محاكاة تقييم الاستقرارية العابرة للتحكم بالمحرك الحثي ثلاثي الطور

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الخلاصه :

يهدف البحث الحالي الى دراسة الاستقرارية العابرة لمسيطر محرك حثي ثلاثي الطور .

اعتمد البحث منهجية التحليل بالمحاكاة , وتم دراسة التيار الساكن والعزم الكهرومغناطيسي وسرعة الدوار كما وقدم البحث انموذج رياضي والتحليل بواسطة محول فورير السريعFFT لدراسة الاستجابة بشكل افضل .

وناقش البحث العوامل المؤثره على استقرارية المحرك.

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Abstract:
This work aim to study the transient stability of a 3- phase induction motor controller.
A simulation based analysis is depended. stator current electromagnetic torque and rotor speed has been studied, a mathematical model and FFT analysis also presented for the transient response, parameters effect stability margin was discussed.

1- Introduction:

Transient stability of a system refers to the stability when subjected to large disturbances such as faults and switching of lines [1]. Hence linearized analysis is not applicable and the nonlinear equation of the system have to be solve in stability evaluation checking transient stability is only one of the many objectives of running a simulation program which can give lot more information such as predict the dynamic performance of the system involving low frequency transient.

2- Mathematical formulation:

Consider a continuous time system of equation [2].

$X=f(x,t)$……………………………………………………..1

The solution of the above equation can expressed as

$X(t)=\emptyset_t(x_0,t_0)$……………………………………………….2

Where x_0 is the initial value of x at time $t=t_0$

The integration algorithms generate a sequence of points $x_0,x_1,x_2,\ldots$..at time $t_0,t_1,t_2,\ldots$……with approximation

$X_{K=}\ \emptyset_{tk}(x_0,t_0)$………………………………………….3

It is usually assumed that the points are uniformly spaced with size h>0,that is .

$T_K=t_0+hk$ for k=0,1,2,3…… …………..4

In the forward Euler method f is approximated as constant evaluated at time t_k .
Thus x_{k+1} can be calculated from
$X_{k+1}=x_k+hf\ (x_k,t_k)$……………………………………….5
By applying forward Euler method ,x_{k+1} can be expressed as
$X_{k+1}=[1+Ah]x_k=[F]x_k$…………………………………….6
For numerical stability, the eigen value (λ_j,j=1,2,3,…….n) of the matrix [F] must satisfy $|\lambda_j| <1$.
And using trapezoidal rule of integration:
$X_{k+1}=x_k+(h/2)[f(x_k,t_k)+f(x_k+1,t_k+1)]$…………………………..7

3- **Induction motor modeling**:
The equivalent circuit for an induction motor shown in fig. (1). And the motor is assumed to

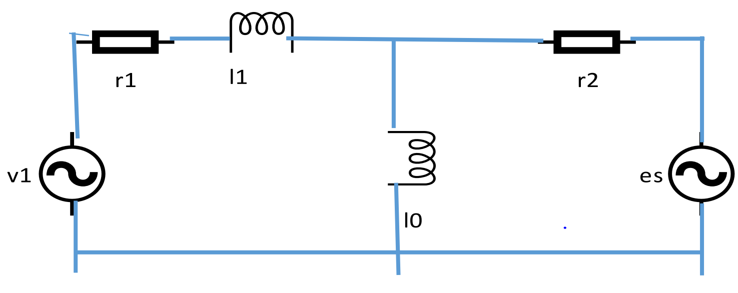


Fig.(1) equivalent circuit of an induction motor.
Be driven by the stator voltage given by (3):
$\vec{V}_1=j\theta\ (t)\ L_k i_{k0}\ \exp[j\theta(t)]$……………………………………….8
And the corresponding magnetizing current i_0 is assumed to be represented by :
$i_{0=}\ i_0\ \exp\{j(\theta + \emptyset_0)\}$…………………………………………….9

