Imperial Journal of Interdisciplinary Research (IJIR)
Vol-3, Issue-10, 2017
ISSN: 2454-1362, http://www.onlinejournal.in

Reactive Power Compensation in High Power Applications by Bidirectionalcasceded H-Bridge Based Statcom

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Abstract*: In this paper, a simple static var compensating scheme using a cascaded two-level inverter-based multilevel inverter is proposed. The topology consists of two standard two-level inverters connected in cascade through open-end windings of a three-phase transformer. The dc-link voltages of the inverters are regulated at different levels to obtain four-level operation. The simulation study is carried out in MATLAB/SIMULINK to predict the performance of the proposed scheme under balanced and unbalanced supply-voltage conditions.*

Index Terms—DC-link voltage balance, multilevel inverter, power quality (PQ), static compensator (STATCOM).

I.INTRODUCTION

THE application of flexible ac transmission systems (FACTS) controllers, such as static compensator (STATCOM) and static synchronous series compensator (SSSC), is increasing in power systems. This is due to their ability to stabilize the transmission systems and to improve power quality (PQ) in distribution systems. STATCOM is popularly accepted as a reliable reactive power controller replacing conventional var compensators, such as the thyristor-switched capacitor (TSC) and thyristor-controlled reactor (TCR). This device provides reactive power compensation, active power oscillation damping, flicker attenuation, voltage regulation, etc. [1].

Generally, in high-power applications, var compensation is achieved using multilevel inverters [2]. These inverters consist of a large number of dc sources which are usually realized by capacitors. Hence, the converters draw a small amount of active power to maintain dc voltage of capacitors and to compensate the losses in the converter. However, due to mismatch in conduction and switching losses of the switching devices, the capacitors voltages are unbalanced. Balancing these voltages is a major research challenge in multilevel inverters. Various control schemes using different topologies are reported in [3]–[7]. Among the three conventional multilevel inverter topologies, cascade H-bridge is the most popular for static var compensation
[5], [6]. However, the aforementioned topology requires a large number of dc capacitors. The control of individual dc-link voltage of the capacitors is difficult.

Static var compensation by cascading conventional multilevel/ two level inverters is an attractive solution for high-power applications. The topology consists of standard multilevel/two-level inverters connected in cascade through open-end windings of a three-phase transformer. Such topologies are popular in high-power drives [8]. One of the advantages of this topology is that by maintaining asymmetric voltages at the dc links of the inverters, the number of levels in the output voltage waveform can be increased. This improves PQ [8]. Therefore, overall control is simple compared to conventional multilevel inverters

In this paper, a static var compensation scheme is proposed for a cascaded two-level inverter-based multilevel inverter. The topology uses standard two-level inverters to achieve multilevel operation. The dc-link voltages of the inverters are regulated at asymmetrical levels to obtain four-level operation. To verify the efficiency of the proposed control strategy, the simulation study is carried out for balanced and unbalanced supply-voltage conditions.

II. PRAPOSED CONCEPT

Modern power systems are of complex networks, where hundreds of generating stations and thousands of load centers are interconnected through long power transmission and distribution networks. Even though the power generation is fairly reliable, the quality of power is not always so reliable. Power distribution system should provide with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency to their customers. PS especially distribution systems, have numerous nonlinear loads, which significantly affect the quality of power.

Apart from nonlinear loads, events like capacitor switching, motor starting and unusual faults could also inflict power quality (PQ) problems. PQ problem is defined as any manifested problem in voltage or current or leading to frequency deviations that result in failure or mal operation of customer equipment. Voltage sags and swells are among the many PQ problems the industrial processes have to face. Voltage sags are more severe. During the past few decades, power industries have proved that the adverse impacts on the PQ can be mitigated or avoided by conventional means, and that techniques using fast controlled force commutated power electronics (PE) are even more effective. PQ compensators can be categorized into two main types. One is shunt connected compensation device that effectively eliminates harmonics.

The STATCOM used in distribution systems is called DSTACOM (Distribution-STACOM) and its configuration is the same, but with small modifications. It can exchange both active and reactive power with the distribution system by varying the amplitude and phase angle of the converter voltage with respect to the line terminal voltage. A multilevel inverter can reduce the device voltage and the output harmonics by increasing the number of output voltage levels. There are several types of multilevel inverters: cascaded R-bridge (CRB), neutral point clamped, flying capacitor. In particular, among these topologies, CRB inverters are being widely used because of their modularity and simplicity. Various modulation methods can be applied to CRB inverters. CRB inverters can also increase the number of output voltage levels easily by increasing the number of R-bridges.

