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Damping of Interarea Oscillations of Power System using Integrated System of UPFC-SMES

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Abstract:

To enhance power transfer capability and reliability power systems are interconnected. Damping of oscillations between synchronous generators and subsystems is the major problem associated with interconnected power systems. This paper proposes a new method which uses uses an Superconducting Magnetic Energy Storage System (SMES) based Unified Power Flow Controller (UPFC) using Fuzzy logic controller for damping of interarea oscillations. Thereby transient voltage profile of the power system has been improved. It is effective to damp interarea oscillations as it provides control of real and reactive power through the line. The effectiveness of this method is compared with existing method which uses PI controller in MATLAB/Simulink.

Keywords:

PWM based Voltage Source Converter, UPFC, SMES, Fuzzy logic controller, Power Oscillation Damping.

I. INTRODUCTION:

Modern power systems are mostly interconnected to meet the increased power demand.The interconnected power system has many advantages like improved reliability and increased reserves, less investment , economic exchange etc. But this interconnection often produces electro mechanical oscillations[4] causing severe problems like damage of generators, increased line losses, reduced power transferring capability, wear and tear of components in the network etc. The oscillations mainly exist because of the synchronous generators which are swinging against each other [4]. These kind of oscillations are introduced in to the system when the rotor of the machines acts like stiff bodies and exchange of oscillating energy among the interlinked machines which happens with the help of transmission lines. In local mode [4, 5] single generator is swinging against the remaining system at 1 to 2 Hz, the impact of the oscillation is restricted to that single generator and the transmission line which is going to connect it with grid. In interarea mode, the oscillations are throughout the network that includes swinging of two unified groups of alternators against each other at 1Hz or less than 1Hz. This occurrence includes so many components of the power system with greatly non- linear loads with dynamic behavior. To damp these oscillations Power system stabilizers are employed which is traditional method. But they are useful for local modes only and they will not provide enough damping in large power systems. So, instead of Power system stabilizers more efficient alternatives are required.

FACTS (Flexible AC Transmission System) technology based on high speed power electronic devices is introduced for the improvement of controllability and optimal usage of the existing power system capacities. The latest generation of FACTS controllers uses the Solid State Synchronous Voltage Sources (SVS) concept that is introduced by L.Guygyi. The SVS acts like an best alternator means it generates 3-ø balanced voltages of variable phase angle and amplitude having fundamental frequency. Voltage source converters (VSC) are used to implement SVS. In order to damp this inter area mode oscillations FACTS controllers [1] such as Unified power flow controllers(UPFC),Static series synchronous compensator (SSSC)[5],Static synchronous compensator (STATCOM)[6] etc. are used. The UPFC is one of the most flexible device, which is a grouping of SSSC and STATCOM, DC link capacitor acts as common between both shunt and series converters. In this paper, a new control method using unified power flow controllers (UPFC) along with superconducting magnetic energy storage system (SMES) [2,3,7,9] using fuzzy logic controller in such a way that interarea oscillations are reduced under transient condition in an efficient way is introduced. SMES has the advantages of minimum energy loss, high efficiency, fast response, high energy density at the time of the conversion etc comparing with other power supplies.

II. UNIFIED POWER FLOW CONTROLLER (UPFC):

The UPFC is superior to the FACTS devices in terms of performance. It contains a single common DC link and two voltage source converters (VSCs) coupled "back to back" using insulated gate bipolar transistor (IGBT). One VSC connected in parallel with the line through shunt transformer and another VSC connected in series with the transmission line through series transformer. The parallel transformer supplies the real power to the series converter through DC link capacitor. The AC voltage is injected by the series converter with variable phase angle and magnitude to the line.

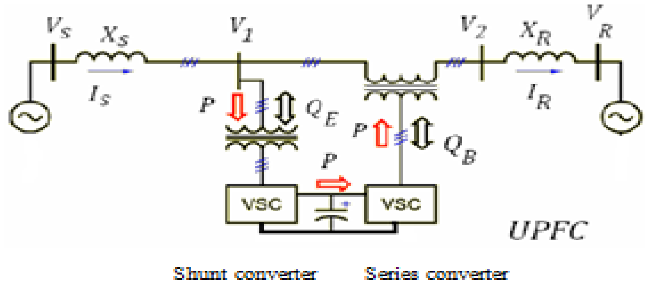

Fig.1: Schematic of UPFC

The reactive and active power exchange in AC system takes place when the line current flowing through series converter. Between the two converters there will be no exchange of reactive power; only real power transfer takes place. Thus independently shunt converter control voltage and series converter provides both active and reactive power flow control. Different methods to control shunt current magnitude, phase angle and series voltage magnitude are presented [1, 5].