And as shown in (3) the following are derived :

$Te=K\ L_0\ Ti_0^2(\emptyset_0+\theta-\omega_r)$……………………………………………..10

$(J/n)\ \omega_r=T_e-T_{sh}$……………………………………………………11

And taking into account the small deviation in the state variables (i_0, $\emptyset_0$,ω_r) from an equilibrium point (i_{00}, $\emptyset_{00}$,ω_{00}) as

$i_{0=}\ i_{00}+\Delta\ i_0\rightarrow i_0=\Delta i_0$...12

$\emptyset_0=\emptyset_{00}+\Delta\ \emptyset_0\rightarrow \emptyset_0=\Delta \emptyset_0$………………………………………13

$\omega_r=\omega_{r0}+\Delta\ \omega_r\rightarrow \omega_r=\Delta\omega_r$……………………………………………..14

Substituting, and neglecting the higher order terms, the linearized equation are derived as follows (3):

$[A]|\Delta i_0,\Delta \acute{o}_0,\Delta\acute{\omega}_r]=0$……………………………………………15

$[A]=[a_{ij}]$ (I,j=1~3)

where:

$a_{11}=a_{22}=\alpha_{11}p^2+\beta_{11}\ p+\gamma_{11}$ $a_{12}=-a_{21}=-\alpha_{12}\ p-\beta_{12}$

$a_{13}=\beta_{13}$ $a_{23}=-\alpha_{23}\ p-\beta-\beta_{23}$

$a_{31}=\beta_{13}$ $a_{32}=-k_2p$

$a_{33}=p+k_2$

$\alpha_{11}=L_1T_0$ $\beta_{11}=r_1T_0+L_1$

$\gamma_{11}=\{L_1\ T_0\theta(\theta-\omega_{r0})\omega\}$ $\alpha_{12}=L_1T_0\ (2\ \theta-\omega_{r0})$

$\beta_{11}=r_1T_0(\theta-\omega_{r0})$ $\beta_{13}=L_1T_0\ \theta$

$\alpha_{23}=L_1T_0$ $\beta_{23}=r_1T_0$

p=a/dt

4- Stability analysis:

Following the induction motor model for the voltage source type inverter ,H can derived (4) that the stator current error will satisfy the following equation :

$e_1=G(s)pj\hat{\lambda}_r(\hat{\omega}_m-\omega_m)$………………………………………16

$G(s) = -s/€\ [s^2 I + s(Xi + yj) + Mi + Ni]^{-1}$

$= \begin{bmatrix} G11 & G12 \\ G21 & G22 \end{bmatrix}$ 17

Where:

$m = [R_r/L_r(h_1 + R_s/\sigma\ L_s + h_3/€) - p\omega_m(h_2 + h_4/€)]$

$n = [R_r/L_r(h_2 + h_4/€) - p\omega_m(h_1 - R_s\ \sigma\ L_s - h3/€)]$

$x = [h_1 + R_s/\sigma\ L_s + R_r/\sigma\ L_r]$ $\qquad$ $y = [h_2 - p\omega_m]$

$H_1 = \begin{bmatrix} h1 & -h2 \\ h2 & h1 \end{bmatrix}$

$H_2 = \begin{bmatrix} h3 & -h4 \\ h4 & h3 \end{bmatrix}$.........18

H_1, H_2 are the observers gains and " " denotes the estimated value it should be noted that equation (16) and (17) are the general form of error equation for most model _ adjustment based speed estimators. And form these equation we can composed the output error transfer function G(s) together with PI speed estimator as shown in fig (2)

