Speed Control of Induction Motor using Model Reference Adaptive System and SVPWM with Zeta Converter

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Abstract— This paper presents a new speed and current estimation technique. The sensor-less speed control method used is model reference adaptive system, which is done by using reference quantities (i.e., currents and voltages) in reference model and actual quantities (i.e., currents) in adjustable model. The current estimation is done by using the vector rotator and extracting the information about the phase currents in two phase stationary reference frame by using corresponding synchronous reference frame variables. This proposed speed control and current estimation technique are immune to the variation of stator resistance. The proposed system uses space vector pulse width modulation (SVPWM) in order to obtain switching pulses for inverter with fewer ripples. In-order to improve the power factor and thereby reducing power quality issues zeta converter is used. The proposed system is simulated in MATLAB/Simulink.

Key words: Induction Motor (IM), Model Reference Adaptive System (MRAS), Current Estimation, Space Vector Pulse Width Modulation(SVPWM), Zeta Converter

I. INTRODUCTION

Squirrel cage induction motors are commonly used in industries, because of its certain advantages like longer life, rugged construction, low maintenance and low cost. In order to control the speed of a three phase induction motor several speed control techniques have been introduced over the past decades. Out of which vector control technique is the most modern method of speed controlling. In vector control, stator current is decomposed into flux producing component and torque producing component, so that flux and torque can be controlled separately as in the case of separately excited DC motors. In vector control, there are two loops, outer loop for speed controlling and inner one for current controlling. Sensors for measuring current, voltage and speed are required in vector controlled drives.

The use of sensors may lead to hardware complexity, maintenance requirements, increase in size and cost. So efforts are taken to reduce or eliminate the number of sensors. By eliminating speed sensors the drive become more robust. Several techniques are used for the sensor-less speed control of induction motor drive. In this, speed is estimated using model reference adaptive system (MRAS). In case of flux based MRAS, the main drawbacks are the presence of pure integrator and dependency on stator resistance. The presence of pure integrator represents a drawback in the low speed region, due to drift and low frequency disturbances. The dependency on stator resistance may cause thermal variations. In case of back-emf based MRAS, presence of pure integrator is overcome but it involves introducing the derivative terms also it depends on stator resistance. In case of reactive power based MRAS, it is independent on stator resistance and pure integrator is absent, hence it suitable for low speed operations. But this technique is unstable in regenerative mode, which is a major issue. To overcome this issue, X-MRAS was proposed, which depends on stator resistance. So modified X-MRAS was introduced, which is stable in all four quadrants and is independent of stator resistance.

II. SPEED AND CURRENT ESTIMATION

In the proposed controller technique, speed is calculated using modified X-MRAS technique and current is computed using current estimation technique. MRAS technique may consist of an adjustable model and a reference model. The adjustable model may depend on the value to be estimated directly or indirectly, and reference model is independent on the value to be estimated. The reference model (X_r) is obtained by using the reference values of voltages and currents, and adjustable model (X_a) is obtained by using the reference values of voltages and actual values of currents. The actual values of currents are obtained by using parks transformation ie, $i_{s\alpha}$ and $\hat{\imath}_{s\beta}$ and transformed to i_d and i_q values of currents. The structure for speed estimation is shown in figure.1. The adjustable model involves the speed of the rotor and rotor position is calculated using equations given

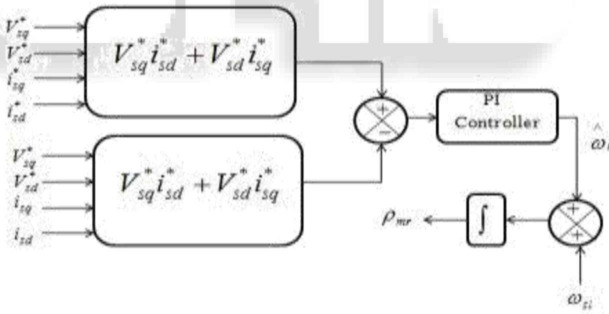

Fig. 1: Block Diagram of Speed Estimation

$$X_r = v^*{}_{sq} i^*{}_{sd} + v^*{}_{sd} i^*{}_{sq}$$
$$X_a = v^*{}_{sq} i_{sd} + v^*{}_{sd} i_{sq}$$

