The Journal of CPRI,
Vol. 12, No. 2, June 2016 pp. 179-186

Improving voltage and power factor using ANFIS in SVC for distribution system

Ramesh Babu U*, Vijay Kumar Reddy V ** and Tara Kalyani S***

Most of the electrical distribution systems are incurring huge losses due to the loads are wide spread, reactive power compensation facilities are inadequate and the reactive power compensation facilities do not have a proper control. A typical Static VAR Compensator (SVC) consists of capacitor bank in binary sequential steps operated in conjunction with a thyristor controlled reactor of the smallest step size. This SVC facilitates smooth control of reactive power closely matched with load requirements so as to maintain a power factor closer to unity. These types of SVCs require an appropriately controlled TCR. This paper deals with a reactor suitable for distribution system of 3-phase, 50Hz, and 415V with load P=25 KW, Q=21.23 KVAR system provided with FC-TCR Simulation which Compares results using Fuzzy Logic Controller (FLC) and Adaptive Neuro-Fuzzy Inference System (ANFIS) Controller. The effectiveness of the different controllers for improving the voltage stability limit, power factor and power transfer capacity of distribution system.

Keywords: *Distribution system, SVC, Fuzzy Logic Controller (FLC), Adaptive Neuro-Fuzzy Inference System (ANFIS), voltage and power factor improvement.*

1.0 INTRODUCTION

The distribution systems are heavily loaded and the system voltage profile is normal at its lower limits. Further increase in the system load leads to voltage collapse of the whole system. Hence the power utility undertakes a progressive and systematic load shedding to maintain the system and prevent it from shutting down. The voltage collapse or the instability is mainly caused by inadequate rapid reactive power support at the critical feeder. In general, capacitors can be applied at almost any voltage level. Individual capacitor units can be added in parallel to achieve the desired kilovar capacity and can be added in series to achieve kilovolt voltage. They are employed at or near rated voltage for economic reasons [1]. The cumulative data gathered for the entire utility industry indicate that approximately 60% of the capacitors are applied to the feeders, 30% to the substation buses, and remaining 10% to the transmission system [2].The application of capacitors to the secondary systems is very rare due to small economic advantages. Zimmerman [3] has developed a nomograph to determine the economic justification, if any, of the secondary capacitors considering in the system only the savings in distribution transformer cost. Flexible AC Transmission Systems, called FACTS, in the recent years is a well known term for higher controllability in power systems by means of power electronic devices. Several FACTS - devices have been introduced for various applications worldwide. A number of new types of devices are in the stage of being introduced in practice. [4].The application of SVC was initialized for the compensation of fast changing loads such as steel mills and arc furnaces. Here

*Assistant Professor, Department of EEE, NBKRIST, SPSR Nellore, Andra Pradesh - 524413, India.
E-mail : uramesh25@gmail.com, Mobile : +91 9949360473
**Director, Department of EEE, NBKRIST, SPSR Nellore, Andra Pradesh - 524413, India.
***Professor, Department of EEE, JNTUH, Hyderabad, T. S. -500085, India.

the objective is to provide dynamic power factor improvement and also balance the currents on the source side when required. The application for power system compensators was commenced in the late seventies. SVC has no inertia compared to synchronous condensers and can have an extremely fast response (2-3 cycles).This enables the control of reactive power in the control range [5]. In recent years, new Artificial Intelligence-based approaches have been proposed to design a FACTS-based supplementary damping controller. These approaches include particle swarm optimization [6, 7], genetic algorithm [8], and differential evolution [9]. Since 1989, Artificial Neural Networks (ANN) methodology has captured the interest of a large number of applications in electrical power engineering. An Adaptive Neuro-Fuzzy Inference System (ANFIS) combines the fuzzy qualitative approach with the adaptive capabilities of neural networks to achieve an improved performance Compared to a standard fuzzy logic controller, a control system based on this concept can be trained [10-12].

2.0 STATIC VAR COMPENSATOR (SVC)

The SVC provides an excellent source of rapidly controllable reactive shunt compensation for dynamic voltage control through its utilization of high-speed thyristor switching/controlled reactive devices. Figure 1 shows single line diagram of SVC

SVC works on the concept of controlling the shunt susceptance (B). This can be achieved by changing the firing angle of the thyristor, Figure 2 illustrates an SVC, including operational concept along with the physical connection. The control objective of the SVC is to maintain a desired voltage at the voltage bus. In the steady-state, the SVC will provide some steady-state control of the voltage to maintain the voltage bus at a pre-defined level. If there is a sudden increase in the load, the voltage bus begins to fall below its set point, in such a condition the SVC will inject reactive power (Q_{net}) into system, thereby increasing the bus voltage back to its net desired voltage level. If load falls suddenly, then bus voltage increases, the SVC (thyristor controlled reactor) will absorb reactive power, resulting in achieving the desired bus voltage. $+Q_{cap}$ is a fixed capacitance value, Therefore the net magnitude of reactive power injected into the system, from Figure 3 Qnet, is controlled by the magnitude of $-Q_{ind}$ reactive power absorbed by the TCR