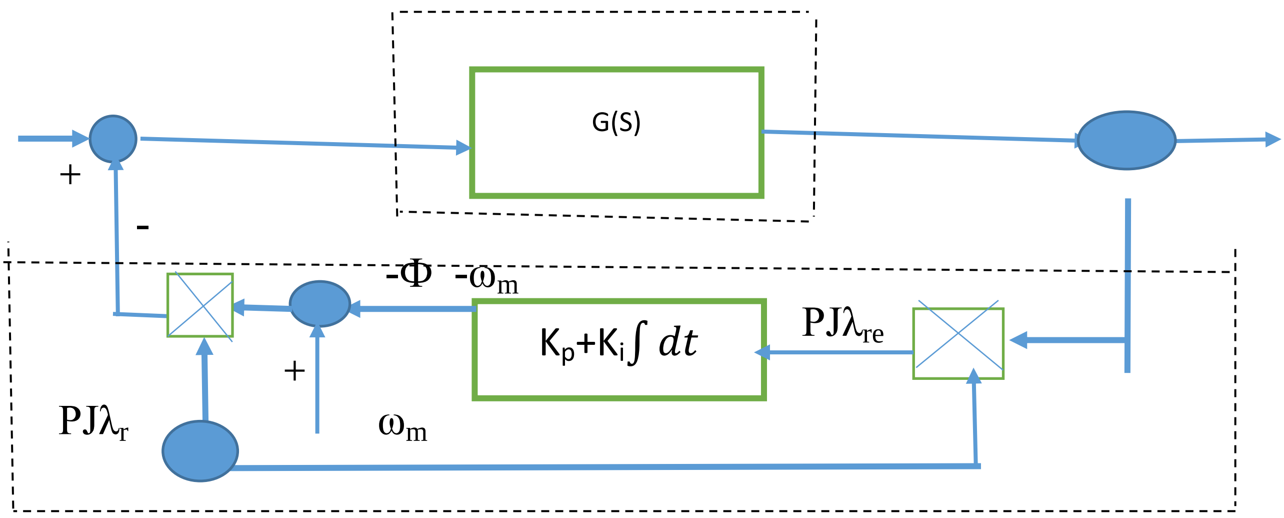
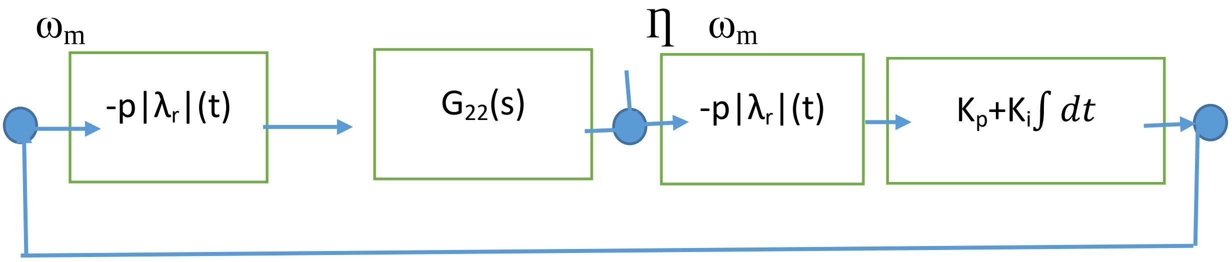


Fig (2) Blok diagram of output error in adaptive observer

To carry out the stability analysis easily we will transfer the estimation error system from the stator frame (α-β) to rotor flux frame (d-q) [4].and then simplify the error system considering also measurement noise as shown in fig (3).



Fig(3) Blok diagram of SISO error system on rotor flux frame

$G_{22}(s)$ is calculated to be

$$G_{22}(s)=\frac{s^2+xs^2+(\omega 0^2+m)s+\omega 0^2x+\omega 0n}{-\varepsilon\,[(s^2+xs-\omega 0y+m)^2+((2\omega 0+y)s+\omega 0x+n)^2]} \quad \text{.........................19}$$

Where ω_0 is the angular frequency of the estimated rotor flux:

$\omega_0 > \omega_c = -n/x$ (critical frequency)..20

$x>0$..21

$\omega_0 n < m_x$..22

Where m,n and x depend on motor parameters and feedback gain H_1, H_2 as given in equation (18).

