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Transient Stability Improvement in Transmission System using SVC with PI-Fuzzy Logic Hybrid Control

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Abstract: *The existing power transmission capabilities can be flexibly controlled and enhanced with the help of new technology called Flexible AC Transmission System (FACTS). This power electronics based technology can be used individually or in coordination with other controllers. Static VAR Compensator (SVC) is a shunt connected FACTS device, used for voltage control and for reactive power compensation. In the existing system, the SVC uses a PI controller, which though simpler and cheaper, not suitable for non-linear characteristics. In order to overcome this, the hybrid controller is designed as a combination of both PI controller and Fuzzy Logic Controller, there by gaining the joint advantages of both types. The designed model has been tested in a 2 machine 3 bus test system using MATLAB software. The simulation results show that the new controller logic gives better and quick performance compared to the other types.*
Keywords: *FACTS; SVC; Fuzzy Logic; Voltage Control*

I. Introduction

In the recent decade, the world's electric power supply systems are widely interconnected to have the advantages like sharing of sources, diversity of loads, reduced fuel and operating cost and improved reliability [1]. The interconnection of power systems have also created problems like low frequency electro mechanical oscillations caused by electrical disturbances [2]. The low frequency oscillations can be classified as Local mode and Inter-area mode. The former which ranges between 1-2 Hz, consist of oscillations of a single generator or a group of generators against the remaining system, while the latter spans between 0.1-1 Hz and consist of oscillations among group of generators [3]. Stability is an important criterion, which governs the power system operation [4]. The term stability indicates the ability to maintain the machines connected to the system in synchronism [5]. With developments in semi-conductor electronics, a new technology called FACTS controllers helps in enhancing the stability of the power system with its fast control characteristics and continuous compensating capability [6]. There are wide varieties of FACTS controllers categorized as series type, shunt type, combined series-series type and combined series-shunt type. Among them, the Static VAR Compensator (SVC), a shunt connected controller provides more reliable operation in damping the power oscillations and improving the transient stability [7]-[9]. The conventional SVC consists of a PI controller, which is easier to design, implement and control. But, they do not provide satisfactory performance in case of large disturbances and for different operating points, since the power system is non-linear [10]. The Fuzzy logic is an effective technique with the capability of tolerating uncertainty and imprecision in the system parameters and operation condition changes [11]-[13]. In this paper, a new model is proposed to incorporate the advantages of both PI and Fuzzy Controller, thereby improving the performance of SVC. The model is tested using a 2 machine 3 bus test system and MATLAB software is used to perform the simulation studies. The performance analysis of the new controller is done by subjecting the system to a three phase fault. The results obtained shows that the proposed controller gives better performance in damping the oscillations during the disturbances and also in regulating other parameters like terminal voltage and transmission line reactive power. The report structure is as follows: In Section II, the SVC modeling is explained along with its operating waveforms. The controllers used in conventional SVC and the importance of Fuzzy Logic Controllers are briefed in Section III. The Fuzzy based rules, input-output membership functions are also discussed in this section. Section IV gives a view of the simulated results obtained by creating a disturbance in the test system. Finally,SectionV gives a description of the work done in this paper.

II. Svc Operation And Modeling

The Static VAR Compensator (SVC) is one of the shunt connected FACTS devices, which is based on power electronics. It helps in voltage regulation, reactive power control and improving the transient stability of the system. The voltage regulation by SVC is done, by controlling the amount of reactive power injected into or absorbed from the power system. It generates reactive power (capacitive mode), when the system voltage is low and absorbs reactive power (inductive mode), when the system voltage is high.

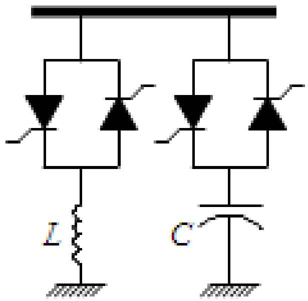

Fig.1. SVC Structure

As shown in Fig. 1, a typical SVC comprises one or more banks of fixed or switched shunt capacitors or reactors, of which at least one bank is switched by Thyristors. The reactive power variation can be achieved by switching the capacitor banks and inductor banks. The capacitors are switched ON and OFF by Thyristor Switched Capacitor (TSC) and the reactors are controlled by Thyristor Controlled Reactor (TCR). The current in the reactor can be varied using Firing delay angle control method, which is shown in Fig. 2.

