Modular Multilevel Converter for Power Quality Improvement

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Abstract - *This paper presents a modular multilevel converter to enhance the reliability and power quality of the system. They have several attractive features over conventional converters. It is an emerging topology for high voltage dc transmission. The proposed converter is built up by identical, but individually controllable sub modules. The proposed scheme has several features such as modular structure, the capability of transformerless operation, easy scalability in terms of voltage and current, utilization of standard components, and excellent quality of the output waveforms. The proposed scheme is validated through MATLAB simulation results. Results for Total Harmonic Distortion has also been shown.*

***Key Words*: Modular Multilevel Converter, Submodule, HVDC, Voltage Source Converter, Total Harmonic Distortion**

1. INTRODUCTION

In recent time research are continuously made finding solution for energy crisis and use of renewable energy resources for generation of power. Due to advancement in semiconductors equipment, have made the converters based HVDC more feasible and reliable solution for HVDC transmission. The HVDC technology is a high power electronics technology used in electric power systems. It is an efficient and flexible method to transmit large amounts of electric power over long distances by overhead transmission lines or underground/submarine cables. In Classic HVDC or Traditional HVDC the semiconductor devices thyristor were used to convert AC to DC or vice versa. Now a new type of HVDC is available which uses more advance power conversion technology. The new HVDC uses IGBTs and Voltage Source Converters and has more advantages than Classic HVDC. The manufacturer ABB Group calls this concept HVDC Light, while Siemens calls a similar concept HVDC PLUS (Power Link Universal System) and Alstom call their product based upon this technology HVDC Max-Sine.

HVDC grids employing multi terminal converters are technically and economically viable solution for future need of bulk power transmission for development of large scale renewable energy. By connecting different power sources such as wind, hydro and solar, HVDC grids have advantages of flexibility and reliability. The renewable energy power source such as offshore wind power farms is usually located in remote areas. Compare to an AC system, HVDC is more economic for transmission over long distance, especially when using cable to transmit the power. An example of VSC-HVDC system is shown below.

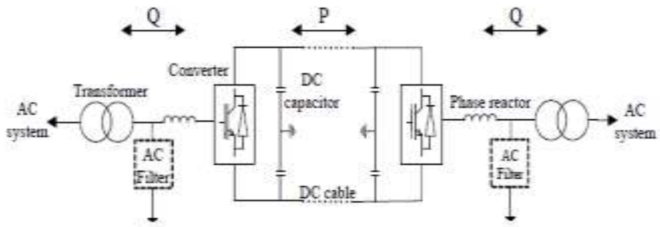

Fig -1: VSC-HVDC System

HVDC Converter bridges can be arranged into following configurations.

1. Monopolar HVDC system
2. Bipolar HVDC system
3. Homopolar HVDC system
4. Back-to-back HVDC system
5. Multiterminal HVDC system

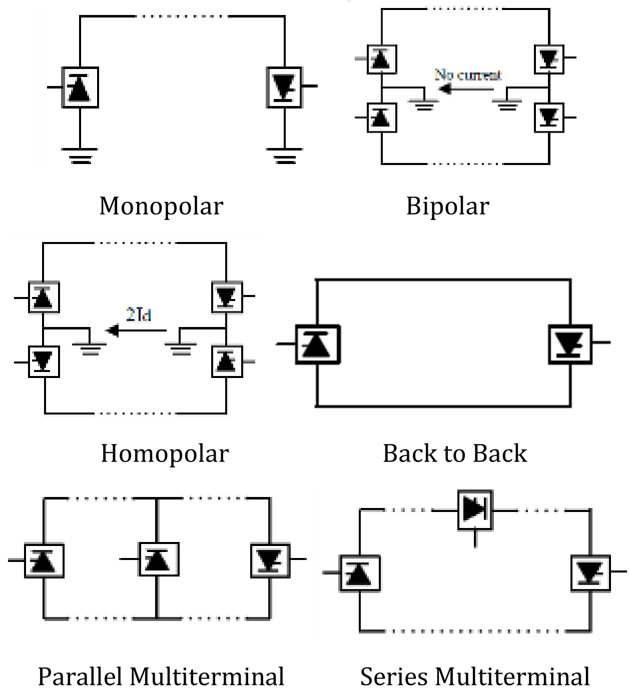

Fig -2: Configurations HVDC Systems

2. MODULAR MULTILEVEL CONVERTERS

The Modular Multilevel Converter (M2C) have been attractive in both industrial applications and academic researches since from its invention. The modular multilevel converters operate by switching of IGBTs or GTOs with PWM techniques which improves the speed of the operation and can control the real and reactive power with maintaining stable voltage and stable frequency.

