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Performance Analysis of High Power Applications using Cascaded Three-Level Inverter Based Multilevel STATCOM

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ABSTRACT:This paper presents cascaded three level inverter based multilevel inverter by a simple static var compensating scheme. Here three phase transformer's open end windings are connected parallel to two standard three level inverter. In order to get the four level operation the dc link voltages of the inverter are set at the different levels. This technique is simulated under balanced and unbalanced supply voltage conditions. This simulation is carried out using MATLAB/SIMULINK. For validation of simulation results a laboratory prototype is processed. TMS320F28335digital signal processor is used for control scheme development. System stability of this prototype is analysed. Transfer functions are derived and dynamic model is developed. The stability of the system and behaviour of the system are observed under different operating conditions.

KEYWORDS: STATCOM, power factor, dc link voltage, three level inverter, performance analysis

I.INTRODUCTION

The demand of static compensator(STATCOM) and static synchronous series compensator(SSSC) is increasing day by day because these are the flexible ac transmission systems(FACTS) controllers for high power applications. The reason for increasing demand is, these improve the power quality(PQ) is distributed systems and ability to stabilise the transmission systems. Conventional var compensators are replaced with STATCOM as it is reliable for reactive power controller. Some of static var compensators are like thyristor controlled reactor(TCR) and thyristor switched capacitor(TSC). STATCOM provides active power oscillation damping, reactive power compensation, voltage regulation, flicker attenuation etc[1].

Using multilevel inverters var compensation is gained in high power applications[2]. These inverters includes capacitors with large number of dc sources. A small amount of active power is drawn from converters in order to maintain the capacitor's dc voltage and to compensate converter losses. The capacitor voltages are unbalanced because of mismatch in switching loss and conduction loss. The main aim of multilevel inverters is to balance these voltages. In all three conventional multilevel inverter techniques most famous static var compensator is H-bridge[3]. The controlling of individual dc link voltage of the capacitors is very difficult as H-bridge technique requires a large number of dc capacitors.

For high power applications static var compensation by cascading conventional multilevel/three level inverters is popular method. In this technique the open end winding of a three phase transformer are connected parallel to standard multilevel/three level inverters. These techniques are the best solution for high power drivers. The number of levels in the output voltage waveforms can be incremented by maintaining asymmetric voltages at the dc links of the inverters. This is main advantage of this technique. This helps in improving power quality(PQ). This makes controller to look simple compared to conventional multilevel inverter.

In this paper cascaded three level inverter based multilevel inverter based static var compensation technique is presented. In this technique multilevel operation is achieved using three level inverters. Four level operation can be

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obtained by regulating dc link voltages at asymmetrical levels. To observe the control strategy of proposed method, the test is carried out for balanced and unbalanced supply voltage conditions. To validate the simulation results a laboratory prototype is developed.

From the simulation it indicated that for certain operating conditions the dc link voltages of three inverters collapse when there is sudden change in the reference current. The complete dynamic model is developed from the equivalent circuit for clear observation of system behavior. At different operating conditions the system behavior is analyzed.
This paper is arranged as follows. Section II talks about previous related work. Section III describes the proposed technique. Simulation results are shown and discussed in section IV. Finally section V concludes the work.

II.RELATED WORK

In [4] five level diode clamped converter designed using 6.6kV transformer less STATCOM. Here four capacitors are connected in series for voltage balancing. This STATCOM consists of buck boost choppers with voltage balancing control. 200V 10k-VA laboratory prototype is generated & results are verified. The effective voltage balancing circuit is achieved.

In [5] five level flying capacitor inverter designed using DSTATCOM. Here the current control method is done in five level FCMLI. A new technique is obtained for FCMLI which includes flying capacitors to balance their voltages and produces the line currents using hysteresis control. By simulation it is clear that proposed DSTATCOM performs better.

In [3] transformer less cascade PWM STATCOM with star configuration is designed for medium voltage applications. The control algorithm is based on “Phase shifted unipolar sinusoidal PWM” with 1kHZ of carrier frequency. Here the voltage balancing control of multiple floating dc capacitors without limit on the cascade number is achieved. Results are tested and validated.

