Online Tuning of Stator Resistance in DTC Drive Based on Wavenet Theory

Majid A. Alwan
Computer Department, College of Engineering, Basrah University.

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Abstract:

Direct torque control (DTC) needs the stator resistance of the induction motor for the estimation of stator flux. The variation of stator resistance due to temperature and stator frequency changes will greatly affect the performance of DTC drive run at low speed. In this paper, a method for the tuning of changes in stator resistance during the operation of the machine is proposed. The tuning method is based on wavenet theory. To show the ability of the proposed method, a PI stator resistance tuner is presented. The tuners observe the magnitude of stator flux of the machine to detect the changes in stator resistance. The performances of the two methods are compared using Matlab/Simulink simulation results. The simulation results show that the proposed wavenet stator resistance tuner efficiently improves the DTC performance, superior to the PI stator resistance tuner.

Keywords: Stator resistance, Wavenet, DTC, Induction Motor.

1- Introduction:

High performance inverter-fed induction motor drives with no mechanical speed sensor are desirable for the industrial applications. A control scheme, which achieves that for induction motor is the direct torque control DTC [1]. The drive uses feedback control of electromagnetic torque and stator flux linkages which are estimated in stator d-q reference frame using the measured stator voltages and currents. The electromagnetic torque T_e and stator flux (magnitude $|\lambda_s|$ and angle θ_s) are determined using the following equations [2,3]

$$\bar{\lambda}_s = \int (\bar{v}_s - R_s \bar{i}_s)\, dt \quad (1)$$

$$T_e = \frac{3}{2} P(\lambda_{ds} i_{qs} - \lambda_{qs} i_{ds}) \quad (2)$$

$$|\lambda_s| = \sqrt{\lambda_{ds}^{\;2} + \lambda_{qs}^{\;2}} \quad (3)$$

$$\theta_s = \tan^{-1} \frac{\lambda_{qs}}{\lambda_{ds}} \quad (4)$$

where $\bar{\lambda}_s = [\lambda_{ds}\ \lambda_{qs}]^T$, $\bar{v}_s = [v_{ds}\ v_{qs}]^T$, $\bar{i}_s = [i_{ds}\ i_{qs}]^T$, $R_s = \begin{bmatrix} R_s & 0 \\ 0 & R_s \end{bmatrix}$ and P is the number of poles.

The estimation of the electromagnetic torque and stator flux does not depend on motor parameters except for stator resistance. The variation of stator resistance due to temperature and frequency degrades the DTC controller performance especially at low speed. Particularly, at low speeds, the stator resistance voltage drop is relatively large and may become comparable to the back emf. Therefore, the accurate value of the stator resistance is of crucial importance for correct operation of the drive, since any mismatch between the actual value and the value used within the torque and flux estimator may lead not only to a substantial performance error but for instability [4]. The tuning for the effect of the variation of stator resistance then becomes necessary.

To overcome this problem, several control schemes have been proposed such as the nonlinear stator flux observer [5,6], real time PI estimator for tuning stator resistance [7,8], online fuzzy stator resistance observer [9,10] and the stator resistance tuner based on artificial neural network (ANN) [11,12].

The combination of ANN with wavelet transform (wavenet), behaves good localization property in both time and frequency space and multi-scale property. It is used for the analysis of non-stationary signals and learning of the nonlinear functions. [13]. This technique is also proposed to tune the stator resistance in DTC drive [14]. The stator current error and the change in stator current error are used as inputs nodes and the synthesized method of recursive orthogonal least squares algorithm is used to fulfill the tuner structure and stator resistance tuning.

In this paper, wavenet control scheme is proposed to tune the stator resistance online during the operation of the DTC drive based on stator flux magnitude and a method of steepest descent gradient for updating online the wavenet parameters. To show the ability of the wavenet tuner, a PI stator resistance tuner is simulated. A brief overview of the DTC control scheme, wavenet structure and learning algorithm are presented followed by the results from Matlab/Simulink simulation. The simulation results show that the drive performance is perfectible using the wavenet stator resistance tuner.

2-Principles of DTC Induction Motor Drive

2.1 Induction Motor Model

Based on the theory of induction motor in the stationary reference frame d-q axis, the voltage (v) and the flux linkage ($\bar{\lambda}$) state equations for the stator and rotor are [2]:

$$\begin{bmatrix} v_{ds} \\ v_{qs} \\ v_{dr} \\ v_{qr} \end{bmatrix} = \begin{bmatrix} R_s + L_s P & 0 & L_m P & 0 \\ 0 & R_s + L_s P & 0 & L_m P \\ L_m P & 0 & R_r + L_r P & 0 \\ 0 & L_m P & 0 & R_r + L_r P \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \\ i_{dr} \\ i_{qr} \end{bmatrix} \quad (5)$$

$$\begin{bmatrix} \lambda_{ds} \\ \lambda_{qs} \\ \lambda_{dr} \\ \lambda_{qr} \end{bmatrix} = \begin{bmatrix} L_{1s} + L_m & 0 & L_m & 0 \\ 0 & L_{1s} + L_m & 0 & L_m \\ L_m & 0 & L_{1r} + L_m & 0 \\ 0 & L_m & 0 & L_{1r} + L_m \end{bmatrix} \begin{bmatrix} i_{ds} \\ i_{qs} \\ i_{dr} \\ i_{qr} \end{bmatrix} \quad (6)$$

where v_{ds}, v_{qs}, i_{ds}, i_{qs}, R_s, L_s, and L_m, are the dq-axis stator voltages, stator currents, stator resistance, stator self inductance and mutual inductance between the stator and the rotor winding, respectively. v_{dr}, v_{qr}, i_{dr}, i_{qr}, R_r, L_r, and P are the dq-axis rotor voltages, rotor currents, rotor resistance, rotor self inductance and derivative operator, respectively. L_{1s} and L_{1r} are the stator and rotor leakage inductances respectively.

The electromagnetic torque (T_e) equation for the induction motor can be expressed as follows:

$$T_e = \frac{3}{2} P(\lambda_{ds} i_{qs} - \lambda_{qs} i_{ds}) \quad (7)$$

The electromagnetic dynamic equation describing the mechanical model of the induction motor is:

$$T_e - T_L = J\, P\omega_m + \beta\omega_m \quad (8)$$

where T_L, J, β and ω_m are the load torque, moment of inertia, friction coefficient and the mechanical speed.

Equations (5)-(8) represent the dynamic mathematical model for induction motor in two phase stationary coordinates

2.2 DTC Scheme for Induction Motor

Direct torque control is one of the advanced control schemes for ac drives. It is characterized by simple control algorithm, easy digital implementation and robust operation [3]. Figure (1) shows a typical block diagram of a DTC based induction motor drive.

