**Advancements in Electrical and Electronics Technology**
Received: Feb 06, 2016, Accepted: Mar 02, 2016, Published: Mar 05, 2015
Adv Electr Electron Technol, Volume 2, Issue 1
http://crescopublications.org/aeet/AEET-2-006.pdf
Article Number: AEET-2-006

Research Article Open Access

# An Advanced ANN System Based DSTATCOM Control for an Application of Electric Ship Power System

**Abdul Anwar Khan[1*], Dawood Shaik[2] and Dr. Abdul Ahad[3]**

[1]M.Tech (P.S) PG Scholar, Department of EEE, Nimra Institute of Science & Technology, Vijayawada, Andhra Pradesh, India

[2] Assistant Professor, Department of EEE, Nimra Institute of Science & Technology, Vijayawada, Andhra Pradesh, India

[3]Professor, Department of EEE, Nimra Institute of Science & Technology, Vijayawada, Andhra Pradesh, India

***Corresponding Author:** Abdul Anwar Khan, M.Tech (P.S) PG Scholar, Department of EEE, Nimra Institute of Science & Technology, Vijayawada, Andhra Pradesh, India.

**Citation:** Abdul Anwar Khan, Dawood Shaik and Dr. Abdul Ahad (2016) An Advanced ANN System Based DSTATCOM Control for an Application of Electric Ship Power System. Adv Electr Electron Technol 2: 006.


## Abstract

Distribution Static Compensator (DSTATCOM) is a shunt compensation device which is generally used to solve power quality problems in distribution systems. In an all-electric ship power system, these power quality problems mainly arise due to the pulsed loads, which causes the degradation of the entire system performance. This paper presents the application of DSTATCOM to improve the power quality in a ship power system during and after pulsed loads. The control strategy of the DSTATCOM plays an important role in maintaining the voltage at the point of common coupling. A novel adaptive control strategy for the DSTATCOM based on artificial neural networks (ANN) is proposed. The optimal parameters of the controller are first found using particle swarm optimization. This provides a sort of innate immunity to common system disturbances. For unusual system disturbances, these optimal parameters are modified online, thus providing adaptive immunity in the control system.

## Introduction

The power system of an all-electric navy ship has an integrated network, where the propulsion load, the distribution loads, sensor and other emergency loads and pulse loads (rail guns, aircraft launchers etc.) – all are part of the same electrical network. Among the loads, the effects of pulsed loads are most detrimental for the power quality of ship power distribution system as the pulsed loads require a very high amount of power for a very short period of time. In order to improve the survivability of a navy ship in battle condition, DSTATCOM or Distribution Static Compensator can be used, which reduces the impact of pulsed loads on the bus voltage and thus keeps the bus voltage at desired level. DSTATCOM is a voltage-source inverter (VSI) based shunt device generally used in distribution system to improve power quality. The main advantage of DSTATCOM is that, it has a very sophisticated power electronics based control which can efficiently regulate the current injection into the distribution bus. The second advantage is that, it has multifarious applications, e.g.

a) Canceling the effect of poor load power factor,

b) Suppressing the effect of harmonic content in load currents,

c) Regulating the voltage of distribution bus against sag/swell etc.

d) Compensating the reactive power requirement of the load and so on

This paper presents the application of DSTATCOM to improve the power quality in a ship power system during and after pulsed loads. In addition, a novel adaptive control strategy for a DSTATCOM based on Artificial Neural networks (ANN) is proposed. Most of the CI techniques are offline and require prior knowledge of the system behavior. But ANN, which is inspired by theoretical immunology and observed immune functions, principles and models, has the potential for online adaptive system identification and control. Abnormal changes in the system response are identified and acted upon without having any prior knowledge. The AIS DSTATCOM controller exhibits innate and adaptive immune system behaviors.

