

**Figure 2:** Single-line diagram of a T-STATCOM based on a single MMC

These are as follows:

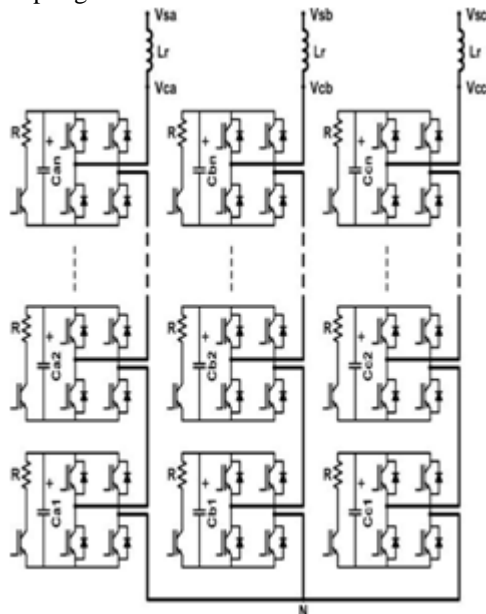
- 1) Flexibility and modularity in the design permit higher MMC voltage ratings by increasing the number of HBs in each phase or by increasing the voltage rating of HV IGBTs in each HB.

#### Snubberless Operation

- 2) The MMC avoids any auxiliary circuit for dc-link capacitor voltage balancing and minimizes dc-link capacitance by the application of MSS algorithm.
- 3) The MMC permits the use of cheaper wire-bond HV IGBT technology.
- 4) The MMC provides a rapid maintenance against failures owing to with drawable HB units.

## 4. Operation Modes

Fig. 3 shows the single-line diagram of a T-STATCOM based on a single MMC. It is shown to be connected to EHV or HV busbar of the transmission system via a MV to EHV or HV coupling transformer.



**Figure 3:** Circuit diagram of a star-connected MMC consisting of  $n$  series connected HBs in each phase

Therefore, in Fig. 3,  $X_r$  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  $i$ , MMC ac voltage  $v_c$ , dc-link capacitor voltage  $v_{d1}$ , and dc-link capacitor current  $i_{C1}$  are also sketched in Fig. 3.  $e_s$ ,  $X_s$ , and  $v_s$  denote, respectively, the internal source voltage, the source reactance, and EHV or HV bus voltage, all referred to the MMC side.

The circuit diagram of a star-connected MMC consisting of  $n$  number of series-connected HBs in each phase is shown in Fig. 2. The dc link of each HB in the MMC 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 MMC is disconnected from the supply for inspection or maintenance purpose.  $L_r$  in Fig. 2 is the equivalent inductance of the total filter reactance  $X_r$  in Fig. 3. 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.

## 5. Simulation Results

### 5.1 Techniques Used

#### 5.1.1 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 MMC consisting of  $n$  number of series-connected HBs in each phase. The dc link of each HB in the MMC 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 MMC is disconnected from the supply for inspection or maintenance purpose.

#### 5.1.2 Reactive Power Control

Complex power input  $S = P_s + jQ_s$  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 MMC losses. However, the sign of  $Q_s$  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.

#### 5.1.3 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.

5.2 Simulation Design

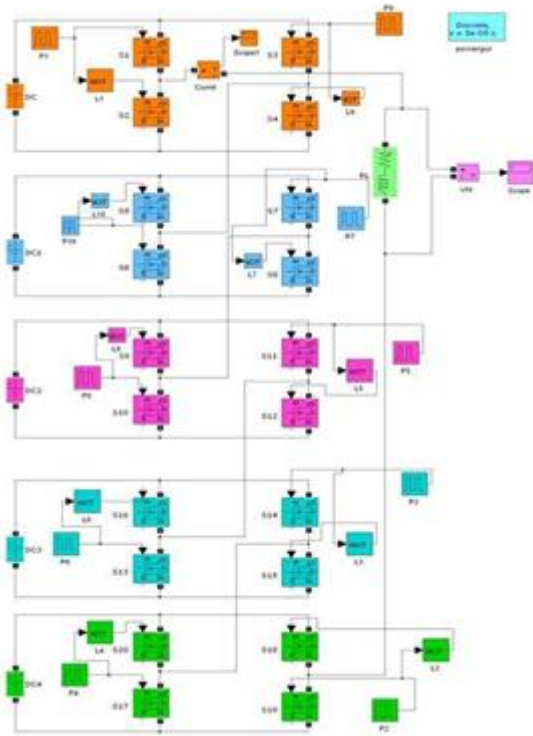


Figure 4: Simulation of a open loop circuit of cascaded multilevel converter based TSTATCOM