The multilevel converters commercially was firstly used in San Francisco. The 3 phase MMC consist of 6 arms or 3 legs as the 2-level converter. The MMC consists of the number independent sub modules in the each arm and the sub modules contain its own capacitor. Each arm contains an inductor with the small resistance. The MMC has no turn-on or-off state for the flowing current. Therefore the current in the MMC flows continuously. The DC current divides equally into 3-phases and a 3-phases AC current splits equally in the upper and lower arms of the each phase. The sub modules existing in the arms are controlled in a way that the capacitor is inserted in the circuit or bypassed. Depending on the current direction the capacitor in the sub module can be charged or discharged. When the sufficient amount of sub modules are connected in series the stepped voltage wave form close to the sinusoidal can be generated. The generated sine wave contains low level harmonics distortion.

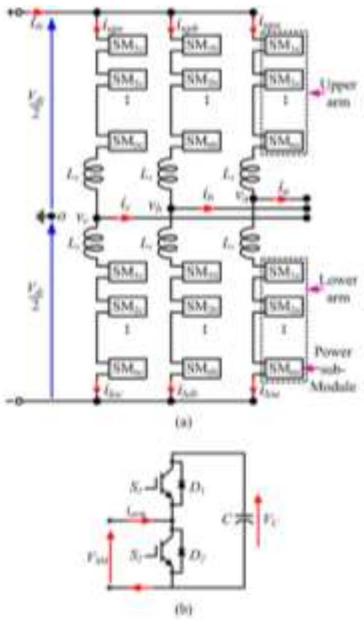

Fig -3: (a) MMC Topology (b) Submodule Topology

The higher is the number of levels, the better is the quality of output voltage which is near to sine wave. So, increasing the number of levels gives a benefit to the harmonic distortion of the generated voltage, but a more complex control system is required, with the respect to the 2-level converter.

3. PROPOSED MODEL

A modular multi-level converter is presented in this work for power quality improvement as shown in Fig.4. A sub block of proposed system MMC topology is shown in Fig.5. Sub-block cells in each arm are shown in Fig.6

