THE REVIEW OF TRANSIENT STABILITY BETWEEN SHUNT AND SERIES FACTS CONTROLLERS

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Abstract *- The main aim of this paper is to damp out power system oscillations and transient stability improvement. Flexible ac transmission system (FACTS) devices are found to be very effective in a transmission network for better utilization of its existing facilities without sacrificing the desired stability margin. The effect of STATCOM for improving the stability and a Static Synchronous Series compensator (SSSC) is used to investigate the effect of this device in controlling active and reactive powers as well as damping power system oscillations in transient mode of the two machine power system at during fault condition is investigated. All the equations used in improving the stability limit by using STATCOM and SSSC are systematically derived. A theoretical comparison of some aspects of STATCOM and SSSC is also made. It is tested on a single machine infinite bus system equipped with a STATCOM and SSSC. In this paper a Mamdani based Fuzzy logic controller and ANN is designed. The choice of the location and sizing of these devices is also presented and an analysis is made on the IEEE 14 bus system using the MATLAB/SIMULINK software.*

Index Terms— **Transient Stability, FACTS, STATCOM, SSSC, Fuzzy logic controller, artificial neural network**

1. INTRODUCTION

Modern electric power system is facing many challenges due to day by day increasing complexity in their operation and structure. In the recent past, one of the problems that got wide attention is the power system instability. With the lack of new generation and transmission facilities and over exploitation of the existing facilities geared by increase in load demand make these types of problems more imminent in modern power systems. Demand of electrical power is continuously rising at a very high rate due to rapid industrial development [1].To meet this demand, it is essential to raise the transmitted power along with the existing transmission facilities. The need for the power flow control in electrical power systems is thus evident. With the increased loading of transmission lines, the problem of transient stability after a major fault can become a transmission power limiting factor. The Power system should adapt to momentary system conditions, in other words, power system should be flexible. In an ac power system, the electrical generation and load must balance at all times up to some extent, the power system is self regulating .If generation is less than load ,the voltage and frequency drop, and thereby the load goes down to equal the generation minus transmission losses. But there are only a few percent margins for such a self Regulation. Hence there is chance of system collapse. Generator excitation controller with only excitation control can improve transient stability for minor faults but it is not sufficient to maintain stability of system for large faults occur near to generator terminals [17].

Thus, this requires a review of traditional methods and the creation of new concepts that emphasize a more efficient use of already existing power system resources without reduction in system stability and security. In the late 1980s, the Electric Power Research Institute (EPRI) introduced a new approach to solve the problem of designing and operating power systems the proposed concept is known as Flexible AC Transmission Systems (FACTS). The two main objectives of FACTS are to increase the transmission capacity and control power flow over designated transmission routes. FACTS are defined by the IEEE as a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability.

2. STATCOM & SSSC CONTROLLER

A Static synchronous compensator is one of the FACTS device operated on principle of reactive power compensation can use to improve the transient stability of the system by increasing (decreasing) the power transfer capability [5].Static synchronous compensator's three modes i.e. capacitive mode, inductive mode and no load mode regulates voltage in transmission system. When Converter a.c. output voltage (Vc) > transmission system voltage (Vs), STATCOM considered to be in Capacitive mode and when Vs > Vc, STATCOM considered to be in inductive mode and in No-Load mode Vs=Vc, no reactive Power exchange takes place [6].

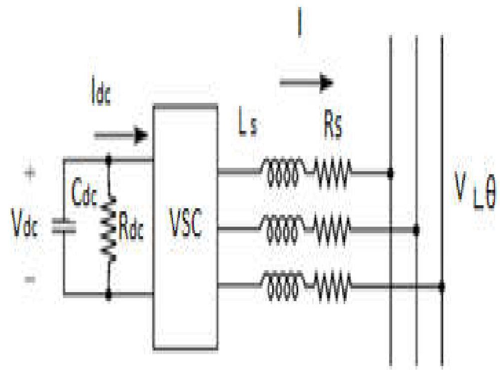

Fig.1 STATCOM's Basic Circuit Diagram

As compare to SSSC, STATCOM provides a number of performance advantages for reactive power control applications because of its greater reactive current output capability at depressed voltage, faster response, better control stability, lower harmonics and small size etc [11],[12].In This paper a Mamdani based Fuzzy logic controller is designed. The inputs to the Fuzzy logic controller are the alternator speed and its derivative and output is firing angle α of the voltage source converter.

