DESIGN OF ARTIFICIAL NEURAL NETWORK BASED TID CONTROLLER FOR TRANSIENT STABILITY IMPROVEMENT

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Abstract**:** *This paper is to present the design of the neural network based TID controller applicable to static VAR compensator (SVC) on two machine 3-bus transmission system to improve the transient stability when sudden disturbances occur in transmission system. i.e three phase fault. The power system network considered is to simulated using phasor simulation method. Comparisons regarding stability are done for the system without controller, PI controller, TID controller and Neural Network based TID controller. Simulation results show that the proposed Adaptive Neural network based TID controller was effective in reducing power system oscillations compared to other controllers.*

Keywords**:** *SVC, TID Controller, Artificial Neural Network*

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I. INTRODUCTION (*HEADING 1*)

The interconnected power systems have been larger and more complex. The interconnected systems are continually increasing in size and extending vast geographical regions. It is becoming more difficult to maintain stability. The transient stability study is an important characteristic with large disturbances. These disturbances can be faults such as: a short circuit on transmission line, loss of a load, loss of a portion of transmissions network etc. The transient is referred as the ability to reclaim its original state even after it is subjected to a disturbance [1].

Different methods are available to improve the performance of the power system during its transient state. One of the solution is the application of flexible AC transmission system (FACTS), which are operating on power electronics technologies [2][3][4]. By using these FACTS devices, the reactive power and voltage profile on the transmission line can be controlled [5] [6] [7]. There are different types of FACTS controllers such as series type, shunt type, combination of series-series type and series-shunt type [8] [9]. SVC is generally used in shunt connected controller which is used to damp out the oscillations with more reliable operation [10] and tends to improve the transient stability. The SVC with PI controller is not suitable for non-linear power system and is not giving better performance for a large disturbance. The Artificial neural network (ANN) tuned TID controller is an effective technique with high accuracy and fast response and is able to
do parallel data processing over PI controller [11] [12]. In this paper, an innovative technique is suggested to assimilate the advantage of both TID and ANN, which leads to improve the performance of SVC. We get the better performance by using TID controller, when compare to PI controller [13]. The two

machine 3 bus system model is tested using MATLAB Simulink software. The performance analysis of new controller is done when subjected to give the 3phase fault. The results shows that the performance of damping oscillations and other parameters like voltage and rotor angle are better by using ANN based TID controller compare to conventional svc with TID controller.

II. STATIC VAR COMPENSATOR (SVC):

SVC is used in a power system to get a better reactive power control. The primary benefits with the use of SVC are system stability improvement and voltage regulation. SVCs main utility is to improve the power factor of the system for abrupt changes in loads.

SVC is a combination of power electronic devices to meet the reactive power needs of loads connected to power system. SVC is employing thyristor controlled, switched reactor and capacitor is as shown in figure 1 and is incorporated at the midpoint of transmission line.

When the SVC is acting as a sink and absorbing reactive power from the transformer then the voltage and currents of the transformer on the side connected to SVC are treated as positive. The SVC voltage is variable it is not constant.

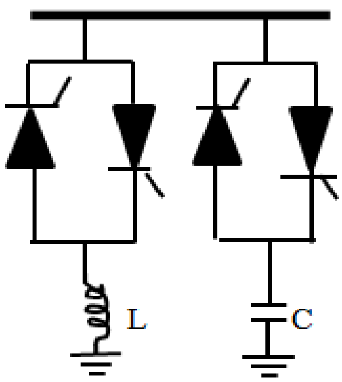

fig.2. Structure of SVC

A modeling of SVC controller is shown in figure 2. B_{SVC} is the output and the representation of the delay incorporated in the system by GPG (gate pulse generator) is given in equation (1).

$$G_C(S) \;=\; \frac{e^{-sT_d}}{1+sT_s} \qquad (1)$$

Where T_d is T/12 for a six pulse converter and T_s is T/4

Where T is the time period of supply voltage, T_m represent the transducer time constant.

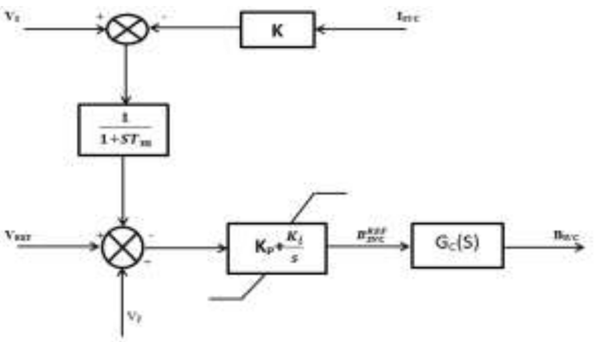

Fig.1. Model of svc controller

Here voltage V_S and SVC current (I_{SVC}) are the control variables (K being the slope of the control signal characteristics). The auxiliary control voltage signal V_F is used for damp out oscillations [1]. It can be derived from bus frequency, line current or synthesized generator rotor velocity. The regulator is PI controller type with provision of proper adjustment of gain within the stable region. The linearizer transfer function $B_L(\alpha)$ is

$$B_S = B_L(\alpha) - B_C \qquad (2)$$

$$B_L(\alpha) = \frac{2(\pi-\alpha)+\sin 2\alpha}{\pi X_L},\ \pi/2 \le \alpha \le \pi \qquad (3)$$

