Study of Closed Loop Control for AC Motor Using Matrix Converter: A Review

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***Abstract*—Considering the wide applications of motors in various applications in diversified field, it has become necessary to have proper control to fulfil the necessary task. Also different applications have different requirement in terms of voltage, current and power and at the same time to improve its performance, the parameters such as total harmonics distortion (THD), ripples, losses are to be controlled. So in case of AC-AC conversion, to minimise the conversion stages, matrix converters are becoming more popular for closed loop control for ac motors. Also with proper switching of devices in matrix converter, could improve the quality of output by the application of appropriate PWM technique. This paper reviews the different closed loop control strategies used in AC motor as well as the application of matrix converters with appropriate PWM control.**

***Index Terms*—Matrix converter, closed loop control, PWM technique.**

INTRODUCTION

AS various industrial applications which require signals with different amplitude, frequency or phase, ac to ac power conversion plays a very vital role. In such system ac to ac converter take power from one system and feds to another ac system as per the required parameters such converters could be classified as direct or indirect converters. Direct converters are preferably used. Direct converters could be classified into three types i.e. AC controller, cycloconverters and matrix converter out of these three topologies matrix converter is the most versatile converter as it reduces the number of conversion stages. The other advantages of matrix converters are,

- They provide sinusoidal input and output waveforms with reduced higher order harmonics
- Have capability of bidirectional energy flow with power factor control
- Eliminates the used of bulky capacitors.

Considering the advantages of matrix converter this research paper reviews the work done by different researchers in the area of matrix converter with closed loop control. Based on the review a conclusion has been made at the end for carrying out the work on matrix in further direction.

I. CONVERTER SYSTEM FOR AC DRIVES

As stated earlier there are three types of converters out of which matrix converter is the most suitable type of converter which could be applicable for ac drive applications. Considering the scope of matrix converter for ac drive applications various research paper are reviewed based on which the following study has been put up.As stated in [1], a three phase matrix converter consisting of 3×3 switches arrangement with bidirectional switching has been considered which is simulated using closed loop control.

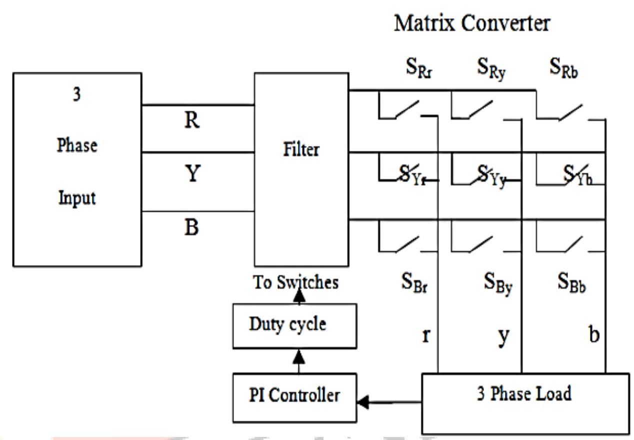


Fig. 1.Closed loop circuit scheme of 3 phase to 3 phase matrix converter.

As shown in fig. 1 the matrix converter is considered with a closed loop system consisting of PI controller. The PI controller has been implemented with mathmatical modeling which includes modeling of power circuit, switching algorithm, load and controller. Thus by adjusting the duty ratio with the use of PI controller the switching performance of matrix converter has been improved in case of RL load. As stated in paper the simulation results are obtained for a reference current of 7 ampere and amplitude of 325 volt with time limit 0.1 msec. Based on the parameters selected the output is realised with three phase passive RL load considering R = 10 Ω and L= 20mH. The output obtained is fed back to matrix converter through PI controller to achieve real time control. The following waveforms are obtained for various parameters such as duty cycle, output voltage, output current for each phase as well as total THD has also been obtained. The waveforms for duty cycle of per phase has been shown in fig.2 and the output current and voltage per phase as shown in fig.3(a)(b).

