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Modeling Simulation and Transfer Matrices Determination for Induction Motor

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Abstract— In this paper a new method for modeling, simulation and the transfer matrices determination for d-q channels of induction motor were developed. Because the induction motor has a nonlinear mathematical model, an original approach based on system theory and a decupled method to avoid the nonlinearities was used. In order to determine the transfer matrices along the inputs (voltages)-state (fluxes)-outputs (currents) channels the Laplace transformation and linear algebra was used. Simulink models, simulation results and transfer matrices for initial and decupled motor has be compared showing very close results and these validate the used method.

Index Terms— Decupled model, Induction machine, State equations, Simulink results, Transfer matrices, Validation results.

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1 INTRODUCTION

The induction motor represents the main drive system for technological machines due to its simplicity and robustness and together with the power electronics (inverters) it also provides a speed and moment control in wide limits. Due to these possibilities in the last decades the induction machine used as an asynchronous motor has benefited from profound studies that have proposed various mathematical models for designing such drives control with notable results [11], [12], [13]. This has resulted in the possibility of implementing advanced control algorithms such as adaptive, optimal or sensorsless. Such applications are possible for linear mathematical models or easy linearizable within a narrow field around the stationary operating point. This solution works well for systems with low dynamics, at which the speed oscillates within reduced limits around the static point. Otherwise the robustness of the system decreases inadmissible. Unfortunately, the induction machine has the nonlinear mathematical model and this is a difficult barrier to be avoided. If we look at the mathematical model given by the equation system (1) the first observation is that we have a complex MIMO system (Multi input multi output) order of four [14]. The second observation is that equations (2), (6), (9) are nonlinear which provide the feedback connection for speed stabilization. The third, quite frustrating, observation that is the impossibility of finding a solution of the equation system (1) in order to appreciate the dynamics of the machine.

The proposed strategy to overcome these difficulties consisted of the following:
Using principle “divide and conquer” to reduce complexity from four to two dimensions. Decoupling the speed nonlinearities and replacing them with two approximate feedback functions. Using MIMO system theory and Laplace transformation to solve the equations and to get the transfer matrices.
We will consider that the "Induction Machine" system is brought in rectangular d-q Clarke coordinates [6], [13]. By analyzing the machine's mode of operation in the order of energy transfer along of d-q channels, it shows that voltages are inputs and fluxes are outputs. For the choice of state, we see that the current is a measurable input effect that contains consistency information about the “history” of the motor's dynamics as a system. Thus, the triplet’s u_d, i_d, Ψ_d and u_q, i_q, Ψ_q represent respectively inputs, states and outputs vectors, each vector having two components, one for stator and other for rotor.

In order to model and simulate the induction machine we will based on theory of state equations and linear algebra. Is used the s, r, u_{ij}, i_{ij}, Ψ_{ij}, L_i, R_i, ω, M, J, M_s indexes for stator, rotor, input voltages, currents, fluxes, inductances, resistances, speed, torque, inertia and load, respectively. With the above notations the induction machine mathematical model is the next [5], [10]:

$$
\begin{aligned}
&\dot{\Psi}_{sd} = -R_s \cdot i_{sd} + u_{sd}\\
&\dot{\Psi}_{rd} = -R_r \cdot i_{rd} + u_{rd} - \omega \cdot \Psi_{rq}\\
&\Psi_{sd} = L_s \cdot i_{sd} + L_m \cdot i_{rd}\\
&\Psi_{rd} = L_r \cdot i_{rd} + L_m \cdot i_{sd}\\
&\dot{\Psi}_{sq} = -R_s \cdot i_{sq} + u_{sq}\\
&\dot{\Psi}_{rq} = -R_r \cdot i_{rq} + u_{rq} + \omega \cdot \Psi_{rd}\\
&\Psi_{sq} = L_s \cdot i_{sq} + L_m \cdot i_{rq}\\
&\Psi_{rq} = L_r \cdot i_{rq} + L_m \cdot i_{sq}\\
&M = \frac{3}{2} \cdot \frac{L_m}{L_s \cdot L_r - L_m^2} (\Psi_{rd} \cdot \Psi_{sq} - \Psi_{rq} \cdot \Psi_{sd})\\
&\dot{\omega} = \frac{M - M_s}{J}
\end{aligned}
\qquad (1)
$$

Equations 2, 6 of the above model are nonlinear, this being the barrier that does not allow determination the solutions of the model. To solve the problem, we will use the method of decoupling the nonlinearities given by above equations and their replacement with a feedback voltage (FV) that approximates their functions. To implement this original method, we need to know the role and variation form of these nonlinearities. For this we have to make the block diagram, the Simulink model and interpret the simulation results.

