PERFORMANCE OF INDUCTION MOTOR DRIVE UNDER LIAPUNOV STABILITY DESIGN CRITERIA

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ABSTRACT

For an optimal linear regulator design, a performance function of the quadratic form must be chosen. The question arises of how to decide the weighting matrix Q of the performance function. A method is developed in this paper based on liapunov stability design. The method begins by linearizing the system equation about an equilibrium point. The system considered is an induction motor driver. The equilibrium points were selected so as to have stable closed loop system. Several cases are investigated. It is found that emphases on control of rectifier current and stator voltage result in a more stable system. This is shown from the non-linear test conducted on the system.

Key words: Optimal, Liapunov stability, Motor drive.

NOMENCLATURE

A	:	System matrix
B	:	Input matrix
V_{qs}	:	Quadrature stator voltage,
i_r	:	Rectifier current
J	:	Performance index
x	:	State variable
u	:	Input vector
Q	:	Positive definite matrix, weighting matrix
R	:	Positive definite, cost function matrix
A_p	:	Closed-loop system
u^T	:	Transpose of u
K	:	Solution of matrix Riccati equation
T_L	:	Load torque
ω_r	:	Speed of rotor
ω_b	:	Base speed
$i_{qs}, i_{ds}, i_{qr}, i_{dr}$	:	d-q phase currents

1.0 INTRODUCTION

Contributions have been made in the problem of stabilizing power systems and drives through excitation control using power signals and speed [1-3]. In view of the development of control theory, however, more work should be done to determine if there is a better way to stabilize a power system and drives. Optimal linear regulator have been designed for power systems and drives. Optimal linear regulator have been designed for power system stabilization [4] and electrical machine drives [5]. There is however, one problem unsolved; that is how to decide the weighting matrix Q of the quadratic performance function from a sound basis instead of leaving entirely to guessing and experience.

The usual procedure of optimal linear regulator design has been discussed [4]. Consider linearized system state equations,

$$\dot{x} = Ax + Bu \qquad \text{.........(1)}$$

An optimal control can be found from the minimization of chosen quadratic performance function

$$J = \frac{1}{2}\int_0^{\alpha} (x'Qx + u'Ru)dt \qquad \text{..........(2)}$$

subject to the system dynamic constraint equation 1. The optimal control is given by

$$u = -R^{-1}B^{T}Kx \qquad \text{.................(3)}$$

and the Riccati matrix K is solved from the nonlinear matrix algebraic equation

$$KA + A^{T}K - KBR^{-1}B^{T}K = -Q \qquad \text{..........(4)}$$

With u taken as the control signal, equation 1 becomes

$$\dot{x} = A_p x \qquad \text{.............(5)}$$

Where,

$$A_p = A - BR^{-1}B^TK \qquad \text{.............(6)}$$

2.0 DRIVE EQUATIONS

The drive equations were obtained in synchronous rotating reference frame [7] in the form

$$\dot{x} = Ax + Bu \qquad \text{..................(7)}$$

Where the equilibrium point to linearize the system equations are i_{qso}, i_{dso}, i_{qro} and i_{dro}.

For the particular case investigated,

$$A = \begin{bmatrix} -64.84 & -632.10 & 68.72 & -309.95 & -8850.83 & 0.00 & 0.00 \\ 632.10 & 64.84 & 309.95 & 68.72 & 408.70 & 0.00 & 0.00 \\ 53.37 & 514.04 & -138.48 & 247.57 & 17834.43 & 0.00 & 0.00 \\ -514.04 & 53.37 & -247.57 & -138.48 & -823.53 & 0.00 & 0.00 \\ 0.00 & 25.00 & -425.00 & 50.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & -0.04 & -2.22 \\ -3.21 & 0.00 & 0.00 & 0.00 & 0.00 & 3.36 & 0.00 \end{bmatrix} \qquad \text{.......(8)}$$

$$B = \begin{bmatrix} 63.26 & 0.00 & -52.06 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 63.26 & 0.00 & -52.06 & 0.00 & 0.00 & 0.00 \\ -52.06 & 0.00 & 104.91 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & -52.06 & 0.00 & 104.91 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & -2.50 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 \\ 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & 0.00 & -1.00 \end{bmatrix} \qquad \text{.......(9)}$$

$$u = (\Delta v_{qs}, 0, 0, 0, \Delta T_r, 0, 0)^T \qquad \text{.........(10)}$$

$$x = \left(\Delta i_{qs}, \Delta i_{ds}, \Delta i_{qr}, \Delta i_{dr}, \frac{\Delta\omega}{\omega_b}, \Delta i_r, \Delta v_{qs}\right)^T \qquad \text{...........(11)}$$

3.0 RESULTS

Figures 1 to 6 show the comparism of eigenvalues plot. Eigenvalues plots are used to study the asymptotic stability based on the collorary of liapunov stability analysis. It is found that the lowest set of eigenvalues is achieved when emphasis is placed on the control of stator current i_{qs} and rotor current i_{dr}. However, the lowest current when emphasis is placed on the control of rectifier current i_r and stator voltage v_{qs} is higher than any of the lowest eigenvalues for all the cases investigated for. The nonlinear test for this particular case is shown in figures 7 to 13.

