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VAR Compensation and Power Quality Improvement by 48-Pulses Three Level STATCOM

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ABSTRACT:Static synchronous compensator (STATCOM) is an interested key FACTS device. It is able to control the amount of reactive power injected into or absorbed from the power system by means of a VSC that uses forced commutated power electronic devices. Static synchronous compensator is a shunt connected device. In this paper presents a novel technique for power quality improvement that considers an advanced STATCOM 48-pulse GTO voltage source converter. The technology of this converter is based on a Zig-Zag transformer and a three level voltage source converter(VSC). The concept enables the compensation of the reactive power by absorbing or generating a flow of current equivalent to the required reactive power. Furthermore, it enables the cancellation of the current harmonics.The performance of the concept is simulated in the MATLAB environment**.**

KEYWORDS: Static Synchronous Compensator, Voltage Source Converter(VSC),Zig-Zag Transformer, Power Quality

I.INTRODUCTION

Transmission systems are undergoing rapid changes as well as continuous restructuring. Besides becoming more heavily loaded, they are being operated in new ways not originally envisioned. In addition, most of the loads are non linear or unbalanced. Consequently, power systems are continuously facing severe quality problems such as poor voltage regulation, harmonics current burden, excessive neutral current, etc. Approaches and techniques enabling the eradication of such power quality problems have been developed so far in an attempt to achieve a more secure and high quality power production.

The power system is an interconnection of generating units to load centres through high voltage electric transmission lines and in general the system is mechanically controlled. It can be divided into three subsystems: generation, transmission and distribution subsystems. In order to provide better electricity the deregulation of power system, which will produce separate generation, transmission and distribution companies, is already being performed[3]. At the same time electric power demand continues to grow and also building of the new generating units and transmission circuits is becoming more difficult because of economic and environmental reasons. Therefore, power utilities are forced to rely on utilization of existing generating units and to load existing transmission lines close to their thermal limits. However, stability has to be maintained at all times. Hence, in order to operate power system effectively, without reduction in the system security and quality of supply, even in the case of contingency conditions such as loss of transmission lines or generating units, which occur frequently, and will most probably occur at a higher frequency under deregulation, a new control scheme need to be implemented.

The load unbalance and the non linear loads result in a significant neutral current in the three-phase four-wire distribution power system. The Zig-Zag transformer has been used to attenuate the neutral current of the three-phase four-wire distribution power system. Zig-Zag transformer can effectively attenuate the neutral current and zero-sequence harmonic currents on the utility side under the balanced utility voltage, the utility side neutral current becomes larger under the unbalanced utility voltage or the distorted utility voltage with zero sequence harmonic components after applying the Zig-Zag transformer, the insertion of an inductor in the utility side of the neutral conductor can alleviate overloading of the neutral current caused by the unbalanced utility voltages and the distorted

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utility voltages with zero sequence harmonic components. The over-load of the neutral conductor is a very serious problem in three-phase four-wire distribution power systems. Although this problem can be solved effectively by using the three-phase four-wire active power filter, the use of three-phase four-wire active power filter is limited due to its high cost. The Zig-Zag transformer is still a popular solution for this problem due to its low cost, easy installation and free maintenance.

Flexible AC transmission system (FACTS) controllers are proving to be very effective in reducing the various power quality problems. The voltage regulation in the distribution feeder is improved by installing a shunt compensator. The static synchronous compensator (STATCOM) is an interested key FACTS device[1]. It is able to control the amount of reactive power injected into or absorbed from the power system by means of a VSC that uses forced-commutated power electronic devices (GTOs,IGSTs or IGCTs). Recently, the substitution of the three-pulse GTO-VSCs by fourty eight pulse ones has been the subject of intensive investigations. The fourty eight-pulse GTO-VSCs enable the power factor correction and voltage regulation along with neutral current compensation, harmonic elimination, and load balancing for both linear and nonlinear loads.

