SIMULATION AND PERFORMANCE OF TWO PHASE INDUCTION MOTOR DRIVE USING MATRIX CONVERTER

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Abstract: This paper investigates two phase induction motor drives with using matrix converter topology. The aim is to reach a set of switches that can produce two phase voltage and current in order to be used in an induction motor. Since it is important to have a desired frequency for motor operation then this task can be achieved using matrix converter. Performance of Two Phase induction motor for 50 Hz frequency is better as compared to one third and three times the fundamental frequency. The proposed strategy can generate the two-phase output voltages/currents where the magnitudes are controlled, and the phase difference is fixed at 90°. Simulation result for two-phase induction motor produced and presented.

Keywords: Two-phase induction motor, Matrix converter, Switching

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INTRODUCTION

Two-phase Induction motors have a lot of applications in technology [2]. Two-phase induction motors are driven by converter-inverter systems. The converter-inverter circuit, however, requires the smoothing capacitors. The smoothing capacitors are degraded by the environmental temperature and affect the lifetime of the motor drive systems. AC-AC converters has many applications in induction motor drives [1-2]. These converters are becoming popular due to the availability of better switching devices.

Asymmetrical and symmetrical two-phase induction motors fed by single-phase supply have been widely used in small power applications [3-4]. Symmetrical induction motors is a two-phase machine, since its windings are displaced ninety degrees apart from each other. A novel single to two-phase matrix converter (iS2MC) for driving a symmetrical two phase induction motor at 50Hz is proposed in this paper [6]. We show the control algorithm of bidirectional switches in the Two Phase Matrix converter. Simulations prove the effectiveness of the two phase matrix converter system [7-8].

b. II. TWOPHASEINDUCTIONMOTOR

The two phase induction motor category is divided into type 1) Symmetrical Motor 2) Asymmetrical Motor. In this proposed work, the symmetrical two phase induction motor is selected. The symmetrical two phase induction motor has two windings, phase A and phase B, spatially displaced at 90 electrical degrees in the stator. In the symmetrical two phase induction motor, the number of turns of windings of phase A is the same as that of phase B.

c. A. Mathematical Model

The two-phase induction motor is composed of two symmetrical windings. Therefore, the auxiliary winding and the main winding is displaced at ninety electrical degrees between these winding and number of turns are same. Fig.1 shows the schematic view of a two phase induction motor, illustrating that the auxiliary (α) windings and main (β) windings are identical sinusoidal distributed windings, but are arranged in space quadrature.
The equivalent circuits representing the symmetrical two-phase induction motor in stationary (αβ) reference frame are shown in Fig. 2. The dynamic model equation of symmetrical two phase induction motor can be written in αβ reference frame variables. The stator and rotor voltage of the two-phase induction motor can be expressed as follows:

\[ V_{\alpha s} = R_{\alpha s} i_{\alpha s} + \frac{d}{dt} \psi_{\alpha s} \] \hspace{1cm} (1)

\[ V_{\beta s} = R_{\beta s} i_{\beta s} + \frac{d}{dt} \psi_{\beta s} \] \hspace{1cm} (2)

**Fig 1. Two-phase induction motor**

**Fig 2. Equivalent circuit of a Symmetrical two-phase induction motor in the stationary (αβ) reference frame**
\[ v_a = R_a + \frac{d}{dt} \psi_a + aw \psi_{\beta} \] (3)

\[ v_{\beta} = R_{\beta} + \frac{d}{dt} \psi_{\beta} - \frac{1}{a} w_r \psi_a \] (4)

The components of stator and rotor flux linkage equations can also be expressed as:

\[ \psi_{sa} = L_{sa} i_{sa} + L_{ma} i_{ra} \] (5)

\[ \psi_{sb} = L_{sb} i_{sb} + L_{mb} i_{rb} \] (6)

\[ \psi_{ra} = L_{ma} i_{sa} + L_{ra} i_{ra} \] (7)

\[ \psi_{rb} = L_{mb} i_{sb} + L_{rb} i_{rb} \] (8)

