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Obtaining Maximum Torque Operation of Single Phase Induction Motor Using Simulation Technique of MATLAB

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Abstract- **Fractional KW electrical machines used in domestic and industrial applications are mostly asymmetrical two phase induction motor supplied by single phase supply. Though many techniques are available for control of three phase induction machine for extracting its best performance, but no such generalized technique is available for controlling Single Phase Induction Motor (SPIM). In this paper, a SPIM is studied, where a dynamic capacitor is used for obtaining maximum torque operation. The SPIM makes use of indirect current control of Voltage Source Inverter (VSI) with a capacitor on its DC bus , so that it can work as a variable capacitor. Then a maximum torque operation is obtained, by connecting this dynamic capacitor in series with the auxiliary winding, and is controlled in such a way to keep the main and auxiliary winding currents in phase quadrature to each other. And along with dynamic capacitor a dynamic model is developed in stator reference frame (d-q). For proposed configuration, performance of the SPIM is studied using MATLAB, to demonstrate the effectiveness of the dynamic capacitor.**

***Keywords: SPIM, Maximum Torque Operation, Indirect Current Control*.**

I. INTRODUCTION

A single phase induction motor can be seen as two phase induction motor as it has main and auxiliary winding which are in phase quadrature with each other. The only difference between supply of a two phase induction motor and single phase induction motor is that, the input voltage applied to the stator winding of two phase induction motor is independently controlled to obtain a two-phase voltage supply.

Lately, there have been various techniques, to develop model of a two phase induction motor. The dynamics of SPIM have been studied and developed with MATLAB software.

In most of the applications the motor usually runs at a fixed speed. At most two or three speeds can be obtained by manual operation. But in this manner, motor operates at low power factor and at less efficiency. Traditionally variable speed operation of SPIM is obtained by the use of voltage control method using Triacs or Thyristors. But these techniques suffer from low power factor, limited speed range and large harmonic injection into the supply

Most single phase motors are constructed with two asymmetrical windings, main and auxiliary winding which are displaced 90 electrical degrees around motor stator. The main winding carries a higher current rating and the auxiliary winding is connected to the ac supply through a series capacitor, to make its current lead the main winding current by approximately 90° in phase [9].

There are various control techniques available for the speed control of induction motor, like voltage frequency i.e V/f control technique, vector control, torque control and several other [7].

In this paper we will use a current control technique for the control of single phase induction motor. For this, the condition for maximum torque of induction machine is applied. The condition is that the current in main winding and that in auxiliary winding should always be 90^0 apart. And this we obtain by controlling the firing angle of voltage source inverter [10].

II. SYSTEM DESCRIPTION

The VSI is controlled to imitate a dynamic capacitor which is used for low cost open loop control of SPIM through an indirect current control scheme. The maximum torque that is available from the machine is being extracted by the dynamic capacitor that is used in this system. There is no necessity of much modification in the already existing equipment for the indirect current control scheme as it can be easily attached to the existing system.

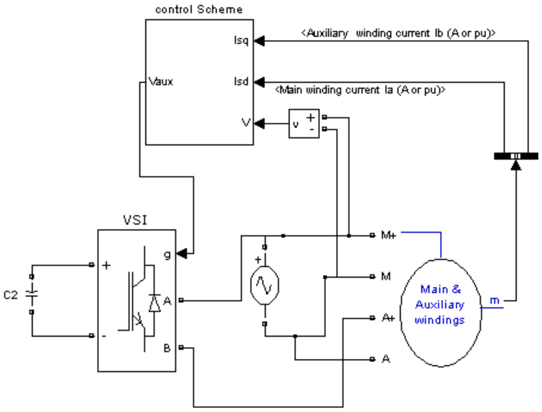

Fig 1: Schematic of a SPIM with a dynamic capacitor

The phase quadrature in between the main field winding and auxiliary field winding is maintained by an indirect current control of VSI so as to obtain the maximum torque from the motor. A d-q stationary reference frame model of the drive with the proposed control scheme is developed. A demonstration of the system's improved performance has been shown through Matlab's Simulation results.