Static Synchronous Series Compensator (SSSC) is one of the important series FACTS devices. SSSC is a solid-state voltage source inverter, injects an almost sinusoidal voltage, of variable magnitude in series with the transmission line. The SSSC were placed on the location in such a way that the capability of SSSC to compensate a particular bus or line could be optimized.

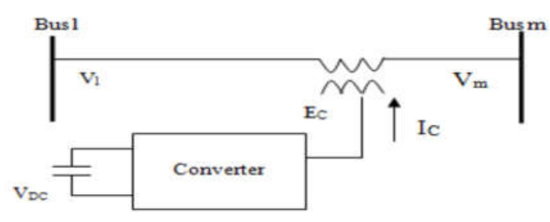

Fig.2 Basic Circuit Diagram

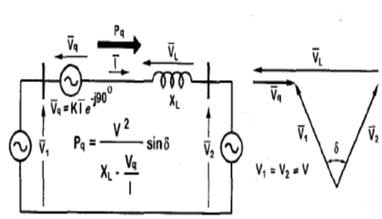

Fig 3 The elementary two-machine system with SSSC and associated phasor diagram

Where,
V1 - voltage magnitude of machine-1.

V2 - voltage magnitude of machine-2.
□□□- phase difference between these voltages.
I - current flowing from machine-1 to machine-2.
VL - voltage drop across the line impedamce.
Pq - active power flowing through the line.
Vq - injected voltage by SSSC.

The SSSC injects the compensating voltage in series with the line irrespective of line current. The transmitted power Pq versus the transmission angle □□relationship therefore becomes a parametric function of the injected voltage, Vq, and it can be expressed for a two machine system as follows:

$$P_q = \frac{V2 \sin\delta}{xl} + \frac{v}{Xl} V_q \cos\frac{\delta}{2} \qquad (1)$$

3. OPERATING PRINCIPLE OF STATCOM & SSSC

STATCOM is made up of a coupling transformer, a VSC and a dc energy storage device. STATCOM is capable of exchanging reactive power with the transmission line because of its small energy storage device i.e. small dc capacitor, if this dc capacitor is replaced with dc storage battery or other dc voltage source, the controller can exchange real and reactive power with the transmission system, extending its region of operation from two to four quadrants. A functional model of a STATCOM is shown in Figure 4

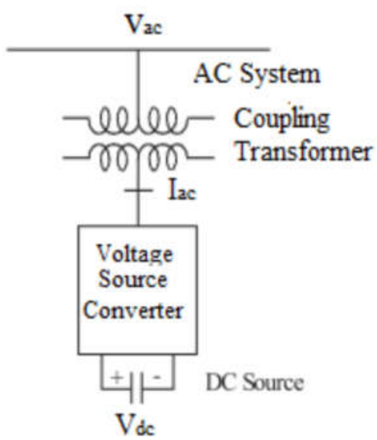

Fig.4 Functional mode of STATCOM

The STATCOM's ability to absorb/supply real power depends on the size of dc capacitor and the real power losses due to switching. Whenever the dc capacitor and the losses are relatively small. The amount of real power transfer is also relatively small. This implies that the STATCOM's output ac current Iac, has to be approximately + 900 with respect to ac system voltage at its line terminals. Varying the amplitude of the converter three-phase output voltage Vout controls the reactive power generation/absorption of the STATCOM. If the amplitude of the converter output voltage Vout is increased above the amplitude of the ac system bus voltage Vac then the ac current Iac, flows through the transformer reactance from the converter to the ac system generating reactive power. In this case, the ac system draws capacitive current that leads by an angle of 90^0 the ac system voltage, assuming that the converter losses are equal to zero. The ac current flows from the ac system to the voltage-sourced converter if the amplitude of the converter output voltage is decreased below that of the ac system, and consequently the converter absorbs reactive power. For an inductive operation, the current lags the ac voltage by an angle of 90^0.

