AC-DC-AC Converter with Reduced Switches as Matrix Converter and Power Factor Improvement

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Abstract - This project presents an AC-DC-AC converter as a matrix converter topology with simple commutation procedure. AC-DC-AC converter is analysed with reduced number of switches which provides the same performance of conventional matrix converter in terms of voltage transfer ratio, unity power factor, no DC link capacitor and pure sine wave with only higher order harmonics in both line and load side around the switching frequency. Moreover, the converter can utilize the conventional PWM technique on inverter side, which greatly simplifies the complexity of control. Theoretical analysis and simulation results are provided to verify its performance. Matrix converter also will be used for improvement in input and output current harmonics. Comparative analysis will be carried out with SVPWM technique for open loop and closed loop system. The whole system has been validated in MATLAB/SIMUINK with variable load demand. Simulations of Matrix converter is loaded by Active three phase Induction Motor.

***Key Words*:** Matrix converter(MC), Simple commutation, Space vector pulse width modulation, Induction motor, speed control, harmonic reduction.

1.INTRODUCTION

In Power electronic different applications recently become common particularly in the applications of AC-DC-AC conversions in modern industrial environments. The AC & DC conversion system is used for AC and DC loads. There is no any system is currently available to get AC and DC output instantly. A concept of multiple converter means that using single control circuit it can give AC and DC output instantly. For the implementation of such a multiple converter matrix topology is used.

In the proposed paper, a direct MC is used with improved modulation technique which in turn reduces the losses also with comparative less number of switches. The Direct MC has recently attracted enormous attention among variable frequency drive devices due to its benefits over conventional variable frequency drives. Due to high complexity in the implementation of its algorithm on microcontrollers, very few industries are using Direct MC for industrial applications. This paper presents a novel and comprehensive method of reducing the complexity of its algorithm. This paper also presents the basic approach towards implementation of multiphase direct matrix converter.

2. Matrix Converter

MC is a universal converter which can perform all operation of AC-DC-AC conversion without any isolation. In a MC the main power elements are Bidirectional switches, which interconnect directly the input supply to the load. The MC replaces the multiple conversion stages and the intermediate energy storage element by a single power conversion stage, and uses a matrix of semiconductor bidirectional switches connecting input and output terminals. With this general arrangement of switches, the power flow through the converter can reverse. Because of the absence of any energy storage element, the instantaneous power input must be equal to the power output, assuming idealized zero-loss switches.

The MC consists of 9 bi-directional switches that allow any output phase to be connected to any input phase. Due to special switching matrix, it is possible to connect any input terminal(R,Y or B) to any output phase (r, y or b) whereas the current in any phase of the load can be drawn from any phase or phases of the input supply.

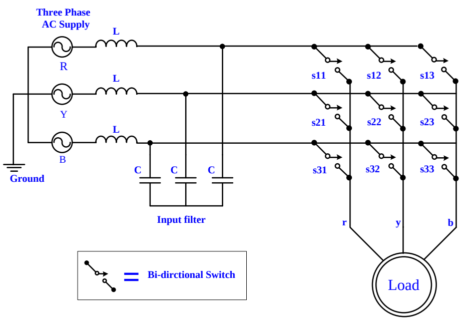

Fig -1: Matrix converter Topology

This circuit is called as the matrix converter because it allots one switch for each possible connection between the input and output. Thus 9 switches are for 9 possible connections. At any instant of time any one bidirectional switch should be turned on so that there is no short circuit on the input side. Nine switches used are 2^9=512 possible states of the converter but only 27 switching combinations are allowed in order to avoid the input getting short circuited, So a suitable switching strategy needed to be adopted. The input LC filter is installed to filter out high-frequency PWM components of the input currents.

The relation between the input voltages, switches and output voltages can be written in the matrix format as in eqn (1).

And For a balanced load the relation between input phase current and output phase current is as in eqn (2) can be shown.

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \begin{bmatrix} s11 & s21 & s31 \\ s12 & s22 & s32 \\ s13 & s23 & s33 \end{bmatrix} \begin{bmatrix} V_{RN} \\ V_{YN} \\ V_{BN} \end{bmatrix} \quad \ldots\ldots\ldots\ldots (1)$$

$$\begin{bmatrix} i_R \\ i_Y \\ i_B \end{bmatrix} = \begin{bmatrix} s11 & s12 & s13 \\ s21 & s22 & s23 \\ s31 & s32 & s33 \end{bmatrix} \begin{bmatrix} i_r \\ i_y \\ i_b \end{bmatrix} \quad \ldots\ldots\ldots\ldots (2)$$

2.1 Switching principle:

The three phase MC topology is shown in fig.1. Since MC connects load directly to the voltage source by using nine bidirectional switch, The input phases of MC should not be shorted due to the input voltage sources, and the output phases should not be opened due to the inductive nature of the load. if the switching function of a switch, S is in fig.1 is define as:

$$S_{ij} = \begin{cases} 1, S_{ij\ close} \\ 0, S_{ij\ open} \end{cases} \quad i \in \{r, y, b\}, j \in \{R, Y, B\} \quad \ldots\ldots\ldots\ldots (3)$$

2.2 Matrix converter Types

MCs are classified into two types depending on the method of control adapted. Both have no intermediate DC storage stage.