2 Modeling and Simulation of Nonlinear Induction Motor

First, using mathematical model (1) the equations were grouped for each channel d-q in order to achieve a comprehensible block diagram as shown in Fig. 1, enfacing the direct and feedback connections. From the equations 2 and 6, we see the nonlinear terms $\omega \cdot \Psi rd$, $\omega \cdot \Psi rq$ which represent the feedback voltages ufd and ufq. These two terms will be decupled and included in a new block, named Feedback voltages block (FV)

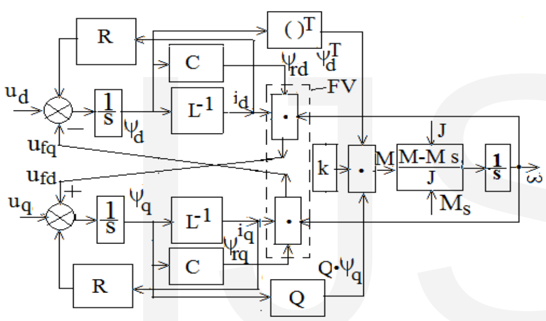

Fig. 1. Block diagram of induction motor

In order to systesize the feedback voltages u_{fd}, u_{fq} the Simulink model was designed as presented in Fig. 2 and were extracted from this the results of simulation [1], [8]. From the simulations results we can see that u_{fd} and u_{fq} has form of the fluxes (sinusoidal), modulated by speed ω. For channel-d the flux depends of cosinus and for channel-q by sinus.

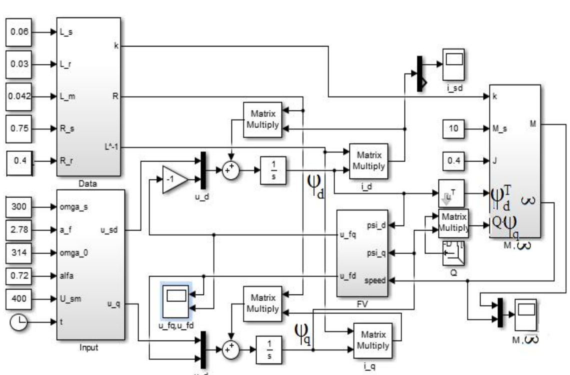

Fig. 2. Simulink model of nonlinear induction motor

In the simulation results of Fig. 3 the feedback voltages are deformed at the start of machine because the nonlinearities.

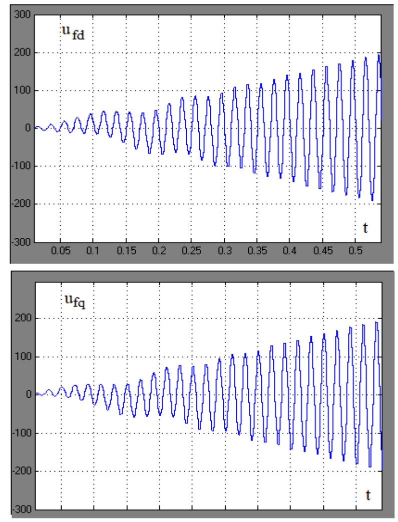

Fig. 3. Feedback voltages from nonlinear model

The torque M have strong oscillations during the acceleration of the machine after which it passes into the stable stationary mode when the machine torque is balanced by the static torque M_s. Speed ω tends to stable stationary value as seen in Fig. 4.

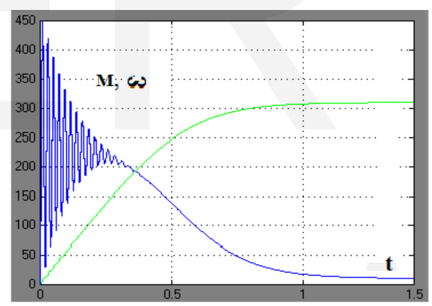

Fig. 4. Torque and speed

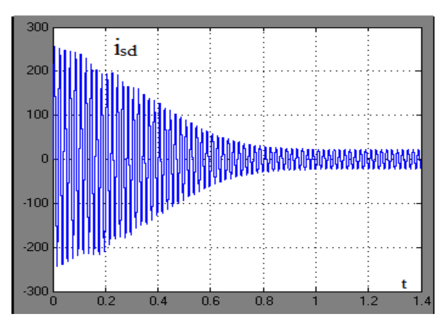

Fig. 5. Variation of stator current on d-channel

The current is high to the motor start, and decrease on static current in steady state, as shown in Fig. 5. In Fig. 6 is presented the speed variation of the motor ω and it's approximated by ω_{ap}. The next equations are the approximation for decupled:

$\omega_{ap} = \omega_s \cdot (1-e^{-a_f \cdot t})$

$$u_{fd} = \omega_s \cdot (1-e^{-a_f \cdot t}) \cdot u_{fd} U_s \cdot \cos(\omega_0 . t) \quad (2)$$

$u_{fq} = \omega_s \cdot (1-e^{-a_f \cdot t}) \cdot U_s \cdot \sin(\omega_0 . t)$

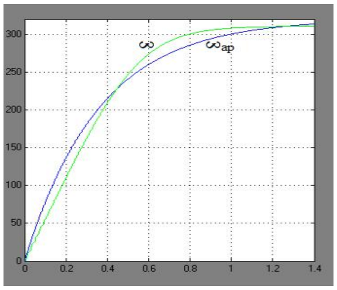

Fig. 6. Approximation of speed ω by ω_{ap}

Fig. 7 shows the approximation of the feedback voltages using equations (2). The main difference occurs in the start-up period of the motor.

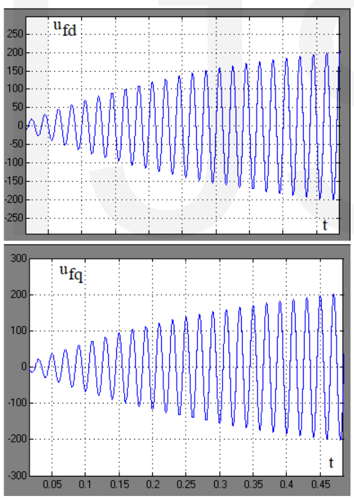

Fig. 7. Feedback voltage approximation diagram

3 Modeling and simulation the linear model induction motor with FV generator

If we decuple the FV from the speed and torques, as see on Figure 1, this become an independent bloc which send the voltages u_{fd}, u_{fq} as inputs to the model which become linear.

We organize the mathematical model as equations of input-state-output. Each of d, q channels have two direct inputs u_{sd}, u_{rd} and u_{sq}, u_{rq} and one pair u_{fq}, u_{fd} produced by FV block:

$u_{sd} = U_{sm} \sin \omega_0 . t$, $u_{rd} = -U_{rm} \cos \omega_0 . t$,

$$u_{fq} = -a \cdot U_{sm} \cdot \frac{\omega_s}{\omega_0} \cdot (1 - e^{-a_f \cdot t}) \cdot \sin \omega_0 \cdot t \quad (3)$$

$u_{sq} = -U_{sm} \cos \omega_0 . t$, $u_{rq} = -U_{rm} \sin \omega_0 . t$

$$u_{fd} = -a \cdot U_{sm} \cdot \frac{\omega_s}{\omega_0} \cdot (1 - e^{-a_f \cdot t}) \cdot \cos \omega_0 \cdot t. \quad (4)$$

The state are currents (i_{sd}, i_{rd}), (i_{sq}, i_{rq}) and output are fluxes (ψ_{sd}, ψ_{rd}), (ψ_{sq}, ψ_{rq}). We use the matrices:

$$L = \begin{bmatrix} L_s & L_m \\ L_m & L_r \end{bmatrix}, \quad L^{-1} = \begin{bmatrix} \frac{L_r}{\Delta} & -\frac{L_m}{\Delta} \\ -\frac{L_m}{\Delta} & \frac{L_s}{\Delta} \end{bmatrix} \quad (5)$$

$$R = \begin{bmatrix} -R_s & 0 \\ 0 & -R_r \end{bmatrix} \quad (6)$$

With the notation before the equations for channel-d are:

$$\begin{bmatrix} \dot{\psi}_{sd} \\ \dot{\psi}_{rd} \end{bmatrix} = \begin{bmatrix} -R_s & 0 \\ 0 & -R_r \end{bmatrix} \times \begin{bmatrix} i_{sd} \\ i_{rd} \end{bmatrix} + \begin{bmatrix} u_{sd} \\ u_{rd} - u_{fq} \end{bmatrix} \quad (7)$$

$$\begin{bmatrix} \psi_{sd} \\ \psi_{rd} \end{bmatrix} = \begin{bmatrix} L_s & L_m \\ L_m & L_r \end{bmatrix} \times \begin{bmatrix} i_{sd} \\ i_{rd} \end{bmatrix} \quad (8)$$