II.48-PULSES THREE LEVEL STATCOM

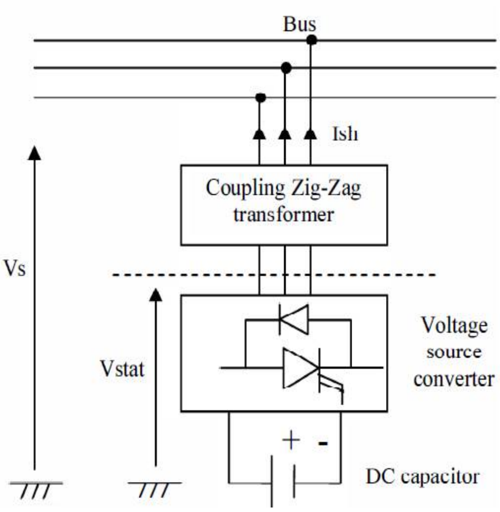

Fig.1 STATCOM Topology

Static synchronous compensator (STATCOM) is an interested key FACTS device. It is able to control the amount of reactive power injected into or absorbed from thepower system by means of a VSC that uses forced-commutated power electronic devices. Static compensator is a shunt connected device as shown in figure 1. It consists of a transformer with leakage reactance X, a three phase GTO voltage source converter (VSC) and a DC capacitor.The STATCOM's main function is the regulation of bus voltage magnitude at the point where it is connected by exchanging reactive power with the AC system[2]. This reactive power transfer is done through the leakage reactance of the transformer by using transformer voltages in phase with the AC system voltage V_s.

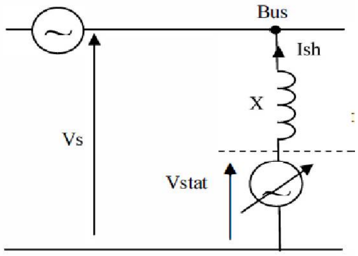

Fig. 2 STATCOM Main Operation

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Basically the STATCOM is a controllable fundamental frequency positive sequence voltage source V_{stat} , is keptin quadrature to the STATCOM current I_{sh}. The STATCOM device operation can be illustrated as in figure 2.When V_{stat} is lower than V_s the current flows from the AC system to the STATCOM. The STATCOM device acts like an inductance absorbing reactive power from the system bus. In the opposite case, the current flows from the STATCOM to the AC system and the facts device acts like a capacitor generating reactive power to the system bus. However, when V_{stat} is equal to V_s, there is no reactive power exchange between STATCOM and AC system. The reactive power exchange between the STATCOM and the system can then be adjusted by controlling the magnitude of the STATCOM output voltage with respect to that of system voltage V_s.

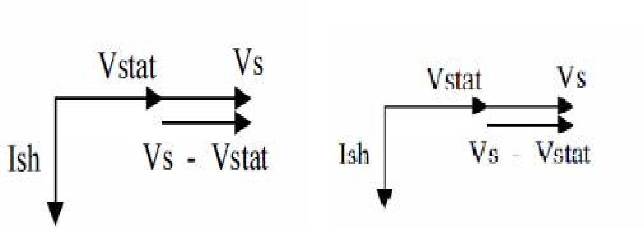

Fig.3 Inductive mode and Capacitive mode of operation

The 48-pulse GTO-VSC consists of four 3-phase 3-level inverters coupled with four phase shifting transformers (PST) introducing phase shift of +/- 7.5 degree. In a multi-pulse operation, the harmonic content is reduced by using several pulses in each half cycle of the output voltage [2]. The output of the converter has a low harmonic content and can also be used for high power FACTS controllers without AC filters.The configuration is obtained by combining four three level inverters with an adequate phase shifts between them. It uses a zig-zag transformer. A zig-zag transformer is a special-purpose transformer with a zig- zag or interconnected star winding connection, such that each output is the vector sum of two phases offset by 120 degree. Its applications are for the creation of a missing neutral connection from an ungrounded 3-phase system topermit the grounding of that neutral to an earth reference point and also harmonic mitigation, as it can suppress triplet harmonic currents, to supply 3-phase power as an autotransformer (serving as the primary and secondary with no isolated circuits),and to supply non-standard, phase-shifted, 3-phase power.