Alternating current transmission systems incorporating power electronics based and other static controllers to enhance controllability and power transfer capability.

The basic applications of facts-devices are:

• Power Flow Control.
• Increase of Transmission Capability.
• Voltage Control.
• Reactive Power Compensation.
• Stability Improvement.
• Power Quality Improvement.
• Power Conditioning.
• Flicker Mitigation.
• Interconnection of Renewable and Distributed Generation and Storages.

Fig. 1 shows the circuit topology of the cascaded two-level inverter-based multilevel STATCOM using standard two-level inverters. The inverters are connected on the low-voltage (LV) side of the transformer and the high-voltage (HV) side is connected to the grid. The dc-link voltages of the inverters are maintained constant and modulation indices are controlled to achieve the required objective.

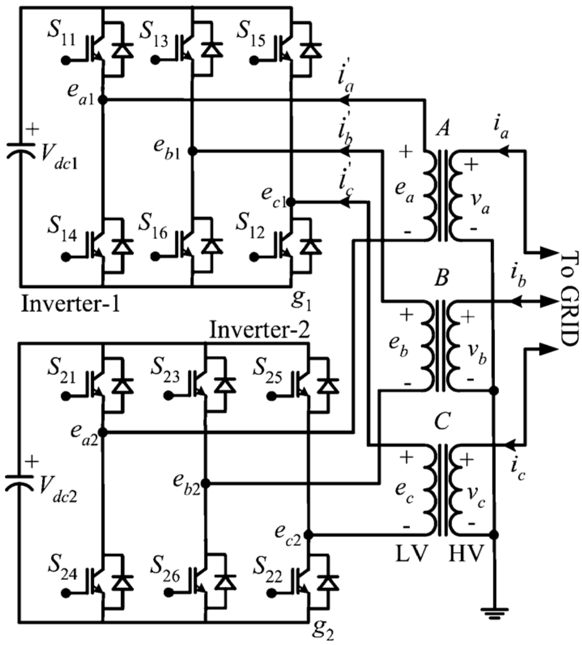


Fig. 1. Cascaded two-level inverter-based multilevel STATCOM.

III. DISTRIBUTION STATIC COMPENSATOR (DSTATCOM)

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Figure, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1. Voltage regulation and compensation of reactive power;
2. Correction of power factor; and
3. Elimination of current harmonics.

Here, such device is employed to provide continuous voltage regulation using an indirectly controlled converter.

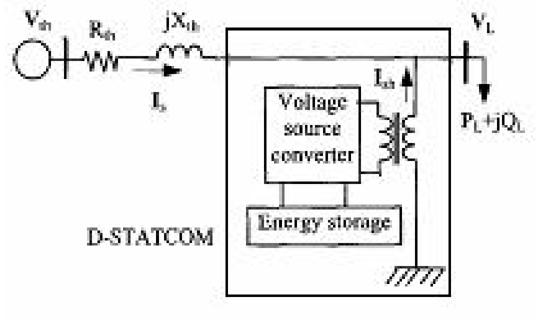


Figure 3.1 Block diagram of D-STATCOM

the shunt injected current I_{sh} corrects the voltage sag by adjusting the voltage drop across the system impedance Z_{th}. The value of I_{sh} can be controlled by adjusting the output voltage of the converter.

The shunt injected current I_{sh} can be written as,

$$I_{sh} = I_L - I_s = I_L - \frac{V_{Th} - V_L}{Z_{Th}}$$

$$I_{sh}\angle\eta = I_L\angle-\theta - \frac{V_{th}}{Z_{th}}\angle(\delta-\beta) + \frac{V_L}{Z_{th}}\angle-\beta$$

The complex power injection of the D-STATCOM can be expressed as,

$$S_{sh} = V_L I_{sh}^*$$

It may be mentioned that the effectiveness of the D-STATCOM in correcting voltage sag depends on the value of Z_{th} or fault level of the load bus. When the shunt injected current I_{sh} is kept in quadrature with V_L, the desired voltage correction can be achieved without injecting any active power into the system. On the other hand, when the value of I_{sh} is minimized, the same voltage correction can be achieved with minimum apparent power injection into the system.

IV.TEST SYSTEM

Figure shows the test system used to carry out the various D-STATCOM simulations.

