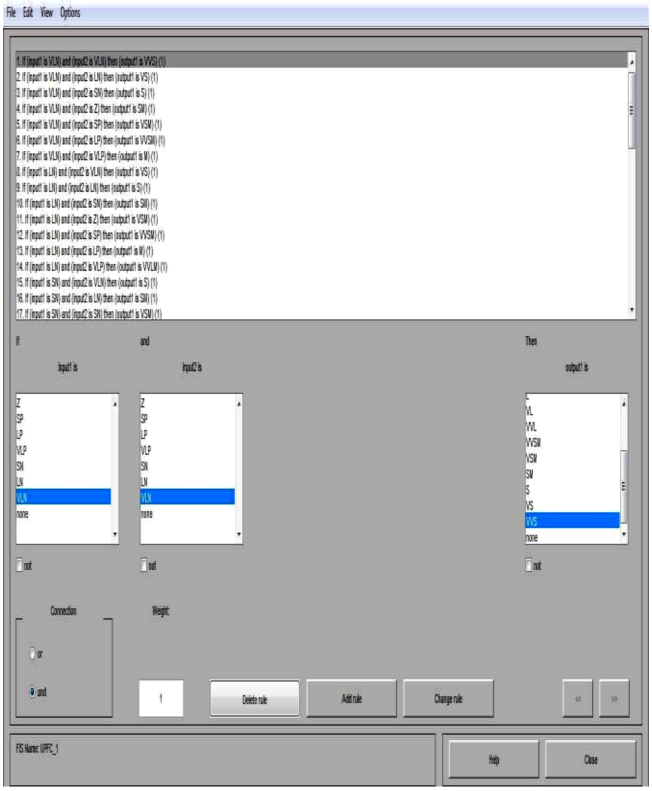
Fig. 6: MATLAB/Sim Power Systems Model of FLC



(a)



(b)

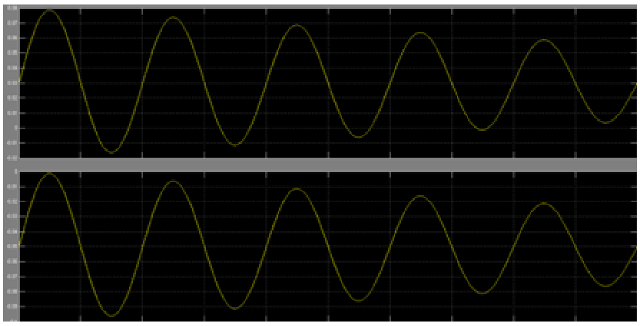


(c)

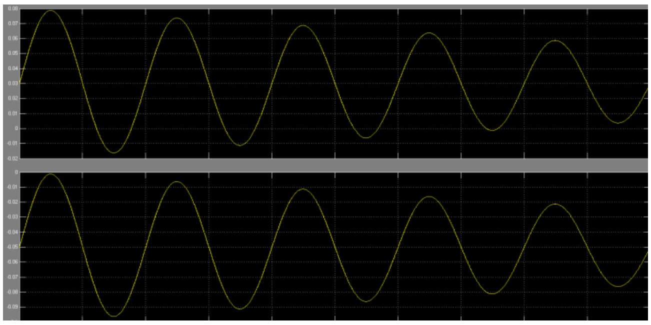
Fig. 7: MATLAB/Simulink Model of Fuzzy Membership Functions (a) Input Variable (b) Output Variable and (c) Fuzzy Rule Base

V. SIMULATION RESULTS

The simulation results shows that the UPFC with fuzzy based controller to damp the low frequency oscillation. The comparison of dynamic response of the system when it is used in UPFC mode With PI and Fuzzy Controller are shown in below figures. Fig 7 shows the active and reactive powers of the systems without transient fault. Fig 8 shows damping oscillations control with PI controller and fuzzy controller for three phase.

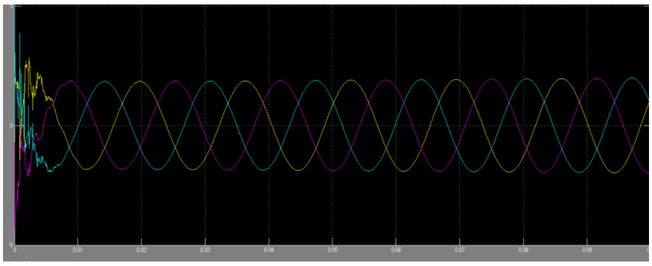


(a)

