Transient Stability Improvement of Two Machine System Using ANN With SSSC

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Abstract---The main aim of this paper is to damp out power system oscillations and transient stability improvement, which has been recognized as one of the major concerns in power system operation. 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. The transient stability and damping oscillations of two machine power system during faulty conditions to be improved by injecting the voltage in series with ANN controller based SSSC.Simulations have been done in MATLAB/SIMULINK environment

Index Terms:- Transient Stability, FACTS, SSSC, Artificial neural network.

I. INTRODUCTION

Nowadays, the need for flexible and fast power flow control in the transmission system is anticipated to increase in the future in view of utility deregulation and power wheeling requirement. The utilities need to operate their power transmission system much more effectively, increasing their utilization degree. Reducing the effective reactance of lines by series compensation is a direct approach to increase transmission capability. However power transfer capability of long transmission lines is limited by stability considerations. Because of the power electronic switching capabilities in terms of control and high speed, more advantages have been done in FACTS devices areas and presence of these devices in transient stability during transient faults resulting in improvement in power system stability.

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.

The main purpose of series compensation in a power system is virtual reduction of line reactance in order to enhance power system stability and increase the load ability of transmission corridors The principle is based on the compensation of the distributed line reactance by the insertion of a series capacitor. The reactive power generated by the capacitor is continuously proportional to the square of the line current. This means that the series capacitor has a self-regulating effect. When the system loading increases, the reactive power generated by the series capacitor increases as well. The response of the series capacitor is automatic, instantaneous and continuous as long as the capacitor current remains within the specified operating limits.A Static Synchronous Series Compensator (SSSC) is a member of the FACTS family that is connected in series with power system.

II. SSSC CONTROLLER

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 injected voltage is almost in quadrature with the line current. A small part of the injected voltage, which is in phase with the line current, provides the losses in the inverter. Most of the injected voltage, which is in quadrature with the line current, emulates an inductive or a capacitive reactance in series with the transmission line. This emulated variable reactance, inserted by the injected voltage source, influences the electric power flow through the transmission line. A SSSC equipped with energy storage system and/or absorbing is also able to exchange real power with power system. 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.

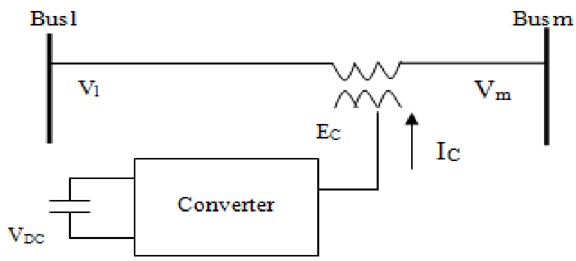

Fig. 1: Basic Circuit Diagram

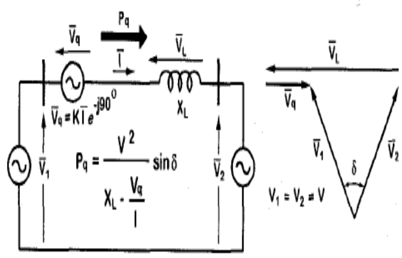

Fig. 2: The elementary two-machine system with SSSC and associated phasor diagram

Where,

- V_1 - voltage magnitude of machine-1.
- V_2 - voltage magnitude of machine-2.

- δ - phase difference between these voltages.
- I - current flowing from machine-1 to machine-2.
- V_L - 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 P_q versus the transmission angle δ relationship therefore becomes a parametric function of the injected voltage, V_q, and it can be expressed for a two machine system as follows:

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

The proposed controller is tested on a two machine power system under Matlab Simulink Environment.

III. Operating Principle Of Sssc

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.

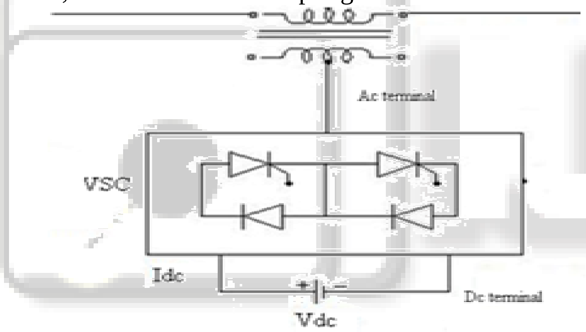

Fig. 3: Functional model of SSSC

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. This voltage acts in opposition to the leading quadrature voltage appearing across the transmission-line inductance, which has a net effect of reducing the line inductance. Similar is the operation of an SSSC that also injects a quadrature voltage, in proportion to the line current but is lagging in phase:

