SVPWM Rectifier-Inverter Nine Switch Topology for Three Phase UPS Applications

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Abstract-This paper proposes a novel three phase nine-switch ac/ac converter topology with space vector pulse width modulation techniques for UPS applications. This converter features sinusoidal inputs and outputs, unity power factor and mainly a reduced Number of active switches. The SVPWM operating principle is elaborated. Simulation of three phase ac to ac converter with conventional method is evaluated compared to the SVPWM control scheme are presented. Also Comprehensive simulation results will be obtained using MATLAB. The performance of the proposed converter is verified by experiments on a 3 kVA prototyping UPS system.

Key words - AC/AC converter, space vector pulse width modulation (SVPWM), reduced switch count topology.

I. INTRODUCTION

Industries like paper mill, sugar mill and textile mills require variable speed drives in many places. The variable speeds are obtained using three phase AC/AC converter with variable frequency (VF) and variable voltage (VV) operation. The CF-mode operation is particularly suitable for applications in UPS, whereas the VF mode can be applied to variable-speed drives. The most popular AC to AC converter configurations used in voltage source inverter (VSI) with a diode rectifier as the front end for adjustable speed drives (ASDs).

Diode rectifier generates highly distorted input line currents and does not have regenerative or dynamic braking capability. So, pulse width modulation (PWM) voltage source rectifier is used to replace the diode rectifier. This work proposes to analyze and develop a novel three phase nine switch AC to AC converter topology with space vector pulse with modulation (SVPWM) voltage source converters. An ideal UPS is desired to produce a regulated sinusoidal output voltage for its critical load under any operating conditions, to have seamless transition between normal operation and power failure modes, and to draw sinusoidal input currents from the utility supply with unity power factor.

A novel nine-switch sinusoidal PWM ac/ac converter topology was discussed [1] and the topology uses only nine IGBT devices for ac to ac conversion through a quasi dc-link circuit. The proposed converter features sinusoidal inputs and outputs, unity input power factor, and low manufacturing cost. The VF-mode version requires IGBT devices with higher ratings and dissipates significantly higher losses, and thus, is not as attractive as its counterpart.

In many applications, a further cost reduction for the drive is an important aspect, and, thus, a reduction of the number of power semiconductors in the converter should be a main consideration [2]. Regarding the inverter, some component minimized topologies have been proposed in the literature. In, a B4 inverter employing four switches and four diodes is suggested as a practical alternative to the B6 inverter with six switches and six diodes. The three-phase dc-link ac–ac five-leg converter in which one of the legs is shared by both the grid and load sides. Scalar and vector PWM techniques, hysteresis current control and overall system control, including a synchronization technique to improve converter rating, have been presented. The overall performance of this topology is superior to the topologies based on the four-leg converter; this is due to a smaller, to the voltage capability that can be split between the rectifier and the inverter, to the fact that the grid and load converter voltages do not depend on the individual capacitor voltages, and because there is no ac fundamental current flowing through the dc-link capacitors. On the other hand, when compared to the six-leg converter, the five-leg converter topology requires less switches at the expense of an increased power rating [3].

The two ac–ac reduced switch-count converter configurations for three-phase to three-phase applications. The configurations use four legs and the capacitor Authorized licensed dc-link midpoint. The configurations are indicated for applications where input-current (power factor and harmonic content) and load-voltage amplitude must be controlled, and at the same time, the grid and load frequencies are equal (e.g., UPS and ac/dc distributed-power-system applications). The configurations are also interesting for applications where the grid and load frequencies are different; however, in this case, it is considered that the voltage ratings of the converters (load and grid sides) are quite different. A methodology to apply space vector modulation technique was proposed to three-phase three-switch two-level unidirectional PWM rectifier. With this methodology, it is not necessary to determine the sectors of vectors, only to impose desired current sectors from input voltage references and the proposed methodology could be applied to other two-level unidirectional PWM rectifiers[5].

