Modular Multilevel Converter & Alternative Arm Converter: A Review

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Abstract – *The Modular Multilevel Converter (MMC) represents an emerging topology with a scalable technology making high voltage and power capability possible. The MMC is built up by identical, but individually controllable sub modules. The Modular Multilevel Converter (MMC) is a new topology for multilevel converters with potential for medium voltage and high voltage applications. This paper presents a review on Modular Multilevel Converter (M2C) & Alternative Arm Converter which was a popular series of topology and has been applied in industries in recent years. It is an emerging technology for various applications including HVDC transmission and wind energy conversion systems. Submodule based M2C & Alternative Arm Converter architecture dominates over other conventional converters topologies, due to various technology, control as well as economic advantages.*

Key Words: **Modular Multilevel Converter, Alternative Arm Converter, Submodule, HVDC, H-Bridge, Voltage Source Converter**

1. INTRODUCTION

The Modular Multilevel Converter (M2C) have been attractive in both industrial applications and academic researches since from its invention**.** From the last two decades the Voltage Source Converters (VSCs) with self commutating control have gained more attention for the HVDC applications [1], [2]. 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. They offer several advantages such as fast response, finer or excellent controllability, much compact size and volume of converter station due to elimination of filters, insignificant harmonic generation. The large number of VSC topologies have introduced and employed for various power system applications and especially for HVDC transmission system. The fully controllable and fast operating multilevel voltage source converters are required for medium and high voltage application.

Generally HVDC is the obvious solution for the bulk power transmission over long distance and offshore wind farms. The power electronics based HVDC converters have gained more interest due to increasingly installations of HVDC networks. The several multilevel voltage source converter topologies are introduced and existing for the power system such as diode clamped converter, flying capacitor converter, cascade H bridge multilevel converter etc. But the problems of such converters are requirement of large number of diodes and bulky capacitors, more switching losses due to high frequency switching operation. To minimize aforementioned problems or drawbacks a new Modular Multilevel Converter and hybrid Alternate Arm Modular Multilevel Converter (AAMMC) topologies have proposed by researchers [3].

2. TOPOLOGY OF CONVERTERS

The topology of converters is divided into two categories.

2.1 Line current commutated converters

Line current commutated converters are based on the thyristor switches. When the first commercial HVDC lines were used, they were based on thyristor valves. The thyristors have three terminals, where anode is positive, cathode-negative and gate represents triggering pulse of the thyristor. Anode has a higher potential than the cathode, therefore current are flowing from anode to cathode, only then when a small pulse are applied to the gate terminal, otherwise the conduction is not happening. The circuit diagram is given in Fig-1 below:
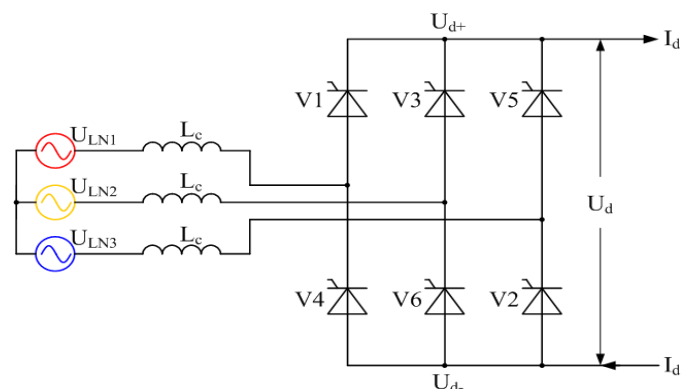

Fig -1: Line Current Commutated Converters

2.2 Voltage Source Converters

The first voltage source converters were introduced in the late 1990*s*. Since then the evolution in design, rapid grow of the power ratings and higher voltage levels are achieved [4]. Mainly the voltage source converters use power electronic valves, which can be turned-on and turned-off at desire.

Usually valves are established with the insulated-gate bipolartransistors (IGBT).

The controllable signal is provided in the gate (G) port, which is the signal with two degrees of freedom turns on and turns off. When the signal has a turn-on command the IGBT starts to conduct current from the collector (C) to emitter (E). The current flow from the collector to emitter is called unidirectional, since it flows only in one way. However, in order to create the bidirectional current flow the anti parallel diode is introduced in the IGBT. Furthermore the IGBT has an excellent and simple switching characteristics, but the switching loses in it are higher than in thyristor based converters [5].

