Power System Stability Enhancement by Neuro Fuzzy Logic Based SVC for Multi Machine System

S. Sabna, D. Prasad, R. Shivakumar

Abstract- This paper presents a hybrid technique to small signal stability enhancement using ANFIS thruster susceptance control of static vary compensator (SVC). Their main objective is to determine the synchronous generator's ability to maintain stability after the occurrence of a fault or following a major change in the network such as the loss of an important generator or a large load. Static vary compensator is proven the fact that it improves the dynamic stability of power system apart from reactive power compensation; it has multiple role in the operation of power system. The main variable to be controlled in the power system for efficient operation is to mitigating the rotor electro-mechanical low frequency oscillations. Simulations are carried out for multi machine power system for without SVC and with ANFIS SVC. The proposed Neuro fuzzy logic based SVC for multi machine power system provides better damping to power system oscillation.

Keywords- Damping of oscillation, Neuro fuzzy controller (ANFIS), static vary compensator (SVC), thruster susceptance control.

I. INTRODUCTION

The electrical power network grows with enormous complexity. In such a complex network with the conventional control mechanisms, there is a lack of controllability of the active and reactive power flows in energized networks. In a complex interconnected ac transmission system, the power flow finds many paths on its way from the source to load. In such networks a load flow study must be performed to find the active and reactive power flows on all the times. Its impedance and voltages at the terminals determine the flow of active and reactive powers on the line. Even though we obtain the reliability of power supply, no control exists on line loading. By adding shunt and series elements, the line impedances may be altered. Since the parameters of the transmission lines of the complex network cannot be altered, the series and shunt connected FACTS devices help in altering the line parameters and the efficiency of the network is increased. Power system stability may be defined as that property of a power system that enable it to remain in a state of equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance.

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S Sabna, PG scholar in Department of Electrical and Electronics Engineering, Sona College of Technology, Salem-5, India. Contact no. 9495250347, (e-mail: sirajsabna@gmail.com).
D Prasad, Working as Assistant Professor in Department of Electrical and Electronics Engineering, Sona College of Technology, Salem-5, India. Contact no. 9894376109, (e-mail: mani.gd@gmail.com).
R Shivakumar, Working as Assistant Professor in Department of Electrical and Electronics Engineering, Sona College of Technology, Salem-5, India. Contact no.9894493375, (e-mail:mukil2005@gmail.com).

Power systems relay on synchronous machine for generation of electrical power, a necessary condition for satisfactory operation is that all synchronous machines remain in synchronism. The power system is a highly nonlinear system whose dynamic performance is influenced by a wide array of devices with different response rates and characteristics. Characteristics of every major elements of power system have an effect on system stability.

The system becomes stable if we can add damping to the oscillation. In order that power system stabilizer is used. The function of the power system stabilizer is to add damping to the generator rotor oscillation. This is achieved by modulating the generator speed deviation so as to develop a component of electrical torque in phase with rotor speed deviation. The ability of the power system to maintain synchronism under small disturbance is known as dynamic stability. This disturbance may due to small variation in loads and generation. Instability may result in two forms.(1): steady increase in rotor angle due to lack of sufficient synchronizing torque.(2): rotor oscillation of increasing amplitude due to lack of sufficient damping torque.

Modern power system is equipped with fast acting static excitation system but they introduce negative damping at the electromechanical oscillation frequencies of the machine. Thus they make the system unstable under local and inter area mode of oscillation. For the machine to remain in synchronism under small disturbance, it is essential to have positive damping for the machine. Power system stabilizer will introduce positive damping to the system. Designing a controller for the non-linear systems, to achieve the a daptiveness is an emerging field of interest in the research area. Several control methods have been proposed. Initially, owing to their simplicity, conventional control techniques like PI and PID control laws were proposed. The lack of intelligence, learning, and adaptation capability in the control methods discussed in general control scheme, reveal the need of continuous expert intervention for the control of non-linear systems. Takagi-Sugeno fuzzy model with parameter uncertainties to approximate the non linear systems was suggested in this paper.