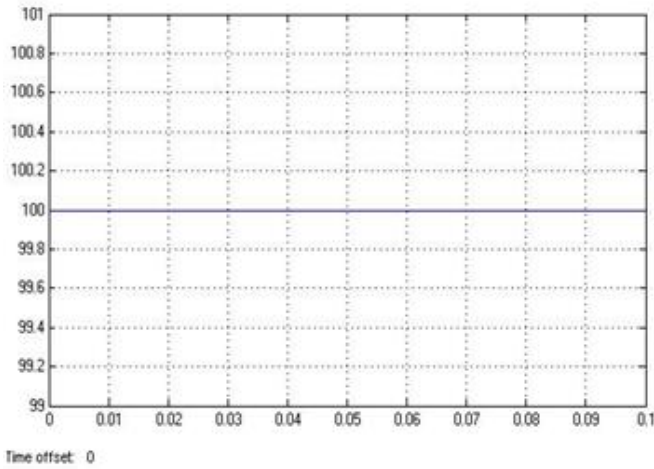


Figure 5: Input voltage Waveform

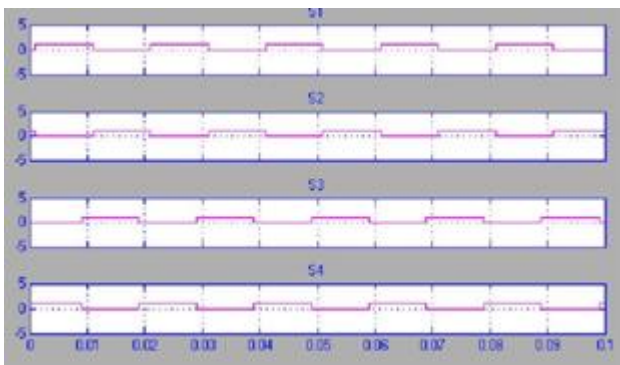


Figure 6: Switching Waveforms S1-S4

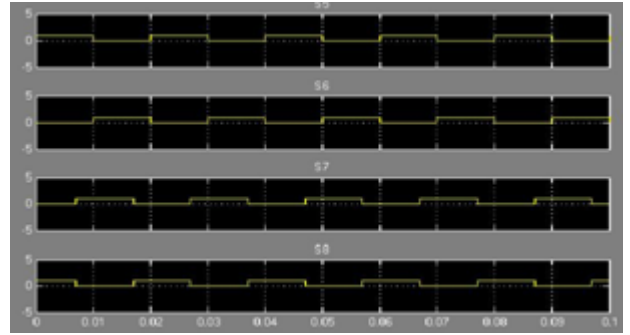


Figure 7: Switching Waveforms S5-S8

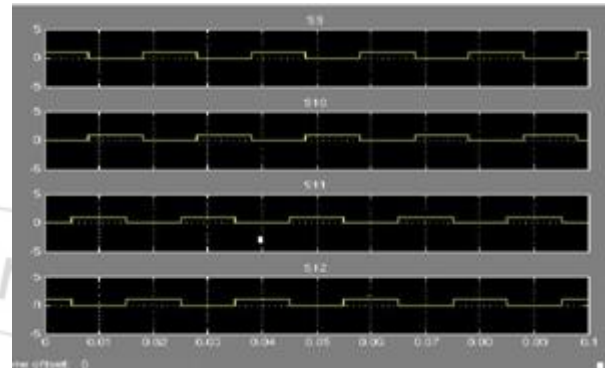


Figure 8: Switching Waveforms S9-S12

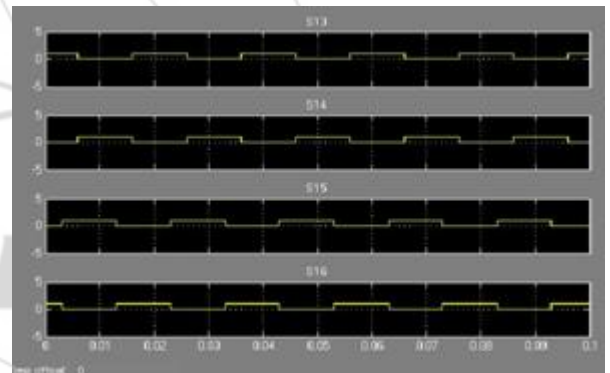


Figure 9: Switching Waveforms S13-S16

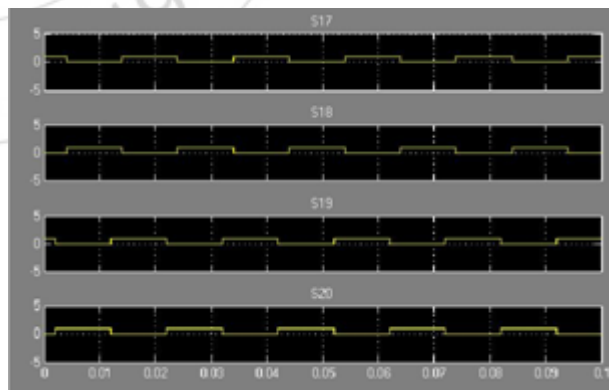


Figure 10: Switching Waveforms S17-S20

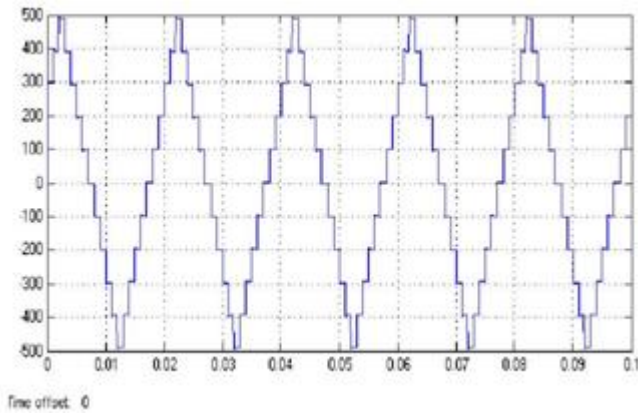


Figure 11: Output voltage Waveform

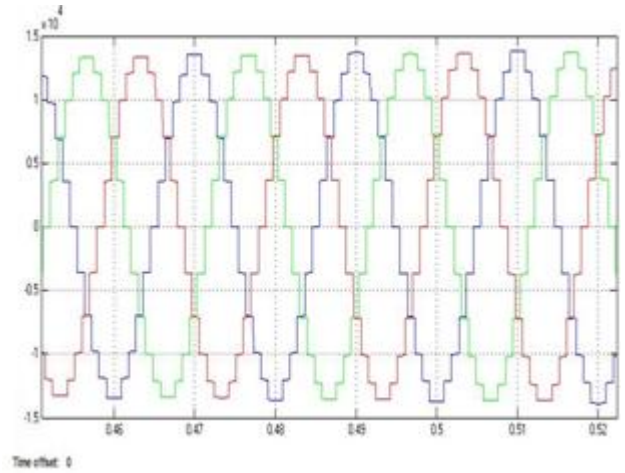