In [7] the new methodology based on detailed small signal model of STATCOM and cascade multilevel inverter is designed for balancing individual dc capacitor voltage by feedback strategy. The control technique cancels the various parts in the model. When H-bridge switch with different switching patterns and have parameter variations then controller can balance individual dc capacitor voltages. The controller performs better in capacitive mode, inductive mode and stand by mode. There is no restrictions on cascade number. The simulation has been carried out and results are validated.
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III. PROPOSED TECHNIQUE

A. STATIC COMPENSATOR (STATCOM)

It has been apperceived that the transmittable power state can be incremented and along with this voltage controlled by felicitous reactive shunt emolument. The main purport of this reactive emolument is make the emolument to more compatible with prevailing load demand by transmuting the natural electrical power. Thus to minimize the line voltage under light load conditions, shunt connected fine-tuned or mechanically switched reactors are applied. And also to maintain the voltage levels under hefty load conditions, using shunt connected, fine-tuned or mechanically switched capacitors are applied.

The ultimate objective of applying reactive shunt emolument in a transmission system is to increment the transmittable puissance. This may be required to ameliorate the steady-state transmission characteristics as well as the stability of the system. VAR emolument is thus utilized for voltage regulation at the midpoint (or some intermediate) to segment the transmission line and at the cessation of the (radial) line to avert voltage instability, as well as for dynamic voltage control to increment transient stability and damp power oscillations.

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B. CASCADED THREE-LEVEL INVERTER-BASED MULTILEVEL STATCOM

Fig 1 shows the power system model and Fig 2 & 3 shows the Simulink diagram, circuit for the cascaded three level inverter based multilevel STATCOM.

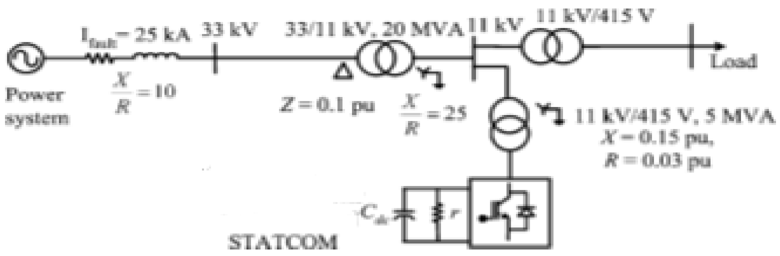

Fig 1. Power system model

Fig 1.Represented that the power system is connected to the Static Compensator Model. A ground fault is added to the circuit with the power system to check the performance of the dc link voltage in balanced and unbalanced conditions. By using the STATCOM model in inverter circuit it will overcome the ground fault which has been added to the circuit and maintains the output waveforms constant.

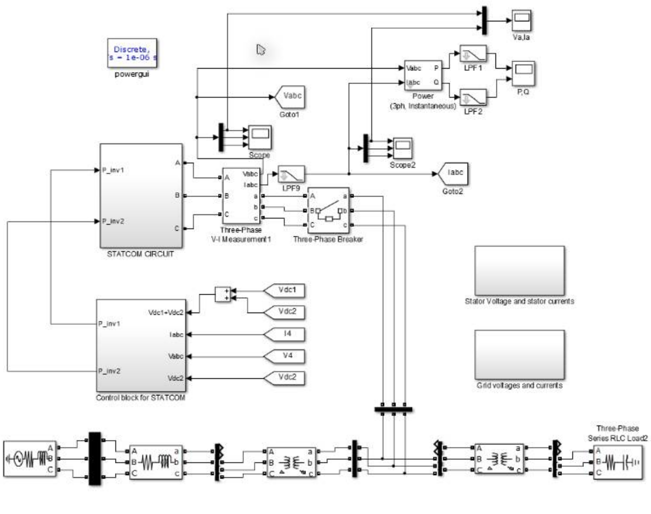

Fig 2. Simulation diagram of three level inverter

By considering the above fig 2. it consist of two three level inverters and a control box that controls the level of the inverters, and 3 phase voltage and current signals are drawn from the inverters, these are measured in three phase VI Measurement block. A ground fault is added to the circuit through the power system to measure the performance of the circuit in Balanced and Unbalanced mode.

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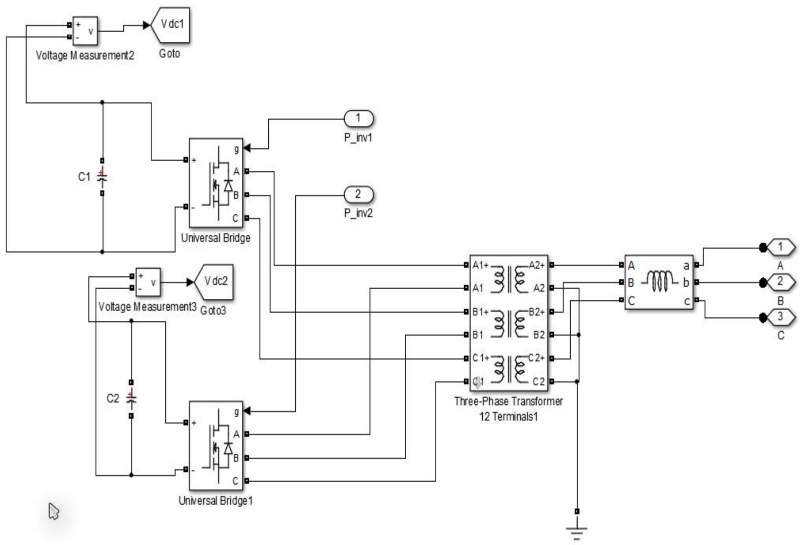