III.CONTROL STRATEGY

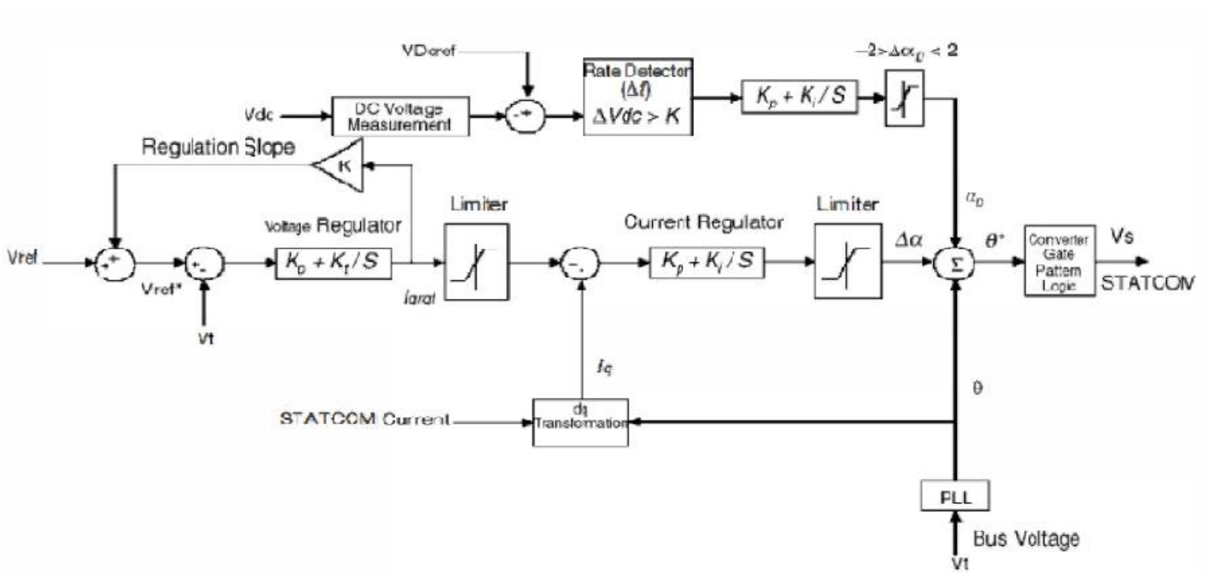

Fig. 4 d-q control

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The decoupled control system shown in figure 4 is based on a d-q decoupled current control strategy using both direct and quadrature current components of the STATCOM AC current. A phase locked loop synchronizes GTO pulses to system voltage .The phase locked loop provides a reference angle which can be used to measure thedirect axis and quadrature axis component of the AC three phase voltage and current. From the measured voltage V_{meas} and the reference voltage V_{ref} , the voltage regulatorblock computes the reactive current reference I_{qref} used by the current regulator block. A selected regulation slope k is incorporated in the voltage regulation to determine thecompensation behavior of the STATCOM device. During STATCOM operation it could happens a rapid variation in the capacitor voltage. In this way the converter absorbs temporarily small amount of real power from the AC system to compensate for any internal losses. To enhance the dynamic performance of the STATCOM, a supplementary regulator loop is added using the DC capacitor voltage. The idea is to keep the capacitor voltage at the desired level. The technique measures the variation in capacitor voltage magnitude noted for a fixed selected short time. If voltagemagnitude change is greater than a specified threshold k , the supplementary loop is activated by implementing a supplementary damping regulator to correct the phase angle of the STATCOM device voltage with respect to the sign of these variations. So the technique can be used to increase or decrease the capacitor voltage and thus theamplitude of the converter output voltage to control the VAR generation or absorption.

IV. RESULTS AND DISCUSSIONS

Performance of the concept is simulated in the MATLAB environment by considering different time intervals. Depending upon the voltages $V_{stat}$and V_s , the STATCOM can be inject or absorb the current ,which is equivalent to the requirement of reactive power.