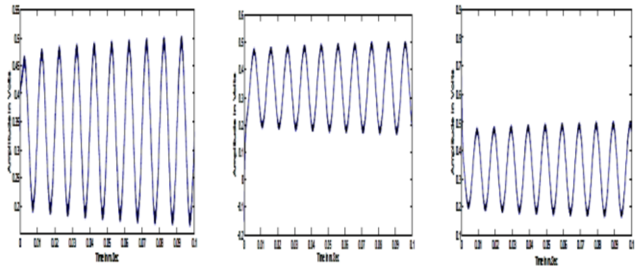
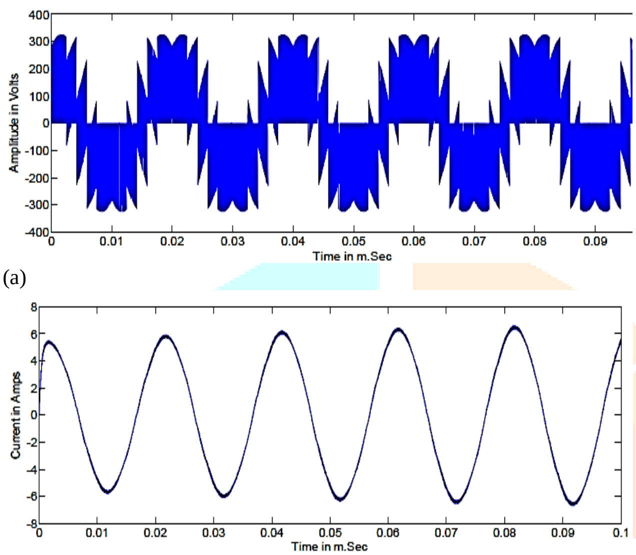


Fig.2. Duty cycle for MRr, MYr, MBr Phases.



(b)

Fig.3. (a)Output Voltage waveform for 'r' Phase, (b) Output Current waveform for'r' Phase.

As per the conclusion, the mathematical modeling and implementation of closed loop PI controller for 3×3 phase power conversion using matrix converter has been successfully done. PI controller was able to control the output of the converter in real time with less computational time.

To study and analyse any type of closed loop control system it is necessary to verify the starting transient, dynamic response and steady state performance which could make the system stable. As mentioned in the research paper [2] a complete dynamic model as shown in fig4 and a new approach of steady state analysis for ac to ac matrix converter fed induction motor has been performed and analysed.

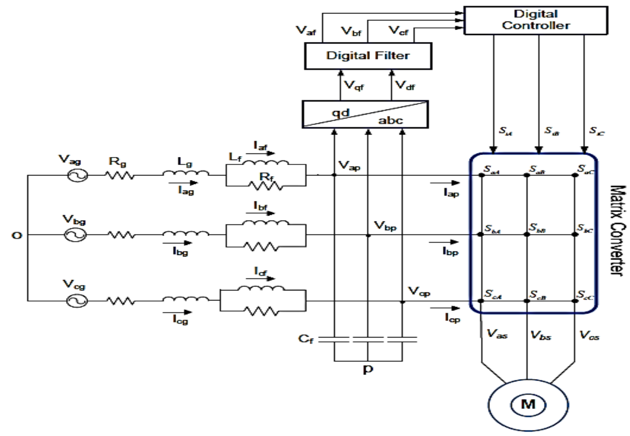


Fig. 4. AC–AC Matrix Converter fed Induction Motor

As stated in the paper for obtaining the transient and dynamic response of the complete system, a dynamic model is considered. This dynamic model consist of input filter, matrix converter fed induction motor, digital controller with a balanced three phase source. Considering the dynamic three phase model equations 1, 2 and 3 are being obtained which includes equation for balance three phase source, filter current and shunt capacitor voltage.

$$V_{abcg}=R_g I_{abcg}+L_g p I_{abcg}+R_f(I_{abcg}-I_{abc})+V_{abcp} \quad (1)$$

$$L_f\, p\, I_{abcf} = R_f\ (I_{abcg} - I_{abcf}) \quad (2)$$

$$C_f\, p V_{abcp} = I_{abcg} - I_{abcp} (3)$$

Where, V_{abcp} – Shunt capacitor voltage

I_{abcf} – Filter current

I_{abcp}- Input current of matrix converter

V_{abcg} – Source voltage

For improving the duty ratio a digital controller model is considered whose input is given through a digital filter with a closed loop. A small signal analysis for the model has also been done to determine the stability limit under constant v/f operation.The dynamic model has simulated for obtaining the transient and dynamic response of the system. Fig. 4 shows the transient and dynamic response of the rotor speed and electromagnetic torque.

