International Journal of Scientific Engineering and Technology ISSN : 2277-1581
Volume No.4 Issue No.6, pp: 365-369 01 June 2015

Stability Enhancement for Transmission Lines using Neural Network in Static Synchronous Series Compensator

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Abstract: In this paper, 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. During the analyzing its found that the SSSC based power oscillation damping system cannot able to sustain the power oscillations neither alone nor with lead-leg POD controller, so this work proposes SSSC structure equipped with the neural network controller to efficiently sustain the power oscillations. SSSC has a source of energy in the DC link which can supply or absorb the reactive and active power to or from the line with additional Neural Network Controller to enhance power quality in greater instant as compare to SSSC system. Complete Simulations have been done in MATLAB/SIMULINK environment.

Results of Simulation obtain for bus-2 in three phase 500 KV transmission line system shows the higher accuracy of this proposed SSSC with neural network controller is achieving the desired value for active and reactive powers, controlling power flows, and damping oscillations properly.

Keywords - Transmission line, Power oscillation damping, Static Synchronous Series compensator (SSSC), Active and Reactive power , Neural Network.

I. INTRODUCTION

An inherent characteristic of electric energy transmission and distribution by alternating current (AC) is that real power is generally associated with reactive power. Distribution lines and AC transmission are reactive power networks that are characterized by their per-Kilometre series inductance and shunt capacitance. As load power factor changes the transmission lines voltage profile change that can cause large change amplitude variations in the receiving end voltage. After any disturbance of the system Power system has ability to regain its original operating condition. Power system transient stability analysis is, generation or transmission system due to fault or switching [1] . Reactive power compensation has identified as a very key measure to improve the transient stability of the system. For increasing system stability margin gain Flexible AC Transmission Systems (FACTS) devices .provides suitable control strategy. Static Synchronous Series compensator (SSSC) is a member of FACTS family which is connected in series with a power system. It is consist solid state Voltage Source Converter (VSC) which generates a controllable alternating current voltage at fundamental frequency. While the primary purpose of a SSSC is to control power flow in steady state also improve transient stability of a power system.

A. OPERATION OF SSSC AND THE CONTROL OF POWER FLOW

The Static Synchronous Series Compensator (SSSC) is one of series FACTS devices. SSSC is a solid-state voltage source inverter, injects an nearly sinusoidal voltage, with variable magnitude in series with the transmission line. The injected voltage is in quadrature with the line current, that provides the losses in the inverter. The injected voltage, which is in quadrature with the line current, follows an inductive or a capacitive reactance in series with the transmission line. This variable reactance, inserted by the injected voltage source and the electric power flow through the transmission line. schematic of a SSSC is shown in Fig. 1(a). The equivalent circuit of the SSSC is shown in Fig. 1(b). Regulation of power flow can control with control The magnitude of Vc. The winding resistance and leakage reactance of the connecting transformer appear is series with the voltage source V_C. If there is no energy source on The DC side, neglecting losses in DC capacitor and the converter, the power balance in steady state .

Equation (1.1) V_c is in quadrature with current I . If V_c lags I by 90, the operating mode is capacitive and the current (magnitude) in the line is increased with resultant increase in power flow. On the other hand, if V_c leads I by 90, the operating mode is inductive, and the line current is decreased. Note that we are assuming the injected voltage is sinusoidal (neglecting harmonics).

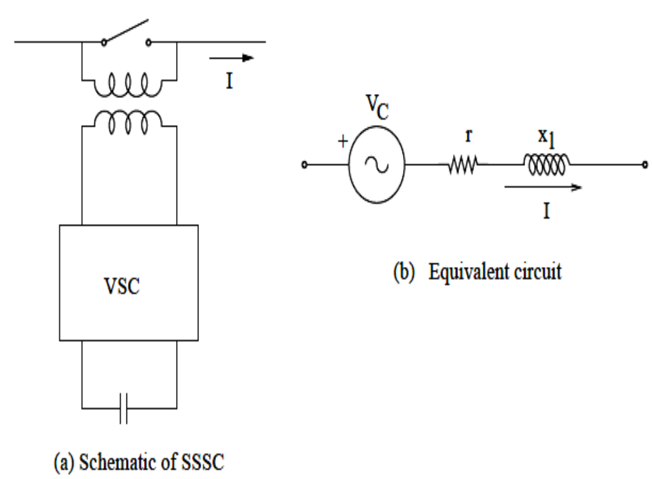

Figure 1. Schematic of SSSC.

