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# A novel SVPWM for 3-phase to 5-phase conversion using matrix converter

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**ABSTRACT**

A novel matrix converter has been developed for 3-phase to 5-phase conversion using a novel space vector pulse width modulation. The matrix converter organized to generate 5-phase AC output voltage from 3-phase input voltage with help of SVPWM method; bidirectional power switches placed in matrix converter controlled by appropriate switching pulse. Space vector pulse width modulation (SVPWM) provides better utilization of applied input voltage, improved output voltage, reduced total harmonic distortion. The bidirectional switch used by the matrix converter decreases stress on the power switch and the influence of harmonic fluctuation in AC output voltage. When compared to traditional approaches, the suggested system offers improved output voltage and current control. Using MATLAB/Simulink and FPGA-cyclone controller, respectively, modelling and experimental results have been given to validate the proposed methodology.



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## 1. INTRODUCTION

In recent years, the usage of power electronic converters has been increased due to more flexiblity and easy to controllable; also much suitable for various applications like industrial, medical, power system deregulation, electric energy transportation and railway application [1]–[8]. Generally for AC power conversion is divided into two stage process AC-DC-AC conversion with help of rectifier and voltage source inverter or multilevel inverter [9]–[14]. However, in recent days matrix converter becomes alternative for conventional AC to AC conversion system; it avoids extra converter in the system and minimize the harmonic during this conversion process. Matrix converter can convert variable voltage magnitude and variable frequency [15]–[19]. In the literature, different PWM implementations for matrix converters have been made; among these, space vector pulse width modulation (SVPWM) offers greater performance in comparison to other pulse width modulation (PWM) implementations [20], [21]. As a result, total harmonic distortion (THD) is reduced, applied input voltage is used more effectively, and other electromagnetic interference problems are also lessened [22]–[25].

In this paper, a novel SVPWM scheme for converting from three to five phases using a matrix converter is presented. The bidirectional switch used by the matrix converter decreases stress on the power switch and the influence of harmonic fluctuation in AC output voltage. When compared to traditional approaches, the suggested system offers improved output voltage and current control.

## 2. OPERATION OF MATRIX CONVERTER

Nine bidirectional switches are part of the matrix converter, allowing any output phase voltage to be coupled to any input phase voltage. Three phase bidirectional switch is connected to the input three phase terminal voltage to reduce harmonic fluctuation, which is shown in Figure 1. The applied instantaneous input power and the output power are not equal. However, matrix converter uses a single stage conversion unit with the use of bidirectional switches rather than multistage conversion and energy storage devices in the converter.

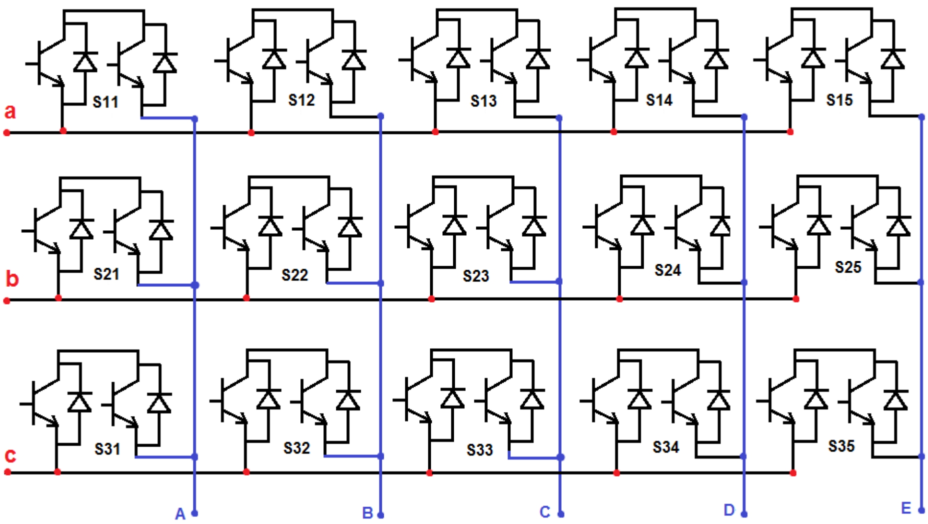



Figure 1. Circuit diagram of 3 to 5 phase matrix converter

## 3. SVPWM CONTROL

In order to identify switching sequences, SVPWM allocates a switching vector to a region of the d-q space. This switching control approach is used with power electronic switches. Figure 2 depicts the structure of the SVPWM control method for matrix converters. It contains 243 switching state vectors overall, distributed among 125 switching planes.

