Multimodules of Diode Clamped Multilevel Converter: A Novel Option for High Power Facts Controller

Mashhood Hasan, Dinesh Kumar and Zafar Khan

Abstract— This paper proposes a multimodules multilevel diode clamped converter for a novel option high power FACTS (Flexible AC Transmission System) controller. The various configurations are being compared for high power FACTS controlling devices and a mathematical design has been developed for switching strategy considering fundamental frequency. A switching pattern is developed for seven level two module converter. There are six degree of freedom in the design of the switching strategy which can mitigate lower order harmonics and equally distribute current between two module.

Keywords— FACTs, Diode clamped, Total Harmonic Distortion, Multimodules, Multilevel.

I. INTRODUCTION

Proliferation in power electronics in the last few decades have led to improvements in power devices and novel concepts in converter topologies and control strategy can improve the power quality. There are three types of voltage source multilevel converters are recognized as potential candidates for FACTS Controllers: (1) the diode-clamped converter, (2) the flying-capacitors converter, and (3) the cascaded-inverters with separated dc sources. Now a days researchers is devoted to the diode-clamped topology based multimodular FACTS controller devices for high power application in a transmission line. However, brief descriptions are given in below to all the 3 candidates and the evaluations which have been made show that the multimodular multilevel diode-clamped topology is the most promising one.

Diode clamped multilevel converter which is shown in Fig.1the structure of the diode-clamped multilevel converter [2-6], which is actually an expanded version of Nabae's Neutral-Point, 3-1evel converter [1]. In the structure, (N-l) dc capacitors divide the total dc link voltage into N levels and each half-Leg consists of (N-1) series-connected valves, with each valve being interconnected to the corresponding level of the dc capacitor via c1amping diodes. The idea is to limit the voltage stress of the valves to the dc link capacitor voltage of the j^{th} level (j=1,2 ... N-1) with the help of these clamping diodes. Thus the voltage ratings of the converter can be increased by adding the number of levels that are connected in series without increasing the individual thyristor rating, provided the technology to ensure that the dc link voltages are equal at all the levels is perfected. However, the clamping diodes have to sustain the high voltage stress as the number of levels increases. The voltage withstand of the diodes can be increased by connecting several units in series. Unlike the thyristors, the turning ON and OFF of the diodes do not depend on gate-triggering so that passive circuits are sufficient to ensure equalization of the voltage stresses in steady-state and in transient.

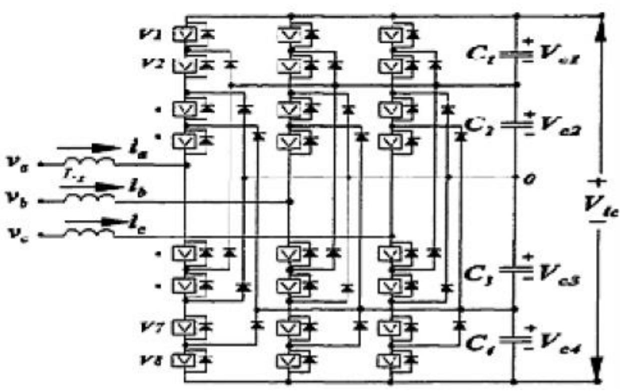

Fig.1

Flying-capacitor multilevel converter which is shown in Fig.2 the structure of the flying-capacitor multilevel converter [2]. In the structure, every pairing of the valves that are symmetrically located on the phase legs is spanned by a dc capacitor.