II. MODELING OF STABILIZERS

A. svc model

Two basic models are recommended for stability programs. These models are based on cigre models. Both models are suitable for continuously controlled SVCs. The basic difference between the two models is in the method of realizing the slope.

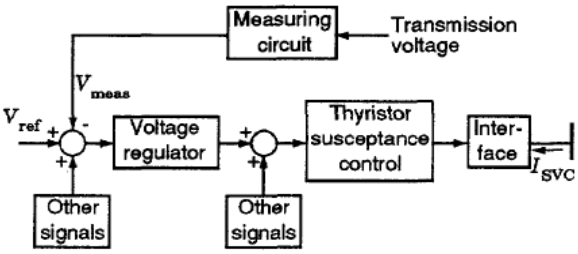

Fig (1): Basic model 1

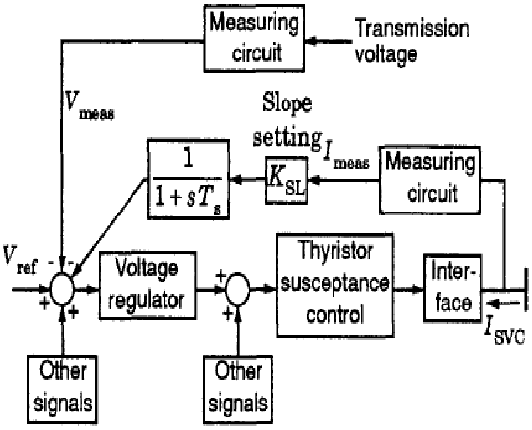

Fig (2): Basic model 2

Basically SVC models consist of four modules Measurement modules, Voltage regulator module, thyistor susceptance control module and network interface module.

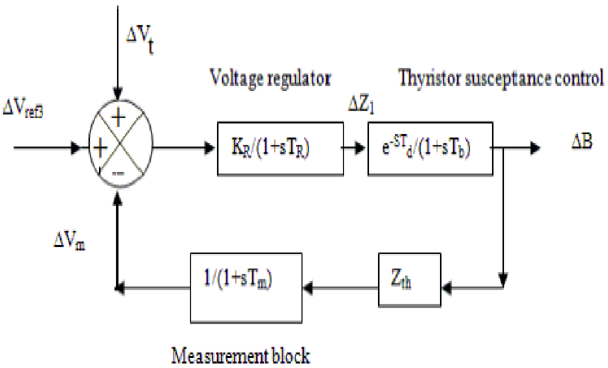

Fig (3): Static var compensator model

The voltage regulator block this estimates the susceptance value from the measurement block. The measurement block measures the current through SVC controller. The thyristor susceptance produces the incremental change in the susceptance value when a firing angle delay is given to it. The Zth is thevinins impedance of SVC controller generally a constant.

III. NEURO FUZZY LOGIC

A. fuzzy neural model

Two possible models of fuzzy neural system are shown below. In first model the fuzzy interface block provides an input vector to multi layered neural network which is shown below.