1) DIRECT MC :

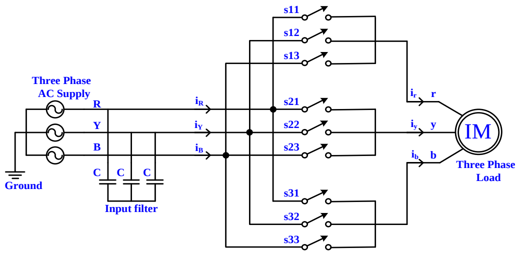

Fig -2: Direct matrix converter topology

DMC performs single stage AC/AC conversion using a complicated control logic for switching the power switches. DMC is a force commutated frequency converter topology which proposes single stage voltage and current conversions commonly through an array nine bidirectional switches. Main attractive feature of this topology is that bidirectional power flow is possible without any energy storage element like electrolytic capacitor or ac inductor which is bulky and limited in life. Other attractive features are improved sinusoidal input and output waveforms, adjustable power factor, simple and compact power circuit, good dynamic response, small input filter components etc. By virtue of these features, MC has all abilities to become good option of traditional ac/dc/ac converters which is very popular and mature technology used in various industries. MC generates output waveforms without any limits on the output frequency and amplitude with only one conversion stage. The DMC in shown Figure-1 has best illustrates topology of DMC where the source and load is directly connected to it.

2) INDIRECT MC:A principle of this control strategy in indirect MC is based on virtual DC-link in MC. In this DC-link is not physically presented, but the switches are divided to the virtual rectifier and virtual inverter on the Fig.3. The IMC topology shown in Fig.3 is treated as a two-stage transformation converter. A rectifier stage to provide an imaginary DC-link during the switching cycle and an inverter stage to generate the three phase desired output voltages.

The purpose of the rectifier is generating the sinusoidal input currents as well as maintaining a constant local-averaged dc output voltage in the DC-link, by modulating the two line-to-line input voltages. Output voltages with variable frequency and variable amplitude can be obtained through the conventional space vector PWM modulation of the inverter stage, using the constant DC voltage obtained from the rectifier stage.

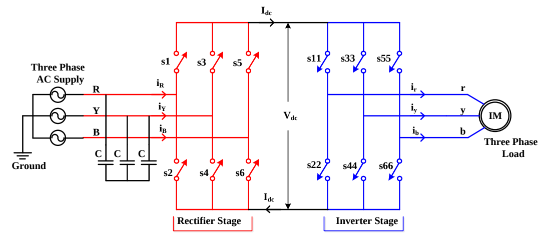

Fig -3: IMC topology

Both converters can achieve the same quality of input current and output voltage if controlled using the same type of modulation, which means that they need the same input filters to achieve the same performance on the line current. Also both converters have the same limitations, mainly regarding the maximum output voltage available and power factor correction especially at very low output power. The main differences between the two converters are efficiency and losses distribution among the devices.

3. BI-DIRECTIONAL SWITCH

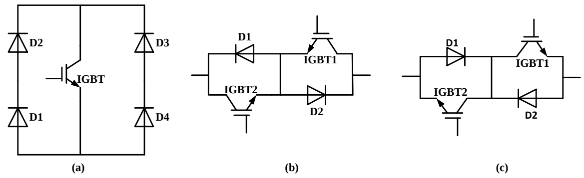

Fig -4: (a) Diode Bridge Arrangement (b) Common Emitter Arrangement (c) Common Collector Arrangement

Bidirectional switch is capable of conducting currents and blocking voltages of both polarities, depending on control actual signal. But at present time a true bi-directional switch is still not available on the market and thus it must be realized by the combination of conventional unidirectional semiconductor devices. Fig.4 shows different bi-directional switch configurations.

The diode-embedded switch arrangement consists of a single transistor at the center of a single-phase diode bridge arrangement as shown in Fig.4(a). Positive current and

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negative current are carried by the same switching device, which decreases the required gate driver to one per commutation cell as well as the power supply to the gate drive.

Common emitter arrangement consists of two IGBTs and two diodes connected in anti-parallel form as shown in Fig.4(b). The arrangement is capable of blocking both voltage polarities and conducting current in both directions. Conduction losses are reduced since there are only two devices that carry the current at any one time. There is independent control of the current direction through each switching device.

Common collector arrangement is similar to the previous one, except the IGBT's are arranged in a common collector configuration as shown in Fig.4(c). The conduction losses are the same as the common emitter arrangement, since only two devices are involved in the conduction path of the current.

It should be pointed out that the development of semiconductor device technology influences the properties (switching frequency, voltage blocking capability, voltage and power ratings, etc.) of the converters. Fast power switches are desirable as the volume of filters may be reduced by increasing the frequency. The development of novel semiconductor devices such as SiC (silicon carbide) or GaN (gallium nitride) switches can potentially improve the converter performance.

4. SVPWM (Space Vector Pulse Width 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 SVM used to drive Three Phase AC powered motors at varying speeds. Basic use of SVM is in three phase inverter. But here indirect SVM algorithm is used with 3-Φ MC, so here two conversion stages is used in algorithm, first one is rectifier stage and second one is inverter stage which can be shown in fig.3. In both stages SVM is used. SVM is different from the PWM methods because, With the other PWM technique the inverter can thought of as three separate push pull driver stages, creating the three phase waveform separately. But in SVM treats the inverter as a single unit. It drives the inverter through eight unique states shown below table.1

Modulation is achieved by switching states of (rectifier/inverter). SVM is a digital modulation technique. It generates the PWM line Voltages (applied to load) in such a way that they are in average equal to a given or reference load line voltage. This is done in each sampling period by selecting the switching states of the (rectifier/inverter) properly and calculating the time period of each state. The state selection and calculation for the state time periods is achieved by the space vector transformation. The SV corresponding to the adjacement states are 60° displaced with respect to each other. No SV are produced corresponding to seventh and eight states.