4.0 CONCLUSION

Eigenvalues plots were used to ascertain the asymptotic stability of the closed-loop system. The real part of the eigenvalues determines whether the root of the equation are placed on the right hand side of the complex plane. It has effect on the state transition matrix, e^{At}, which is the response of the system when all other forcing functions are zero. From the result of the non-linear test, it is seen that the eigenvalues can indeed be used to judge the stability of the system, because of convenience inorder to determine the test control option without necessarily going into non-linear test. The only limitation is that the perturbation should not exceed a limit that will make the linearization invalid.

5.0 REFERENCES

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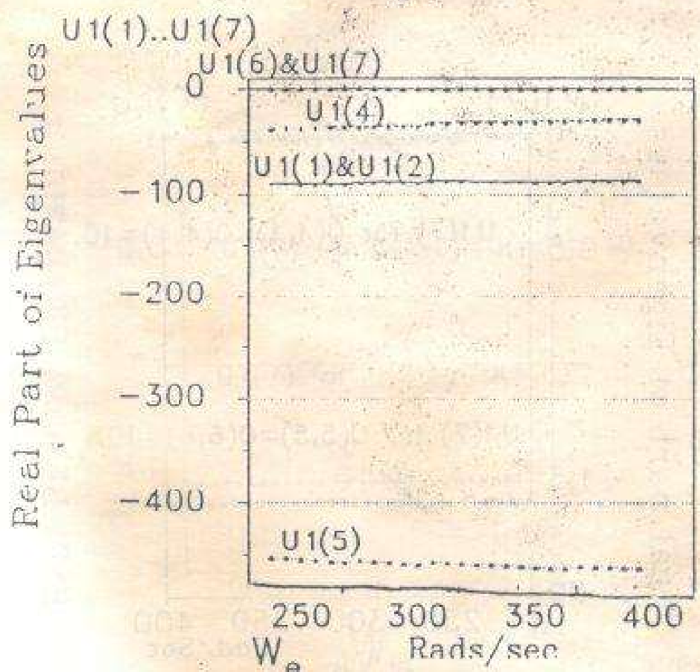

Fig. 1 Eigenvalues of the closed-loop System With Q(1, 1)=Q(4,4)= 10.

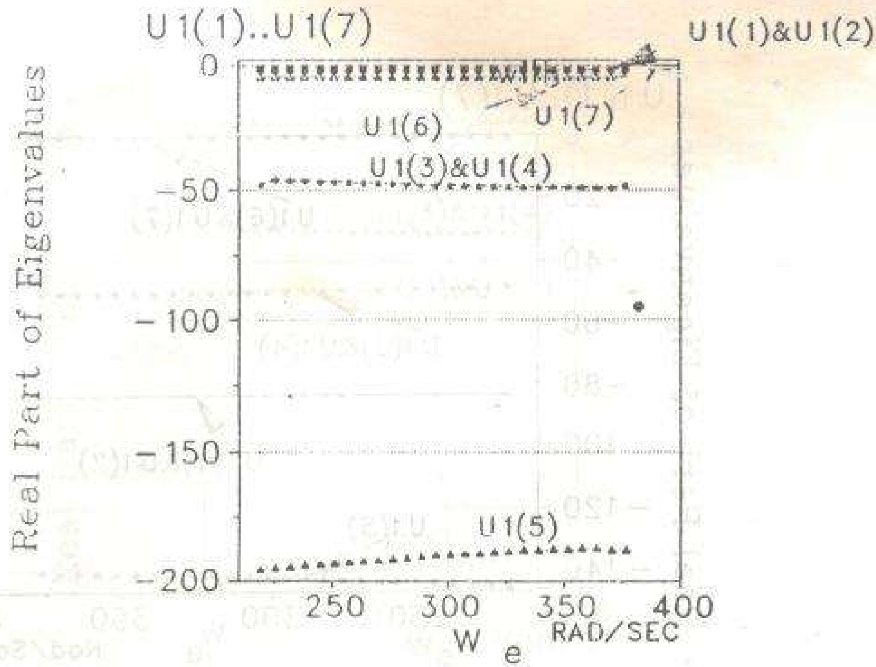

Fig. 2 Eigenvalues Plot of the Closed-Loop System With Q(5,5)=Q(6,6)= 10.