Where X_L is the inductive reactance of SVC and α being the firing angle of the thyristor. The mathematical equation representing the dynamic model of the system is given in equation (4)

$$B_L(t) = \frac{1}{T_R}(-B_L(t)+B_C+k_b u_b(t)) \qquad (4)$$

Where $B_L(t)$ is the inductive susceptance of SVC; B_C the capacitive susceptance SVC; T_R represents the regulator time constant of SVC, k_b being the gain, u_b being the input of the SVC regulator. To study the performance of the proposed controller using MATLAB simulation a LLL-G fault is created between bus 1 and bus 2 and the system is analyzed.

ARTIFICIAL NEURAL NETWORK

The neural network proposed will have two hidden layers with four neurons in each and an output layer. The input layer is fed with the transmission line parameter and the weights and biases of each hidden layer are modified and adjusted using activation function. 70% of the data is used to train the network and 30% of the data is taken as target data for testing the network. The weights and biased are adjusted to get minimum error. Number of iterations depends on the number of epoch fixed. At the end of each epoch the output of the network is calculated and compared with the target data, error is calculated. In this paper the training of the network is done by the back propagation method which uses gradient descent method for minimization of error and sigma function is selected as activation function

The output function of the network is

$$Y = f \sum_{i=1}^{n} \left(w_{ji} x_i + b_j\right) \qquad (5)$$

The output of the hidden layer is

$$x_i = f \sum_{i=1}^{n} (w_{ki} p_i + b_k) \qquad (6)$$

The output of the entire system from equation 5 & 6

$$Y = f \sum_{i=1}^{n} \left[w_{ji} - \{f \sum_{i=1}^{n} w_{ki} p_i + b_k\} + b_j\right] \qquad (7)$$

Where w_{ji} is the weight of output layer, w_{ki} is the weight of hidden layer, b_j and b_k represent the bias of hidden and output layer respectively. P_i being the input to the system, x_i being fed to the output layer.

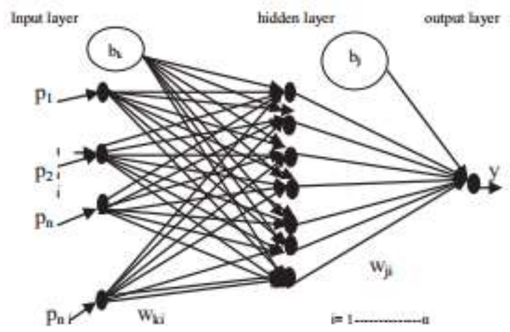

Fig.3. Architecture of multi-layer-nfeed forward ANN

III. TID CONTROLLER

Figure 4 represents the TID controller which is much similar to PID controller. In TID controller in place of proportional component tilted component is used which is represented by the function $1/S^n$. Some advantages of TID controller are improved transient response, simplified tuning and better overall response [11]. The designed controller is used to improve the transient state stability of two machine three bus system which is verified through simulation using MATLAB.

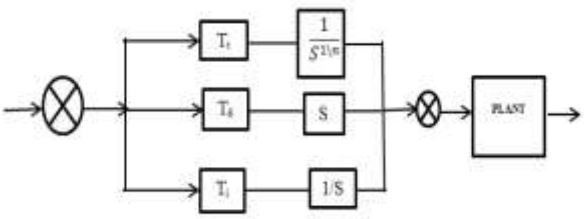

Fig .4. Block diagram of TID controller

Transfer function of TID controller is given by equation

$$E(s) = \left(\frac{T_i}{s} + \frac{T_t}{s^{\frac{1}{n}}} + T_d s\right) G(s) \qquad (8)$$

Where T_T=gain of tilt integrator; T_I=gain of integrator; T_D= gain of derivative;

G(s)= plant transfer function; E(s)= error of the system

V. SIMULATION RESULTS:

The system considered to check the performance of design controller consists of thousand MVA hydraulic generator supplying 5000 MW resistive load connected through 700 km long transmission line. The architecture of the system is shown below.

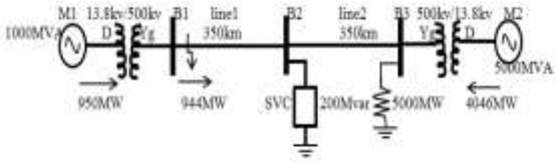

Fig. 5. Single line diagram of 2 machine 3 bus system

The MATLAB Simulink model and the designed controller is shown in figure6 to figure8. A 3- phase fault occurs in between bus1 and bus2 for period of 0.1s. During the fault, system becomes unstable. Svc with PI controller is installed in system for getting stable condition. For improve the svc performance by replaces the PI controller with TID controller. The performance of ANN based TID is better than the svc with PI and SVC with TID controller. The compared results are shown in figure 9 to figure 12.