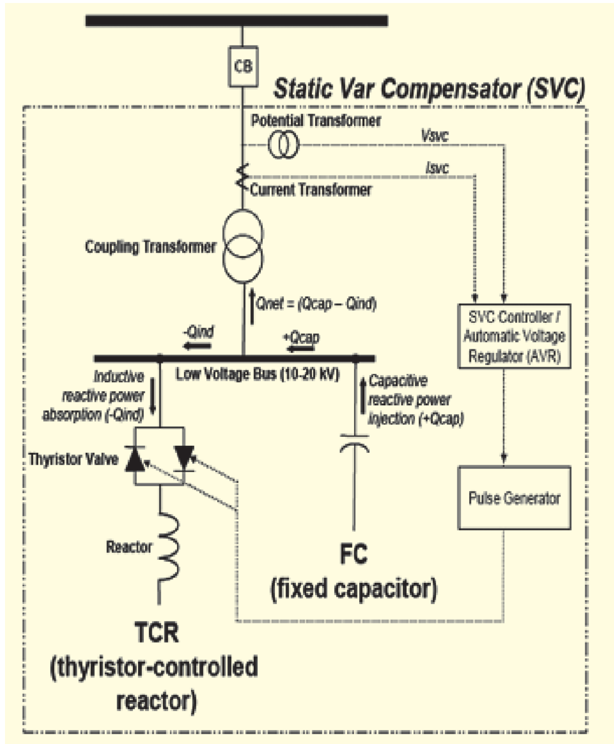

FIG. 1 STATIC VAR COMPENSATORE(FC-TCR)

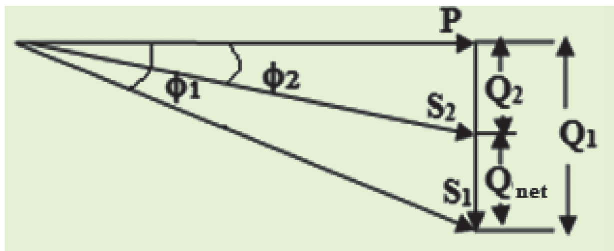

FIG. 2 POWER TRIANGLE OF SVC

$$Q_1 = P \tan\Phi_1 \quad ....(1)$$

$$Q_2 = P \tan\Phi_2 \quad ....(2)$$

$$Q_{net} = Q_1 - Q_2 \quad ....(3)$$

$$I_{net} = \frac{Q_{net}}{\sqrt{3} \times V_{L-L}} \quad ....(4)$$

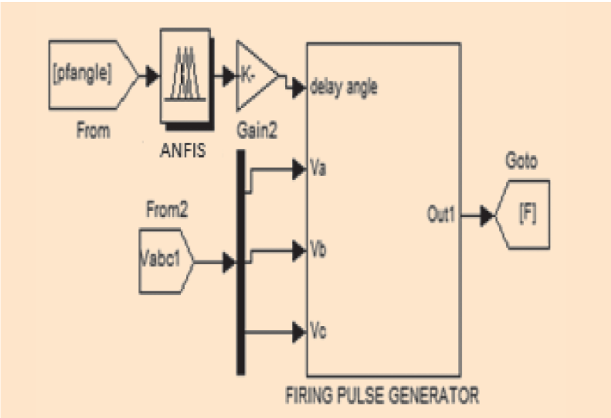

FIG. 3 CONTROL SYSTEM

3.0 METHODOLOGY

3.1 Fuzzy Logic Controller (FLC)

Mamdani based fuzzy logic interfacing rule is adopted for correction of power factor. Complex power is taken from power measuring block, in which power factor angle is taken as input of fuzzy controller. According to power factor angle, control output (firing angle) is provided by fuzzy controller. Input (the power factor angle) has 8 membership functions i.e very very small , very small, small, medium, large, very large, huge, very huge and the output (the firing angle) has 8 membership functions. And rules are

1. If power factor angle is very very small, then firing angle is very very small
2. If power factor angle is very small, then firing angle is very small
3. If power factor angle is small, then firing angle is small
4. If power factor angle is medium, then firing angle is medium
5. If power factor angle is large, then firing angle is large
6. If power factor angle is very large, then firing angle is very large
7. If power factor angle is huge, then firing angle is huge
8. If power factor angle is very huge, then firing angle is very huge

When power factor angle is very very large, firing angle is very very large. Controlled output is supplied to variable delay circuit and the thyristor. According to the output of variable time delay circuit, firing angle of thyristor is changed. Figure 4, 5 shows the input output membership functions of fuzzy logic controller

