International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2013): 4.438

Modular Multi-Level Converter Based T-STATCOM

Gudishe Sateesh[1], **Devarashetti Nagaraju**[2]

[1, 2]Sri Venkateswara Engineering College, JNTU-Hyderabad, India

Abstract: ***This project deals with the design methodology for modular multilevel converter (MMC)-based transmission-type STATCOM (T-STATCOM). Sizing of the MMC module, the number of H-bridges (HBs) in each phase of the MMC, ac voltage rating of the MMC, the number of paralleled MMC 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: T-STATCOM, MMC, IGBT, SVM, SHEM, HVDC

1. Introduction

This paper deals with the sizing and system design considerations and a detailed methodology for the power-stage design and implementation of an HV IGBT-based MMC 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 MMC are achieved in view of total harmonic distortion (THD) at point of common coupling (PCC), total demand distortion (TDD) of the line currents, and individual harmonic current limits recommended by the IEEE Std. 519-1992.

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.

2. 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.

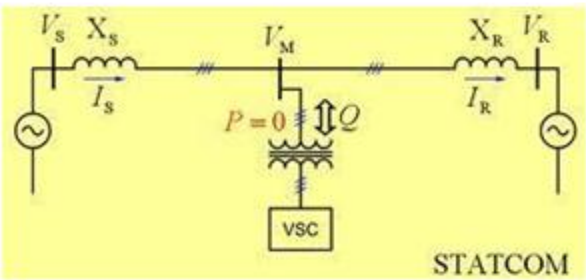

Figure 1: Line diagram of STATCOM

Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation as shown in fig.1. 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 DC capacitor 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.

3. Modules Description

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 MMC 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 MMC 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 MMC 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 MMC presented in this paper has some advantages over the commercially available CMC and DCMC systems.

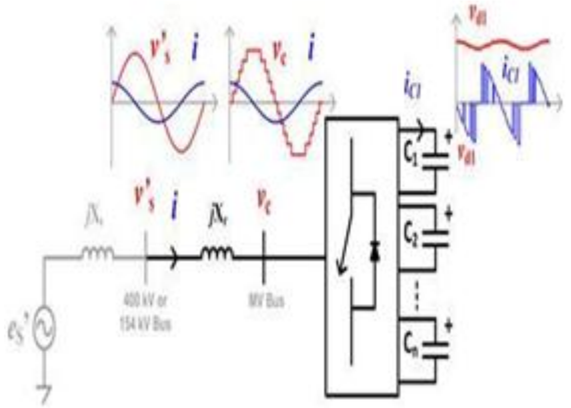

Figure 2: Single-line diagram of a T-STATCOM based on a single MMC

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.

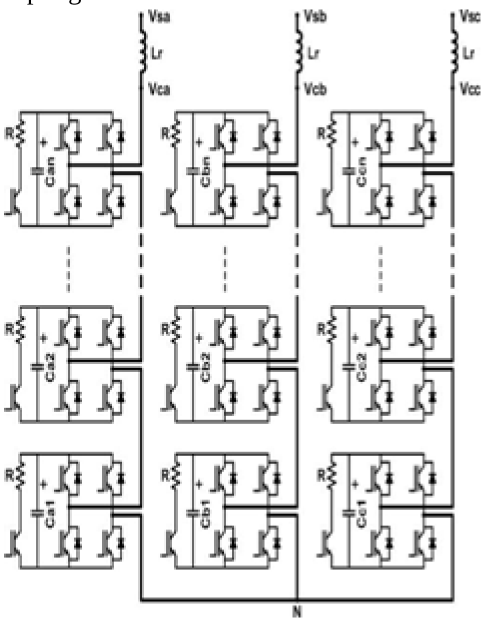

Figure 3: Circuit diagram of a star-connected MMC consisting of *n* series connected HBs in each phase

Therefore, in Fig. 3, *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*, MMC ac voltage *vc* , dc-link capacitor voltage *vd*1 , and dc-link capacitor current *iC*1 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. *Lr* in Fig. 2 is the equivalent inductance of the total filter reactance *Xr* 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 = 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 MMC 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.

