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Cascaded Multilevel Converter Based T-STATCOM

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Abstract: **The main purpose of these project is maintain the stable voltage regulation in the transmission lines by using the cascaded multi level converter, In This converter we are using insulated gate bipolar transistor (IGBT) technology. This project deals with the design methodology for cascaded multilevel converter (CMC)-based transmission-type STATCOM (T-STATCOM). Sizing of the CMC module, the number of H-bridges (HBs) in each phase of the CMC, ac voltage rating of the CMC, the number of paralleled CMC modules in the T-STATCOM system, the optimum value of series filter reactors, and the determination of bus bar in the power grid to which the T-STATCOM system is going to be connected, current status of high voltage (HV) insulated gate bipolar transistor (IGBT) technology, and the required reactive power variation range for the T-STATCOM application. The equalization of dc-link capacitor voltages is achieved according to the modified selective swapping (MSS) algorithm. An L-shaped laminated bus has been designed and the HV IGBT driver circuit has been modified for the optimum switching performance of HV IGBT modules the simulation is carried over by the MATLAB-SIMULINK software.**

Keywords: **CMI, STATCOM, Power Quality, Reactive Power, H Bridge, Circuit Diagram.**

I. INTRODUCTION

A power inverter, or inverter, is an electronic device or circuitry that changes direct current (DC) to alternating current (AC). The input voltage, output voltage and frequency, and overall power handling, are dependent on the design of the specific device or circuitry. A power inverter can be entirely electronic or may be a combination of mechanical effects (such as a rotary apparatus) and electronic circuitry. Static inverters do not use moving parts in the conversion process. Typical applications for power inverters include :Portable consumer devices that allow the user to connect a battery, or set of batteries, to the device to produce AC power to run various electrical items such as lights, televisions, kitchen appliances, and power tools. Use in power generation systems such as electric utility companies or solar generating systems to convert DC power to AC power. Use within any larger electronic system where an engineering need exists for deriving an AC source from a DC source.

II. MODULE DESCRIPTION

Cascade Multilevel Inverter:

Cascade Multilevel Inverter (CMLI) is one of the most important topology in the family of multilevel and multi pulse inverters. It requires least number of components with compare to diode-clamped and flying capacitors type multilevel inverters and no specially designed transformer is needed as compared to multi pulse inverter. It has modular structure with simple switching strategy and occupies less space

STATCOM:

A static synchronous compensator (STATCOM), also known as a "static synchronous condenser" ("STATCON"), is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. It is a member of the FACTS family of devices.

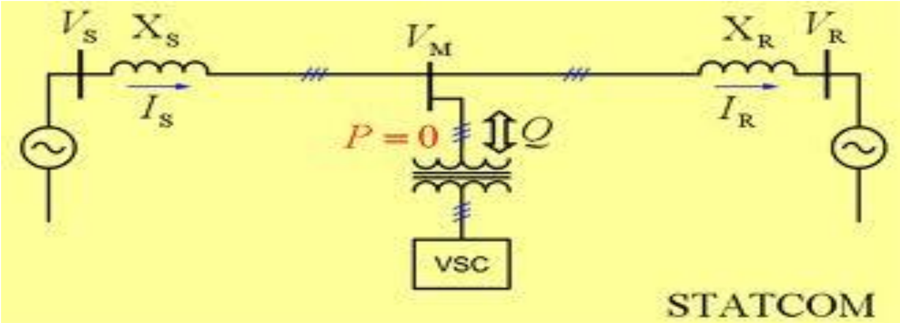

Fig.1 Line diagram of STATCOM

Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. There are however, other uses, the most common use is for voltage stability. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DCcapacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source. For example, if the terminal voltage of the VSC is higher than the AC voltage at the point of connection, the STATCOM generates reactive current; on the other hand, when the amplitude of the voltage source is lower than the AC voltage, it absorbs reactive power. The response time of a STATCOM is shorter than that of an SVC, mainly due to the fast switching times provided by the IGBTs of the voltage source converter. The STATCOM also provides better reactive power support at low AC voltages than an SVC, since the reactive power from a STATCOM decreases linearly with the AC voltage (as the current can be maintained at the rated value even down to low AC voltage). A static VAR compensator (SVC) can also be used for voltage stability. However, a STATCOM has better characteristics than a SVC. When the system voltage drops sufficiently to force the STATCOM output current to its ceiling, its maximum reactive output current will not be affected by the voltage magnitude. Therefore, it exhibits constant current characteristics when the voltage is low under the limit. In contrast the SVC's reactive output is proportional to the square of the voltage magnitude. This makes the provided reactive power decrease rapidly when voltage decreases, thus reducing its stability. In addition, the speed of response of a STATCOM is faster than that of an SVC and the harmonic emission is lower. On the other hand STATCOMs typically exhibit higher losses and may be more expensive than SVCs, so the (older) SVC technology is still widespread.

