Theoritical Modelling Of DSTATCOM For Minimizing Harmonic Distortion

D.Sai Sathvik, Harshith Ch, Anuddep Vurity, S.Jagadish Kumar

Abstract: With the possible future of a localized grid connected photovoltaic power system, the emphasis on the power quality at the distribution level has become much more of a priority. However, one of the major problems with self-generated power supply is the lack of power quality consistency due to the generation of harmonics via local non-linear loads. In an effort to overcome the aforementioned limitation, a custom grid-connected DSTASTCOM is proposed, which can theoretically reduce the generating harmonics to improve the overall power quality. The control strategy is based on the D-Q frame control theory and is theorized to provide a cost-effective alternative to the more conventional and expensive equipment.

Keywords: D-Q theory, Power Quality, Grid, Harmonics, Non-Linear

1. INTRODUCTION

In recent times, the low voltage counterpart of the more widely known flexible ac transmission system (FACTS) technology, generally used for high voltage power transmission applications, has emerged as a credible solution to solve many of the problems relating to continuity of supply at the local consumer level. The quality of electrical power may be described as a set of parameters, including:

- Continuity of Service (Whether the electrical power is subject to voltage drops or overages below or above a threshold level thereby causing blackouts)
- Variation in magnitude of voltage
- Transient currents and voltages
- Harmonic content in the waveforms for AC power

As the easiest controllable quantity in an electrical system mostly is voltage, hence quite often it is referred as voltage quality. If supply voltage dips because of a fault, then this will affect illumination of the light and the output power of induction motor. Heavy consumption of reactive power is the cause for lower voltage quality. Today these Problems have an even higher impact on secure and reliable power supplies in the world of localization and privatization of electrical systems and energy transfer. New developments in fast and reliable semiconductors devices (GTO and IGBT) allowed new power electronic configurations to be introduced to the tasks of power Transmission and load flow control. The FACTS devices offer a reliable and faster control over the transmission parameters, i.e. Voltage, line impedance, and phase angle between the sending end voltage and receiving end voltage. On the other hand, the custom power is for low voltage distribution, and improving the poor quality and reliability of supply affecting sensitive loads. Custom power devices are very similar to the FACTS. Most widely known custom power devices are DSTATCOM, UPQC, DVR among them. The DSTATCOM is very well known and can provide a cost effective solution for the compensation of reactive power and unbalanced loading in a distribution system.

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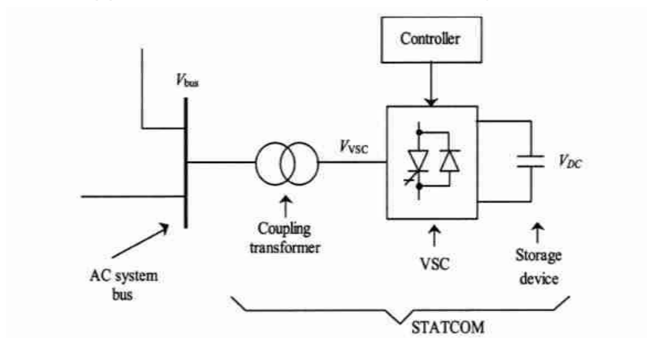
2 DSTATCOM WORKING

2.1 Operating Principle and Construction

The working principle of a DSTATCOM that is installed in a power system is the generation of a controllable ac voltage source by a voltage source inverter (VSI) connected to a dc capacitor (energy storage device). The ac voltage source, in general, appears behind a transformer leakage reactance. The reactive and active power transfer between the power system and the DSTATCOM is caused by the voltage difference across this reactance. The DSTATCOM is connected to the power networks where the voltage-quality problem is a concern. All required currents and voltages are measured and are fed into the controller to be compared with the commands. The controller then performs feedback control and outputs a set of switching signals to drive the main semiconductor switches (IGBT's, which are used at the distribution level) of the power converter accordingly.