A. UPFC Shunt Branch:

In the shunt branch of UPFC, the shunt converter generates a set of variable 3-ø output voltages at a frequency of AC power system from the DC voltage source provided by the charged.

The 3-ø output voltages are in phase with and connected to AC system voltage through a small tie line of reactance (0.1-0.15 p.u.). That is, if the amplitude of the converter output voltage is more than the the AC system voltage due to increase in the loads of system then current will increase and voltage level decreases, in such cases the currents will flow from converter to the AC system through tie line and the converter produces reactive power (capacitive) to the system. Similarly if the the converter output voltage is lower than AC system voltage then the current in the AC power system flow in to the converter and the converter will absorb reactive power (inductive) from the system. If the AC system voltage is equal to the amplitude of converter output voltage then there will be no reactive power exchange. the synchronous compensator reactive current is given by

$$I = \frac{1-\frac{V_C}{V_L}}{X} V_L \qquad (1)$$

The expression for the reactive power exchanged is given as

$$Q = \frac{1-\frac{V_C}{V_L}}{X} V_L^2 \qquad (2)$$

Where VL = voltage of the transmission line,
VC = output voltage of the Converter
X = Total reactance of System short circuit reactance and Transformer leakage reactance

B. UPFC Series Branch:

In the UPFC series branch, the series converter is a variable voltage source which is coupled in series with the transmission line to control current. One side of converter is connected to capacitor and the other side is connected to AC system. If any dynamic change in the system occurs, the series branch operates for controlling reactive and active powers. Series converter indicates the main function of the UPFC by injecting an ac voltage with variable phase angle and magnitude at the fundamental frequency connected with a transmission line through an insertion transformer. The synchronous ac voltage source is nothing but the injected voltage. Reactive and real power exchange between ac system and voltage source depend up on the transmission line current flowing through the voltage source.

The negative or positive real power demand at the dc link is indicated by the dc power which is obtained from the inverter at the ac bus. Inverter internally generates the reactive power which is exchanged at the ac terminal. Under any sudden disturbance condition, the energy stored in DC capacitor is not capable of damping so to overcome this we go for substantial power supplies such as SMES.

III. SUPERCONDUCTING MAGNETIC ENERGY STORAGE SYSTEM (SMES):

Superconducting Magnetic Energy Storage unit stores energy in the form of magnetic field which is generated by dc current passing through the superconducting coil. Even though SMES device have no moving parts and highly efficient, SMES should be cryogenically cooled in order to continue the superconducting properties of the wire, thus incurs maintenance and energy costs. Because of their property of huge amount of energy release in a fraction of seconds, it is highly recommended for the improvement of power quality.

A usual SMES system contains three parts i.e., cryogenically cooled refrigerator, power conditioning system and superconducting coil. If the superconducting coil is charged once, it stores in the form of magnetic field. This stored energy is released back to the power conditioning system uses inverter/rectifier, by discharging the coil. In between the VSI and energy source there is a need of one more electronic equipment known as chopper. The energy source compensates the capacitor charge through chopper needed by VSI. The chopper is a two-quadrant n-phase DC-DC converter as shown in figure2.

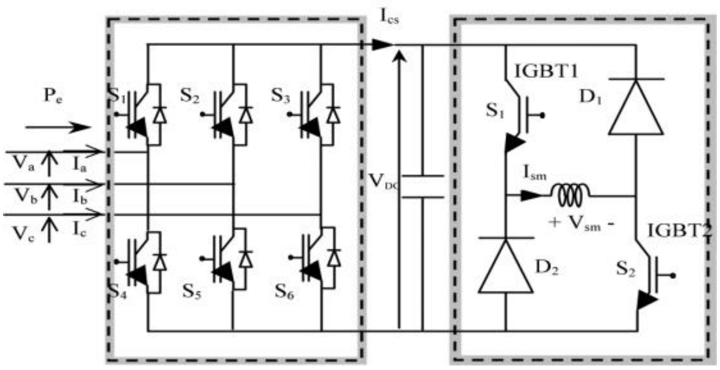

Fig. 2: The Configuration of SMES unit with Chopper

The chopper operates in three modes they are storage in the SMES device, discharge and charge. In the charging mode of superconducting coil, it is operated in step down configuration. 'D' is the duty cycle of IGBT "S1" and the other IGBT "S2" is always kept ON. The coil voltage is related with the dc bus voltage as