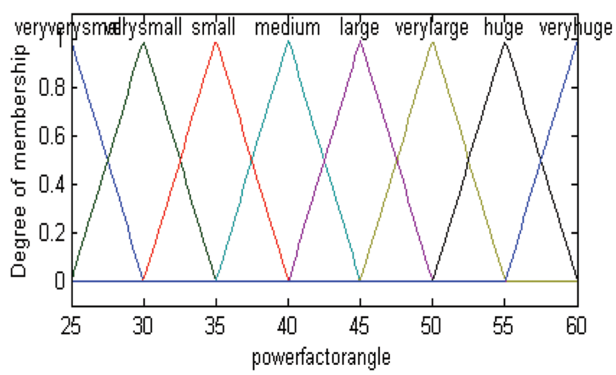

FIG. 4 INPUT MEMBERSHIP FUNCTION OF FLC

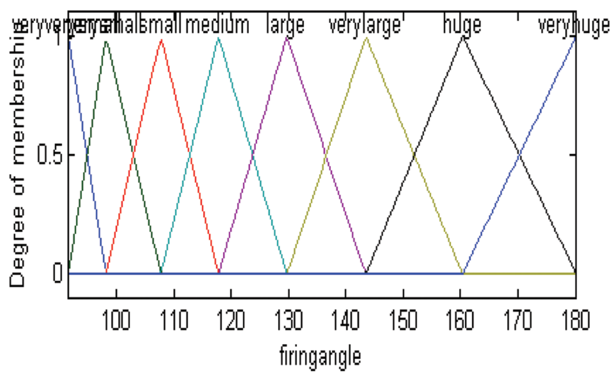

FIG. 5 OUTPUT MEMBERSHIP FUNCTION OF FLC

Adaptive Neuro-Fuzzy Inference System (ANFIS) represent fuzzy dynamic models or fuzzy systems. This brings a two fold advantage. First, any model-based technique (including a nonlinear one) can be applied to the fuzzy dynamic models with tuning. Second, the controller itself can be considered as a fuzzy system. Since the fuzzy model of the nonlinear process is usually based on a set of local linear models which are smoothly merged by the fuzzy model structure, a natural and straight forward approach is to design one local controller for each local model of the process consisting of one input and one output, Figure 6 shows the input Membership function before training and Figure 7 shows input after

ANFIS training, Figure 8 shows ANFIS input output diagram.

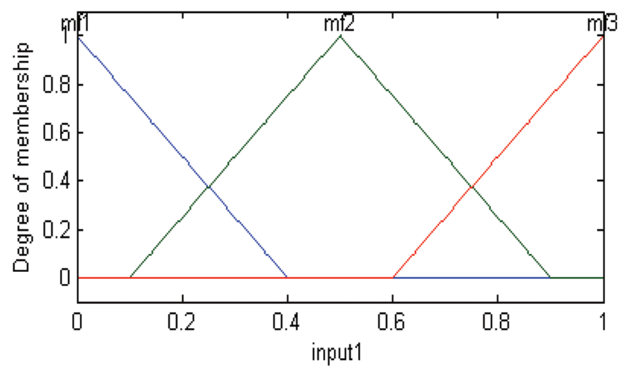

FIG. 6 INPUT MEMBERSHIP FUNCTION BEFORE TRAINING

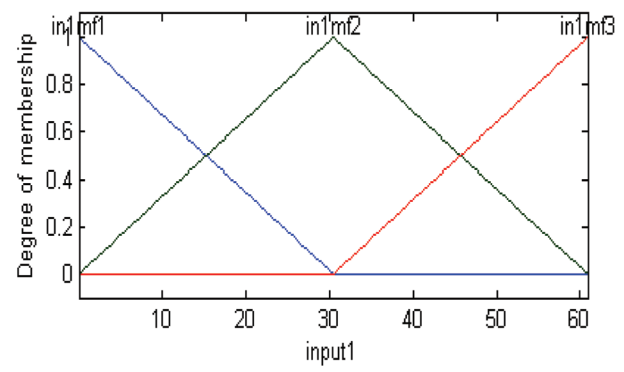

FIG. 7 INPUT MEMBERSHIP FUNCTION AFTER TRAINING

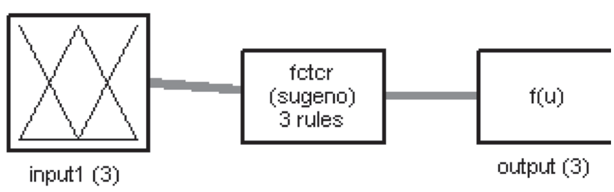

FIG. 8 ANFIS INPUT-OUTPUT DIAGRAM

4.0 RESULTS AND DISCUSSIONS

Test case is taken as a Source with 415 V, 50 Hz connected 3 Phase series RLC load with star grounded P = 25 KW Q=21.23 through a series RLC branch. Step time is taken as 0.1 sec to add load, total run time is for 0.5 sec. First it is tested without SVC after it is tested SVC with Fuzzy Logic Controller and SVC with ANFIS controller. Table 1 shows Parameters of Respective Controllers. Figure 9 shows the test system without SVC Figure 10-13 shows the Load Voltage, Current, Power Factor, Active and Reactive power. Figure 14-21 for SVC with FLC and Figure 22-29 for SVC with ANFIS