In contrast to classic SPWM, it has improved harmonic content level reduction and increased output voltage amplitude. The voltage across the proposed matrix converter has reduced harmonic input current source and minimized voltage volatility. The following procedures are used to produce the gating pulses for the matrix converter's bi-directional switches.

- Sector selection for placement of the reference vector based on magnitude and angle calculations
- Sector regions are accurately identified through triangle identification.
- The gating time is calculated with help of general equations.
- Based on calculations for magnitude and angle, sectors are chosen for the reference vector's placement.

Due to the fact that redundant switching states are only feasible in tiny vectors, all of the switching state vectors in SVPWM are situated in a complicated hexagonal region. The sinusoidal voltage is viewed by the SVPWM as a vector with constant amplitude, rotating at constant frequency, and a control variable.

$$V_{sa1} = \frac{2}{5}(V_{as} + a_n V_{bs} + a_n^2 V_{cs} + a_n^3 V_{ds} + a_n^4 V_{es}) \quad (1)$$

$$V_{sa3} = \frac{2}{5}(V_{as} + a_n V_{cs} + a_n^2 V_{es} + a_n^3 V_{bs} + a_n^4 V_{ds}) \quad (2)$$

$$a_n = e^{\frac{j2\pi}{5}} \quad (3)$$

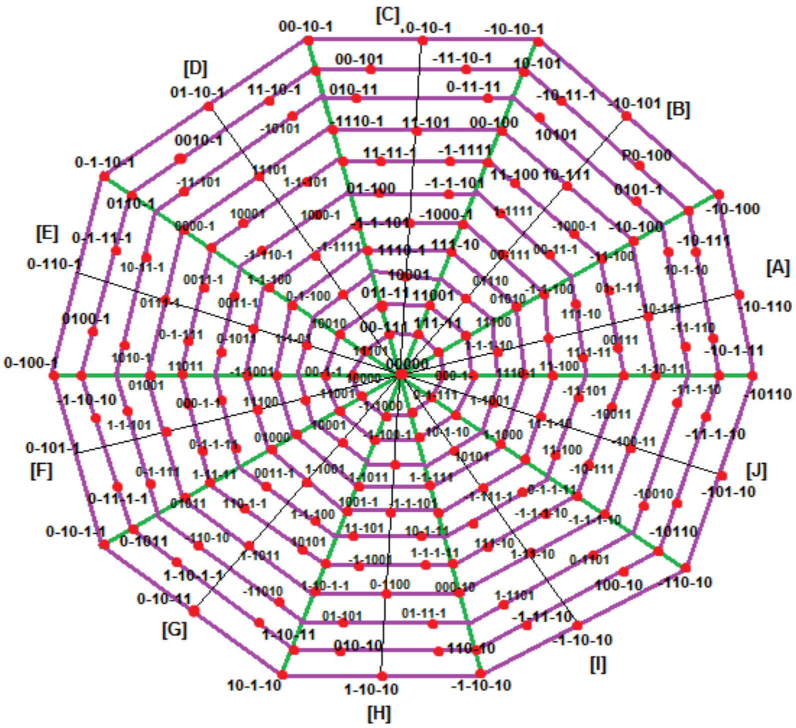



Figure 2. Structure of SVPWM control algorithm for matrix converter

The total of 243 switching state vectors is reduced to 116 switching state vectors after the reference vector is found, as shown in Figure 3. The switching pulse generation in that switching state vector is chosen. According to the nearest state vector approach, switching vectors are employed for THD minimization, and only small and big vectors are used to accomplish the minimized THD level, as shown in Figure 4.