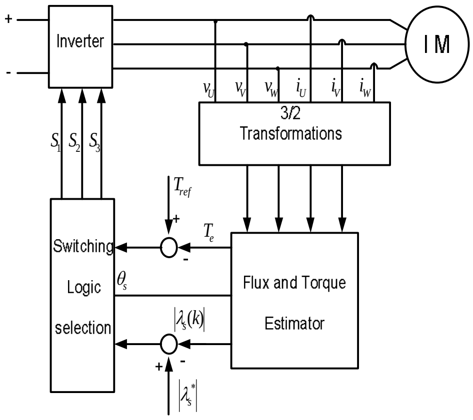

Fig. (1) Block diagram of DTC scheme.

The stator flux reference is compared with the estimated flux and the difference is sent to flux comparator of two outputs 0 and 1. The torque reference is compared with the estimated one and the difference is sent to torque comparator of three outputs 0,1 and -1. The output of the later is 0 or 1 for a certain speed direction. For the opposite direction the output of this comparator is 0 or -1. The outputs of the flux and torque comparators are sent to a switching logic unit for proper selection of the voltage vector of a two level voltage source inverter (VSI). The VSI has six nonzero voltage vectors and two zero voltage vectors [2,3]. The stator flux (magnitude and angle) is directly related with stator voltage vectors which affects stator flux and electromagnetic torque. Thus stator resistance tuning has an important effect on flux and torque estimation.

3. Wavenet Structure and Learning Algorithm

3.1- Wavelet Transform

Wavelet is a little wave of a least minimum oscillation sieving with special satisfaction condition. The wavelet function is defined as follows [15]:

$$h_{a,b}(t) = \frac{1}{\sqrt{|a|}} \; h\left(\frac{t-b}{a}\right) \qquad (9)$$

The corresponding families of dilated and translated wavelet are defined as follows:

$$\left[\; h_{m,n}(x) = a^{\frac{2}{m}} \; h(a^{-m}\; x - nb),\; (m,n) \in z^2 \;\right] \qquad (10)$$

where

$\{h_{m,n}(x)\}$ is called discrete daughter wavelets, $(m,n) \in z^2$ represent the successes resolution level, a and b are the dilation and translation respectively.

Any function $h(x) \in L^2(R)$ (the set of all square integrable or a finite energy function) that satisfy the admissibility condition;

$$\int_R \frac{|h(w)^2|}{|w|} < \propto \qquad (11)$$

is defined as a wavelet function, where $h(w)$ is the Fourier transform of $h(x)$. The wavelet transform is defined as follows [13].

$$\langle h_{m,n}, f \rangle = \int h_{m,n}(t)\; f(t)\; dt \qquad 12)$$

and by using a linear combination of discrete wavelet basis function, equation (12) yields to:

$$f(t) = \sum \langle h_{m,n}, f \rangle \; h_{m,n}(t) \qquad (13)$$

The wavelet transform is widely applied to the analysis of time and frequency space. Therefore it is useful for the analysis of non-stationary signals and the learning of the nonlinear functions.

3.2 Wavenet Structure

Wavenet is a multi-layer feed forward network based on wavelet transform. The structure of wavenet is similar to that of the feed forward network except that the sigmoid function was replaced by wavelet basis function [15] as illustrated in Fig.(2).

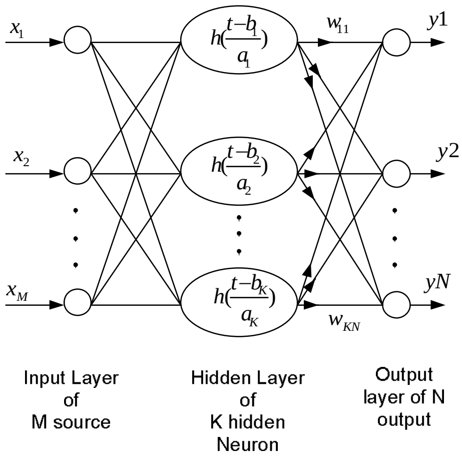

Fig.(2) The structure of wavenet.

The wavenet structure can be expressed by the following formula:

$$y_i = f\left[\sum_{k=1}^{K} w_{ki} \sum_{m=1}^{M} X_m(t)\ h_m((t-b_k)/a_k)\right] \quad (14)$$

where $X_m(m=1,2,...,M)$ is the input for the m-th training vector $X(t)$, $y_i(i=1,2,.....,N)$ is the output for the i-th training vector $Y(t)$, M is the node number of the input layers, K is the node number of hidden layers, w_{ki} is the weight between the k-th node of the hidden layer and the i-th node of the output layer, $h(t)$ is the mother wavelet and f is the nonlinear function.

3.3 Learning Algorithm

In order to determine the adjustable weighs $w_{KN}\ (k=1,2,...K,\ \ n=1,2,...N)$ and the adjustable parameters a_k and b_k, a least mean square (LMS) energy minimizing function can be applied:

$$E = \frac{1}{2}\sum_{l=1}^{q}\sum_{i=1}^{N}[e^l(t)]^2 \quad (15)$$

where $e^l(t) = F_i^l(t) - y_i^l(t)$, q and $F_i^l(t)$ are the number of training samples and the desired value of $y_i^l(t)$. To minimize the energy error E, a method of steepest descent which requires the gradients $\frac{\partial E}{\partial w_{ki}}, \frac{\partial E}{\partial a_k}$ *and* $\frac{\partial E}{\partial b_k}$ is used for updating the incremental changes to each parameter w_{ki}, a_k, *and* b_k. The gradients of E are:

$$\frac{\partial E}{\partial w_{ki}} = -\sum_{l=1}^{q}\sum_{i=1}^{N}\sum_{m=1}^{M} e^l(t)\ X^l(m)\ h(\tau) \quad (16)$$

$$\frac{\partial E}{\partial b_k} = -\sum_{l=1}^{q}\sum_{i=1}^{N}\sum_{m=1}^{M} e^l(t)\ X^l(m)^* \ w_{ki}\frac{\partial h(\tau)}{\partial b_k} \quad (17)$$

$$\frac{\partial E}{\partial a_k} = -\sum_{l=1}^{q}\sum_{i=1}^{N}\sum_{m=1}^{M} e^l(t)\ X^l(m)\ * \ w_{ki}\ \tau\frac{\partial h(\tau)}{\partial b_k} = \tau\frac{\partial E}{\partial b_k} \quad (18)$$

where $\tau = \frac{t-b_k}{a_k}$. The updated weights w_{ki} and the parameters a_k and b_k are:

$$w_{ki}(n+1) = w_{ki}(n) - b_w\frac{\partial E}{\partial w_{ki}} + a_w\,\Delta w_{ki}(n) \quad (19)$$

$$a_k(n+1) = a_k(n) - b_a\frac{\partial E}{\partial a_k} + a_a\,\Delta a_k(n) \quad (20)$$

$$b_k(n+1) = b_k(n) - b_b\frac{\partial E}{\partial b_k} + a_b\,\Delta b_k(n) \quad (21)$$

where b_w, b_a, and b_b are steps size, a_w, a_a, and a_b are the forgetting factors which are variable factors and can greatly reduce the number of iterations for convergence.

