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# Applications of DSTATCOM Using MATLAB/Simulation in Power System

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***Abstract*** **– D-STATCOM (Distribution Static Compensator) is a shunt device which is generally used to solve power quality problems in distribution systems. D-STATCOM is a shunt device used in correcting power factor, maintaining constant distribution voltage and mitigating harmonics in a distribution network. D-STATCOM is used for Grid Connected Power System, for Voltage Fluctuation, for Wind Power Smoothening and Hydrogen Generation etc. This paper D-STATCOM is used in Marine Power System for Power Quality Improvement. Relevant solutions which applied nowadays to improve power quality of electric network according to the five aspects of power quality-harmonics, fluctuation and flick of voltage, Voltage deviation, unbalance of 3-phase voltage and current frequency deviation. Simulation is done using Sim Power Systems of MATLAB/Simulink to validate the proposed global system. The measurement system containing two main parts:- Hardware part and the virtual part- software (Recording, Processing, Graphical interfacing). In this paper we are concluding the result of software parts only. The performance of the proposed DSTATCOM system is validated through simulations using MATLAB software with its Simulink and Power System Blockset (PSB) toolboxes.**

***Keywords*** **– D-STATCOM, Voltage Sag, Controler, Power Quality.**

## I. Introduction

Power quality is certainly a major concern in the present era. it becomes especially important with the insertion of sophisticated devices, whose performance is very sensitive to the quality of power supply. A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a mis-operation of end user equipments. Modern industrial processes are mainly based on electronic devices such as PLC's, power electronic devices, drives etc., and since their controls are sensitive to disturbances such as voltage sag, swell and harmonics, voltage sag is most important power quality problems It contributes more than 80% of power quality (PQ) problems that exist in power systems, and more concern problems faced by many industries and utilities. [1]. By definition, a voltage sag is an rms (root mean square) reduction in the AC voltage at the power frequency, for duration from a half-cycle to a few seconds. Voltage sag is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Typical faults are single-phase or multiple-phase short circuits, which leads to high currents. The high current results in a voltage drop over the network impedance. Voltage sags are not tolerated by sensitive equipments used in modern industrial plants such as process controllers, programmable logic controllers (PLC), adjustable speed drive (ASD) and robotics. Various methods have been applied to reduce or mitigate voltage sags. [2] The conventional methods are by using capacitor banks, introduction of new parallel feeders and by installing uninterruptible power supplies (UPS). However, the PQ problems are not solved completely due to uncontrollable reactive power compensation and high costs of new feeders and UPS. The D-STATCOM has emerged as a promising device to provide not only for voltage sags mitigation but a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction and harmonic control.

## II. Basic Principle of DSTATCOM

A DSTATCOM is a controlled reactive source, which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and/or absorbing reactive power. The operating principles of a DSTATCOM are based on the exact equivalence of the conventional rotating synchronous compensator.

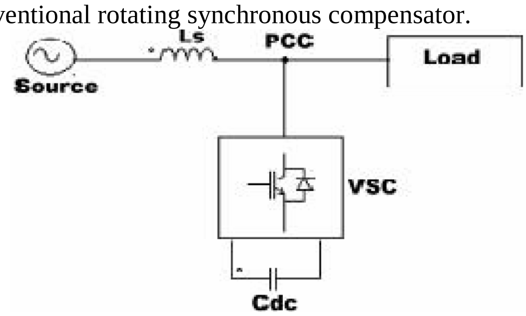


Fig.1. Basic Structure of DSTATCOM

The AC terminals of the VSC are connected to the Point of Common Coupling (PCC) through an inductance, which could be a filter inductance or the leakage inductance of the coupling transformer, as shown in figure 1. The DC side of the converter is connected to a DC

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capacitor, which carries the input ripple current of the converter and is the main reactive energy storage element. This capacitor could be charged by a battery source, or could be recharged by the converter itself. If the output voltage of the VSC is equal to the AC terminal voltage, no reactive power is delivered to the system. If the output voltage is greater than the AC terminal voltage, the DSTATCOM is in the capacitive mode of operation and vice versa. The quantity of reactive power flow is proportional to the difference in the two voltages. It is to be noted that voltage regulation at PCC and power factor correction cannot be achieved simultaneously. For a DSTATCOM used for voltage regulation at the PCC, the compensation should be such that the supply currents should lead the supply voltages; whereas, for power factor Correction, the supply current should be in phase with the supply voltages. The control strategies studied in this paper are applied with a view to study-ing the performance of a DSTATCOM for power factor correction and harmonic mitigation.