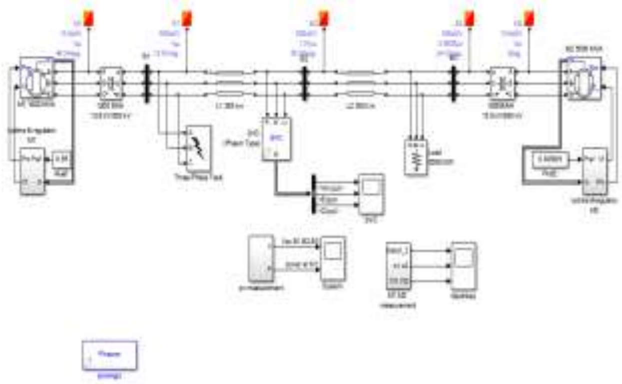

Fig. 6. Simulink model

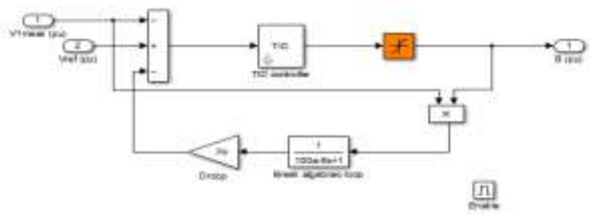

Fig.7. Simulink model for TID controller

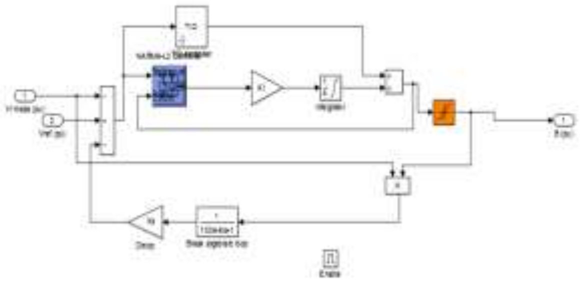

Fig. 8. Simulink model for ANN based TID controller

In figure 9, a 3 phase fault is created at t=1 s. as a cause of which the system looses its synchronism. The first overshoot in the rotor angle is conderably reduced with ANN tuned TID based SVC relative to conventional SVC with TID.

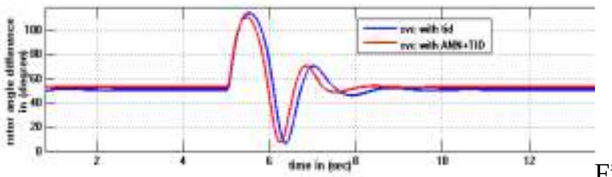

Fig. 9. Rotor angle difference at generator

figure10 shows that the power at the bus1 is settled at t=7s faster when compare to svc with TID at t=8s

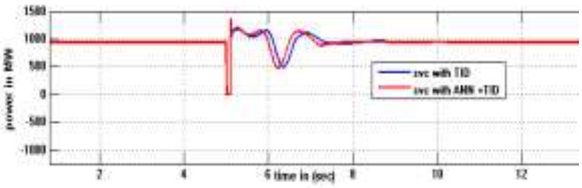

Fig.10. Power at the Bus1

figure11 shows that the speed of generator 1 is settled at t=7s faster than the conventional svc with TID at t=8s

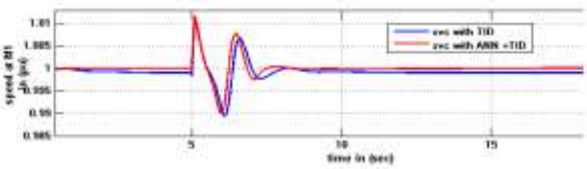

Fig. 11. Speed at generator1

Due to fault occurs at bus1, the terminal voltage is also affected. From fig.12, the oscillations is reduced at t=7s compare to conventional svc with TID controller at t=8s

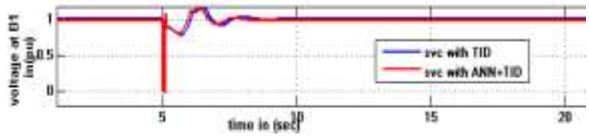

Fig. 12. Voltage at bus1

VI. CONCULUSION

In this paper, the transient response of 2 machine 3 bus system is improved by using ANN tuned TID controller based SVC relative to SVC with TID controller. The proposed controller will have dual advantage of TID and ANN controllers. The robustness of the proposed controller is tested in MATLAB on multiple constraints such as rotor angle difference, bus voltages, generator speed and power at transmission line. The proposed controller is proved to be more robust and quite stable.

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