Using equation (5)-(8), as for the stator and rotor current equation are given by:

\[ i_{sa} = \frac{L_{ra} \psi_{sa} - L_{ma} \psi_{ra}}{L_{sa} L_{ra} - L_{ma}^2} \] (9)

\[ i_{sb} = \frac{L_{rb} \psi_{sb} - L_{mb} \psi_{rb}}{L_{sb} L_{rb} - L_{mb}^2} \] (10)

\[ i_{ra} = \frac{L_{sa} \psi_{ra} - L_{ma} \psi_{sa}}{L_{sa} L_{ra} - L_{ma}^2} \] (11)

\[ i_{rb} = \frac{L_{sb} \psi_{sb} - L_{mb} \psi_{sb}}{L_{sb} L_{rb} - L_{mb}^2} \] (12)

The equation of electromagnetic torque produced by the machine is then given by the equation:

\[ T_e = p (L_{mb} i_{sb} i_{ra} - L_{ma} i_{sa} i_{rb}) \] (13)

The mechanical dynamic is modelled by the equation:

\[ J \frac{d}{dt} w_r = T_e - T_i \] (14)

d. **III. CIRCUIT CONFIGURATION**

Figure 3 shows the circuit configuration of single to two phase matrix converter with no capacitor or inductor in the circuit. Each bidirectional switch consists of two diodes and two IGBT. The switches S_{a1}, S_{a2}, S_{a3}, S_{a4} form phase A and S_{b1}, S_{b2}, S_{b3} and S_{b4} form phase B. Single phase is converted into two phase by using switches. The two phase output obtained from
single phase supply is used for driving two phase induction motor. \( V_{in} \) is the supply voltage and \( V_a, V_b \) are phase A and phase B voltages respectively.

\[
\begin{align*}
S_a & = V_a \\
S_b & = V_b \\
S_{a1} & = S_{b1} \\
S_{b2} & = S_{b3} \\
S_{b4} & = \left( V_a + V_b \right) \\
S_{a2} & = S_{a3} \\
S_{a4} & = \left( V_a + V_b \right)
\end{align*}
\]

**Fig 3. Configuration of Single Phase to Two Phase Matrix Converter**

e. **IV.DEVELOPMENT OF CONTROL ALGORITHM**

Figure 4 and 5 show the relation of the input and output voltage reference, the actual output and the switching pattern of phase A and phase B respectively.

The voltage \( V_{in}, V_{ref_a}, V_{ref_b} \) are defined as follows.

\[
\begin{align*}
V_{in} &= V_i \sin (\omega_i t) \quad \text{......(1)} \\
V_{ref_a} &= V_o \sin (\omega_o t + \frac{\pi}{4}) \quad \text{......(2)} \\
V_{ref_b} &= V_o \sin (\omega_o t - \frac{\pi}{4}) \quad \text{......(3)}
\end{align*}
\]

The two phase voltages are specified by reference voltage \( V_{ref_a} \) and \( V_{ref_b} \). Input voltage frequency and output voltage frequency are defined as \( \omega_i = 2\pi f_i \) and \( \omega_o = 2\pi f_o \), respectively. The phase difference of reference to \( V_{in} \) are set to \( \pm \frac{\pi}{4} \). So that \( V_{ref_a} + V_{ref_b} = V_{in} \) holds if \( f_o = f_i \) and \( V_o = \frac{1}{\sqrt{2}} V_i \) as shown in figure 2 and 3. \( V_{ref,a} + V_{ref,b} = V_{in} \) means that the voltage utilization ratio of the single phase to two phase matrix converter is at maximum.
A. Algorithm to control switches

1) In case \(|V_{ref\,a}|<|V_{in}|\) (mode II & mode III as shown in fig.2 and 3.), Keep \(V_a=V_{ref\,a}\) with buck conversion from \(V_{in}\) or \(-V_{in}\).

2) In case \(|V_{ref\,a}|\geq|V_{in}|\) (mode I & mode IV in fig.9 and 10) Keep \(V_a=V_{in}\) or \(V_a=-V_{in}\). So as to be the same as \(V_{ref\,a}\).

