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Simulation Of Induction Motor Modelling In MATLAB Software.

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Abstract

Induction Motor has inherent coupling effect due to its construction. Any changes made in the stator or rotor parameters changes the other parameters also. For example; both torque and flux are the function of voltage or current and frequency. This means that when torque is increased, flux tends to decrease. Therefore, change of one parameter affects the other parameter which is not desirable. This paper presents the decoupling of parameters termed as 'Induction Motor Modelling'. Induction Motor Modelling helps to control each parameter separately.

1. Introduction

Induction motor is used in every industry. Therefore, its performance characteristics improvement will prove to be very beneficial. By performing Induction Motor Modelling, the parameters which were earlier inter-dependent due to coupling effect, now become independent due de-coupling of parameters. By proper controlling of these parameters the current or voltage, frequency, output torque, speed can be controlled. Therefore, Induction Motor Modelling helps in controlling the parameters which will give the desired results in the output.

2. Induction Motor Modelling

In Induction Motor Modelling the three-phase supply is converted to two-phase supply. This conversion is done with the help of 'Parks Transformation Matrix'. After conversion, one phase is known as d-axis and the other phase is known as q-axis. The supply current is in the stationary reference frame. Hence, the after the conversion from three-phase to two-phase, the two axis currents is also in stationary reference frame. It is made into rotating reference frame by adding unit vectors to the equation.

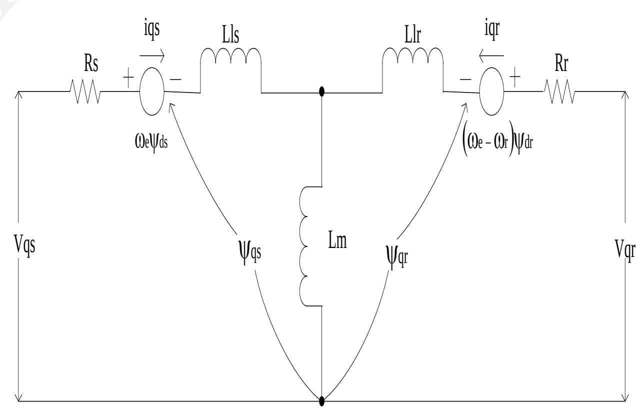

Fig. 1. Equivalent (q-axis) circuit of induction motor

$$\psi_{qs} = \frac{F_{qs}}{\omega_b}$$

$$\psi_{qr} = \frac{F_{qr}}{\omega_b}$$

$$\psi_{ds} = \frac{F_{ds}}{\omega_b}$$

$$\psi_{dr} = \frac{F_{dr}}{\omega_b}$$

$$Lls = Ls - Lm$$

$$Llr = Lr - Lm$$

The above equations shows the flux linkages and mutual inductances of induction motor.

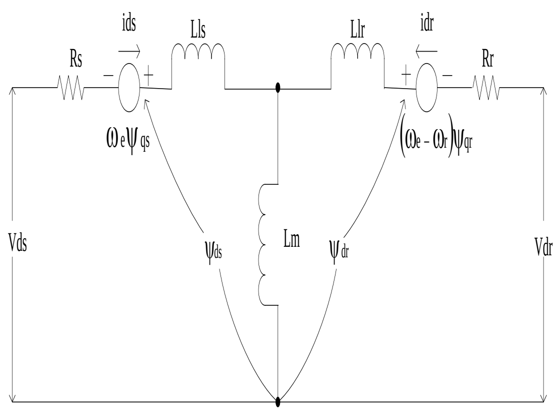

Fig. 2. Equivalent circuit (d-axis) of induction motor

Park's Transformation matrix in Simulink:-

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \begin{bmatrix} +\frac{2}{3} & -\frac{1}{3} & -\frac{1}{3} \\ -\frac{1}{3} & +\frac{2}{3} & -\frac{1}{3} \\ -\frac{1}{3} & -\frac{1}{3} & +\frac{2}{3} \end{bmatrix} \begin{bmatrix} V_{a0} \\ V_{b0} \\ V_{c0} \end{bmatrix}$$

But the above matrix is in simple form, therefore cannot be implemented. It needs unit vectors to convert the d-q axis in synchronously rotating reference frame.

$$\begin{bmatrix} V^s qs \\ V^s ds \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & -\frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \end{bmatrix} \begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix}$$

$$Vqs = V^s qs.\cos\theta_e - V^s ds.\sin\theta_e$$

$$Vds = V^s qs.\sin\theta_e + V^s ds.\cos\theta_e$$

The above matrix is used in Simulink to get the d and q axis voltage with the help of unit vectors, $\cos\theta_e$ and $\sin\theta_e$ to convert the two phases in synchronously rotating reference frame.