The boundary for stability is the point when $\omega_{0,}$ ω_c, considering that:

$\omega_0 = p\ \omega_m + \omega_{se}$ 23

$\omega_c = p\ \omega_m/1+\tau$...24

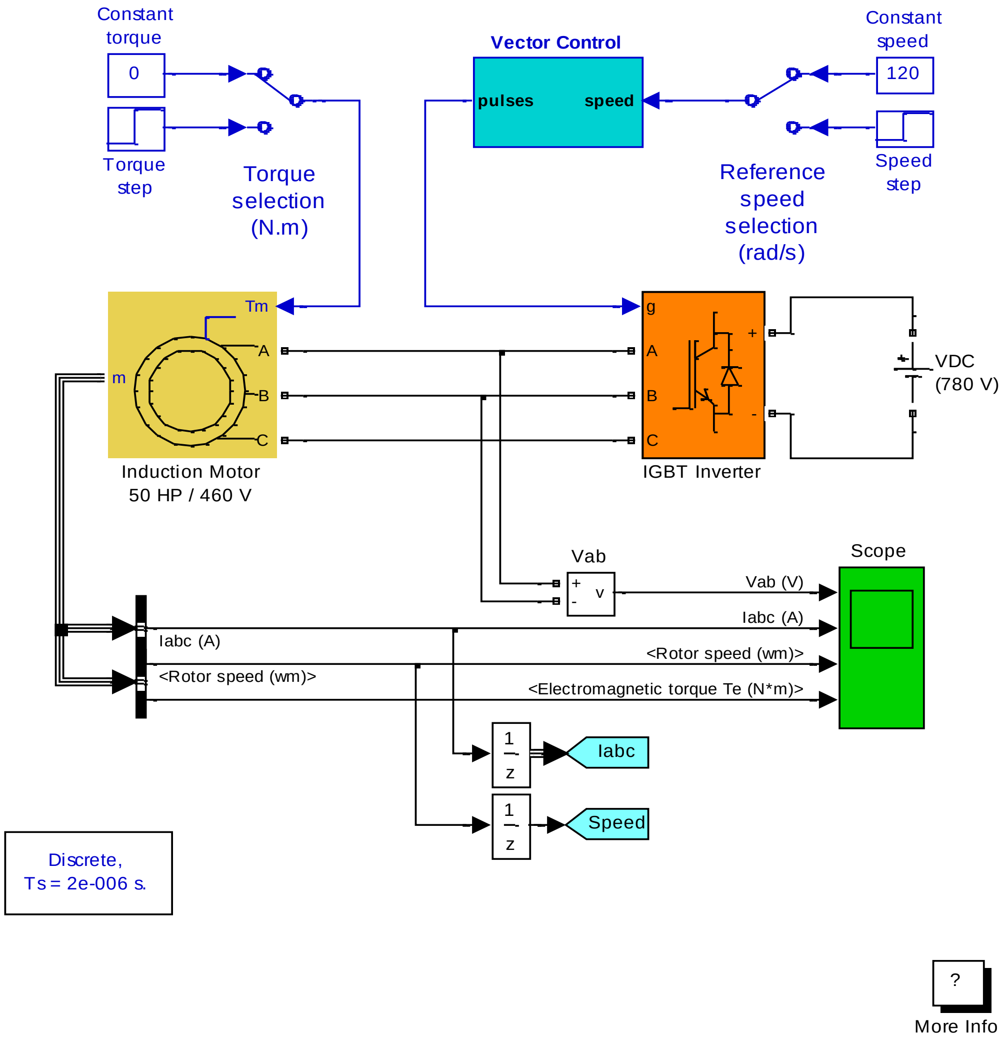
When τ can be changed by feedback gain h_3,we can find that the stability boundary is given by:

$$\omega_m = \frac{(1+\eta)Rr}{\eta p|\lambda r|^2} Tm \quad \ldots\ldots \quad 25$$

From the condition equ(20) and equation (18),(25) we can compare conceptually the unstable region on the torque – speed plane for the system with and without error feedback.