GENERAL:

The switching instants are fixed and the fundamental component of the compensator current is controlled by controlling the magnitude of dc link voltage rather than controlling the modulation index. The parallel compensator is operated in current controlled mode and provides on line elimination of the higher order harmonics generated by the main compensator.

A sinusoidal reference current i_{ref} in phase with the utility voltage is synthesized and the source current is forced to follow this reference within a hysteresis band. The source current is sensed and compared with the reference current. The error thus obtained decides the switching pattern of the parallel compensator

TABLE 1 SOME PRACTICAL APPLICATIONS OF STATCOM SYSTEMS

System	**Ratings**	**Converter Topology**	**Semiconductor Switch**
Static VAR Generator, Japan, 1980	20MVA/77kV	Multipulse/2-level Voltage Source Converter (VSC)	Conventional fast switching thyristor (SCR)
Static VAR Generator, Japan, 1993	80MVA/154kV	Multipulse/2-level VSC	Conventional fast switching thyristor (SCR)
TVA STATCON, Tennessee, 1995	±100MVAr/161kV	Multipulse/2-level VSC	4.5kV/4.0kA GTO
Seattle Iron&Metals	5MVA/4.16kV	2-level VSC	1.2kV/0.6kA IGBT

D-STATCOM, Washington, 1999			
Henan STATCOM, China, 1999	20MVA/220kV	Multipulse/2-level VSC	4.5kV/4.0kA GTO
VELCO STATCOM, Vermont-USA, 2001	2x43MVA/115KV	2-level VSC	6.0kV/6.0kA GTO

REACTIVE POWER:

Reactive loads such as inductors and capacitors dissipate zero power, yet the fact that they drop voltage and draw current gives the deceptive impression that they actually do dissipate power. This "phantom power" is called reactive power, and it is measured in a unit called Volt-Amps-Reactive (VAR), rather than watts. The mathematical symbol for reactive power is (unfortunately) the capital letter Q.

H BRIDGE:

An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards. Most DC-to-AC converters (power inverters), most AC/AC converters, the DC-to-DC push–pull converter, most motor controllers, and many other kinds of power electronics use H bridges. In particular, a bipolar stepper motor is almost invariably driven by a motor controller containing two H bridges.