Or

$$X_a = v^*{}_{sq} i_{s\alpha} e^{-j\rho_{mr}} + v^*{}_{sd} \hat{\imath}_{s\beta} e^{-j\rho_{mr}}$$
$$\rho_{mr} = \int \omega_e \, dt$$

Where

$$\omega_e = \hat{\omega}_r + \omega_{sl}$$

As the system runs with only one current sensor (assume as phase A current), the proposed current estimation computes only one current. By using transformation matrix, α axis current in two phase stationary reference frame is obtained as shown.

$$i_{s\alpha} = \frac{3}{2} i_a$$

By using reference values of d and q axis currents (i.e., i^*_{sd} and i^*_{sq}) and position of the rotor flux vector (ρ_{mr})

estimation of β axis current is computed as shown. Figure 2 shows the block diagram of proposed system

$$\hat{\imath}_{s\beta} = i^*_{sq} cos\ \rho_{mr} + i^*_{sd}\ sin\ \rho_{mr}$$

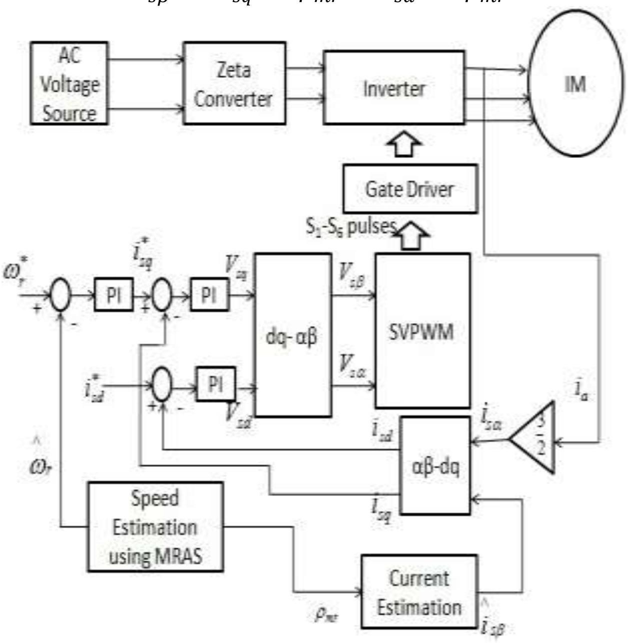

Fig. 2: Block Diagram of Proposed System

III. SPACE VECTOR PULSE WIDTH MODULATION

Switching pulses for the inverter is given using SVPWM. Space vector is a vector having magnitude of $\frac{3}{2}$ V_m, which rotates at ω rad/s. Three phase inverter has 3 legs each containing two switches, and the possible eight switching states are (000),(001),(110),(010),(011),(101),(100),(111). Out of these eight states (000), (111) are called the null states and remaining six is known as active states. When the upper leg switch is turned on it is indicated as 1, or else 0. All the switching states can be represented in the form of a regular hexagon with six sectors as shown in figure 3. The six corners are occupied by the active states and the null states are at the centre. In the figure shown the space vector lies in the first sector.

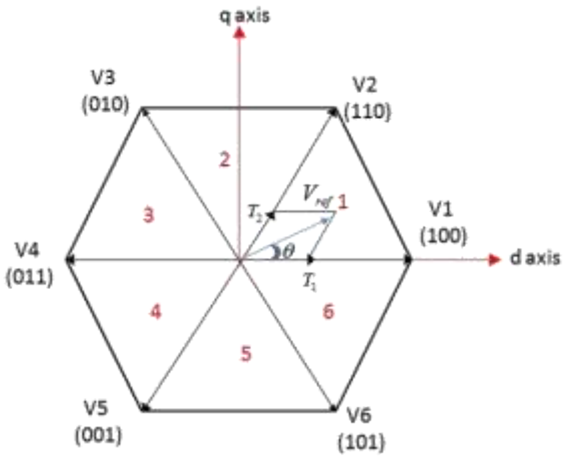

Fig 3. Space Vector Diagram

$$T_1 = \frac{3}{2V_{dc}} V_{ref} T_Z \frac{\sin(60-\theta)^{\circ}}{\sin 60^{\circ}}$$

$$T_2 = \frac{3}{2V_{dc}} V_{ref} T_Z \frac{\sin\theta}{\sin 60^{\circ}}$$

T_1 and T_2 are the switching periods for the voltages V_1 and V_2.