4. DTC Performance under Stator Resistance Variation

A three-phase induction motor was used to obtain the simulation results for a variation in the value of motor stator resistance according to a certain pattern while the flux and torque estimator uses the unchanged value of stator resistance. The nominal value of stator resistance for the machine is $0.21\,\Omega$. Figure (3) shows a stator resistance pattern used to obtain the simulation. The pattern starts at a stator resistance of 0.21 Ω and it keeps constant for 3 seconds, then increases to 1.4 times its nominal value for 4 seconds and remains constant for 2 seconds. After that it goes down to the initial value at the same rate change and then remains constant for 3 seconds.

Simulation results are determined using full load condition of the induction motor, motor parameters are given in the Appendix, rated stator flux and a speed command of 100 rad./sec. The drive is operated at steady state for 8 seconds and at this time, the stator resistance of the motor is varied according to the pattern given in Fig. (3). The stator current magnitude and stator flux are calculated as follows

$$\left|\bar{i}_s\right| = \sqrt{(i_{ds})^2 + (i_{qs})^2} \qquad (22)$$

$$\left|\bar{\lambda}_s\right| = \sqrt{(\lambda_{ds})^2 + (\lambda_{qs})^2} \qquad (23)$$

The values of stator current and flux linkage magnitudes have been filtered to attenuate any ripple. Figures (4) and (5) present the developed electromagnetic torque and stator current magnitude for a stator resistance change pattern of Fig. (3) respectively. These plots show the effects of the stator resistance change under the conventional DTC drive. When the stator resistance increases, the developed electromagnetic torque and stator current magnitude increase nonlinearly. Similarly, when the stator resistance decreases, the developed electromagnetic torque and stator current magnitude decrease also nonlinearly. Figure (6) shows the same effects on rotor speed. The speed decreases nonlinearly with increasing in stator resistance and increases also nonlinearly with decreasing in stator resistance. Figure (7) gives the trajectory of stator flux linkage during the stator resistance variation. Thus all the previous variables are not held at the specified commands. This means that the drive performance is affected by stator resistance variation and tuning of stator resistance is necessary to preserve the drive control.

Figure (8) shows the stator current magnitude change for stator resistance change which combines Figs. (5) and (3). It can be seen from this figure that the trajectory of the current is not the same for the increase and decrease in stator resistance. Thus the relation between the two variables is nonlinear