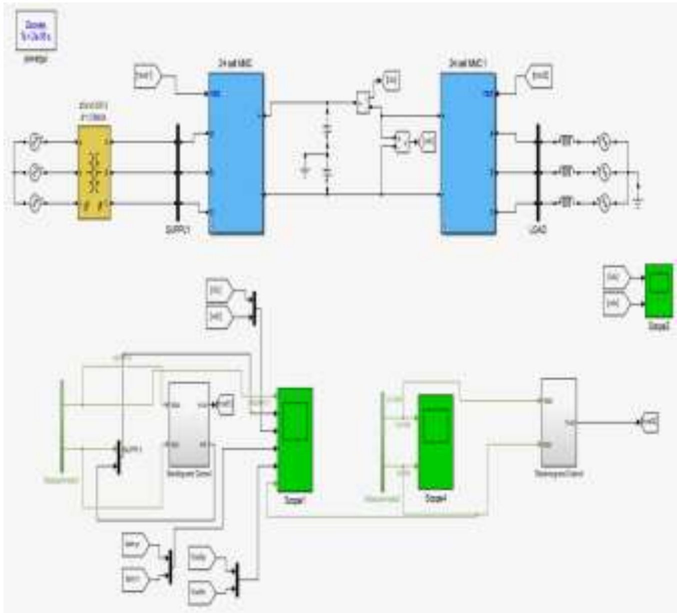

Fig -4: Proposed MATLAB Model

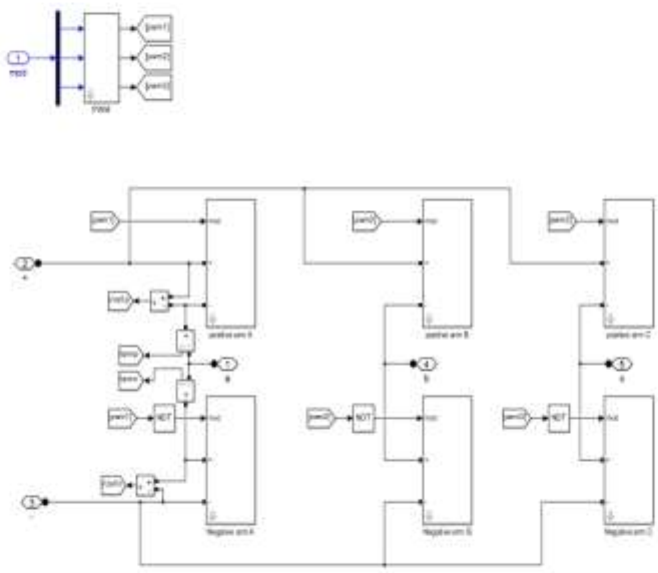

Fig -5: Sub- block of Proposed Model

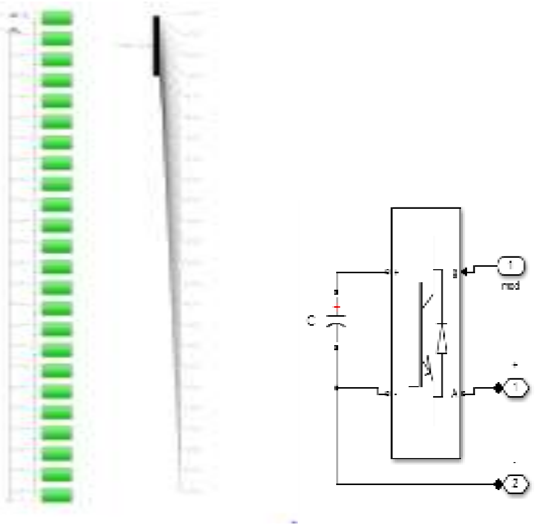

Fig -6: Sub block cells in each arm with 2-Level converter in each cell

This topology consists of two standard 3-phase converters with AC sides connected to the 3-phase source load compared as a generating station to 3-Phase 6-wire load with DC as HVDC link of transmission system. It could be said that the multi-level converter is a derivation of the 24 cell cascade H-bridge like standard for each arm of 3-phase inverter. The advantage of this choice is the great availability and the high reliability of the components because they are standards wide commercialized.

4. SIMULATION RESULTS

In this simulation, output voltage and current are imposed and the operation of the system is then observed. Total harmonic distortion (THD) is derived respectively. THD is defined as the ratio of the sum of the amplitudes of all harmonic components to the amplitudes of fundamental frequency the same load is used to test the output voltage and current based on the previous method. Observed THD Value is 3.66 %. The proposed methods have a low harmonic and their phase currents are close to sinusoidal.

