Applied Soft Computing 13 (2013) 1750–1758

Contents lists available at SciVerse ScienceDirect

Applied Soft Computing

journal homepage: www.elsevier.com/locate/asoc

# Design of artificial neuron controller for STATCOM in dSPACE environment

S. Arockia Edwin Xavier*, P. Venkatesh, M. Saravanan

*EEE Department, Thiagarajar College of Engineering, Madurai 625 015, Tamilnadu, India*

ARTICLE INFO

*Article history:*
Received 29 July 2011
Received in revised form 3 January 2013
Accepted 6 January 2013
Available online 17 January 2013

*Keywords:*
Artificial Neural Network
dSPACE DS1104
STATCOM
PI controller
Pulse width modulation

ABSTRACT

Reactive power compensation is an important issue in the control of electric power system. Reactive power from the source increases the transmission losses and reduces the power transmission capability of the transmission lines. Moreover, reactive power should not be transmitted through the transmission line to a longer distance. Hence Flexible AC Transmission Systems (FACTS) devices such as static compensator (STATCOM) unified power flow controller (UPFC) and static volt–ampere compensator (SVC) are used to alleviate these problems. In this paper, a voltage source converter (VSC) based STATCOM is developed with PI and Artificial Neural Network Controller (ANNC). The conventional PI controller has more tuning difficulties while the system parameter changes, whereas a trained neural network requires less computation time. The ANNC has the ability to generalize and can interpolate in between the training data. The ANNC designed was tested on a 75 V, ±3KVAR STATCOM in real time environment via state-of-the-art of digital signal processor advanced control engineering (dSPACE) DS1104 board and it was found that it was producing better results than the PI controller.



## 1. Introduction

The improvement in power semiconductor devices acts as a major factor for the increased importance of power electronics in future power system. A power electronic converter based high speed 360° phase shifter can control power flow between two systems, regardless of frequency, voltage and impedance variations [1]. The operation of different FACTS devices such as SSR damper, phase angle regulator, static condenser, STATCOM and Thyristor Controlled Series Capacitor (TCSC) were discussed and the role of the above devices in the future power system was also studied [2]. STATCOM is designed based on VSC topology and sinusoidal PWM technique is used to control the amplitude and phase of converter output voltage. TMS320F240 DSP based ±3 KVAR rating STATCOM is reported for compensating lagging and leading power factor loads [3]. A high power self commutating inverter based static condenser (STATCON) is developed and two types of modules for voltage and phase angle control are explained from the basic fundamental equations and transient response curve is given [4]. Experimental ±5 KVAR STATCOM model using DSP, with sinusoidal PWM control having the carrier frequency of 2.8 kHz is developed. PI controller is designed using 'dq' frame linearized model and system parameters variations such as, variation of load of 2.3 kW and closed loop dynamics are observed in 30 kVA and 110 V system [5].

The mathematical model of STATCOM based on space vector theory and also the behavior of STATCOM for voltage regulation with simple PI controller is simulated with ATP-EMTP. The value of the capacitor is changed in steps and the frequency of oscillations for various steps is studied. Magnitude of reactive current injected/absorbed by STATCOM is linearly proportional to phase angle. It is also observed that the bus voltage is recovered within three cycles after the load disturbance is given [6]. A discrete linear time varying model of the three-phase VSC is developed and this model is employed to determine the steady-state operating characteristics of a VSC in closed loop form, as a function of converter duty cycle and phase angle [7]. A schematic for the reconfigurable FACTS system is designed and a real time control for the above FACTS system is also developed. The state models for STATCOM, Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC) are designed using 'dq' co-ordinates. A PI based controller is developed for the above models. Simulations and experimental results are compared and verified [8].

A novel switching function model for the STATCOM, SSSC and the UPFC based on a multi-pulse voltage-sourced converter topology had been developed [9]. Recent advances in computing hardware, sophisticated power system, and component modeling techniques are significantly increasing the application of real time digital simulation in power system industry. Real time operation implies that an event in the system which lasts for 1 s is simulated on the simulator exactly in 1 s. The performance of the STATCOM controller is validated in real time using a detailed model of the power system implemented using Linux PC-based, multi-processor technology [10]. In the hardware in loop (HIL) simulation, an actual controller for STATCOM is connected in closed loop with a real-time virtual plant model. The challenges of real-time simulation such as, achieving a very small time step with a power system

* Corresponding authors. Tel.: +91 452 2482240; fax: +91 452 2483427.
*E-mail address:* saexeee@tce.edu (S. Arockia Edwin Xavier).

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http://dx.doi.org/10.1016/j.asoc.2013.01.005