Fig 3. STATCOM circuit

Above fig 3, shows the circuit diagram for the STATCOM, Here the both inverters are connected to the lower end of the 3 phase transformer , and the other side that is higher end of the transformer is connected to the Grid. To achieve the required objective the dc link voltages are maintained constant.

IV. SIMULATION RESULTS

Thesimulationstudy is carried out using MATLAB/SIMULINK, system parameters are shown in below table1.

Table 1: Simulation system Parameters

Rated power	5MVA
Transformer voltage rating	11kV/400
AC supply frequency, f	50Hz
Inverter-1 dc link voltage, V_{dc1}	659 V
Inverter-1 dc link voltage, V_{dc2}	241 V
Transformer leakage reactance, X_1	15%
Transformer resistance, R	3%
DC link capacitance,$C_{1,}$ C_2	50mF
Switching frequency	1200Hz

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In below fig 4, it shows the graph of line Voltage Vs Time, and the fig 5 shows graph of STATCOM current Vs time, .Fromthe both figures, itcanbe observe that the dc linkvoltagesoftheinvertersareregulatedattheirrespective referencevalueswhentheSTATCOMmodeischangedfromcapacitive to inductive. Moreover, the dc-link voltage of inverter 2 attains its reference value faster compared to that of inverter 1.

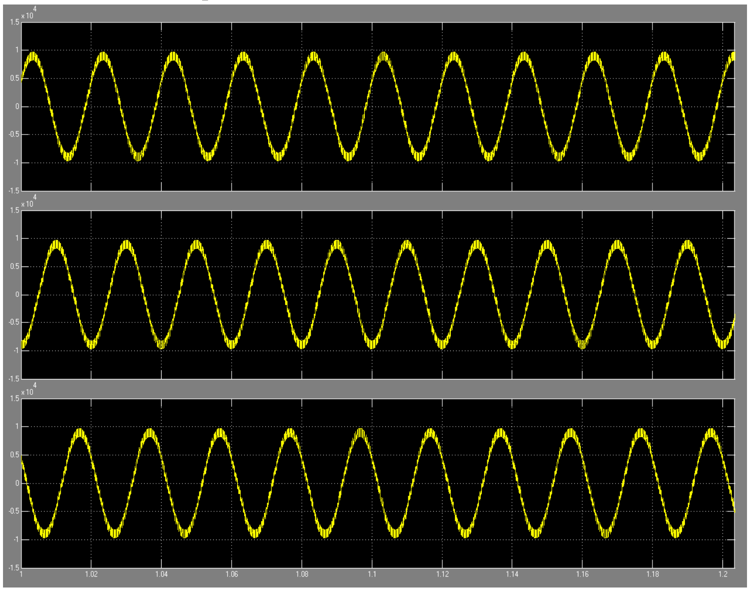

Fig 4. Line Voltage

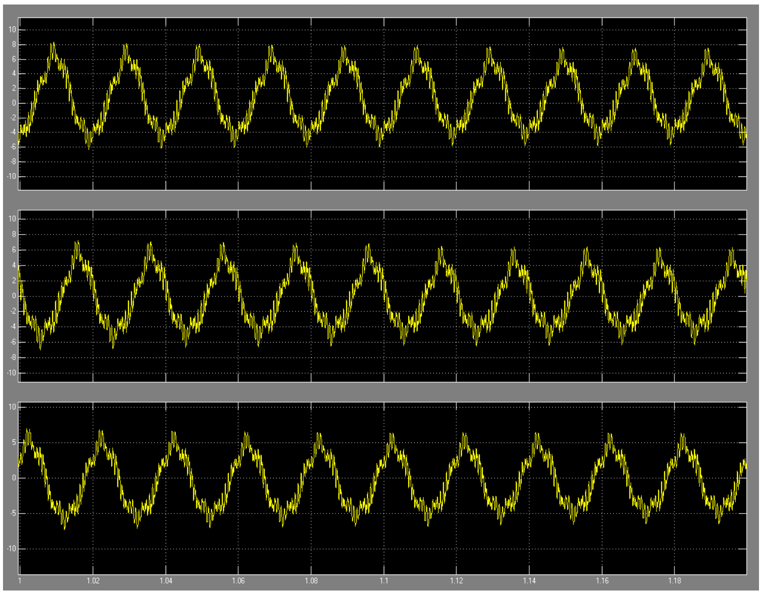

Fig 5. STATCOM Currents

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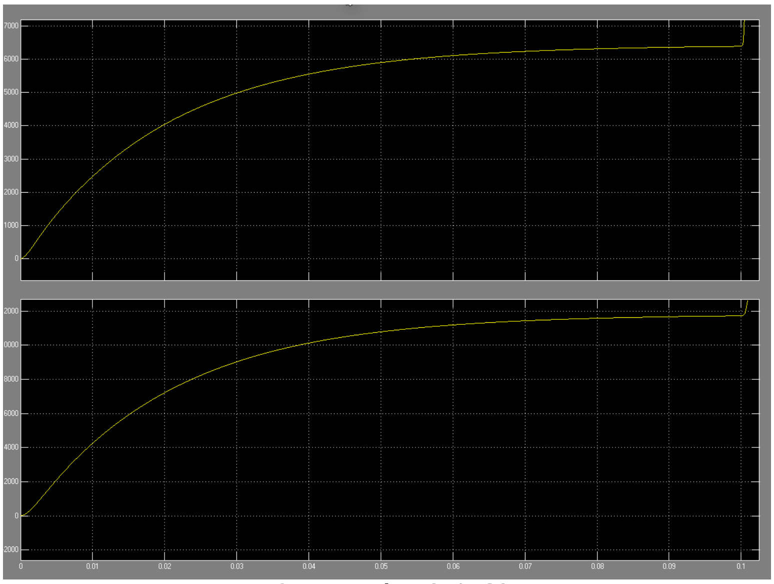