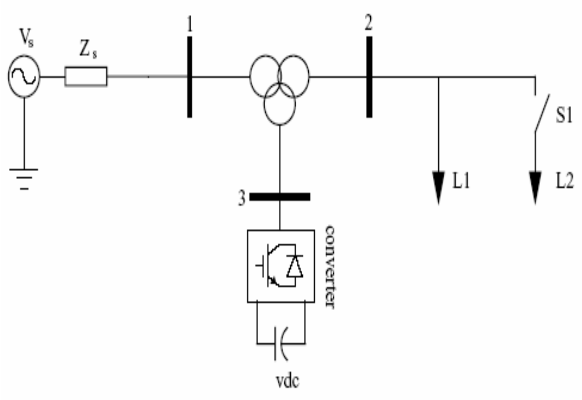


Fig.4 Single line diagram of the test system for D-STATCOM

V. MODELING AND SIMULATION RESULTS

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include-

- Math and computation
- Algorithm development
- Data acquisition
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows solving many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or FORTRAN.

5.1MATLAB/SIMULATION RESULTS

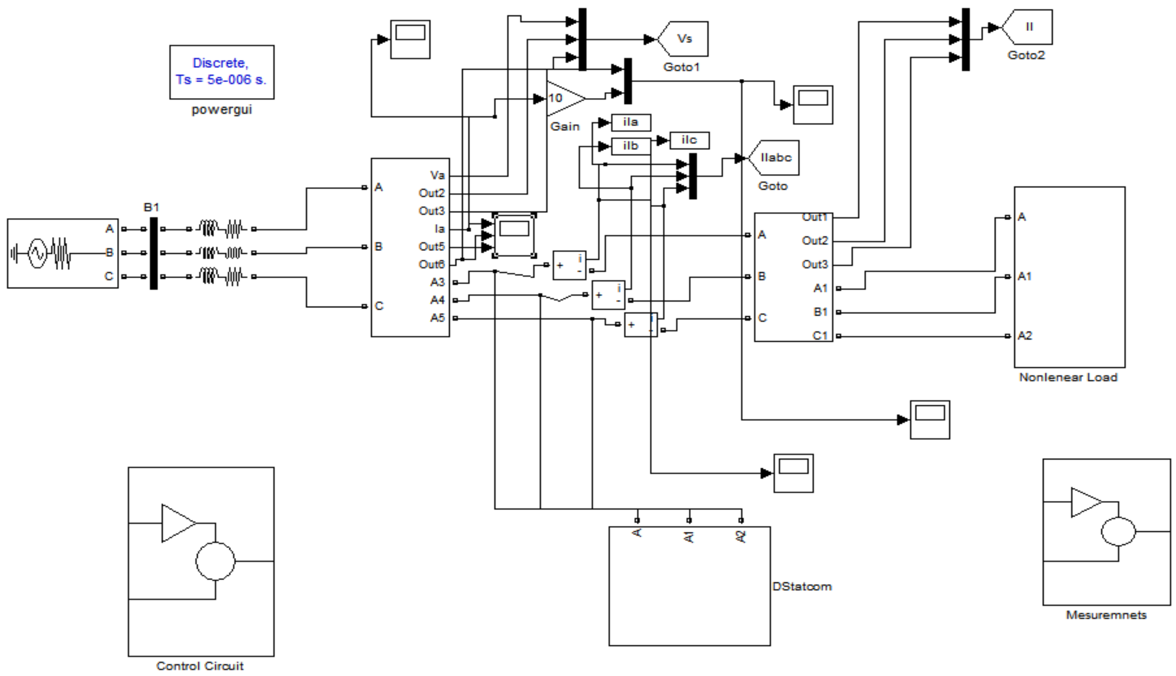


Fig.5.1 Multilevel statcom

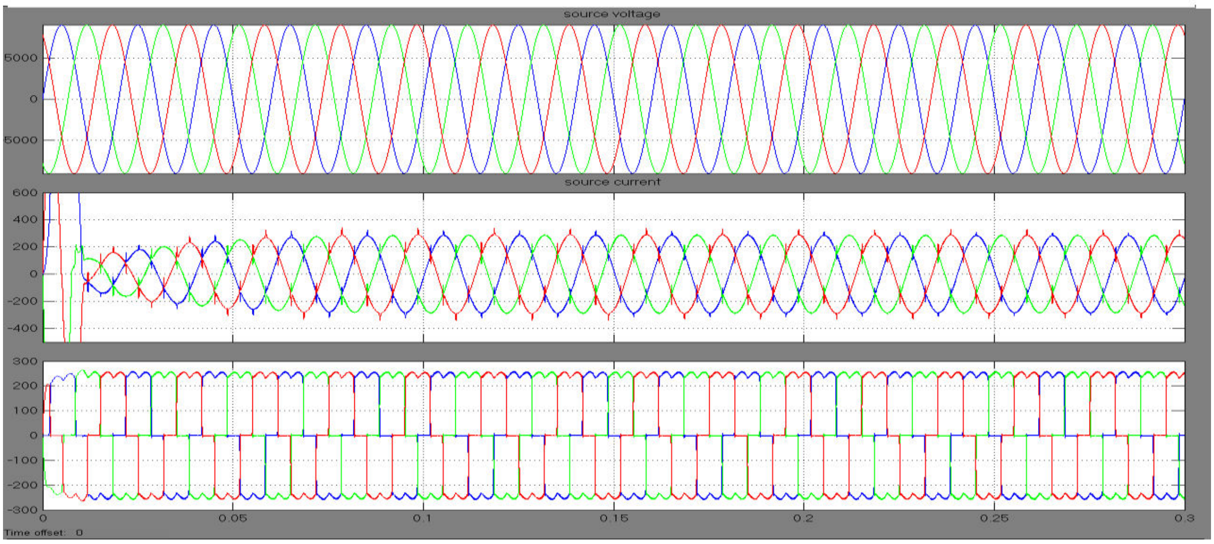


Fig.5.2 Sourse voltage,current and load current with statcom

Scale: a) on y-axis voltage in kv
On x-axis time secs
b) on y- axis current in amperes
on x-axis time in secs
c) on y- axis current in amperes
time in secs