TABLE 1

TEST CASE PERAMETERS

Perameter	No load	With load		
		No SVC	FLC-SVC	ANFIS-SVC
V (P.U)	1.0	0.80	0.90	0.96
P.F	1.0	0.76	0.96	0.99
P KW	--	25.0	31.48	32.47
Q KVAR	--	21.23	09.18	04.62

4.1 Test system without SVC

After adding load at 0.1 sec voltage fall to 0.8 p.u and Power actor to 0.76 as shown on figures

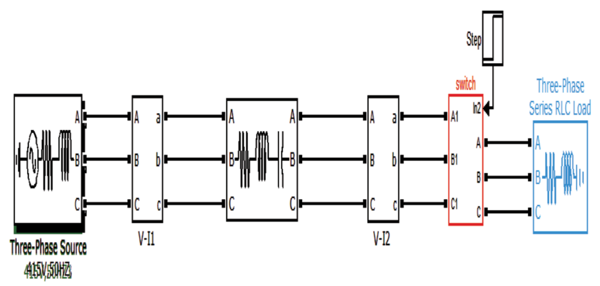

FIG. 9 TEST SYSTEM WITHOUT CONTROLLER

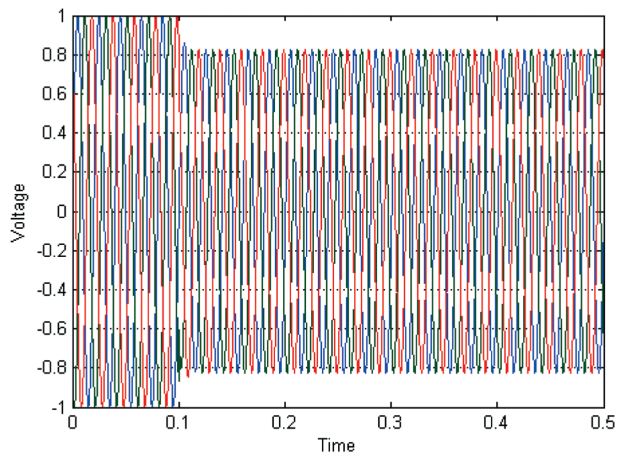

FIG. 10 LOAD VOLTAGE

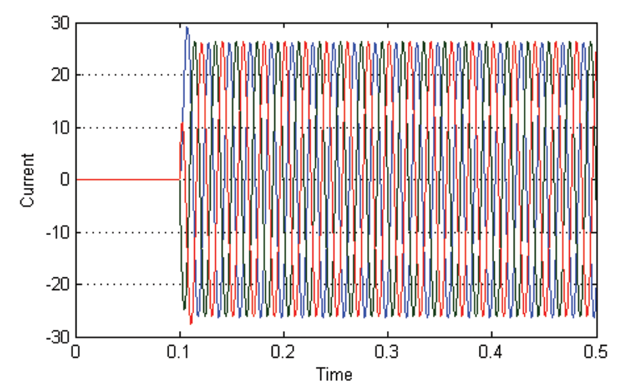

FIG. 11 LOAD CURRENT

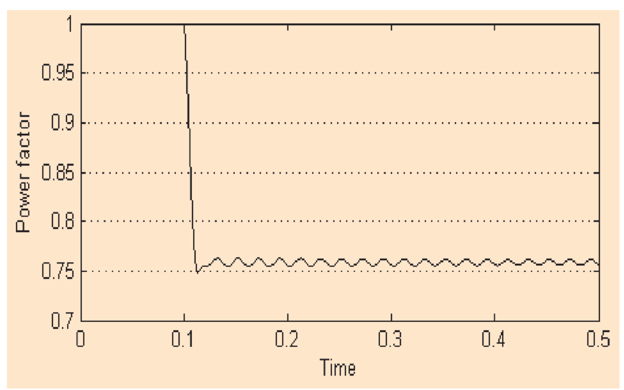

FIG. 12 POWER FACTOR

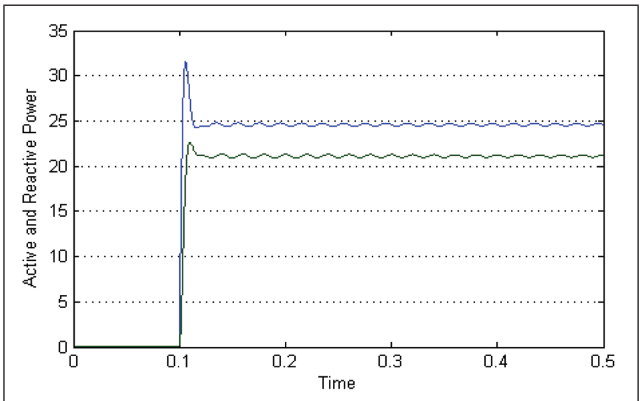

FIG. 13 ACTIVE AND REACTIVE POWER

4.2 Fuzzy Logic Controller

By adding SVC with fuzzy improved voltage sag to 0.9 p.u and power actor to 0.96 and reactive power reduced to 9.183 as shown in following Figures.