The SPIM system uses an indirect current control scheme to control VSI with a capacitor on dc bus to emulate a dynamic capacitor [1]. A schematic diagram of a SPIM along with a dynamic capacitor is shown in the Fig 1. The DC capacitor is charged initially and the voltage across it is maintained by controlling the switching of VSI. Switching of VSI is also governed by magnitude and phase of auxiliary winding current. The value of capacitor is large enough to suppress the ac ripples on the dc-bus of VSI. The dynamic capacitor is connected in series with an auxiliary winding of SPIM as shown in Fig. 1.The auxiliary winding current is in phase quadrature with the main winding current by an indirect current control of VSI. The phase quadrature is maintained irrespective to the load torque and the machine speed, such that it always generates the maximum electromagnetic torque from the machine. The changes in the load torque or the rotor speed of the machine vary the main winding current; correspondingly control circuit changes the switching pattern of VSI to control auxiliary current in order to maintain the phase quadrature in two winding currents. The indirect current controlled VSI controls the auxiliary winding current, which under any start or run condition of SPIM yield the highest available output torque.

III. MATHEMATICAL MODELING OF SPIM

As mentioned earlier, most single phase induction motors are constructed with two asymmetrical windings, main and auxiliary winding which are displaced 90 electrical degrees around motor stator. The main winding carries a higher current rating, and therefore auxiliary winding has fewer turns [5]. Fig. 2 shows the schematic view of a two phase induction motor, illustrating that the auxiliary (q) windings and main (d) windings are not identical sinusoidal distributed windings, but are arranged in space quadrature[6].

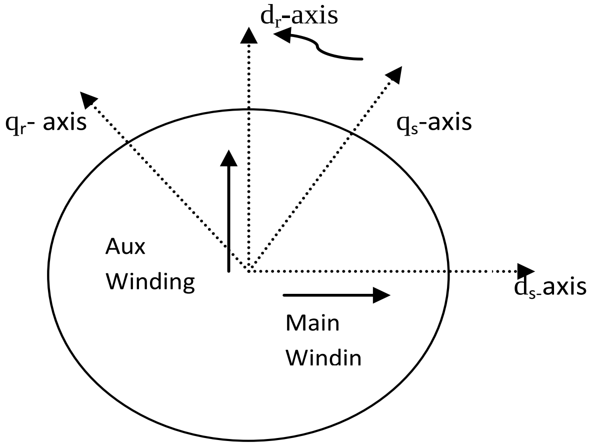

Fig 2 : Asymmetrical two-phase induction motor.

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Fig 3. and Fig 4 shows the equivalent circuits of asymmetrical two-phase induction motor in stationary (d-q) reference frame.

For the asymmetrical two phase induction motor the dynamic model equation can be written as d-q reference frame variables. The two phase Induction Motor's stator and rotor voltage can be expressed as follows [4]:

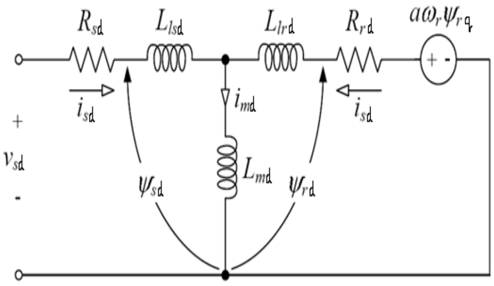

Fig 3: Main winding in d-axis

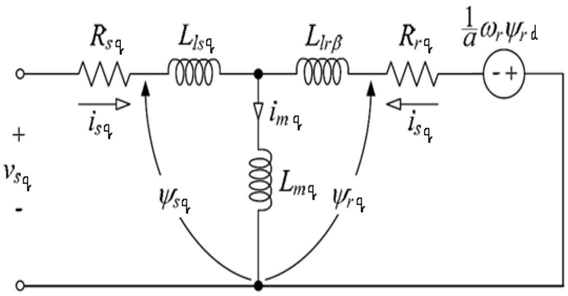

Fig 4: Auxiliary Winding in q-axis

Figures 3 and 4.[8] Shows the equivalent circuit of an asymmetrical two-phase induction motor in the stationary (dq) reference frame