Space vector		Switching state	On Switches
Zero vector	V_0	000	s22,s44,s66
Active vector	V_1	100	s11,s44,s66
	V_2	110	s11,s33,s66
	V_3	010	s22,s33,s66
	V_4	011	s22,s33,s55
	V_5	001	s22,s44,s66
	V_6	101	s11,s44,s55
Zero vector	V_7	111	s11,s33,s55

Table -1: Switching state vectors

This modulation is based on transforming the input and output quantities into the space vectors. 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 alpha beta (α,β) transformation. It is mathematical transformation employed to simplify the analysis of three-phase circuits. It is also called as a Clarke transformation. Conceptually it is similar to the dq0 transformation**.** The reference vector is then synthesized using a combination of the two adjacent active switching vectors and one or both of the zero vectors. Various strategies of selecting the order of the vectors and which zero vector(s) to use exist. Strategy selection will affect the harmonic content and the switching losses. fig.5(a) shows the abc to alpha beta(α,β) conversion.

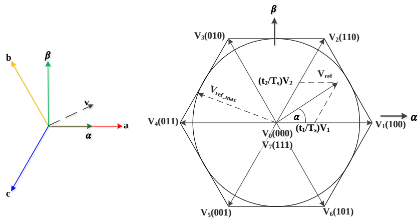

Fig -5: (a) abc to alpha beta conversion (b) space vector hexagon

$$V_\alpha = \sqrt{\tfrac{2}{3}}[V_a - \tfrac{1}{2}V_b - \tfrac{1}{2}V_c] \qquad \ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$V_\beta = \sqrt{\tfrac{2}{3}}[\tfrac{\sqrt{3}}{2}V_b - \tfrac{\sqrt{3}}{2}V_c] \qquad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

The indirect transfer function approaches is employed in both voltage source rectifier (VSR) and voltage source inverter(VSI).

Voltage source rectifier space vector modulation: The VSR input current vector diagram is shown in fig.6(b) the space vector of desired input current can be approximate by two adjacement as shown in fig.6(c)This stage connects virtual dc link to the most positive input line voltage through two switches, one from upper side and one from lower side of the converter. Thus chopping of positive line to line voltages synthesizes the dc link voltage V_{dc}. Same way input currents are synthesized from output dc current I_{dc} as shown in (6).

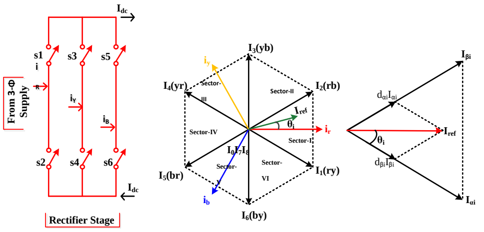

Fig -6: (a) VSR stage of of MC (b) Input current vector diagram in Hexagon form (c) Sector of VSR Hexagon

To avoid open circuit on dc link side, only nine switching combinations are allowed from which six are active vectors I_1 to I_6 and three are zero vectors (I_0 I_7 I_8). These space vectors of VSR are configured in form of hexagon in complex plane as shown in Fig.6(b) Fig.6(c) shows one sector of hexagon in which reference vector Iref lies.

$$\begin{bmatrix} I_r \\ I_y \\ I_b \end{bmatrix} = \begin{bmatrix} s1 & s2 \\ s3 & s4 \\ s5 & s6 \end{bmatrix} \cdot \begin{bmatrix} I_{dc+} \\ I_{dc-} \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots (6)$$

$$\begin{bmatrix} V_{dc+} \\ V_{dc-} \end{bmatrix} = \begin{bmatrix} s1 & s3 & s5 \\ s2 & s4 & s6 \end{bmatrix} \cdot \begin{bmatrix} V_r \\ V_y \\ V_b \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots (7)$$

$\mathbf{I_{ref}}$ is synthesized by impressing the switching vectors $\mathbf{I_{\alpha i}}$ and $\mathbf{I_{\beta i}}$ with duty cycles $\mathbf{d_{\alpha i}}$ and $\mathbf{d_{\beta i}}$ respectively as per the basic theory of SVM. I_{ref} is considered constant during switching period. α_0 indicates the angle of $\mathbf{I_{ref}}$ within sector. $\mathbf{m_i}$ is current modulation index, which in this case is fixed to unity.The duty cycles of the active vectors are given by (8) to (11).

$$I_{ref} = I_{\alpha i} d_{\alpha i} + I_{\beta i} d_{\beta i} \quad \ldots\ldots\ldots\ldots\ldots (8)$$

$$d_{\alpha i} = \frac{T_{\alpha i}}{T_s} = m_i \sin\left(\frac{\pi}{3} - \theta_i\right) \quad \ldots\ldots\ldots\ldots\ldots (9)$$

$$d_{\beta i} = \frac{T_{\beta i}}{T_s} = m_i \sin(\theta_i) \quad \ldots\ldots\ldots\ldots\ldots (10)$$

$$d_{0i} = \frac{T_{0i}}{T_s} = 1 - d_{\alpha i} - d_{\beta i} \quad \ldots\ldots\ldots\ldots\ldots (11)$$

Where $0 \le m_i \le 1, \& m_i = \frac{I_{ref}}{I_{dc}}$.

