ANN Controlled STATCOM for Improving Transient Stability of the Power System

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***Abstract* — In this paper, an ANN controller is designed for static synchronous compensator (STATCOM) to enhance the transient stability of the power system. The ANN controller is designed using a radial basis network. Radial basis networks can be used to approximate functions. The control signals to the ANN controller are the generator speed and its derivative and the target is the voltage source inverter firing angle alpha. The nonlinear ANN controller is used to overcome the problems generated by different uncertainties existing in power systems when designing electromechanical oscillation damping controllers. Proposed controller is implemented on a single machine infinite bus system to confirm the performance of the controller through simulation results.**

***Keywords*—:** Power System, FACTS, STATCOM, Transient Stability, ANN Controller

I INTRODUCTION

The FACTS (Flexible AC Transmission Systems) technology [l] is a new research area in power engineering. It introduces the modern power electronic technology into traditional ac power systems and significantly enhances power system controllability and transfer limit. Using proper controllers, FACTS devices are also able to ameliorate the dynamic behavior of the system, in the vein of transient, small signal and voltage stability. Transient stability is an important security criterion in the design of power systems. Transient stability analysis is considered when the power system is confronted with large disturbances like sudden changes in load, generation or transmission system configuration due to fault or switching are examples of large disturbances. Power system should retain its synchronism during and after all these kind of disturbances.

The STATCOM is the solid-state-based power converter version of the SVC. The concept of STATCOM was proposed by Gyugyi in 1976. Operating as a shunt-connected SVC, its capacitive or inductive output currents can be controlled independently from its connected AC bus voltage. Because of the fast-switching characteristic of power converters, the STATCOM provides much faster response as compared to the SVC. In addition, in the event of a rapid change in system voltage, the capacitor voltage does not change instantaneously; therefore, the STATCOM effectively reacts for the desired responses. For example, if the system voltage drops for any reason, there is a tendency for the STATCOM to inject capacitive power to support the dipped voltages.

STATCOM is one of the parallel FACTS devices that is usually used for voltage regulation. It can also be used to improve power system stability by injecting reactive power to the network [1]. This function of STATCOM needs some more supplementary input signals. Several controllers have been used to perform this control strategy such as conventional PI controller, rule based controller [6] and energy function based controller.

The STATCOM comprises a voltage source shunt converter connected through a transformer and filter across a load bus where the voltage is to be regulated. The shunt converter is usually modeled as a controllable voltage source generated by the inverting action of the converter with a DC voltage applied through a charged capacitor. The static synchronous compensator (STATCOM) is based on the principle that a voltage-source inverter generates a controllable AC voltage source behind a transformer-leakage reactance so that the voltage difference across the reactance produces active and reactive power exchange between the STATCOM and the transmission network. The converter controls the current injected to the power system and as the energy exchanges by the STATCOM is limited by the capacitor stored energy, only reactive power can be exchanged in steady state.

This paper presents an ANN based control strategy for STATCOM to improve power system transient stability and performance. Artificial Neuron is a single processing element whose output is calculated by multiplying its inputs by a weighted vector, summing the results and applying an activation function to the sum. One of the most interesting features of neural networks is their learning ability. This is achieved by presenting a training set of different examples to the network and using learning algorithms, which changes the weights (or parameters of activation functions) in such a way that the network will reproduce a correct output with the correct input values. The most significant advantage of ANN controller is that it is an intelligent controller. The ANN controller is also a nonlinear controller and not so sensitive to system topology, parameter and operation condition change as the conventional linear controller. These features make it very attractive for power systems applications. Artificial neural network performs as a powerful tool to confront uncertainties. Power systems are large scale systems with high nonlinearity, so there is a considerable uncertainty in every part of them. It can be the result of different phenomena according to system nature, lake of information or measurements. The ANN approach provides a model-free method for STATCOM control and can be effective over a wide range of power system changes. It allows the designer to incorporate experimental knowledge in adjustment of controller parameters.