The SSSC is one of the most recent FACTS devices for power transmission series compensation. It can be considered as a synchronous voltage source as it can inject an almost sinusoidal voltage of variable and controllable amplitude and phase angle in series with a transmission line. The injected voltage is almost in quadrature with the line current. A small part of the injected voltage that is in phase with the line current provides the losses in the inverter .The basic structure of SSSC which basically consists of a capacitor, an inverter and a coupling transformer.

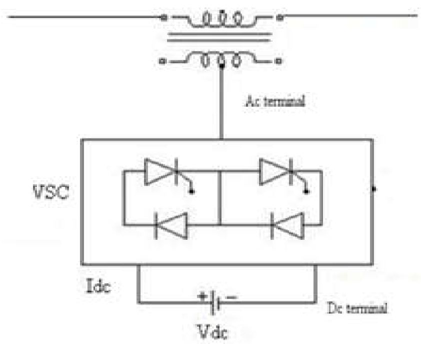

Fig.5 Functional model of SSSC

Most of the injected voltage, which is in quadrature with the line current, provides the effect of inserting an inductive or capacitive reactance in series with the transmission line. The SSSC may have four basic control modes. These are bus voltage control, line power flow control, line reactance control and series voltage control. A series capacitor compensates the transmission-line inductance by presenting a lagging quadrature voltage with respect to the transmission-line current.

4. TWO MACHINE SYSTEM

Fig 4 shows single line diagram of two area system (area 1 & area 2). Area1 (1000 MW hydraulic generation plant) connected to Area 2(5000 MW hydraulic generation Plant.) through 500 kV, 700 km transmission line.

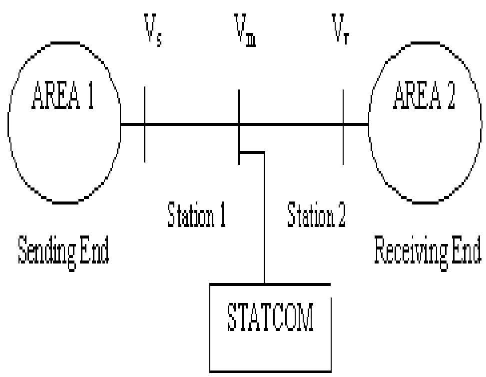

Fig.6 Single Line Diagram of Two Area Interconnected system

Both plants fed to a load center, modelled by a 5000 MW resistive load. System is initialized so that line carries 950 MW which is close to its surge impedance loading. In order to maintain system stability Static synchronous compensator of 200 MVA is connected at midpoint of transmission line. By connecting it at midpoint the power transfers capability of system increases significantly [13], [14].

5. FUZZY LOGIC CONTROLLER

Fuzzy modeling is the method of describing the characteristics of a system using Fuzzy inference rules.

The method has a distinguishing feature in that it can express linguistically complex non-linear system. It is however, very hand to identify the rules and tune the membership functions of the reasoning. Fuzzy Controllers are normally built with Fuzzy rules. These Fuzzy rules are obtained either from domain experts or by observing the people who are currently doing the control.

The membership functions for the Fuzzy sets will be derive from the information available from the domain experts and/or observed control actions. The building of such rules and membership functions require tuning. That is, performance of the controller must be measured and the membership functions and rules adjusted based upon the performance. This process will be time consuming.