Voltage source inverter space vector modulation: In this section VSI stage of indirect topology is considered for application of SVM as shown in Fig.7(a) Output of inverter is synthesized from the input dc voltage. Mathematically this can be represented by (12). Same way dc link current $\mathbf{I_{dc}}$ can be obtained by multiplying output currents with switching matrix of inverter as shown in (13).

$$\begin{bmatrix} V_R \\ V_Y \\ V_B \end{bmatrix} = \begin{bmatrix} s11 & s22 \\ s33 & s44 \\ s55 & s66 \end{bmatrix} \cdot \begin{bmatrix} V_{dc+} \\ V_{dc-} \end{bmatrix} \quad \ldots\ldots\ldots\ldots (12)$$

$$\begin{bmatrix} I_{dc+} \\ I_{dc-} \end{bmatrix} = \begin{bmatrix} s11 & s33 & s55 \\ s22 & s44 & s66 \end{bmatrix} \cdot \begin{bmatrix} I_R \\ I_Y \\ I_B \end{bmatrix} \quad \ldots\ldots\ldots (13)$$

Desired output voltages are obtained from the different space vectors. This includes six active vectors namely V_1 to V_6 producing non-zero output voltage and two zero vectors (V_0 and V_7) producing zero output voltage. Only 8 switching combinations are allowed to avoid short circuit in three half bridges of inverter stage. In complex plane, these eight switching space vectors can be configured as a hexagon. Any arbitrary V_{out} can be synthesized by suitable selection of switching space vectors. The radius of inner circle of hexagon represents maximum magnitude of voltage which can be obtained at output of inverter which is 0.866 times the amplitude of the active vectors.

The reference voltage Vref is synthesized by impressing the adjacent active vectors $V_{\alpha v}$ and $V_{\beta v}$ with duty cycles $d_{\alpha v}$ and $d_{\beta v}$ respectively. Mathematically this can be represented by (14). The duty cycles of active vectors are calculated by (14) to (17). Where θ_v is angle of reference voltage vector within sector, m_v is voltage transfer ratio. Where, $0 \le m_v \le 1 \; \& \; m_v = \frac{V_{ref}}{V_{dc}}$.

$$V_{ref} = V_{\alpha v} d_{\alpha v} + V_{\beta v} d_{\beta v} \quad \ldots\ldots\ldots (14)$$

$$d_{\alpha v} = \frac{T_{\alpha v}}{T_s} = m_v \sin\left(\frac{\pi}{2} - \theta_v\right) \quad \ldots\ldots\ldots (15)$$

$$d_{\beta v} = \frac{T_{\beta v}}{T_s} = m_v \sin(\theta_v) \quad \ldots\ldots\ldots (16)$$

$$d_{0v} = \frac{T_{0v}}{T_s} = 1 - d_{\alpha v} - d_{\beta v} \quad \ldots\ldots\ldots (17)$$

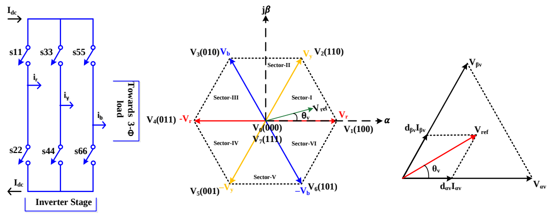

Fig -7: (a) VSI stage of of MC (b) Output voltage vector diagram in Hexagon form (c) Sector of VSI Hexagon

5. SIMMULATION and RESULTS

Simulations are carried out for Induction motor using MATLAB software. The simulation parameters are as follows:

1. Power Supply (line to line Voltage) is 440V/50Hz.
2. Output frequency of converter =50Hz.
3. All switches in MC are ideal.
4. Switching Frequency used=10 KHz.
5. Induction motor = 5hp/440V(phase to phase0,50Hz

The system consists of a 3-Φ MC constructed from 9 back-to-back IGBT switches. The MC is supplied by 440 V,50 Hz 3-Φ source and drives 3-Φ induction Motor. The switching algorithm is based on space-vector modulation described in which considers the MC as a rectifier and inverter connected via a DC link with no energy storage. Indirect space-vector modulation allows direct control of input current and output voltage. The switching algorithm utilizes a symmetric switching sequence. In open loop control system output of motor can be directly measured and observe through scope. In closed loop system the output of motor is given to the control circuit as a feed back as shown in fig.9