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

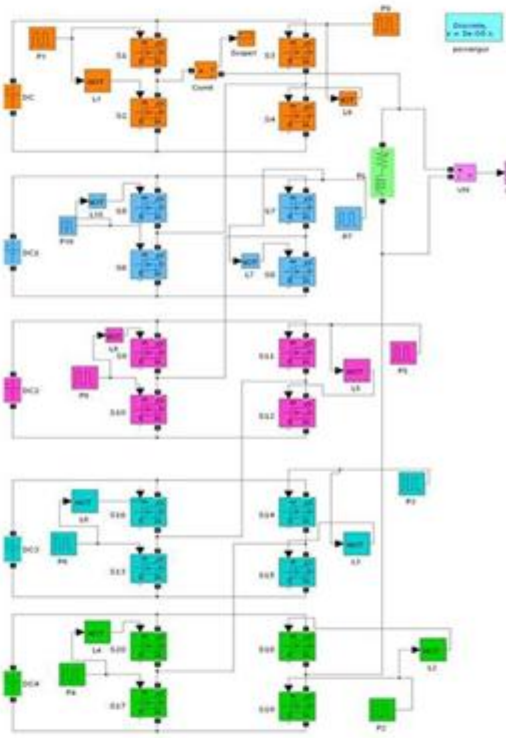

Figure 4: Simulation of a open loop circuit of cascaded multilevel converter based TSTATCOM