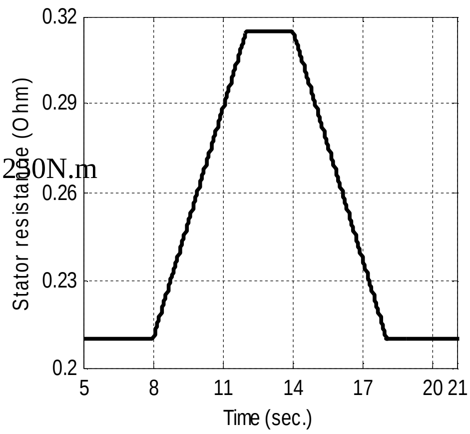

Fig. (3) Stator resistance Pattern used to obtain the simulation

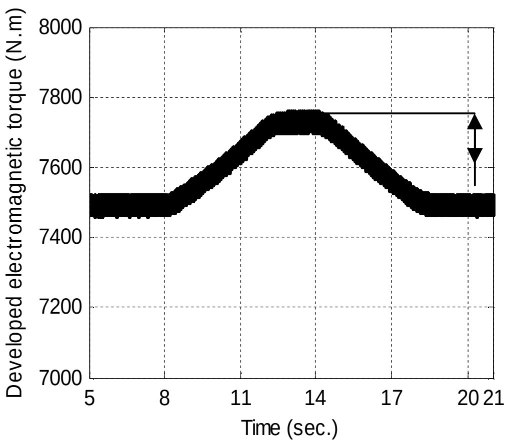

Fig.(4) Torque variation without R_s tuning

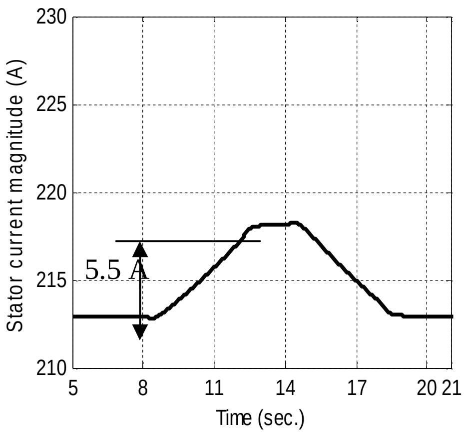

Fig.(5) Current variation without R_s tuning

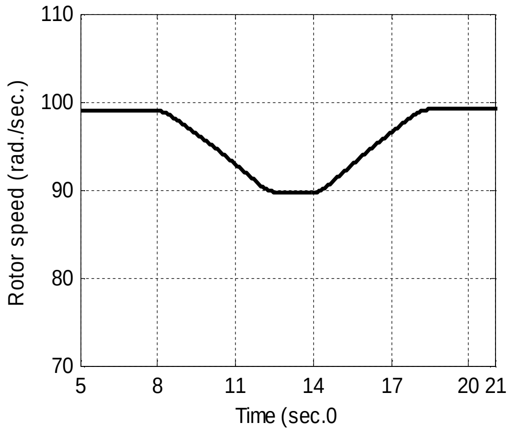

Fig.(6) Speed variation without R_s tuning

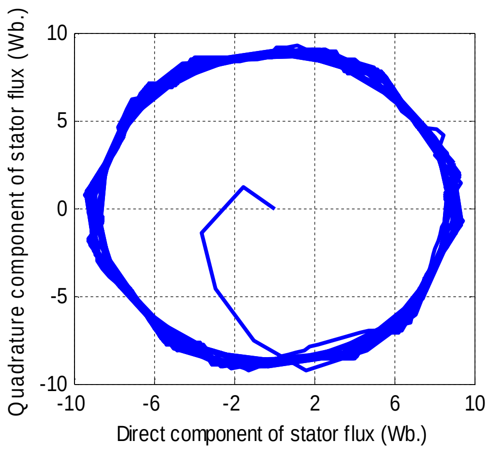

Fig.(7) Flux trajectory without R_s tuning

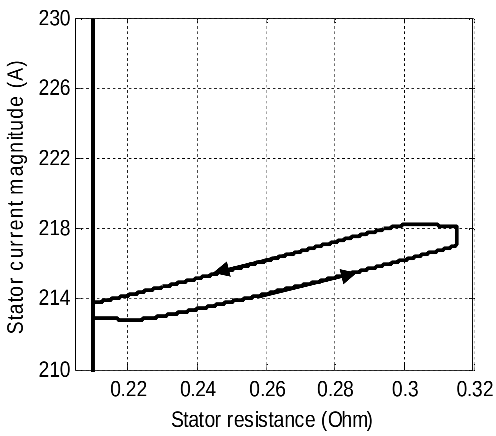

Fig.(8) Stator current-resistance relation

5 DTC Drive Based on PI and Wavenet Stator Resistance Tuners

A tuner has been designed to estimate the change in stator resistance of the induction motor during its operation. The tuner observes the magnitude of stator flux linkage, and if a change is detected, a corresponding change in the stator resistance is made. Two tuners have been designed based on PI control and wavenet theory and tested to improve the DTC drive during the operation.

5.1 PI Resistance Tuner

The block diagram of the PI stator resistance tuner is shown in Fig. (9)

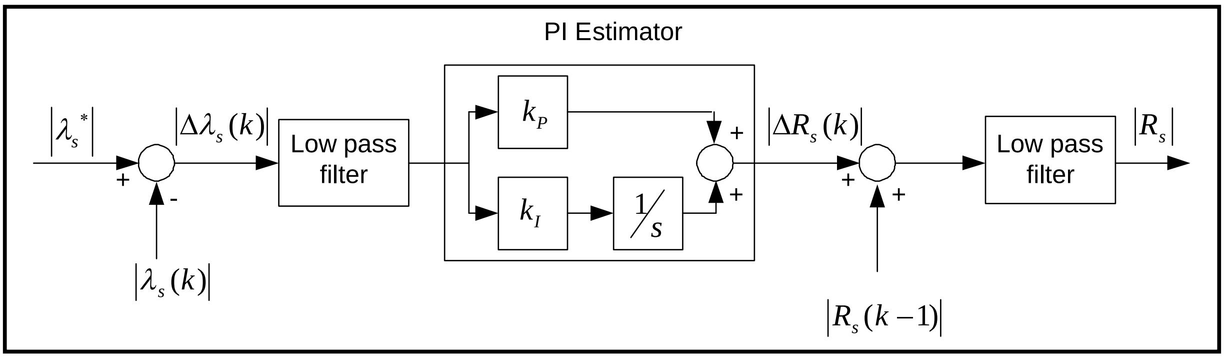

Fig. (9) Block diagram of PI stator resistance tuner

The error $|\Delta\lambda_s(k)|$ between the magnitudes of the estimated stator flux linkage $|\lambda_s(k)|$ and its reference $|\lambda_s^*|$ is proportional to the stator resistance change. This error is used as an input to the PI estimator. The technique is based on the principle that the change in stator resistance will cause a change in the magnitude of stator flux linkage. The equation for PI resistance tuner is given by

$$|\Delta R_s| = (k_P + k_I \frac{1}{s})|\Delta\lambda_s| \tag{24}$$

where K_P and K_I are the proportional and integral gains respectively. The error $|\Delta\lambda_s(k)|$ is passed through a low pass filter with a very low cutoff frequency in order to eliminate high frequency components contained in the magnitude of estimated stator flux linkage. Then the signal is passed through a PI estimator. The coefficients of PI estimator k_P and k_I are determined by trial and error. The output of the PI estimator represents the change in the stator resistance $|\Delta R_s(k)|$ due to change in motor stator resistance. The change $|\Delta R_s(k)|$ is continuously added to the previously tuned stator resistance $|R_s(k-1)|$. The final tuned resistance $|R_s|$ is again passed through a low pass filter to have a smooth variation of stator resistance value. The tuned resistance is used directly in the torque and flux estimator.

5.2 Wavenet Resistance Tuner

Based on wavenet structure presented in section 3, a wavenet network is proposed to tune the stator resistance of the induction motor in DTC drive. Figure (10) shows the structure of the wavenet network and the set up for its online training is shown in Fig.(11)

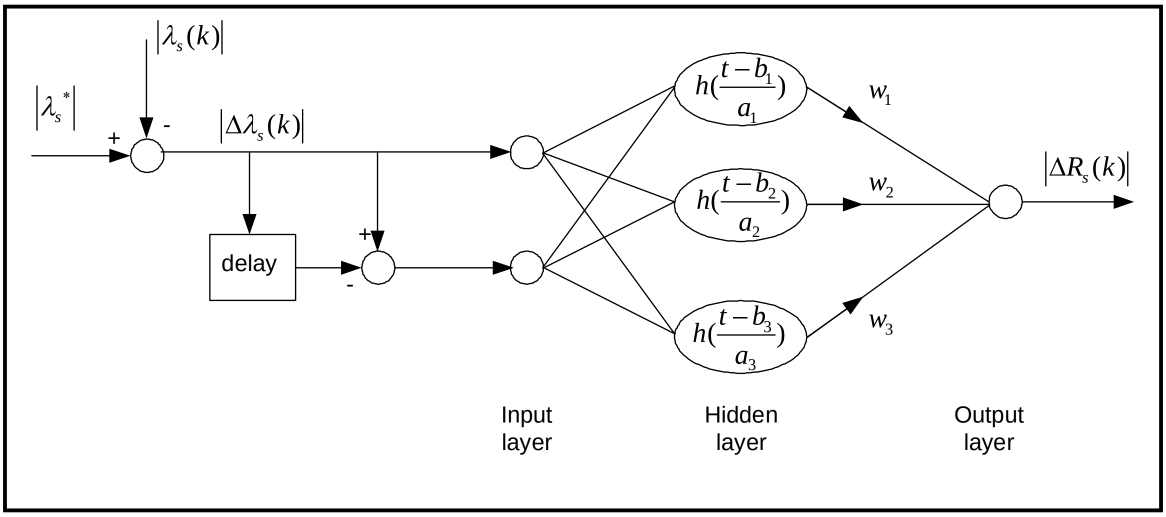

Fig. (10) The wavenet resistance tuner structure

The inputs to the wavenet tuner are the magnitude of stator flux linkage error $|e(k)|$ and the change in this error $|\Delta e(k)|$. They are defined as