II STATCOM MODELLING

The STATCOM is modeled as a three-phase GTO-based voltage sourced converter behind a step down transformer
(SDT) having leakage reactance X_{SDT} and a dc capacitor.

The Following assumptions have been made for building the mathematical model of the system :

- There should be constant mechanical power input to the system.
- Detailed dynamics model for exciter and governor are neglected.
- STATCOM generates a constant inductive current.
- Voltage e_q behind transient reactance $' X_d$, is considered to be constant.
- The STATCOM is modeled as a controllable reactive current source with time delay.

The controllable AC-voltage source generated by the voltage source converter is $v_o(t) = v_o \sin(\omega t - \psi)$ which is behind the transformer leakage reactance. The active and reactive system depends upon the voltage difference between the STATCOM-bus AC voltage *VL (t)* and *Vo* (*t*) which can be controlled by adjusting the magnitude *Vo* and the phase Ψ.

STATCOM can be represented by a controlled shunt current source as shown in Fig.1.

The STATCOM current is always in quadrature with its terminal voltage and can be written as [4]:

$$I_{STATCOM} = I_{STATCOM} e^{j(\delta_k \pm 90)}$$

(1)

Positive and negative signs are for inductive and capacitive modes respectively. In the capacitive mode, the voltage magnitude and angle of bus k can be represented as

$$V_m = \frac{E' X_2 Cos(\delta - \delta_m) + VX_1 Cos\delta_m + X_1 X_2 I_{STATCOM}}{X_1 + X_2}$$

(2)

$$\delta_m = \tan^{-1}\left(\frac{E' X_2 Sin\delta}{VX_1 + E' X_2 Cos\delta}\right)$$

(3)

Where Ei ,E ,Vm, δ , δ_m are the generator internal voltage, infinite bus voltage, STATCOM bus voltage, generator internal angle and STATCOM bus angle respectively. The output power of the machine can be written as:

$$P_c = \frac{E' V_m}{X_1} Sin(\delta - \delta_m)$$

(4)

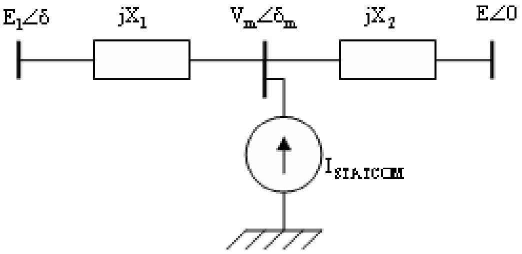
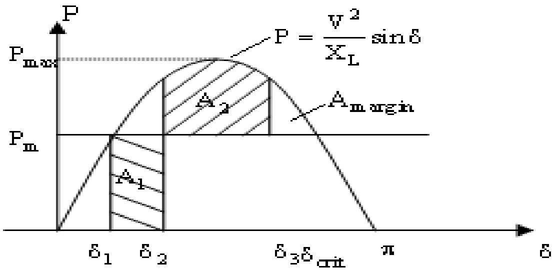


Fig.1. Single machine infinite bus system with STATCOM



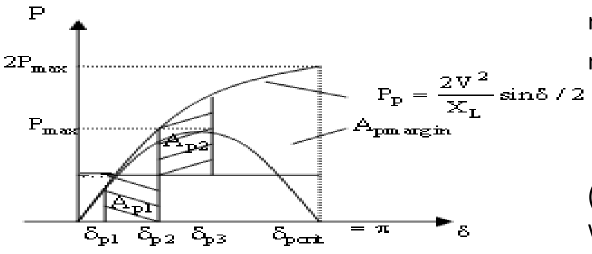


Fig.2. Transient stability margin for a power system (a) without STATCOM and (b) with STATCOM

III ANN CONTROLLER FOR STATCOM

The ANN controller is designed using a radial basis network. The given inputs are the generator frequency w and its derivative dw/dt which are shown in Fig.3 and Fig.4 and the target is the voltage source inverter firing angle alpha.