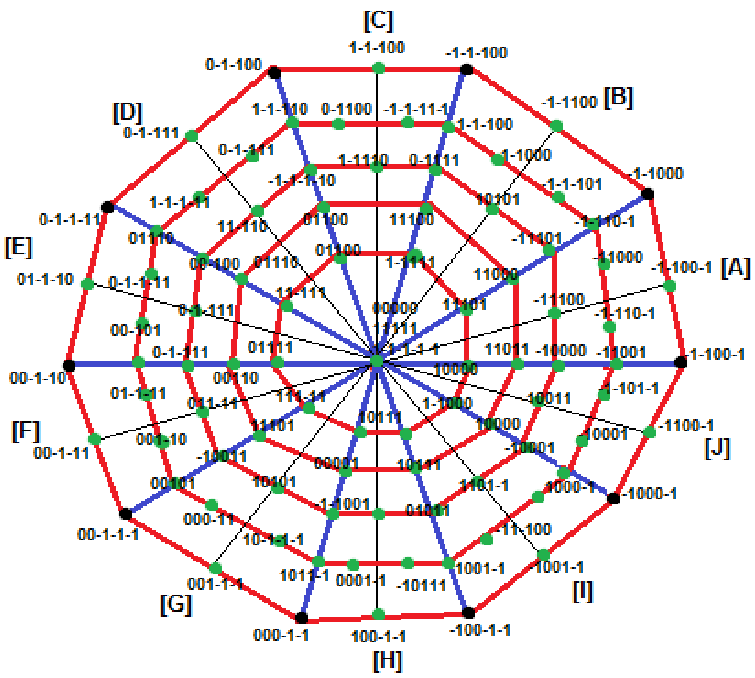



Figure 3. Eligible switching state vectors for THD minimization

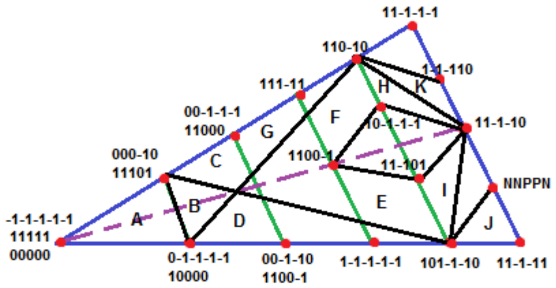



Figure 4. switching state vector location in a triangle

Each triangle's switching time is calculated using the following (4)-(8).

$$T_a = \frac{2*V_{AN}}{V_{ac}} T \tag{4}$$

$$T_b = \frac{2*V_{BN}}{V_{ac}} T \tag{5}$$

$$T_c = \frac{2*V_{CN}}{V_{ac}} T \tag{6}$$

$$T_d = \frac{2*V_{DN}}{V_{ac}} T \tag{7}$$

$$T_e = \frac{2*V_{EN}}{V_{ac}} T \tag{8}$$

Where $V_{AN}$, $V_{BN}$, $V_{CN}$, $V_{DN}$, and $V_{EN}$ are different phase voltages of the matrix converter, and T is the overall switching frequency. These equations allow for the generation of switching pulses for three-to-five phase matrix converters. SVPWM technology for matrix converter system allows for three phases to five phase conversion and THD mitigation.

## 4. SIMULATION RESULTS

In MATLAB/Simulink, the proposed innovative matrix converter's simulation was created. With the use of bi-directional switches, a smart technology matrix converter transforms a fixed three-phase voltage into a five-phase variable voltage and variable frequency. The system's bi-directional switch is managed by correctly generating switching pulses using the SVPWM approach. Figure 5 depicts the block architecture of a system that uses a 3 to 5 phase matrix converter and contains a 3-phase AC source, input filter, 3 to 5 phase matrix converters, and SVPWM switching pulse production utilizing an FPGA controller.

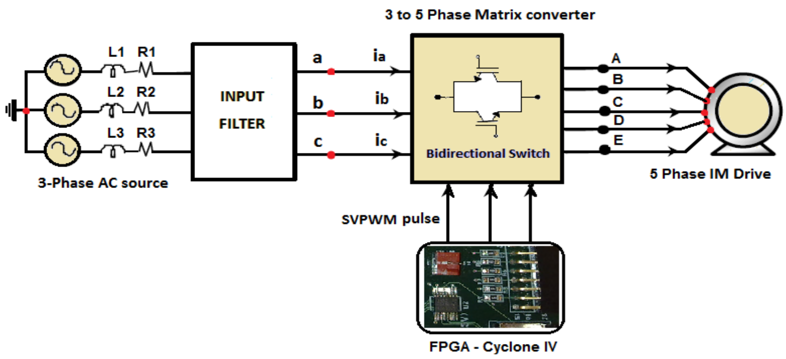



Figure 5. Block diagram of 3 to 5 phase matrix converter system

Figure 6 illustrates the creation of switching pulses using the SVPWM algorithm with a switching frequency of 1 kHz. Figure 7 illustrates the simulation results of a three to five phase matrix converter.