## DSTATCOM and Its Control Structure

The simplest structure of a DSTATCOM is shown in Figure 1. The principle of operation of DSTATCOM is based on the fact that the real and reactive power can be adjusted by adjusting the voltage magnitude of the inverter (*VC*) and the angle difference between the bus and the inverter output ($\alpha$). The equations for active and reactive power are:

In steady state operation, the angle $\alpha$ is very close to zero. Now, if *VPCC* < *VC*, reactive power flows from the DSTATCOM to the bus. So, by controlling the inverter voltage magnitude *VC*, the reactive power flow from the DSTATCOM can be regulated. This can be done in several ways. In this paper, a GTO based square wave Voltage Source Converter (VSC) is used to generate the alternating voltage from the DC bus. In this type of inverters, the fundamental component of the inverter output voltage is proportional to the DC bus voltage. So, the control objective is to regulate *VDC* as per requirement. Also, the phase angle should be maintained so that the AC generated voltage is in phase with the bus voltage. The schematic diagram of the control circuit is shown in Figure 2. Here, the PLL synchronizes the GTO pulses to the system voltage and generates a reference angle. This reference angle is used to calculate positive sequence component of the DSTATCOM current using a-b-c to d-q- 0 transformation. The voltage regulator block calculates the difference between reference voltage and measured bus voltage and the output is passed through a ANN controller to generate the reactive current reference *Iq_ref*. This *Iq_ref* is then passed through a current regulator block to generate the angle α. This current regulator block also consists of a PI controller to keep the angle α close to zero.

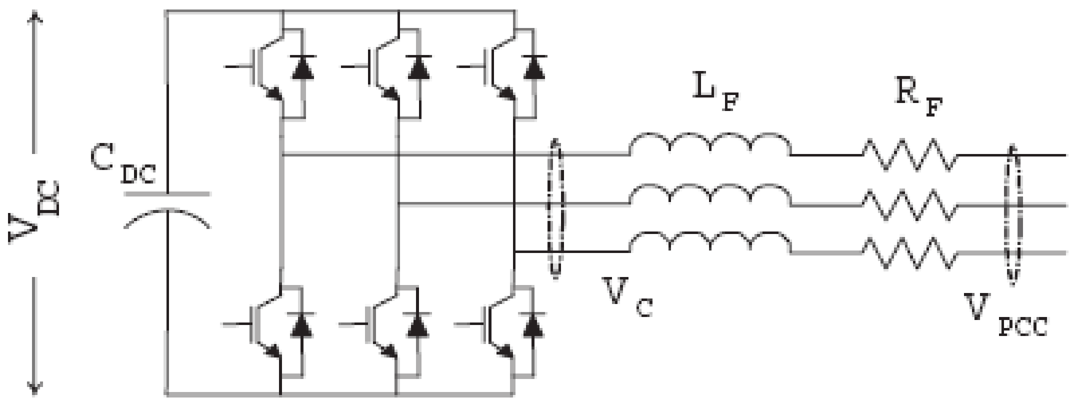


**Figure 1:** Schematic diagram of DSTATCOM

The Firing Pulse Generator block generates square pulses for the inverter from the output of the PLL and the current regulator block. If due to the application of a pulsed load the bus voltage reduces to some extent, the voltage regulator changes the *Iq_ref* and as a result the current regulator increases the angle α so that more active power flows from bus to the DSTATCOM and energizes the capacitor. So the DC voltage increases and consequently the AC output of the inverter also increases and the necessary reactive power flows from DSTATCOM to the bus.