$$|e(k)| = |\Delta\lambda_s(k)| = |\lambda_s^*| - |\lambda_s(k)| \quad (25)$$

$$|\Delta e(k)| = |e(k)| - |e(k-1)| \quad (26)$$

The tuned resistance is given by

$$|R_s(k)| = |R_s(k-1)| + |\Delta R_s(k)| \quad (27)$$

$$|\Delta R_s(k)| = f\left[\sum_{k=1}^{3} w_k \sum_{m=1}^{2} x_m(t)\ h_m((t-b_k)/a_k)\right] \quad (28)$$

where $|\Delta\lambda_s^*|$ is the stator flux command and $|\Delta\lambda_s(k)|$ is the estimated stator flux. A 3 nodes are used in the hidden layer and the Mexican hat is chosen as a wavelet function

$$h(\tau) = \frac{2}{\sqrt{3}}\ \pi^{\frac{1}{4}}\ (1-\tau^2)\ e^{-\frac{\tau^2}{2}} \quad (29)$$

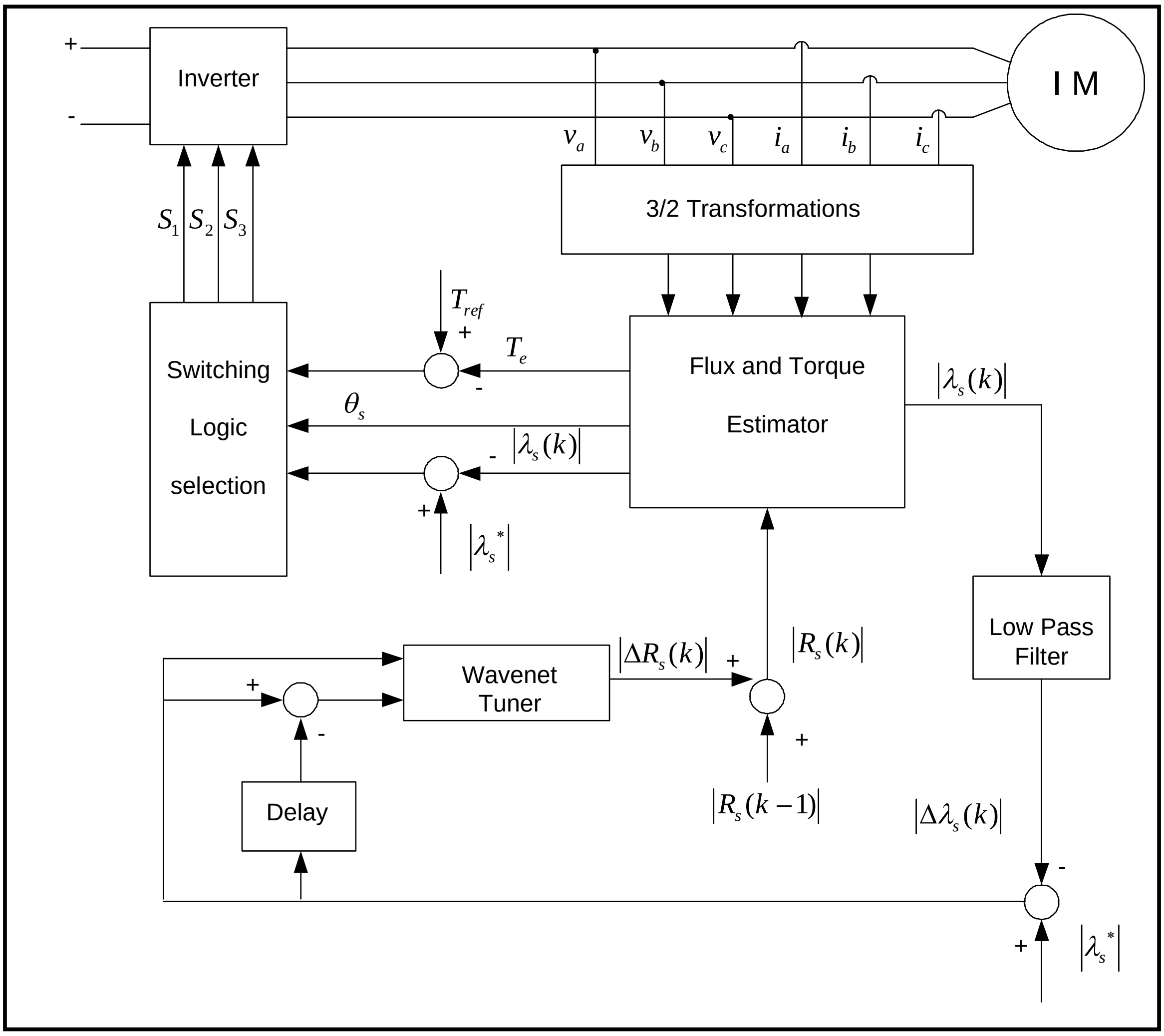

Fig.(11) DTC drive with wavenet tuner

5 Simulation Results with PI and Wavenet Stator Resistance Tuners

To study the performance of the PI and wavenet resistance tuners with DTC drive, the simulation of the system was performed using Matlab/Simulink library. The same stator resistance pattern used in section 4 is used to examine the two tuners. The stator flux command is determined from conventional DTC operation which gives its relation with torque command for different speed commands. This relation can be build up in a look up table and used in the simulation.

Figure (12) presents the stator flux command for different torque and speed commands. Simulations were determined using full load torque and 100 rad./sec. speed command. From this figure, the flux command for the mentioned case will be 8.943 Wb.

The Simulink model of the combination of the resistance tuners with DTC drive is shown in Fig. (13). The induction motor stator resistance is taken from the resistance pattern given in Fig. (3) while the stator resistance used in flux and torque estimator is taken either from PI or wavenet resistance tuner.

