Reduction of Sub-Synchronous Resonance using Artificial Neural Network

Zahra Amini[1] and Abbas Kargar[2]
[1,2]Department of Power Engineering, Shahrekord University of Technology, Shahrekord, Iran
[1]zahraamini90sku@gmail.com, [2]kargar@ieee.org

Abstract– **When a turbine-generator is connected to a long transmission line may produce side effects such as SSR phenomena that arise. The goal is to use the capabilities of the Series Compensator (DSSC) as a member of the family of D-FACTS is to reduce the SSR. Controller to achieve the desired objective artificial neural network is used. Through simulation and study the system stability in the time domain performance index (PI) based on power system dynamics is considered. The simulation results using Matlab/Simulink have been shown that a neural network can reduce these fluctuations.**

Keywords– **Equipment FACTS, Neural Network and Sub-Synchronous Resonance (SSR)**

I. INTRODUCTION

Series compensated long transmission lines in order to improve power transmission networks are in the power of great importance [1]. Series compensation of transmission lines, reducing the normal load impedance by increasing the electrical length of the line, had a significant impact in promoting stable and improves voltage profiles [2]. Compensated in such networks, electrical networks and modes of interaction between states leads to a phenomenon harmful to the mechanical shaft of the turbine generator under synchronous oscillations (SSR) is [3].

Sub-synchronous resonance phenomenon often occurs in series with the capacitor compensated systems. SSR oscillation phenomenon is that it occurs in the range of electrical and mechanical oscillations gradually increases, and the turbine rotor - Generator simultaneously is that the fluctuations it is not controlled and proper protection, these fluctuations can lead to fatigue or even broken rotor axis [2].

One of the most moving moments SSR phenomenon that different forms of large disturbances in networks with series capacitor compensation is achieved. The currents passing through the Zyrsnkrvn frequency (fe) of the generator stator leads the field at the same frequency, this causes two torque oscillation frequencies $fm = fo \pm fe$ (fo -frequency based system), the rotor is . However, if the frequencies of the two modes of oscillation of the rotor torque fluctuations were nearly equal, the rotor torque grows quickly and thus damaging the rotor axis. In many ways, the various articles under the synchronous oscillations have been proposed to reduce the phenomenon that transmission systems can be AC (FACTS) and also the generator excitation system and power system stabilizer (PSS) effective as noted. FACTS devices are used to reduce the synchronous oscillations have been successful.

Another smart way to reduce oscillations about the synchronous oscillations can be reduced by using a neural network noted [4]. Usefulness of artificial neural networks are able to solve problems of power systems. They are able to input and output of a power system using constant learning process and no need to do the programming of complex [5]. (DSSC) is a new concept of Synchronous Series Compensator (SSSC) is derived. DSSC much lower cost and higher reliability of the SSSC provides. In this paper, the DSSC with controllers' supplements to reduce undesirable oscillations caused by SSR is used. The configuration of the power system for the SSR and response system controller is also provided. In the next section the basic structure and basic configuration of the control DSSC based on indirect control method is presented. ANN will be handled as described below:

II. CONFIGURE THE POWER SYSTEM FOR THE ANALYSIS OF SSR

Figure 1 shows a single line of power systems [6]. The system includes a generator voltage of 22 kV, 600MVA the infinite bus connected through a transformer and two parallel transmissions. Steam turbine is a mechanical system consisting of a high pressure turbine (HP), low-pressure turbine (LP), generator (G) and rotational excitation (EX) on the axis are shown in Figure 1. The power system studied in [7] is given. Other parameters used are the following:

$$L = 80 \text{ mH}; R = 7.4 \Omega; f = 60 \text{ HZ}$$

In the first case, the performance of DSSC modules and control system has been studied in particular. The aim is to clarify the fact that there is no controller, the rotor will suffer, and fluctuations in the system increases. To simulate a three-phase ground fault occurs in the middle of a transmission line is applied at t = 3s after 168 milliseconds it is removed.

III. THE STRUCTURE OF DSSC

DSSC is actually a single-phase SSSC model, but is smaller in size [8], which is used to control the flow Drkhtvt transmission and distribution. Low power DSSC requires the installation of several modules in each line transmission. Figure 2 shows schematically the module components [8].