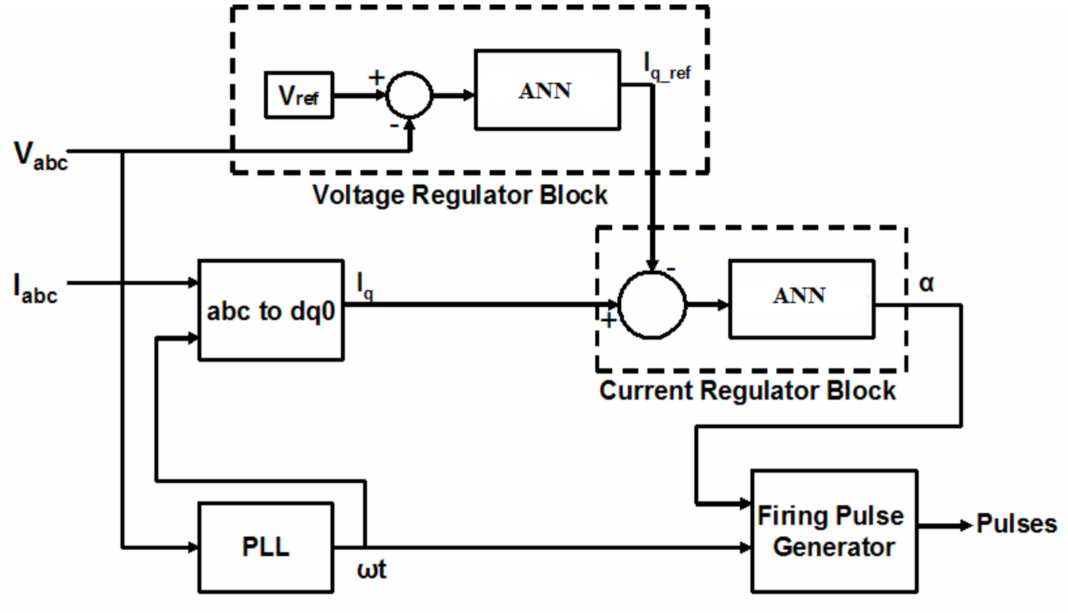


**Figure 2:** Control Structure for the DSTATCOM

## PSO Based Tuning of DSTATCOM Controller

Particle swarm optimization is a population based search algorithm modeled after the motion of flock of birds and school of fish. A swarm is considered to be a collection of particles, where each particle represents a potential solution to a given problem. The particle changes its position within the swarm based on the experience and knowledge of its neighbors. Basically it 'flies' over the search space to find out the optimal solution. Initially a population of random solutions is considered. A random velocity is also assigned to each particle with which they start flying within the search space. Also, each particle has a memory which keeps track of its previous best position and the corresponding fitness. This previous best value is called the '*pbest*' of a particle. The best of all the '*pbest*' values is called '*gbest*', of the swarm. The fundamental concept of PSO technique is that the particles always accelerate towards their '*pbest*' and '*gbest*' positions at each search instant *k*. Figure 3 demonstrates the concept of PSO, where

a) *xid(k)* is the current position of *ith* particle with *d* dimensions at instant *k*.
b) *xid(k+1)* is the position of *ith* particle with d dimensions at instant *(k+1)*.
c) *vid(k)* is the initial velocity of the *ith* particle with *d* dimensions at instant k.
d) *vid(k+1)* is the initial velocity of the *ith* particle with *d* dimensions at instant *(k+1)*.
e) *w* is the inertia weight which stands for the tendency of the particle to maintain its previous position.
f) *c1* is the cognitive acceleration constant, which stands for the particles' tendency to move towards its '*pbest*' position.