- $V_c = -jkX_cI_c$ (2)
- Where,
- Vc - injected compensating voltage.
- Ic - line current
- Xc - series reactance of the transmission line
- K - Degree of series compensation

Reactive power exchange is controlled by the magnitude of the injected voltage to the transmission line, and angle control is used to regulate the active power exchange. The inductive or capacitive mode of operation is set by the injected voltage phase angle with respect to the transmission line current. When injected voltage is leading the line current, reactive power is absorbed and SSSC operates in inductive mode. In capacitive
mode injected voltage is lagging the line current and injects reactive power to the transmission line.

IV. 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.

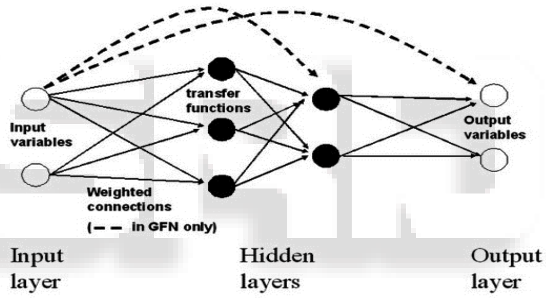

Fig. 4: Functional Basic structure of ANN

V. Mathematical Model

A. *General Mathematical Model Of Neural Network:*

- Input data set for neural network: X = {x1, x2, ,xn}
- Set of neural network hidden layers: L = {l1, l2, lk}
- Set of neurons for each j-th hidden layer: P j = {p1, p2,, pr}
- Set of neural network outputs: C = {c1, c2, …, cm}
- Weights for each input of i-th neuron of j-th layer: Wi^j = {wi1, wi2, …, win, win}
- Bias for each i-th neuron of j-th layer: bi^j
- Input summation function for each i-th neuron of j-th layer: si^j = _(Wij*X) +bi^j

Transfer function for all neurons of j-th layer: Fj(sj)

B. *Feed-Forward Back Propagation Neural Network:*

Authors propose to use feed-forward back propagation network for controller of DC drive. The transfer functions F for such kind of network can be any differentiable transfer function such as Hyperbolic tangent sigmoid transfer function, Log sigmoid transfer function, Linear transfer function., etc..,

VI. Two Machine System

The dynamic performance of SSSC is presented by real time voltage and current waveforms. Using MATLAB software the system has been obtained. In the simulation one SSSC has been utilized to control the power flow in the 500 KV transmission systems.

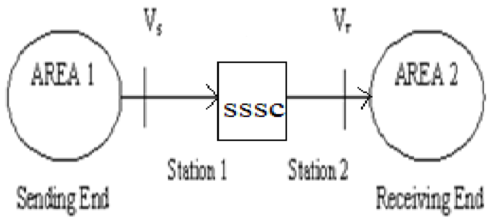

Fig. 5: Single Line Diagram of Two Area Interconnected system

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 series compensator of 200 MVA is connected at midpoint of transmission line. By connecting it at midpoint the power transfers capability of system increases significantly.

VII. 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 SSSC 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.

VIII. SIMULATION RESULTS

A. 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 6 and 7

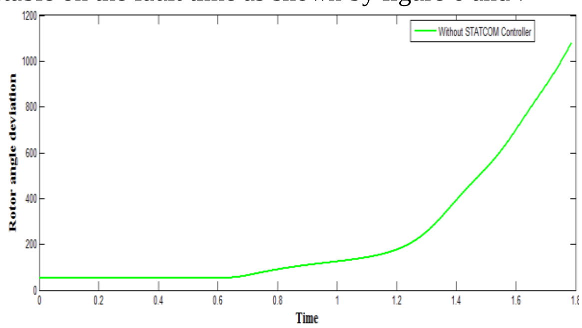

Fig. 6: Deviation of Rotor angle with time (under fault)

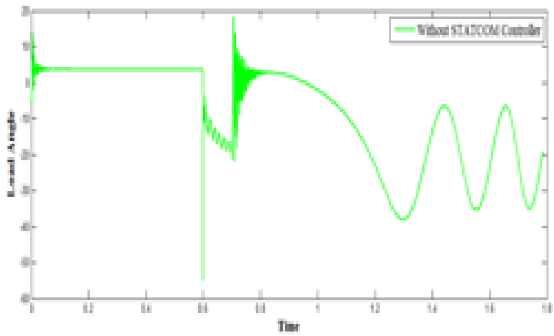

Fig. 7: Angle with time (under fault)