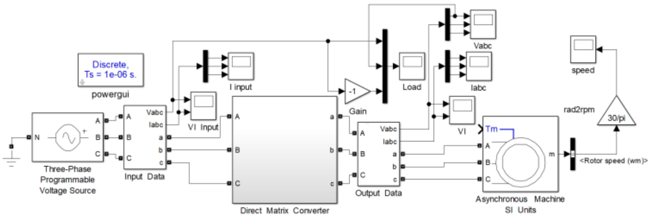

Fig -8: 3-Φ IM faded 3-Φ to 3-Φ DMC with Open Loop

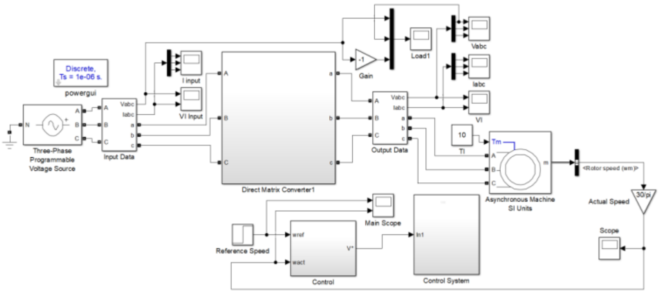

Fig -9: 3-Φ IM Faded 3-Φ to 3-Φ DMC with Closed Loop

Fig.10 shows the control circuit of the speed control of motor where two input signal is taken. Reference speed and actual speed of motor and compare both speed and give the output signal to the PI(proportional integral) controller. The PI Controller is a simple way to achieve a robust and fast responding closed loop system. By adjusting two parameters he drive can quickly respond to errors between the reference speed and actual speed while also eliminating any long term error in the system. This allows the motor to achieve precise speed control of the motor. Saturation block is used to limit input signal to the upper and lower saturation values. Sine wave is generated for sinusoidal reference input signal which helps in maintaining the input power factor unity. Output of the control circuit is given to the SVPWM control circuit of matrix converter as a input signal.

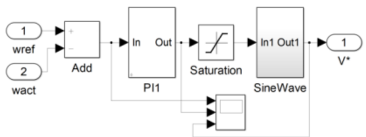

Fig -10: Control circuit of Speed Control of Induction Motor

MC consists of nine bi-directional sectors with reverse blocking capability, arranged as three sets of three so that any of the three input phases can be connected to any of the three output lines, as shown in Fig.11(a). A bi-directional 36 diodes is used for blocking the voltage in MC. Fig.11(b) shows the internal arrangement of bidirectional switch where four diode and one IGBT is used.

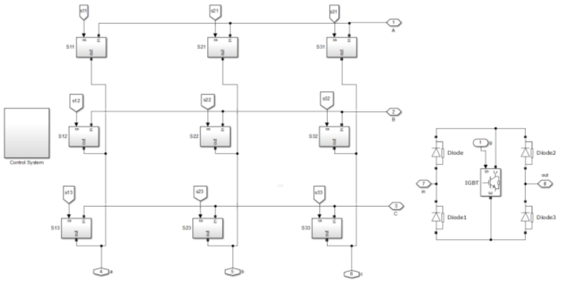

Fig -11 (a) 3-Φ to 3-Φ DMC

The MC switching generation signal combination with the SVM rectification sequence and the combinations from 1 to 9 which are the sectors (v0-v1-v2-v3-v4-v5-v6-v7-v8) are used as a gate signal of the IGBT transistor as can be shown in the fig.12. The first 6 states can be constructed from the current mode (qR) and the other 6 state as constructed from the voltage mode circuit (ql). The combinations of these 12 signals are used to construct the SVM used to control the MC. Where in g is the output angle in the SVM rectification system to generate left (gl) and right (gR) axis of the sector when the voltage and current mode acts as the inputs to the circuits.

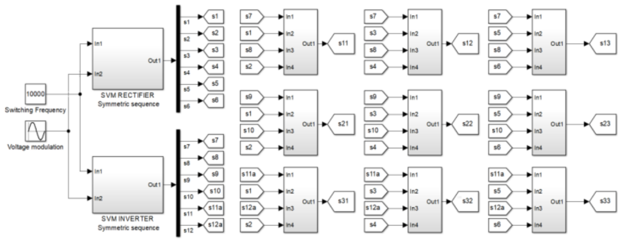

Fig -12: Switching signal construction

The symmetric sequence unit used the current mod as the input to generate (v1-v2-v0) as shown in Fig.13.

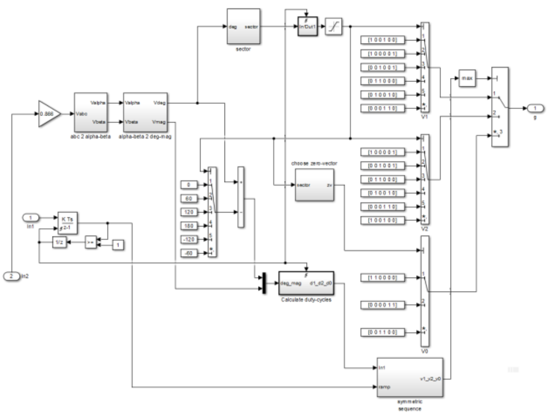

Fig -13: MC SVM symmetric switching for Rectifier

Inversion matrix sequence of the SVM modulation when the voltage mod input to generate (v1-v2-v7- v8) with the switching pattern is constructed as in the Fig.14

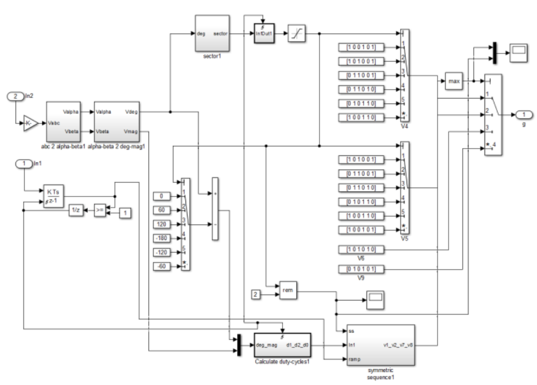

Fig -14: MC SVM symmetric switching for Inverter

Figure.15 is simmulink implementation of Equation (4.1) and (4.2) for the voltage reference alone. It is the transformation of the voltage Vabc to αβ co-ordinate. The same applies for the transformation of the current reference to αβ frame.