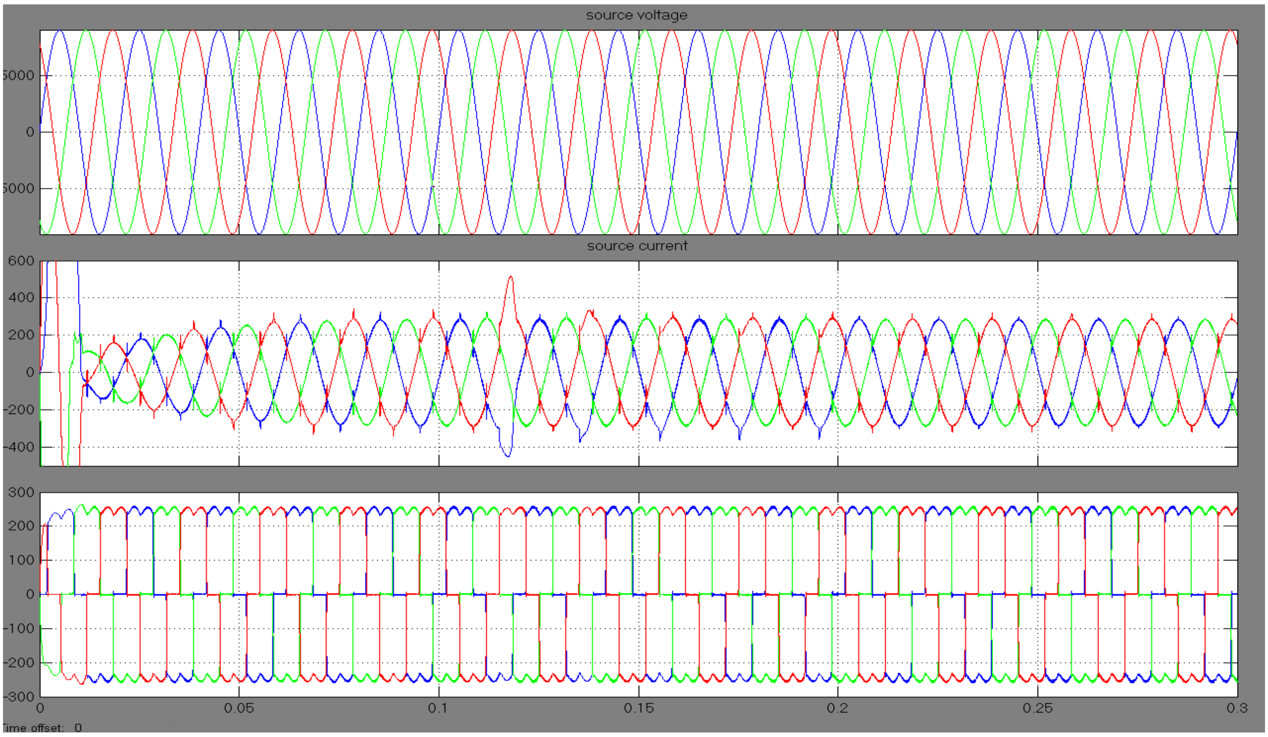


Fig.5.3 Wave form of fault mitigation method