*. **Fig 2.1** Block diagram of the voltage source converter based DSTATCOM*

The AC voltage control is obtained by utilizing firing angle control. Ideally the output voltage of the VSI is in phase with the bus (where the DSTATCOM is connected.) voltage. In steady state, the dc side capacitance is maintained at a fixed voltage and there is no real power exchange, except for losses. The DSTATCOM differs from other reactive power generating devices (such as shunt Capacitors, Static VAR Compensators etc.) in the sense that the ability for energy storage is not an absolute necessity but is only required for compensation during system imbalance or for harmonic absorption. There are two control objectives implemented in the DSTATCOM. One is the ac voltage regulation of the power system at the bus where the DSTATCOM is connected. And the other is dc voltage control across the capacitor inside the DSTATCOM. It is widely known that shunt reactive power injection can be used to control the bus voltage. In conventional control scheme, there are two voltage regulators designed for these purposes. AC voltage regulator for bus voltage control and DC voltage regulator for capacitor voltage control. In the simplest strategy, both the regulators are proportional integral (PI) type controllers.

2.2 Modes of Operation

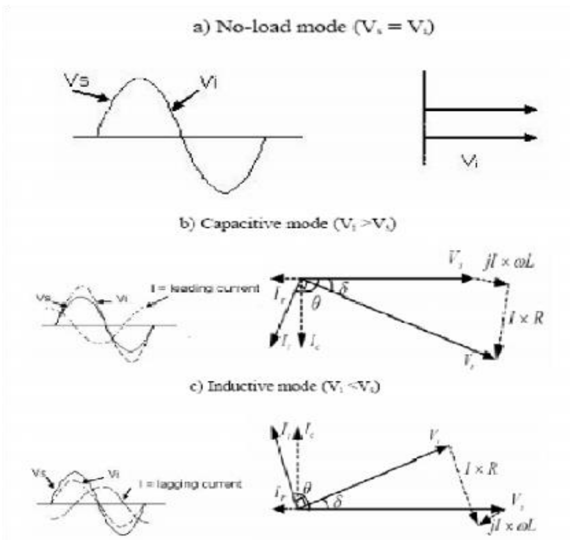


Fig 2.2 *Modes of DSTATCOM Operation*

The main principle of DSTATCOM is as follows:

- Vi > VM → DSTATCOM will supply the reactive power
- Vi < VM → DSTATCOM will absorb the reactive power
- Vi =VM → DSTATCOM will not exchange the reactive power which is also a balanced condition.

Where,
Vi = Inverter voltage in volt
VM = Point of common coupling voltage in volt
VS = Source voltage in volt

Each control algorithm calculates the compensated current of compensator to supply or absorb the reactive power. The compensated current is given by

IC = IL – IS

Where,
IC = Compensated current in ampere.
IL = Load current in ampere.
IS = Source current in ampere.

2.3 Control Theory

The method used here to separate the harmonic components from the fundamental components is by generating reference frame current by using synchronous reference theory. In theory, Park transformation is carried out to transform the load current into a synchronous reference current to eliminate the harmonics in source current. The main advantage of this method is that it takes only the load current under consideration for generating reference current and hence independent on source current and voltage distortion. A separate PLL block it used for maintaining synchronism between reference and voltage for better performance of the system. Since instantaneous action is not taking place in this method so the method is little bit slow than p-q method for detection and elimination of harmonics. According to the synchronous fundamental dq frame theory, the Park transform is used to make the transition from the three-phase coordinate system of the current obtained from the current transducers, to a two-phase orthogonal coordinate system rotating at an imposed speed. Following this transformation, the current projections on the two axes will be - a DC component due to the current harmonic with the angular frequency equal to the dq frame rotating speed; - an AC component, due to the current harmonics of angular frequencies different from the dq frame rotating speed.