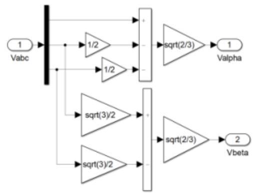

Fig -15: ABC to Alpha Beta Conversion

Eqn (5.3) and (5.4) shows the simulated conversion of Alpha and beta (αβ,) to magnitude and degree

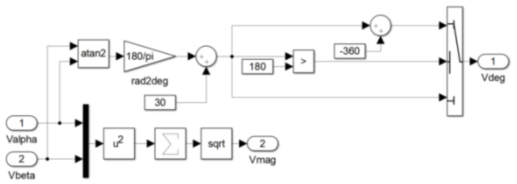

Fig -16: Alpha Beta to Degree and Magnitude Conversion

$$V_{mag} = \sqrt{\left((V_\alpha)^2 + (V_\beta)^2\right)} \qquad \ldots\ldots\ldots\ldots(18)$$

$$V_{deg} = a\tan 2\left(\frac{V_\beta}{V_\alpha}\right) \qquad \ldots\ldots\ldots\ldots(19)$$

Figure 17. Shows the sector identification of the voltage space vector from the angle Vdeg. Based on the current and voltage sector, this block determines which set of vectors are to be Applied and shows how the vectors to be applied are identified.

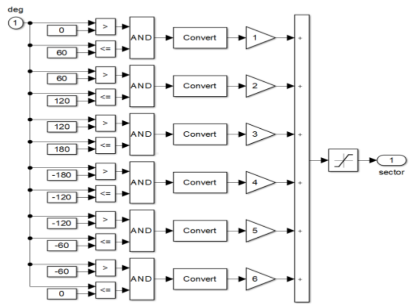

Fig -17: Sector Identification

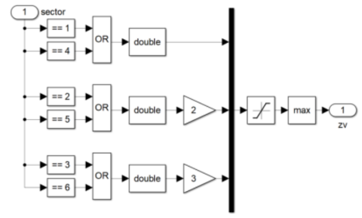

Fig -18: Zero Vector implementation

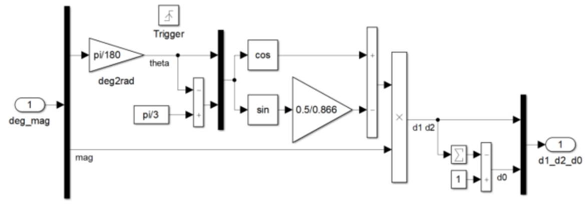

Fig -19: Simulink implementation of duty cycle calculation

Eqn (20) and (21) shows the simulated implementation of duty cycle calculation

$$d_1\_d_2 = \left(\cos(v) - \left(\tfrac{\pi}{3} - v\right)\sin\left(\tfrac{0.5}{0.866}\right)\right) * |v| \ \ldots (20)$$

$$d_0 = 1 - \sum d_1\_d_2 \qquad \ldots\ldots\ldots\ldots\ldots (21)$$

5.1 Results

For the motor the simulation is being done in 2.0 second for speed and for output current and voltage of MC with motor connected as a load simulation is done in 0.25 second.

5.1.1 For open loop:

Fig.20 shows the input voltage fed to the MC and the equivalent current drawn by the MC from input supply. As it is clear from the current waveform that during transient period which lasts around 10ms current is bit high which attains constant value at steady state.

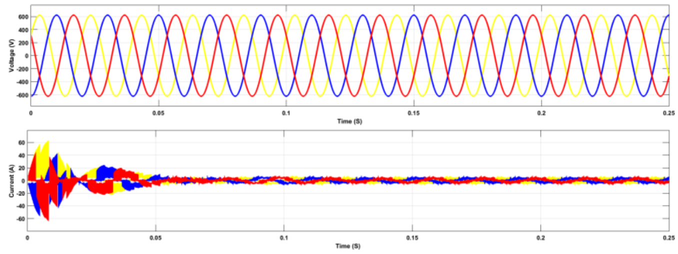

Fig -20: Input voltage and input current of MC for motor

Fig.21 shows the three phase voltage available at the output of MC be fed to the Induction Motor. This are the individual per phase output voltage of MC.

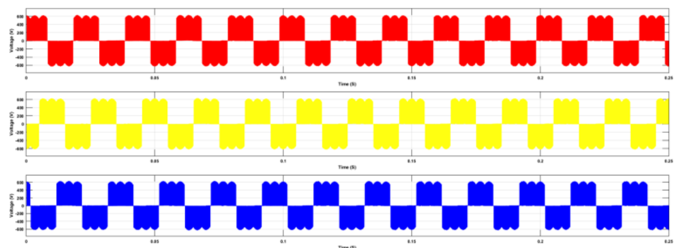

Fig -21: 3-Φ Output voltage of MC for motor

Fig.22 shows the three phase current waveform at the output of terminals of MC. During the transient period output current is unstable, and it will be stable with constant value at steady sate.