The structure consists mainly of a transformer, a processing unit as a controller, inverter to generate sinusoidal voltage, transformer (STT) to insert voltage transmission line, a supply of energy, CPU, and hardware interfaces to send and receive signals to r controller is formed [9]. Eliminate or reduce the harmonic voltage generated by an LC filter connected to the output of the inverter is made. STT-conductor transmission line transformer using a secondary turns ratio (100:1) is designed, highly evolved. A typical neural network shown in Figure 5, it is composed of three layers. Here, as in entrances fuzzy neural network controller and the rate of change of velocity variations are derived. Using the inputs to the neural network is formed and trained.

IV. SSR CONTROL USING NEURAL NETWORKS

A. Neural Network Training

In order to train a neural network to determine the network weights and most important of all is learning to talk. Training a neural network depends on the network type. Weight adjustment is done via the following equation:

$$wji\ (n+1) = wji\ (n) + \Sigma \Delta wji\ (n) \quad (1)$$

In this regard, n number of replicates Δjiwji (n), the change in weight for each pattern. Also,

$$\Delta jiwji\ (n+1) = \eta\ \delta jioji + \alpha\ \Delta jiwji\ (n) \quad (2)$$

In this equation: η learning rate, δ activation function derived from the training error and α depend on the speed of movement.

B. Control DSSC with Neutral Network

The main task of the control DSSC is in line with the direct control of the target can be achieved [10]. Figure 3 schematically illustrates the indirect control of a DSSC. Figure 4 schematically illustrates the control DSSC with neutral network.