$$-V_{smes} = (1-D) * V_{DC} \tag{3}$$

The operating mode of chopper is changed to standby mode, once charging is completed for the superconducting coil. In this case the IGBT "S1" is always kept OFF and the IGBT "S2" is always kept ON. The chopper in the discharge mode is operated in step up configuration. Here the IGBT "S2" is operated with duty cycle D while the IGBT "S1" is kept OFF at all times. The coil voltage is related with dc bus voltage as

$$V_{DC} = K_a V_{inv} \tag{5}$$

Where

$$K_a = K * a \tag{6}$$

K=Pulse number,

a=coupling transformer ratio.

IV. UNIFIED POWER FLOW CONTROLLER WITH SMES:

The UPFC is a combination of STATCOM and SSSC. The dq components of shunt current are I_{d_1} and I_{q_1} respectively. Whereas I_{d_2} and I_{q_2} are dq components of series current. The sending end and receiving end voltages are $V_1\underline{|\theta_1}$ and $V_2\underline{|\theta_2}$. The UPFC is controlled by varying output voltage magnitudes K_1 and K_2 of the shunt and series converter and phase angles α_1 and α_2 of the series converter. The SMES and the DC capacitor are connected through a bidirectional dc-dc converter shown in figure 3.

The SMES voltage and dc-link capacitor voltage are related through duty cycle ratio D as follows

$$V_{dc} = \left\{ \frac{D}{1-D} \right\} V_{dcsmes} \tag{7}$$

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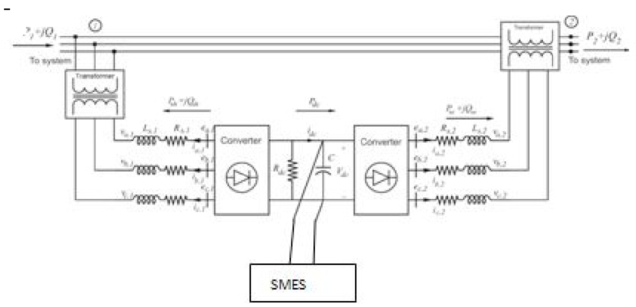

Fig.3: UPFC with SMES diagram

Based on Duty cycle the charging and discharging of SMES takes place. For example, average voltage of SMES is positive if D<0.5, therefore chopper will absorbs the energy and it will be in charging mode and SMES current is increased. When D>0.5 chopper injects energy into the power system and operates in discharging mode. When D=0.5 the chopper will be in standby mode and the SMES average voltage across is zero, so there will be no exchange of energy with the power system.

In the internal shunt control scheme the voltage across capacitor is compared with constant value and the error is given as input to PI controller which produces reference value of active current product with current vector of sending end voltage. This current vector is compared with receiving end current and according to the error the PWM generator generates pulses accordingly shunt converter produces output voltage based on converter output voltage the exchange of reactive and real power, storage across capacitor takes place. But the Shunt converter in maintaining required voltage across capacitor for series converter is not effective by using PI controller.

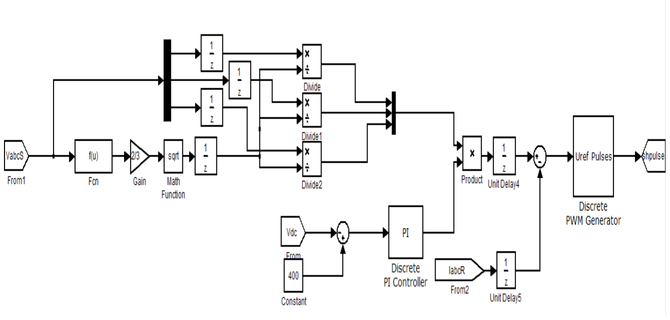

Fig.4: Internal Shunt Control of UPFC with SMES using PI control

V. DESIGN OF FUZZY LOGIC CONTROLLER:

Classical controllers are highly dominated by Fuzzy logic controllers. Fuzzy logic controllers are nothing but a Fuzzy code designed to control something. Fuzzy logic technology allows the use of experimental results in designing and engineering experience in an embedded system. Advantages of Fuzzy logic controllers are very robust, can be easily varied; can use multiple outputs sources and multiple inputs, very quick and cheaper to implement. The Fuzzy controller includes three steps i.e. Fuzzification, Fuzzy Inference System and Defuzzification as shown in figure 5.

