4th National Conference on Advances in Engineering and Applied Science
Organized by : Anjuman College of Engineering and Technology (ACET) Nagpur,
Maharashtra, India, In association with
International Journal of Scientific Research in Science and Technology

Induction Motor Modelling or De-coupling of Parameters Using MATLAB

Naintara Wasnik[1],Yamin Ansari[2], Nahid Khan[3]

[1]Assistant Professor, Electrical Engineering Department, Yeshwantrao Chavan College of Engineering, Nagpur, Maharashtra, India

[2,3]Assistant Professor, Anjuman College of Engineering & Technology ,Sadar Nagpur, Maharashtra, India

ABSTRACT

Any changes made in the stator or rotor parameters of the induction motor can result in changes in other parameters also due to its inherent coupling effect of construction. For example; both torque and flux are the function of voltage or current and frequency. Which means that increase in torque will result in decrease in the flux, i.e. change due to one parameter affecting the other is not preferable. This paper presents the decoupling of parameters which is also known as "MODELLING OF INDUCTION MOTOR". Parameters can be controlled separately using Induction Motor Modelling.

Keywords : Induction Motor De-Coupling, Q-Axis Current, D-Axis Current, Park's Transformation, Simulation.

I. INTRODUCTION

Since it is used in almost every industry. Hence, enhancing its working characteristic will prove to be very advantageous. Due to de-coupling effect the variables of the Induction Motor becomes independent which were earlier dependent due to coupling effect. By de-coupling of various parameters of Induction Motor like current or voltage, frequency, output torque, speed can be controlled. Therefore, by modelling of Induction motor (i.e. de-coupling of Induction Motor) helps to control the above parameters independently which will help in providing the desired results in the output.

II. Induction Motor Modelling

Parks Transformation Matrix is the method used to convert three-phase supply of Induction Motor into two-phase supply that is three-phases of Induction Motor (a, b, c) to two-phases (d & q). The supply current is in the stationary reference frame. Hence, 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 [1], [2].
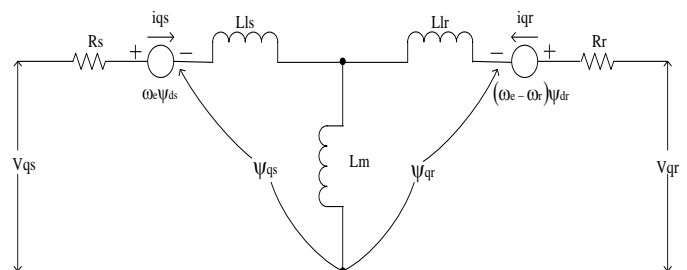

Fig. 1. Equivalent (q-axis) circuit of induction motor

$$\psi_{qs} = \frac{F_{qs}}{\omega b}$$

$$\psi_{qr} = \frac{F_{qr}}{\omega b}$$

$$\psi ds = \frac{Fds}{\omega b}$$

$$\psi dr = \frac{Fdr}{\omega b}$$

$$Lls = Ls - Lm$$

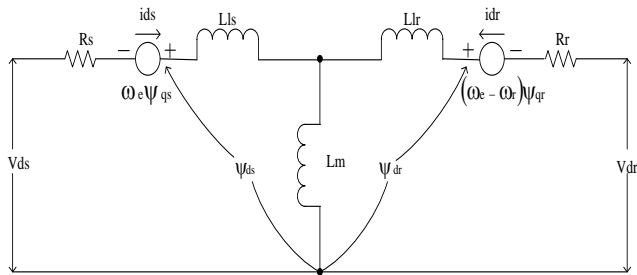The flux linkages and mutual inductance of induction motor are represented above.

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

Park's Transformation matrix in Simulink:-

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

The above matrix is in simplest form therefore implementation of the same cannot be done. To convert the d-q axis in synchronously rotating reference frame unit vectors is needed.