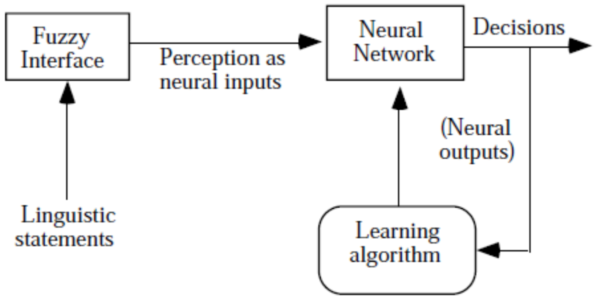

Fig (4): fuzzy neural system model 1

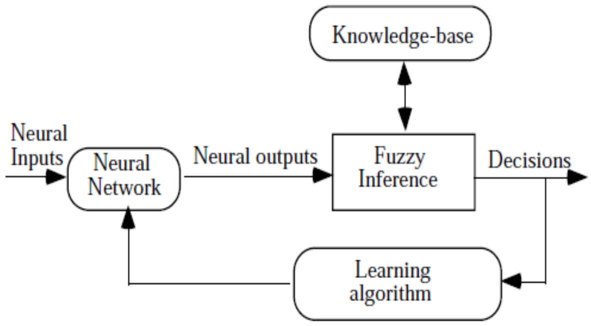

Fig (5): fuzzy neural system model 2

In the second model the multi layered neural network drives the fuzzy inference mechanism which is shown in fig 5.

B. anfis

Adaptive neuro fuzzy inference system (ANFIS) is a class of adaptive network that are functionally equivalent to fuzzy inference system. The ANFIS based SVC is designed with two input “speed (w)”, and “change in speed (Δw)”, and one “control output (Δu)”. These two inputs are given to the fuzzy logic controller and it is fuzzified by Gaussian membership function for seven linguistic variables viz., negative big(NB), negative medium(NM), negative small(NS), zero(ZE), positive small(PS), positive medium(PM), positive big(PB). The input output membership function is shown below.

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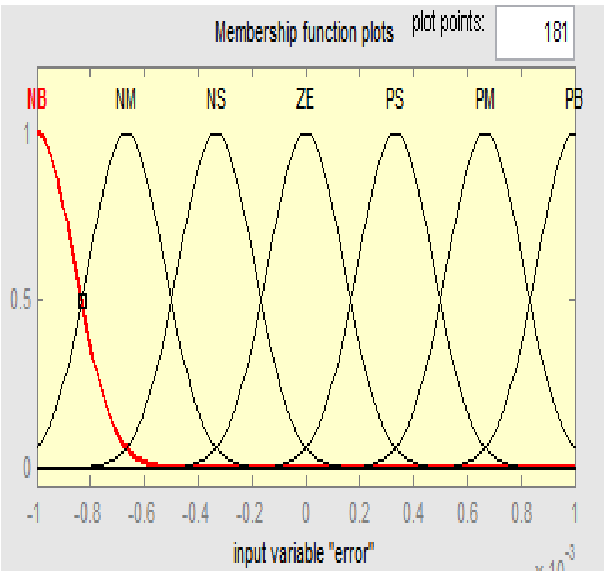