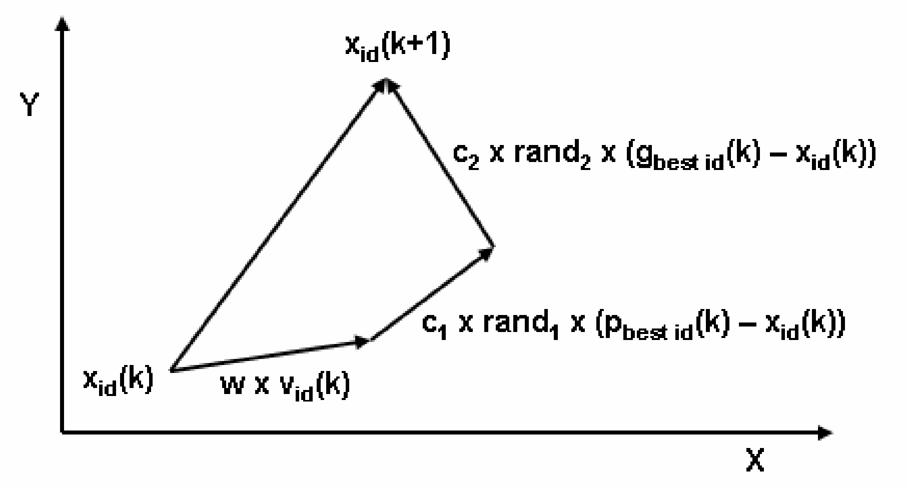


**Figure 3:** Concept of changing a particle's position in two dimensions

g) *c2* is the social acceleration constant which represents the tendency of the particle to move towards the '*gbest*' position.

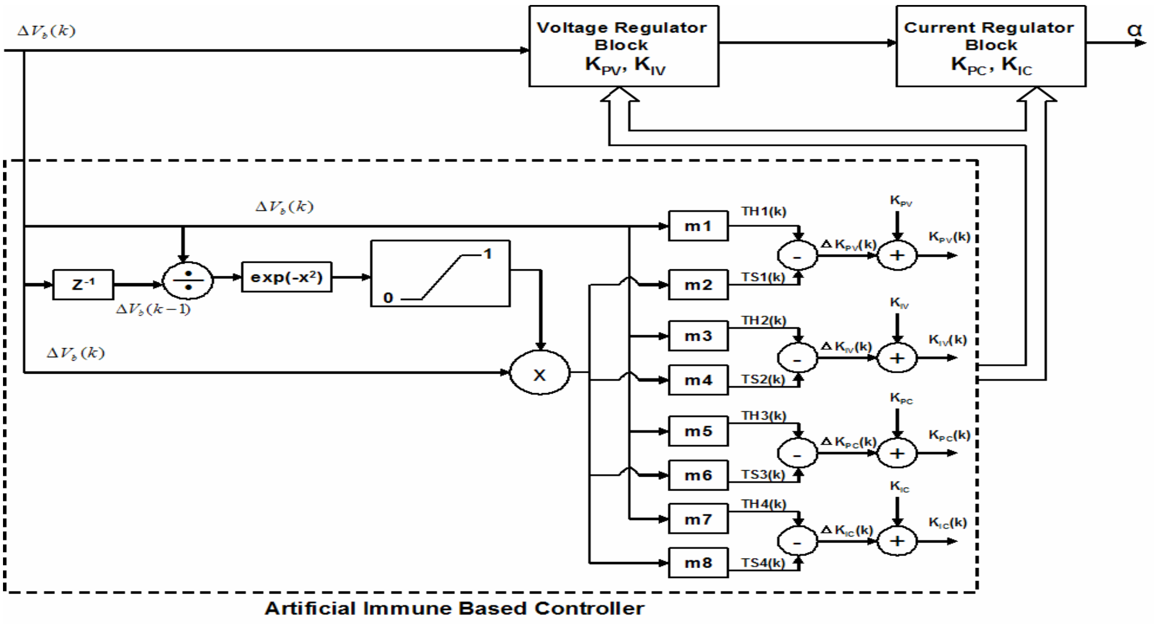


**Figure 4:** Adaptive Controller for the DSTATCOM

## Results

As the DSTATCOM controller is tuned by PSO for a specific operating range, it achieves an innate immunity towards the pulsed load disturbances close to this range. So, ANN based adaptive controller action cannot be distinguished for a pulsed load of the same range. To observe the effect of ANN control strategy three unusual disturbances are simulated. The first one is a pulsed load of 20 MW/40 MVAR with duration of 100 milliseconds. The second one is of same magnitude but having duration 200 milliseconds and the third one is the worst operating condition with a pulsed load of 20 MW/50 MVAR and duration 200 milliseconds. The performance of the PSO tuned DSTATCOM controller and the ANN based adaptive controller are compared with each other as well as with a system having no DSTATCOM connected to it.