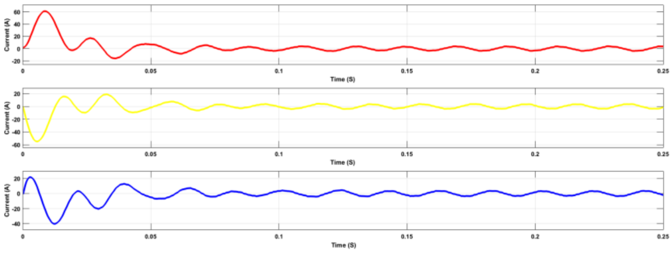

Fig -22: Individual per phase Output current of MC for motor

Fig.23 shows the output voltage and output current for three phases of MC.

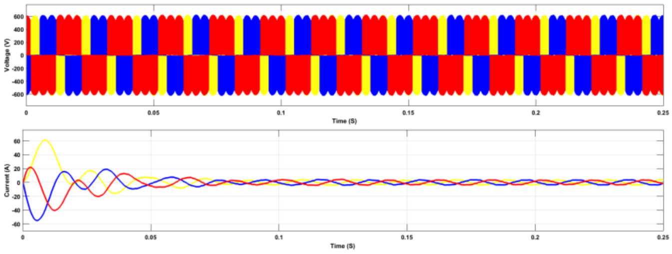

Fig -23: Output voltage and Output current of MC for motor

Fig.24 shows the comparison between the input and output voltage.

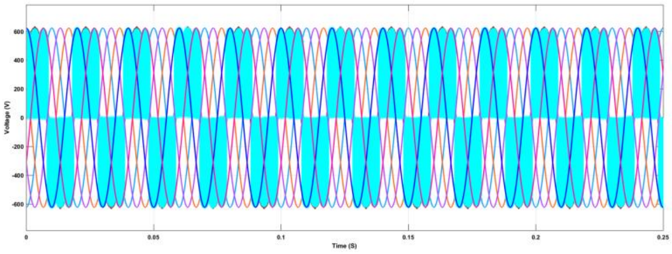

Fig -24: Output voltage of MC for motor

Fig.25 shows the speed of the induction motor. Here in fig.25 shows, for a few time the speed of motor can be unbalanced. At the starting the speed of motor is decreasing below 1300 rpm and then rapidly increasing above 1550 rpm then after some time speed of motor will be balanced near to 1500 rpm. By proper controlling of the MC the speed of the induction motor can be controlled

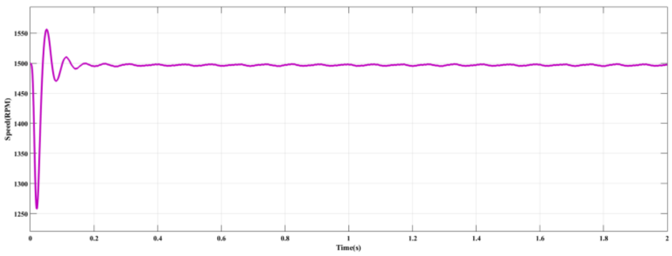

Figure.25 Speed of three phase induction motor

5.1.2 For Closed loop:

Fig.26 shows the input voltage fed to the MC and the equivalent current drawn by the MC from input supply. As it is clear from the current waveform that during transient period which lasts around 10ms current is bit high which attains constant value at steady state.

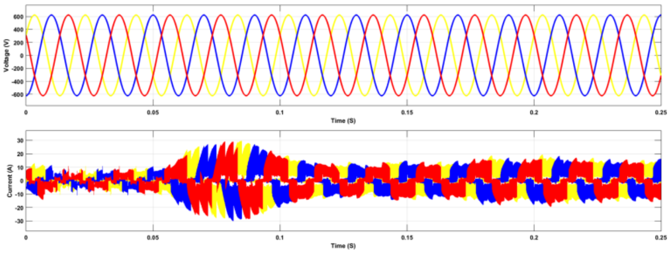

Figure.26 Input voltage and input current of MC for motor

Fig. 27 shows the three phase voltage available at the output of MC to be fed to the Induction Motor.

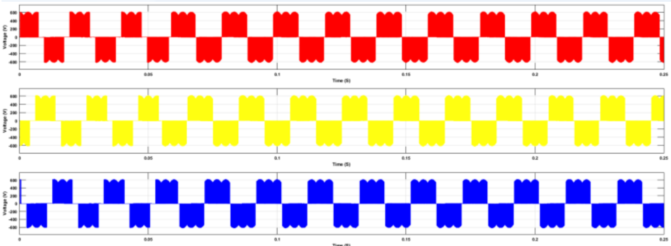

Figure -27: 3-Φ Output voltage of MC for motor

Fig.28 shows the three phase current waveform at the output of terminals of MC. During the transient period output current is unstable, and it will be stable with constant value at steady sate.

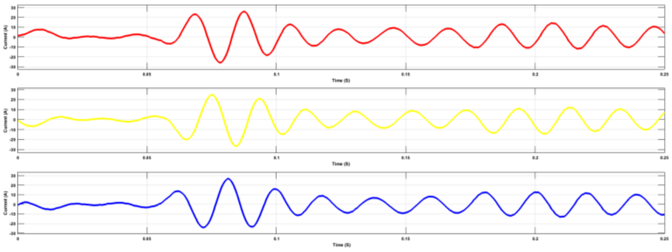

Figure -28: Output Current of MC for Motor

Fig.29 shows the output voltage and output current for three phases of MC. The output voltage and current waveforms were observed for a induction motor.

