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SVM TECHNIQUE APPLIED TO DC-LINK THREE -PHASE THREE LEG AC/AC CONVERTER USING NINE IGBT

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ABSTRACT

This paper presents the implementation of a novel three phase three leg AC/AC converter. The converter employs only nine switches and has the capability of delivering sinusoidal input and outputs with unity power factor. In this paper, a new three-phase to three-phase converter for ac motor drives is presented. The converter provides both an input rectifier and an output inverter by sharing a leg in order to reduce the number of power switches. The features of such a converter are compared to those of the back-to-back two-level voltage source converter and matrix converter.

Key words: AC/AC converter, Space vector modulation, pulse width modulation (PWM), three leg converter.

INTRODUCTION

Three-phase ac–ac power conversion can be achieved with this configuration in which nine semiconductor switches (three legs) are employed [1]**.** Three-phase ac/dc/ac and ac/ac converters with variable frequency (VF) and variable voltage operation have found wide applications in the industry. With the recent progress in power semiconductor device technology followed by advancements in power electronic control methods, variable frequency inverter-fed ac drives are being adopted for a wide variety of applications. Recently there has been growing interest in low cost ac drives to meet the needs for reducing cost. Improvements in power semiconductor switch technology have significantly reduced the cost and size of such drives and improved waveform quality.

Three-phase AC/AC converter operation have found wide application in industry. The most popular configuration uses voltage source inverter (VSI) with a diode rectifier as the front end for adjustable speed drives (ASDs), uninterruptible power supplies (UPS), and other industrial applications [2].

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They have the problems of poor power quality in terms of injected current harmonics, voltage distortion and poor power factor at input ac mains and slowly varying rippled dc output at load end, low efficiency, and do not have regenerative or dynamic braking capability. In view of their increased applications, a new breed of converters has been developed using new solid-state self-commutating devices such as MOSFETs, insulated gate bipolar transistors (IGBTs), gate-turn-off thyristors (GTO) etc. Such converters are generally classified as power factor correctors (PFC), pulsewidth-modulation (PWM) rectifiers, switch-mode rectifiers, multilevel rectifiers, etc. because of the strict requirement of power quality at the input ac mains, there are several standards converter have been developed and the severity of power quality problems can be mitigated by using a back-to back two-level voltage source converter (B2B 2L-VSC), shown in Fig. 1, where a pulse width modulation (PWM) voltage source rectifier is used to replace the diode rectifier [3].

The back to back two-level voltage source converter (B2B 2L-VSC) requires a relatively high number (12) of active switches such as insulated gate bipolar transistors (IGBTs). It also needs a dc-link capacitor that is responsible for increased cost and a limited lifespan. To reduce the device count and eliminate the dc-capacitor filter, there are various converter topologies have been in the literature.

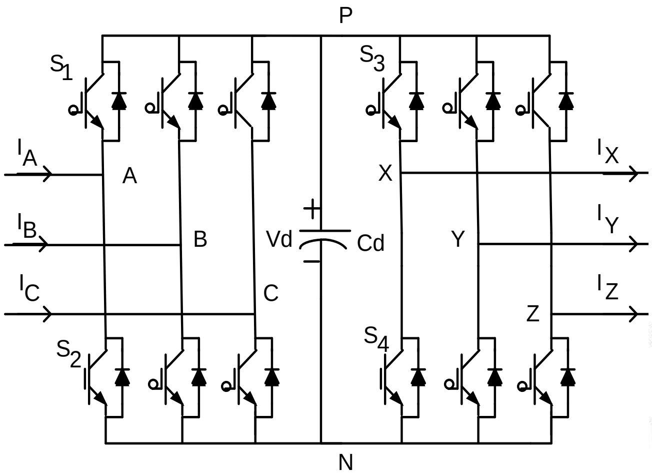

Fig. 1. B2B 2L-VSC.

The first approach reported in [4]–[6] puts two dc capacitors in cascade and takes their midpoint as one of the input–output terminals, whereas an entire phase leg for the rectifier and/or inverter can be saved. It is possible to reduce the total number of switches, as the second approach suggests [7], [8], by sharing one of the three phase legs between the rectifier and inverter with proper control. In addition, combined use of dc midpoint connection and phase leg sharing has been in [9], where only four legs are needed to perform three-phase ac to ac conversion with bidirectional power flow and control the power factor. Although all the earlier references achieve the goal of reducing the number of switches and thus reducing the cost, they unexceptionally have limits or involve complex control due to their unbalanced topological structure. For unidirectional industrial applications, diodes can be used in place of active switches in the rectifier part, such as the VIENNA rectifier [10], three-phase three-switch buck-type rectifier [11], and three-phase three-switch two-level rectifier [12]. These converters may also be regarded as topologies with a saved number of switches, despite their employment of a large number of diodes.