5- Simulation Results:

This research use the block diagram shown in fig (4) to simulate the induction motor with electrical drive.



Fig(4) vector control of a variable frequency induction motor drive

The three component of stator currents (i_a,i_b,i_c)are shown in fig (5)

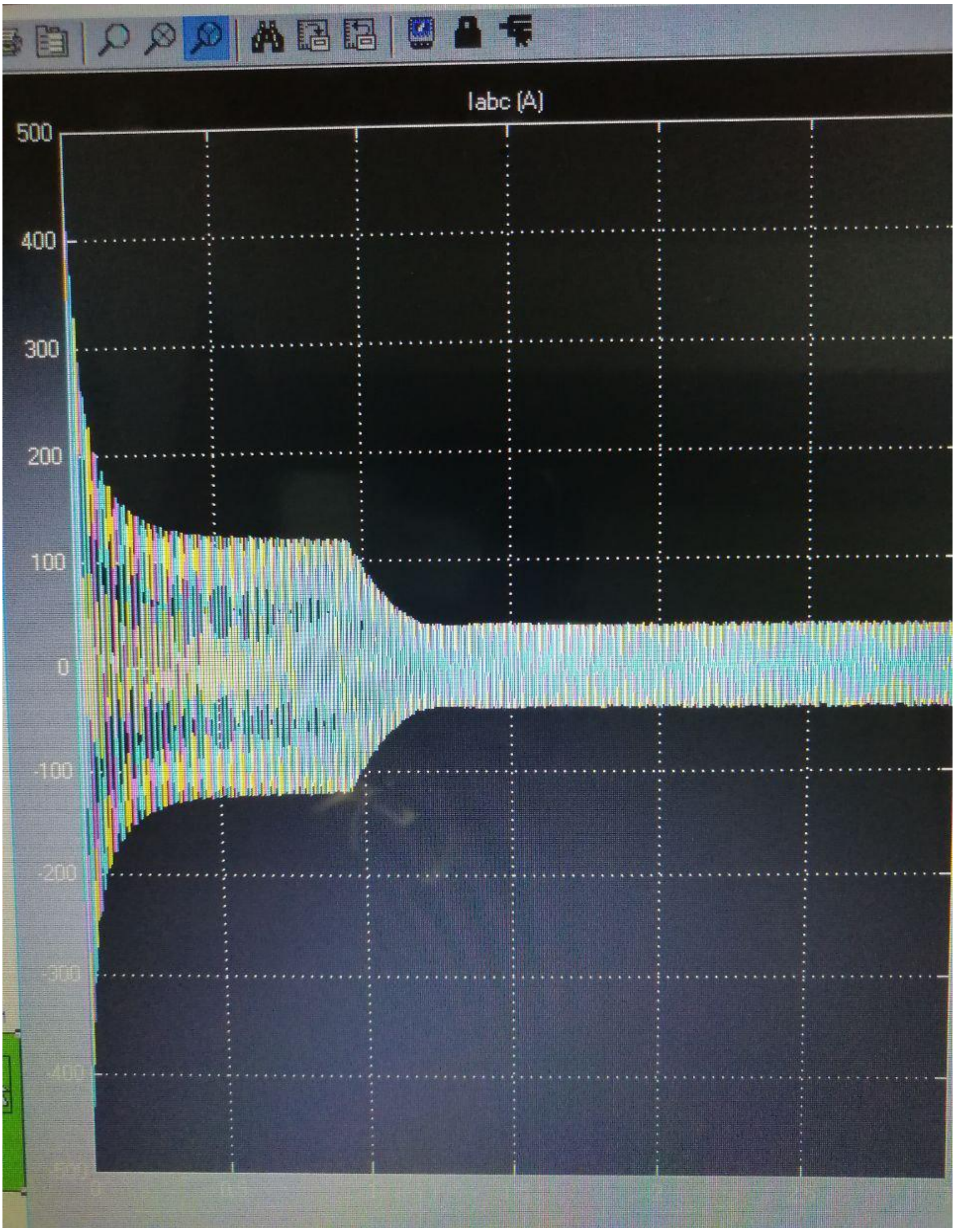


Fig (5) stator currents (i_a,i_b,i_c)

And its FFT analysis is shown in fig (6) which shown the main component at (60)Hz , i.e around the operation frequency.