Fig 6. Power without STATCOM

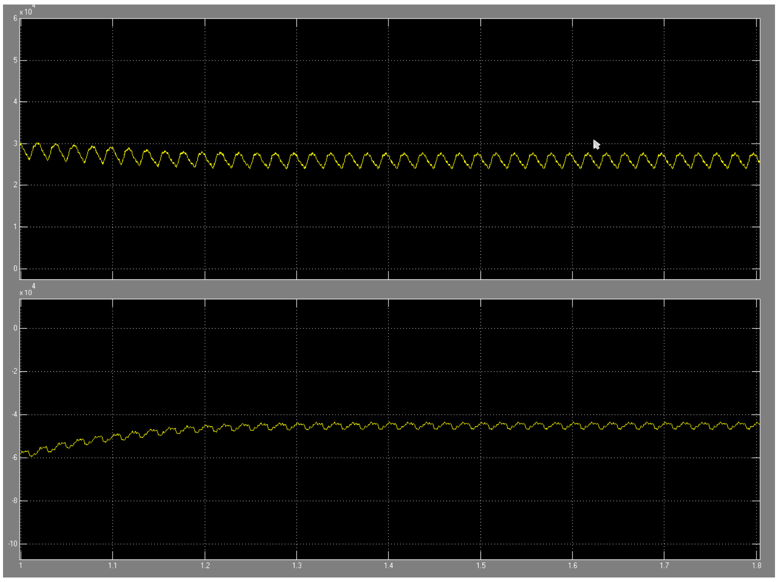

Fig 7. Power with STATCOM

Fig 6 & 7 d Shows the Graph of the system power when the system is not connected to the STATCOM circuit and System is connected to the STATCOM circuit, form the figures it can be observe that when the system is connected to the Static Compensator circuit, real and reactive power will be stable.

V.CONCLUSION

In this paper a proposal has been made for a simple var compensating scheme for cascaded three level inverter based multilevel inverter. The basic concepts of static var compensator are discussed. The scheme provides reactive power compensation and regulation of dc link voltages of inverter at symmetrical levels. The simulation results verify the control scheme proposed. The performance of the compensator has been tested by simulation on a network with

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balanced and unbalanced supply conditions. When there is change in reference current then system becomes instability. Under various operating conditions the system behaviour is observed. The simulation results confirm that the poles of the transfer function always lie on the left half of s-plane. For some of operating conditions zeros lie on the right half of s-plane The results confirm that the proposed scheme offers better performance with high gain.

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