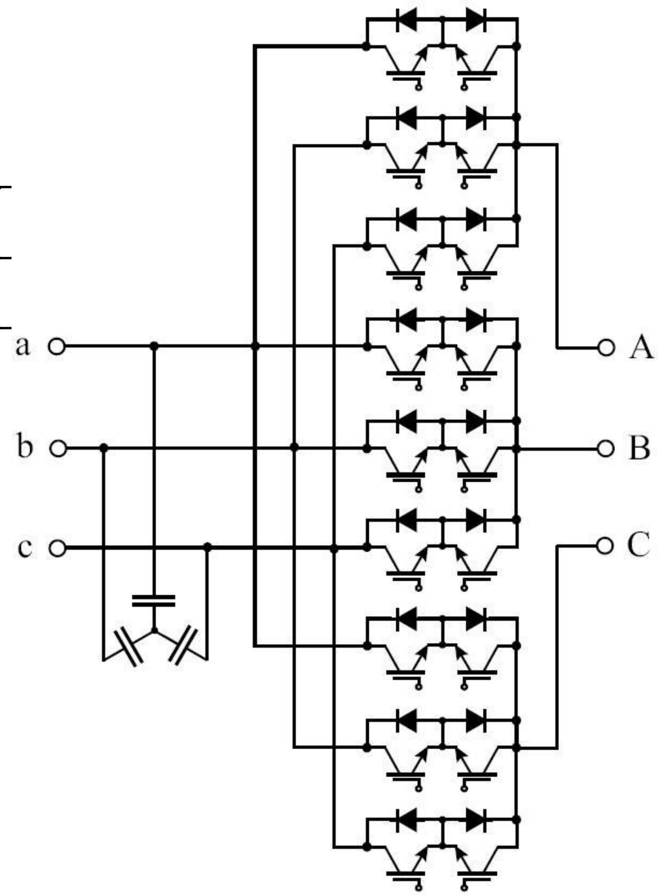

Fig.2 matrix converter

Three phase matrix converters provide bi-directional power flow, sinusoidal input/output waveforms, and controllable input power factor. For these reasons matrix converters have received considerable attention in the last years. And they may become a good alternative to back-to back converters. Further more. The matrix converter allows a compact design. Due to the lack of dc-link capacitors [13]-[15].

Unlike VSCs that inevitably require the dc-link stage, the matrix converter presents a radicals change in topology and directly converts a fixed ac input to an adjustable ac output voltage as shown in Fig. 2. There is no dc-link circuit, the dc capacitor is not necessary in the voltage source converter and therefore reduction in cost as well as improved reliability. However, the conventional matrix converter (CMC) normally needs 18 active switches and its switching scheme is so complex. The high semiconductor cost and complex control have made this topology less attractive. It is also Similar to the situation of VSCs, efforts to reduce the number of active switches for a matrix converter have been made in recent publications, whereas a couple of topological variants such as the sparse matrix converter (SMC) were proposed . The SMC provides equivalent functionality to the CMC. It is used 15 switches with the semiconductor cost still higher than that of the B2B 2 L-VSC.

In this paper, a three-phase ac/ac converter topology is. Different from all other topologies, this converter has only three legs with only nine active switches for bidirectional ac/ac power conversion.

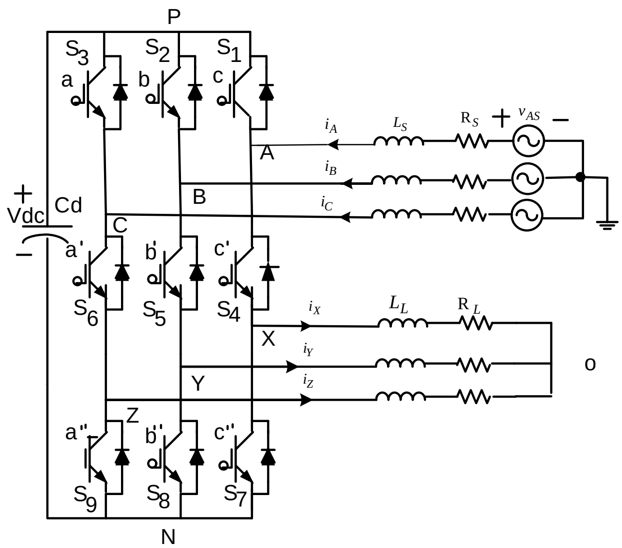

Fig. 3. nine-switch ac/ac converter with a quasi-dc link.