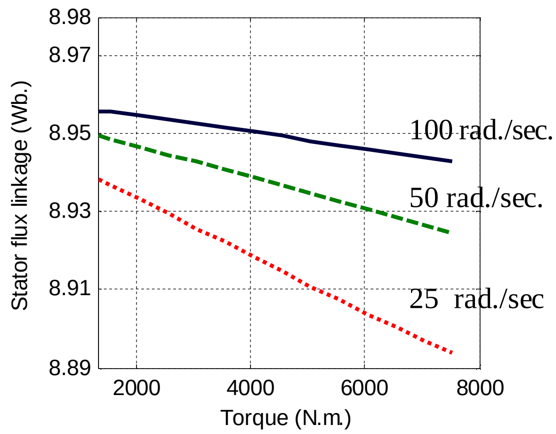

Fig.(12)Stator flux linkage as a function of torque for different speed commands

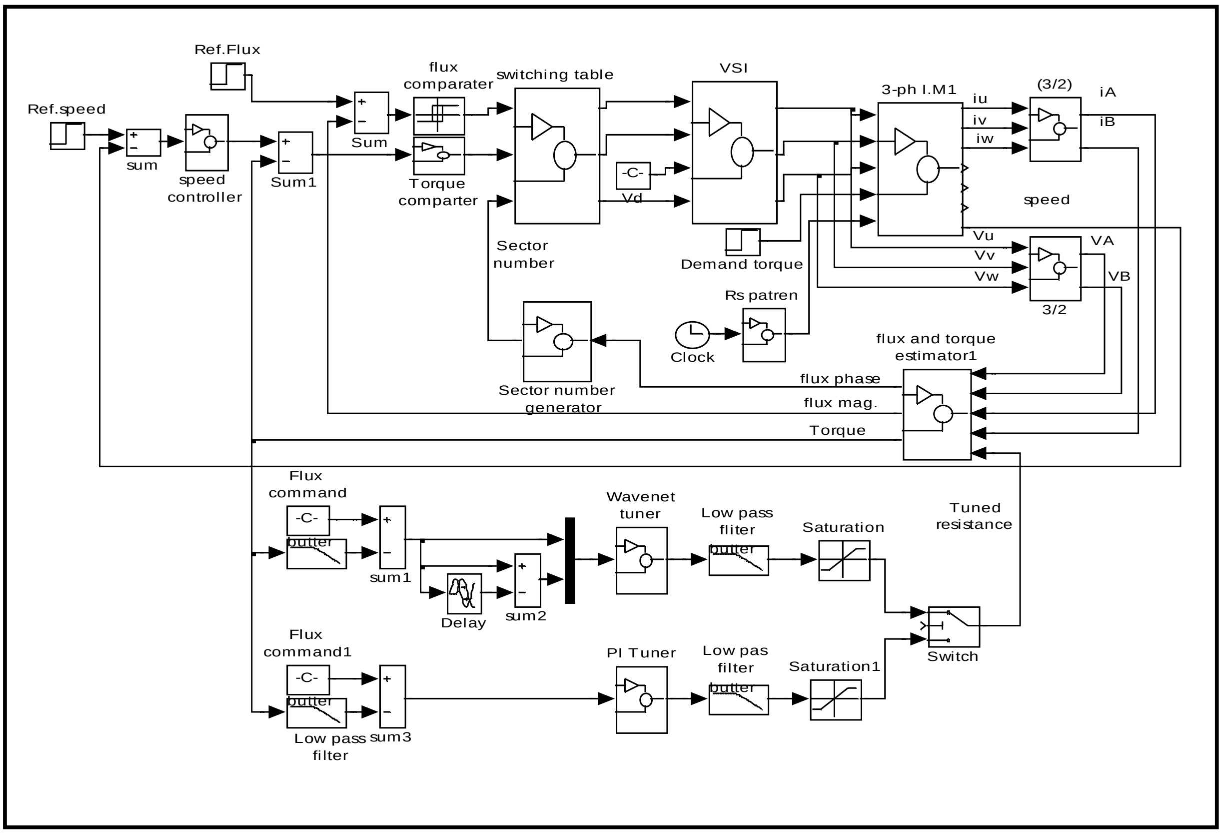

Fig. (13) Simulink model of DTC drive with PI and wavenet tuners

Figures (14) and (15) show the actual and tuned stator resistances of the machine with PI and wavenet resistance tuners respectively. In both tuners, the tuned stator resistance follows closely to the actual stator resistance of the machine. The wavenet tuner is able to tune the resistance change better than the PI tuner. Figure (16) shows the developed electromagnetic torque with the resistance tuner for PI and wavenet tuners. With wavenet tuner, the torque stays approximately constant all the time, but with PI tuner, there are small changes in torque during the resistance changes. The stator current magnitude, rotor speed and trajectory of stator flux linkage for PI and wavenet tuners are shown in Figs. (17) to (20) respectively. From the performance of the tuners, it is obvious that resistance tuner based on wavenet control is better than the resistance tuner based on PI control.