2.3 Two Level Converters

Two-level converters were the first generation of the voltage source converters, introduced. The 2-level VSC converters are using self commutated IGBT switches, which are able to turn on and turn off at will. The topology of the 2-level VSC converter is represented in the Fig-2.
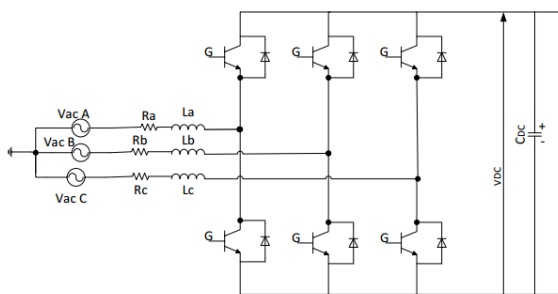
Fig -2: Two Level Three Phase VSC Topology

2.4 Multilevel Converters:

The rapid progress in the power electronics technology leads to maximum use for high voltage transmission and distribution systems, for the applications of high power motor drives etc. In order to obtain desired high voltage and high power having good controllability, the multilevel converters are designed for high voltage applications. The different innovative techniques are applied to multilevel converters and the designs have gained more attention in few years. The multilevel converters are represented by following topologies:

a)Diode Clamped multilevel converter or Neutral Point Clamped multilevel converter.

b)Capacitor Clamped multilevel converter or Flying Capacitor multilevel converter.
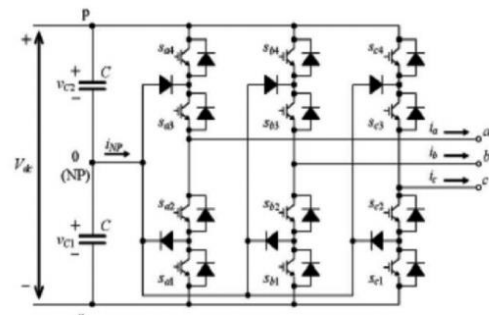
c) Cascaded H- bridge multilevel converter.

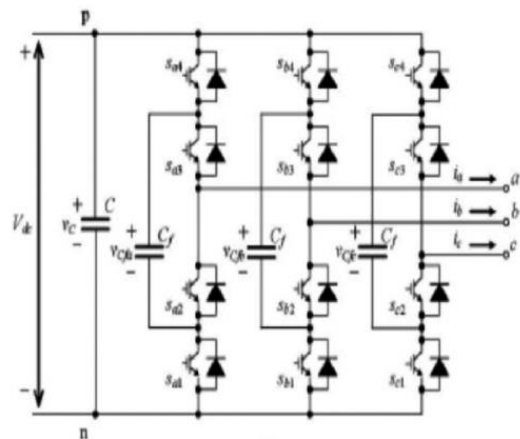**Fig -3**: Diode Clamped Multilevel Converter

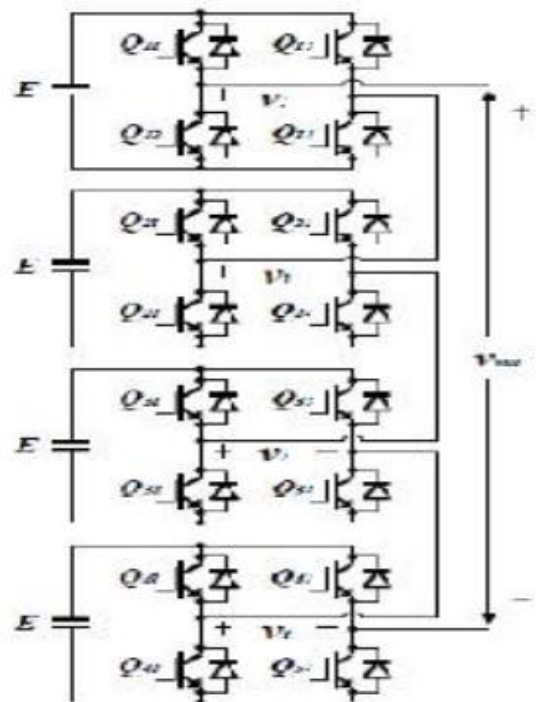**Fig -4**: Capacitor Clamped Multilevel Converter

Fig -5: Cascaded H- Bridge Multilevel Converter

3. MODULAR MULTILEVEL CONVERTERS

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. Different from a 2-level converter the MMC consists of the number independent submodules in the each arm and the submodules contain its own capacitor. Each arm contains an inductor with the small resistance [6]. The operation principle of the MMC is a bit different than other converters, because the MMC has no turn-on or tun-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 submodules existing in the arms are controlled in a way that the capacitor is inserted in the circuit or bypassed. This results for submodules act as the independent converters, where inserted voltage can be 0 or *Vstcell*. Depending on the current direction the capacitor in the submodule can be charged or discharged. When the sufficient amount of submodules 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. The circuit diagram is shown in Fig - 6
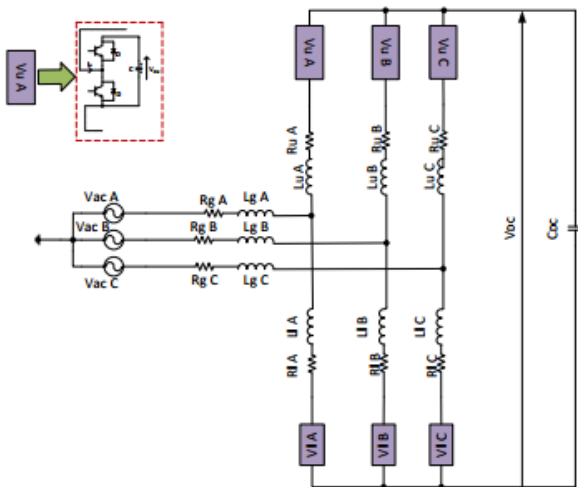