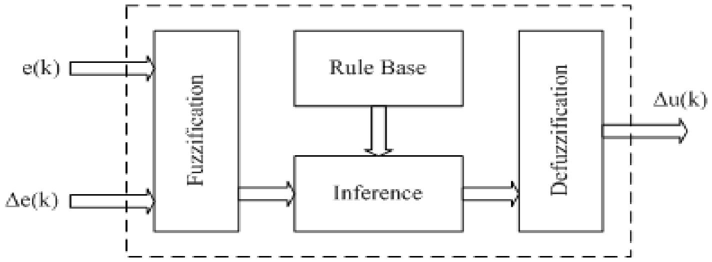

Figure 5. Fuzzy logic Control scheme

In this case the error and change in error are inputs to fuzzy quantities based on this membership functions are determined. Here we have seven membership functions for each input so that 49 rules are formed. Fuzzy inference system is a decision making system, it uses "if-then" rules along with "OR or AND" for making necessary decision. In the defuzzification block the fuzzy quantities are converted to Crisp quantities. The Rules which are used in Fuzzy inference system are as shown below

TABLE 1. Fuzzy Rule Table

CIE E	NL	NM	NS	ZE	PS	PM	PL
NL	PL	PL	PL	PM	PM	PS	ZE
NM	PL	PM	PM	PM	PS	ZE	NS
NS	PL	PM	PS	PS	ZE	NS	NM
ZE	PM	PM	PS	ZE	NS	NM	NM
PS	PS	ZE	NS	NM	NM	NM	NL
PM	PS	ZE	NS	NM	NM	NM	NL
PL	ZE	NS	NM	NM	NL	NL	NL

The various membership functions used in fuzzy are triangle, trapezoidal, Gaussian and sigmoid. In this paper triangular membership function is used, advantage of using triangular function is it produces fast response and complexity in calculations reduced.

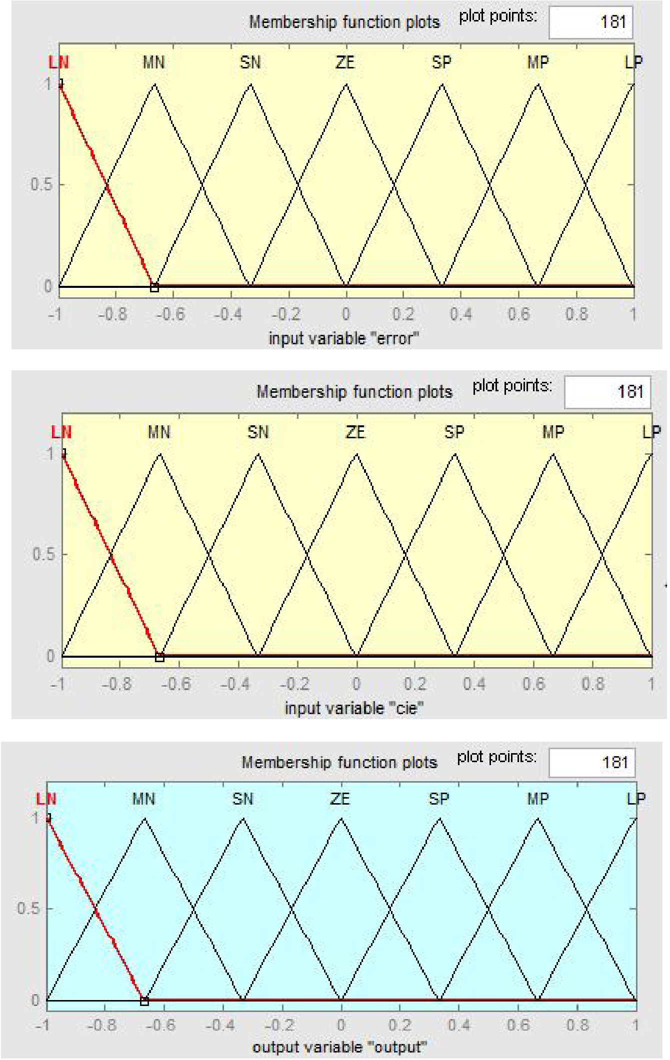

Fig.6. Input and Output membership functions of FLC

In this case the inference engine used is mamdani. The input and output memberships used in this work is shown in fig 6. Here all the membership functions are uniformly distributed in the range [-1, 1]. In mamdani inference system the rules are simulated and gives the output in fuzzy. Then defuzzification is done in order to convert the fuzzy values into the real scalar values using centroid method.