$$V_{sd} = R_{sd}.\ I_{sd} + d/dt\ (\psi_{sd}) \qquad (1)$$

$$V_{sq}= R_{sq}.\ I_{sq} + d/dt(\ \psi_{sq}) \qquad (2)$$

$$V_{rd} = 0= R_{rd}.\ I_{rd} + d/dt\ (\psi_{rd})+ a\omega_r\psi_{rq} \qquad (3)$$

$$V_{rq} = 0= R_{rq}.\ I_{rq} + d/dt\ (\psi_{rq})\text{-}1/\ a\omega_r\psi_{rd} \qquad (4)$$

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

$$\psi_{sd} = L_{sd}\, I_{sd} + L_{md}I_{rd} \qquad (5)$$

$$\psi_{sq} = L_{sq}\, I_{sq} + L_{mq}I_{rq} \qquad (6)$$

$$\psi_{rd} = L_{md}\, I_{sd} + L_{rd}I_{rd} \qquad (7)$$

$$\psi_{rq} = L_{mq}\, I_{sq} + L_{rq}I_{rq} \qquad (8)$$

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

$$I_{sd} = (L_{rd}\psi_{sd}\text{-}\ L_{md}\psi_{rd})\ /\ (L_{sd}L_{rd} - L^2_{md}) \qquad (9)$$

$$I_{sq} =(\ L_{rq}\psi_{sq}\text{-}\ L_{mq}\psi_{rq})\ /\ (L_{sq}L_{rq} - L^2_{mq}) \qquad (10)$$

$$I_{rd} = (L_{sd}\psi_{rd}\text{-}\ L_{md}\psi_{sd})\ /\ (L_{sd}L_{rd} - L^2_{md}) \qquad (11)$$

$$I_{rq} = (L_{sq}\psi_{rq}\text{-}\ L_{mq}\psi_{rq})\ /\ (L_{sq}L_{rq} - L^2_{mq}) \qquad (12)$$

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

$$T_e= p_p\ (L_{mq}I_{sq}I_{rd}\text{-}\ L_{md}I_{sd}I_{rq}) \qquad (13)$$

And the mechanical dynamics is modeled by the equation

$$J\ d/dt\ (\omega_r) = T_e - T_L \qquad (14)$$

IV. CONTROL & SIMULATION SCHEME

The main winding of SPIM is directly connected to ac supply, whereas auxiliary winding in series with the dynamic capacitor is connected across ac supply [1]. The motor is connected to a fan load, where the load torque is proportional to the speed. In order to extract the maximum torque, the phase angle adjustment of the auxiliary winding current is controlled through the VSI with a capacitor on DC bus for the control of auxiliary current, such that the two currents always remain in phase quadrature. The main winding current is chosen as a reference. The VSI is controlled to emulate a dynamic capacitor. The computation of reference auxiliary winding current is based on the fact that a dynamic capacitor is acting as an ideal capacitor modifying only the reactive power burden in terms of leading current. The real component of current consists of the part previously being computed in an auxiliary winding along with the component of the current required to maintain the DC bus of VSI. The main winding current is transformed in real and reactive components using abc-dq transformation. The implementation of the scheme in MATLAB environment is shown in Fig.5. The in-phase sine and cosine components for phase voltage are computed through the single-phase PLL. To obtain the real and reactive components of the single-phase main and auxiliary currents, each current is phase displaced by 90^0 to emulate the stationary reference frame. These components of currents in stationary reference frame are transformed with Park's transformation in dq-reference frame. The real component of the auxiliary current is modified to accommodate the inverter losses by maintaining the dc-bus constant. Further the magnitude of the auxiliary current is computed by the implementation of equations in dq frame as shown in Fig.5. Knowing the magnitude of real and reactive components of the auxiliary current, the magnitude of reference auxiliary current is computed as per eq.(1) as depicted in Fig.5. This is then multiplied by unit vector in quadrature with the main winding current to get the reference auxiliary winding current. The leading quadrature component is obtained by inverse Park's transformation of the main winding components, selecting the second output, which is lagging behind the main winding current by 90^0 and inverting the waveform, thus the leading quadrature current unit template is obtained.