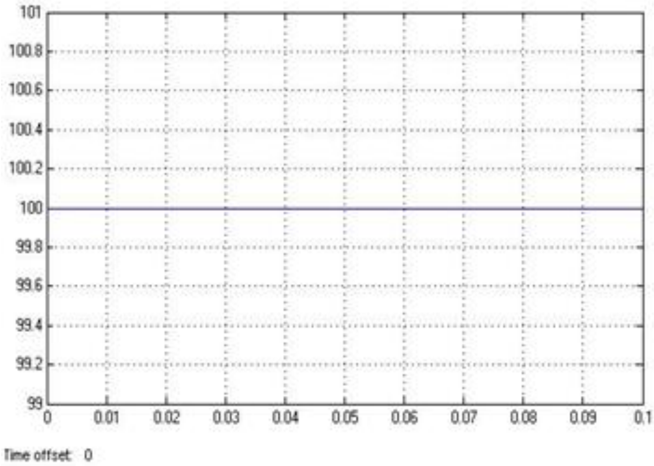

Figure 5: Input voltage Waveform

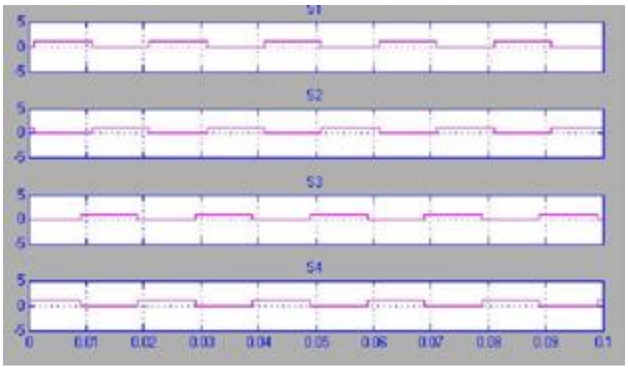

Figure 6: Switching Waveforms S1-S4

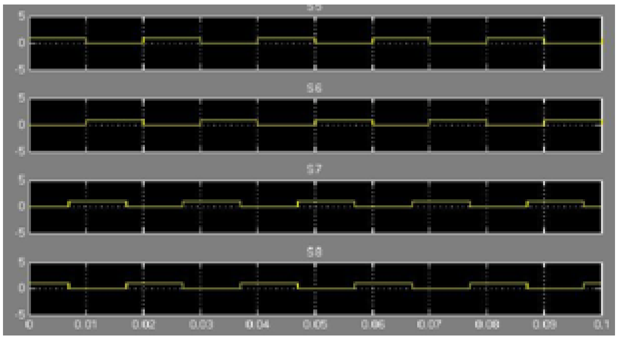

Figure 7: Switching Waveforms S5-S8

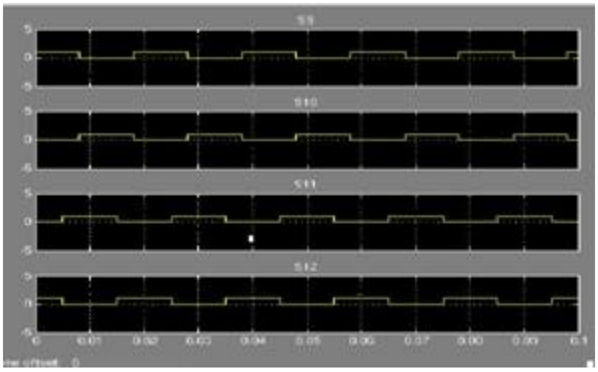

Figure 8: Switching Waveforms S9-S12

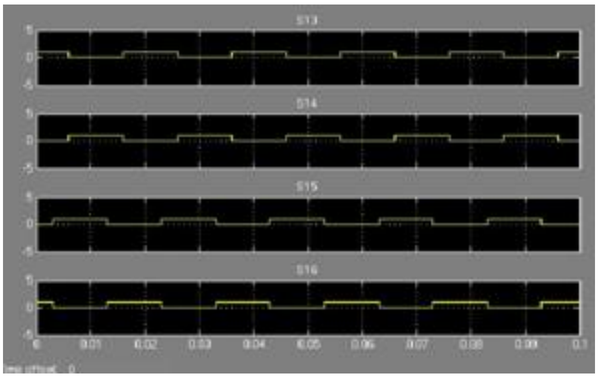

Figure 9: Switching Waveforms S12-S16

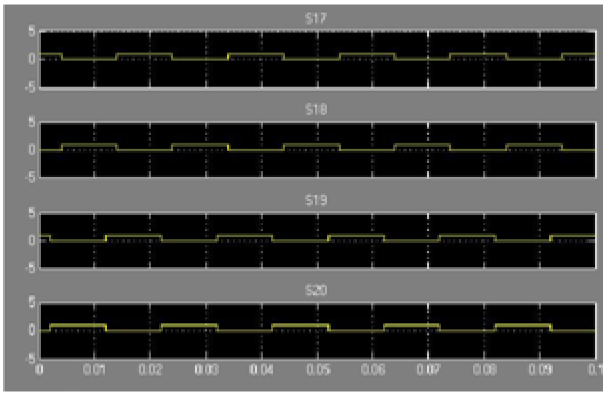

Figure 10: Switching Waveforms S17-S20

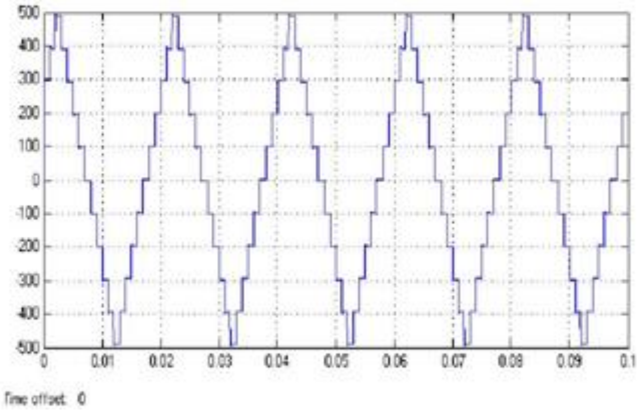

Figure 11: Output voltage Waveform

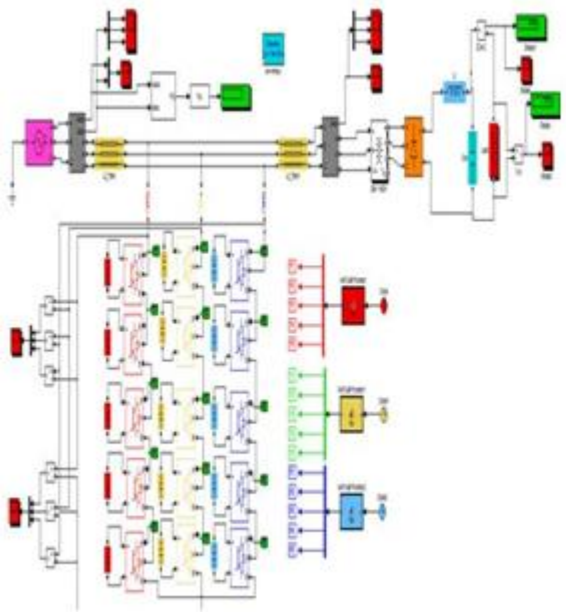

Figure 12: Simulation of a open loop circuit of Modular multilevel converter based STSTATCOM