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

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

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

To convert the two phases (d and q) in synchronously rotating reference frame the above matrix is used in MATLAB to get d and q axis voltage with the help of unit vectors, cosθ and sinθ [5].
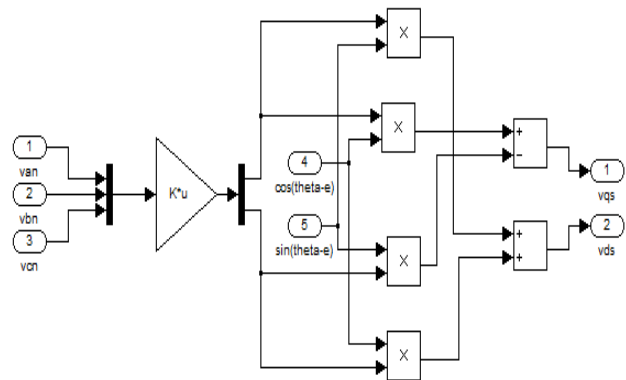

Fig. 3. Implementation of Park's Transformation in Simulink

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:-

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

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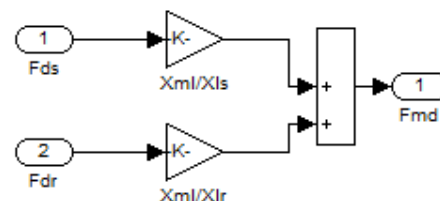

Fig. 4. Simulation implementation of mutual flux

Putting these equations we get

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

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

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

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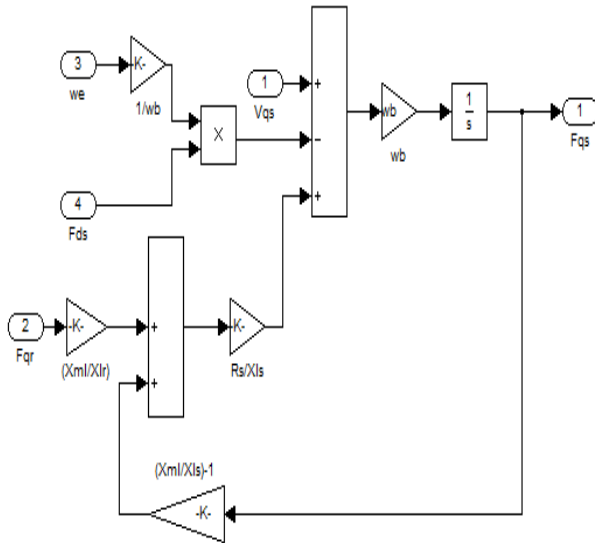

Fig. 5. Simulation implementation of flux equation

Similarly, remaining flux equations can be implemented.

Once, the flux linkages are known, d-axis and q-axis currents can be calculated 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
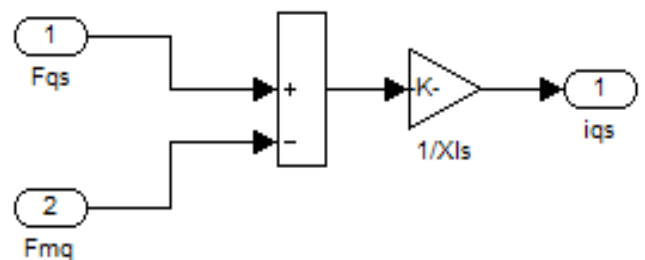Xlr – rotor leakage reactance

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

Finally the torque can be computed 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
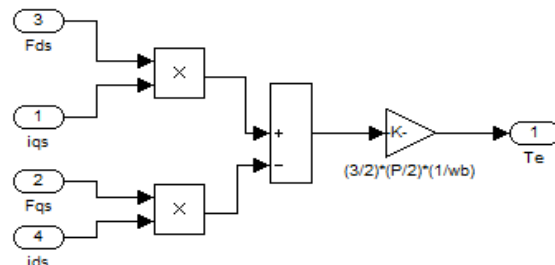ωr – rotor angular electrical speed

Fig. 7. Simulation implementation of torque equation

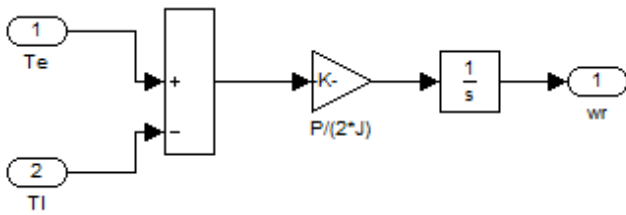The speed calculation is calculated as given below:-