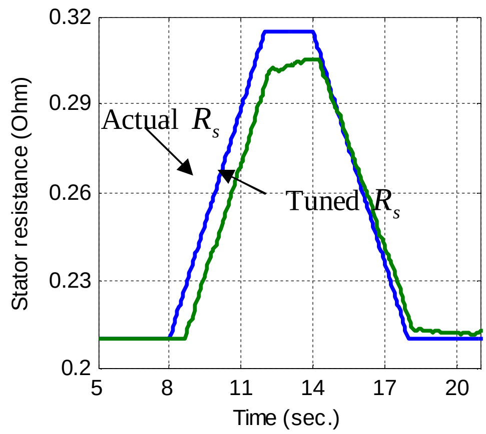

Fig.(14)Actual and tuned R_s with PI stator resistance tuner

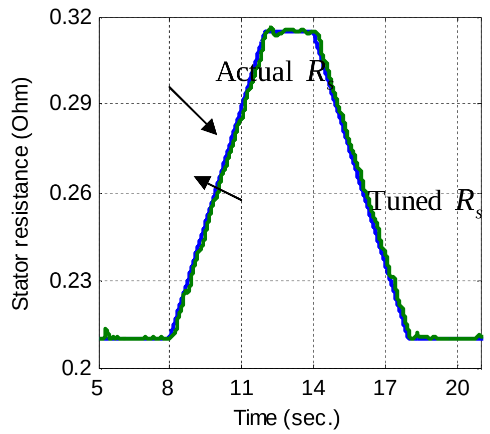

Fig.(15)Actual and tuned R_s with wavenet stator resistance tuner

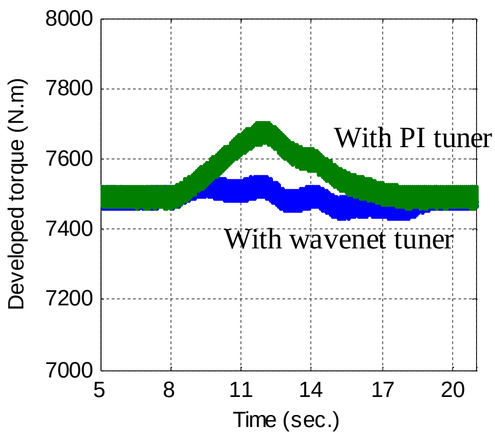

Fig.(16) Developed torque with PI and wavenet stator resistance tuner

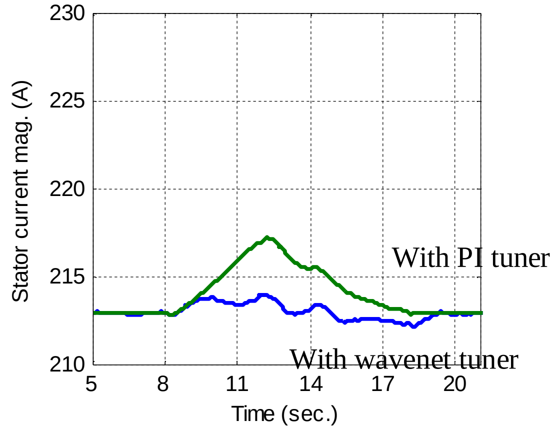

Fig.(17) Stator current with PI and wavenet stator resistance tuner

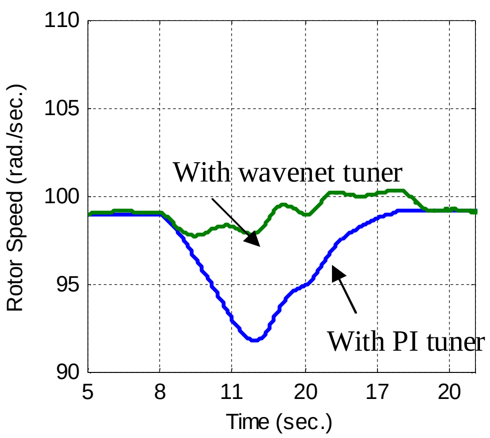

Fig.(18) Rotor speed with PI and wavenet stator resistance tuner

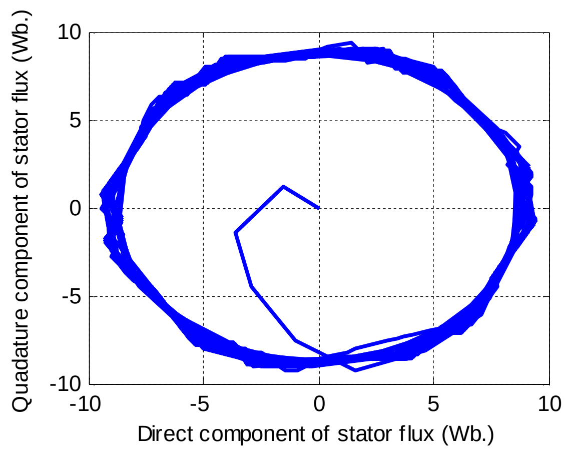

Fig.(19) Stator flux trajectory with PI stator resistance tuner

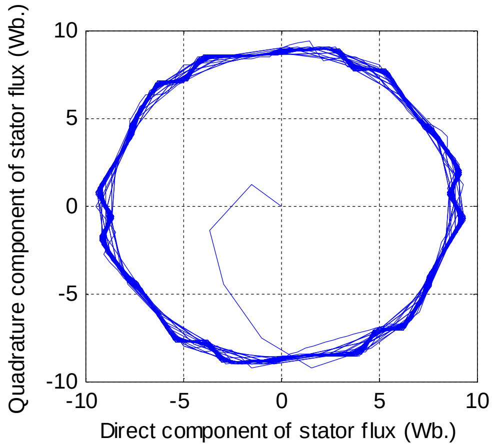

Fig.(20) Stator flux trajectory with wavenet stator resistance tuner

6 Extended Examining of Wavenet Resistance Tuner

The wavenet tuner proposed in the previous section has been examined for another pattern of stator resistance. This examination is necessary to prove the ability of the tuner to compensate the effect of stator variations in DTC drive. Practically, the stator resistance change has a wide variation which may be extended to 1.7 or 1.8 times its nominal value due to the temperature and the stator frequency variations [6]. Therefore, a stator resistance pattern including this resistance change is proposed to examine the performance of the wavenet tuner with DTC drive. This Pattern starts at a nominal resistance of 0.21 Ω when the motor runs at steady state full load torque and 100 rad./sec. command speed. At t=8sec., the stator resistance increases linearly to 1.4 times its nominal value during 4 sec., then remains constant for 4 sec. After that it increases linearly also up to 1.8 times its nominal value during 4 sec. and stays constant at this value. This process and its tuned resistance with wavenet tuner are shown in Fig. (21). The changes in the developed electromagnetic torque, stator current magnitude and speed with and without wavenet resistance tuner are shown in Figs (5.22) to (5.24) respectively. The errors in the filtered torque and stator current magnitude are shown in Figs. (25) and (26). The results showed that the wavenet resistance tuner was effective in tuning for the changes in stator resistance for the mentioned resistance pattern.