B. 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 8 and 9.

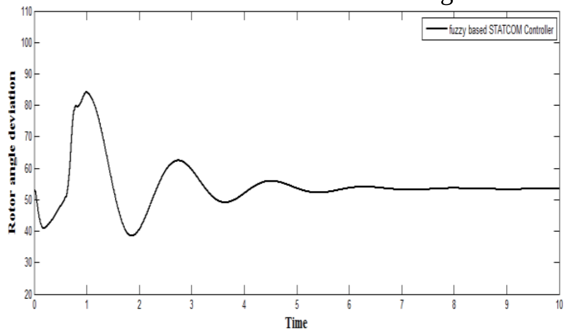

Fig.8 Rotor angle deviation with time (after clearing fault)

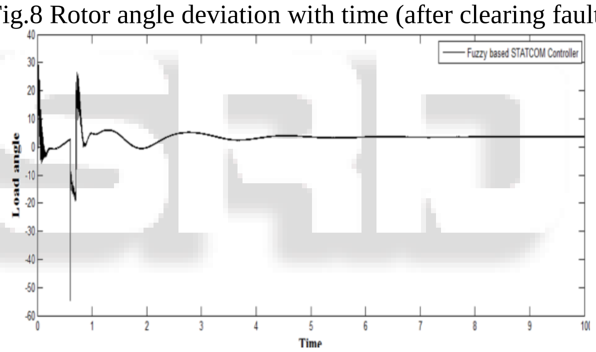

Fig. 9: Load angle with time (after clearing fault)

The Figure10 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 12.

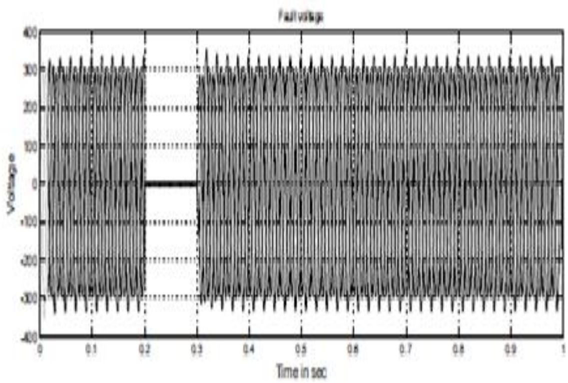

Fig. 10: Three Phase Fault Voltage

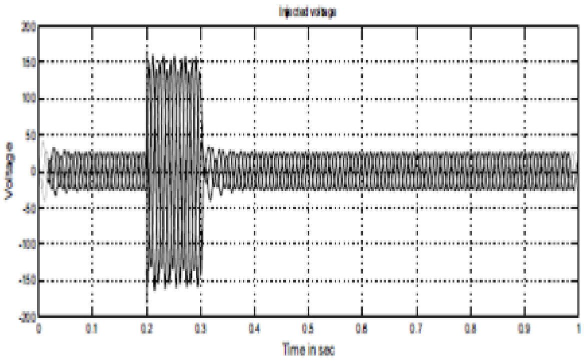

Fig. 11: Three Phase injected Voltage

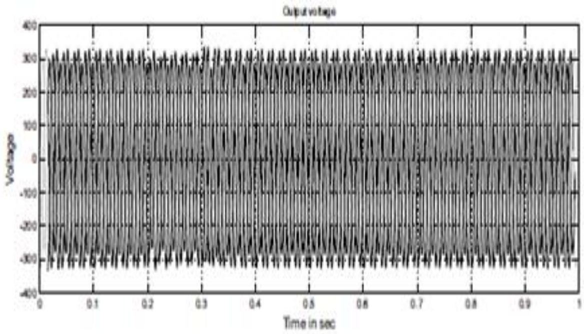

Fig. 12: Three Phase clearing fault Voltage

IX. CONCLUSION

In This Paper, neural network controller is successfully designed 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. Simulation results indicated that the ANN based SSSC controller installed with two machine system provides better damping characteristics and provides improved transient stability.

X. 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.
- SSSC: 500KV, 200MVA, Vref =1 V, Ts=20×10^{-6}
- Cp =Cm=5000×10^{-6}
- Science writers are [9].

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