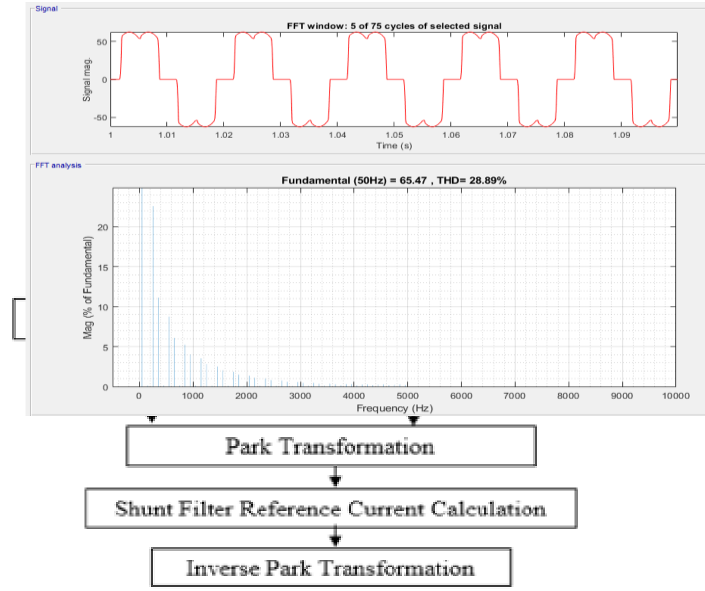


Fig 2.3 *D-Q method control strategy*

For the extraction of the DC component, low-pass filters are commonly used, and for the extraction of the AC components, high-pass filters are used. One disadvantage of this method is the necessity to obtain the dq frame angular position (angle), which involves the use of a PLL for determining the mains voltage phase. Another disadvantage is that the DC component is extracted using numeric low pass filters. In this case, the lower is the cutting frequency the higher is the filter response time. This can be avoided using the running window averaging technique to compute the mean value of the phasor projection for the selected harmonic over the specified period. In this case, the response time is equal to the harmonic period. Assuming that the current fundamental is to be extracted, so the DQ frame is rotating with the speed of 100π rad/sec.

3 MATHEMATICAL MODELLING & SIMULATION USING

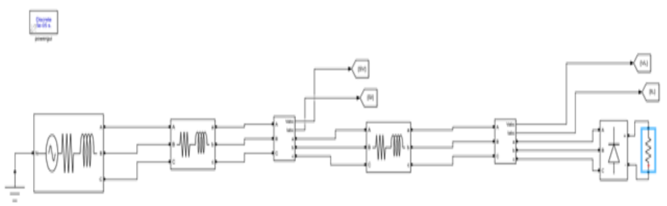
Matlab

3.1 Simulink Proposed Model

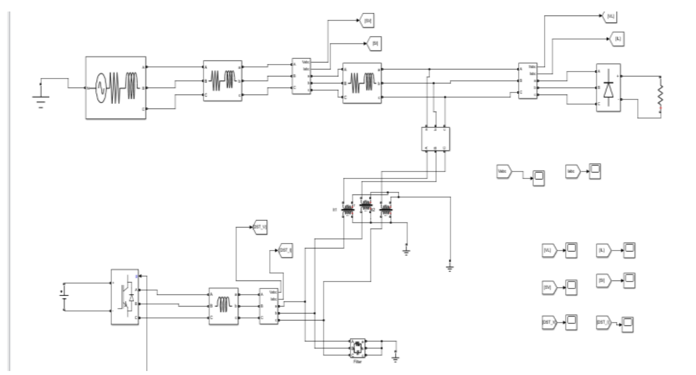
Fig 3.1 *Test system without DSTATCOM*
Fig 3.2 *Test system with DSTATCOM*

3.2 Simulation Results

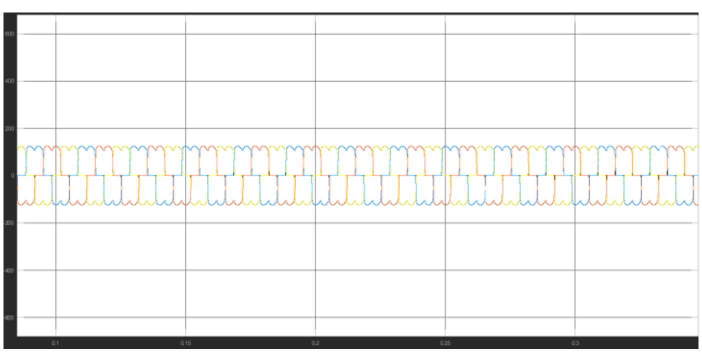
The Performance of DSTATCOM in power distribution system is studied using MATLAB/ SIMULINK of MATLAB 2015b