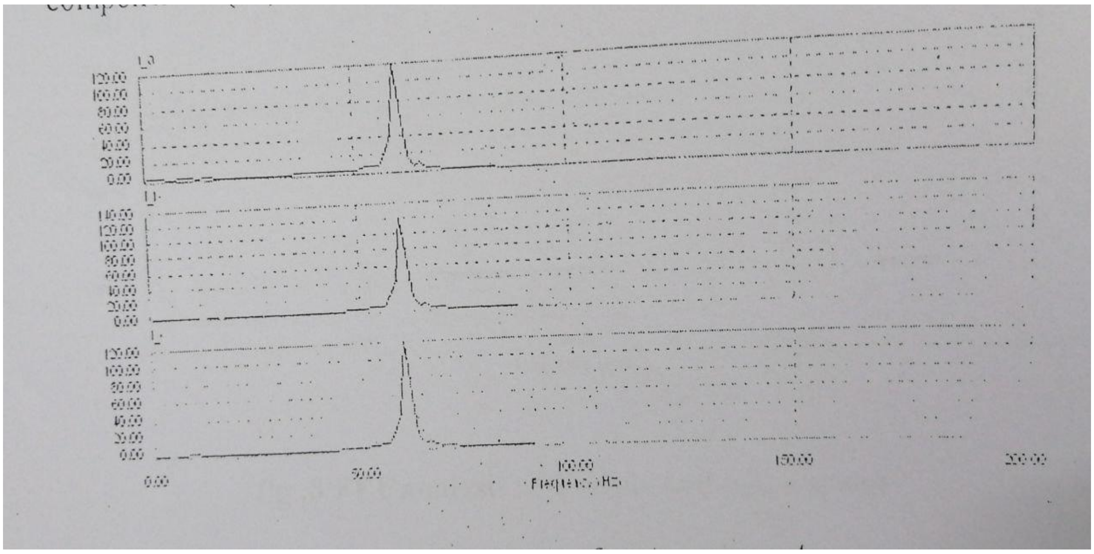


Fig (6)FFT analysis of stator currents

For the electromagnetic torque and rotor speed simulation results shown in fig (7) and their relative FFT analysis is in fig (8)