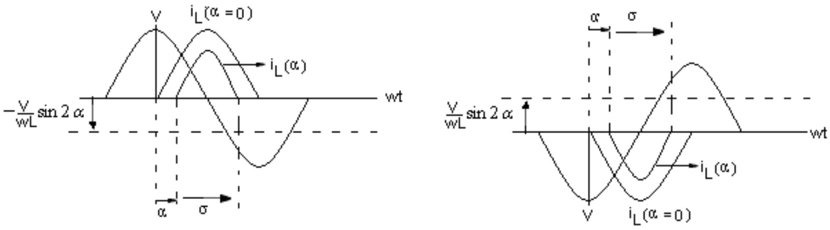

Fig. 2. Firing Delay Angle Control

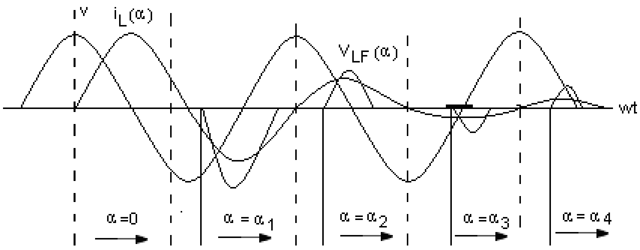

Fig. 3. SVC Operating Waveforms

From the Fig. 3, it is evident that the reactive current magnitude can be varied from maximum (α=0) to zero (α=π/2). The term iL(α) represents reactor current and iLF(α) is its fundamental component. The dynamic equation of SVC is given as,

$$\frac{d\Delta B_L}{dt} = \frac{1}{T_\alpha}\left[-\Delta B_L + K_\alpha (V_{ref} - V_t + \Delta V_s)\right] (1)$$

where Tα and Kα are time and gain constants respectively. The susceptance BL, is associated with the reactive power injected into the system in order to maintain the voltage level between suitable limits. The susceptance variation for SVC operating in and out of the control region is shown in Fig. 4.

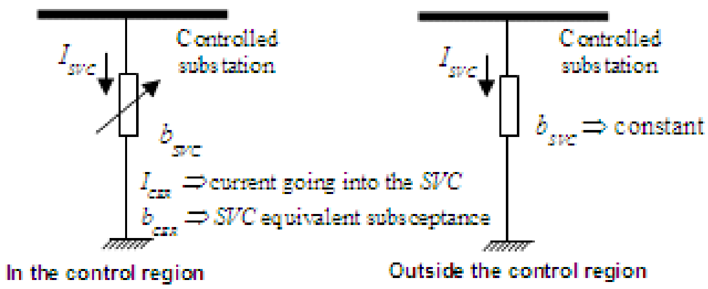

Fig. 4. SVC representation in different operating regions

The variable inductive susceptance BL is given by

$$B_L = \frac{-(2x-2\alpha+\sin 2\alpha)}{\pi x_s}, \pi/2 \le \alpha \le \pi \quad (2)$$

where xS is the reactance of the fixed inductor of the SVC and α is the thyristor firing angle. Fig.5. shows the basic architecture of SVC Control scheme. This model is known as Phasor type in MATLAB, which can be used for transient stability studies and to observe the impact of SVC on electromechanical oscillations and transmission capacity.

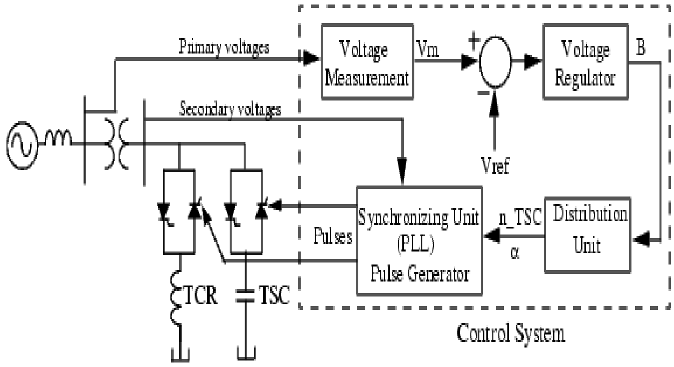

Fig.5. Basic configuration of SVC Control Scheme

The block consists of a Step down transformer, Voltage regulator, TCR and TSC units, a Phase Locked Loop (PLL). The functions of the above blocks are:

- Positive sequence voltage is measured using a Voltage Measurement system.
- The Voltage regulator uses the voltage error to calculate the susceptance (B) of SVC in order to maintain a constant system voltage.
- The distribution unit computes the firing angle (α) for TCRs.
- The synchronising unit uses a PLL to synchronise secondary voltage and the pulse generator sends the required pulses to the thyristors.