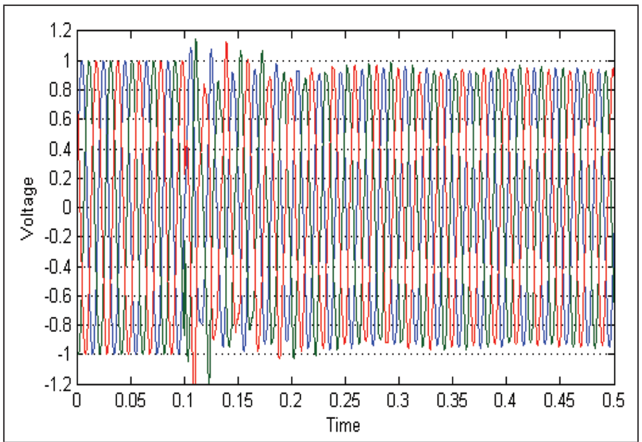

FIG. 14 LOAD VOLTAGE

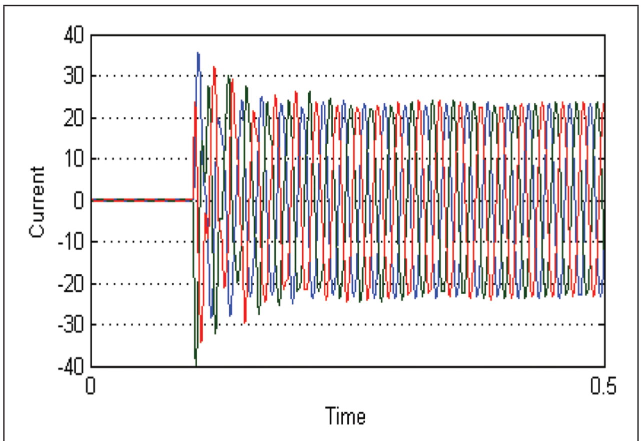

FIG. 15 LOAD CURRENT

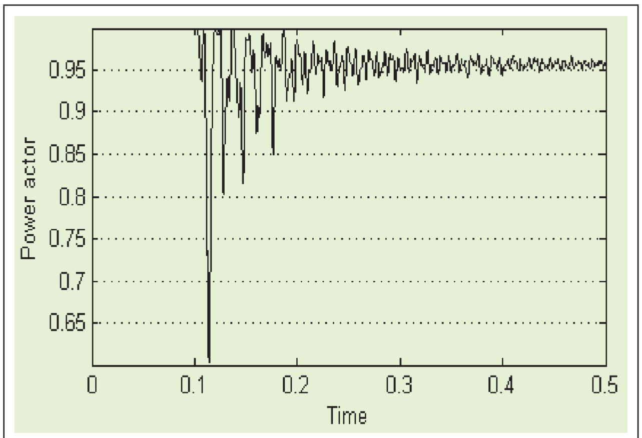

FIG. 16 POWER FACTOR

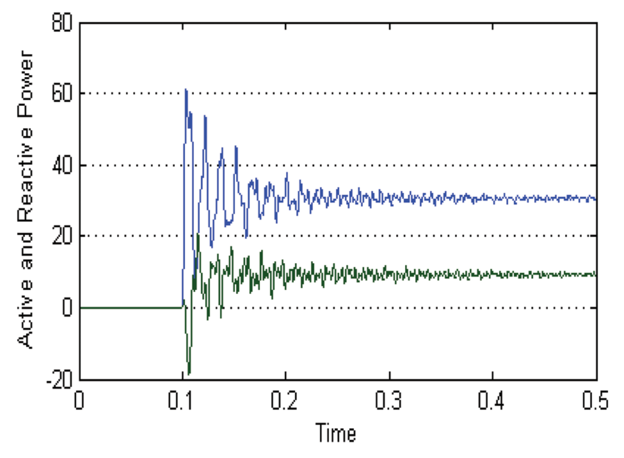

FIG. 17 ACTIVE AND REACTIVE POWER

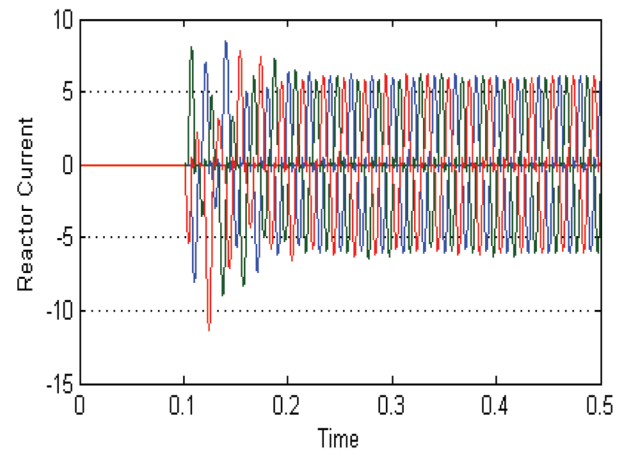

FIG. 18 REACTOR CURRENT

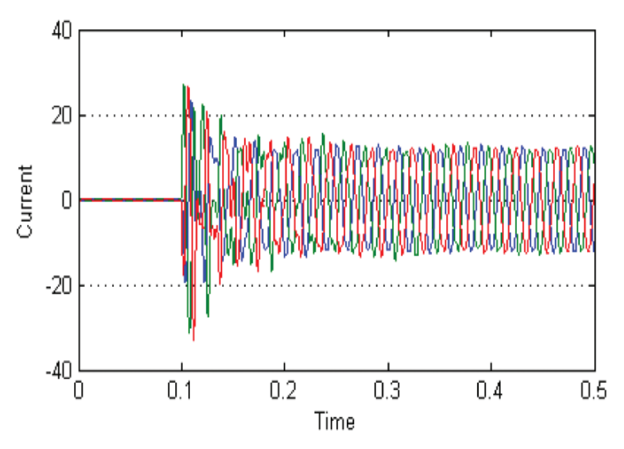