The basic configuration of Fuzzy logic control based as shown in Fig. 7. Consists of four main parts i.e.
(i) Fuzzification,
(ii) Rule base,
(iii) Inference Engine and
(iv) Defuzzification

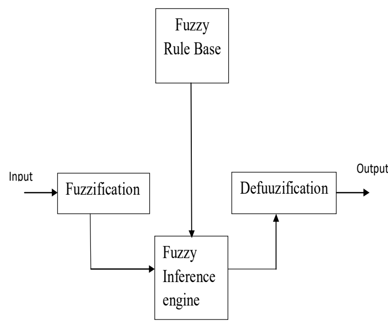

Fig.7 A Fuzzy System

6. ARTIFICAL NEURAL NETWORK CONTROLLER

Clustering analysis is based on artificial neural network model. Neural network mathematical model is based on perceptron structure. Each neuron is a perceptron with input data set, weight for each input data, activation function and output, which usually has binary value. Neural network consists of several layers. Each layer may have definite or indefinite number of neurons. Neural networks give possibility to analyse an object by input parameter set and to detect predefined class of the object on the output. That means, neural network should be trained to detect classes and classes are predefined. Most power full data. Multiprocessor computing system.ANN possess a large number of processing elements called nodes/neurons which operate in parallel. Neurons are connected with others by connection link. Each link is associated with weights which contain information about the input signal.

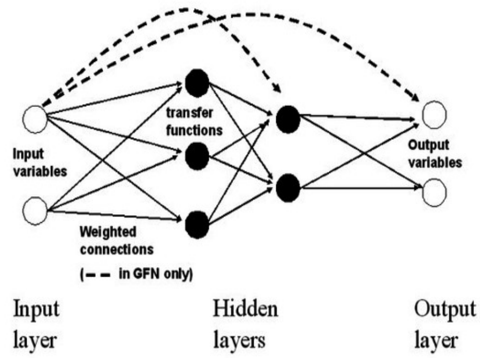

Fig 8. Functional Basic structure of ANN

7. SIMULATION

Simulink Model of two machines (M1 & M2) system, each machine equipped with a Governor, excitation system and Power system stabilizer. These components are included in Turbine & Regulator1 and Turbine & Regulator 2. Both machine connected through a 500 kv, 700km transmission line. Resistive load of 5000MW connected on Machine M2 side. GTO based STATCOM having rating of 200 MVA connected at midpoint of transmission line. Given simulation model run for under discrete mode with sample time (Ts) set at 20×10-6sec.

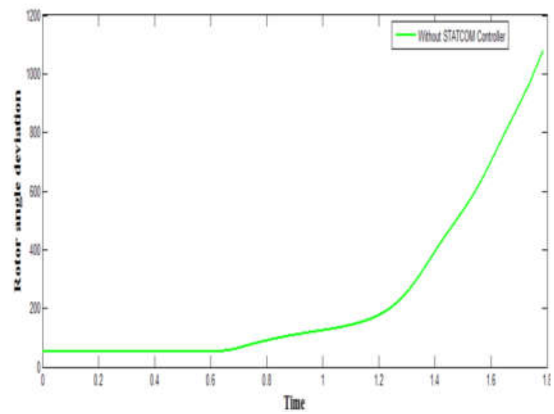

Fig.9 Deviation of Rotor angle with time (under fault)

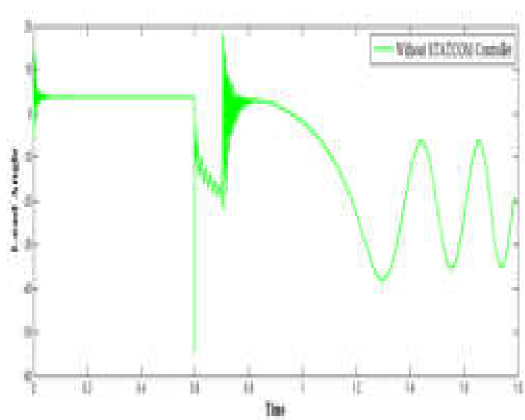

Fig.10 angle with time (under fault)

I. SYSTEM INSTALLED WITH FUZZY BASED STATCOM CONTROLLER

Now System is installed with Fuzzy based STATCOM Controller and fault having clearing time of 0.1 sec is given during time period of 0.2 sec to 0.3 sec as shown in the figure 11 and 12.