Since the losses are always present, the phase shift between current and V_c is less than 90 (in steady state). In general, It can be written as

$$\mathrm{Re}[V_C I^*] = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1.1)$$

$$\begin{aligned}\hat{V}_C &= V_C(\cos\gamma - j\sin\gamma)e^{j\phi} \quad \ldots\ldots\ldots(1.2)\\ &= (V_{Cp} - jV_{Cr})e^{j\phi}\end{aligned}$$

Equation (1.2) where Φ is the phase angle of the line current, γ is the angle by which lags the current. V_{Cp} and V_{Cr} are the in-phase and quadrature components of the injected voltage (with reference to the line current). We can also term them as active (or real) and reactive components. The real component is required to meet the losses in the converter and the DC capacitor.

II. METHODOLOGY

A Static Synchronous Series compensator (SSSC) is a member of FACTS family which is connected in series with a power system. Its consist of a solid state Voltage Source Converter (VSC) which generates a controllable alternating current and voltage at fundamental frequency. When the voltage injected is kept in quadrature with the line current, it can follow as inductive or capacitive reactance so as to influence the power flow through the transmission line (Gyugyi, 1994; and Sen, 1998). While the primary purpose of a SSSC is to control power flow in steady state and also improve transient stability of a power system. In this 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. During the investigation it is found that the SSSC based power oscillation damping system cannot able to sustain the power oscillations neither alone nor with lead leg POD controller, hence this project work proposes a novel SSSC structure equipped with the Neural Network Controller to efficiently sustain the power oscillations. Simulations have been done in MATLAB/SIMULINK environment. Simulation results shows for selected bus-2 in three phase 500 KV transmission line system shows the accuracy of this compensator.

FACTS devices member in controlling power flows, achieving the desired value for reactive and active powers, and damping oscillations appropriately.

A. Modeling of Neural Network Controller for SSSC

A neural network is a generalized approach of making the learning algorithm and making a decision for accurate controlling operation in various applications. The approach of neural net work basically works on the provided priories information and makes a suitable decision for a given testing input based on the provided training information. This approach is analogous to the human controlling approach where all the past observations are taken as the reference information and are used as a decision variable. As already discussed in previous section this project work proposes a novel SSSC structure equipped with the neural network (NN) controller to efficiently sustain the power oscillations. This sub section deals with the modeling of neural network controller for SSSC. During the analysis of neural network controllers it is found that, for real time processing complex neural network structures are not reliable, therefore in this project work a simple feed forward back propagation neural network is developed for power oscillation damping.

The fundamental steps taken for NN controller modeling are as follows:

Step 1: - Analyze the input for the NN controller.
Step 2:- Select the type of NN.
Step 3:- Analyze the desired output for the NN controlle

After successful development and training of the proposed neural network controller using table-1 the training and testing scenario is shown in the following figure.

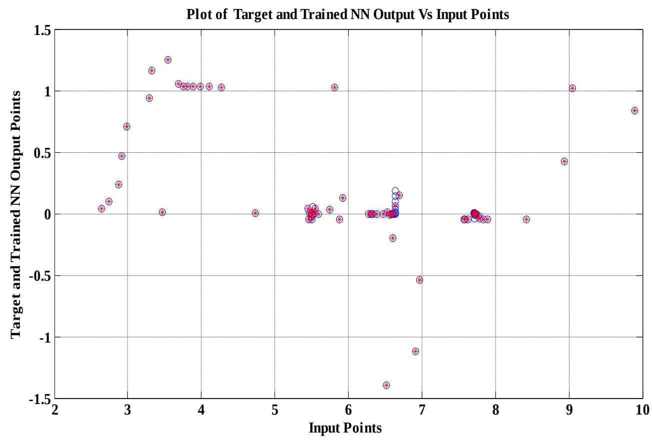

Figure. 2.1 Plot of Target and Trained Neural Network (NN) V/s input point .