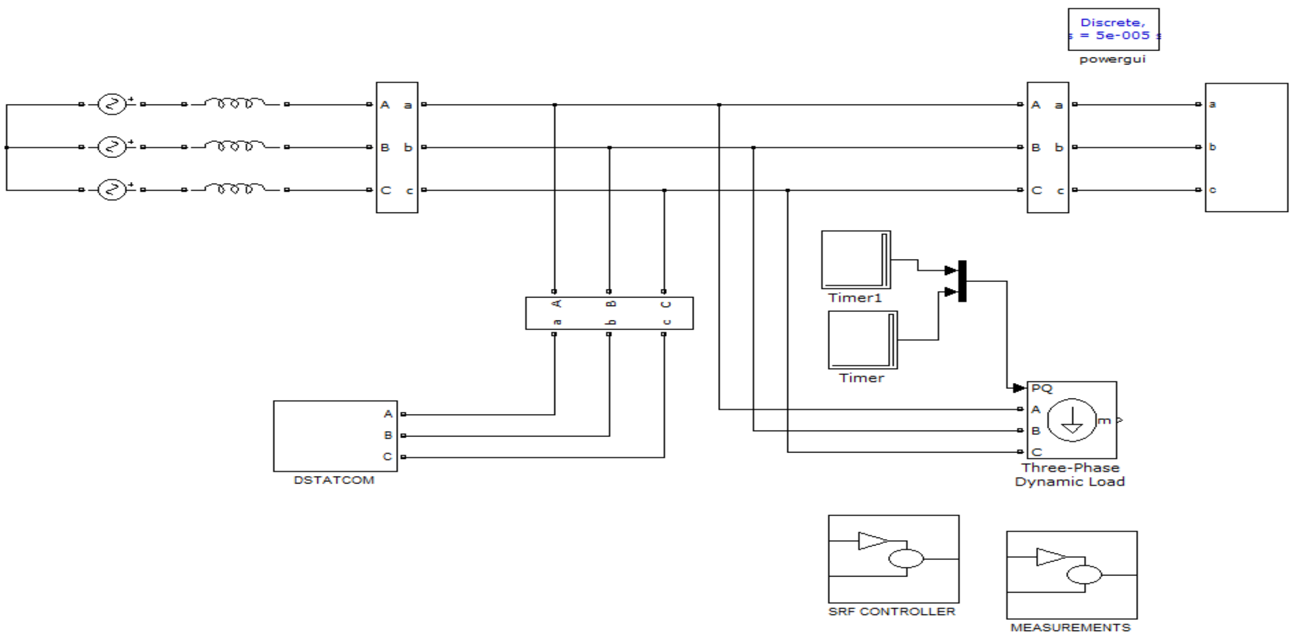


**Figure 5:** Simulation diagram of DSTATCOM.

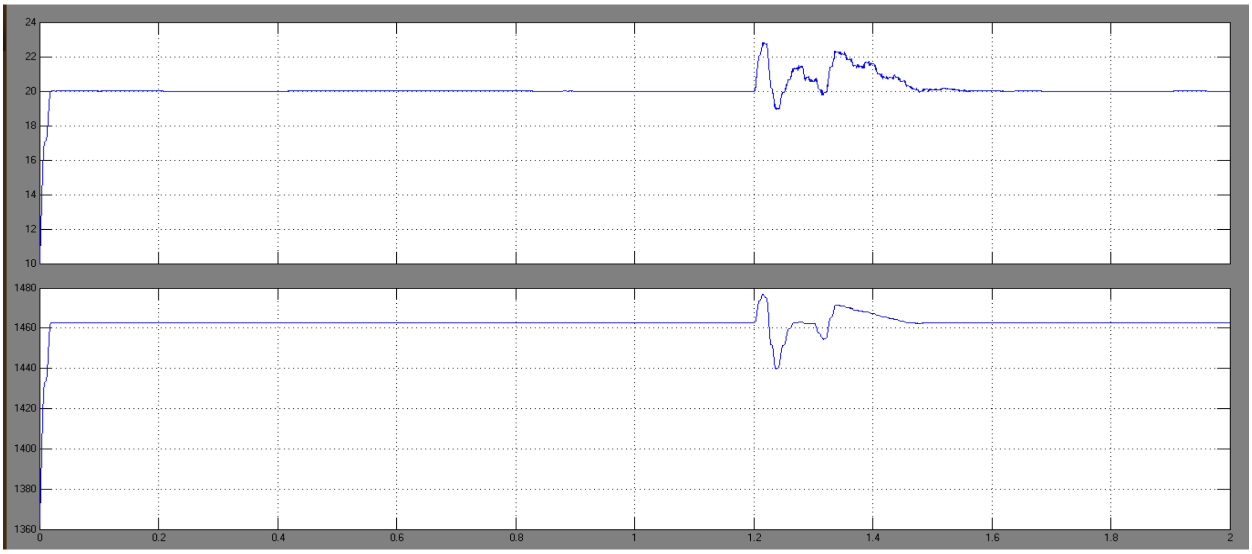


**Figure:** Proportional voltage, Integral voltage

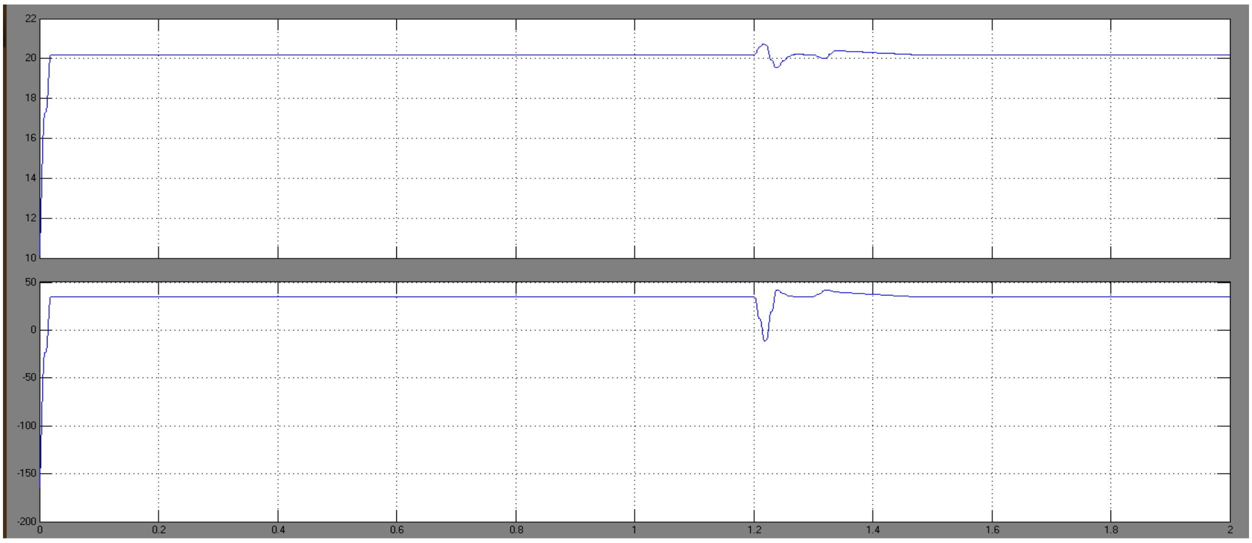


**Figure**: Proportional current, Integral current

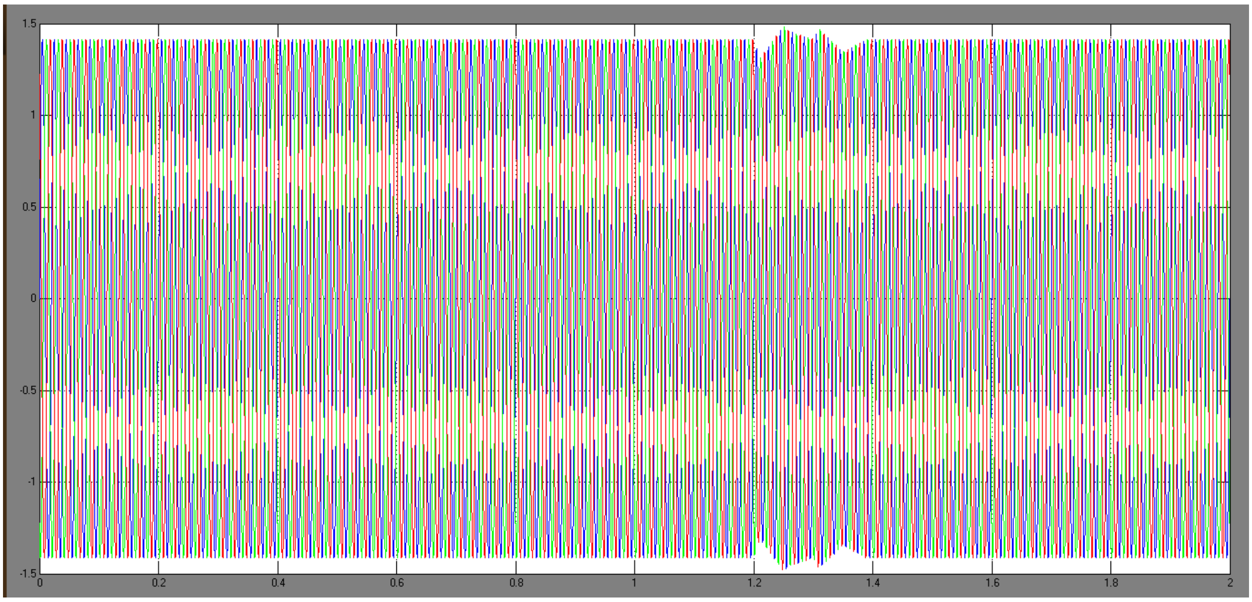


**Figure:** Three phase Source voltage

## Conclusion

This paper has presented the application of DSTATCOM to improve the power quality in a ship power system during and after pulsed loads. In addition, an adaptive control strategy of DSTATCOM based on artificial immune system has been developed. The innate immunity to common disturbances is achieved using a controller whose optimal parameters are determined by particle swarm optimization algorithm. For unknown disturbances, adaptive immunity is developed