6. Results

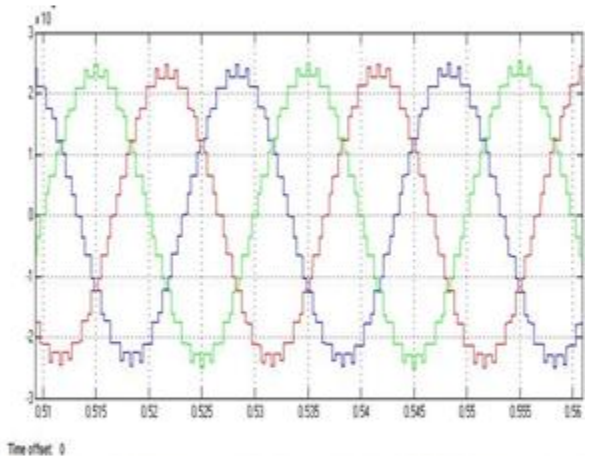

Figure 13: Output phase voltage Waveform

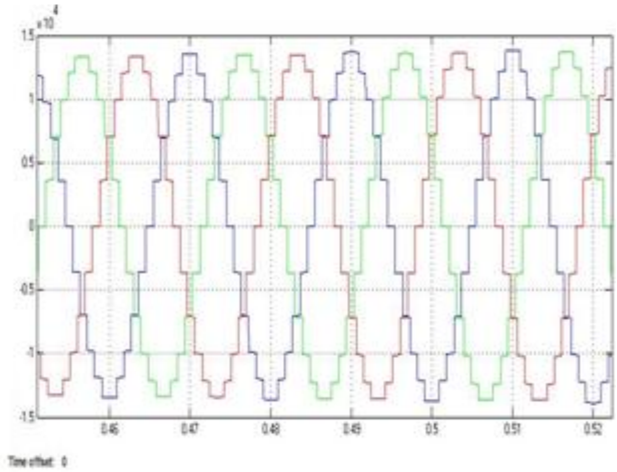

Figure 14: Output line voltage Waveform

7. Conclusion

The system can be extended for more voltage range. Increase in more voltage range will increases 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:

[1] Y. Sumi, Y. Harumoto, T. Hasegawa, M. Yano, K. Ikeda, and T.Matsuura, "New static VAr control using force-commutated inverters," *IEEE Power Eng. Review*, vol. PER-1, no. 9, pp. 33–34, Sep. 1981

[2] S. Mori, K. Matsuno, T. Hasegawa, S. Ohnishi, M. Takeda, M. Seto, S. Murakami, and F. Ishiguro, "Development of a large staticVAr generator using self-commutated inverters for improving power system stability," *IEEE Trans. Power Systems*, vol. 8, no. 1, pp. 371–377, Feb. 1993.

[3] C. Schauder, M. Gernhardt, E. Stacey, T. Lemak, L. Gyugyi, T. W. Cease, and A. Edris, "Development of a •}100 MVAr static condenser for voltage control of transmission systems," *IEEE Trans. Power Delivery*, vol. 10, no. 3, pp. 1486–1496, Jul. 1995.

[4] G. F. Reed, J. E. Greaf, T. Matsumoto, Y. Yonehata, M. Takeda, T. Aritsuka, Y. Hamasaki, F. Ojima, A. P. Sidell, R. E. Chervus, and C. K. Nebecker, "Application of a 5 MVA, 4.16 kV D-STATCOM system for voltage flicker compensation at Seattle Iron and Metals," in *Proc. IEEE Power Eng. Soc. Summer Meeting*, 2000, vol. 3, pp. 1605–1611.

[5] L. Wenhua, L. Xu, L. Feng, L. Chenglian, and G. Hang, "Development of 20 MVA static synchronous compensator," in *Proc. IEEE Power Eng. Soc. Winter Meeting* , 2000, vol. 4, pp. 2648–2653.