Fig -6: Modular Multilevel Converter

4. ALTERNATIVE ARM MODULAR MULTILEVEL CONVERTER

The Alternate Arm Modular Multilevel Converter (AAMMC) is recently proposed advanced hybrid multilevel converter topology. It is composed of the hybrid combination of the two level converter as the director switches and modular multilevel converter as series connected H- bridge cells or submodules [7]. A 3-phase converter consist of 3 legs, one leg per-phase. One leg consist of the 2 arms: upper and lower. The arms are identical and has arm resistor, arm inductor, director switches and

submodules. The submodule of the upper arm *VuA* is illustrated in the Fig 7 , where *u* indicates upper arm and *A* denotes phase. Several submodules are connected in the series in order to generate close to the sinusoidal stepped voltage signal. The director switches in each arm are IGBT connected in series, which also are represented in the Fig 7. Each arm has an inductor and the resistor, which shows arm resistance and director switch resistance combined together. Operation principle of the AAC is similar to 2-level converter it has so called director switches, which direct current to the upper or lower arms. The director switches are IGBT, connected in series, because of to withstand higher voltage ratings, when they are open. Like the MMC the hybrid model has stack of cells in each arm responsible for the multistep voltage generation. The main advantage is, that only half of

the voltage period is generated in one arm, therefore allowing to reduce amount of the cells in stack. Unlike the MMC the AAC current does not flow continuously, because the director switches can interrupt it, therefore the AAC has a turn-on and turn-off states for the flowing current.

The main features of an AAMMC are low typical losses than MMC per converter due to soft switching technique for operation and alternate conduction mode of operation of the arms, it may require less number of cells for its control and operation, less volume of the converter station. The circuit diagram of AAMMC is shown in Fig-7.
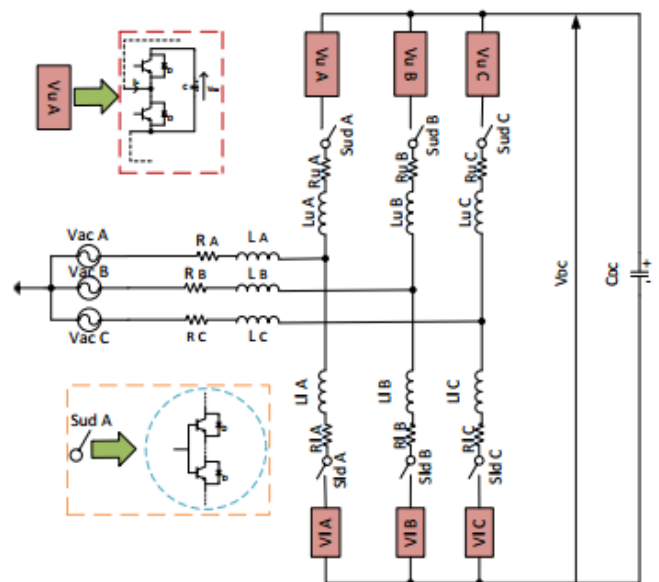

Fig -6: Alternative Arm Modular Multilevel Converter

5. ADVANTAGES OF AAMMC

It offers various advantages over existing converters such as [3]

• scalable and modular structure

- low switching losses

- DC fault tolerance property so it does not require the AC/DC breakers of large size and ratings for HVDC systems.

- Lower number of cells as compared to modular multilevel converter.

- Generation of almost sinusoidal harmonic free AC currents.

6. APPLICATIONS

The power electronics technology plays significant role in the expansion of power system. The high power electronics technology or system is required for transmission and distribution system with power quality. For the traction drive system the applications [8] of multilevel converter are being investigated. The advantages of this system are it can generate almost perfect waveforms of current and voltage due to amplitude modulation instead of pulse width modulation. Such topology also applicable for electrical vehicles, large traction equipments, electrical buses and locomotives.

- Transformer less multilevel converter can be used for large electrical drives with advanced power electronics technology to meet high power demand more than 250 KW for hybrid electric vehicles [9].

- The cascaded multilevel converters are the most suitable for grid connected renewable energy sources [10] such as photovoltaic system due to features like modular structure, smaller dv/dt scalable operation and control.

- The multilevel converters are also beneficial for industrial applications such as mining, metal industry oil and gas industry mills and automotive applications [11].

- Generally the multilevel converters are best suited for medium voltage and high power applications.

7. CONCLUSION

Thus the different types of converter topologies have been discussed covering major focus on modular multilevel converter and alternative arm converter. Also the advantages of AAMMC were studied along with their application areas.

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, "Multilevel Converters 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.