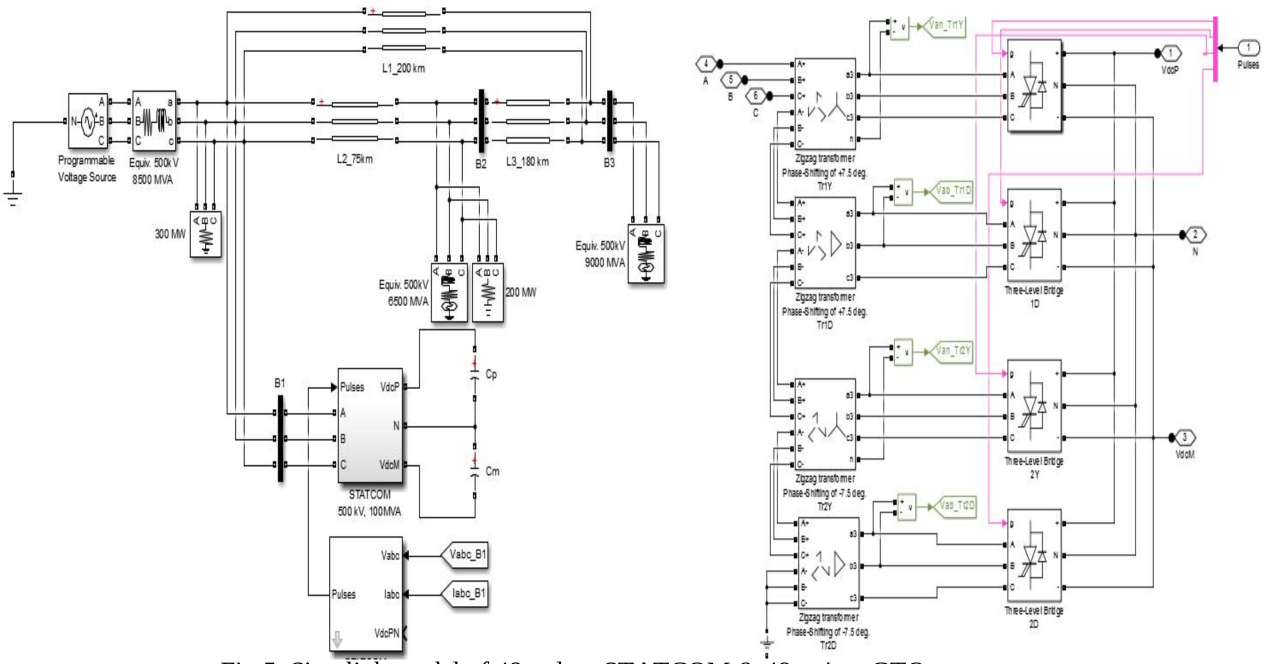

Fig.5 Simulink model of 48 pulses STATCOM & 48 pulses GTO converter

When Vstat is lower than Vs the current flows from the AC system to the STATCOM. The STATCOM device acts like an inductance absorbing reactive power from the system bus. In the opposite case, the current flows from the STATCOM to the AC system and the facts device acts like a capacitor generating reactive power to the system bus. However, when Vstat is equal to Vs, there is no reactive power exchange between STATCOM and AC system. The

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Case 1: Time Interval {[0.15, 0.25], [0.25, 0.35]}   Case 2: Time Interval {[0.05, 0.15], [0.15, 0.25]}