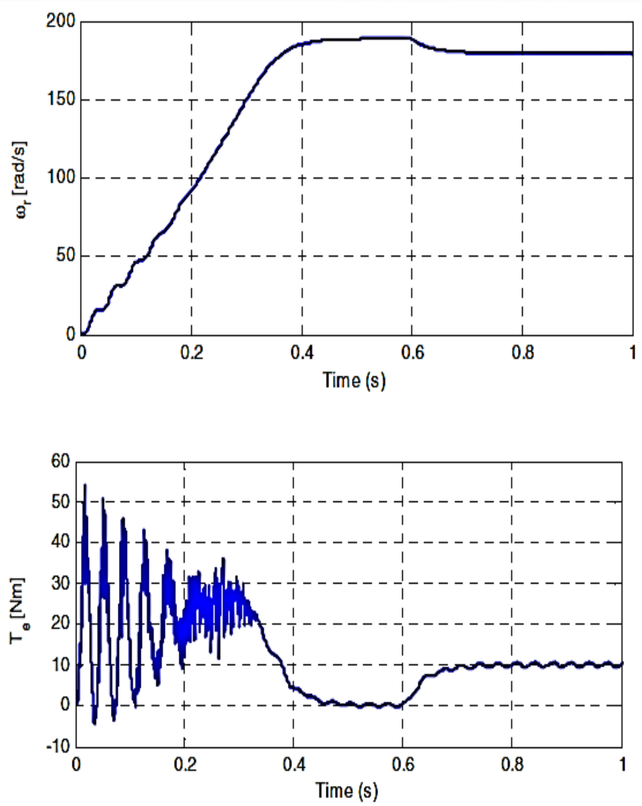


Fig.4. Starting transient and dynamic response of rotor speed and electromagnetic torque.

As per the characteristics shown above, at starting the motor experiences high electromagnetic torque with rising motor speed until and unless both the parameters reach to a steady state values.

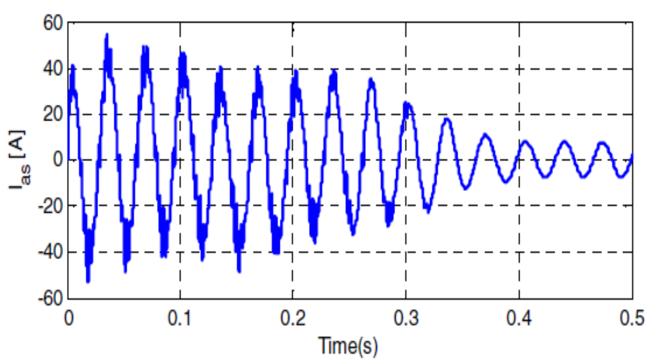


Fig.5 Starting transient of phase 'a' stator current

Also as shown in fig 5 the stator draws a very high current initially and tries to get stable after certain time. As per the selection of various parameters such as source parameters, filter parameters and induction motor parameters the results are obtained which shows the starting transient and dynamic response to a sudden change of load during steady state operation. The simulation of dynamic model clearly differentiates the stable and unstable operations when the drive system is operated under constant v/f operation.

For improving the output waveform or signal under loading condition it is necessary to control the matrix converter in such a way that it should be able to lower the THD values to improve the output voltage and current. For this purpose various types of modulation techniques may be implemented and tested. The research paper[3] focuses on utilization of various modulation techniques such as pulse width modulation (PWM), sinusoidal pulse width modulation(SPWM) and space vector pulse width modulation(SVPWM) for improving the performance of matrix converter. A MATLAB/Simulink model as shown in Fig. 7 has been considered.

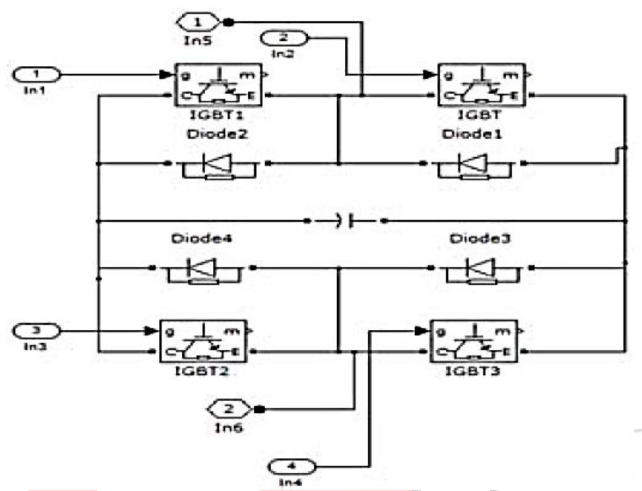


Fig.7. Simulink diagram of H-Bridge Switch Cell with Capacitor

It consists of nine modular H-bridge capacitor clamp switch connected to each phase. This converter has been tested by considering PWM and SVPWM technique. The results for voltage and current obtained by considering various parameters such as input voltage=480v, input current=27Amp, supply frequency= 50Hz and switching frequency= 2 kHz.