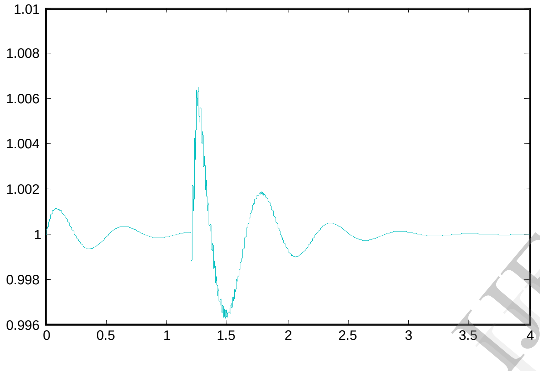


Fig.3. Generator frequency with ANN controller

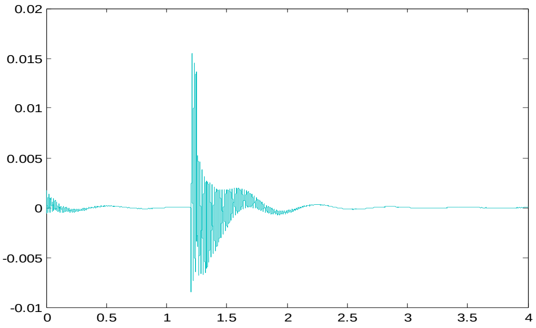


Fig.4 Derivative of frequency with ANN controller

The radial basis neural networks functionally resemble the multilayer neural networks (both are general modeling tools for nonlinear functions), but they have replaced the multiplayer neural networks in many applications, at least because the radial basis networks greatly reduce the training time and make related analyses much easier.Radial basis networks can be used to approximate functions. Radial basis networks consist of a linear input layer, a linear output layer, and a nonlinear hidden layer[7]. The relation between the input vector x and an output node y_i can be expressed by

$$y_i = \sum_{j=1}^{N} c_{ij} g_{\sigma j}(x, \xi_j)$$

(5)

where g is a radially symmetric kernal function of a nonlinear hidden neuron, with ξ_i and σ_j denoting the centroid and width of the jth nonlinear neuron. The output of g depends on the distance between **x** and ξ and on the size of σ .Similar to the multilayer neural networks, the radial basis neural networks have been shown to be universal approximators of nonlinear functions.

The command used in designing the ANN controller is:

"net = newrbe(input,target,spread)"

NEWRBE designs a radial basis network with zero error on the design vectors. NEWRBE creates a two layer network. The first layer has RADBAS neurons, and calculates its weighted inputs with DIST, and its net input with NETPROD. The second layer has PURELIN neurons, and calculates its weighted input with DOTPROD and its net inputs with NETSUM. Both layer's have biases. Fig.5 shows a radial basis network. NEWRBE sets the first layer weights to input', and the first layer biases are all set to 0.8326/SPREAD, resulting in radial basis functions that cross 0.5 at weighted inputs of +/- SPREAD.

The second layer weights IW{2,1} and biases b{2} are found by simulating the first layer outputs A{1}, and then solving the following linear expression:

[W{2,1} b{2}] * [A{1}; ones] = Target

The larger the SPREAD, is the smoother the function approximation will be. Too large a spread can cause numerical problems.

