Current Control of the Matrix Converter Fed Induction Motor Drive

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Abstract— This paper deals with the designed method of realization of rotor flux oriented control of the induction machine fed by matrix converter with current control. Matrix converter belongs to the category of direct frequency converters that produce output voltage by means of direct switching of proper input phase voltage to the output. This fact can introduce some problems into control algorithm compared to drive fed by conventional voltage source inverter.

1. INTRODUCTION

The induction machines (IM) are mostly used as electro-mechanical converters in area of controlled electric drives. Their application is advantageous because they are durable, robust and they do not need much maintenance. However their control is more difficult compared to DC machines or permanent magnet synchronous machines. In order to reach high dynamic of the drive the input command for the converter feeding IM have to be required current or voltage vector which application on terminals of the IM will produce desired flux and torque of the IM. This requirement can be reached by splitting IM control into two separate loops [1]. One control loop is responsible for flux production and the second one is responsible for torque production. The demanded vector is then vector combination of both components obtained from control loops.

Several control algorithms are known that offer possibility of separate control of torque and flux current components. To them belongs Field Oriented Control (FOC) or Direct Torque Control (DTC). Most of them needs for their operation information about hardly measurable inner motor values like electromagnetic flux and torque. To estimate these values, models of the machines are used.

2. MATRIX CONVERTER

Matrix converter (MC) does not contain a DC-link in its power circuit and thus is less voluminous compared to indirect frequency converters. It makes converter suitable for applications, where the weight of the device is more important than its price and where the increased reliability is required, too. The fact that output voltage is produced by direct switching of the proper input voltage to the output terminals sets limit of maximal output voltage amplitude to 86.6% of the input voltage amplitude without overmodulation. This can be quite disadvantageous especially in controlled drives where field weakening have to start earlier compared to indirect frequency converters. In contrast, this way of conversion offers abilities as the input power factor control and the possibility to work in all four quadrants [2, 3].

There are many modulation strategies for the MC, however, recently direct space vector or indirect space vector modulations are the most employed ones. The ISVM method is based on partitioning of the converter virtually into two parts according to the function that they perform. The MC can be then taken as a junction of virtual current source rectifier and virtual voltage source inverter with virtual DC link inserted between them. The virtual inverter then generates output voltage in the same way as VSI. The virtual rectifier directs output current to input phases to consume sinusoidal currents with defined power factor [3–5]. The switched voltage vectors are selected from space vectors available for both parts (Fig. 1). However, the special behavior of the input and output of the converter have to be respected during transistor switching. Because the input of the matrix converter is kind of voltage source, therefore in every switching moment none of the input phases shall be shortcircuited. Similarly the load connected to the output of the converter has mostly inductive character, therefore any of the converter output phases cannot be disconnected.

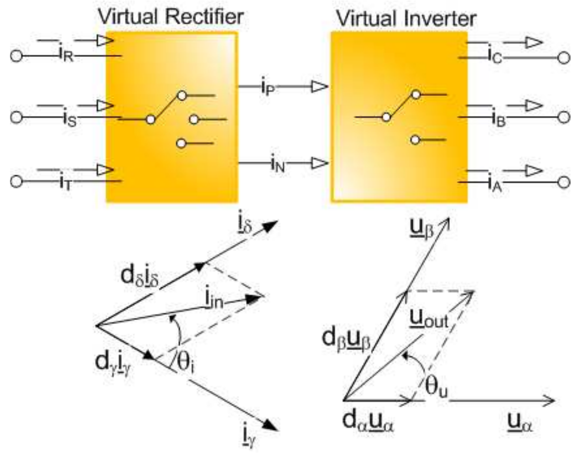

Figure 1: Matrix converter virtual DC link representation.

Duty times for both parts are calculated as

$$\begin{aligned} d_\alpha &= m_I \sin\left(\frac{\pi}{3} - \theta_U\right) \\ d_\beta &= m_I \sin(\theta_U) \\ d_0 &= 1 - d_\alpha - d_\beta \end{aligned} \tag{1}$$

$$\begin{aligned} d_\gamma &= m_R \sin\left(\frac{\pi}{3} - \theta_I\right) \\ d_\delta &= m_R \sin(\theta_I) \\ d_0 &= 1 - d_\gamma - d_\delta \end{aligned} \tag{2}$$

Duty times of one modulation step are then calculated as combination of (1) and (2)

$$\begin{aligned} d_{\alpha\gamma} &= m_R m_I \sin\left(\frac{\pi}{3} - \Theta_I\right) \sin\left(\frac{\pi}{3} - \Theta_R\right) \\ d_{\alpha\delta} &= m_R m_I \sin\left(\frac{\pi}{3} - \Theta_I\right) \sin(\Theta_R) \\ d_{\beta\gamma} &= m_R m_I \sin(\Theta_I) \sin\left(\frac{\pi}{3} - \Theta_R\right) \\ d_{\beta\delta} &= m_R m_I \sin\left(\frac{\pi}{3} - \Theta_I\right) \sin(\Theta_R) \end{aligned} \tag{3}$$

3. MATRIX CONVERTER INDUCTION MOTOR DRIVE

Advantages of the induction machine as the electro-mechanical converter in modern drive can't be questioned, however, its control is more complicated and requires control algorithms based on separate control of the flux and torque. Field oriented control strategies are well known for this purposes. They use voltage as a controlled quantity. Although current feeding of the IM is also possible (Fig. 2).