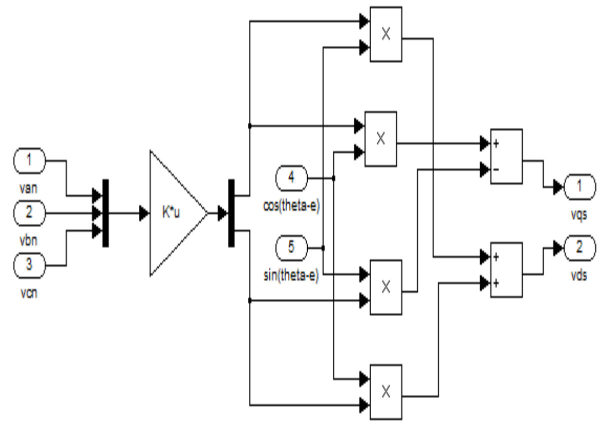

Fig. 3. Implementation of Park's Transformation in Simulink

Equations in the form of flux linkages:-

$$\frac{dFqs}{dt} = \omega b\left[Vqs - \frac{\omega e}{\omega b}Fds + \frac{Rs}{Xls}(Fmq + Fqs)\right]$$

$$\frac{dFds}{dt} = \omega b\left[Vds + \frac{\omega e}{\omega b}Fqs + \frac{Rs}{Xls}(Fmd + Fds)\right]$$

$$\frac{dFqr}{dt} = \omega b\left[Vqr - \frac{(\omega e - \omega r)}{\omega b}Fdr + \frac{Rr}{Xlr}(Fmq - Fqr)\right]$$

$$\frac{dFdr}{dt} = \omega b\left[Vdr + \frac{(\omega e - \omega r)}{\omega b}Fqr + \frac{Rr}{Xlr}(Fmd - Fdr)\right]$$

Mutual Flux linkages are calculated as given below:-

$$Fmq = Xml\left[\frac{Fqs}{Xls} + \frac{Fqr}{Xlr}\right]$$

$$Fmd = Xml\left[\frac{Fds}{Xls} + \frac{Fdr}{Xlr}\right]$$

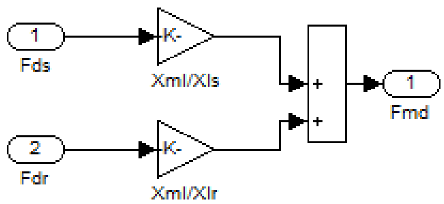

Fig. 4. Simulation implementation of mutual flux

Putting these equations we get:-

$$\frac{dFqs}{dt}=\omega b\left[Vqs-\frac{\omega e}{\omega b}Fds+\frac{Rs}{Xls}\left(\frac{Xml}{Xlr}Fqr+\left(\frac{Xml}{Xls}-1\right)Fqs\right)\right]$$

$$\frac{dFds}{dt}=\omega b\left[Vds+\frac{\omega e}{\omega b}Fqs+\frac{Rs}{Xls}\left(\frac{Xml}{Xlr}Fdr+\left(\frac{Xml}{Xls}-1\right)Fds\right)\right]$$

$$\frac{dFqr}{dt}=\omega b\left[-\frac{(\omega e-\omega r)}{\omega b}Fdr+\frac{Rr}{Xlr}\left(\frac{Xml}{Xls}Fqs+\left(\frac{Xml}{Xlr}-1\right)Fqr\right)\right]$$

$$\frac{dFdr}{dt}=\omega b\left[\frac{(\omega e-\omega r)}{\omega b}Fqr+\frac{Rr}{Xlr}\left(\frac{Xml}{Xls}Fds+\left(\frac{Xml}{Xlr}-1\right)Fdr\right)\right]$$

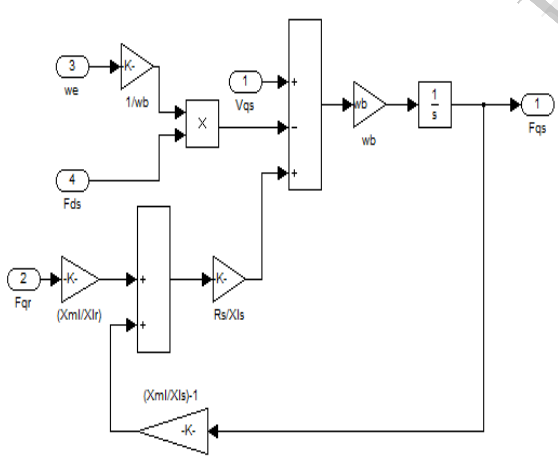

Fig. 5. Simulation implementation of flux equation.