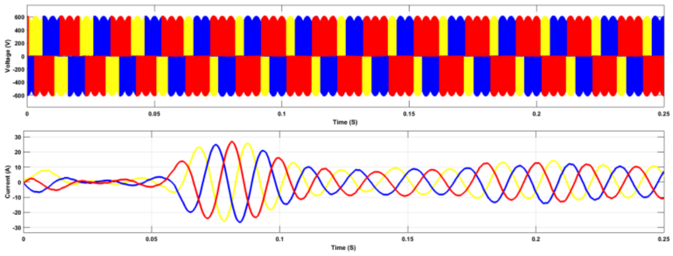

Figure.29 Output voltage and Output current of MC for motor

Fig.30 shows the three phase voltage available at the input and output of MC to be fed to the stator of Induction Motor. This is the comparison of input and output voltage of MC.

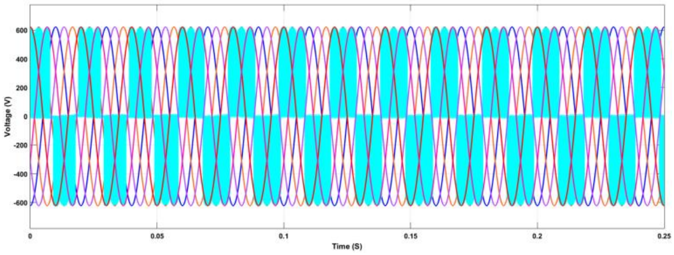

Figure.30 Intput voltage and Output Voltage of MC for motor

Fig.31 shows the speed of the induction motor. Here two speeds are shown, one is reference speed and other one is actual speed of motor. So by comparing two speeds we can show the how the actual speed is near to the reference speed. proper controlling of the matrix converter the speed of the induction motor can be controlled.

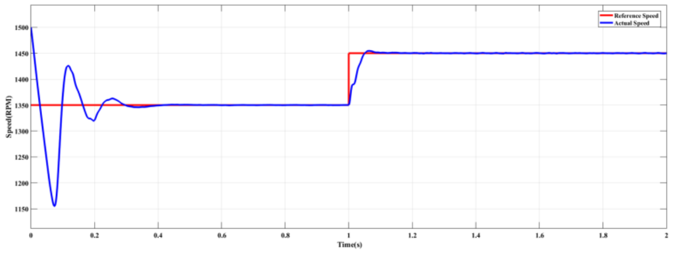

Figure.31 speed of Motor

6. FFT ANALYSIS

Here THD(FFT) analysis is done for the output current of matrix converter faded induction motor for open loop and closed loop system. output current waveform and THD when the frequency of output voltage waveform is 50 Hz and PWM frequency is 10000 Hz:

For Open Loop

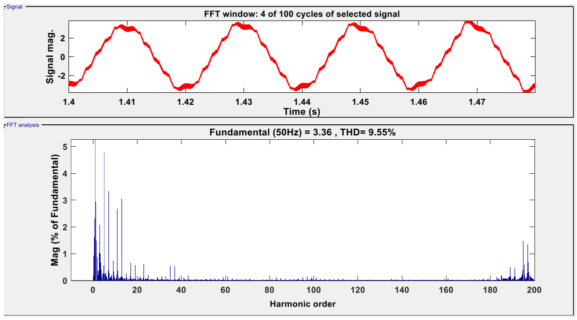

Figure.5.31 THD Analysis of s Converter for open loop

For Closed Loop

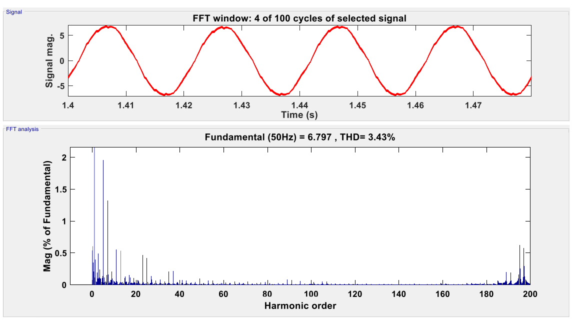

Figure -5.32: THD Analysis of MC for Closed loop

THD in output current for open loop is 9.55% which is not affordable for good operation as per IEEE standard and for Closed loop THD is 3.43 which can be affordable for good operation as per IEE standard. it can further be improved using an appropriate filter.

6. CONCLUSION

The Simulation results of Three phase matrix Converter proves that it can be operated as traditional power converter. The combination of IGBT and diode is used as a bi-directional switch. The output voltage wave forms shown for 3-Φ to 3-Φ DMC for 3-Φ Induction motor with open loop and closed loop system. From the detailed observation it is well known that Matrix Converter can avoid the need of other conventional converters topologies in future. Three phase MC have better output as compare to cyclo converter and harmonics also can be less as compare to other converter topologies. These converters are highly applicable for adjustable speed drives or variable frequency drives because of variable desired frequency can be attained. Secondly, any desired output voltage can be achieved. Therefore, interconnected systems can be free of synchronization issues by employing these converters. The multi-operation of SVPWM based three phase AC to three phase AC system is simulated in MATLAB/Simulink 2016 software and the results proves the performance of the 3-Φ to 3-Φ MC.

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