V_{ref} denotes the space vector and T_z represents the total switching time. θ denotes, in which sector the space vector lies. Switching time periods for each sector can be calculated depending upon this angle. Total switching time is the sum of time of the null vectors (T_0) and switching periods of voltages V_1 and V_2. The main advantage of SVPWM is that only one switch is turned on at a time, which in turn reduces the switching losses as compared with sine PWM.

IV. ZETA CONVERTER

Zeta converter is designed to improve the power factor, so that to minimize the power quality issues. The circuit diagram is shown in figure 4. It consist of an input and output capacitor, C_{in} and C_0. The zeta converter will act like output voltage regulator. The reference voltage is compared with the voltage across the DC link capacitor and the error signal obtained is given to the PI controller and necessary compensation of output voltage is made by switching the zeta converter.

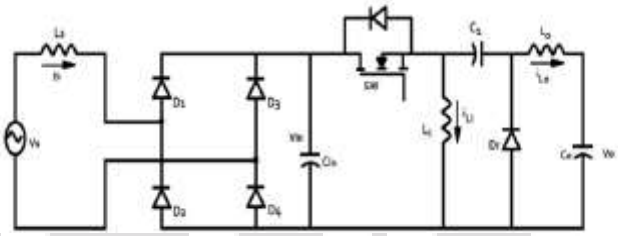

Fig. 4: Zeta Converter

When the switch SW is turned ON, energy from the input supply is being stored in inductance L_1 and L_0 and capacitor C_1. Diode D_F is reverse biased during this time. When the switch SW is turned OFF, diode D_F will be forward biased. Energy stored in inductor L_1 is supplied to capacitor C_1 , and energy stored in inductor L_0 is supplied to capacitor C_0.Thereby obtaining a regulated output voltage using a zeta converter.

Design of zeta converter is as shown in equations:

$$V_{out} = \frac{V_{in} D}{1-D}$$

$$V_{in} = \frac{2\sqrt{2}\, v_s}{\pi}$$

$$L_1 = \frac{V_{in} D}{f_s\, \Delta I_{L_1}}$$

$$C_1 = \frac{I_{out} D}{f_s\, \Delta V_{C_1}}$$

$$L_0 = \frac{V_{out}(1-D)}{f_s\, \Delta I_{L_1}}$$

$$C_0 = \frac{I_{L_0}}{2 * 2\pi f\ \Delta V_{out}}$$

V. SIMULATION RESULTS

The simulation of speed control of induction motor using SVPWM and model reference adaptive system with Zeta converter was simulated using MATLAB/Simulink. The overall simulation diagram is shown in figure 5.

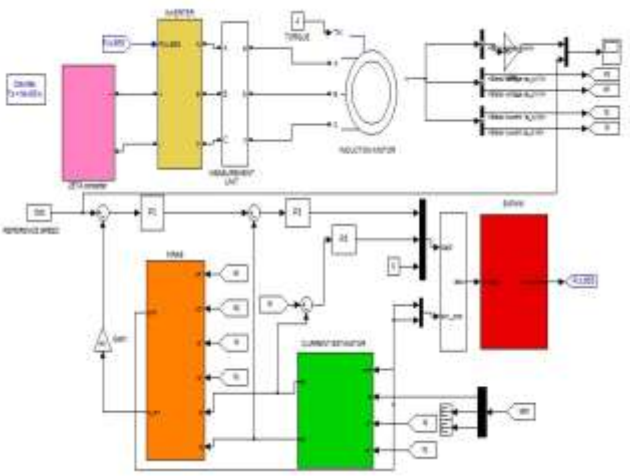

Fig 5: Simulation Diagram of Proposed System

Figure 6 shows the six switching pulses for the voltage source inverter using SVPWM technique. By this method switching losses can be reduced, since there is only one switching at a time. Figure 7 shows the d and q axis current, which are in 90° phase shift. Figure 8 shows the regulated output voltage of 300 V which is obtained using zeta converter. Figure 9 shows the speed of the IM obtained from MRAS technique, reference speed of 1300 rpm is given and actual speed of nearby value is obtained within 0.5 seconds at loaded condition.