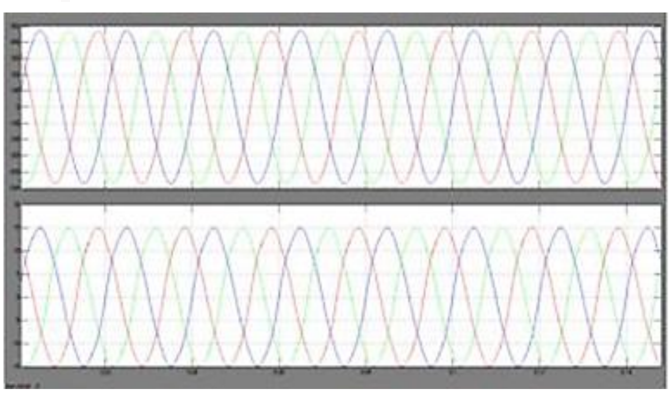


Fig.8.Output Voltage and Current Waveform of Matrix Converter using PWM Technique

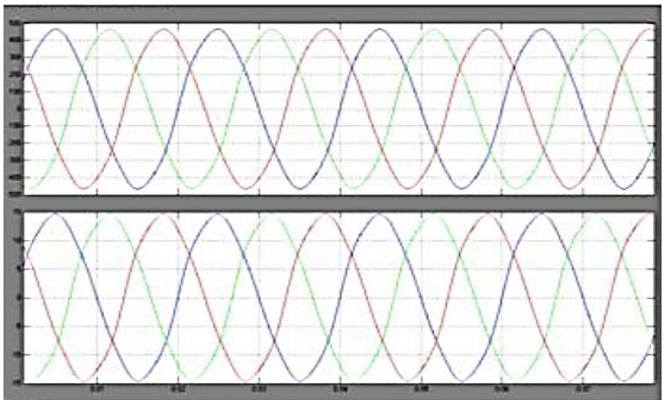


Fig.9 Output Voltage and Current Waveform of Matrix Converter using SVPWM Technique

Fig. 8 shows output voltage and current for matrix converter using PWM technique and fig.9 shows the output voltage and current waveform using SVPWM technique with RL load. As per theperformance of both the techniques the results of THD values was nearly reduced to half after considering SVPWM. Thus this research paper compares the PWM technique for matrix converters were the results shows that SVPWM technique is superior to other modulation technique.

In addition to lowering the THD values and improving the output and input current waveform, it is also necessary to maintain the power factor near to unity which improves the power quality. This research paper [4] concentrates on utilizing combination of two PWM techniques i.e. Generalized Scalar Pulse Width Modulation (GSPWM) and Space Vector Pulse Width Modulation (SPWM) for single switch in a three phase induction motor fed matrix converter. To make the power factor unity the rectifier side of direct matrix converter is controlled using GSPWM. This PWM technique also reduced the switching losses. As shown in fig. 10 the switch of induction motor fed matrix converter is controlled by the combination of two pulses. First pulse is obtained through GSPWM and other is obtained using SVPWM.

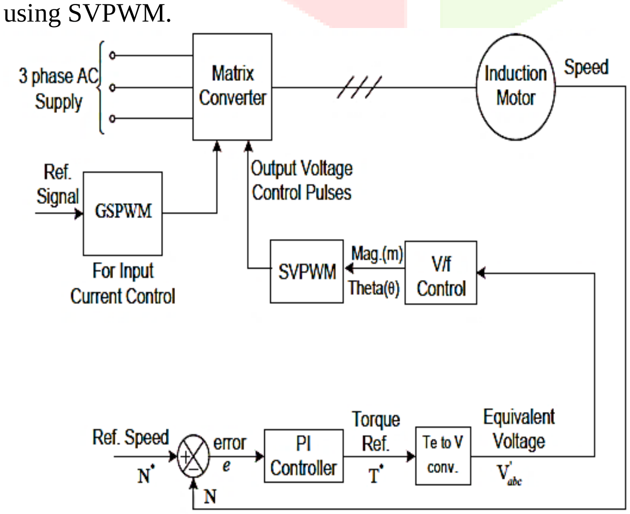


Fig.10. Proposed Model for speed control of Induction motor

The control pulse obtained from SVPWM is generated by considering the reference speed from induction motor. The speed of induction motor is always compared with the reference speed to generate an error which is input for PI controller. The PI controller sets the reference torque and generates an equivalent voltage which isapplied to v/f control. The output of v/f control is given to SVPWM for generating the control pulses. The second pulse is directly generated by considering sinusoidal reference input for maintaining the power factor. The matlab model was simulated by considering certain parameters for induction motor and the output was analysed. Fig.11 and 12 shows the three phase voltage and current also Fig. 13 shows the input power factor for the matrix converter connected to the induction motor.