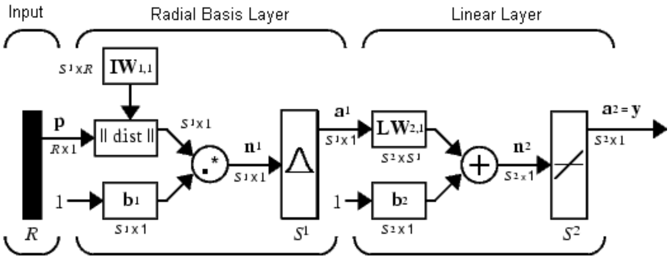


Fig.5. Radial basis network

The Artificial neural network controller implementation in the simulink model is done with the help of "MATLAB Fcn" block available in the matlab simulink library. The MATLAB Fcn block applies the specified MATLAB function or expression to the input. The interfacing of neural network program with simulink model is done with the help of MATLAB Fcn. Fig.5.1 shows the implementation of ANN controller in the simulink model. The inputs to this controller are w and dw/dt whereas the target is the voltage source converter firing angle alpha.

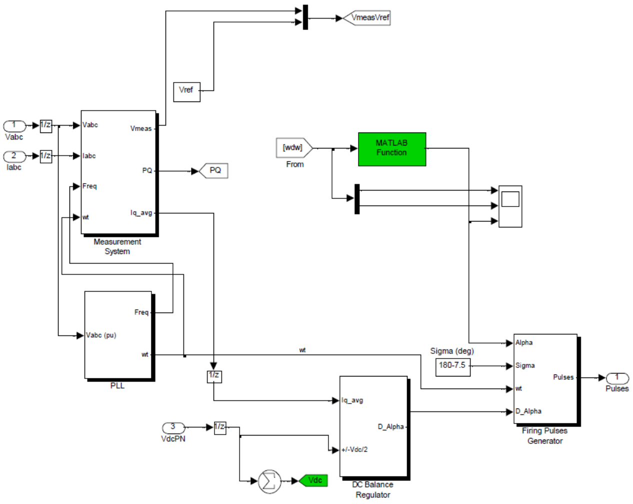


Fig.5.1 ANN controller implementation in simulink

IV SIMULATION RESULTS

The proposed controller is implemented in MATLAB/ SIMULINK and it is linked to PSCAD in which the test system is implemented. Proposed controller is tested through a number of disturbances including three phase to ground faults on a Single Machine Infinite Bus (SMIB) system.The fault is given to the system for a period of 0.05 seconds. The results obtained are described below:

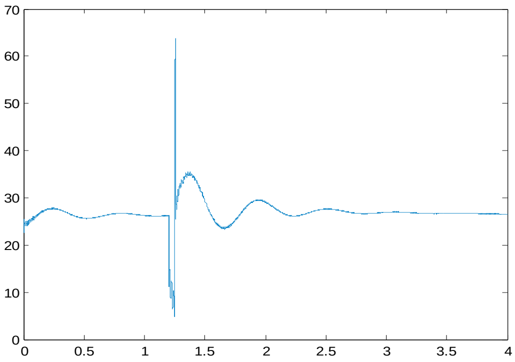


Fig.6. Load angle with ANN controller

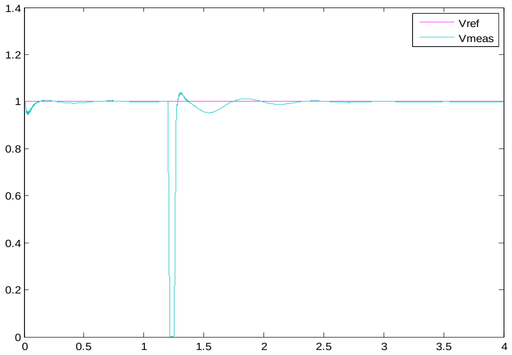


Fig.7. Vref vs Vmeas with ANN controller

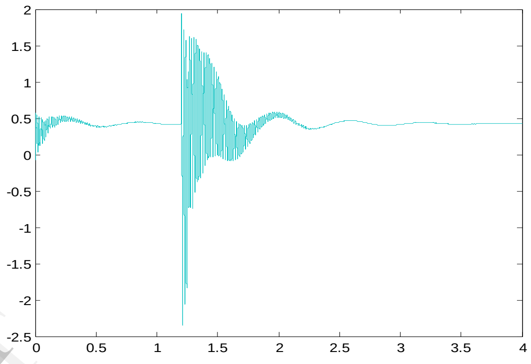


Fig.8. VSC firing angle alpha with ANN controller

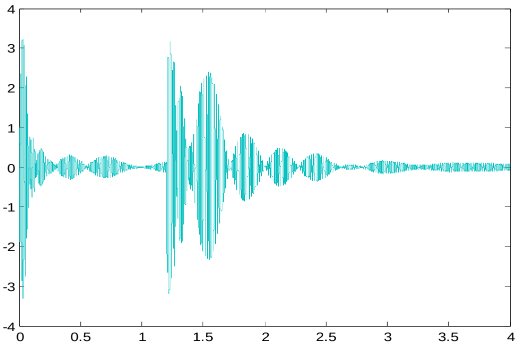


Fig.9. STATCOM Current with ANN controller

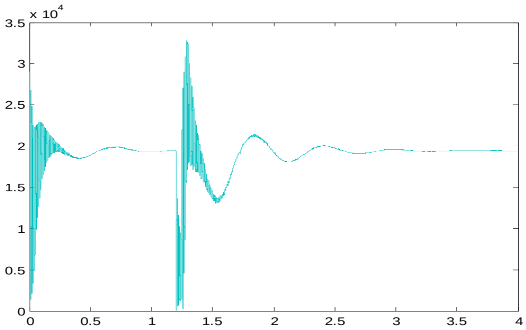


Fig.10. Capacitor voltage with ANN controller

A three phase to ground fault is being introduced in the system for a period of 1.2 second to 1.25 second. The above responses show that the artificial neural network controller provides a good damping under severe fault conditions.

V CONCLUSIONS

In this paper, an ANN based controller is proposed to provide a suitable control signal for STATCOM in the power system. The role of the ANN is to make a decision on the voltage source converter firing angle alpha which controls the operation of the STATCOM . The proposed controller has two control parameters generator frequency and its derivative. Controller input parameters are chosen carefully to provide considerable damping for power system.

This controller provides a complementary signal for STATCOM to improve stability of the system in the vein of transient stability. The above control strategy is applied to a single machine infinite bus system. The controllers designed were tested for a number of conditions including three phase to ground fault. Simulation results indicate that the proposed controllers provide extremely good damping characteristics over a good range of operating conditions

VI. APPENDIX

Data of SMIB system:

Generator: H=3.6s, f=60 Hz, X'_d= 0.3 pu
Transmission lines: X_L=0.5 pu
Transformer: X_T=0.16 pu
Infinite bus: 0.995O

The machine was initially delivering a power of 0.9 pu at terminal voltage of 1.05 pu.

REFERENCES

[1]Hingorani and N.G. Gyungyi- "Understanding Facts Devices"-IEEE Press, 2000.
[2]N.G. Hingorani, "Flexible ac transmission systems," IEEE Spectrum, pp. 40-45, April 1993.
[3]Laszlo Gyugyi, "Dynamic compensation of ac transmission line by solid state synchronous voltage sources," IEEE transaction on power delivery, 9(2):pp. 904-911, April 1994.
[4]H.F. Wang, "Phillips-Heffron model of power systems installed with STATCOM and applications," IEE Proceedings ,146(5), Sep. 1999.
[5]Tapia, O.R.; Ramirez and J.M, "Power Systems Neural Voltage Control by a StatCom," IEEE International Joint Conference on Neural Networks, July 2006.
[6] J.A. Anderson- "An introduction to neural networks"-Prentice Hall.
[7]Juan M. Ramirez, Ruben Tapia O, Julio C. Rosas and José A. Vega; "StatCom's Voltage. Regulation by a Neurocontroller" IEEE PES General Meeting, 2007
[8]J.S.R. Jang, C.T. Sun and E. Mizutani-"Neuro-Fuzzy and Soft Computing"- Prentice Hall.