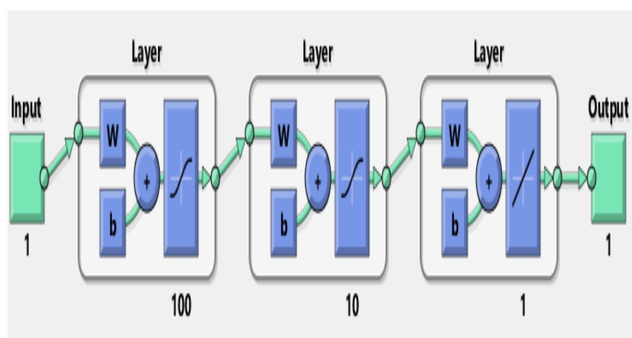

Figure 2.2 Structure of developed Neural Network (NN) controller.

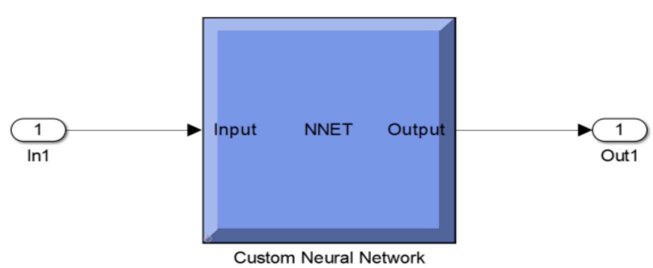

Figure. 2.3 Simulation block of NN controller

International Journal of Scientific Engineering and Technology
Volume No.4 Issue No.6, pp: 365-369
ISSN : 2277-1581
01 June 2015

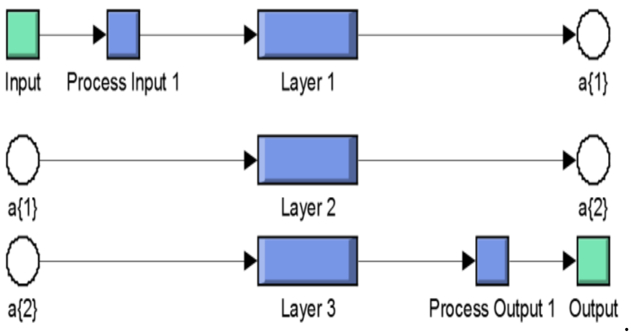

Figure. 2.4 Internal architecture of NN controller.

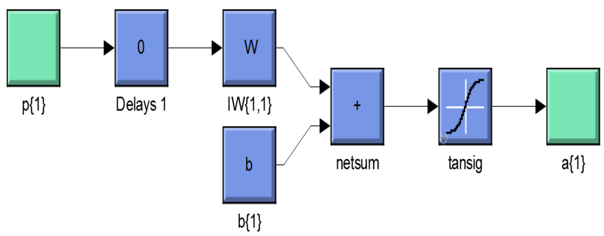

Figure. 2.5 Internal architecture of First Layer.

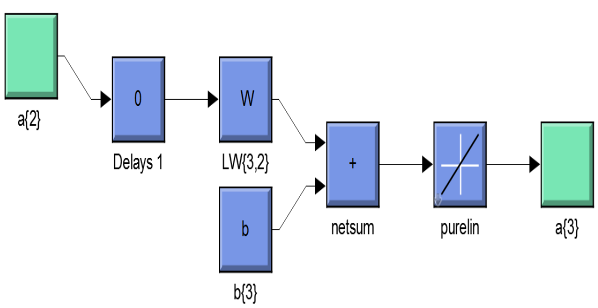

Figure. 2.6 Internal architecture of Second Layer.