Fig (6): membership function for input 1

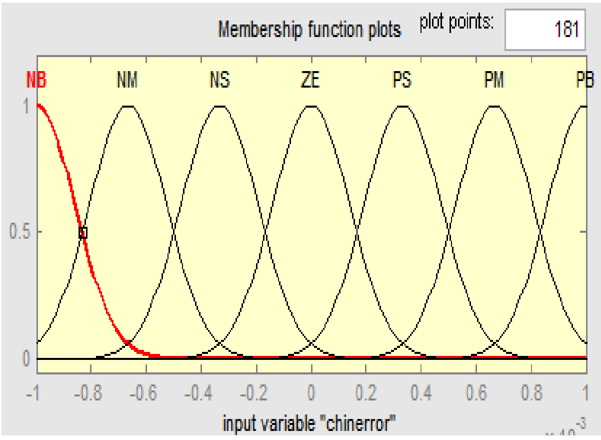

Fig (7): membership function for input 2

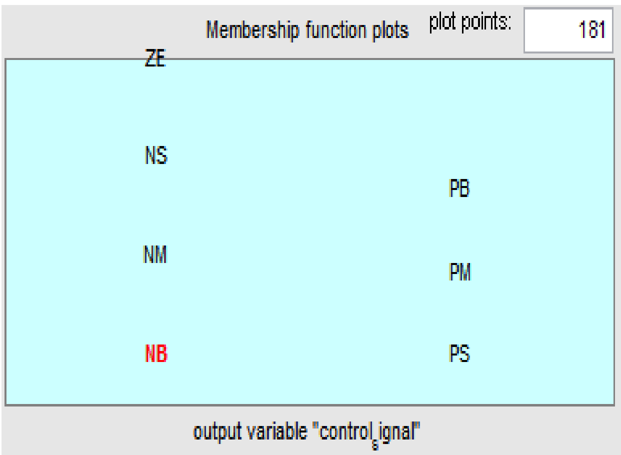

Fig (8): membership function for output

The linguistic variables are specified by Gaussian membership function as a result 49 rules are devised. The rule base contains the fuzzy IF-THEN rules of sugeno's first order type.

Table (1): fuzzy rules

ω / $\Delta\omega$	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NM	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

IV. ANFIS ARCHITECTURE

The architecture of the ANFIS sensing the two inputs is shown in below fig.

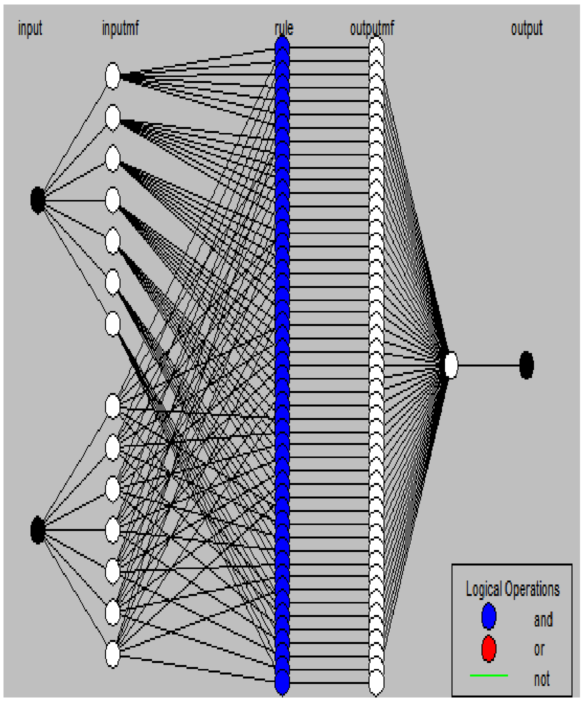

Fig (9): architecture of ANFIS

The node functions in each layer are as described below.
LAYER 1- Each node in this layer is a adaptive node performing Gaussian membership function

$$O_{1,i} = \mu_{A,i}(x_i) = \exp\left[-\frac{(x_i - c_{ij})^2}{\sigma_j^2}\right]$$

where i=1, 2…7, j=1, 2…7

X_i, is the input to this layer and c_{ij}, is the center of the membership function

LAYER 2- every node in this layer represents the firing strength of the rule. The nodes on this layer performs fuzzy AND operation.

$$O_{2,i} = w_i = \mu_{A,i}(x_i) \wedge \mu_{B,i}(y_i)$$

i=1…7.

LAYER 3- the node of this layer calculates the normalized firing strength of each rule.

$$O_{3,i} = \bar{w}_i = \frac{w_i}{\Sigma w_i} \qquad i=1\ldots49.$$

w_i –firing strength of a rule.

LAYER 4-the node in this layer output the weighted consequent part of the rule table.

$$O_{4,i} = \bar{w}_i f_i = \bar{w}_i (p_i x + q_i y + r_i)$$

i=1,…49

where $\{p_i, q_i, r_i\}$ is the parameter set of this node.

LAYER 5-the single node in this layer computes the overall output as the summation of all the incoming signals.

$$O_{5,i} = \sum w_i f_i \Big/ \sum w_i$$

i=1…49.

where $O_{5,i}$ denote the output of the i[th] node in layer 5.