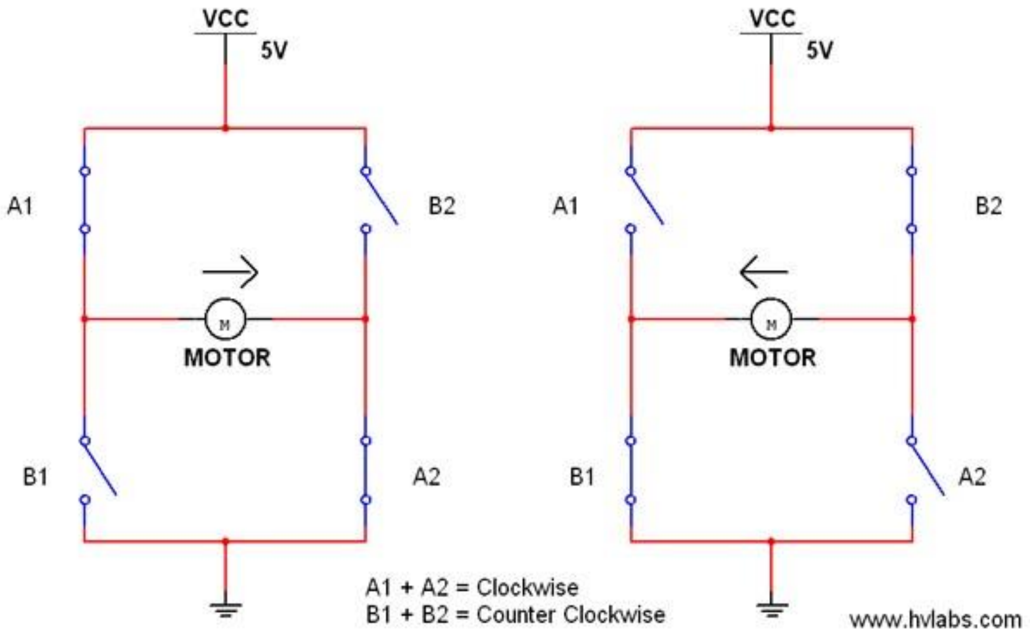

Fig 2 H-Bridge Operation diagram

POWER QUALITY:

Power quality determines the fitness of electrical power to consumer devices. Synchronization of the voltage frequency and phase allows electrical systems to function in their intended manner without significant loss of performance or life. The term is used to describe electric power that drives an electrical load and the load's ability to function properly. Without the proper power, an electrical device (or load) may malfunction, fail prematurely or not operate at all. There are many ways in which electric power can be of poor quality and many more causes of such poor quality power. The electric power industry comprises electricity generation (AC power), electric power transmission and ultimately electricity distribution to an electricity meter located at the premises of the end user of the electric power. The electricity then moves through the wiring system of the end user until it reaches the load. The complexity of the system to move electric energy from the point of production to the point of consumption combined with variations in weather, generation, demand and other factors provide many opportunities for the quality of supply to be compromised.

SMART GRIDS:

Modern systems use sensors called phasor measurement units (PMU) distributed throughout their network to monitor power quality and in some cases respond automatically to them. Using such smart grids features of rapid sensing and automated self healing of anomalies in the network promises to bring higher quality power and less downtime while simultaneously supporting power from intermittent power sources and distributed generation, which would if unchecked degrade power quality.

Single Diagram of T-SATCOM based on CMC

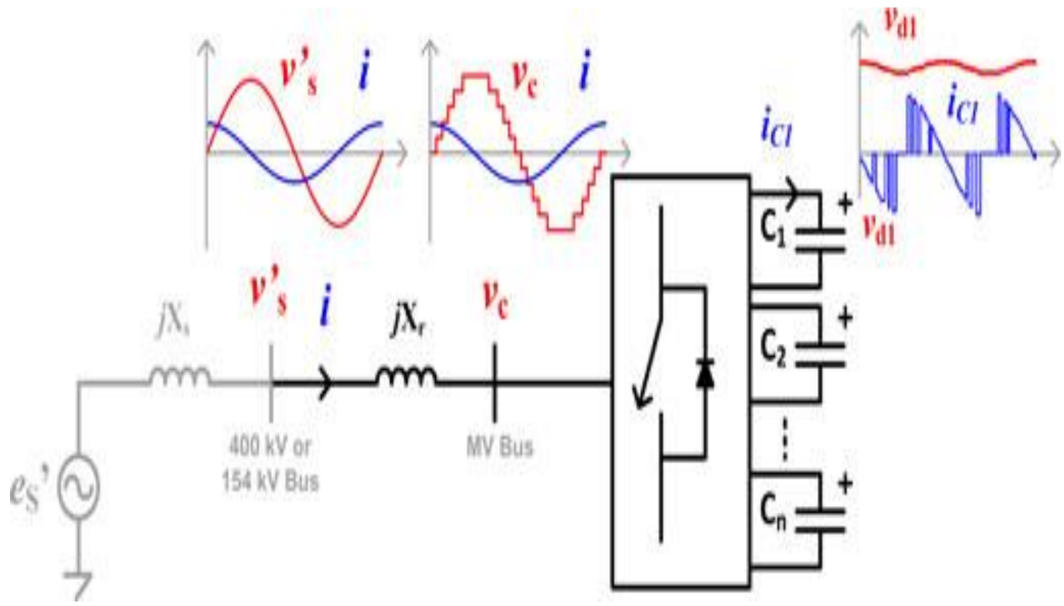

Fig: 3 Single-line diagram of a T-STATCOM based on a single CMC.