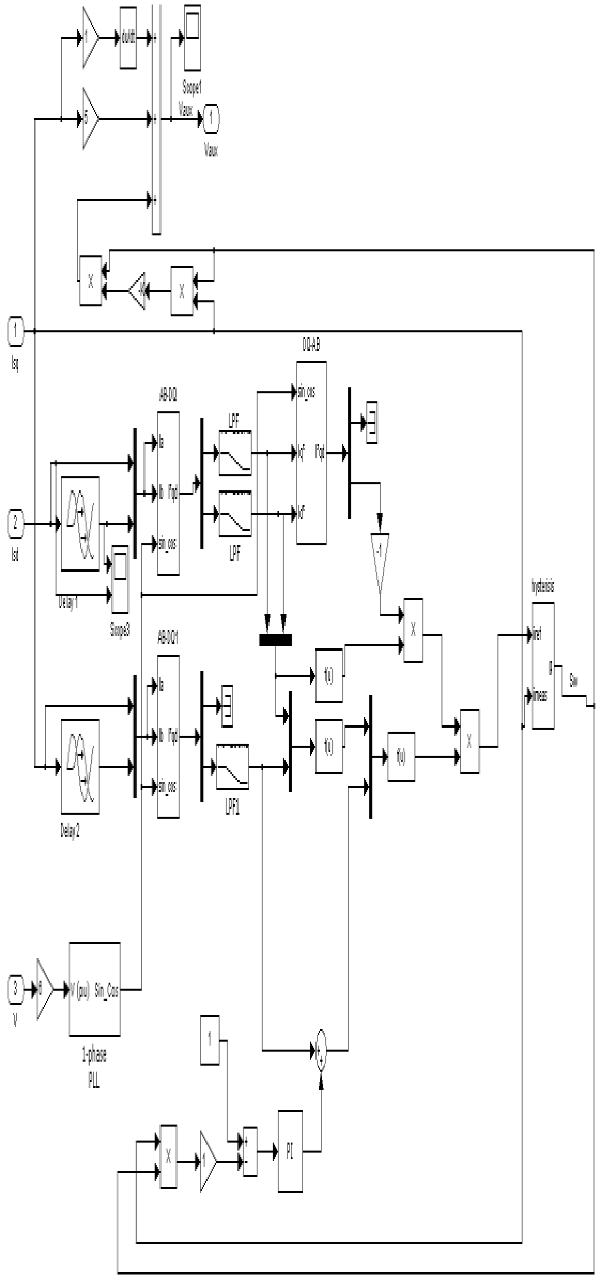

Fig 5: Simulink Model

The implemented scheme is shown in Fig.5. The auxiliary winding current control loop is implemented using standard hysteresis current controller to switch the VSI to act as a dynamic capacitor with indirect current control. The dynamic capacitor thus operates the machine to run for maximum available torque condition irrespective to the nature of the load torque and the motor speed. Thus, an optimal torque may be extracted from the motor.