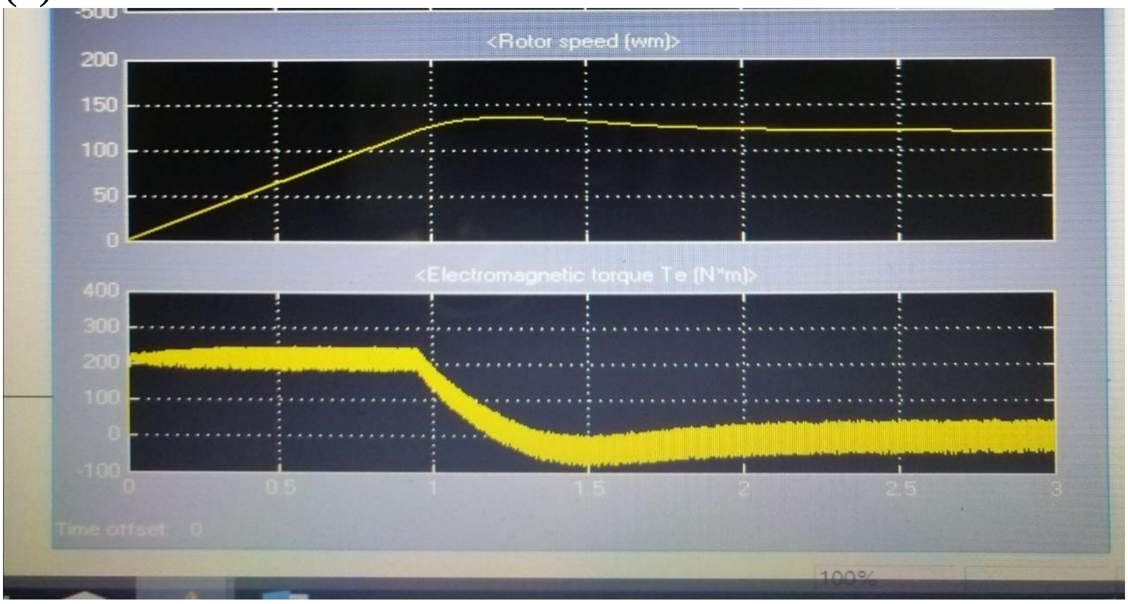


Fig (7) torque and rotor speed

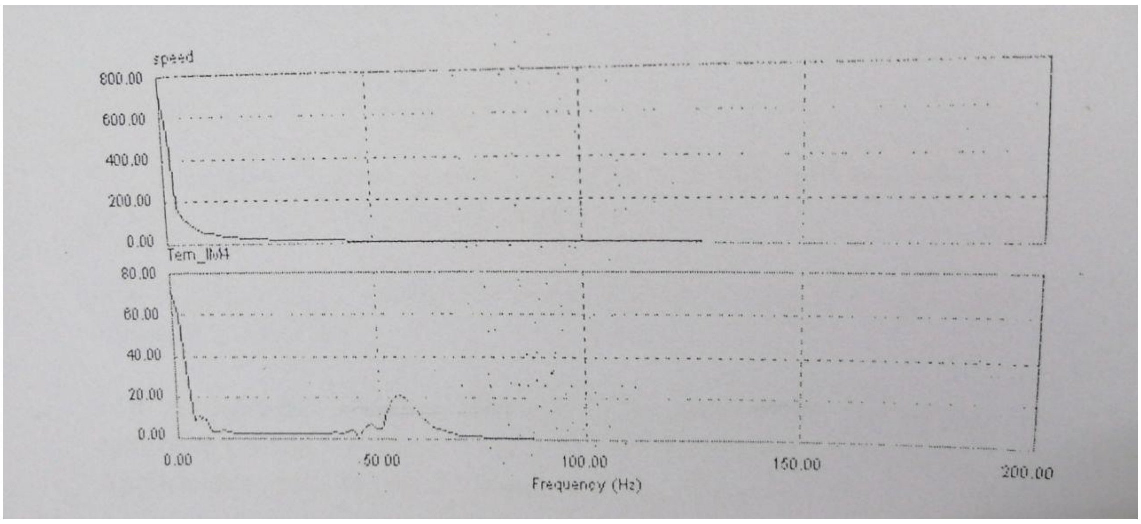


Fig (8) FFT analysis of torque and rotor speed

The results shown if we a high K_i gain for fast tracking of motor speed and a low K_p gain for this phenomena is the phase shift of $G_{22}(s)$ is about -90° at the frequency nearly equal to the operation frequency ω_0, then the design of the controller should insure that the $\omega_0 > \omega_m$.

6- Conclusion:

The transient responses for stator currents electromagnetic torque and rotor speed was analysis . also FFT analysis of the above results was presented stability and its conditions was inspected for good performance of induction motor controller.

Appendix:

Motor parameters

R_s=0.297 L_s=0.00139 R_r=0.156

L_r=0.00074 L_m=0.041

2P=6 moment of mertia=0.4 V_{LL}=220v

f=60Hz

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