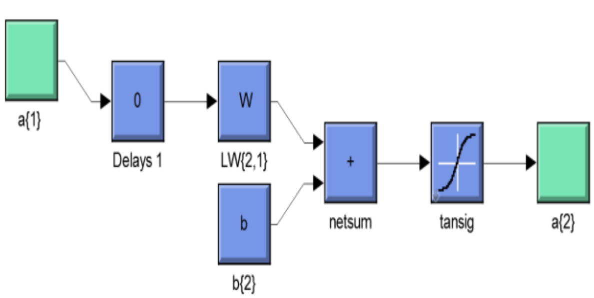

Figure. 2.7 Internal architecture of Third Layer.

TABLE -1 Shows Fifty, Input And Target Points Defined For The Proposed Neural Network Controller

S. No.	NN Input	NN Target
1	6.64	0.194566484
2	6.64	0.194566484
3	6.639996119	0.194363244
4	6.639992325	0.194160165
5	6.639986833	0.193849427
6	6.639980512	0.193463118
7	6.639972809	0.192946522
8	6.63996319	0.192214921
9	6.639952266	0.191229545
10	6.639943257	0.190247973
11	6.639933983	0.189026727
12	6.639926208	0.187811364
13	6.639917712	0.186320117
14	6.639909528	0.184837732
15	6.639900915	0.18336416
16	6.639891357	0.181899359
17	6.639880543	0.180443285
18	6.639865411	0.178672875
19	6.639848233	0.176915402
20	6.639829247	0.175170789
21	6.639808807	0.173438959
22	6.6397873	0.171719835
23	6.639765076	0.170013337
24	6.639742405	0.168319386
25	6.639719463	0.166637902
26	6.639696	0.164969
27	6.639673	0.163312
28	6.63965	0.161667
29	6.639626	0.160035
30	6.639598	0.158069
31	6.639569	0.156121
32	6.639542	0.154191
33	6.639515	0.152278
34	6.63949	0.150382
35	6.639467	0.148503
36	6.639446	0.146641
37	6.639427	0.144796
38	6.63941	0.142967
39	6.639396	0.141155
40	6.639382	0.139359
41	6.63937	0.13758
42	6.639368	0.137286
43	6.639368	0.137286
44	6.639368	0.137286
45	6.639357	0.135525
46	6.639346	0.133781
47	6.639336	0.132052
48	6.639328	0.130339
49	6.63932	0.128641
50	6.639313	0.126959

International Journal of Scientific Engineering and Technology
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Development of SSSC Equipped with NN controller based Power Oscillation Damping System

The actual simulation of the proposed SSSC with NN controller has been successfully implemented in the MATLAB Simulink version 2012b, and the actual simulation model of the project work is shown in Fig. (2.8).

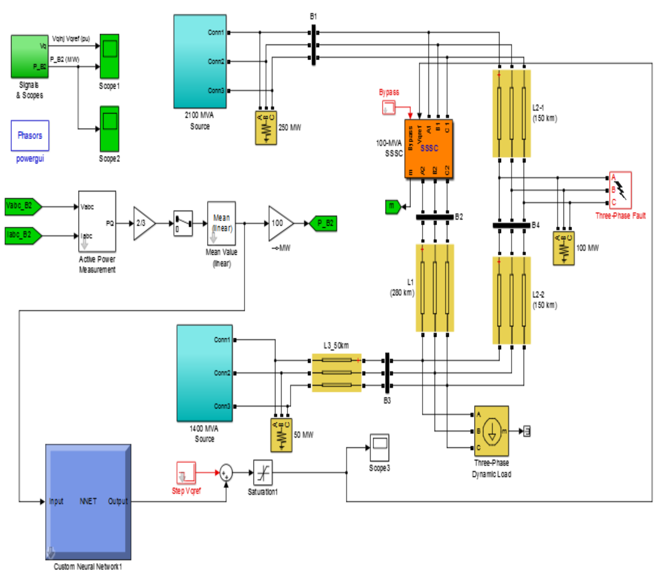

Figure 2.8 Shows actual simulation model of the Proposed Work.