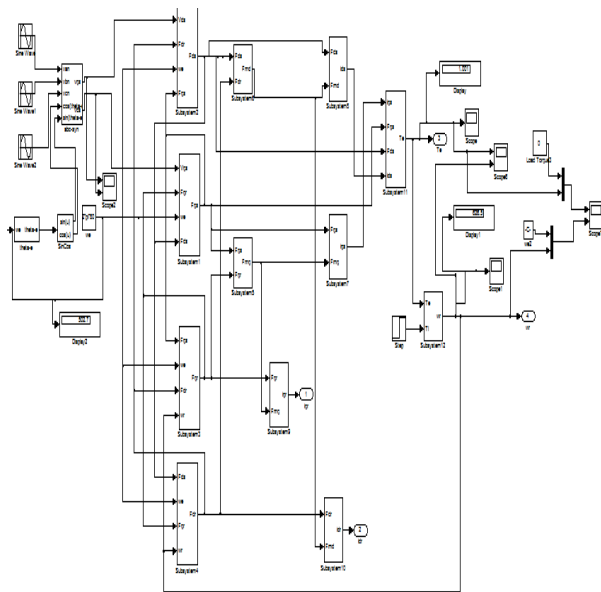Fig. 8. Simulation implementation of speed equation

III. SIMULATION DIAGRAM

Fig. 9. Simulation diagram of induction motor Modelling

The three-phase supply i.e. va, vb and vc is converted into two-phase supply i.e. vqs and vds by Park's Transformation. Self- flux linkages are found depending upon these voltages which further helps in obtaining mutual flux linkages. These mutual flux linkages help in calculating the two-phase currents, iqs and ids. These two currents provide final torque Te i.e. electromagnetic torque.

Here the current 'ids' is aligned in the direction of flux and the current 'iqs' is aligned in the direction of torque. Because of sluggish response of flux, it is kept constant. Hence, current iqs is controlled to control the output torque (Te). This is the key benefit of

Induction Motor Modelling which gives de-coupling effect of parameters and also these parameters can be independently controlled.

IV. SIMULATION RESULTS

The electromagnetic torque and the load torque are shown in the figure below. The load torque is given as step input which acts as a variable load torque.
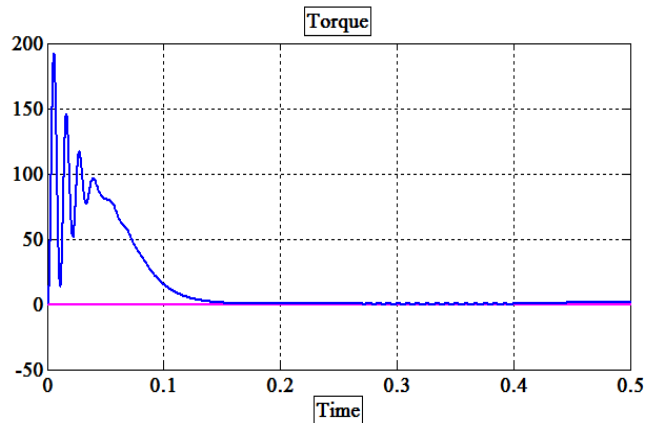

Fig. 10. Simulation results of electromagnetic torque matching the load torque

Here, after the initial transients the electromagnetic torque is matching the load torque. Therefore, Induction Motor Modelling facilitates independent control over the parameters to get the desired outputs. Also, for better and independent control of parameters, any additional control technique can be applied to the input side of induction motor after the Induction Motor Modelling is done [9], [10]
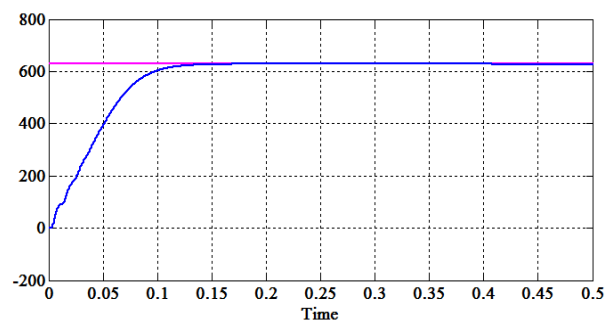