Fig.7 shows the block diagram of proposed control scheme. The PI controller was replaced by Fuzzy logic controller. The error in voltage across capacitor compared to constant value is taken as input to fuzzy logic controller.

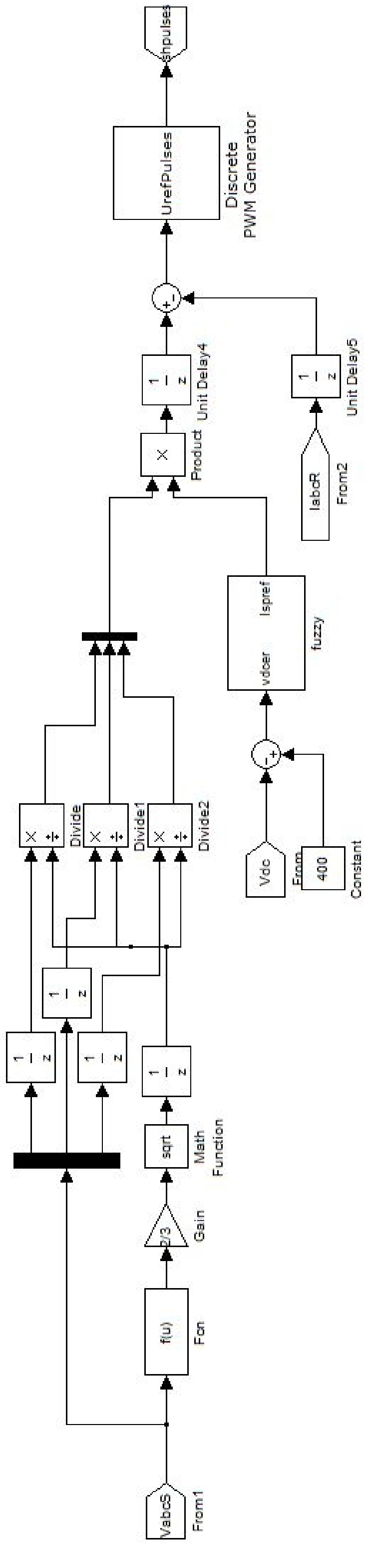

Figure7. Internal Shunt Control of UPFC with SMES using Fuzzy controller

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VI. SIMULINK Model of SMES Based UPFC System:

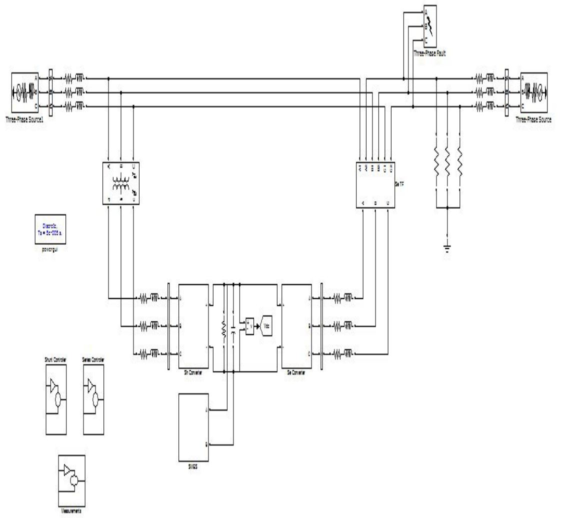

Fig. 8: Simulink model of UPFC with SMES

The Simulink model consists of two three phase sources connected by a tie line with a three phase fault, small resistive load and UPFC device along with SMES. UPFC device is operated by its internal shunt and series control circuit whereas SMES is operated by chopper control circuit.   A three phase fault is created in line for t=0.0167sec to 0.41sec. The variation of active power, reactive power, voltage across capacitor, voltage and currents at both ends are observed for both PI and Fuzzy controllers.