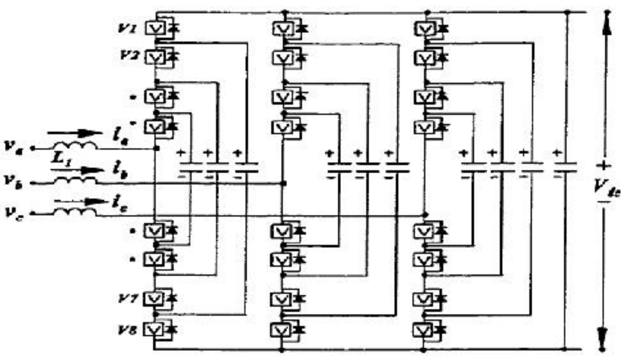

Fig.2

The size of the voltage increment between any capacitor and the capacitor bracketing it on the outside

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determines the size of the forward voltage stress of the switching valves clamped by the two dc capacitors. For a N-Level converter, it requires 6(N-l) switching valves and (3N-5) dc capacitors. The structure appears to be simple and symmetric. However, compared with diode-clamped converter, it requires a large number of capacitors, which normally entails the same number of complicated controllers or independent dc power suppliers to maintain their voltages at the specified levels.

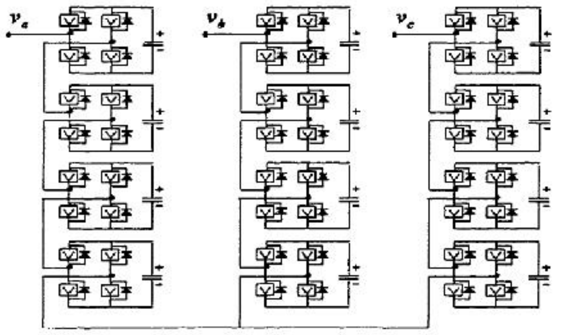

Fig.3

Cascade multilevel converter is shown in Fig.3 the structure of the cascade multilevel inverters [7,8], in which full single phase H-bridge inverter modules are connected in series, with each module being fed by the voltage from a separate dc capacitance. The N-Level cascaded-inverter uses 6(N-I) switching va1ves and 3(N-l)/2 dc capacitors.

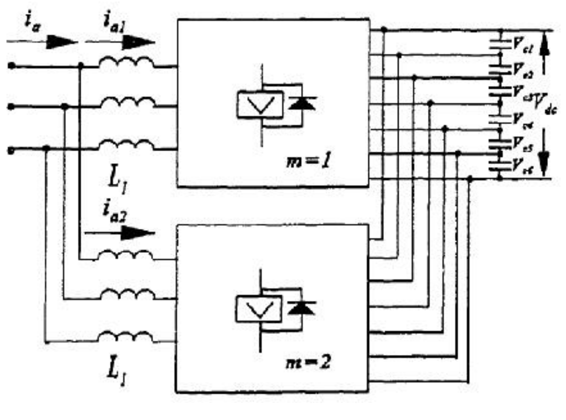

Fig.

II. MATHEMATICAL DESIGN OF SWITCHING STRATEGY

The mathematical calculation of Fundamental Frequency Switching strategy [30-32] is preferred because it gives the idea of Kth harmonics for mth module. Fundamental Frequency Switching strategy is suitable for high power converter. It requires only one switching at each cycle of the utility standard frequency.

The magnitude of fundamental harmonic of the ac output voltage for K^{th} harmonics and m^{th} module.

$$V_{km} = \frac{4V_{dc}}{3k\pi}\left[\cos(k\alpha_{1m}) + \cos(k\alpha_{2m}) + \cos(k\alpha_{3m})\right] \quad (1)$$

for k=1,3,5…… m=1,2

For eliminating lower order of harmonics and balancing the currents in individual module if it is to be setting

$$V_{k1} + V_{k2} = 0 \quad (2)$$

since $\left|\cos(k\alpha_{im})\right| < 1$ (i=1,2,3), it follows from (1) that the K^{th} harmonic voltage of the m^{th} module satisfies the inequality.

$$V_{km} \leq {4V_{dc}}/{k\pi} \quad (3)$$

as the filter reactance with respect to the K^{th} harmonic is

$$X_k = jk\omega L_1 \quad (4)$$

the magnitude of the kth current is

$$\left|I_{km}\right| < \frac{V_{km}}{\left|X_k\right|} < \frac{4V_{dc}}{k^2\omega L_1} \quad (5)$$

.as the I_{km} in (5) varies inversely with K^2, the square of the harmonic number, the harmonic current decreases rapidly with the increasing k. Furthermore, as even and triplen harmonies do not exist, the lowest harmonies number not already considered in the equalization of the rms voltage is k=17 From (5), it is clear that the tilter inductance L_i can be quite economically sized without causing noticeable unbalance.