based on immune feedback principles. The simulation results show that the voltage regulation at the point of common coupling is much better with a DSTATCOM. Also, it is evident from the results, that as the system faces severe and unexpected disturbances, the role of ANN based adaptive controller becomes more prominent. This ensures a better survivability of an electric ship against unusual system disturbances created by pulsed loads.

## References


[1] M. Steurer, M. Andrus, J. Langston, L. Qi, S. Suryanarayanan, S. Woodruff and P.F. Ribeiro, "Investigating the Impact of Pulsed Power Charging Demands on Shipboard Power Quality", Proceedings of the IEEE Electric Ship Technologies Symposium, 2007, ESTE '07, pp. 315-321.

[2] A. Shukla, A. Ghosh and A. Joshi "Control Schemes for DC Capacitor Voltages Equalization in Diode-Clamped Multilevel Inverter-Based DSTATCOM", IEEE Transactions on Power Delivery, vol 23, no 2, April 2008.pp1139-1149.

[3] A. Ghosh and G. Ledwich, "Applications of Power Electronics to Power Distribution Systems", IEEE Tutorial Course, 2006.

[4] M. K. Mishra, A. Joshi, and A. Ghosh, "Control schemes for equalization of capacitor voltages in neutral clamped shunt compensator" IEEE Trans. Power Del., vol. 18, no. 2, pp. 538– 544, Apr. 2003.

[5] A. Shukla, A. Ghosh, and A. Joshi, "Hysteresis current control operation of flying capacitor multilevel inverter and its application in shunt compensation of distribution systems," IEEE Trans. Power Del., vol. 22, no. 1, pp. 396–405, Jan. 2007.

[6] A. Shukla, IEEE, A. Ghosh, and A. Joshi "State Feedback Control of Multilevel Inverters for DSTATCOM Applications," IEEE Transaction.