NINE-SWITCH CONVERTER TOPOLOGY

Fig. 3 shows the three-phase nine-switch converter topology. These converters have only three legs with three switches installed on each of them. The recency herein is that the middle switch in each individual leg is shared by both the rectifier and the inverter, thus reducing the switch count by 33% and 50% in comparison to the B2B 2L-Voltage source converter and CMC, respectively. The input power is delivered to the output partially through the middle three switches and partially through a quasi dc link circuit. For the convenience of discussion, we can consider that the rectifier of the nine-switch converter is composed of the top

Three and middle three switches, now those the inverter consists of the middle three and bottom three switches. The converter has two modes of operation: 1) constant frequency (CF) mode, where the output frequency of the inverter is constant and also the same as that of the utility supply, as long as the inverter output voltage is adjustable; and 2) variable frequency (VF) mode, where both magnitude and frequency of the inverter output voltage are adjustable. The CF-mode operation is particularly suitable for applications in UPS, whereas the VF mode can be applied to variable-speed drives.

MODULATION SCHEMES

Switching Constraint

The reduction of the number of switches in the converter topology imposes certain switching constraints for the switching pattern design. In the back-to-back converter, the rectifier leg voltage V_{AN} , which is the voltage at note *A* with respect to the negative dc bus *N*, can be controlled by switches S_1 and S_2 in the rectifier, while the inverter leg voltage *XN v* can be controlled by S_3 and S_4 in the inverter

Shown in Fig. 1. This means that the rectifier and inverter leg voltages can be controlled independently. The back-to-back converter topology has four switching states per phase as defined in Table 1. For the nine-switch topology, we need to control the input and output voltages independently through three switches per leg, where the middle two switches are shared by the rectifier and inverter. The converter has only three switching states per phase as illustrated in Table 1. It can be observed that switching state 4 for the back-to-back converter does not exist in the nine-switch converter, which notifies that the inverter leg voltage V_{XN} cannot be higher that the rectifier leg voltage V_{AN}. This is, in fact, the main constraint for switching scheme design of the nine-switch converter.

TABLE 1: SWITCHING STATES OF BACK-TO-BACK CONVERTER

Back-to-back converter						
Switching State	S_1	S_2	S_3	S_4	V_{AN}	V_{XN}
1	On	Off	On	Off	V_d	V_d
2	Off	On	Off	On	0	0
3	On	Off	Off	On	V_d	0
4	Off	On	On	Off	0	V_d

TABLE 2: SWITCHING STATES OF PROPOSED CONVERTER

Proposed nine switch converter					
Switching State	S_1	S_4	S_7	V_{AN}	V_{XN}
1	On	Off	On	V_d	V_d

2	Off	On	Off	0	0
3	On	Off	Off	V_d	0

The principle of carrier based sinusoidal modulation schemes and space vector modulation (SVM) schemes can be applied to the nine-switching converter. When designing the switching pattern, the switching constraint discussed above must be satisfied.

Fig. 4 illustrates the carrier based sinusoidal PWM scheme for the nine-switch converter. The rectifier modulating wave *Vmr* and the inverter modulating wave *Vmi* are arranged such that *Vmr* is always higher than *Vmi*. These two modulating waveforms are compared with a common triangular carrier *Vc*. The generated rectifier and inverter leg voltages, V_{AN} and V_{XN}, are shown in the figure. This arrangement guarantees that switch state 4 in the back-to-back converter is eliminated here for the nine-switch converter.

It should be pointed out that although *Vmr* is always higher

Than *Vmi*, this does not necessarily mean that the fundamental component of the inverter output voltage V_{XY} should be lower than that of the rectifier input voltage V_{AB} . In fact, the inverter output voltage can be higher than that of the rectifier input voltage due to the boost nature of the rectifier.