FIG. 19 CAPACITOR CURRENT

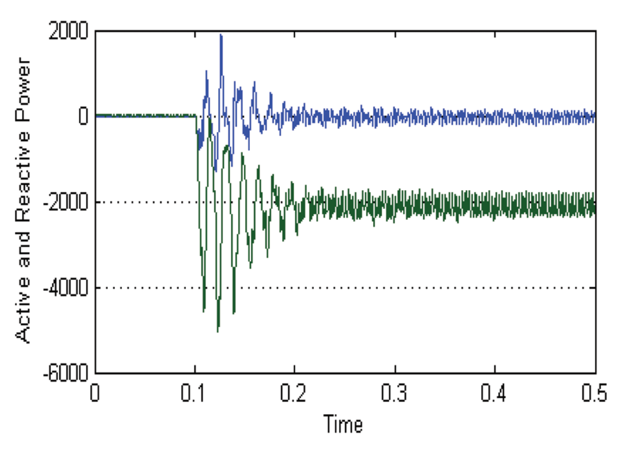

FIG. 20 REACTOR POWER

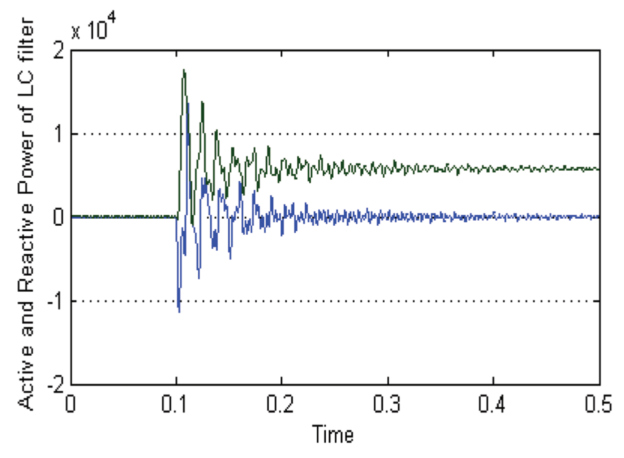

FIG. 21 CAPACITIVE POWER

4.3 ANFIS

By providing SVC with ANFIS improved voltage to 0.96 p.u and power factor to 0.99 and reactive power reduced to 4.626 kvar and damping of oscillations also reduced in voltage