III. Fuzzy Logic Controller

The SVC Voltage regulator employs PI Controller, which is both economical and simpler. Hence, the PI controller is utilized in most of the current industrial applications. However, this controller fails when the controlled object is highly nonlinear and uncertain. Therefore, an idea is proposed to combine the PI controller along with a Fuzzy logic based controller, in order to keep the benefits of PI controller and thereby overcome its disadvantages too. The Fuzzy Logic is a rule based controller, where a set of rules represents a control decision mechanism to correct the effect of certain causes coming from power system. This approach utilizes qualitative knowledge of a system while designing the controller. The block diagram structure of Fuzzy controller is shown in Fig. 6. The inputs to the fuzzy system are voltage error and change of error, while its output is taken as the control signal and the synchronous firing pulses are provided to the thyristors by the pulse generators.

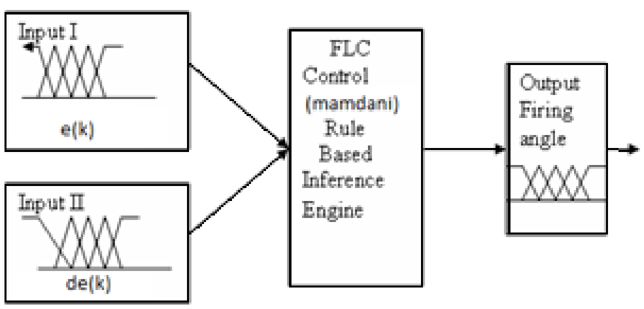

Fig.6. Structure of Fuzzy Logic Controller

The Fuzzy controller has three stages namely, Fuzzification, Rule-Base and Defuzzification.

A. Fuzzification

A fuzzy set is a collection of distinct elements with a varying degree of inclusion or relevance. If X is a set of elements, then a fuzzy set A in X is defined to be a set of ordered pairs, A={(x,μA(x))| x ε X}, where μA(x) is called the Membership function (MF). MF is a curve which defines how each point in the input space is mapped to a membership value between 0 and 1.

B. Rule-Base

In the fuzzy model, the relationship between the input and output features are represented by IF premise THEN consequent. The fuzzy rules can be generated and framed with the help of an expert operator's experience and knowledge.

Rule 1: *If voltage error, e(k) is low AND change of error de(k) is ok, then the output (Susceptance) is low.*
Rule 2: *If voltage error, e(k) is ok AND change of error de(k) is ok, then the output (Susceptance) is ok.*
Thus the two inputs and single output of Fuzzy Logic Controller will result in a total of 9 rules, which are listed in TABLE I.

TABLE I. RULE BASE OF FUZZY CONTROLLER

e[k]	$\dot{e}[k]\Delta u_f[k]$		
	Low	**Ok**	**High**
Low	Low	Low	Ok
Ok	Low	Ok	High
High	Ok	High	High

C. Defuzzification

Defuzzification is a process of converting the conclusions of a rule-based system into a final crisp quantity. There are various methods like Centroid method, Weighted Average method and Max-membership method available for this purpose. The Centre of Gravity (COG) law is employed here and the output expression is given by(3),

$$\frac{\sum_{i=1}^{5} bi \int \mu_i}{\sum_{i=1}^{5} \int \mu_i} \qquad (3)$$

Where bi denotes the center of the membership function and μi is the membership of member i of output fuzzy set.

IV. Simulation Results

The proposed controller is tested for various operating conditions in a multi-machine system, whose details are as follows. A system setup consisting of 2 machines with 3 buses are considered for the study. Plant 1 (M1) is a 1000 MW hydraulic generation plant connected to a load centre through a long 500 KV, 700 km transmission line. The Load centre is modeled as 5000 MW resistive load and supplied by the remote plant 2 (M2) of 1000 MVA capacity and a local generation of 5000 MVA. The test system is shown in the Fig.7.