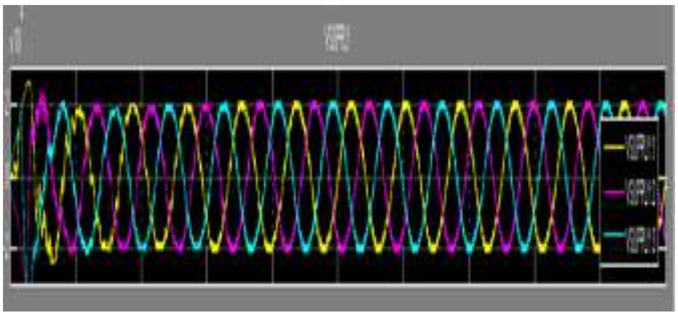

Fig -7: Waveform of V Supply

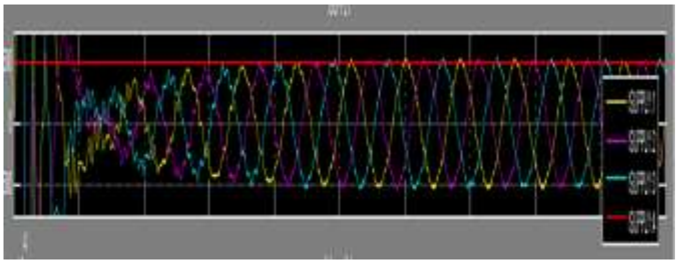

Fig -8: Waveform of I Supply

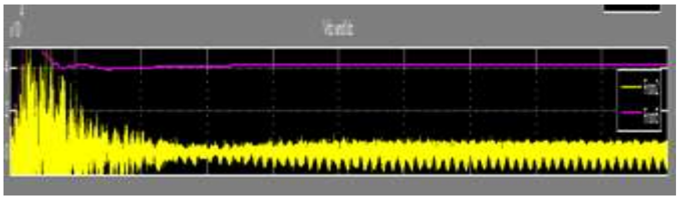

Fig -9: Waveform of Vdc & Idc

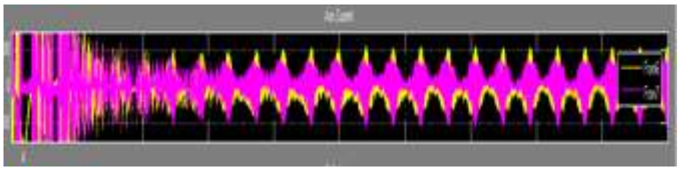

Fig -10: Waveform of Arm Current

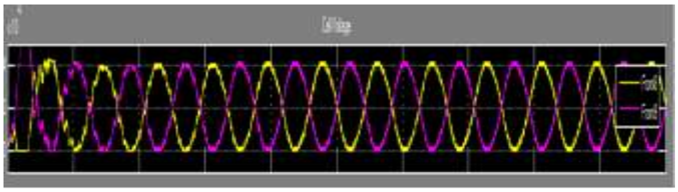

Fig -11: Waveform of Cell Voltage

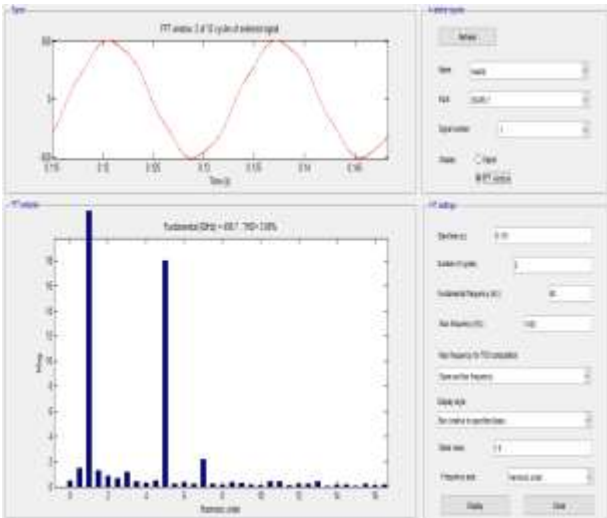

Fig -12: FFT Analysis

5. CONCLUSION

In this work a modular multilevel converter is shown for power quality improvement. Thus multi-level converters are gaining more attention due to their numerous advantages like Low THD, Low *dv/dt.* On devices and good voltage sharing for semiconductors, identical modules, scalable and no dc link limitations, lower losses etc. The large no of cells in these converters leads to high quality waveform which is much close to sine wave.

REFERENCES

[1] Elisabeth N. Abildgaard, Marta Molinas, "Modeling and Control of the Modular Multilevel Converter (MMC)", Elsevier, pp. 227-236, 2012

[2] Amirnaser Yazdani, Voltage-Sourced Converters In Power systems: Modeling, Control, and Applications, IEEE press, Wiley publication, ISBN 978-0-470-52156-4, 2010

[3] J.M Kharade, Prof. A.R. Thorat, "Simulation of an Alternate Arm Modular Multilevel Converter with Overlap Angle Control for Capacitor Voltage Balancing", International Conference on Industrial Instrumentation and Control (ICIC), 2015.

[4] Vijay K Sood. HVDC and FACTS controllers: applications of static converters in power systems. Springer Science & Business Media, 2006.

[5] Abdus Sattar et al. Insulated gate bipolar transistor (IGBT) basics. In IXYS Corporation. IXAN0063. Citeseer, 1998

[6] Jyoti M. Kharade, Dr. Niteen G. Savagave, "A Review of HVDC Converter Topologies", IJIRSET,2017

[7] Michael M. C. Merlin, Tim C. Green," The Alternate Arm Converter:a New Hybrid Multi-level Converter with DC-fault Blocking Capability", IEEE Transaction On Power Delivery

[8] Leon M. Tolbert, Fang Zheng Peng, Thomas G. Habetler, "MultilevelConverters for Large Electric Drives", IEEE Trans. Industry Applications, Vol. 35, No. 1, pp.36-44, January/February 1999

[9] Leon M. Tolebert, Fang Z. Peng, Thomas G. Habetler, "Multilevel inverters for electric vehicle applications", WEPT'98, Michigan, Oct. 1998, pp. 79-84

[10] Yan Gangui, Liu Jigang, MU Gang, Liu Yu, Liu Yang, Song Wei, "Research on Modular Multilevel Converter suitable for direct-drive wind power system", Elsevier, 2012 International Conference on Future Electrical Power and Energy Systems, pp. 1497-1506

[11] Leopoldo G. Franquelo, Jose Rodríguez, Jose I. Leon, Samir Kouro,Ramon Portillo, Maria A.M. Prats, "The age of multilevel converters arrives", IEEE Industrial Electronics Magazine, pp. 28- 39, June 2008

[12] Marcelo A. Perez, Senior Member, IEEE, Steffen Bernet, Member, IEEE, Jose Rodriguez, Fellow, IEEE, "Circuit Topologies, Modeling, Control Schemes, and Applications of Modular Multilevel Converters" IEEE Transactions on Power Electronics, VOL. 30, NO. 1, Jan 2015.

[13] J. Ainsworth, M. Davies, P. Fitz, K. Owen, and D. Trainer, "Static var compensator (statcom) based on single-phase chain circuit converters," Generation, Transmission and Distribution, IEE Proceedings-, vol. 145, no. 4, pp. 381 -386, jul 1998.

[14] A. Lesnicar and R. Marquardt, "An innovative modular multilevel converter topology suitable for a wide power range," in Power Tech Conference Proceedings, 2003 IEEE Bologna, vol. 3, jun 2003.

[15] S. Allebrod, R. Hamerski, and R. Marquardt, "New transformerless, scalable modular multilevel converters for hvdc-transmission," in Power Electronics Specialists Conference, 2008. PESC 2008. IEEE, jun 2008, pp. 174-179.