## III. Basic Configuration and Operation of D-STATCOM

The D-STATCOM is a three-phase and shunt connected power electronics based device. It is connected near the load at the distribution systems. The major components of a D-STATCOM are shown in figure 2. It consists of a dc capacitor, three-phase inverter (IGBT, thyristor) module, ac filter, coupling transformer and a control strategy. The basic electronic block of the D-STATCOM is the voltage-sourced inverter that converts an input dc voltage into a three-phase output voltage at fundamental frequency.

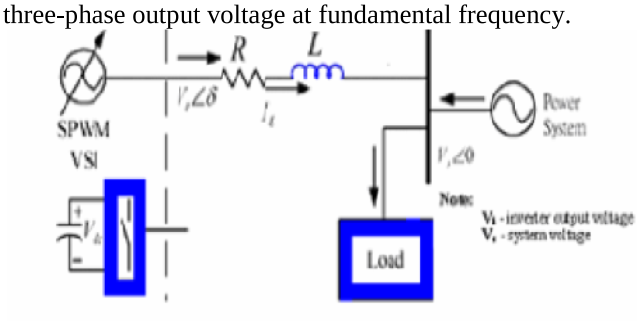


Fig.2. Basic Block Diagram of DSTATCOM

The D-STACOM employs an inverter to convert the DC link voltage $V_{dc}$ on the capacitor to a voltage source of adjustable magnitude and phase. Therefore the D-STATCOM can be treated as a voltage-controlled source. The D-STATCOM can also be seen as a current-controlled source.

Figure 2 shows the inductance L and resistance R which represent the equivalent circuit elements of the stepdown transformer and the inverter will is the main component of the D-STATCOM. The voltage Vi is the effective output voltage of the D-STATCOM and δ is the power angle. The reactive power output of the D-STATCOM inductive or capacitive depending can be either on the operation mode of the DSTATCOM. The construction controller of the D-STATCOM is used to operate the inverter in such a way that the phase angle between the inverter voltage and the line voltage is dynamically adjusted so that the D-STATCOM generates or absorbs the desired VAR at the point of connection. The phase of the output voltage of the thyristor-based inverter, $V_i$, is controlled in the same way as the distribution system voltage $V_s$.

The situation of marine power quality inclined to worse. The reasons are listed in the following A large amount of control equipments and power electronic devices are put into marine use in order to promote automatization of ship operation and to save energy. e.g., concerning the variation of main engine cooling water temperature, the conventional control method of regulation of valve baffle position is now substituted by speed regulation of motors of cooling water pumps in order to save energy. As well as more and more frequent application of shaft driven generator has been observed. But the operation of all these equipments and devices contributes to the power quality deterioration to a wide extension. Since the capacity of marine electric facilities is always with a plentiful margin, the power factor of marine power plant under normal operation is rather low.

## IV. Operation Modes of D-STATCOM

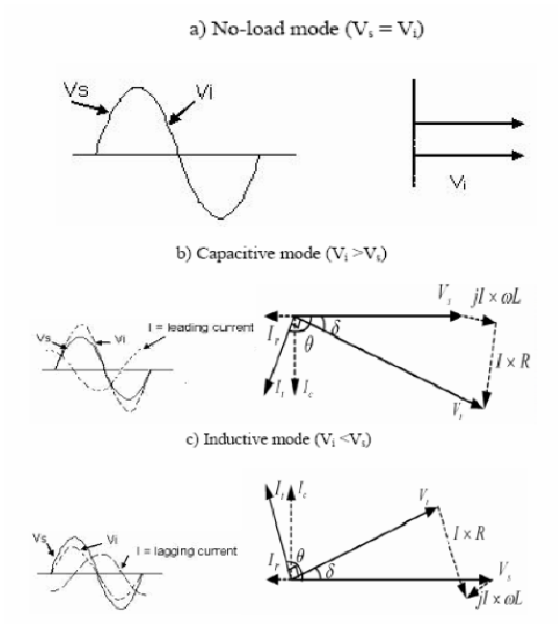


Fig.3. Operation Modes of D-STATCOM

### *4.1 Commonly Used Solutions to Improve Electric Power Quality:*

There are three ways that is commonly applied to improve voltage deviation of electrical power system.