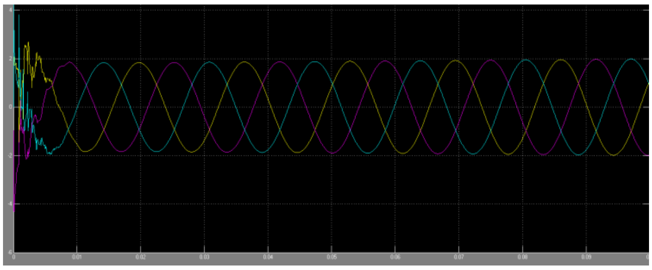


(b)

Fig. 8. Active Power and Reactive power control
(a) with PI Controller, (b) with Fuzzy based controller

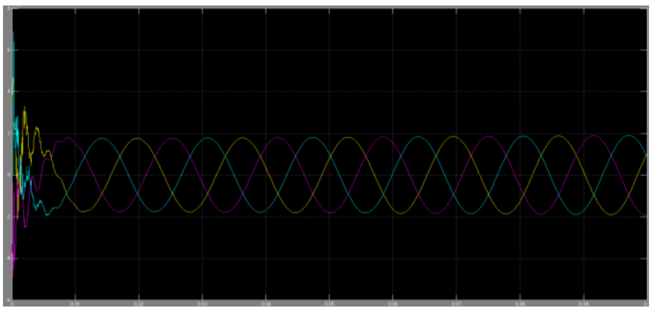


(a)

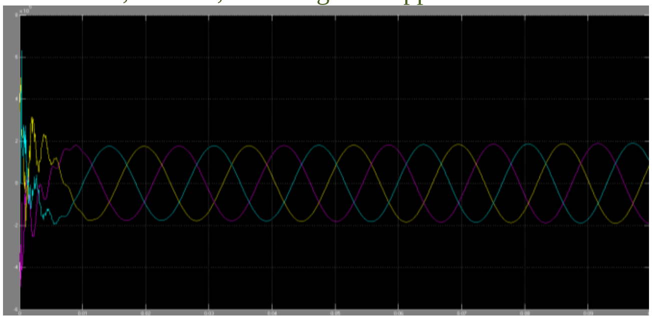


(b)

Fig.9 Damping oscillations control
(a) with PI controller, (b) with Fuzzy based controller
(Phase-B1)

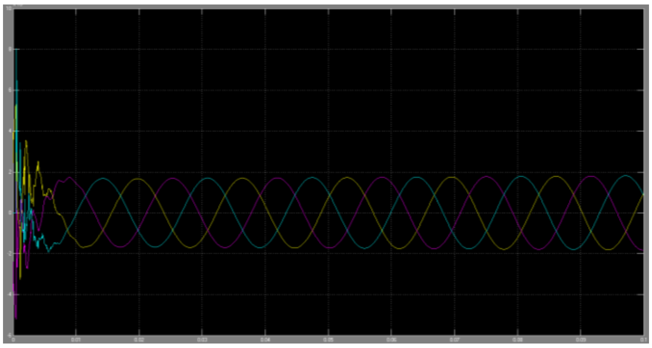


(a)

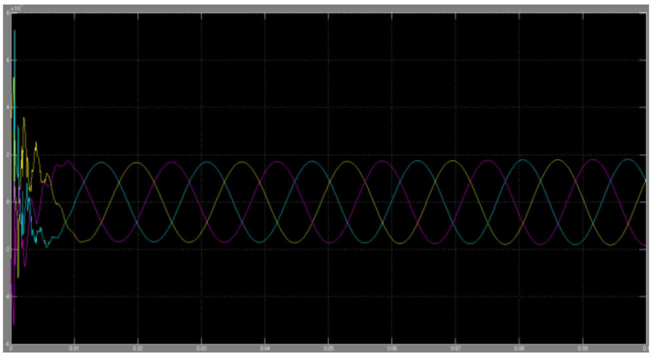


(b)

Fig.10 Damping oscillations control (a) with PI controller, (b) with Fuzzy based controller (Phase-B2)



(a)



(b)

Fig.11 Damping oscillations control
(a) with PI controller, (b) with Fuzzy based controller
(Phase-B3)

VI. CONCLUSION

The substantial contribution of the study effort presented in this paper as follows:

A simple Fuzzy logic controller for a unified power flow controller (UPFC) in a single machine infinite bus (SMIB) system has been implemented using SimPowerSystems environment tool box in MATLAB Software. The dynamic behavior of the original SMIB system with UPFC devices is determined through the proposed model of the system. It was observed that the system performance is improved with the UPFC and it becomes easier to control with fuzzy logic.

Simulation results shows that Fuzzy based controller slightly increases the power flow control by increasing the damping rate and decreases the amplitude of low frequency oscillations. Results comparison between conventional PI controller and the proposed Fuzzy based controller for UPFC indicates that the proposed fuzzy based controller has less settling time and less overshoot when compared with the conventional PI controller.

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BIOGRAPHIES

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