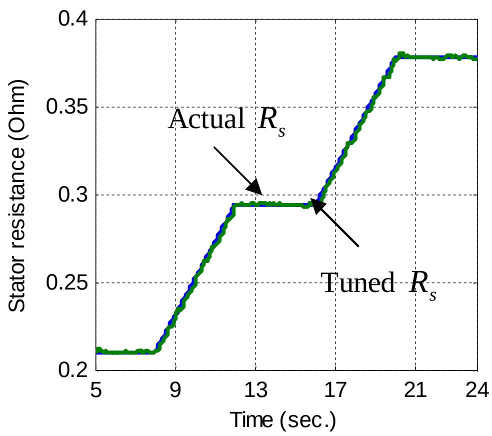

Fig.(21) Actual and tuned stator resistance

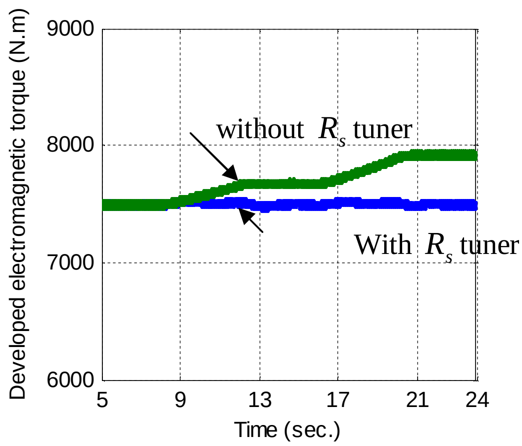

Fig.(22) Developed torque with and without stator resistance tuner

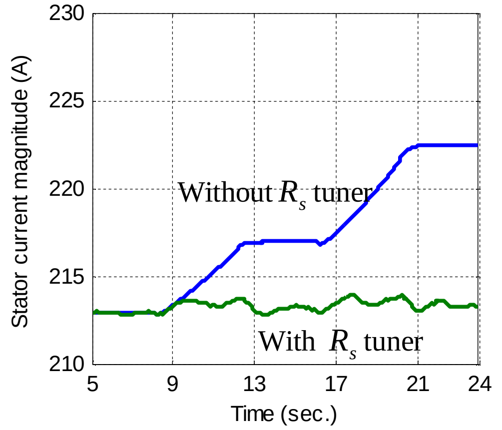

Fig.(23) Stator current with and without stator resistance tuner

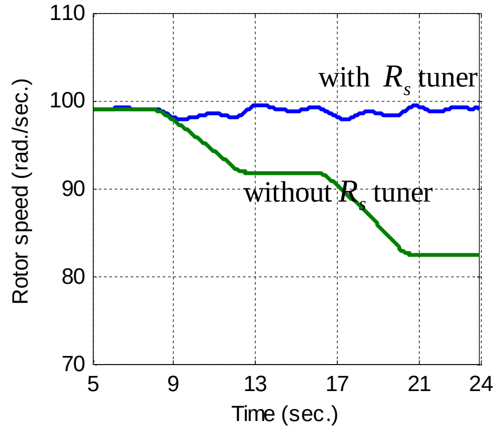

Fig.(24) Rotor speed with and without stator resistance tuner

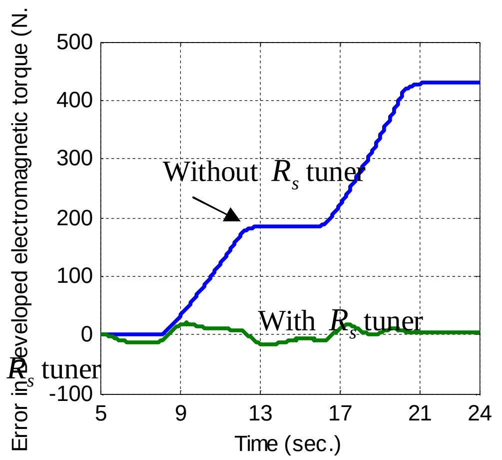

Fig.(25) Error in developed torque with and without stator resistance tuner

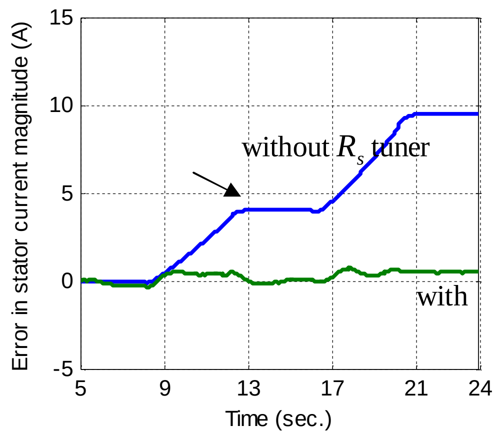

Fig.(26) Error in stator current with and without stator resistance tuner

7 :Conclusions

The principles of a DTC drive, wavenet structure and its algorithm have been analyzed. A stator resistance tuners using PI control and wavenet theory have been presented followed by Matlab/Simulink results. The simulation results show the following contributions

(a) The DTC drive needs to estimate the stator flux and developed torque. This estimation does not depend on motor parameters except for the stator resistance.

(b) The variation of stator resistance due to change in temperature and frequency degrade the performance of DTC controller by introducing errors in the estimated stator flux, which affect the stator current, developed electromagnetic torque and rotor speed. For example, a change of 1.4 times stator resistance value introduces 3% error in the developed torque and 3% in the stator current magnitude. This error increases to 6% and 5% for the torque and current respectively when the stator resistance change increases to 1.8% of its nominal value.

(c) A PI and online wavenet stator resistance tuners are designed and applied to eliminate the effect of the stator resistance variation in DTC controlled induction motor drives. The performances of the tuners are examined using Matlab/Simulink of DTC drive combined with these tuners.

(d) The online wavenet stator resistance tuner shows a better performance than PI stator resistance tuner. With PI stator resistance tuner, some error stays with the developed torque and current while with online wavenet resistance tuner, the error is approximately eliminated.

Appendix

The nameplate and the parameters of the three-phase induction motor used for simulation are given in Table (1) [3].

Table (1): Motor nameplate and parameters

Motor Rating		Motor Parameters	
Power	1250hp	R_s	0.21 Ω
Voltage	4160V	R_r	0.146 Ω
Torque	7410N.m	L_{1s}	5.2mH
Stator flux	9Wb.	L_{1r}	5.2mH
Current	150A	M	0.155H
Speed	1189rpm	P	6

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التوليف الحي لمقاومة الجزء الثابت في نظام التحكم المباشر للعزم اعتمادا على نظرية المويجة العصبية

ماجد عبد النبي علوان

قسم هندسة الحاسبات – كلية الهندسة – جامعة البصرة

الخلاصة

يحتاج نظام التحكم المباشر للعزم مقاومة الجزء الثابت للمحرك الحثي في استنباط الفيض المغناطيسي للجزء الثابت. ان تغير مقاومة الجزء الثابت نتيجه لتغيرات الحرارة وتردد الجزء الثابت يؤثر بشكل كبير على اداء النظام عند السرع الواطئه. في هذا البحث اقترحت طريقة لتوليف هذه المقاومة نتيجة للتغيرات المذكورة أثناء العمل اعتمادا على نظرية المويجة العصبية. ولإظهار مقدره هذه الطريقه استحضرت الطريقه التكاملية التناسبية "PI" لتوليف مقاومه الجزء الثابت. ان كل من مولفي المقاومة يقوم برصد قيمه الفيض المغناطيسي للجزء الثابت لكشف التغيرات في المقاومة لغرض توليفها. تمت مقارنة أداء طريقتي التوليف باستخدام نتائج المحاكاة من برنامج Matlab/Simulink. اظهرت نتاتج المحاكاة إن طريقة توليف مقاومة الجزء الثابت باستخدام نظرية المويجة العصبية تفوق الطريقة التكاملية التناسبية للتوليف في تحسين اداء النظام للتغيرات الحاصله في مقاومة الجزء الثابت للمحرك.