Figure 14: Output line voltage Waveform

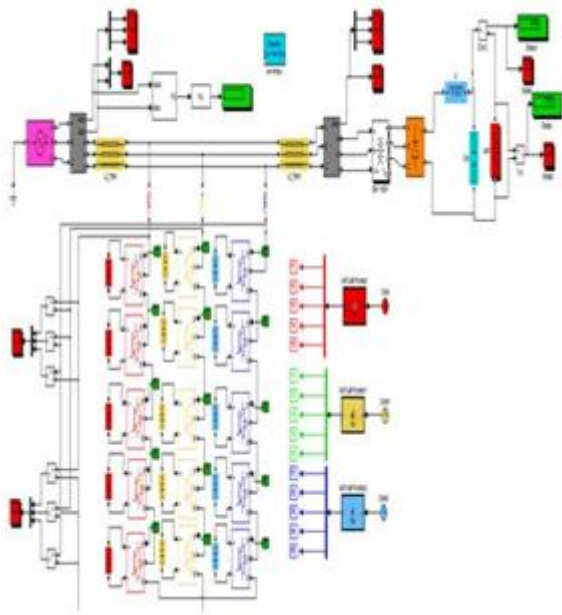


Figure 12: Simulation of an open loop circuit of Modular multilevel converter based STSTATCOM

## 6. Results

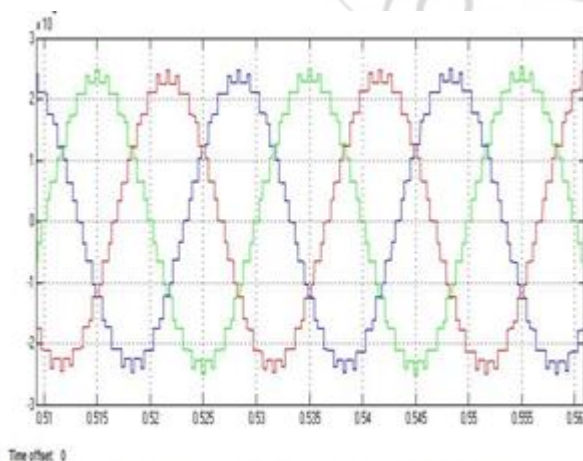


Figure 13: Output phase voltage Waveform

## 7. Conclusion

The system can be extended for more voltage range. Increase in more voltage range will increase the voltage gain and efficiency of the converter system. The output AC voltage can be rectified and we can use the DC loads also

## References:

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