III. COMPARISION AMONG THE CONFIGURATION

There are different configuration are evaluated for the purpose of determining which is the most promising structure to follow in the research of the thesis. In the comparison, formulas of the components count of the thyristors, the diodes, the capacitors etc. required for the four different structures to implement the N-Level converter and M module. Table 1.1 lists the number of solid switches, dc capacitors and clamping diodes required to implement a N-level converter and M module. Obviously, the cascade structure and the flying-capacitance structure require more capacitors and the diode-clamped structure needs more clamping diodes.

	Diode clamped converter	Flying capacitor converter	Cascaded converter	Multimodules multilevel diode clamped converter
Switching valve	6(N-1)	6(N-1)	6(N-1)	M*6(N-1)
Dc capacitor	(N-1)	(N-1)*(N-2)*3/2+(N-1)	3(N-1)/2	M*(N-1)
Clamping diode	(N-1)*(N-2)*3	0	0	M*(N-1)*(N-2)*3
Application in FACTS	STATCOM,SSSC and UPFC	STATCOM	STATCOM	STATCOM,SSSC and UPFC

Table 1.1 shows the comparative formulas for counting components

Compared with the diode-clamped structure both the cascade structure and the flying-capacitor structure require many more dc capacitors and complex capacitor voltage controllers. In addition, both of them cannot be used for application in the back-to-back rectifier converter dc link, which is the core of the Unified Power Flow Controller (UPFC) and the Asynchronous Link. Although the diode-clamped structure will be required more c1amping diodes, however it incurs less cost. .Unlike the other two structures, the 3-phase legs of the diode-clamped structure share the common series-connected dc capacitors. Therefore, it can be used in almost all kinds of FACTS controllers, including those based on the aforesaid back-to-back, rectifier/inverter dc link Based on above comparisons, the multimodules diode-clamped multilevel converter are preferred.

IV.SIMULATION RESULT

The six unknown switching angles α_{im} (i=1,2,3; m=1,2) in equations 1 and 2 are solved numerically using Matlab software.

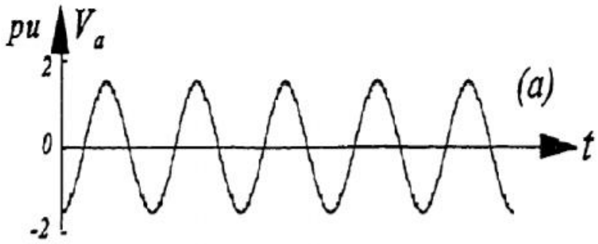

Fig. a

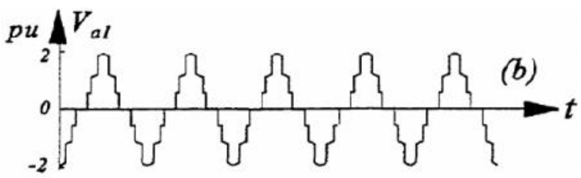

Fig. b

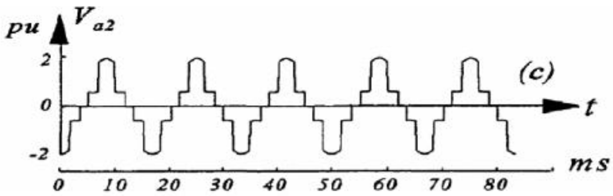

Fig. c

V.CONCLUSION

Multimodules of diode clamped multilevel converter has been seen multi advantage over various configuration. It perform three major task (i) it achieve low total harmonic distortion in voltage and current,(ii) direct fast control output voltage magnitude (iii) equal distribution of current in separate modules. This configuration adopted for all the FACTS controlling device simply because of less cost and easy controlling.

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