VII. RESULTS AND COMPARISON:

For the system a 3-fault is created on bus at time t=0.0167 sec to 0.41 sec. The duration of fault and location were chosen to provide a significant disturbance to the interior of the power system and the comparison indicates how inter area oscillations are damped and dc link compensation.

A. Voltage and Current Waveforms at the Sending end and Receiving end:

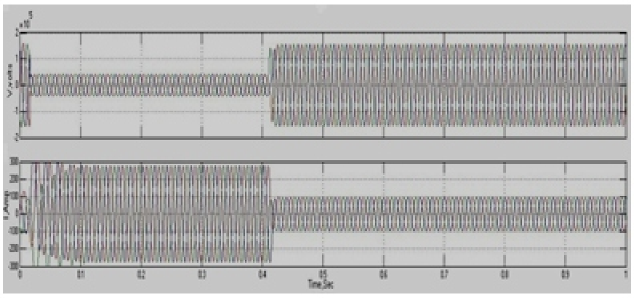

Fig.9: Voltage and Current Waveforms at Sending end

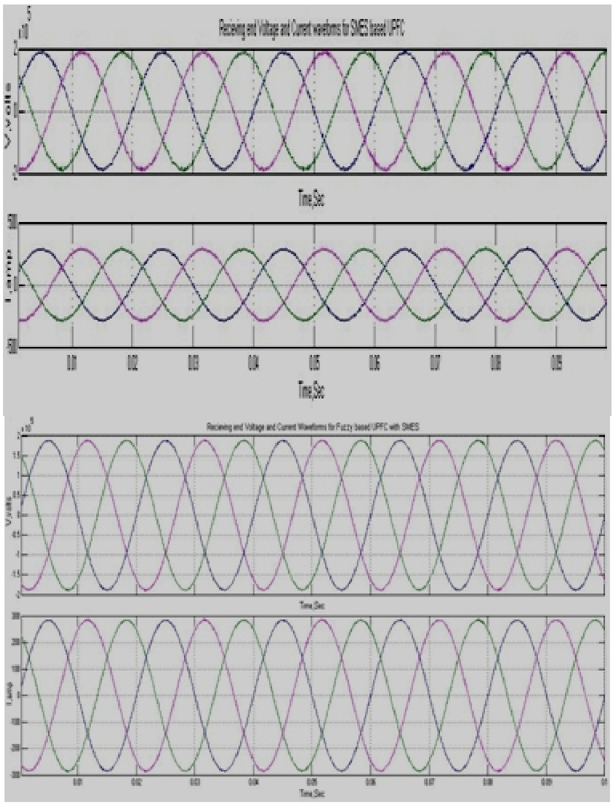

Fig.10: Receiving end voltage and current waveforms for PI and Fuzzy controller

From both waveforms it is clear that at the sending end during the fault the voltage drops and current increases. At the receiving end the ripples in voltage and current are almost reduced by using fuzzy controller compared to PI. Thus using fuzzy the Voltage profile is improved.

B. Active power Comparison of UPFC with SMES for both PI and FUZZY controllers:

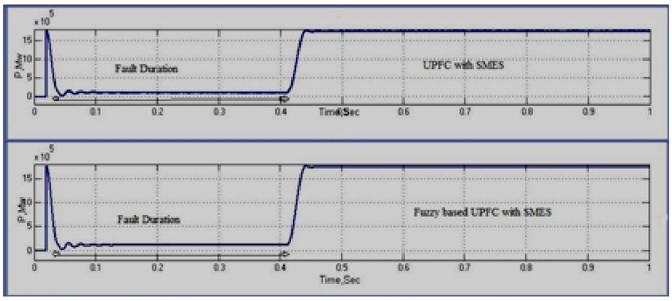

Figure 11. Active power using PI and Fuzzy controller

It is clear from simulation results that before the settling of active power the power oscillations are high when we use UPFC with SMES using PI controller. Also the oscillations are damped quickly using Fuzzy controller.