V. SIMULATION AND RESULTS

The performance of the designed ANFIS SVC was investigated on power system model of the three machines nine bus systems with third generator considered as the infinite bus. Simulations are carried out for two different case studies such as without SVC and with ANFIS SVC. From the obtained graph it can be seen that ANFIS SVC provides better damping to oscillation than without SVC. The various responses their case studies are shown below.

For machine 1

Simulation results for the initial condition such as

real power = 0.3pu,

Reactive power = 0.9pu

Power disturbance =0.0004,

Disturbance clearing time=25sec,

Simulation time = 25sec are shown below.

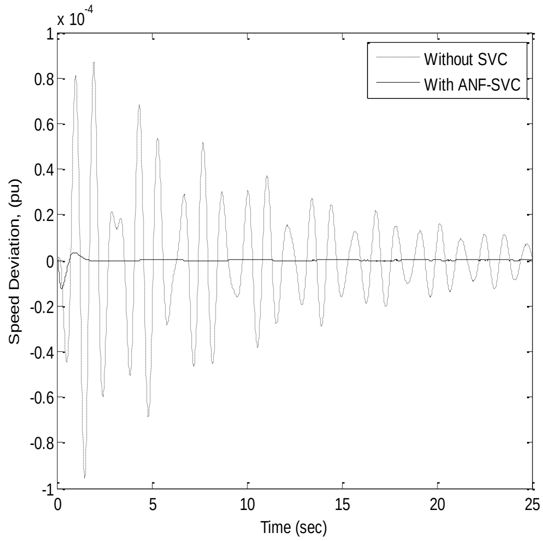

Fig (10): Speed deviation vs. time

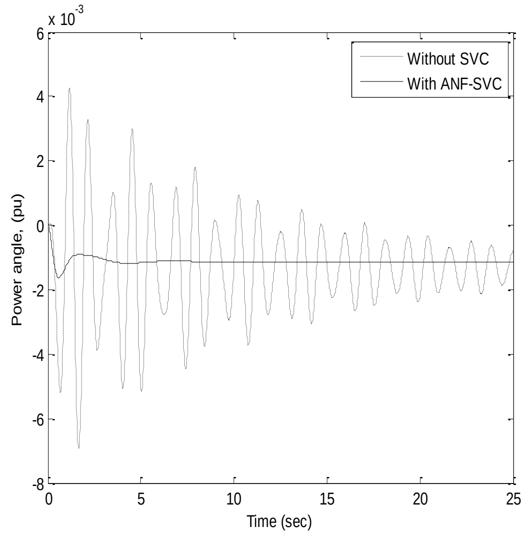

Fig (11): power angle vs. time

Case studies	$\Delta\delta$		Δw	
	tss(s)	Mp(pu)	tss(s)	Mp(pu)
without SVC	25	.0049	26	.00008
with ANFIS SVC	9	-.0001	4.8	.0000037

Table (2): results of machine1

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For machine 2
Simulation results for the initial condition such as real power = 0.3pu,
Reactive power = 0.9pu
Power disturbance =0.0004,
Disturbance clearing time=25sec,
Simulation time = 25sec are shown below.