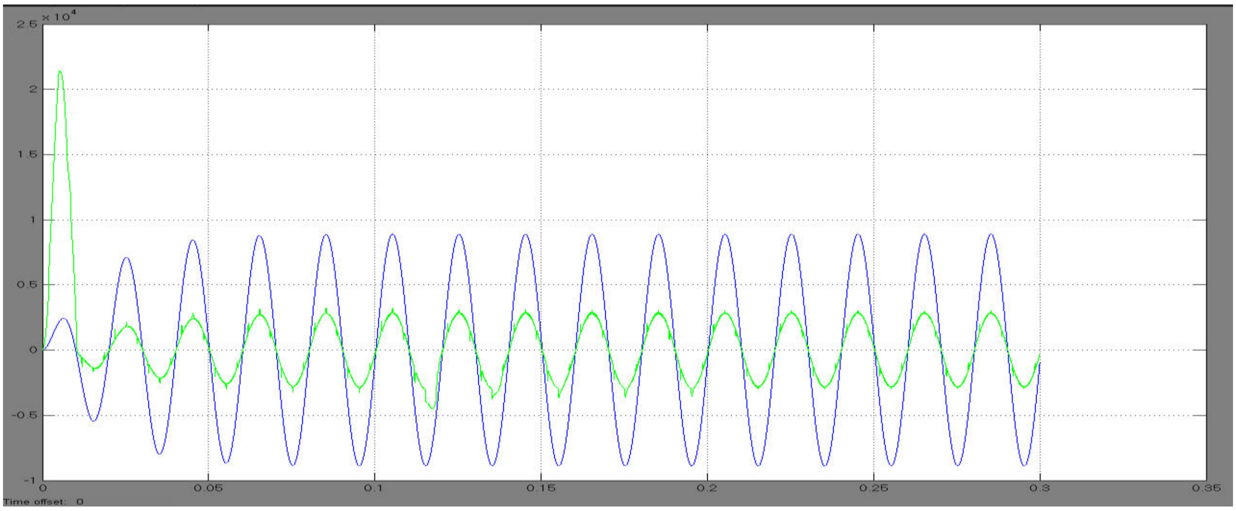
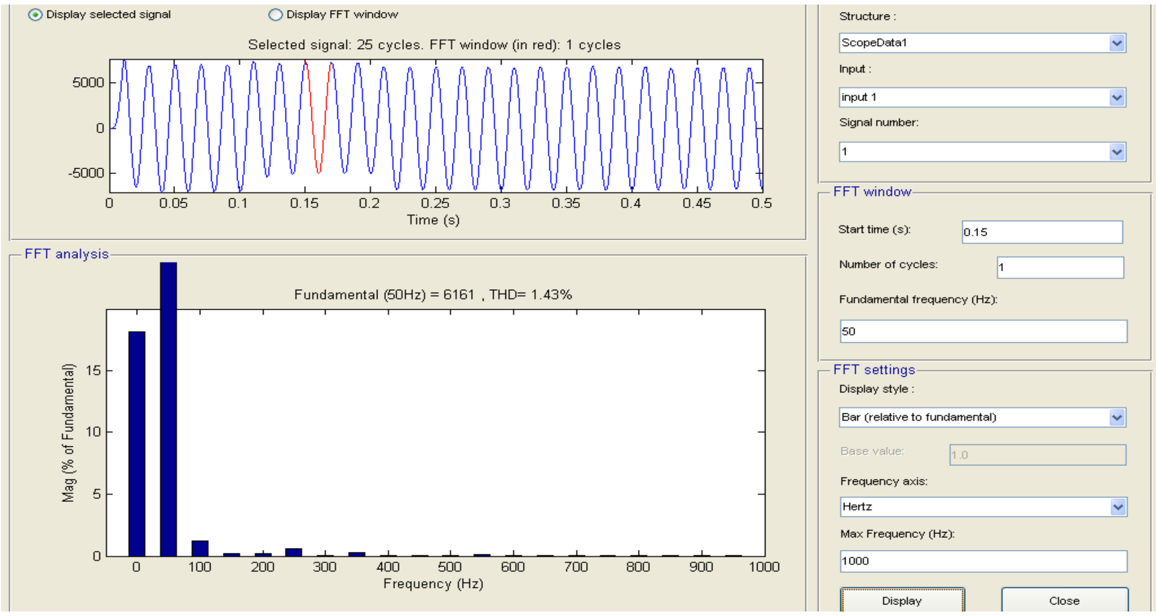