i) The most effective solution is reactive power compensation, as SVC - Static Var Compensator (typically, TCR-Thyristor Controlled Reactors and TSC-Thyristor Switched Capacitors), SVG - Static Var Generator and APFCC-Active Power Factor Correction Circuit. Other solutions include regulation of field current

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of synchromotor, application of on-load voltage regulation transformer.

ii) A large number of research solutions have been selected to solve the problem of fluctuation and flick of voltage and almost all these solutions simultaneously have the function of harmonic suppression.

iii) To suppress harmonics in electrical power quality. The most effective solution is to apply filters. The commonly applied filters are passive power filter (usually passive LC filter) and active power filter (APF). APF normally has two types according to the ways it connects to the object that is compensated shunt APF and series APF. Among which, shunt APF is common in practical application.

*4.2 Power Quality Improvement in Ship Networks:*

Marine electrical power network demands even higher quality of electrical power energy while compared with overland power network. Requirements that should be met during the process of measurement for electrical power quality assessment are:

i) Be able to catch instantaneous interference very quickly, e.g. variation of amplitude, distortion of waveform and rate of enlargement of amplitude.

ii) quick and accurate measurement for harmonics and inter harmonics.

iii) be able to reveal the characteristics and regulations of the electrical power quality indices as well as regulations of the variation along with variation of time using an effective analysis and automatic identification system.

*4.3 Voltage Source Convertors (VSC):*

A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual. The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage dip mitigation, but also for other power quality issues, e.g. flicker and harmonic.

*4.4 Commonly applied solutions to improve marine electrical power quality (Division of the ship power system):*

One of the recommendations of the SOLAS convention concerns an appropriate configuration of the main switchboard. Regarding this recommendation for a ship power station with a high power, the main switch board should be divided into sections. Then, the loads with increased sensitivity for changes of voltage supply parameters (for example GMDSS systems) and devices with special significance for ship safety may be supplied from the separated sub-system. Specialized constructional and technological solutions are employed, e.g. to employ12-phase (or 24- phase) frequency transformer and low reactance generators, as well as special earthing to drain the frequencies induced in protective shields. To install filters and power factor correction circuits for quick and accurate suppression of dominant harmonics and reactive power compensation.

## V. MATLAB BASED TEST SYSTEM AND METHODOLOGY

The ship power system actually consists of four generators and two propulsion motors. But, to study the effect of DSTATCOM, a simplified model consisting of one generator of 36 MW/45 MVA and a propulsion motor of 20 MW is considered in this paper. The model of the test system is built in MATLAB/SIMULINK environment.

To enhance the performance of distribution system, D-STATCOM was connected to the distribution system. D-STATCOM was designed using MATLAB simulink version R2008b. The test system shown in figure 4 comprises a 230kV, 50Hz transmission system, represented by a Thevenin's equivalent, feeding into the primary side of a 3-winding transformer connected in Y/Y/Y, 230/11/11 kV. A varying load is connected to the 11 kV, secondary side of the transformer. A two-level D-STATCOM is connected to the 11 kV tertiary winding to provide instantaneous voltage support at the load point. A 75 μF capacitor on the dc side provides the DSTATCOM energy storage capabilities. Circuit Breaker is used to control the period of operation of the D-STATCOM.

## VI. SIMULATION AND RESULTS

The simulation diagram of D-STATCOM is shown in figure below:

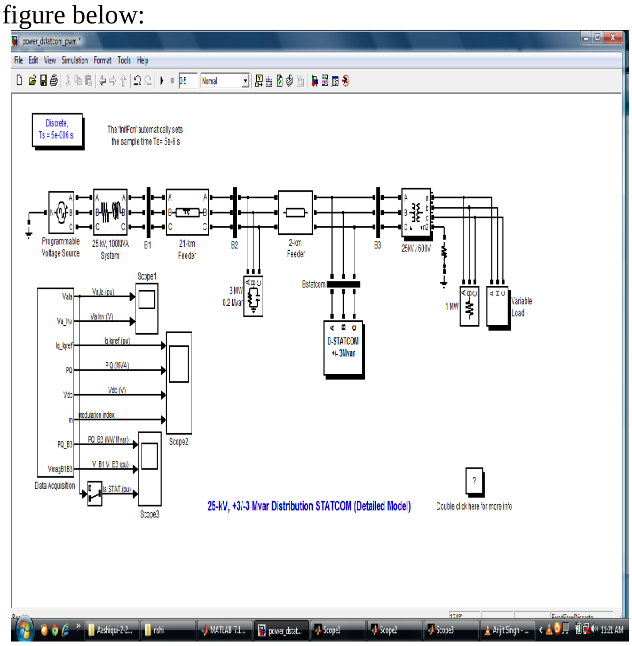
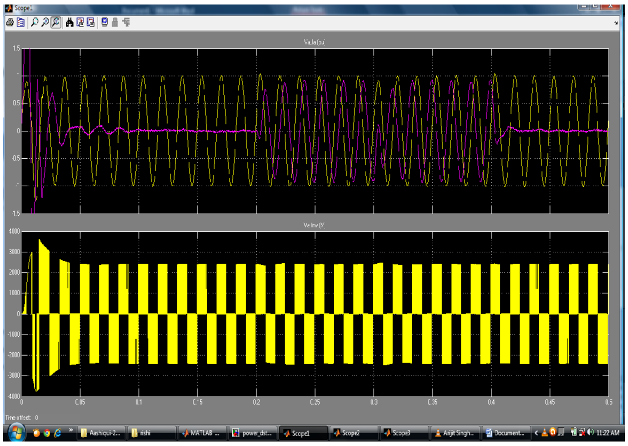
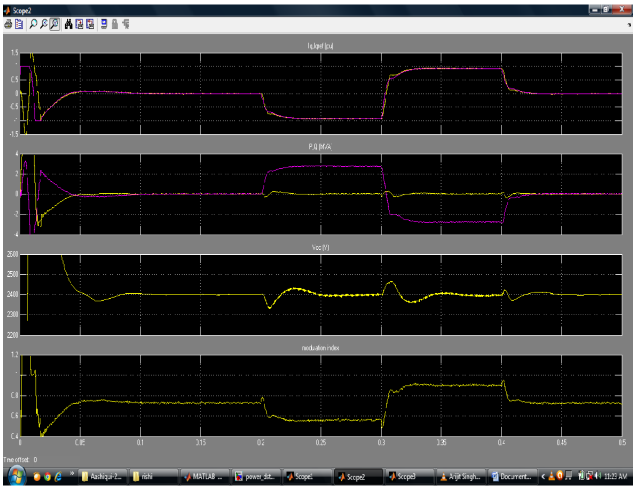



Fig.4. Simulation Diagram of D-STATCOM

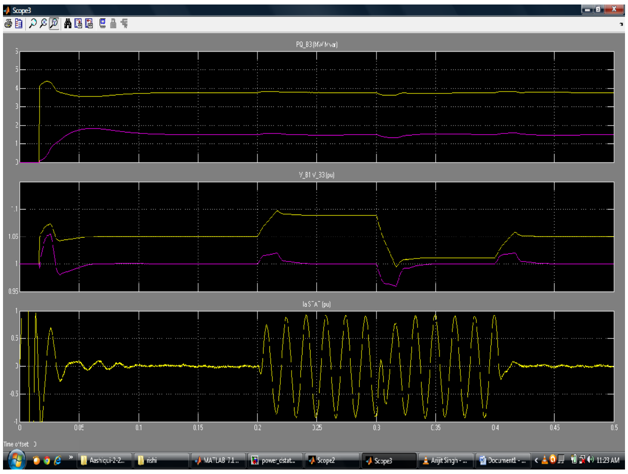
The results obtained in MATLAB through various scopes is shown below:



Scope 1



Scope 2



Scope 3

Fig.5. Results of D-STATCOM

The variable load was kept constant and dynamic response of a D-STATCOM was observed. In Scope 1 the phase A voltage and current waveforms of the D-STATCOM while scope 2 shows controller signal. After transient lasting 0.15 sec the steady state is reached. In scope 3 variation of P and Q at bus B3 as well as voltages at buses B1 and B3 are shown.

## VII. CONCLUSION

From above simulation results we conclude that D-STATCOM is promising device which is used for voltage sag, swell mitigation at distribution side. A detailed model of a D-STATCOM has been developed for use in SIMULINK environment with power system blockset and expected results are obtained.

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