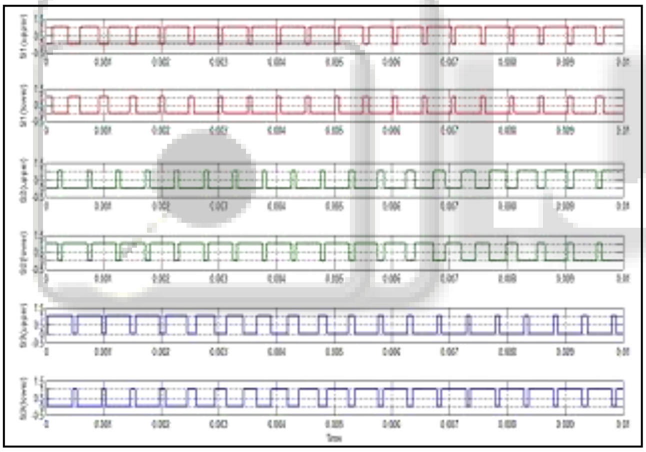

Fig. 6: SVPWM Pulses

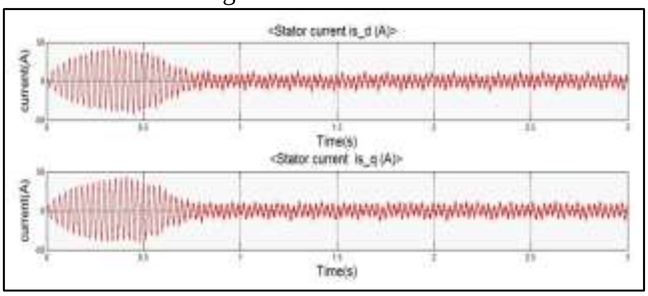

Fig. 7: d-q Current Waveform

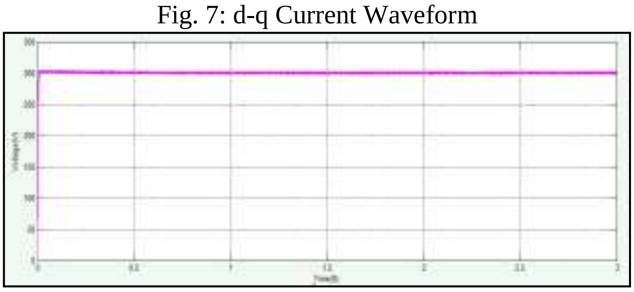

Fig. 8: Output of Zeta Converter

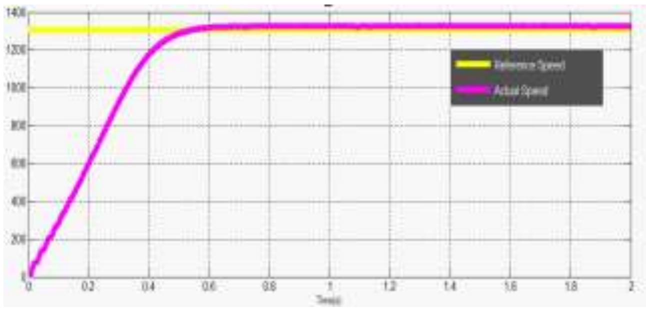

Fig. 9: Actual and Reference Speed Obtained at Loaded Condition

VI. CONCLUSION

Three phase induction motors are widely used in industrial applications mainly because of its numerous advantages like better speed control, low cost and rugged construction. Several speed control techniques have been used for induction motor. Vector control techniques are the modern speed control method. In the proposed system, speed of induction motor is controlled using model reference adaptive system along with SVPWM techniques and zeta converter. Model reference adaptive system and current estimation techniques are used in-order to obtain rotor speed and currents respectively and both techniques does not involve stator resistance. By using this method, speed sensors can be eliminated thereby can make the system better noise immune, lower cost, reduced size of drive machine, no additional mounting space is required. According to the voltages obtained, SVPWM pulses are produced and given to the three phase voltage source inverter, which in turn reduces the speed ripples. Zeta converters are provided in-order to obtain a regulated DC output voltage. The proposed system is simulated, and by using the proposed system speed can controlled in a better way.

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