The functionality of a conventional three-phase ac-ac matrix converter could be achieved by employing only 15 IGBTs based on the SMC concept. A zero dc-link current commutation scheme provides lower control complexity and potentially higher reliability compared to the multistep commutation strategies. Zero dc-link current commutation also allows the input stage of an IMC to be realized by four-quadrant switches. This results in the VSMC topology, which comprises of only 12 IGBTs. An isolated four-quadrant switch is commercially available and therefore the SMC and the VSMC are of great interest to industry as an alternative to the CMC concept [6]. Although theoretically an infinite number of zero-sequence signals, and, therefore, modulation methods could be developed, the performance and simplicity constraints of practical PWM-VSI drives reduce the possibility to a small number.

Over the last three decades of PWM technology evolution, about ten high-performance carrier-based PWM methods were developed, and of these only several have gained wide acceptance. The triangle intersection implementation of the space-vector PWM (SVPWM) method and the two third harmonic injection PWM (THIPWM) methods are the other three CPWM methods [7].

Of all the types, the online UPS characterized by the double-conversion structure provides the best overall performance. Fig. 1shows the simplified block diagram of an online double-conversion UPS that satisfies the above requirements. It is composed of a PWM rectifier, a PWM inverter, a battery and a static transfer switch.
As shown in Fig. 1b, the proposed UPS system has a simple and balanced structure which contains only one power conversion stage. Under normal operation, the power is delivered to the critical load partially through ac/ac direct conversion and partially through the dc circuit.

II. NINE SWITCH CONVERTER TOPOLOGY

Figure 1c shows that three phase AC to AC converter with SVPWM using nine IGBTs convertor for UPS applications. For the nine-switch topology, the control of the input and output voltages has to be accomplished through the three switches on each leg. Because the middle switches are shared by the rectifier and inverter, the proposed converter has only three switching states per phase, as listed in Table. It can be observed that switching state 4 for the B2B 2L-VSC does not exist in the nine-switch converter, which implies that the inverter leg voltage v_{XN} cannot be higher than the rectifier leg voltage v_{AN} at any instant. This is, in fact, the main constraint for the switching scheme design of the nine-switch converter. 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, whereas the inverter consists of the middle three and bottom three switches.

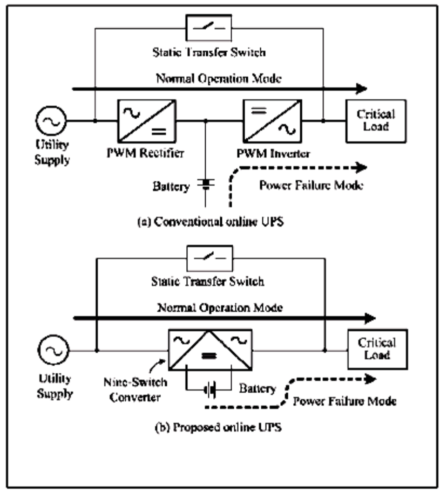


Figure 1 (a) & (b) simplified block diagram of the conventional and proposed online UPS system

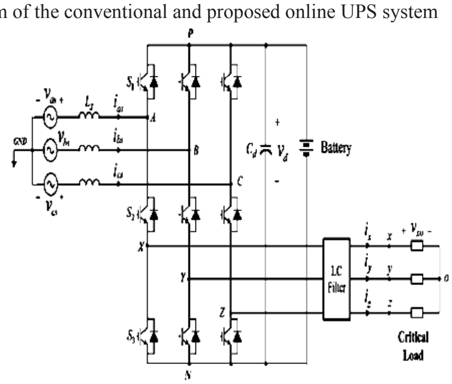


Figure 1c Proposed nine-switch converter for UPS applications

(b) Proposed nine-switch converter					
Switching State	S_1	S_2	S_3	v_{AN}	v_{XN}
1	On	On	Off	V_d	V_d
2	Off	On	On	0	0
3	On	Off	On	V_d	0

Table 1 Switching states and converter leg voltages

The table 1 shows the switching operation of three phase ac to ac converter with nine switch topology. The switch s1 and s2 on the circuit converts ac supply in to dc supply. At that time s3 is off so only rectifier operation is at first stage. Then s1 off s2 and s3 on then the middle leg operate as a inverter.