This project deals with the sizing and system design considerations and a detailed methodology for the power-stage design and implementation of an HV IGBT-based CMC for T-STATCOM applications.. System design, optimization of the input filter reactor, and the choice of the number of HBs in each phase of the wye-connected CMC are achieved in view of total harmonic distortion (THD) at point of common coupling (PCC), total demand distortion (TDD) of the line currents. The selective harmonic elimination method (SHEM) is applied to synthesize T-STATCOM voltage waveforms at power frequency (50 Hz) and the modified selective swapping (MSS) algorithm is exercised to balance the dc-link capacitor voltages, perfectly. The power stage is carefully designed and its performance is optimized in view of the current HV IGBT technology. Field prototype of the resulting 11-level CMC with five HBs in each phase is then implemented to deliver 10 MVAr to 154 kV transmission bus (PCC) via a series filter reactor and a 154/10.5 kV coupling transformer. The CMC presented in this paper has some advantages over the commercially available CMC and DCMC systems. These are as follows:

1) Flexibility and modularity in the design permit higher CMC voltage ratings by increasing the number of HBs in each phase or by increasing the voltage rating of HV IGBTs in each HB.

2) Snubberless operation.

3) The CMC avoids any auxiliary circuit for dc-link capacitor voltage balancing and minimizes dc-link capacitance by the application of MSS algorithm.

4) The CMC permits the use of cheaper wire-bond HV IGBT technology.

5) The CMC provides a rapid maintenance against failures owing to with drawable HB units.

Circuit Diagram of T-SATCOM based on CMC

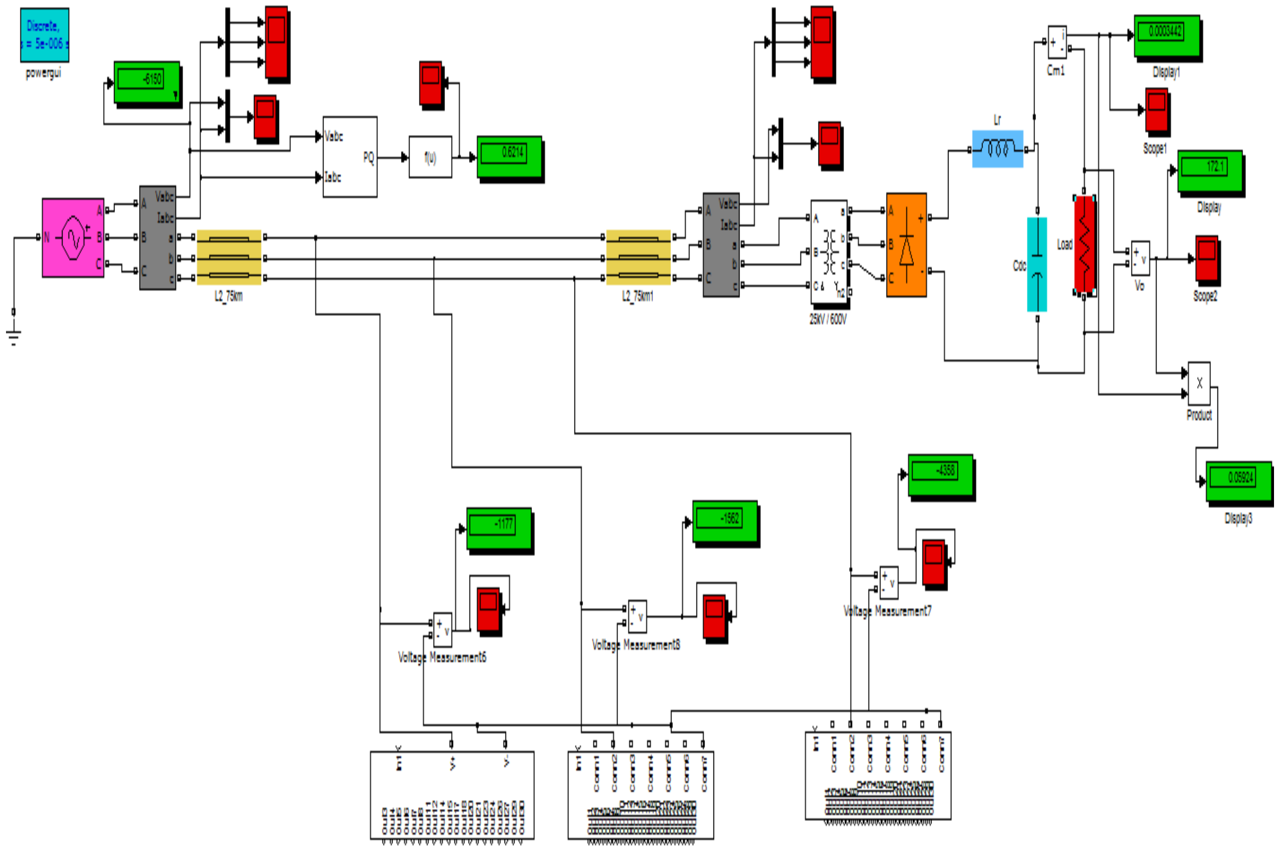

Fig 4 Circuit Diagram of T-SATCOM based on CMC

Operation Modes:

The single-line diagram of a T-STATCOM based on a single CMC. It is shown to be connected to EHV or HV busbar of the transmission system via a MV to EHV or HV coupling transformer. Therefore, in Fig. 1, *Xr* represents the total leakage reactance of the coupling transformer and if needed the reactance of the series filter reactor. Waveforms of EHV or HV bus voltage *v_s*, T-STATCOM line current *i*, CMC ac voltage *VC*, dc-link capacitor voltage *vd*1, and dc-link capacitor current *iC*1 are also sketched in Fig. 1. *E_ s, X_ s,* and *v_ s* denote, respectively, the internal source voltage, the source reactance, and EHV or HV bus voltage, all referred to the CMC side.

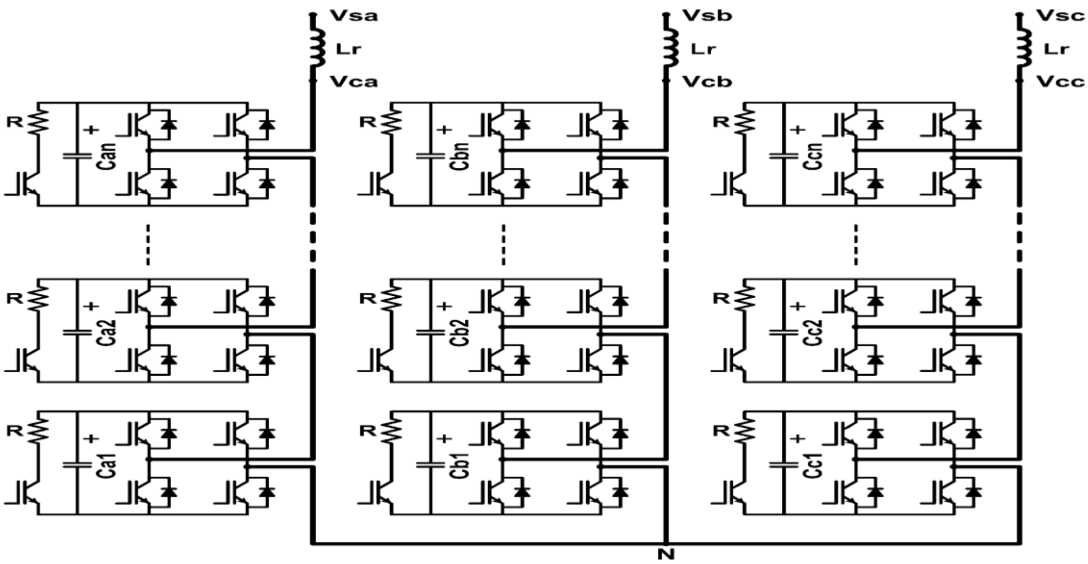

Fig. 5 Circuit diagram of a star-connected CMC consisting of *n* series connected HBs in each phase

The circuit diagram of a star-connected CMC consisting of *n* number of series-connected HBs in each phase is shown in Fig. 2. The dc link of each HB in the CMC is equipped with a dc/dc converter controlled discharge resistor *R* to protect the dc-link capacitor *C* against dangerous over voltages and also to discharge *C* when the CMC is disconnected from the supply for inspection or maintenance purpose. *Lr* in Fig. 2 is the equivalent inductance of the total filter reactance *Xr* in Fig. 1. A T-STATCOM system operates at power frequency (50 Hz or 60 Hz) as a shunt-connected flexible ac transmission system (FACTS) device and performs one or more than one of the following functions at the EHV or HV bus to which the T-STATCOM is connected:

1) Terminal voltage regulation

2) Control of reactive power flow in O/H lines

3) Power system stability improvement.