Fig. 5.4 both voltage and current are in phase (unity power factor)



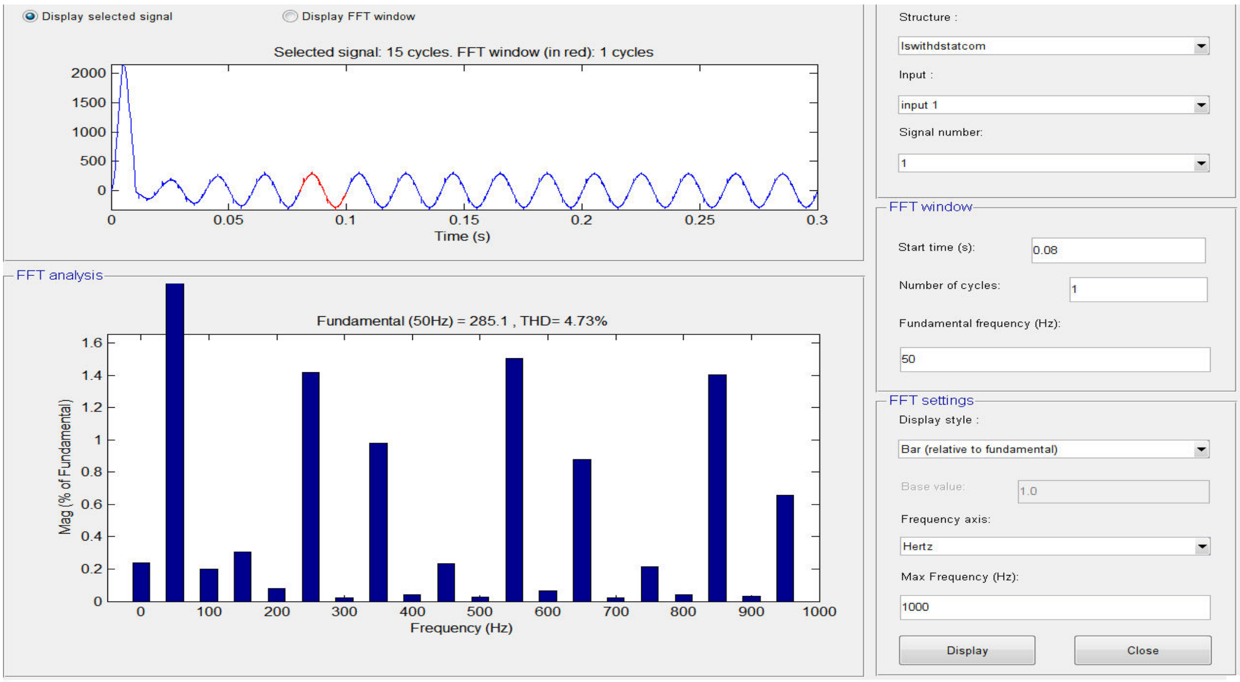


Fig.5.5,5.6 Harmonic spectrum of phase-A source current with DSTATCOM

Improving of power quality and power factor by using DSTATCOM. Without Dstatcom harmonic contents are more and THD level is more than 5%. With Dstatcom is redused to less than 5% i.e. 4.014%. Corresponding wave forms are as shown in above figures. In fault mitigation system if any fault occures the output is not effected. If we are not giving the triggering pulse to any one switch in Converter Bridge still the output is constant and THD level is same as previous value. The wave forms are as shown in the above figures.

VI.CONCLUSION

DC-link voltage balance is one of the major issues in cascaded Inverter-based STATCOMs. In this paper, a simple var compensating scheme is proposed for a cascaded two-level inverter- based multilevel inverter. The scheme ensures regulation of dc-link voltages of inverters at asymmetrical levels and reactive power compensation. The performance of the scheme is validated by simulation and experimentations under balanced and unbalanced voltage conditions. Further, the cause for instability when there is a change in reference current is investigated. The dynamic model is developed and transfer functions are derived. System behavior is analyzed for various operating conditions. From the analysis, it is inferred that the system is a nonminimum phase type, that is, poles of the transfer function always lie on the left half of the -plane. However, zeros shift to the right half of the -plane for certain operating conditions. For such a system, oscillatory instability for high controller gains exists.

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