III. MODULATION SCHEME OF SVPWM

The zero-sequence signal of SVPWM is generated by employing the minimum magnitude test which compares the magnitudes of the three reference signals and selects the signal with minimum magnitude. Scaling this signal by 0.5, the zero-sequence signal of SVPWM is found. Assume, then analog implementation of SVPWM which employs a diode rectifier circuit to collect the minimum magnitude signal from the three reference signals is possibly the earliest zero-sequence signal injection PWM method reported. About a decade later, this modulator reappeared in the literature with direct digital implementation. Since the direct digital implementation utilized the space vector theory, the method was named SVPWM. In addition to its implementation simplicity, the SVPWM method has superior performance characteristics and is possibly the most popular method.

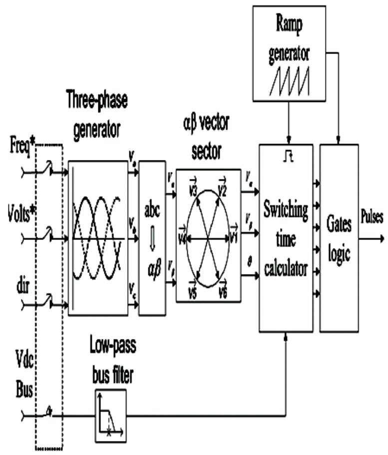
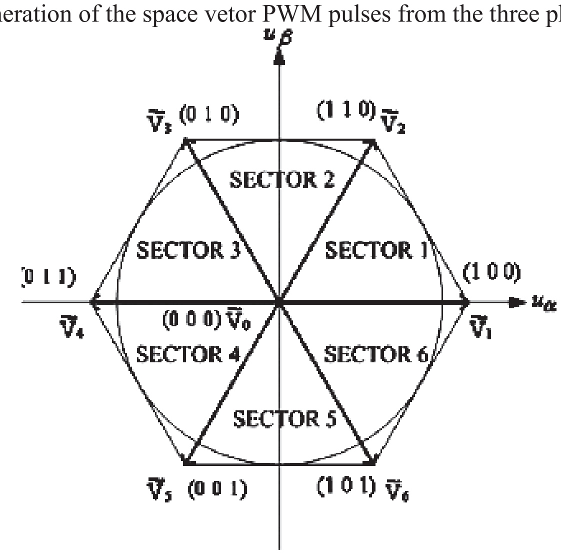


Figure 2. space vector modulator

The figure 2 shows the generation of the space vetor PWM pulses from the three phase AC voltages.



Vector	Coordinates [α β]
$\overline{V}_0$ (0 0 0)	$[0 \quad 0]$
$\overline{V}_1$ (1 0 0)	$[\sqrt{3/2} \quad 0]$
$\overline{V}_2$ (1 1 0)	$[1/\sqrt{6} \quad \sqrt{2}/2]$
$\overline{V}_3$ (0 1 0)	$[-1/\sqrt{6} \quad \sqrt{2}/2]$
$\overline{V}_4$ (0 1 1)	$[-\sqrt{3/2} \quad 0]$
$\overline{V}_5$ (0 0 1)	$[-1/\sqrt{6} \quad -\sqrt{2}/2]$
$\overline{V}_6$ (1 0 1)	$[1/\sqrt{6} \quad -\sqrt{2}/2]$

Figure 3. Space vector co ordinates

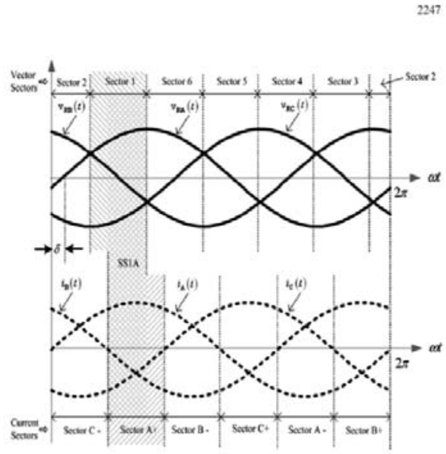


Figure 4 subsectors definition

In figure 3, For control of the voltage phasor both in its magnitude and phase. The requested voltage vectors phase and magnitude are sampled, say once every switching period. The phase of the requested voltage vector identifies the nearest two non zero voltage vectors. The requested voltage vector can be synthesised by using fractions of the two nearest voltage vectors which amounts to applying these two vectors one at a time for a fraction of the switching period. The nearest zero voltage vector to the two voltage vectors is applied for the remaining switching period. Figure 4 shows the subsectors definition. The duty cycle for each of the voltage vectors is determined by the phasor projection of the requested voltage vetor on to the two nearest voltage vectors. This method of controlling the input voltages to the machine through a sysnthesis of voltage phasor rather than the individual line to line voltages has the many advantages.