Figure 7(a) depicts the three-phase input voltage applied to the matrix converter; Figures 7(a) and 7(b) depict the five-phase output voltage and current produced by the SVPWM algorithm. Figure 8 illustrates the THD analysis of the suggested system, which shows output voltage with 0.12% and output current with 0.19%.

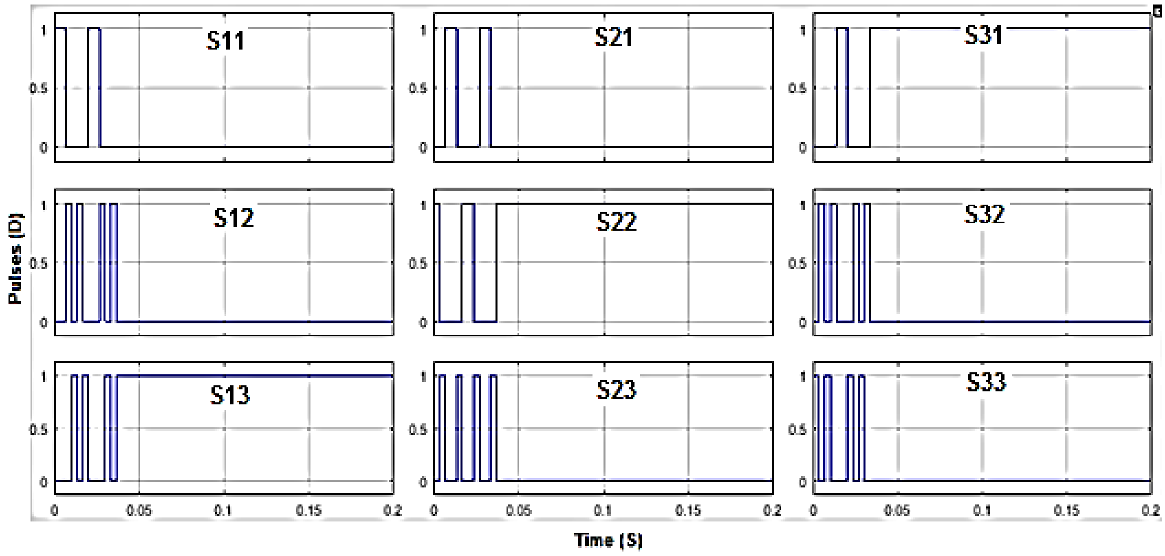



Figure 6. Switching pulse generation using SVPWM algorithm

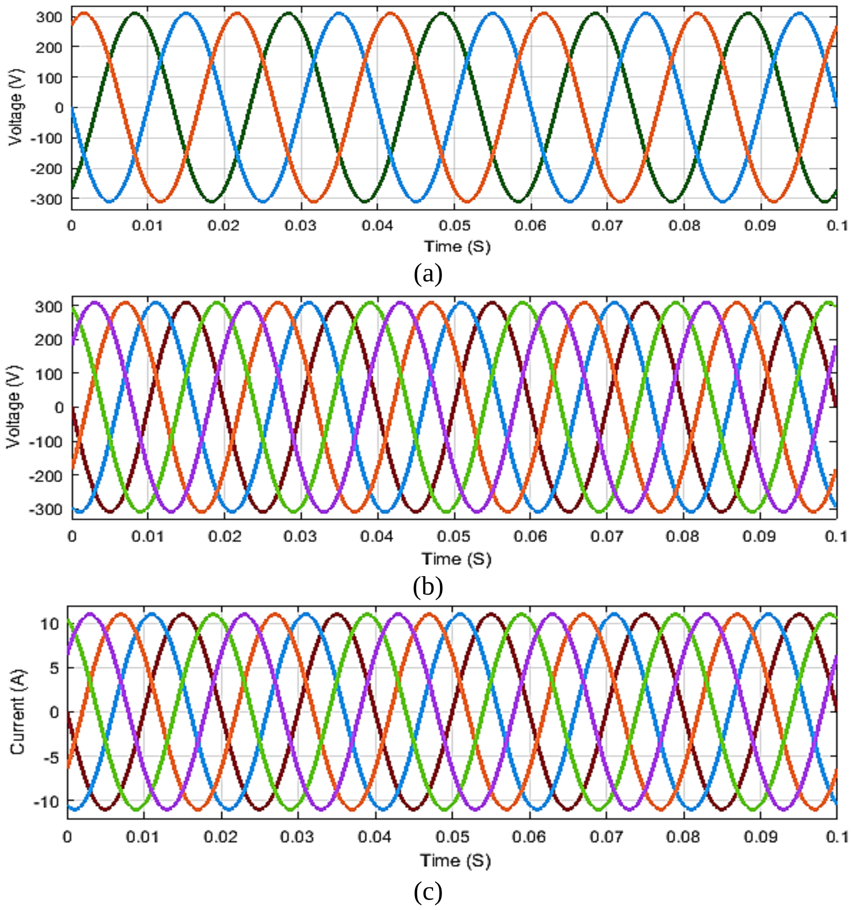
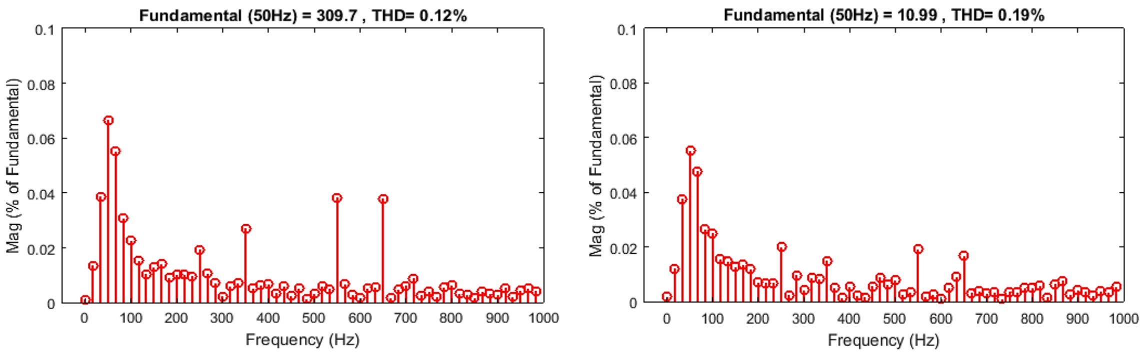