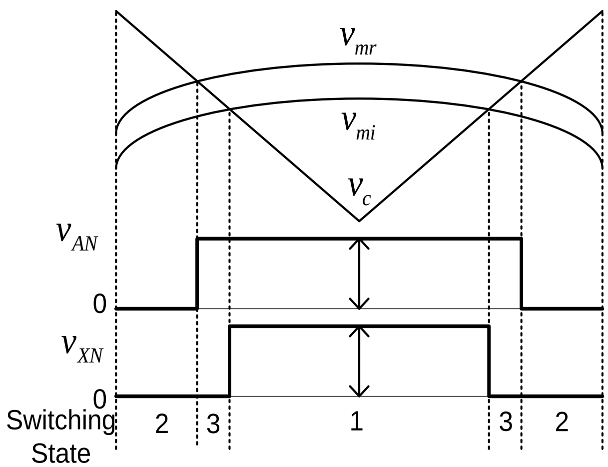

Fig.4. PWM waveform generation,

SPACE VECTOR MODULATION

Space vector modulation (SVM) is an algorithm for the control of pulse width modulation (PWM). It is used for the creation of alternating current (AC) waveforms; most commonly to drive 3 phase AC powered motors at varying speeds from DC using multiple class-D amplifiers. There are different variations of SVM that result in different quality and computational requirements. There are another active area of development is in the reduction of total harmonic distortion (THD) created by the rapid switching inherent to these algorithms.

A three phase inverter to the right must be controlled as shown in Fig. 5, So that at no time are both switches in the same leg turned on or else the DC supply would be shorted. This requirement may be met by the factitive operation of the switches within a leg. i.e. if A^+ is on then A^- is off and vice versa. This steerage to eight possible switching vectors for the inverter, V_0 through V_7 with six active switching vectors and two zero vectors.

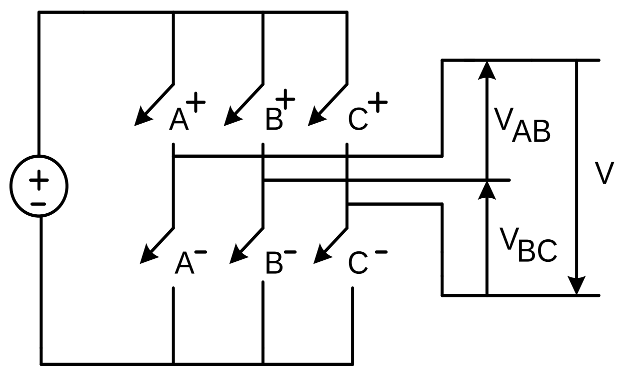

Fig.5 Topology of a basic three phase inverter

To implement space vector modulation a reference signal V_{ref} is sampled with a frequency f_s ($T_s = 1/f_s$). The reference signal may be generated from three separate phase references using the $\alpha\beta\gamma$ transform. The reference vector is then synthesized using a combination of the two adjacent active switching vectors and one or both of the zero vectors. There are various strategies of selecting the order of the vectors and which zero vector(s) to use exist. Strategic selection will affect the harmonic content and the switching losses.

In this Fig.6 shows All eight possible swiching vectors for a three-leg inverter using space vector modulation. An example Vref is shown in the first sector.Vref max is the maximum amplitude of Vref before nonlinear overmodulation is reached.

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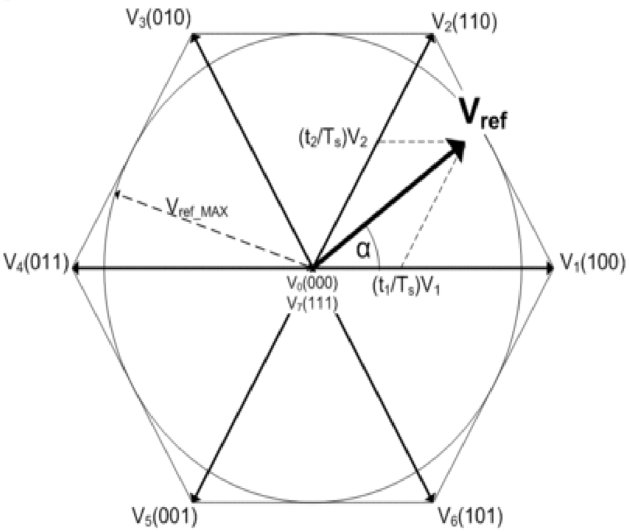

Fig.6.Space vector diagram of the effective vectors

SIMULATION ANALYSIS

Simulations are carried out using MATLAB software. The simulation parameter is taken as 230/50Hz power supply. The output frequency has been taken 50 Hz. Assumption has been made that all the switches are ideal. And its switching frequency used 6 kHz. The rectifier modulation index m_r=0.8 inverter modulation index m_i=0.8.