The same equations can be written for channel-q:

$$\begin{bmatrix} \dot{\psi}_{sq} \\ \dot{\psi}_{rq} \end{bmatrix} = \begin{bmatrix} -R_s & 0 \\ 0 & -R_r \end{bmatrix} \times \begin{bmatrix} i_{sq} \\ i_{rq} \end{bmatrix} + \begin{bmatrix} u_{sq} \\ u_{rq} + u_{fd} \end{bmatrix} \quad (9)$$

$$\begin{bmatrix} \psi_{sq} \\ \psi_{rq} \end{bmatrix} = \begin{bmatrix} L_s & L_m \\ L_m & L_r \end{bmatrix} \times \begin{bmatrix} i_{sq} \\ i_{rq} \end{bmatrix} \quad (10)$$

Combing equations (7) and (8), (9) and (10), $\Delta = L_s L_r - L_m^2$, for u_{rd}=u_{rq}=0, that mean induction motor with squirrel cage rotor, we get the input-state-state-output equations:

$$\begin{bmatrix} L_s & L_m \\ L_m & L_r \end{bmatrix} \times \begin{bmatrix} \dot{i}_{sd} \\ \dot{i}_{rd} \end{bmatrix} = \begin{bmatrix} -R_s & 0 \\ 0 & -R_r \end{bmatrix} \times \begin{bmatrix} i_{sd} \\ i_{rd} \end{bmatrix} + \begin{bmatrix} u_{sd} \\ -u_{fq} \end{bmatrix} \quad (11)$$

$$\begin{bmatrix} \psi_{sd} \\ \psi_{rd} \end{bmatrix} = \begin{bmatrix} L_s & L_m \\ L_m & L_r \end{bmatrix} \times \begin{bmatrix} i_{sd} \\ i_{rd} \end{bmatrix} \qquad \Delta = L_s L_r - L_m^2, \quad (12)$$

$$\begin{bmatrix} L_s & L_m \\ L_m & L_r \end{bmatrix} \times \begin{bmatrix} \dot{i}_{sq} \\ \dot{i}_{rq} \end{bmatrix} = \begin{bmatrix} -R_s & 0 \\ 0 & -R_r \end{bmatrix} \times \begin{bmatrix} i_{sq} \\ i_{rq} \end{bmatrix} + \begin{bmatrix} u_{sq} \\ u_{fd} \end{bmatrix} \quad (13)$$

$$\begin{bmatrix} \Psi_{sq} \\ \Psi_{rq} \end{bmatrix} = \begin{bmatrix} L_s & L_m \\ L_m & L_r \end{bmatrix} \times \begin{bmatrix} i_{sq} \\ i_{rq} \end{bmatrix} \quad (14)$$

We introduce the following vectors $i_d=[i_{sd}, i_{rd}]^T$, $i_q=[i_{sq}, i_{rq}]^T$, $u_d=[u_{sd}, -u_{fq}]^T$, $u_q=[u_{sq}, u_{fd}]^T$, $\Psi_d=[\Psi_{sd}, \Psi_{rd}]^T$, $\Psi_q=[\Psi_{sq}, \Psi_{rq}]^T$. With these notation, the equations before was written more compact as follows:

$$L\cdot(\dot{i_d}) = R\cdot i_d + [u_{sd}, -u_{fq}]^T, \quad \Psi_d = L\cdot i_d$$

$$L\cdot(\dot{i_q}) = R\cdot i_q + [u_{sq}, u_{fd}]^T, \quad \Psi_q = L\cdot i_q \quad (15)$$

$$u_{fq} = -a \times U_{sm} \times \frac{w_s}{w_0} \times (1 - e^{-a_f \times t}) \times \sin w_0 \times t$$

$$u_{fd} = -a \times U_{sm} \times \frac{w_s}{w_0} \times (1 - e^{-a_f \times t}) \times \cos w_0 \times t. \quad (16)$$

$$M = k\cdot \Psi_d^{\,T}\cdot Q\cdot \Psi_q \qquad Q = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$$

Based on the equations group (15), (16) in Fig. 8. are presented the Block diagram, for decupled linear approximations voltages of induction motor. We can see the two channels layout in parallel with two input-state-output variables. The FV generate feedback voltages u_{fd} and u_{fq} which become inputs for channels.