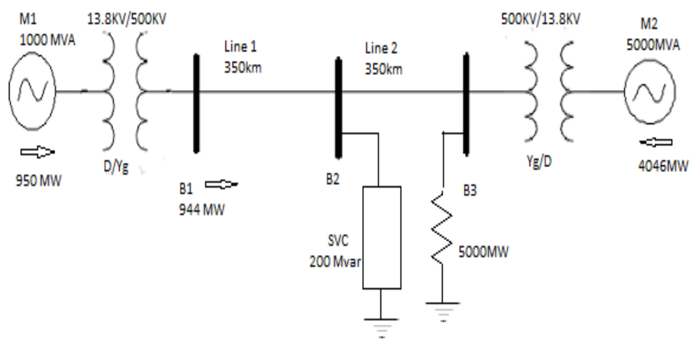

Fig.7. Single Line diagram of 2-Machine 3-Bus system

The MATLAB Simulink model of the test system is shown in Fig. 8 and Fig. 9. A three phase fault is made to occur at Bus 1 for 0.1 sec from t1=5 sec to t2=5.1 sec. The effectiveness of the SVC with the newly designed controller and that with conventional controller are observed and compared in Fig. 10 to Fig. 13. As soon as the fault occurs, the SVC will try to inject reactive power into the line when the voltage goes below the reference value, in order to regulate the voltage.

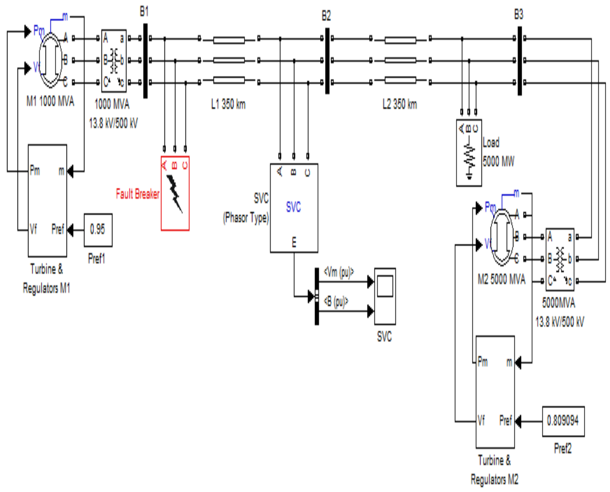

Fig.8. 2-Machine 3-Bus Test system modeled in Simulink/MATLAB

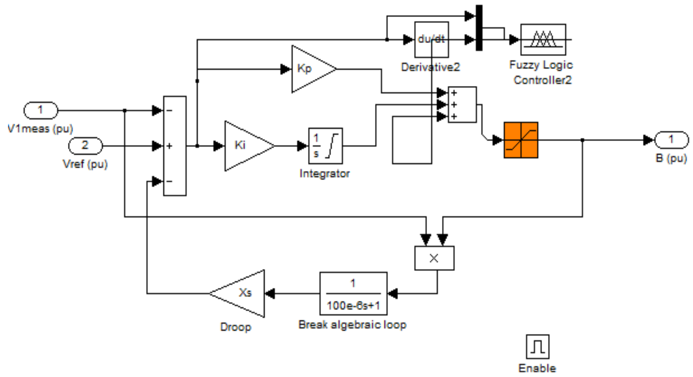

Fig.9. 2-Machine 3-Bus Test system modeled in Simulink/MATLAB

Fig.10 is the output of rotor angle difference, speeds of the two generators and voltages where the fault is created at t1=5sec and the system came into stability after 10sec from the fault.

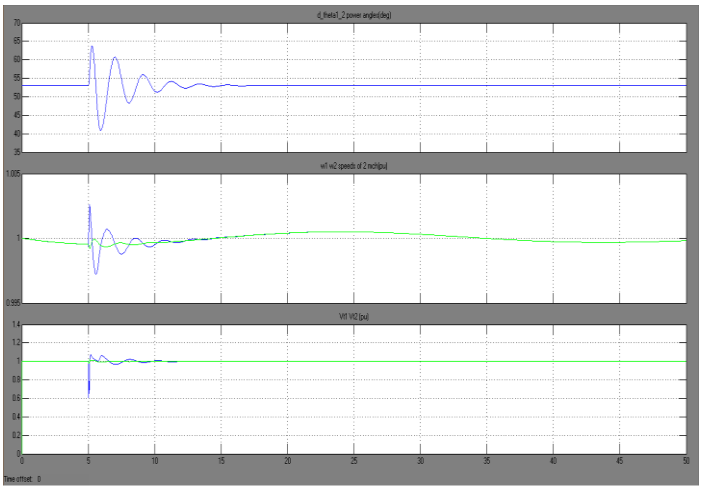

Fig.10 output with PI control

Fig.11 is the output of the system rotor angle difference, speeds of the two generators and voltages with fuzzy control of SVC. Same as conventional PI control in fuzzy control also fault is created at t1=5sec and the system remained unstable for almost 7sec after the fault, that is the system became stable after 7sec which is less time compared to conventional PI controller.