version. Data Acquisition is done in separate blocks and



scopes are given to the simulation model to analyze the power quality of the system. Case 1: Transmission line with nonlinear resistive load The first simulation contains no D-STATCOM and a three-phase resistive load of 10 ohms is connected using a rectifier (nonlinear). During the period 200-600 ms. The source



current and THD graphs are as shown below

Fig 3.3 source current without DSTATCOM (60 Hz peak)

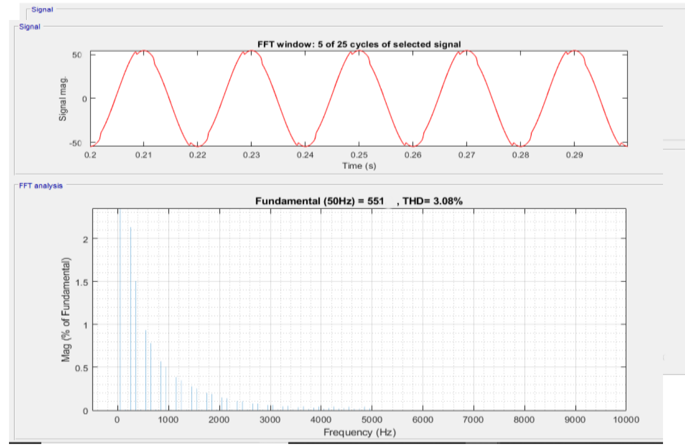


Fig 3.4 *THD without DSTATCOM (60 Hz peak)*

The THD of the current harmonics without DSTATCOM line is 28.89%

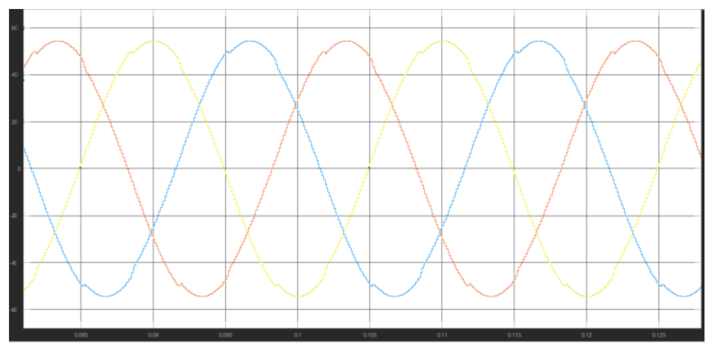


Fig 3.5 *Source current with DSTATCOM (60 Hz peak)*

The second simulation contains D-STATCOM and a three-phase resistive load of 10 ohms is connected using a rectifier (nonlinear). During the period 200-600 ms. The source current and THD compensated are as shown below The THD of the current harmonics with DSTATCOM line is 5.74%

Case 2: Transmission line with nonlinear resistive and inductive load

The third simulation contains no D-STATCOM and a three-phase RL (10ohms,1mH) load is connected using a rectifier(nonlinear). During the period 200-600 ms. The source current and THD compensated are as shown below

Fig 3.8 THD without DSTATCOM

The THD of the current harmonics with DSTATCOM line is 27.55%

The fourth simulation contains D-STATCOM and a three-phase RL (10ohms,1mH) load is connected using a rectifier(nonlinear). During the period 200-600 ms. The source current and THD compensated are as shown below