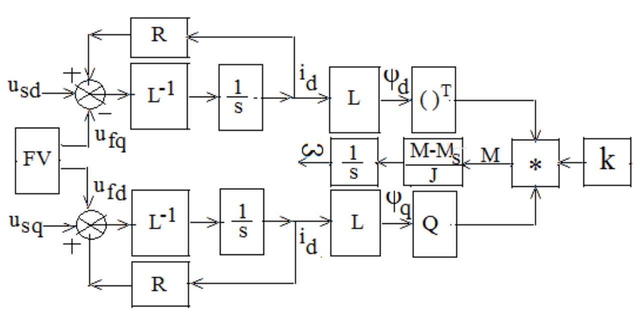

Fig. 8. Block diagram for decupled FV linear voltage

In Fig. 9. was designed the model for decupled FV linear model case and was extracted the simulatin results. There are: feedback voltages u_{fd}, u_{fq}; torque M, speed ω and stator current on d-chanel i_{sd}. These are presented on the Fig. 10 to 12.

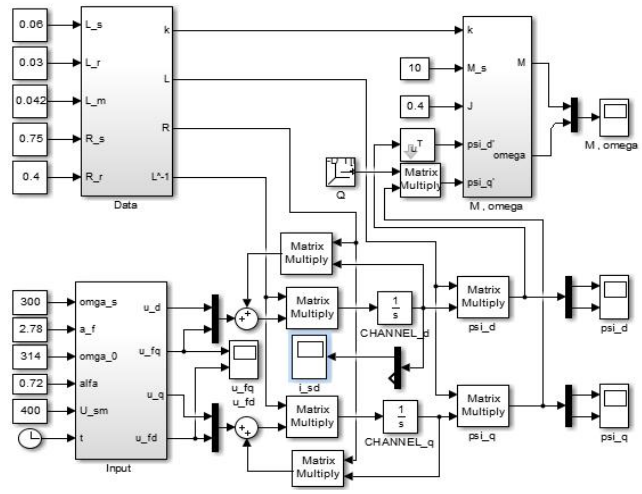

Fig. 9: Simulink model for decupled FV case

In Fig. 10, 11 and 12 can see the simulation results of decupled voltages (u_{fq}, u_{fd}), torque, speed (M, ω) and current i_{sd}. Comparing simulation results of decupled linear model with initial nonlinear model they are almost similar which validate the method.

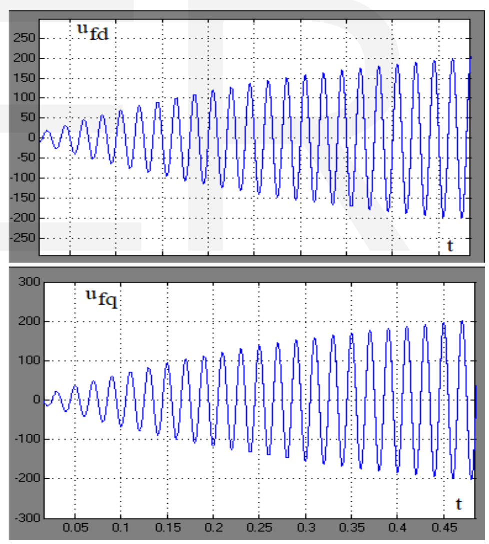

Fig. 10. Output voltages on channels d-q generated by FV

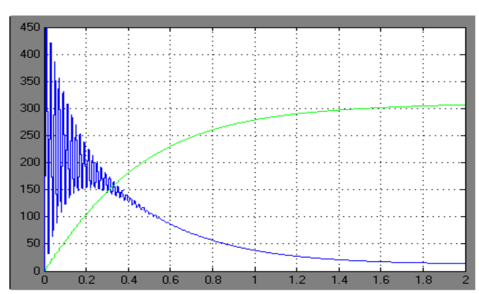

Fig. 11. Torque M and speed ω of decupled FV model

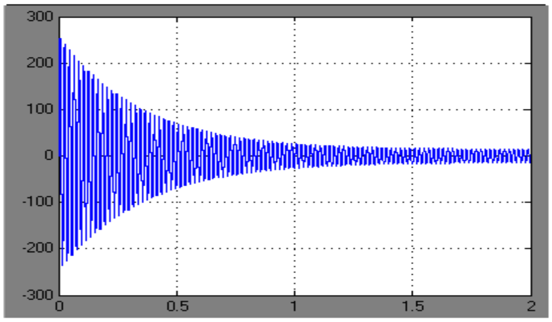

Fig. 12. Current i_{sd} of the decupled FV model

4 Induction motor transfer matrices with FV generator on d-q channels

Obtaining the response of the induction motor system defined by the nonlinear mathematical model (1) means finding the solution of this system of differential equations. In the general case, this cannot normally be obtained. That is why we are turning to the method of transforming the model by decoupling the nonlinearities and replacing them with a feedback function generator FV. In this case, the problem can be solved using the systems theory and the abstract linear algebra [1], [2], [4]. A practical way to determine the response of the linearized system is to use Laplace transformation to obtain a variant of the response in the operational form depending on the s argument. This method uses the transfer matrix multiplied by the input vector to determine the output vector under initial zero conditions. Using the Laplace transformation for the before equations we get the final solutions:

$$i_d = (Ls - R)^{-1} \cdot \mathrm{u_d}, \quad \Psi_d = \mathrm{L} \cdot i_d \qquad (17)$$

$$i_q = (Ls - R)^{-1} \cdot u_q, \quad \Psi_q = \mathrm{L} \cdot i_q \qquad (18)$$

Previous equations can be used to obtain $G_s(s)$ transfer matrix (voltages-currents) and inputs-outputs (voltages-fluxes) G(s). The matrices are the same for both d-q channels:

$$G_s(s)=(Ls-R)^{-1}, \; G(s)=L \cdot (Ls-R)^{-1}=LG_s(s) \qquad (19)$$

Using electromagnetics parameter L, R the final transfer matrix from voltages to currents is $G_s(s)$ is:

$$\begin{bmatrix} \dfrac{\frac{L_r}{\Delta}s + \frac{R_r}{\Delta}}{s^2 + \frac{L_sR_r + L_rR_s}{\Delta}s + \frac{R_sR_r}{\Delta}} & \dfrac{-\frac{L_m}{\Delta}s}{s^2 + \frac{L_sR_r + L_rR_s}{\Delta}s + \frac{R_sR_r}{\Delta}} \\ \dfrac{-\frac{L_m}{\Delta}s}{s^2 + \frac{L_sR_r + L_rR_s}{\Delta}s + \frac{R_sR_r}{\Delta}} & \dfrac{\frac{L_s}{\Delta}s + \frac{R_s}{\Delta}}{s^2 + \frac{L_sR_r + L_rR_s}{\Delta}s + \frac{R_sR_r}{\Delta}} \end{bmatrix}$$

Also, the transfer matrix from voltages to fluxes G(s) is:

$$\begin{bmatrix} \dfrac{s + \frac{R_rL_s}{\Delta}}{s^2 + \frac{L_sR_r + L_rR_s}{\Delta}s + \frac{R_sR_r}{\Delta}} & \dfrac{\frac{L_mR_s}{\Delta}}{s^2 + \frac{L_sR_r + L_rR_s}{\Delta}s + \frac{R_sR_r}{\Delta}} \\ \dfrac{\frac{L_mR_r}{\Delta}}{s^2 + \frac{L_sR_r + L_rR_s}{\Delta}s + \frac{R_sR_r}{\Delta}} & \dfrac{s + \frac{L_rR_s}{\Delta}}{s^2 + \frac{L_sR_r + L_rR_s}{\Delta}s + \frac{R_sR_r}{\Delta}} \end{bmatrix}$$

5 Numeric application

In this paragraph will be applied the procedure presented in the before paragraph to a real induction motor for determined the transfer matrices and the model. After we be compared if the results are similar to the real ones.
The induction motor has the electromagnetic parameters: R_s=0.75 Ω; R_r=0. 4 Ω; L_s=0.06 H; L_r=0.03 H; L_m=0.042 H;
Nominal electro mechanics' parameters are: U_{sm}=400 V; ω_0=314 s^{-1}; ω=300s^{-1}; a_f=2.78; α=0.72; M_s=10 Nm; J=0.4 kgm^2;
Input-state transfer matrix $G_s(s)$ for d-q channel provide the state response:

$$\begin{bmatrix} i_{sd} \\ i_{rd} \end{bmatrix} = G_s(s) \times \begin{bmatrix} u_{sd} \\ u_{fq} \end{bmatrix}, \quad \begin{bmatrix} i_{sq} \\ i_{rq} \end{bmatrix} = G_s(s) \times \begin{bmatrix} u_{sq} \\ u_{fd} \end{bmatrix} \qquad (20)$$

Replacing the parameter values in the transfer matrix $G_s(s)$ obtained the final form of $G_s(s)$:

$$G_s(s) = \begin{bmatrix} \dfrac{833s+1111}{s^2+1292s+8333} & -\dfrac{1166s}{s^2+1292s+8333} \\ -\dfrac{1166s}{s^2+1292s+8333} & \dfrac{1666s+20833}{s^2+1292s+8333} \end{bmatrix}$$