C. Reactive Power comparison of UPFC with SMES for both PI and FUZZY controllers:

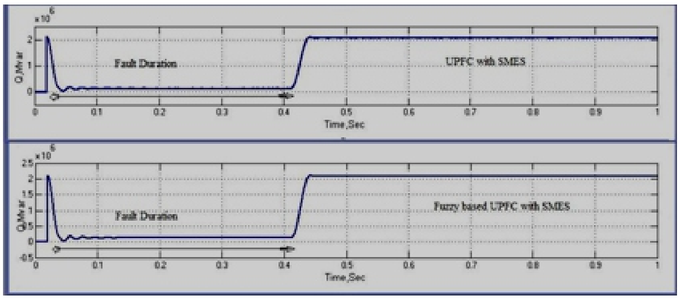

Fig.12: Reactive Power using PI and Fuzzy controller

It is clear from simulation results that before the settling of reactive power the power oscillations are high when we use UPFC with SMES using PI controller. Also the oscillations are damped quickly using Fuzzy controller.

D. DC link voltage comparison of UPFC with SMES for both PI and Fuzzy controllers:

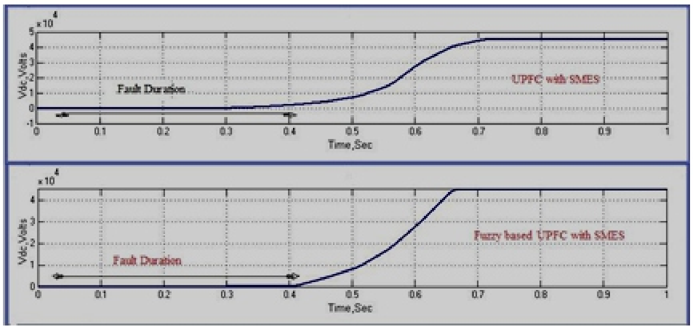

Fig.13: DC link Voltage using PI and Fuzzy controller

It is clear from the simulation results that under transient duration the SMES tries to maintain required voltage across capacitor within small duration and it is also observed that the settling time for the test system by using fuzzy controller is minimum compared to PI controller.

CONCLUSION:

The control strategy to damp the tie line oscillations by maintaining required active and reactive power through the line using UPFC-SMES had been done by using MATLAB/SIMULINK.

From the results it had been shown that Transient stability of power system using fuzzy Logic Controller had been improved compared to conventional controllers. It is also clear from the results that the UPFC with SMES using fuzzy is very effective in maintaining active and reactive power through the line by maintaining voltage stability across capacitor reducing harmonic content and fluctuations.Other soft computing techniques can also be used to improve Transient Stability of a Power System.

REFERENCES:

[1] Hingorani, N. G; Gyugyi, L. Understanding FACTS, Concept and Technology of Flexible AC Transmission Systems. IEEE press, 2000.

[2] Harikrishna 1, D; Srikanth, N. V; Chandrasekhar, Y. Improvement of Transient Stability Using Fuzzy Logic Controlled SMES. Majlesi Journal of Electrical Engineering, Vol. 5, No. 4, December 2011.

[3] Hassan Taher Dorrah; Tamer Shehada; Said Abdel Moteleb, M. Enhancement Stability for Power System Applications using FACTS Controllers and SMES. Journal of Cybernetics and Informatics, 2011.

[4] Klein, M; Rogers, G. J; Kundur. A Fundamental Study of Interarea oscillation in Power Systems. Transactions on Power Systems, Vol. 10, No. 1, February 2010.

[5] Mahyar Zarghami; Mariesa; crow, L; JagannathanSarangapani; Yilu Liu; and StanAtcitty. A Novel Approach to Interarea Oscillation Damping by Unified Power Flow Controllers Utilizing Ultra Capacitors. IEEE Transactions on Power Systems, Vol. 25, No. 1, February 2010.

[6] Ravi Gupta; Sharma, N. K; Tiwari, P; Astha Gupt;, Nitisha Nigam; Anubha Gupta. Application of Energy Storage Devices in Power Systems. International Journal of Engineering Science and Technology, Vol. 3, No. 1, 2011, pp.289-297.

[7] Sreelal Elamana; Rathiman, A. Interarea Oscillation Damping By Unified Power Flow Controller-Superconducting Magnetic Energy Storage Integrated System. IJEAT, Vol. 2, Issue-3, February 2013.

[8] Thangavel, M; Shiny Jasmine, S. Enhancement of Voltage Stability and Power Oscillation Damping Using Static Synchronous Series Compensator with SMES. IJART, Vol. 2, Issue-3, 2012, 94-98.

[9] Vadirajacharya, Dr. K. Superconducting Magnetic Energy Storage Based DVR. International Journal of Engineering Research and Technology (IJERT), Vol. 3, Issue, 4. June-2010.