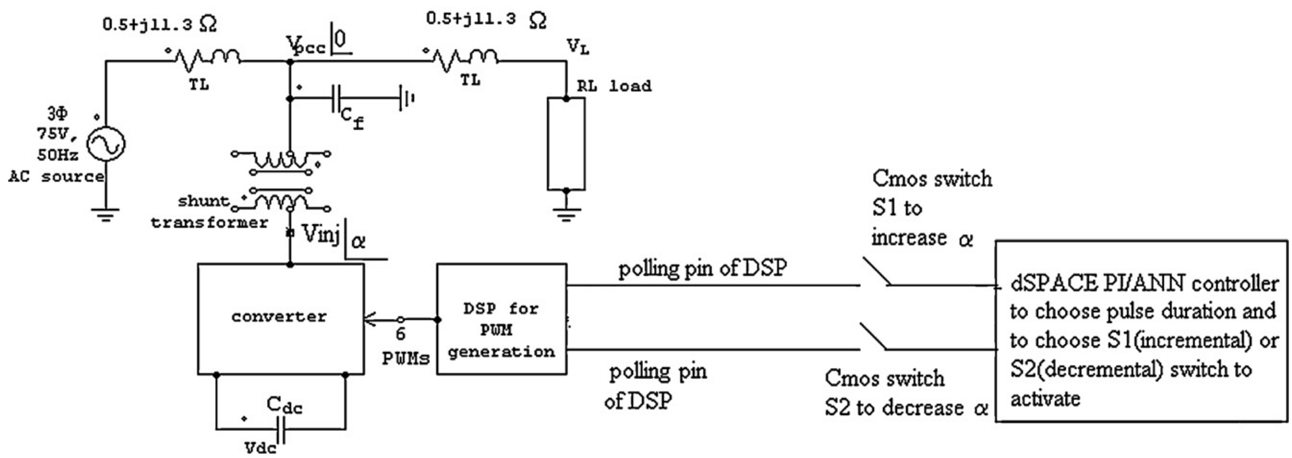


**Fig. 1.** Single line diagram of a STATCOM connected to a power system with PI/ANN controller.

containing multi-switch devices, preventing the non-characteristic harmonics, and achieving the simulator scalability by distributing the simulation execution over several processors had been overcome using PC based RT-LAB simulator [11]. A VSC based STATCOM is modeled using MATLAB simulink tool boxes. A real time hardware for STATCOM is developed and using dSPACE software and DSP controller, the modulation index and phase angle are adjusted to get the required reactive power compensation. Simulation and experimental results are compared [12]. A neuro fuzzy controller is designed for STATCOM in such a way that it improves the damping of the rotor speed deviations of its neighboring generator [13]. A coordination controller is developed to minimize the number of tap-changes in the transformer while maintaining an acceptable STATCOM output voltage magnitude at the substation bus [14]. In [15] a transformer less STATCOM has been developed and experimentally verified at 200 V system. In [16] the improvement of power system stability was made by modeling and designing of cascade pi and fuzzy logic controllers for STATCOM.

From the literature survey, it is found that numbers of controllers have been suggested for the STATCOM. The controller for the STATCOM has been designed and simulated using different simulation software. There is a lack of proto type model of power system with intelligent controllers for STATCOM. There is also a lack of clear comparison of performance of different controllers in dSPACE environment, which is a real time simulation software and has lot of advantages over other simulation software. This research aims at covering this gap, by introducing the intelligent controller ANNC for STATCOM which is connected to the transmission line. The best controller out of PI and ANNC is suggested when STATCOM is subjected to different loading conditions.

In order to fully understand how to effectively incorporate FACTS devices in the existing power system, a hardware prototype for verification is necessary in addition to software simulation. A PI controller is implemented in a neural network called ANNC is presented in this paper. The ANNC is trained in such a way to reduce the steady state error, peak overshoot and settling time. The STATCOM is simulated with the trained neural network to achieve the desired performance using matlab/simulink. The performance of the above STATCOM is experimentally verified with PI and ANNC. The reference value of point of common coupling voltage ($V_{pcc}$) is varied while the real time simulation is running and then the ability of STATCOM to track the reference $V_{pcc}$ ($V_{pccref}$) is observed.

A real time simulation of a power system with STATCOM under load disturbance is done with PI and ANN controller using a practical hardware of ±3 KVAR, 75 V STATCOM and its performance is experimentally verified via state-of-the-art dSPACE DS1104.

## 2. Proposed STATCOM with PI/ANN controller

Fig. 1 shows the single line diagram of a power system with STATCOM. The STATCOM is connected at the middle of the transmission line. It consists of a VSC, a dc capacitor $C_{dc}$, shunt transformer, controller and a filter capacitor ($C_f$). The VSC in STATCOM is modeled by connecting a 3 arm IGBT bridge. Each IGBT is anti-paralleled by a diode. Sine triangular PWM technique is used to generate the AC sinusoidal output. The modulating signal is of 50 Hz sine wave and the carrier wave is of 20 kHz triangular wave. The converter output is in PWM form. In order to bring it to sine waveform, a LC filter is connected to filter out the content of carrier wave having frequency of 20 kHz. The inductance of shunt transformer will act as 'L' for the LC filter.

dSPACE demonstrates high-end control development from block diagram design to on line controller optimization. It is possible to test even the most complex control systems in real time using dSPACE. It is possible to implement the simulink model of any system on dSPACE real time hardware within seconds. It is also possible to observe the effects of parameter changes on system's behavior. It helps in varying the system parameters while doing the simulation so that the dynamic performance of the system can be easily observed. The DS1104 board consists of 8 ADCs and 8 DACs for interfacing.

The dSPACE layout of STATCOM model is created in SIMULINK environment. Then this model layout is converted into DSP code which runs in the in-built TMS320F240 DSP processor in the dSPACE controller. A dSPACE connector panel (CLP1104) ports provide easy access to all input and output signals of the DS1104 board.

Since in dSPACE the simulation step size is 1 ms it is not possible to generate a carrier wave of 20 kHz in the simulink model of STATCOM. In order to produce a sine triangular PWM for STATCOM a dedicated DSP TMS320F2407 is used. In that a sine wave of 50 Hz and carrier wave of 20 kHz is compared and PWM is produced. A Phase Locked Loop (PLL) for synchronization with the bus voltage is used. A dead zone of 5 μs is used in between the positive and negative group switching of IGBTs in VSC to avoid short circuit.

In order to vary the reactive power injected/absorbed by the STATCOM, the STATCOM injected voltage phase angle '$\alpha$' is varied. To vary the phase angle, two CMOS switches (increment and decrement) which are connected to two polling pins of the DSP TMS320F240 are used. The signal on the polling pin is given through increment switch from dSPACE and it is used to increment '$\alpha$' and that of given through decrement switch is used to decrement '$\alpha$'. The modulation index is kept constant at 0.5.