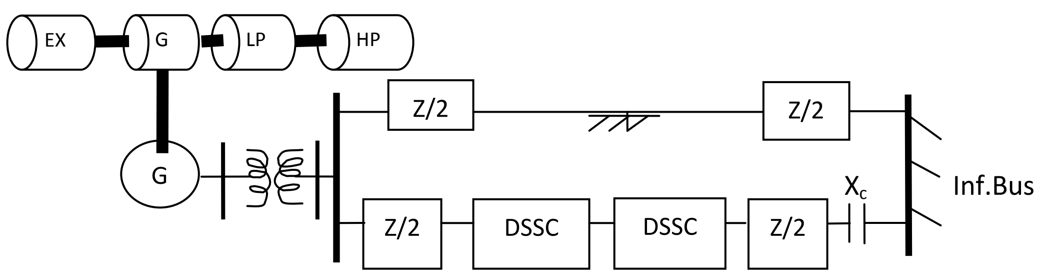

Fig. 1. The model aggregated with DSSC for SSR analysis

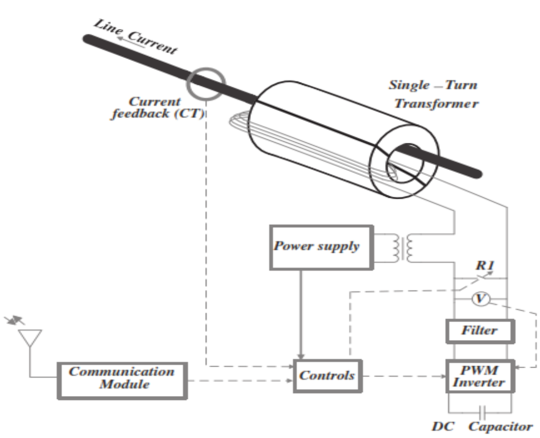

Fig. 2. Circuit schematic of a DSSC module

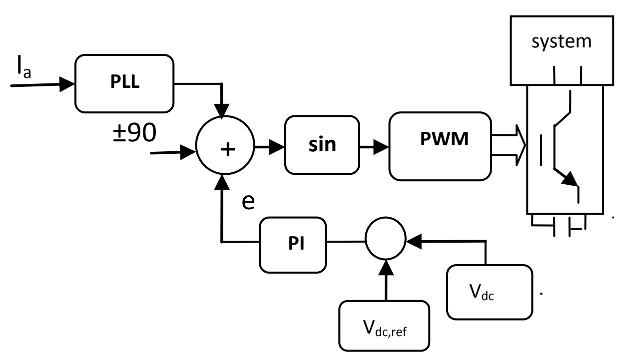

Fig. 3. Indirect control of the DSSC

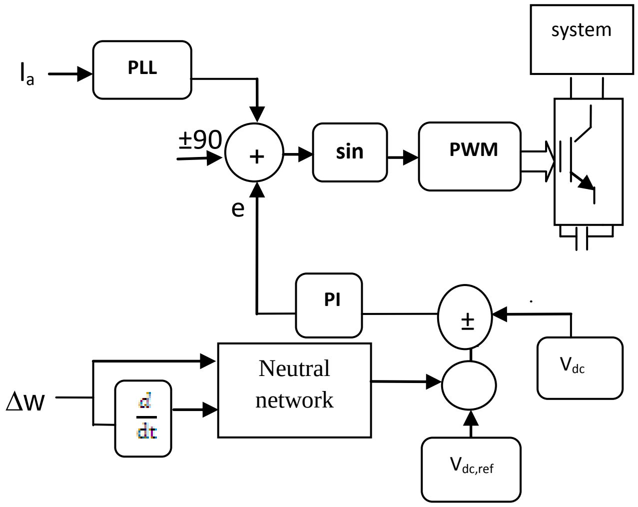

Fig. 4. Neutral supplemented to DSSC controller

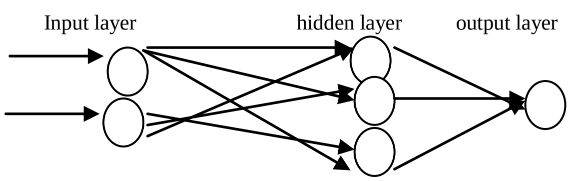

Fig. 5. Multi-layer Neural Network

V. SIMULATION RESULTS

Simulation results will be presented in this section. For the first case, without controller, three phases to ground fault occurs at time 3 seconds and 168 milliseconds after it is removed. When the compensation mechanism for controlling the amplitude fluctuations do not use the electric torque is increased and several times the amount his name to be. When the error disappears, fluctuations between the turbine generator shaft would be large and the system is totally unsustainable and can not be controlled by any suitable method axis.

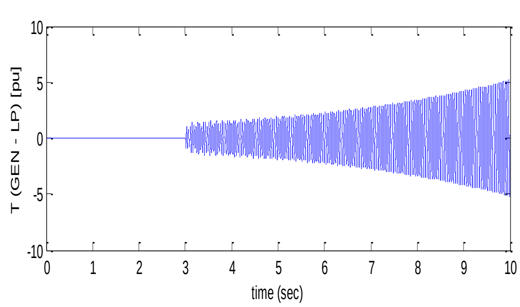

Fig. 6. Torque the low pressure turbine (LP) and the generator without controller

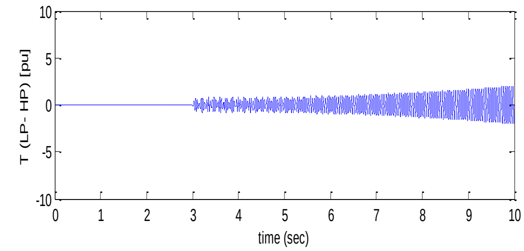

Fig. 7. Torque the low pressure turbine (LP) and high pressure (HP) without controller

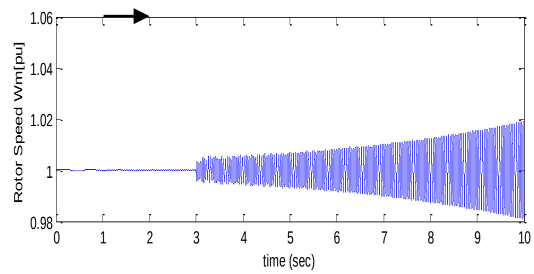

Fig. 8. The speed of the rotor without controller

Using neural network as a fuzzy logic controller is shown that the amplitude of oscillations of the electric torque is reduced.

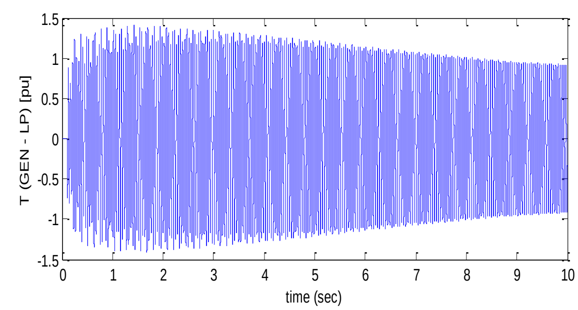

Fig. 9. Torque between the LP turbine and low pressure turbine generators using neural networks

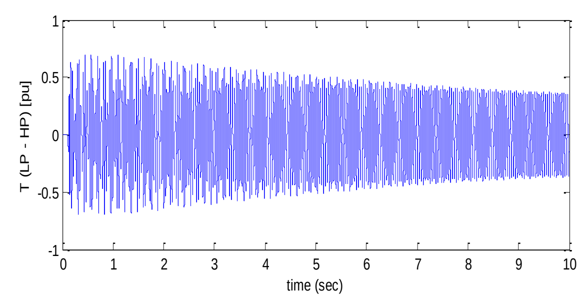

Fig. 10. Torque the low pressure turbine (LP) and high pressure (HP) using neural networks