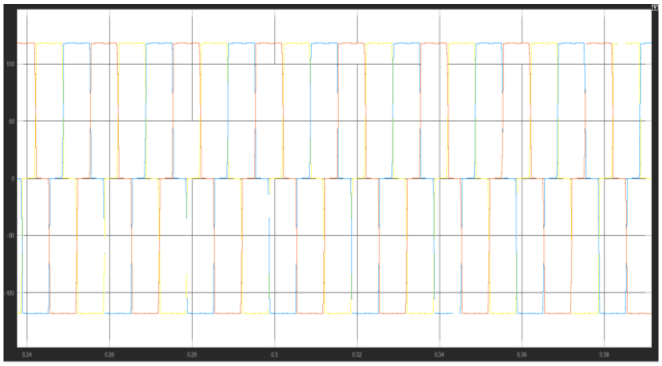


***Fig 3.6** THD with DSTATCOM*

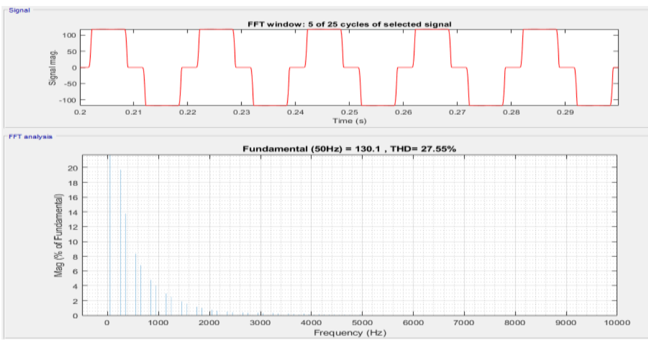


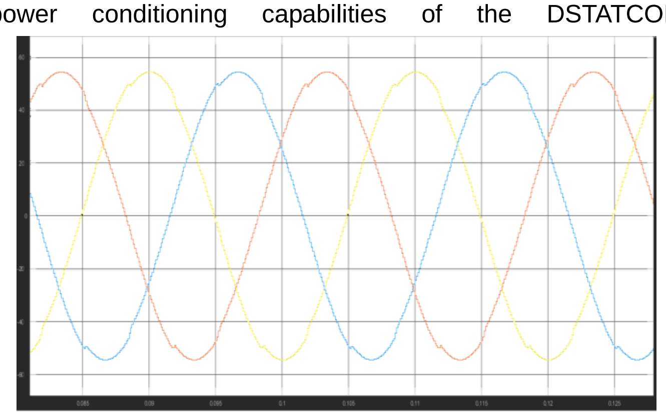
***Fig 3.7** Source Current without DSTATCOM (60 Hz Peak)*

Fig 3.9 source current with DSTATCOM (60 Hz Peak)

Fig 3.10 THD with DSTATCOM

4 CONCLUSION

The main objective of the project was to investigate the power conditioning capabilities of the DSTATCOM.



Synchronous Reference Frame control strategy has been executed and investigated for harmonic cancellation, to reduce the THD of source current, reactive power compensation, load balancing and power factor improvement. To achieve these objectives DC capacitor voltage of the inverter has been controlled through various Artificial Intelligence Techniques.

In the present work, Power Quality and its problems has been discussed with their mitigation techniques. Different types of Custom Power devices are discussed in which particularly MATLAB/SIMULINK model of D-STATCOM has been modelled and simulated for Field Oriented Control (FOC) Induction Motor drive using the Synchronous Reference Frame (SRF) control theory. MATLAB/SIMULINK model of 7 level DC-MLI has also been developed. It is clearly observed from the test results that D-STATCOM efficiently eliminates the harmonics from source current making the 0% THD level for source current. With the use of Multi level inverter, the output waveform is more sinusoidal with reduced harmonic distortion. From the present work, it can be concluded that D-STATCOM finds applications in effectively enhancing the Power Quality level at distribution side of the Power System.

5 FUTURE SCOPE

In the present work, D-STATCOM effectively eliminates harmonic content from the load current. Present work can be extended in the following ways:

- To mitigate Power Quality problems using D-STATCOM for Renewable Energy based distribution system.
- D-STATCOM with hybrid Multi pulse converter-based system can be implemented.

Hybrid Multilevel inverter-based D-STATCOM system can be explored.

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