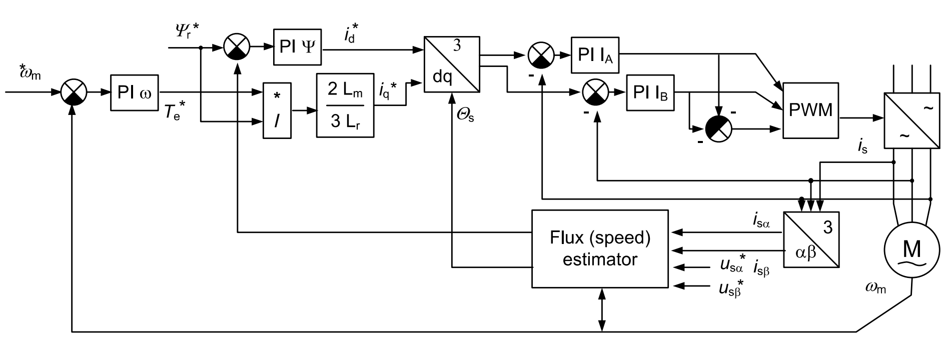

Figure 2: PWM control structure.

Problem of current source inverters (CSI) is that compared to voltage source inverters (VSI), CSI has to be designed for exact motor. That is why also methods how to replace CSI by VSI with current control were developed. The inverter then requires closed loop control with feedback directly from AC output currents. That is why the currents have to have wide bandwidth from nearly zero frequency up to carrier frequency. Usually two current sensors are enough because without connected neutral point the third current of IM is to be added to zero. Moreover, this solution avoids zero sequence component errors. The output of the converter then looks different to CSI output. It has waveform of the reference current with superimposed PWM ripple. Form this point of view such controller should have several differences:

- it requires reference signals in actual time domain,
- harmonics content can be reduced with increase of PWM frequency,
- current controllers have to operate with AC signals instead of DC,
- the precision is higher because the controllers has not to work in dynamic operation,
- the higher accuracy of the field orientation is reached.

Figure 3 shows reactions of the flux and speed controllers on changes in reference values. Responses of the flux controller are depicted in the Fig. 3. It is obvious, that actual value of the IM

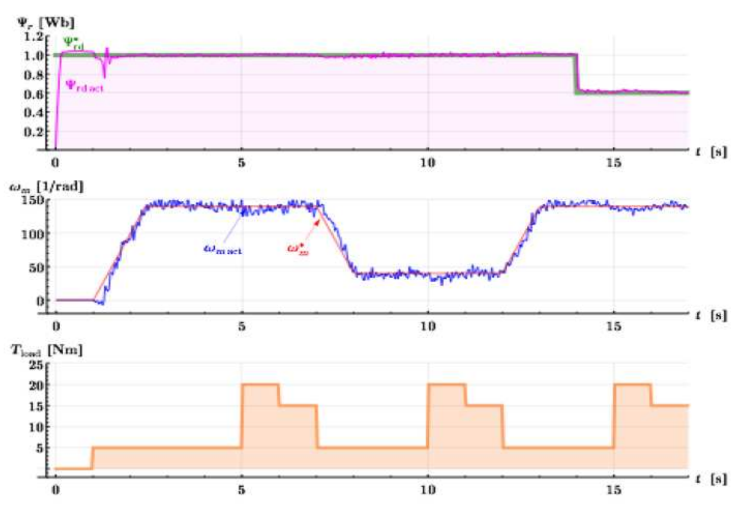

Figure 3: PWM control — speed and flux.

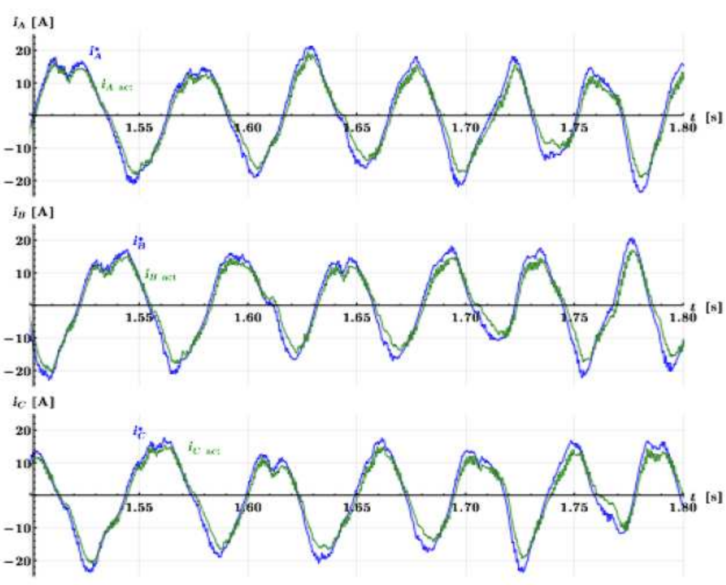

Figure 4: PWM control — required and actual current.

flux (green) tracks required value (magenta) very well. Small errors during speed and load torque transitions are caused by behaviour of current P-controllers. Speed controller reactions show that required speed of the drive is satisfactorily held.

Figure 4 shows behaviour of the particular current controllers. Because the input signals are AC quantities only, proportional controllers fit this application.

4. SUMMARY

The current based control strategy for the induction machine and matrix converter has been presented. Results show that both flux and speed of the IM are controlled with good accuracy. The P controllers enable to replace the CSI by voltage source converter control currents. It has been also shown that with proper modulation strategy matrix converter can be treated as conventional VSI.

ACKNOWLEDGMENT

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