III. TECHNIQUES USED

SYSTEM DESCRIPTION:

It is shown to be connected to EHV or HV busbar of the transmission system via a MV to EHV or HV coupling transformer. The circuit diagram of a star-connected CMC consisting of n number of series-connected HBs in each phase. The dc link of each HB in the CMC is equipped with a dc/dc converter controlled discharge resistor R to protect the dc-link capacitor C against dangerous over voltages and also to discharge C when the CMC is disconnected from the supply for inspection or maintenance purpose.

REACTIVE POWER CONTROL:

Complex power input S = Ps + jQs to the T-STATCOM at EHV or HV bus is defined according to power sink convention. Active power P is always positive in the steady state to compensate for coupling transformer, series filter reactor, and CMC losses. However, the sign of Qs depends upon the operation mode of the T-STATCOM, i.e., positive for the inductive operation mode and negative for the capacitive operation mode. Since series resistances of the coupling transformer and series filter reactor are ignored.

WAVEFORM SYNTHESIZING:

The three-phase voltage waveforms of the CMC are created by superimposing rectangular waves produced by n number of HBs. These voltage waveforms can be approximated to pure sine waves at supply frequency. Although line-to-neutral voltage waveforms have third harmonic voltage component and its integer multiples, these harmonics will not be present in the line-to-line voltage waveforms when the CMC performs balanced operation in the steady state. A similar conclusion can be drawn also for the even harmonic voltage components.

SIMULATION RESULTS:

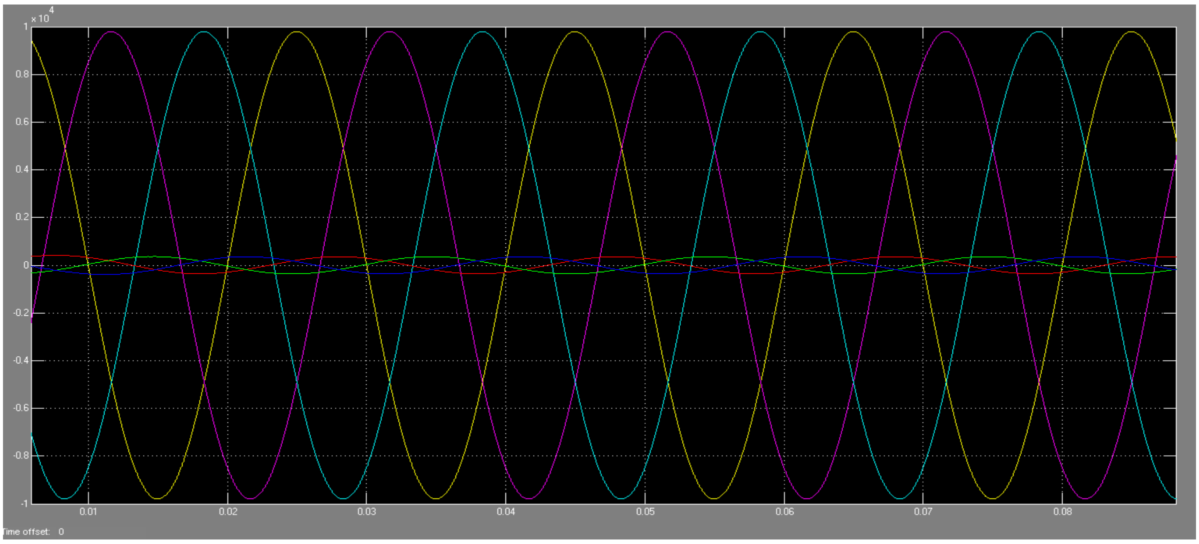

Fig.6 Input Voltage and current wave forms

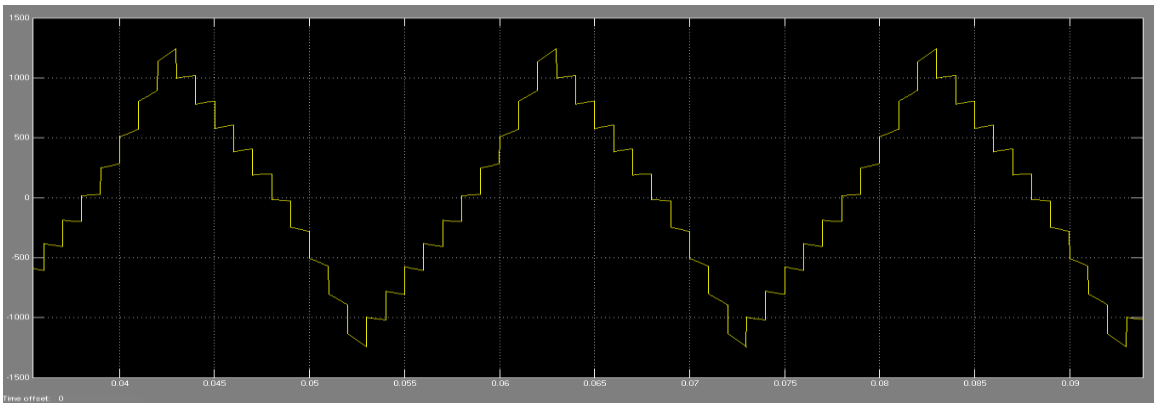

Fig.7 Output Wave Form of CMC at R-Phase

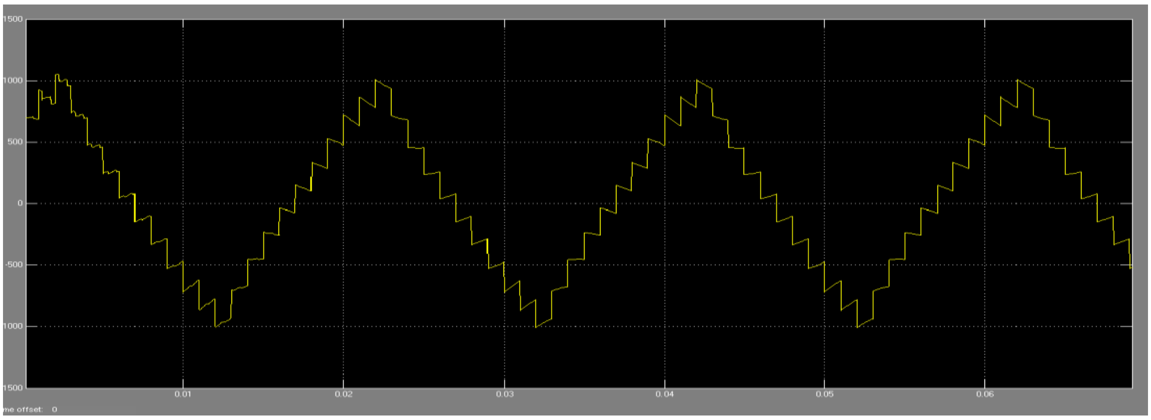

Fig.8 Output Wave Form of CMC at Y-Phase

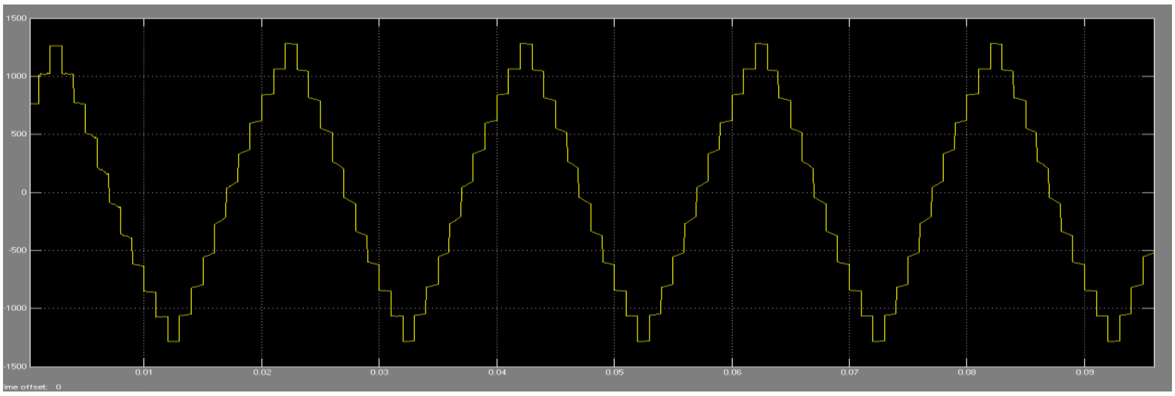

Fig.9 Output Wave Form of CMC at B-Phase

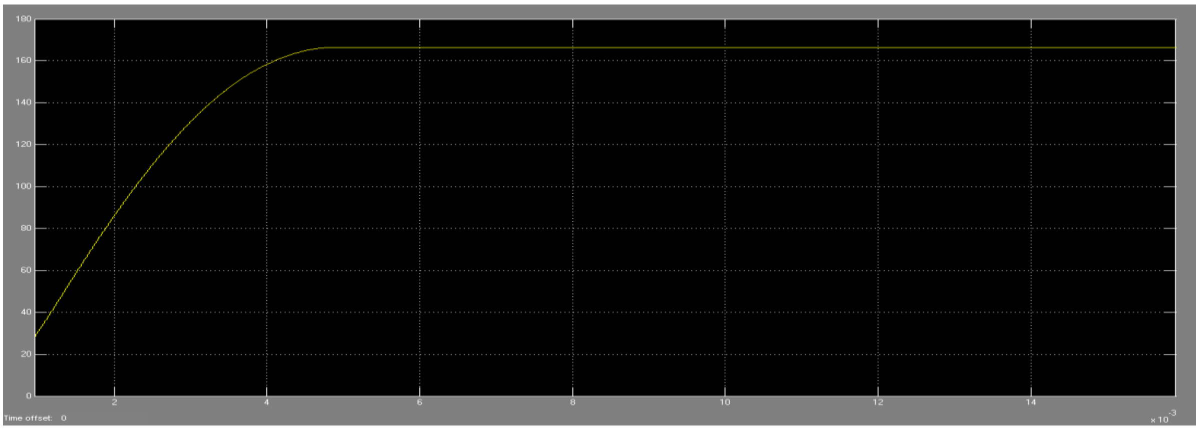

Fig.10 Output Voltage Wave Form at R-load

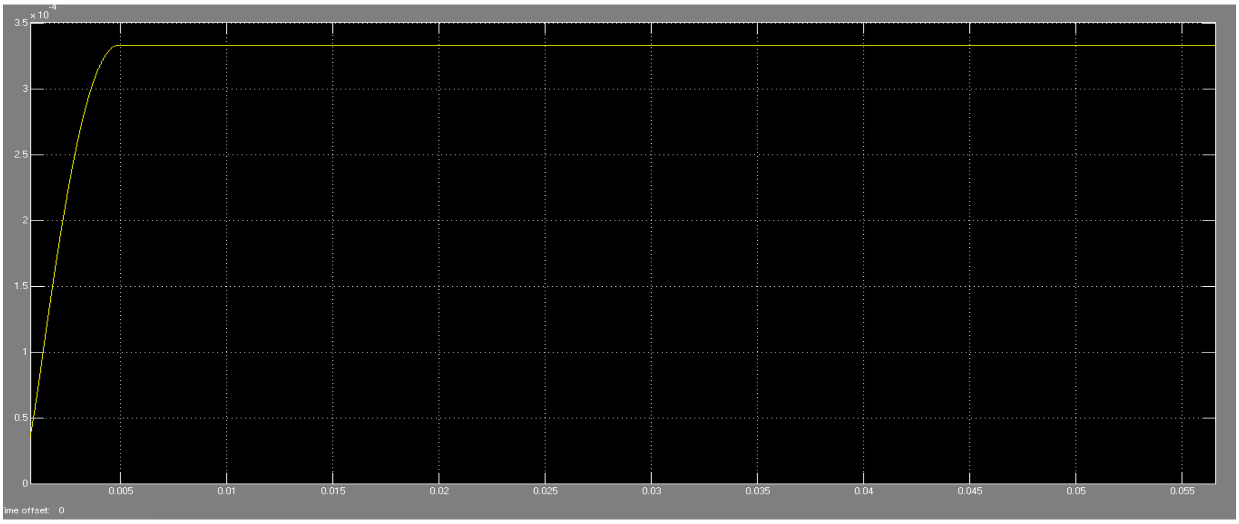

Fig.11 Output Current Wave Form at R-load

IV. CONCLUSION

The cascaded controller is designed for seven levels CMC based STATCOM. This control scheme regulates the capacitor voltage of the STATCOM and maintains rated supply voltage for any load variation within the rated value. It has been shown that the CMC is able to reduce the THD values of output voltage and current effectively. The CMC based STATCOM ensures that compensates the reactive power and reduces the harmonics in output of STATCOM.

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