IV. SIMULATION ANALYSIS

The performance of the proposed nine switch converter topology is simulated with the Matlab/Simulink software. In the simulation, the utility supply is rated at 208V and 50Hz with a source inductance of Ls = 2.5 mH. The converter is rated at 5 kVA is driving a three-phase RL load of RL= 8Ω and LL = 2.5mH. The DC capacitor CD is 2350μF. SVPWM method is used to modulate the converter for its superior performance over SPWM and higher dc voltage utilization. The rectifier is controlled by a vector control scheme with unity power factor operation.

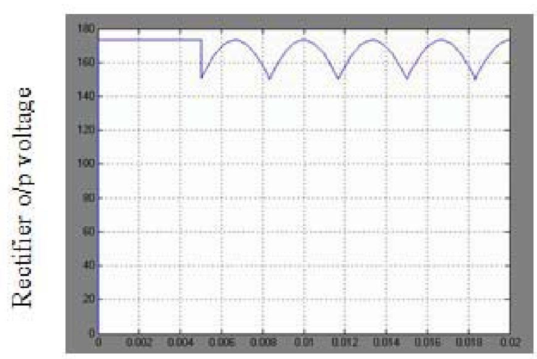


Figure 5 Conventional method rectifier output

Figure 5 shows the conventional nine switch AC to AC converter with quasi DC link rectifier output

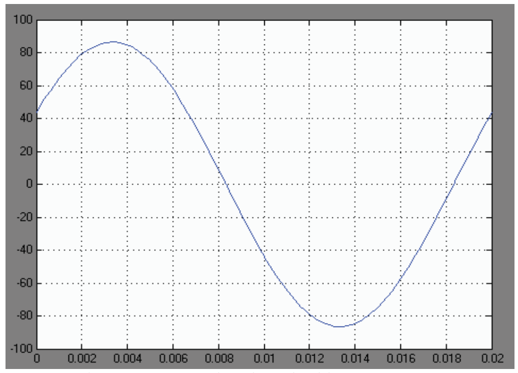


Figure 6 Conventional method inverter output

Figure 6. shows the conventional nine switch AC to AC inverter with quasi DC link inverter output

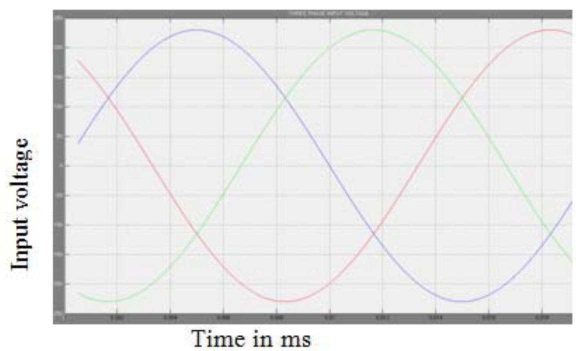


Figure 7 Three phase input voltages

Figure 7 shows the three phase 230 volts input voltage of the AC to AC converter topology