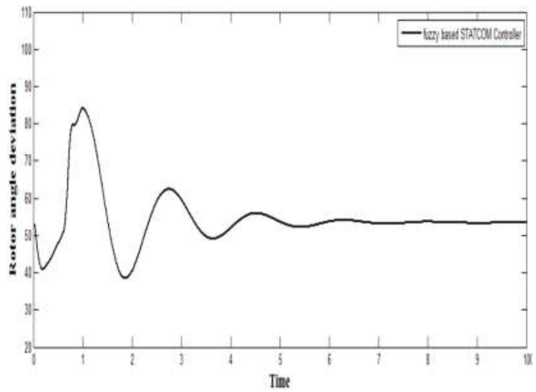

Fig.11 Rotor angle deviation with time (after clearing fault)

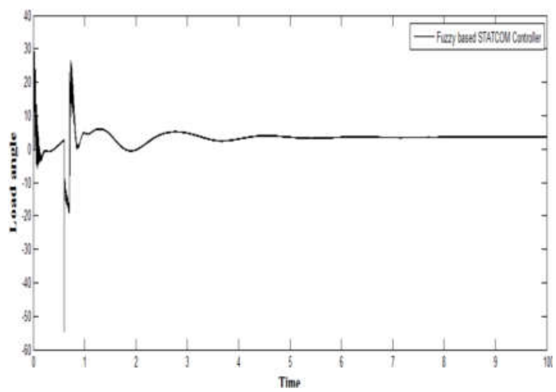

Fig.12 Load angle with time (after clearing fault)

The Figure12 shows that the voltage under fault conditions. When the three phase fault occurred at the transmission line, the system voltage gets unbalanced. Due to unbalance of the voltage, Transient stability, random variations of voltage magnitudes, mainly due to loads, and involving speed variations. To avoid these problems by installing the STATCOM at the midpoint of transmission line, the voltage will be get balanced and as possible to improve the transient stability and the system becomes stable as shown in figure 13.

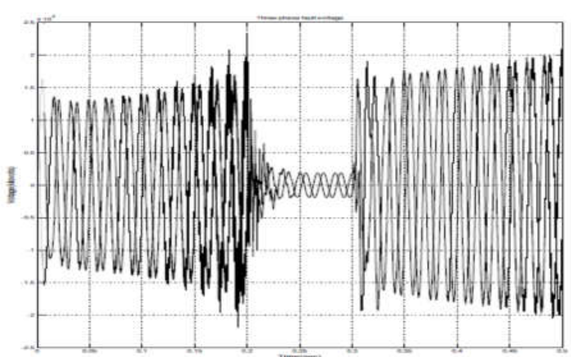

Fig.13 Three Phase Fault Voltage

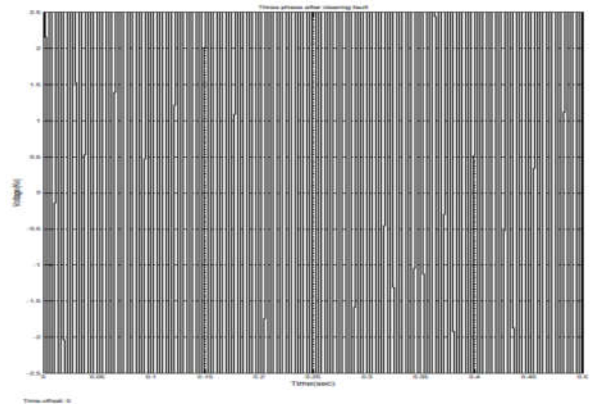

Fig.14 Three Phase clearing fault Voltage

1. SIMULATION RESULTS

II. SYSTEM WITHOUT SSSC

It has been found that the SSSC is capable of controlling the flow of power at a desired point on the transmission line. It is also observed that the SSSC injects a fast changing voltage in series with the line irrespective of the magnitude and phase of the line current. Based on obtained simulation results the performance of the SSSC has been examined in a simple two-machine system, and applications of the SSSC will be extended in future to a complex and multi-machine system to investigate the problems related to the various modes of power oscillation in the power systems.