Currents as state on the d-q channels are given by the equations billow:

$$i_{sd} = \frac{833s + 1111}{s^2 + 1292s + 8333} \cdot u_{sd} - \frac{1166s}{s^2 + 1292s + 8333} \cdot u_{fq}$$

$$i_{rd} = -\frac{1166s}{s^2+1292s+8333} \cdot u_{sd} - \frac{1666s+20833}{s^2+1292s+8333} \cdot u_{fq}$$

$$i_{sq} = \frac{833s + 1111}{s^2 + 1292s + 8333} \cdot u_{sq} - \frac{1166s}{s^2 + 1292s + 8333} \cdot u_{fd}$$

$$i_{rq} = -\frac{1166s}{s^2 + 129s + 8333} \cdot u_{rq} - \frac{1666s + 20833}{s^2 + 1292s + 8333} \cdot u_{fd}$$

Input-output transfer matrix G(s) for d-q channel provide the output response in general format and in numerical values:

$$\begin{bmatrix}\Psi_{sd}\\ \Psi_{rd}\end{bmatrix} = G(s)\cdot\begin{bmatrix}u_{sd}\\ u_{fq}\end{bmatrix}, \quad \begin{bmatrix}\Psi_{sq}\\ \Psi_{rq}\end{bmatrix} = G(s)\cdot\begin{bmatrix}u_{sq}\\ u_{fd}\end{bmatrix} \quad (21)$$

$$G(s)=\begin{bmatrix}\frac{s+667}{s^2+1292s+8333} & \frac{875}{s^2+1292s+8333}\\ \frac{467}{s^2+1292s+8333} & \frac{s+625}{s^2+1292s+8333}\end{bmatrix}$$

Fluxes as outputs on the d-q channels are given by equations:

$$\Psi_{sd} = \frac{s+667}{s^2+1292s+8333}\cdot u_{sd} + \frac{875}{s^2+1292s+8333}\cdot u_{fq}$$

$$\Psi_{rd} = \frac{467}{s^2+1292s+8333}\cdot u_{sd} + \frac{s+625}{s^2+1292s+8333}\cdot u_{fq}$$

$$\Psi_{sq} = \frac{s+667}{s^2+1292s+8333}\cdot u_{sq} + \frac{875}{s^2+1292s+8333}\cdot u_{fd}$$

$$\Psi_{rq} = \frac{467}{s^2+1292s+8333}\cdot u_{rq} + \frac{s+625}{s^2+1292s+8333}\cdot u_{fd}$$

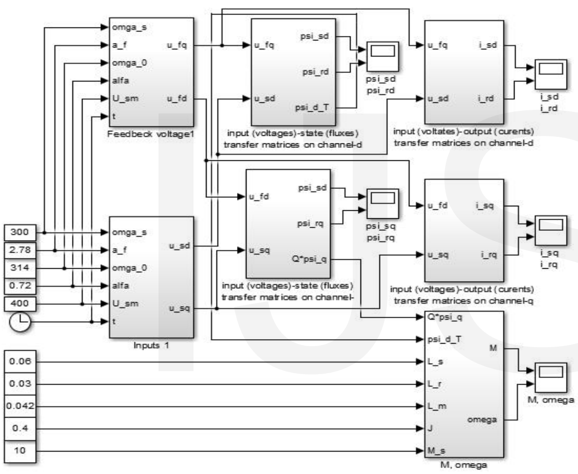

Fig. 13. Simulink model for the FV motor with matrices

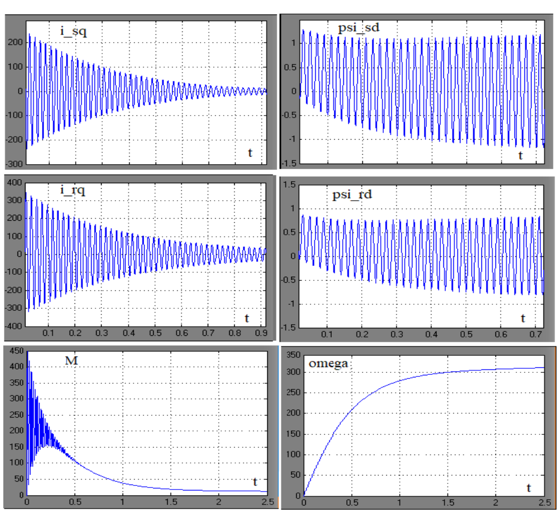

Fig. 14. Output response of induction motor with transfer matrices

This Simulink model with matrices of Figures 13 and the simulation results of Figure 14 approximate with accuracy the nonlinear induction motor model. The forms of transfer matrices can be used to developed the advance algorithms like adaptive, optimal, sensor less etc [3], [7], [9].