Similarly, rest of the flux equations can be implemented.

Once, the flux linkages are known, direct-axis and quadrature-axis currents can be formulated as given below:-

$$iqs=\frac{1}{Xls}\left[Fqs-Fmq\right]$$

$$ids=\frac{1}{Xls}\left[Fds-Fmd\right]$$

$$iqr=\frac{1}{Xlr}\left[Fqr-Fmq\right]$$

$$idr=\frac{1}{Xlr}\left[Fdr-Fmd\right]$$

Where,

d - direct axis
q - quadrature axis
s - stator variable
r - rotor variable
F - flux linkages
Vqs, Vds - q and d-axis votages
Vqr, Vdr - q and d-axis voltages
Fmq and Fmd - q and d-axis magnetizing flux linkages
Xls – stator leakage reactance
Xlr – rotor leakage reactance

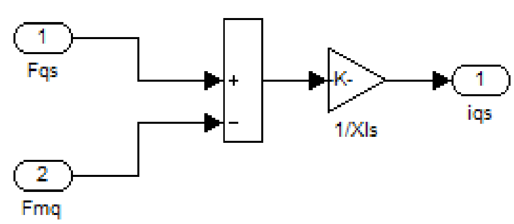

Fig. 6. Simulation implementation of q-axis current equation

Finally the torque can be calculated as:-

$$Te=\frac{3}{2}\frac{P}{2}\left(\frac{1}{\omega b}Fds.iqs-Fqs.ids\right)$$

Where, Te is electromagnetic torque

Tl - load torque
ωe – stator angular electrical frequency
ωb – motor angular electrical base frequency
ωr – rotor angular electrical speed

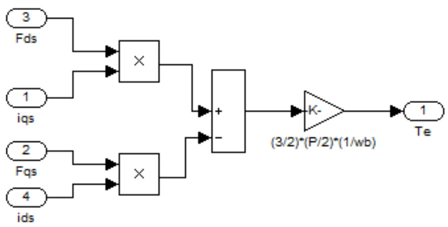

Fig. 7. Simulation implementation of torque equation

The speed calculation is calculated as given below:-

$$Te - Tl = J\left(\frac{2}{P}\right)\frac{d\omega r}{dt}$$

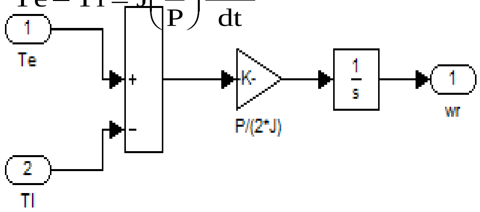

Fig. 8. Simulation implementation of speed equation

3. Simulation diagram

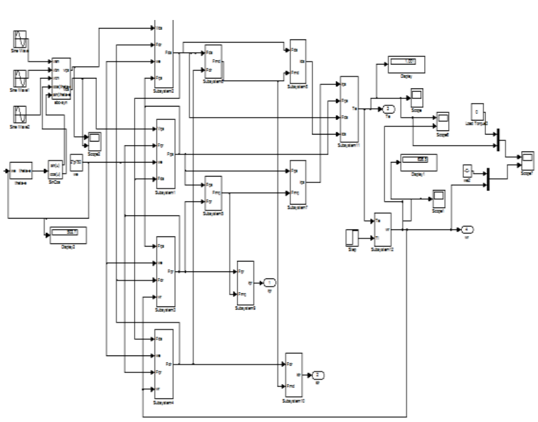

Fig. 9. Simulation diagram of induction motor Modelling

The three-phase supply is converted into two-phase supply by Park's Transformation, i.e. va, vb and vc is converted into vqs and vds. Depending upon these voltages, self flux linkages are found. Then with the help of these flux linkages, mutual flux linkages are obtained. The two-phase currents, iqs and ids are calculated with the help of these mutual flux linkages. These two currents gives final torque Te i.e. electromagnetic torque.