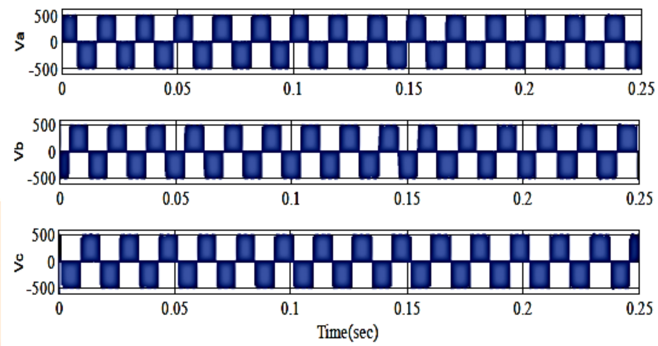


Fig.11. Voltage at the output of matrix converter fed to the stator

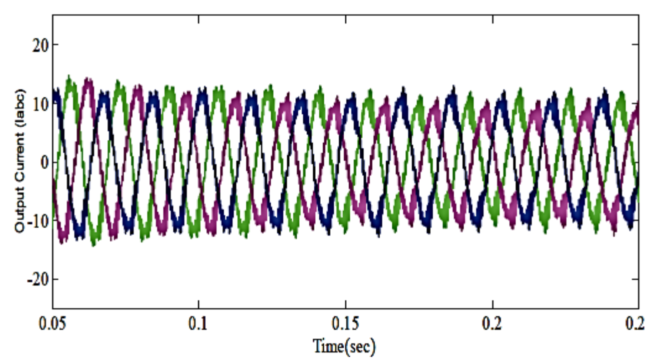


Fig. 12. Output current of matrix converter

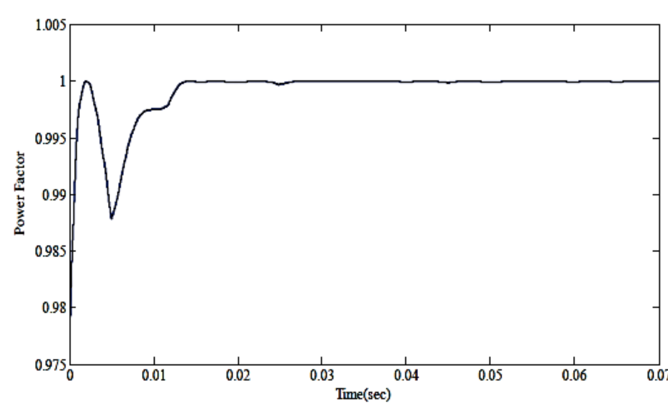


Fig. 13. Input Power Factor

As per the output voltage and current of matrix converter, the induction motor parameters were analysed such as motor speed, stator voltage and electromagnetic torque. It has been observed that the v/f ratio was almost constant which gives the improved performance of induction motor. FFT analyses for the model has been carried out and it is observed that the THD values is at an acceptable range. It is also observed that the power factor value is maintained at almost unity.

II. CONCLUSION

As per the various paper reviewed, the first paper concentrates on PI control based close loop system used in induction motor fed matrix converter. As per the paper the performance of induction motor could be improve by improving the switching instants. In the second paper the author has tried to perform stability analysis for a closed loop induction motor fed matrix converter. The result of this paper shows that the transient and dynamic responses could be obtained which could be used to improve the performance of the system. The third paper has highlighted various types of modulation techniques used for generating controlling pulses for matrix converters. After considering PWM, SPWM & SVPWM, as per the author the SVPWM technique is much better as compare to other technique. While considering the output parameters it is also necessary to maintain the input power factor near to unity, in paper 4 the author has successfully modeled the induction motor fed matrix converter with closed loop system, in which two modulation techniques have been considered for one switch. Out of these two modulation technique one is used for maintaining unity power factor and other for improving the output signal under loading condition.

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