6 Conclusions

The induction motor has benefited from profound studies and was proposed various mathematical models for designing some controllers with notable results like field and torque oriented control. Regarding the implementation of advanced algorithms such as Adaptive Control, Optimal, Sensor Less or Kalman Filters, for the systems control with induction motor, results are still awaited. The induction machine has the nonlinear mathematical model and this is a difficult barrier to be avoided. It is quite frustrating observation, the impossibility of finding a solution or some transfer matrices for the equations system (1) in order to appreciate the dynamics of the machine. In this paper is used a decupling method to avoid the difficulties of nonlinearity influences. This method goes to get a MIMO linear system which can be solved using theory and linear algebra. To get a better approximation of nonlinearities was designed the Simulink model and the simulation result was analyzed as shown in the figures above. An important result is the linear model with Feedback Voltage (FV) which generate the outputs very similar with the original one. The next important result is the obtaining the transfer matrices for d-q channels, a new model based on these matrices and the expected results. The matrices can be used for approach the implementation advanced algorithms [3], [17]. In the final part of the paper the Simulink model with transfer matrices were tested on a real induction machine and the results were the ones expected.

References

[1] G. Besancon, Nonlinear Observer and Applications, Springer-Verlag, Berlin, Heidelberg, 2007.
[2] L. von Bertolonffy, General System Theory, Library of congress, New York, 1972.
[3] L. Bogdanffy, E. Pop, G. Ilcea, "HIL Simulation as Rapid Prototyping Method in Control Engineering", International Journal of Circuits and Electronics, Vol-1, 2016, ISSN 2367-8879, pp.83-88.
[4] L. Bogdanffy, E. Pop, Ionut-Alin Popa, "Rapid Prototyping for Optimal Control of Electrical Drives", International Journal of Control Systems and Robotics, Vol-1, 2016, ISSN 2367-8817, pp.133-138.
[5] I. Boldea, S.A. Nasar, Vector Control of AC Drive, CRC Press LLC, 1992.
[6] S. L. Constantinescu, K. Soal, Electrische Machinen und Antriebssysteme, Springer, 1999.
[7] P. Ioannu, B. Fidan, Robust Adaptive Control, Prentice Hall, 1995.
[8] V. Ionescu, A. Varga, Teoria sistemelor, Editura All, Bucuresti 1994.

[9] J. Juang, M.Q. Phan, Identification and Control of Mechanical Systems, Cambridge University Press, 2004.
[10] A. Kelemen, Sisteme de Reglare cu Orientare Dupa Camp, Editura Tehnica Bucuresti, 1989.
[11] P. Kovacs, Analiza regimurilor tranzitorii ale masinilor electrice, Ed. Tehnica, Bucuresti, 1980.
[12] W. Leonhard, Control of Electrical Drives, Springer Verlag, Berlin, 1996.
[13] N. Mohan, Advanced electric drives: Analysis, Control, and Modeling Using MATLAB / Simulink, John Wiley & Sons, 2014.
[14] E. Pop, R. Bubatu, Teoria sistemelor, educatie prin E-Learning, Universitas Press, Petrosani, 2012.
[15] E. Pop, "Practically Algorithm, Modeling and Simulation of Luenberger Observer ", Proceedings of the 12th International Conference on Applied Computer, Kuala Lumpur, April 2-4, 2013, pp. 53-59.
[16] E. Pop, C. Covaciu, A. Avram, F. Neghina, "Adaptive Control Strategy for Conveyor Drive Systems", Proceedings of the 8th WSEAS International Conference on Circuits, Systems, Electronics, Control and Signal, Puerto de la Cruz, Tenerife, Canary Island, Spain, ISBN 970 960 474 139 7, ISSN 1790 5117, pp. 156-161, 2009.
[17] E. Pop, F. Neghina, M. Leba, C. Barbu, Controlul adaptiv al sistemelor automate, Editura Didactica si Pedagogica, Bucuresti, ISBN 978 973 30 2699, 2010.
[18] E. Pop, M. Leba, "Simulation and Design of Nonlinear Controllers based on Distributions Theory", Proceedings of the 6th WSEAS International Conference on System Science and Simulation in Engineering (ICOSSSE '07), Venice, Italy, ISBN 978 960 6766 14 5, ISSN 1790 5117, pp. 103-108, 2007.

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