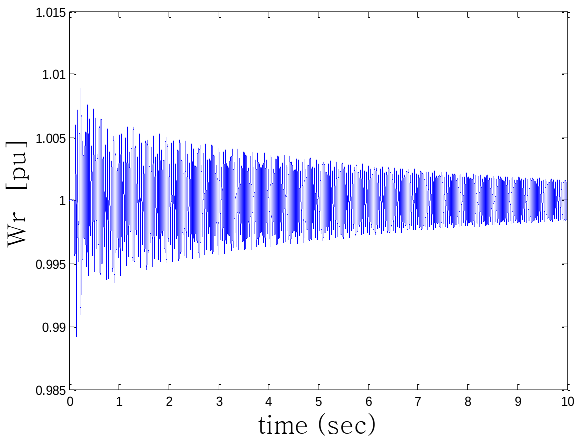

Fig. 11. The speed of the rotor using neural networks

VI. CONCLUSIONS

This paper will review the terms of the incidence of SSR in Series Compensated Networks. Was expressed as a fixed capacitor compensated line is used, the resonant frequency of the electrical network may be synchronized with rotor torsional frequencies and cause interference to SSR. In case of not using a domain controller for the electric torque oscillations increases and reaches to several times its nominal value. If not properly controlled can shaft torque with rotor damage. But if the DSSC as a compensator with neural network is used to optimize the SSR is observed that the network is secure. Using data obtained from the neural network model was designed and trained, as the simulation results shows good performance in synchronous neural networks to reduce the oscillations.

Appendix:

Controller coefficients PI

$K_p=0.5, K_I=0.1$

REFERENCES

[1]. RM. Mathur, RK. Varma, "Thyristor-based FACTS controllers for electrical transmission systems". New York, USA: IEEE Press and Wiley Interscience;2002.

[2]. MRA. Pahlavani, HA. Ohammad pour, "Damping of sub-synchronous resonance and low-frequency power oscillation in a series-compensated transmission line using gate-controlled series capacitor". Electr Power Sys Res 2011;81(2):308–17

[3]. S. Mohammad. Widyan, ‘‘On the effect of AVR gain on bifurcations of subsynchronous resonance in power systems’’. Electr Power Energy Syst 2010;32(6):60–76.

[4]. P. Fajri, S. Afsharnia, D. Nazarpour and MA. Avallaei, "Modeling simulation and group control of distributed static series compensators capabl of damping subynchronousresonance Distrib". IET Gen Transm. Am J Eng Appl Sci 2008:347–57[ISSN 1941-7020]. 2010;4(3):456–66.

[5]. SL. Ho, S. Yang, G. Ni, EWC. Lo and HC. Wong ,"A particle swarm optimization based method for multi objective design optimizations". IEEE Trans Magnet2005;41(5):1756–9.

[6]. IEEE SSR Working Group, "Second benchmark model for computer simulationof of subsynchronous resonance". IEEE Trans Power Apparatus Syst1985;104(5):1057–64.

[7]. IEEE SSR Working Group, "Second benchmark model for computer simulation. Subsynchronous resonance"..IEEE transmission and distribution Conference. New Orleans, Louisiana; 2005.

[8]. J. Khazaie, M. Mokhtari, M. Khalilyan and D. Nazarpour, "SubSynchronous Resonance damping using Distributed Staticeries Compensator (DSSC) enhanced with fuzzy logic controller" *ELSEVIER* Electrical Engineering Department, Urmia University, 10 May 2012.

[9]. D. Divan. "Distributed intelligent power networks-a new concept for improving T&D system utilization and performance" In: IEEE transmission and distribution Conference. New Orleans, Louisiana; 2005.

[10]. NG. Hingorani, L. Gyugyi," Understanding FACTS: concepts and technology of flexible ac transmission system". NY: IEEE Press; 2000.

Zahra Amini was born in shahrekord, Iran. She received his B.Sc. degree from the Department of Electrical Engineering, shahrekord University, shahrekord, Iran. Now she is a student in Power Engineering at shahrekord University.

Abbas Kargar received his B.Sc., M.Sc., and Ph.D. degrees with honors in Power Engineering from Isfahan University of Technology (IUT), Iran. He has been with the Department of Power Engineering at shahrekord University, Iran. His current research interests include Power systems, and smart System and power electronics.