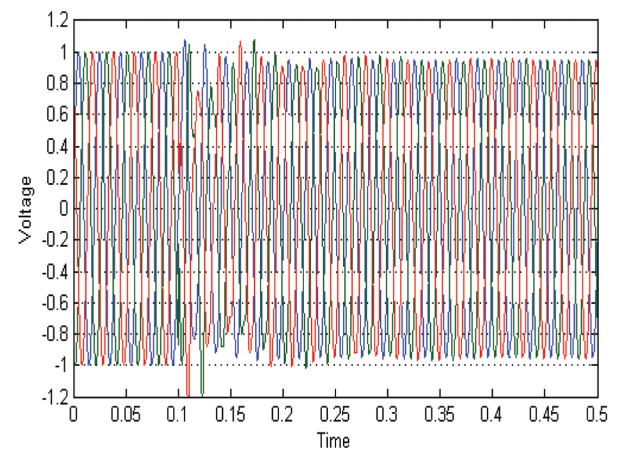

FIG. 22 LOAD VOLTAGE

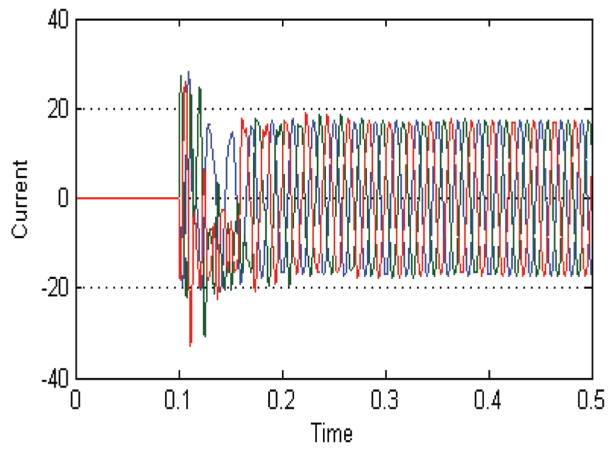

FIG. 23 LOAD CURRENT

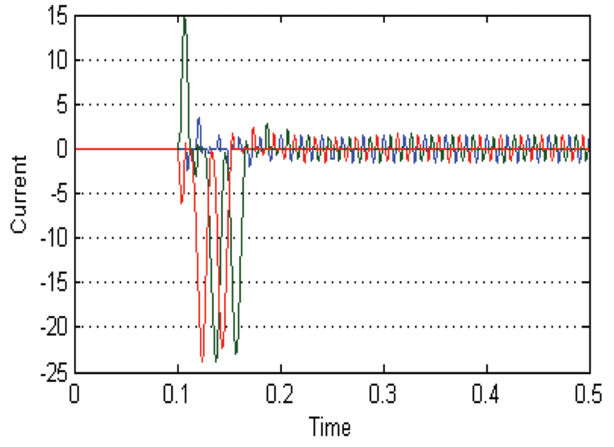

FIG. 26 REACTOR CURRENT

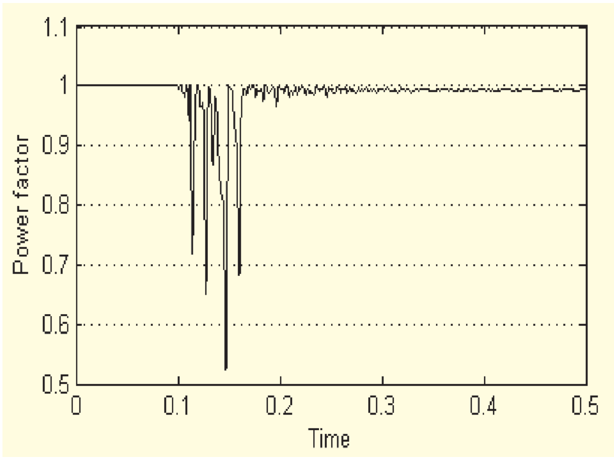

FIG. 24 POWER FACTOR

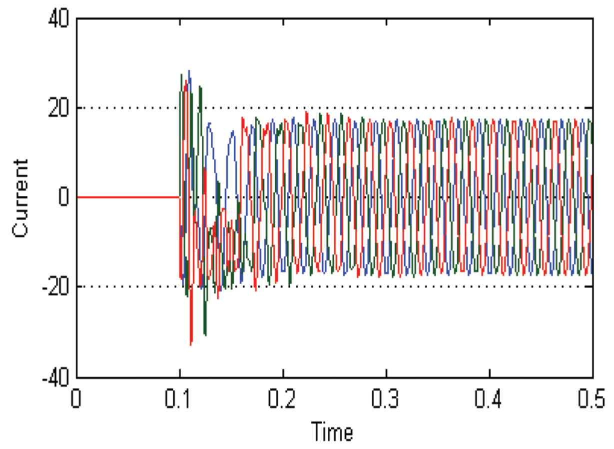

FIG. 27 CAPACITOR CURRENT

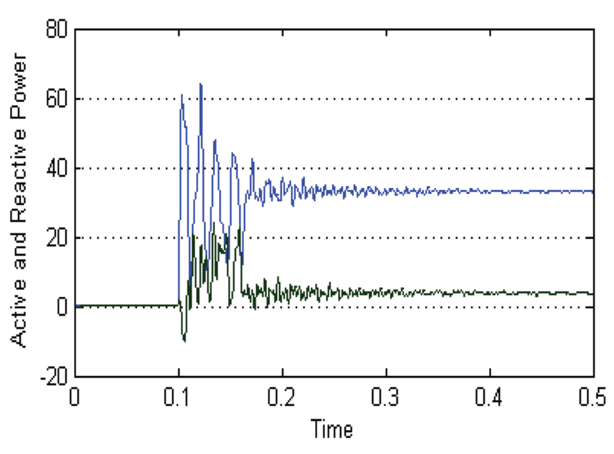

FIG. 25 ACTIVE AND REACTIVE POWER

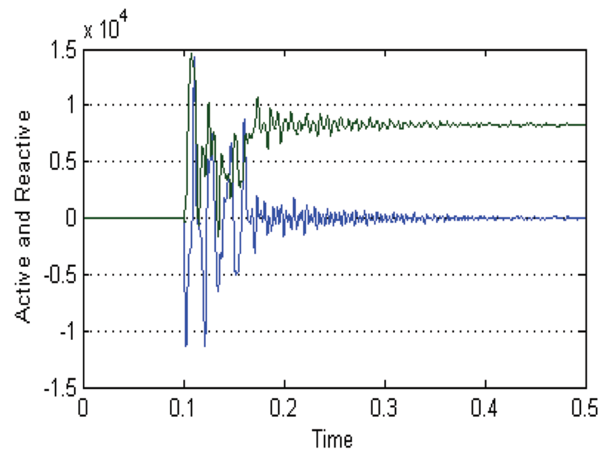

FIG. 28 REACTOR POWER

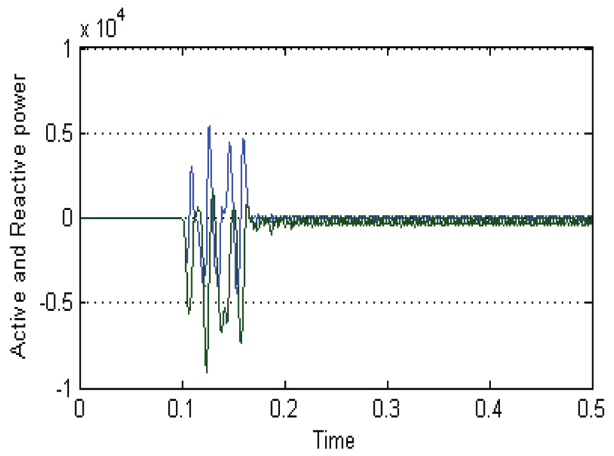

FIG. 29 CAPACITOR POWER

5.0 CONCLUSIONS

SVC facilitates smooth control of reactive power closely matched with load requirements so as to maintain a power factor closer to unity with ANFIS when compare to Fuzzy Controller

REFERENCES

[1] Turan Gonen: Electric Power Distribution System Engineering CRC Press Taylor & Francis Group Second Edition

[2] R H Hopkinson Economic Power Factor-Key to kvar Supply, Electr. Forum, Vol. 6, No. 3, pp. 20-22,1980.

[3] R A Zimmerman, Economics Merits of Secondary Capacitors, AIEE Trans., Vol. 72, pp. 694-97,1953.

[4] X Zhang, C Rehtanz : Flexible AC Transmission systems: Modelling and control Springer book