The performance of the nine-switch converter topology is simulated with the MATLAB/Simulink software. The Simulation results as shown below. Fig. 7 shows the three phase input voltage waveform applied to the converter side. Fig. 8 shows the Three Phase Output Voltages of the converter. The constant voltage waveform across the capacitors had shown in Fig. 9 and Fig. 10 shows the input power factor which is settled to unity after transient period.

Unity Power Factor Operation

The input power factor of the converter can be leading, lagging, or unity. Fig. 9 shows the measured of the converter with unity power factor operation. And the converter modulation index was *mr = mi* =0.8. It should be noted that the control of the rectifier and inverter is decoupled, and therefore, the inverter operation will not affect the operation of the rectifier.

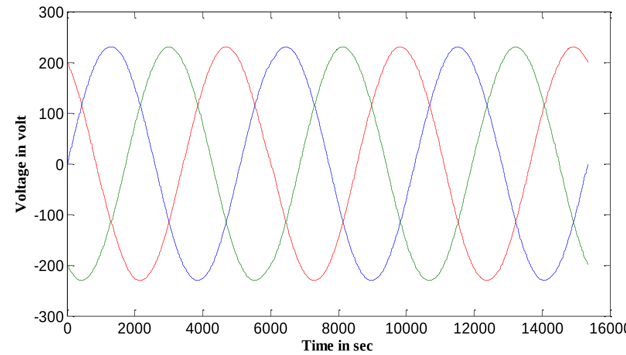

Fig.7 Input voltage waveform

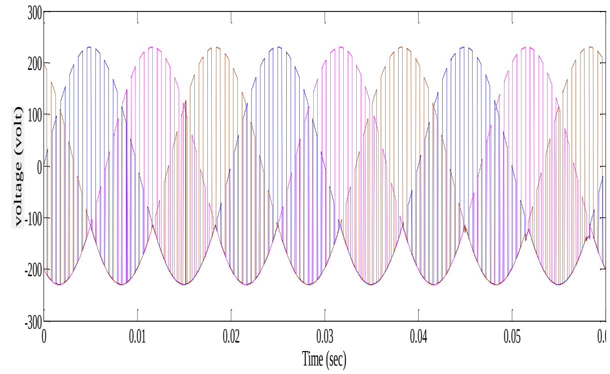

Fig.8 output voltage waveform

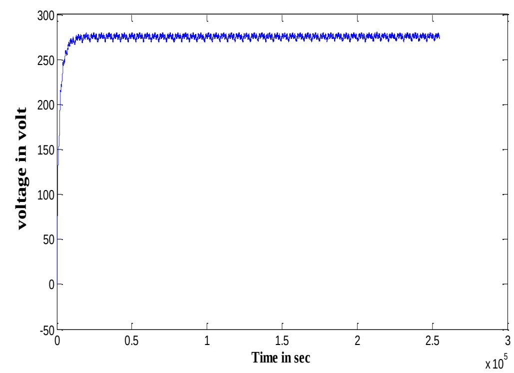

Fig.9 Output voltage waveform

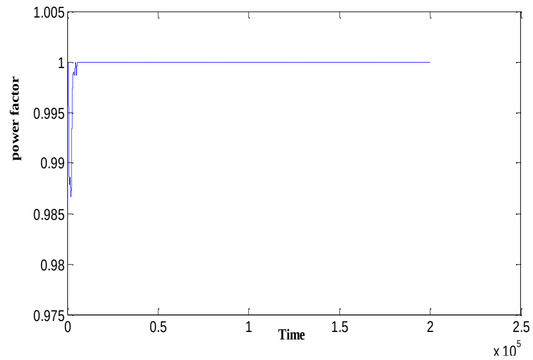

Fig 10. Unity input power factor

CONCLUSIONS

In this paper, the effectiveness of the proposed technique has been clearly justified. The topology uses only nine IGBT devices for ac to ac conversion through a quasi dc-link circuit. And the space vector modulation technique is used for improving input power factor. To control the nine switches only six pulses are required and successfully implemented. Compared with the conventional back-to-back PWM VSC where 12 switches were used and the matrix converter that uses 18 switches and hence shows the effectiveness of the proposed technique.

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