Figure 7. Simulation results (a) input voltage, (b) output voltage, and (c) output current

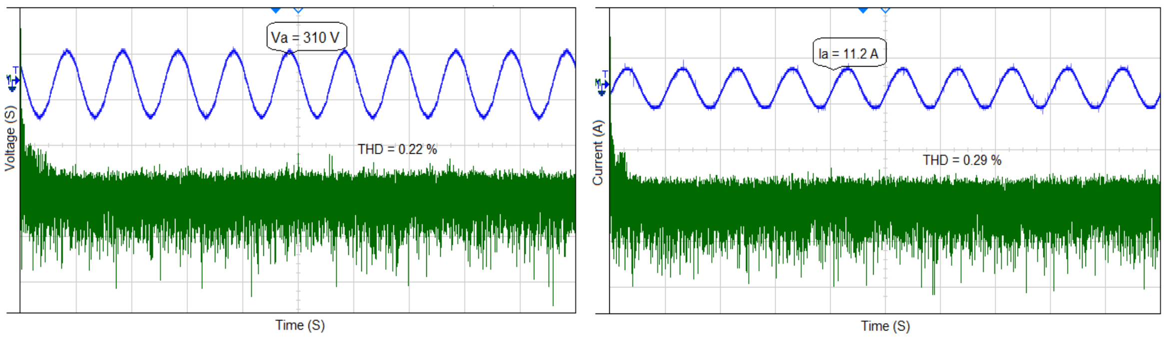



(a) (b)

Figure 8. THD investigation (a) output voltage and (b) output current

## 5. EXPERIMENTAL RESULTS

Hardware setup of a 3-phase matrix converter designed and experienced was used to confirm the simulation results of the suggested strategy. SVPWM is used to regulate the output of a new matrix converter, which is connected via an FPGA-cyclone controller. The system uses a 3-HP induction motor drive with a switching frequency of 1 kHz, an operating frequency of 50 Hz, and these frequencies together. Figure 9 displays the output voltage and current of the experimental findings with THD.




(a) (b)

Figure 9. Experimental results: output voltage and current with THD
(a) output voltage-phase A and (b) output current-phase A

## 6. CONCLUSION

This study uses a matrix converter to construct a novel SVPWM control for a 3 to 5 phase conversion. SVPWM control offers improved input voltage usage. With this system's better output voltage and current management, total harmonic distortion is minimized. These three to five phase conversions, which results in an effective power conversion, is well suited for industrial applications. The suggested outputs are tested using the cyclone processor with a 1 kHz switching frequency and MATLAB/Simulink.

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