[5] K R Padiyar, FACTS Controllers in Power Transmission and Distribution New age International Publishers, New Delhi, 1999

[6] S Panda, and N P Padhy, Comparison of particle swarm optimization and genetic algorithm for FACTS-based controller design, Appl. Soft Comput., Vol. 8, No. 4, pp. 1418-1427, 2008

[7] S Panda, N P Padhy and R N Patel, Power system stability improvement by PSO optimized SSSC-based damping controller, Electr. Power Comp. Syst., Vol. 36, No. 5, pp. 468-490, 2008.

[8] M A Abido, Analysis and assessment of STATCOM-based damping stabilizers for power system stability enhancement, Electr. Power Syst. Research, Vol. 73, No. 2, pp. 177-185, Feb. 2005

[9] S Panda, Differential evolutionary algorithm for TCSC-based controller design, Simulat. Model. Pract. Theory, Vol. 17, No. 10, pp.1618-1634, 2009.

[10] J Shing, R Jang, ANFIS: adaptive network-based fuzzy inference system, IEEE Transactions on System Man and Cybernetics, Vol. 23, No. 3, pp. 665-685, 1993.

[11] R Segala, A Sharma, M L Kothari, A self-tuning power system stabilizer based on artificial neural network, Electrical Power and Energy Systems Vol. 26, pp. 423-430, 2004.

[12] P R Gandhi, S K Joshi, GA and ANFIS based Power System Stabilizer "981-1-4799-1303-9/13 2013 IEEE Conference