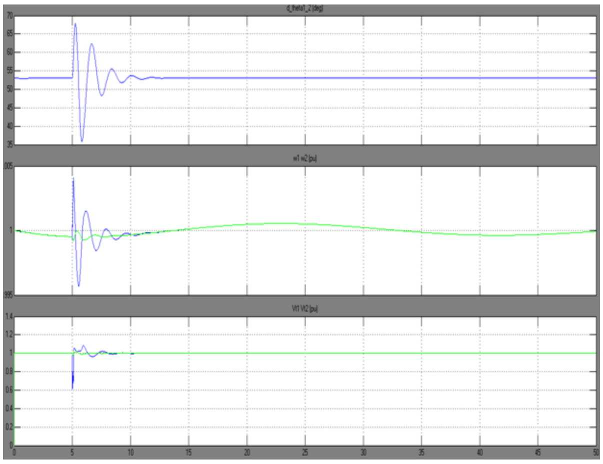

Fig.11 output with fuzzy control

Fig.12 shows the out with PI-Fuzzy logic hybrid control where the fault is created at t1=5sec and the system came into stability at 8sec i.e. 3sec after the transients started.

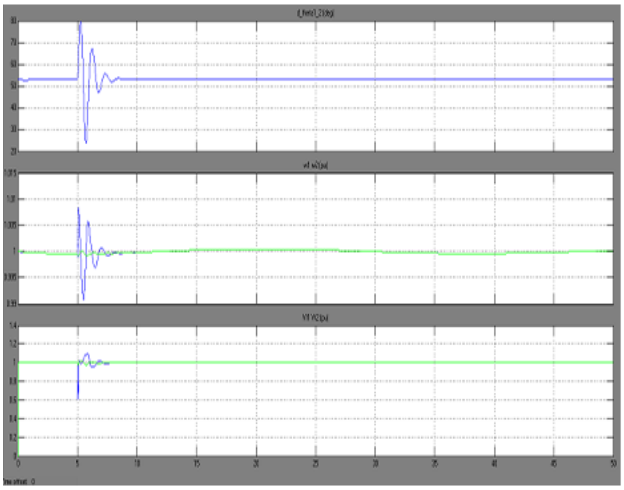

Fig.12 out with PI-Fuzzy logic hybrid control

Fig.13(a), fig.13(b), fig.13(c) represent transmission line active power of the system with PI control, Fuzzy logic control and PI-Fuzzy logic hybrid control respectively.

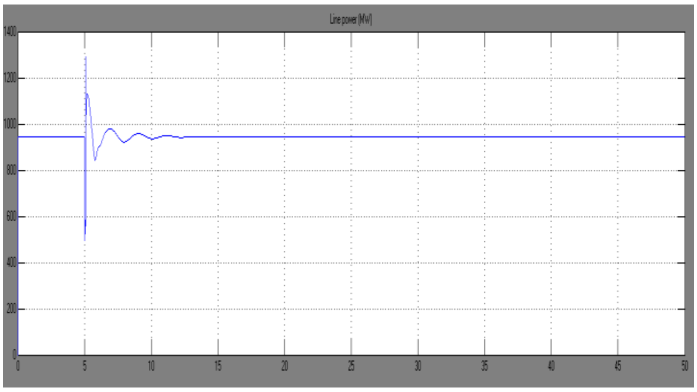

Fig.13(a) transmission line active power of the system when pi control is used for SVC

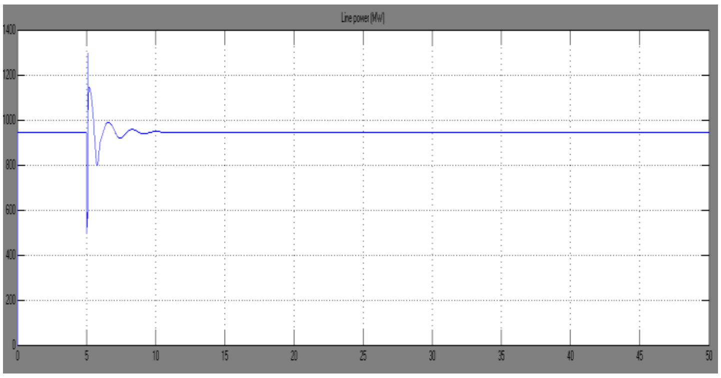

Fig.13 (b) transmission line active power of the system when Fuzzy logic control is used for SVC