A three phase fault having clearing time of 0.1 sec is given at 0.2 sec. System installed without SSSC becomes unstable on the fault time as shown by figure 15 and 16

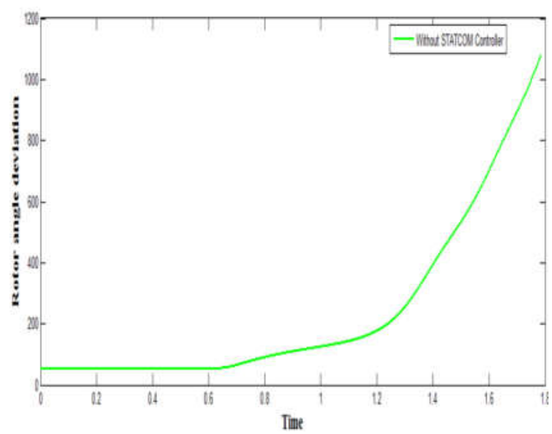

Fig.15 Deviation of Rotor angle with time (under fault)

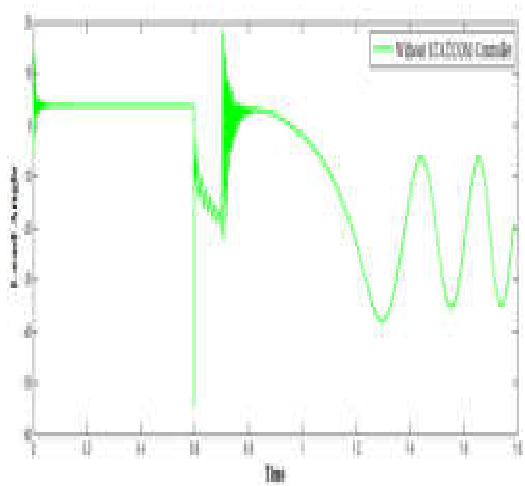

Fig.16 angle with time (under fault)

III. SYSTEM INSTALLED WITH ANN BASED SSSC CONTROLLER

Now System is installed with Fuzzy based SSSC Controller and fault having clearing time of 0.1 sec is given during time period of 0.2 sec to 0.3 sec as shown in the figure 17 and 18

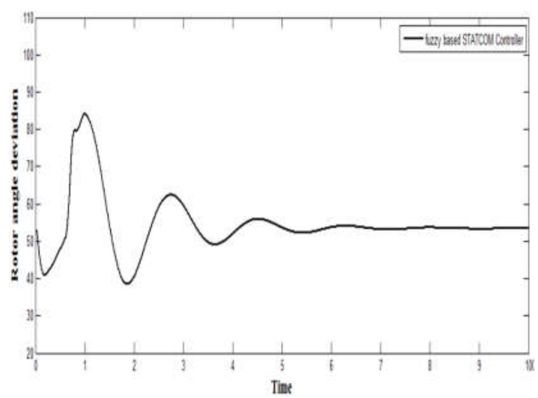

Fig.17 Rotor angle deviation with time (after clearing fault)

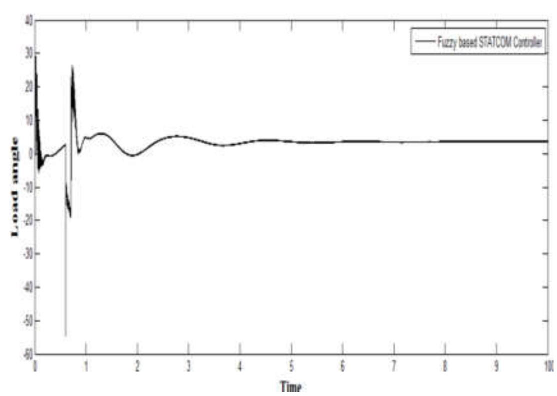

Fig.18 Load angle with time (after clearing fault)

The Figure20 shows that the voltage under fault conditions. When the three phase fault occurred at the transmission line, the system voltage gets unbalanced. Due to unbalance of the voltage, Transient stability, random variations of voltage magnitudes, mainly due to loads, and involving speed variations. To avoid these problems by installing the SSSC at the midpoint of transmission line, the voltage will be get balanced and as possible to improve the transient stability and the system becomes stable as shown in figure 19