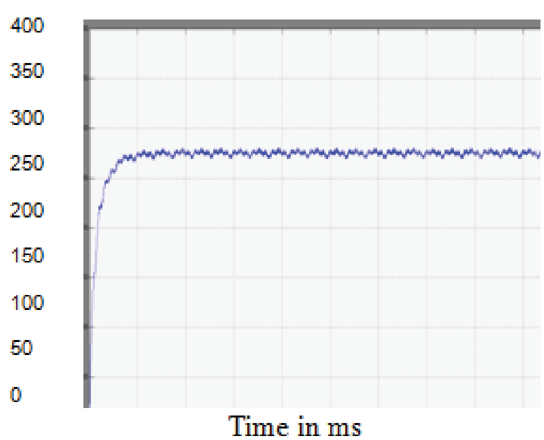
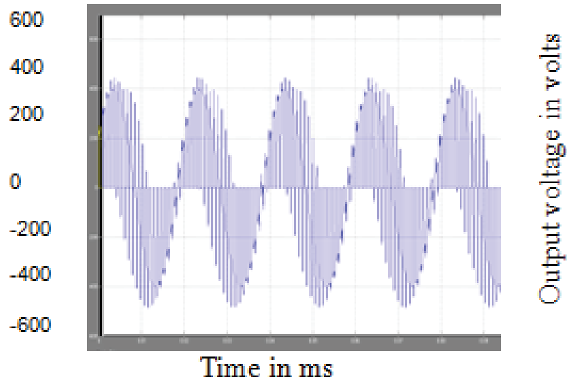


Figure 8, rectifier output of nine switch topology using SVPWM

Figure 8, rectifier output of nine switch topology using SVPWM, the waveform gets from the Rectifier unit 320 volts. During the operation the dc voltage 320 v rectifier output maintained. The inverter operation does not affect the converter operation.



There is no need to carrier sine wave for rectifier controls. To get 440 volts ac variable supply at unity power factor also possible. To get the variable output compared to conventional method switching losses are less. Inverter output using SVPWM control techniques. Figure 9shows the inverter output of nine switch topology with SVPWM to vary the voltage without using carrier signal Like SPWM.

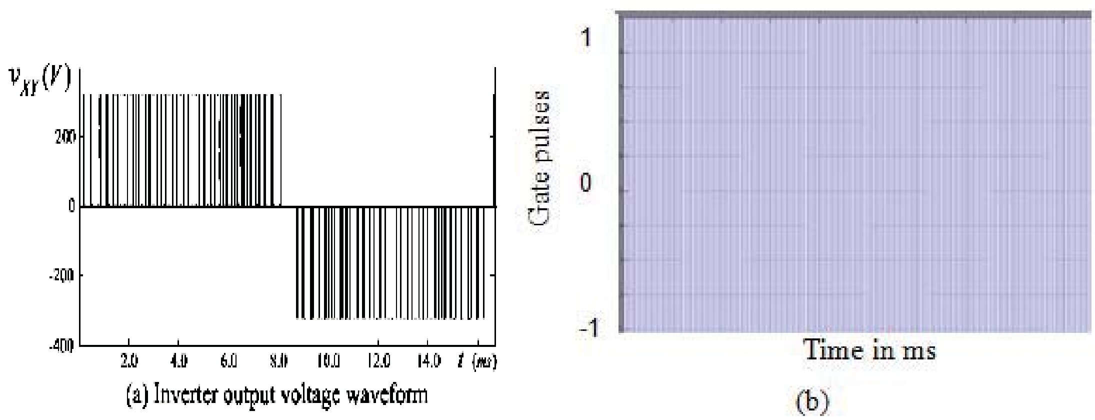


Figure 10 a & b Space vector PWM pulses

Figure 10 shows that Space vector PWM pulse from 0 to 1. The sine wave or triangular wave carrier frequency not needed in the above method compared to sinusoidal PWM.

V. CONCLUSION

A novel nine switch to SVPWM ac/ac converter topology was proposed in this paper .The topology uses only nine IGBT devises for ac to ac conversion through a quasi dc link circuit. The proposed converter is reduced by 33% and 50%.the operating principle of the converter was elaborated with SVPWM schemes. The proposed converter features sinusoidal inputs and outputs unity input power factor and reduced cost. Simulation results of conventional method AND SVPWM output was discussed. The space vector PWM higher fundamental voltages compared to sine triangle PWM based controllers, also low voltage and current ripples. This method not using pulse width modulation carrier frequency signals. It is particularly suitable for online UPS applications, where the output voltage of the converter is usually kept in phase with the utility supply voltage. The operating principle of the converter is discussed and a novel space vector modulation scheme is developed. The performance of the converter topology is verified through simulation and experiments on 3kVA prototyping UPS system.

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