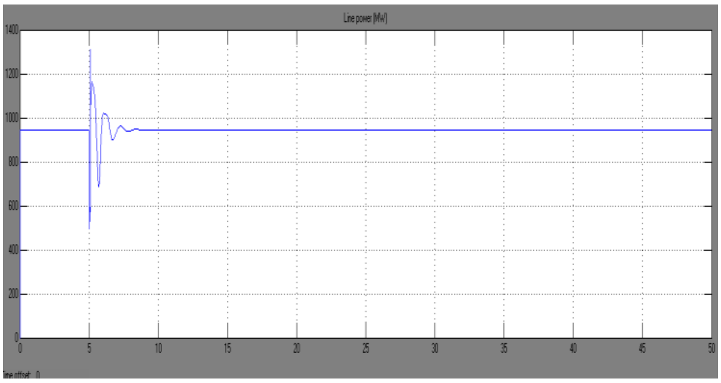

Fig.13(c) transmission line active power of the system when PI-Fuzzy logic hybrid control is used for SVC

The simulation results shown above clearly highlights the improved performance of the newly designed controller in terms of reduced angular oscillations, regulating the terminal voltage, synchronizing the speed compared to the PI controller and Fuzzy logic based used in conventional SVC.

V. Conclusion

A Fuzzy controller combined with a PI controller for SVC mechanism is discussed in this paper. The idea is to combine the advantages of both the controllers to derive a better performance out of SVC. Mamdani based Fuzzy logic is employed in the proposed model and the design is tested in a 2 machine 3 bus power system. The simulation is done using MATLAB software. The simulation studies are carried out on various parameters like rotor angle difference, machine speed, terminal voltage and transmission line active power. The controller performance of all types are also compared in above areas and it is observed that the hybrid controller which is a combination of PI and Fuzzy based SVC controller gives enhanced performance in terms of stability and reliability of the system during the disturbances.

References

[1]. G. Hingorani and L. Gyugyi, "Understanding FACTS, Concepts, and Technology of Flexible AC Transmission Systems", Piscataway, NJ:IEEE Press, 2000.

[2]. A.A Edris, R Aapa, M H Baker, L Bohman, K Clark, "Proposed terms and definitions for flexible ac transmission system (FACTS)", IEEE Trans. on Power Delivery, Vol. 12, No.4, 1997,pp.1848-1853

[3]. M. M. Farsangi, Y. H. Song, and K. Y. Lee, "Choice of FACTS device control inputs for damping interarea oscillations",IEEE Trans. On PowerSystems, vol. 19, no. 2, pp. 1135-1143, May 2004.

[4]. P. Kundur 1994, "Power system stability and control", McGraw Hill

[5]. M.H.Haque, "Application of energy function to assess the first swing stability of a power system with a SVC", IEE Proc. Gener. Transm. Distrib., Vol.152,No.6,Nov.2005, pp.806-812.

[6]. Ghadir Radman, Reshma S Raje, "Dynamic model for power systems with multiple FACTS controllers", Electric Power Systems Research , Vol. 78, 2008, pp.361-371.

[7]. B T Ooi, M Kazerrani, R Marcean, Z Wolanski, F D Galiana, D.Megillis, G. Joos, "Mid point sitting of FACTS devices in transmission lines", IEEE Tran. On Power Delivery, Vol.1 No.4, 1997, pp.1717-1722.

[8]. C. H. Cheng and Y. Y. Hsu, "Damping of generator oscillations using an adaptive static VAR compensator", IEEE Trans on Power Systems, vol. 7, no. 2, pp. 718-725, May 1992.

[9]. S. M. Barakati, S. Khanmohamadi, S. H. Hosseini, "Improving the Power Stability using Fuzzy Logic Controlled Static Var Compensator", The 4th Iranian Conference on Electrical Engineering, ICEE-97, 1996.

[10]. M. Moallem, M. Keshavarzi, "The use of Static var Compensator in order to damping of Low Frequency Oscillations', The 4th Iranian Conference on Electrical Engineering, ICEE-97, 1996.

[11]. Timothy J. Ross, "Fuzzy Logic with engineering application", McGraw- Hill, Inc. 1995 [5]

[12]. Qun Gu, Anupama Pandey and Shelli K Starrett, "Fuzzy logic control schemes for static VAR compensator to control system damping using global signal", Electric Power Systems Research , Vol.67, 2003,pp. 115- 122.
[13]. A.Kazemi and M.V.Sohrforouzani, "Power system damping using Fuzzy controlled FACTS Devices", International conference on Power system Technology, POWERCON 2004, Singapore.

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