V. STARTING CHARACTERISTEICS OF SPIM WITH DYNAMIC CAPACITOR UNDER LOAD TORQUE=0.25 p.u

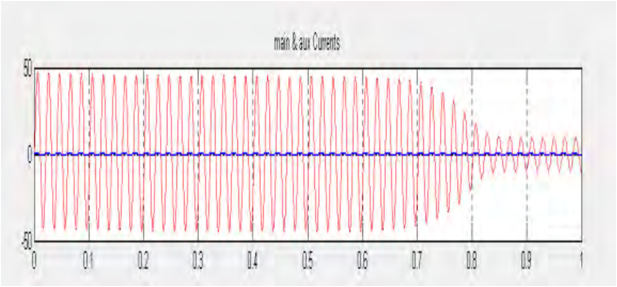

Fig 6: Main & Auxiliary Winding Currents

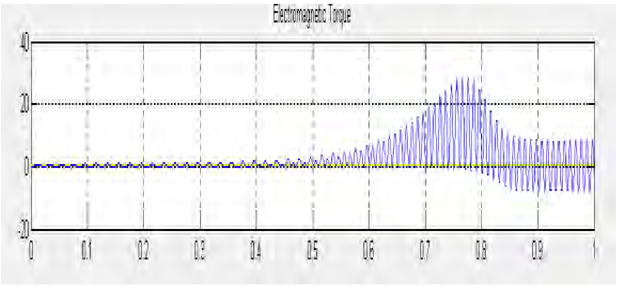

Fig 7: Electromagnetic Torque

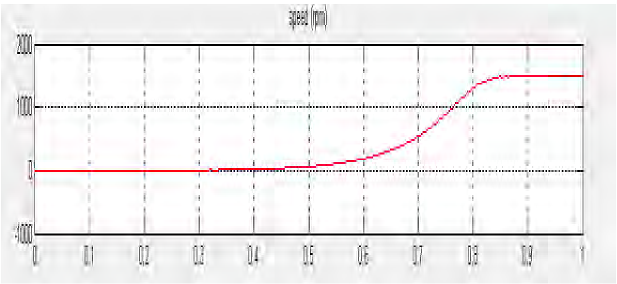

Fig 8: Rotor Speed (rpm)

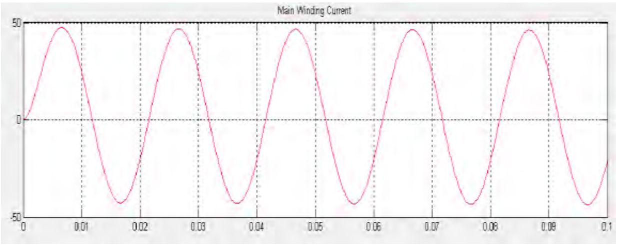

Fig 9: Main Winding Currents with Simulation time =0.1 Sec

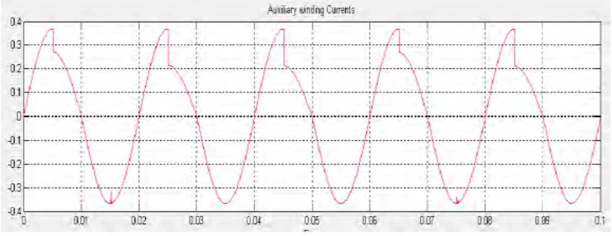

Fig 10: Auxiliary Winding Currents with Simulation time =0.1 Sec

VI. CONCLUSION & FUTURE SCOPE

The observed performance of SPIM with dynamic capacitor presents its ability to operate the motor at near maximum torque condition throughout its operation. The indirect current control technique using computation of auxiliary current components in dq-frame operates the VSI to act as a dynamic capacitor maintaining the main and auxiliary current components in almost phase quadrature. It has been observed that overall current rating of the motor reduces for obtaining requisite torque, which may reduce the size, frame and cost of the motor. The scheme has advantage of simplicity and may be used as an attachment to the already existing machines without any modification in their structure.

VII. PARAMETERS OF THE MOTOR

Rated output power	360 VA
Rated speed(RPM)	1750
Stator Resistance	2.02
Stator leakage reactance	8.54 e-3
Magnetizing Reactance	180 e-3
Inertia(J)	0.0147
Rated Frequency	50 Hz
Rated Voltage	220 V
Rotor Resistance	4.12
Rotor Leakage Reactance	1.34 e-3
No. of Poles	2

Table 1 : Parameters of The SPIM

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