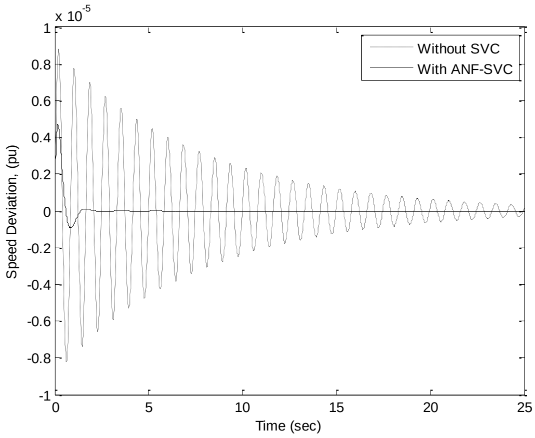

Fig (12): Speed deviation vs. time

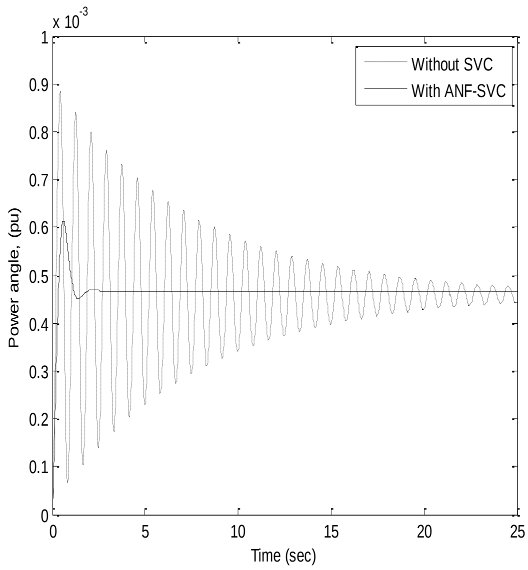

Fig (13): power angle vs. time

Case studies	Δδ		Δw	
	tss(s)	Mp(pu)	tss(s)	Mp(pu)
without SVC	27	.0089	28	.000089
with ANFIS SVC	2.8	.0006	3	.000004

Table (3): results of machine1

VI. CONCLUSIONS

In this paper a novel approach has been adopted to enhance the small signal stability enhancement using neuro fuzzy logic based SVC. Design of an adaptive neuro-fuzzy controller employing a first-order Sugeno-type fuzzy inference system is described in this paper. The centers of the membership functions and consequence parameters of the neuro-fuzzy controller are adjusted on-line using back-propagation algorithm. The adaptive controller is applied to an SVC. The simulation are carried out for two different case studies such as with ANFIS SVC and without SVC on multi machine power system and the simulation results shown that ANFIS based SVC provide better damping to oscillation with a reduced settling time, it settles the oscillation smoothly and quickly and thereby enhancing the stability of the system. Results of simulation studies show an improvement in the overall system damping characteristics with the proposed controller The simulation results demonstrate the effectiveness and robustness of the controller.

REFERENCES

1. M.CibaTherase M.MarsalineBeno, N.AlbertSingh, ,M.Mohamed Syed Ibrahim, "Design of pss for damping of low frequency oscillations using bacteria foraging tuned non linear neuro fuzzy controller", IEEE GCC Conference 2011.
2. D. Harikrishna and N.V. Srikanth, "Unified Philips-Heffron Model of Multi-Machine Power System equipped with PID damping controlled SVC for Power Oscillation Damping", INDICON 2009, IEEE India Council Conference, pp 481 – 484, Dec – 2009.
3. IEEE special stability controls working group, "Static VAR compensator models for power flow and Dynamic performance simulation", IEEE Transaction on power systems, Vol. 19, No. 1,pp. 229 – 239, February – 1994.
4. E.Z. Zhou, 'Application of static VAR compensators to increase power system damping', IEEE Trans. on Power Systems, Vol.8, No.2, PP May 1993.
5. Yousin. Tang & A.P Sakis Meliopoylos, 'Power Systems small signal stability analysis with FACTS elements', IEEE, on Power delivery, vol.12, no. 3, July-1997.
6. Kitty Phorang & Prof.Dr.Yoshibumi Mizutani, 'Damping improvement of oscillation in power system by fuzzy logic based SVC stabilizer', IEEE–2002.
7. Farsangi, M.M. Song, Y.H. Lee, K.Y. Kerman Univ., Iran,"Choice of FACTS device control inputs for damping inter-area oscillations", IEEE Transactions on Power Systems, pp. 1135-1143, Vol. 19, May – 2004.
8. Prabha kundur 'power system stability and control" Tata McGraw hill education private limited.
9. Robert fuller, "Neuro fuzzy methods for modeling and fault diagnosis", Eotvos lorand university 2001.

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