Here the current ids is oriented in the direction of flux and the current iqs is oriented in the direction of torque. Since the variation of flux gives sluggish response, it is kept constant. Therefore, to control the output torque, current iqs is controlled. This is the major benefit of Induction Motor Modelling which gives de-coupling effect and also the parameters can be independently controlled.

4. Simulation results

Figure shown below shows the electromagnetic torque and the load torque. The load torque is given as step input. This step input acts as a variable load torque.

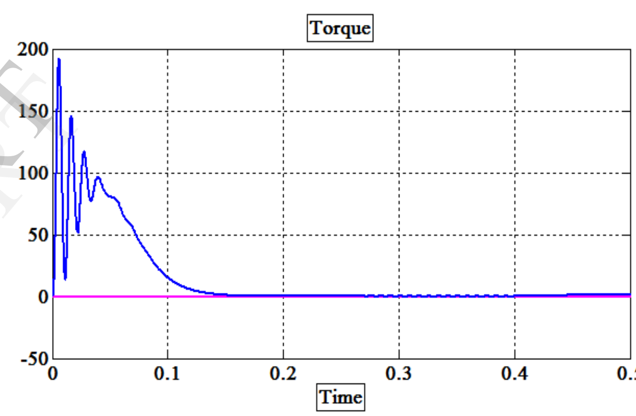

Fig. 10. Simulation results of electromagnetic torque matching the load torque

Here, the electromagnetic torque is matching the load torque, after the initial transients. Therefore, Induction Motor Modelling provides the facility of independent control over the parameters to get the desired outputs. Also any additional control technique can be applied to the input side of induction motor after the Induction Motor Modelling is done for better and independent control of parameters.

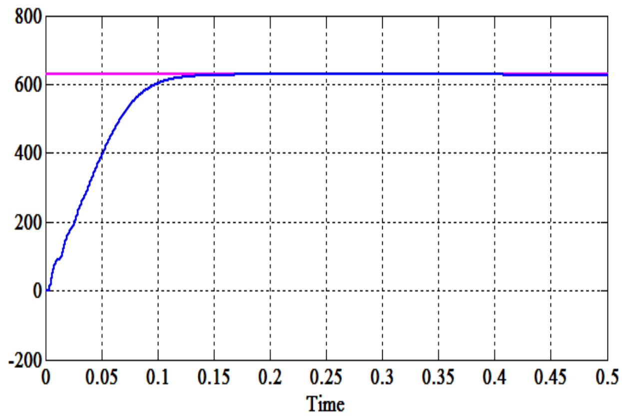

Fig. 11. Simulation result of speed of induction motor

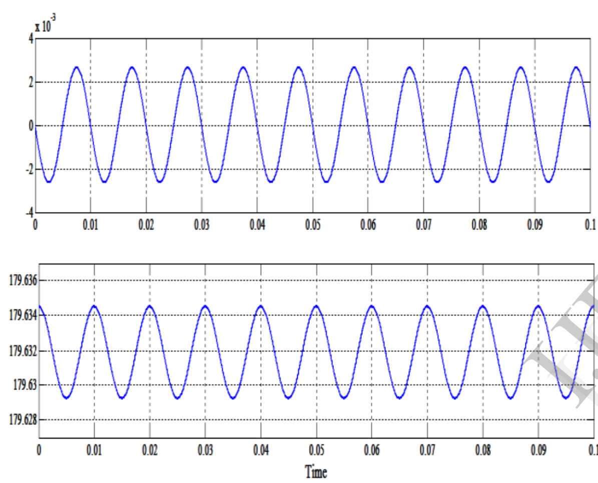

Fig. 12. Simulation results of Park's Transformation matrix, i.e. d-q axis currents which are 90° apart

5. Conclusion

Induction Motor Modelling helps us to de-couple the parameters. It gives the advantage of independent control over the parameters. Also any advance control technique can be applied to Induction Motor Modelling to enhance the performance of induction motor considering Induction Motor Modelling as the base technique.

In this modelling, we find direct-axis and quadrature-axis currents. This shows that id and iq are 90° apart from each other, id lies in the direction of flux and iq lies in the direction of torque. Therefore the parameters are easily accessible for control which was not possible without this technique. Hence, parameters become independent variables because of which change of one parameter does not affect the other parameters.

6. References

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