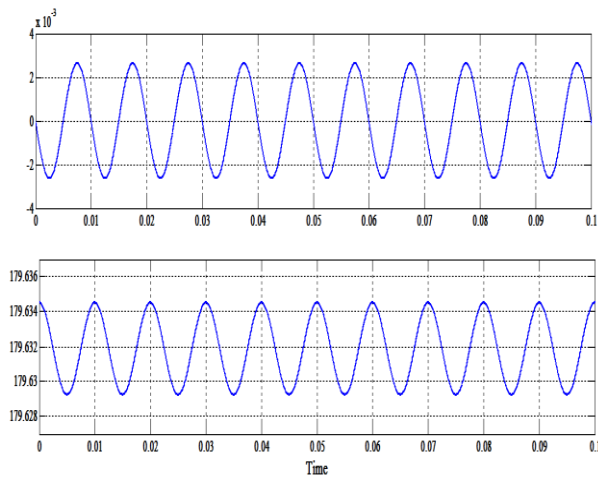Fig. 11. Simulation result of speed of induction motor

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

V. CONCLUSION

Induction Motor Modelling has the benefit of de-coupling the parameters which in turn gives us the advantage of independent control over the parameters. Also, considering Induction Motor Modelling as the base technique, any advance control technique can be applied to Induction Motor Modelling to reinforce the performance of induction motor.

In this modelling, we find d-axis and q-axis currents (i.e. direct-axis and quadrature-axis currents), which are 90° apart from each other. Current 'id' lies in the direction of flux and current 'iq' lies in the direction of torque. Therefore the variables or parameters are easily available for control which was not possible without this technique. Hence, inter-dependent variables become independent parameters because of which change of one parameter does not affect the other parameters.

VI. REFERENCES

[1]. Dal Y. Ohm, "Dynamic Model of Induction Motors for Vector Control".

[2]. Burak Ozpineci & Leon M. Tolbert, "Simulink Implementation of Induction Machine Model – A Modular Approach", 0-7803-7817-2/03/$17.00 ©2003 IEEE

[3]. A A Ansari, and D M Deshpande, "Mathematical Model of Asynchronous Machine in MATLAB Simulink", A. Ansari et. al. / International Journal of Engineering Science and Technology 1 Vol. 2(5), 2010, 1260-1267.

[4]. Sifat Shah, A. Rashid, and MKL Bhatti, "Direct Quadrate (D-Q) Modeling of 3-Phase Induction Motor Using MatLab / Simulink", Canadian Journal on Electrical and Electronics Engineering Vol. 3, No. 5, May 2012

[5]. M. V. Palandurkar, J.P. Modak and S. G. Tarnekar, "Elimination of a Flywheel in a Process Machine by Controlling Power Frequency of the Main Drive", M. V. Palandurkar et al. / International Journal of Engineering Science and Technology (IJEST), ISSN : 0975-5462 Vol. 3 No. 4 April 2011

[6]. Lionel Hutt, Donald Vollrath and Casey Carey, "Modern VVVF Drives", Educational Focus: Elevator Drive Systems

[7]. Dong Hwa Kim, Kaoro Hirota, "Vector control for loss minimization of induction motor using GA-PSO", Applied soft computing, Volume 8, Issue 4, September, 2008.

[8]. Paul C. Krause, Oleg Wasynczuk and Scott D. Sudhoff, "Analysis of Electric Machinery and Drive Systems", Second Edition, IEEE Press

[9]. Bimal K. Bose, "Modern Power Electronics and AC Drives", Prentice Hall PTR, © 2002.

[10]. R. Krishnan, "Electric Motor Devices, modeling, Analysis and control",Prentice-Hall, Inc., New Jersy, ©2001.