III. Results and Discussions

The Power oscillation damping for proposed SSSC equipped with neural network controller has been successfully implemented in the Matlab Simulink. This section deploys the results obtained and steady state and dynamic performance analysis of results obtained. For the comparative analysis a three phase fault is generated on times 1.33 and 1.5 sec using three phase fault generator.

A. Results Obtained for the proposed transmission line with SSSC equipped with proposed Neural Network controller

Now let us consider the SSSC equipped with proposed neural network controller (NN) in the same transmission line system with same amount of three phase fault. Fig. (3.1) shows the reference voltage and modified reference voltage by neural network reference voltage controller. Finally Fig. (3.2) shows the plot of Plot of VQ $_{\text{Reference}}$ and VQ $_{\text{Injected}}$ by proposed SSSC

With NN controler

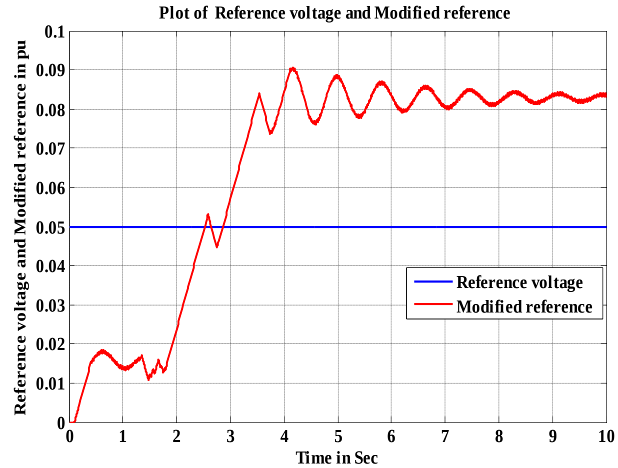

Figure 3.1 shows the reference voltage and modified reference voltage by neural network reference voltage controller

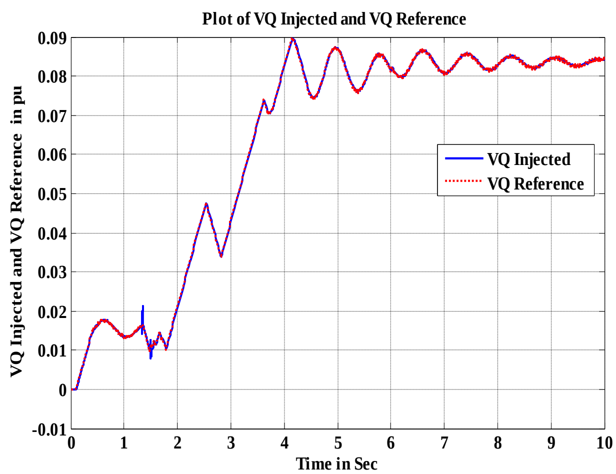

Figure 3.2 Plot of VQ $_{\text{Injected}}$ and VQ $_{\text{Reference}}$ by SSSC with NN Controller

From the resultant figures it is clear that the SSSC with lead leg reference voltage controller provides good damping for power oscillation but still the results having good amount of power oscillation and there is an efficient controller with SSSC with Neural Network which efficiently reduced the power oscillations.

IV. Conclusion

In this Paper, 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. During the investigation it is found that the SSSC based power oscillation damping system cannot able to sustain the power oscillations neither alone nor with lead leg POD controller, hence this project work proposes a novel SSSC structure equipped with the Neural Network Controller to efficiently sustain the power oscillations. Complete Simulations have been done in MATLAB/SIMULINK environment. Simulation results shows of selected bus-2 in three phase 500 KV transmission line system shows the accuracy of this compensator as one of the FACTS devices member controlling power flows, achieving the desired value for active and reactive powers, and also damping oscillations appropriately.

The result section provides complete idea about the power oscillation damping capability of the SSSC with Neural Network Controller. Moreover the system developed is able to provide damping for power oscillations.

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