Signs of two parameters \(V_{ref\,a} \times V_{in}\) and \(|V_{ref\,a}| - |V_{in}|\) are sufficient to determine the switching mode of eight bidirectional switches \(S_{a1}, S_{a2}, S_{a3}, S_{a4}\) from phase a and \(S_{b1}, S_{b2}, S_{b3}\) and \(S_{b4}\) from phase b as defined in table I and II respectively. The switching modes of \(S_{a3}\) and \(S_{a4}\) are defined as inverted owes of \(S_{a1}\) and \(S_{a2}\) respectively, to make continuous loops in circuit for fly-back current of the motor.
TABLE I Switching table for phase A

<table>
<thead>
<tr>
<th>Mode</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vrefa</td>
<td>•</td>
<td>Vin</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Vrefa</td>
<td>-</td>
<td>Vin</td>
<td>-</td>
</tr>
<tr>
<td>$S_{a1}$</td>
<td>ON</td>
<td>PWM</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>$S_{a2}$</td>
<td>OFF</td>
<td>OFF</td>
<td>PWM</td>
<td>ON</td>
</tr>
<tr>
<td>$S_{a3}$</td>
<td>OFF</td>
<td>PWM</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>$S_{a4}$</td>
<td>ON</td>
<td>ON</td>
<td>PWM</td>
<td>OFF</td>
</tr>
</tbody>
</table>

TABLE II Switching Table for Phase B

<table>
<thead>
<tr>
<th>Mode</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Vrefb</td>
<td>•</td>
<td>Vin</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Vrefb</td>
<td>-</td>
<td>Vin</td>
<td>-</td>
</tr>
<tr>
<td>$S_{b1}$</td>
<td>ON</td>
<td>PWM</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>$S_{b2}$</td>
<td>OFF</td>
<td>OFF</td>
<td>PWM</td>
<td>ON</td>
</tr>
<tr>
<td>$S_{b3}$</td>
<td>OFF</td>
<td>PWM</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>$S_{b4}$</td>
<td>ON</td>
<td>ON</td>
<td>PWM</td>
<td>OFF</td>
</tr>
</tbody>
</table>

B. Simulation of Two Phase Induction Motor with two phase matrix converter

Matlab/Simulink model is developed to examine the performance of symmetrical two-phase induction motor. The equation from (1)-(4) and (9)-(14) have been implemented in Simulink using different blocks. Fig.6 shows MATLAB blocks connected for simulating the system. The system is simulated by using system parameter as shown in TABLE III.

TABLE III Parameters of Two Phase Induction Motor

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stator Resistance ($R_{sα}, R_{sβ}$)</td>
<td>4.58Ω</td>
</tr>
<tr>
<td>Rotor Resistance ($R_{rα}, R_{rβ}$)</td>
<td>4.93Ω</td>
</tr>
<tr>
<td>Stator Inductance ($L_{sα}, L_{sβ}$)</td>
<td>0.2197H</td>
</tr>
<tr>
<td>Rotor Inductance ($L_{rα}, L_{rβ}$)</td>
<td>0.2168H</td>
</tr>
<tr>
<td>Mutual Inductance ($L_{ma}, L_{mb}$)</td>
<td>0.2118H</td>
</tr>
<tr>
<td>Moment of Inertia ($J$)</td>
<td>2.89x10^{-3}Kg-m^2</td>
</tr>
<tr>
<td>No of Poles</td>
<td>4</td>
</tr>
<tr>
<td>A</td>
<td>1</td>
</tr>
</tbody>
</table>
V. SIMULATION RESULT

We simulated the matrix converter with ideal switches with two phase induction motor as load. Fig.6 shows the two phase voltages simulated for 50Hz. Fig 7 shows the simulated stator currents for various frequencies. Fig.8 shows the speeds of motor for various frequencies.

Fig 6. Simulated two phase output voltages when frequency is 50Hz

Fig.7 Simulated two phase currents for 50Hz
VI CONCLUSION

A two phase supply is generated from single phase with the help of matrix converter. The matrix converter does not have any energy storage element. Similarly it uses simple algorithm. It also emphasizes the fact that for production of rotating field minimum phases required are two.

Though the performance of motor is not very satisfactory and locus of rotating field is not exactly circular for very simple application which does not require accuracy and exact position control this system can be used. e.g. running a lifesaving gadget in hospital or rural area for a short period such system can be used.

XII. REFERENCES


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