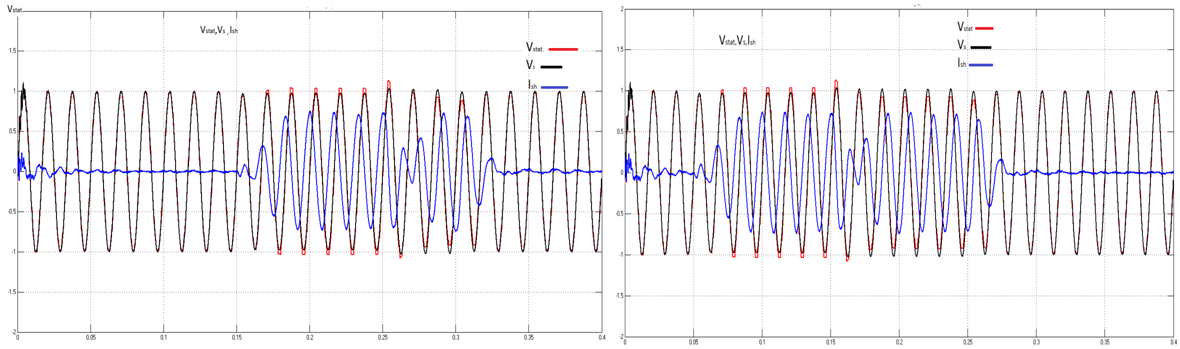

Fig. 7 Reactive power compensation

reactive power exchange between the STATCOM and the system can then be adjusted by controlling the magnitude of the STATCOM output voltage with respect to that of system voltage V_s. We can take two different interval for analysing the capacitive and inductive mode of operation. Figure 5 shows the Simulink model of STATCOM based 48 pulses three level GTO for VAR compensation. The system can be simulated with 60 Hz frequency.

Capacitive mode of operation: When V_{stat} is higher than V_s the current flows from the STATCOM to the AC system. The STATCOM device acts like a capacitor generating reactive power to the system bus. During interval [0.15, 0.25] and [0.05, 0.15]STATCOM acts likes a capacitor generating reactive power to the system. The capacitor voltage will be increases from the desired value and after compensation it reaches the desired value.

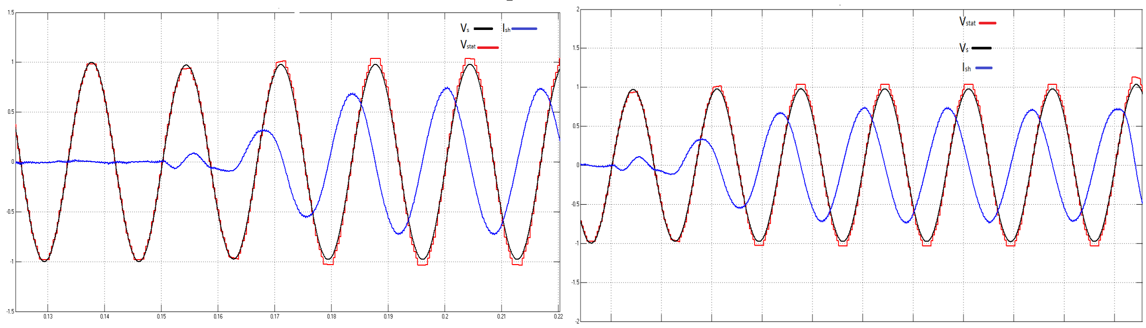

Fig.8 Capacitive mode of operation; Time interval {[0.15, 0.25], [0.05, 0.15]}

Inductive mode of operation: When V_{stat} is lower than V_s the current flows from the AC system to the STATCOM. The STATCOM device acts like an inductance absorbing reactive power from the system bus. During interval [0.25, 0.35] and [0.15, 0.25]STATCOM device acts like an inductance absorbing reactive power from the system bus.