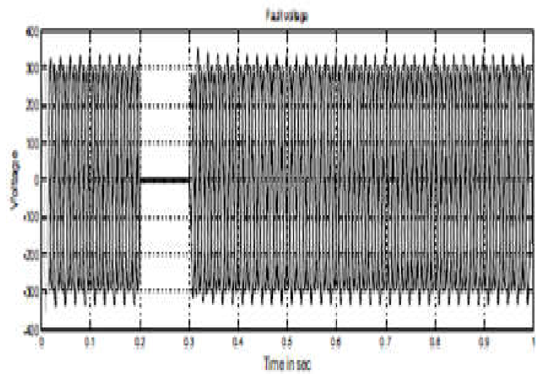

Fig.19 Three Phase Fault Voltage

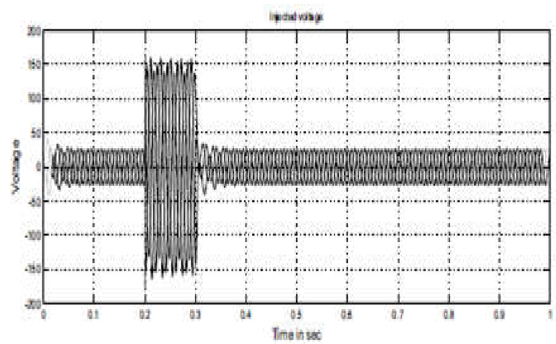

Fig.20 Three Phase injected Voltage

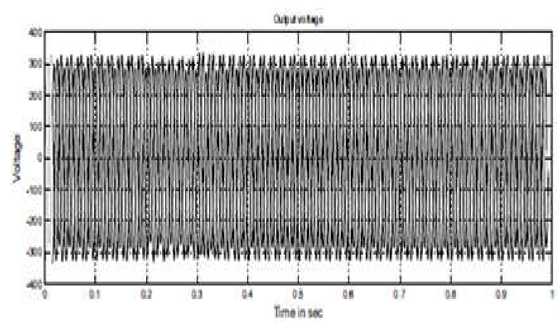

Fig.21 Three Phase clearing fault Voltage

8. CONCLUSION

In This Paper, Mamdani based Fuzzy logic controller is successfully designed to control the STATCOM for improving transient stability of the power system. Simulation results indicate that Fuzzy based STATCOM controller provides better transient stability and Simulation results indicated that the Fuzzy based STATCOM controller installed with two machine system As well as to control the SSSC for improving transient stability and damping of the power system. Controller inputs are chosen carefully to provide better damping to the system and its range are determined by the simulation results of training data process. Simulation results indicate that ANN based SSSC controller provides better transient stability and damping power system oscillation. The results show that there is a need for controllers to adjust to new settings in its characteristics and make it adaptive to system conditions. Both resistance and reactance decrease as compared to the values of resistance and reactance measured without SSSC.

SSSC device that is not contemporarily being used in the transmission lines. But with SSSC, the system is losing its synchronism and is unstable. This shows the capability of SSSC in improving the transient stability margin of a power system. Comparing the both results STATCOM transient stability is capable of not losing the its synchronism and is stable.

I. APPENDIX

Data for various components used in Matlab Simulink model of Fig 6 are as follows:
Generator Parameters:M1 =1000 MVA,
M2=5000 MVA
V =13.8 KV, f =60 Hz, Xd =1.305, Xd'= 0.296,
Xd'' =0.252, Xq =0.474, Xq''=0.243,
X=0.18, H= 3.7
Transformer Parameters: T1=1000MVA, T2=5000MVA
13.8/500 KV, Rm=Lm=500 ohm
Transmission Line Parameters per km: R1=0.01755Ω, R_0=0.2758 Ω, L_1=0.8737mH, L_0=3.22mH, C_1=13.33nF, C_2=8.297nF.
STATCOM: 500KV, 200MVA, Vref =1 V, Ts=20×10^{-6}
Cp =Cm=5000×10^{-6}
Science writers are [9].

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