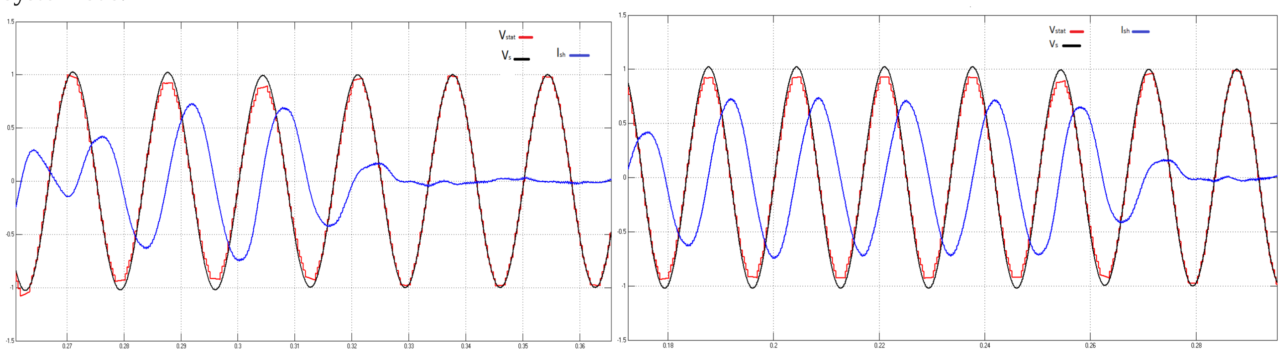

Fig. 9 Inductive mode of operation ; Time interval {[0.25, 0.35], [0.15, 0.25]}

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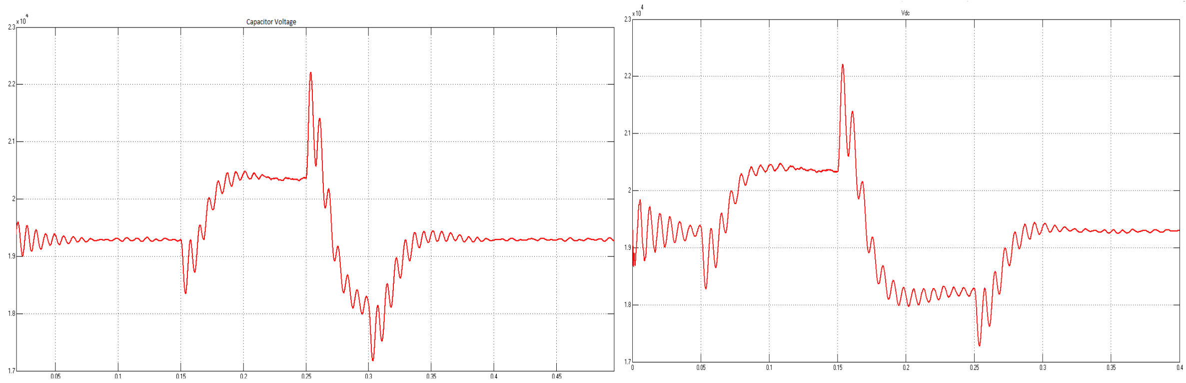

Fig. 10 Capacitor voltage

The 48-pulse GTO-VSC consists of four 3-phase 3-level inverters coupled with four phase shifting transformers (PST) introducing phase shift of +/- 7.5 degree. In a multi-pulse operation, the harmonic content is reduced by using several pulses in each half cycle of the output voltage . The FFT analysis shows that, harmonic content was reduced.Except for 25^{th}, 23^{rd}thistransformer arrangement neutralises all odd harmonics upto the 45^{th} harmonics.

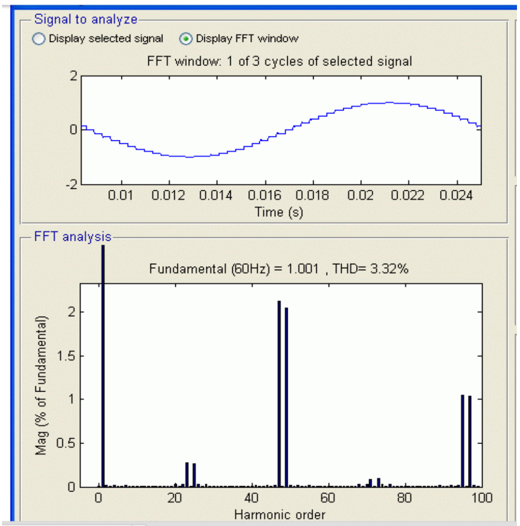

Fig. 11 FFT analysis of converter

V.CONCLUSIONS

In this paper, a STATCOM based 48 pulses converter for power quality improvement and VAR compensation is explained.The STATCOM is able to exchange reactive power with the AC system by absorbingor generating a rate of current equivalent to required reactive power. The task of the control system consists of increasing or decreasing the capacitor DC voltage so that the generated AC voltage has the correct amplitude for the required reactive power. The control system must also keep the AC generated voltage in phase with the system voltage at the STATCOM connection bus in order to generate or absorb reactive power only. The STATCOM's main function is the regulation of bus voltage magnitude at the point where it is connected by exchanging reactive power with the AC system. This reactive power transfer is done through the leakage reactance of the transformer by using transformer voltages in phase with the AC system voltage. Because of the 48 pulses converter harmonic content was reduced. THD of 48 pulses converter is about 3.32 percentage.

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