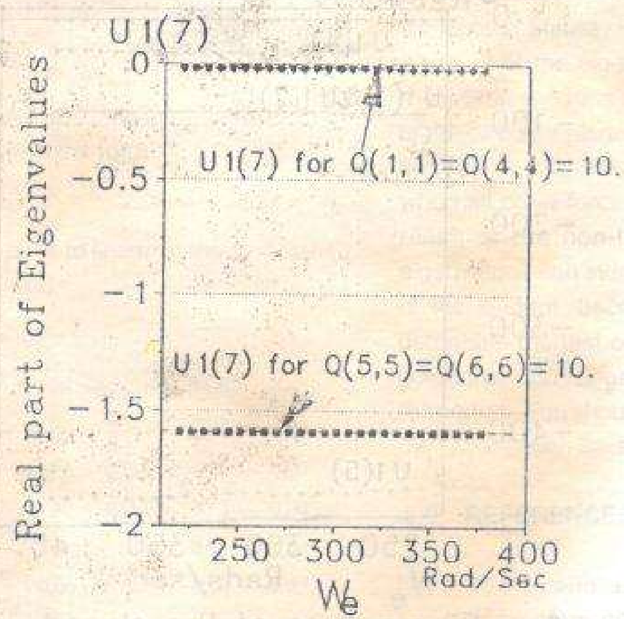

Fig. 3 Comparism of Eigenvalues Plot for different Weighting factor

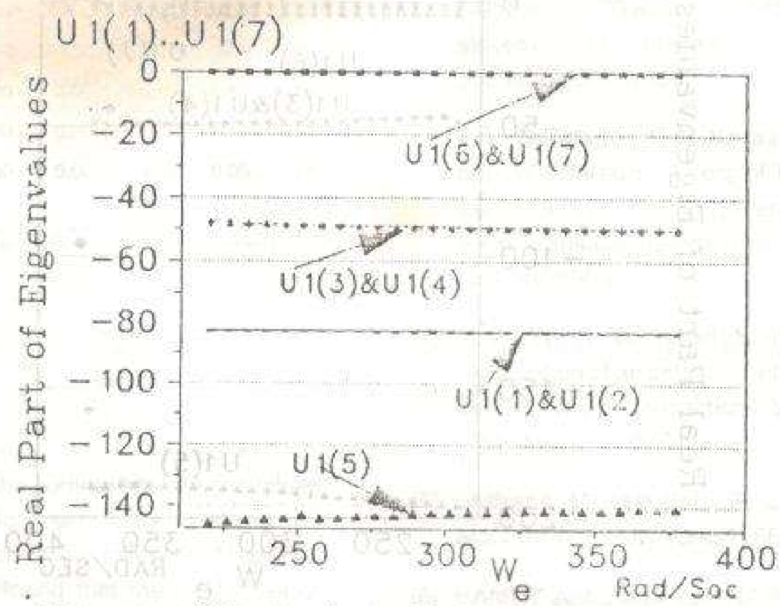

Fig 4 Eigenvalues Plot of the Closed-Loop System With Q(2,2)=Q(3,3)=10.

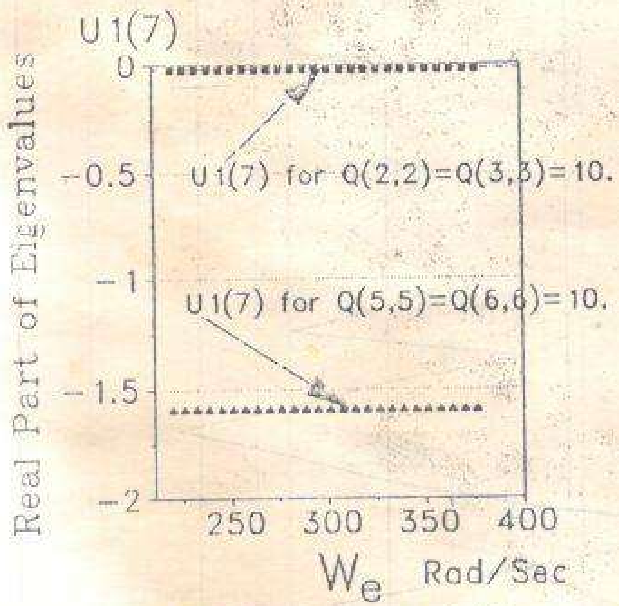

Fig. 5 Comparism of Eigenvalue Plot for Different Weigthing Factors

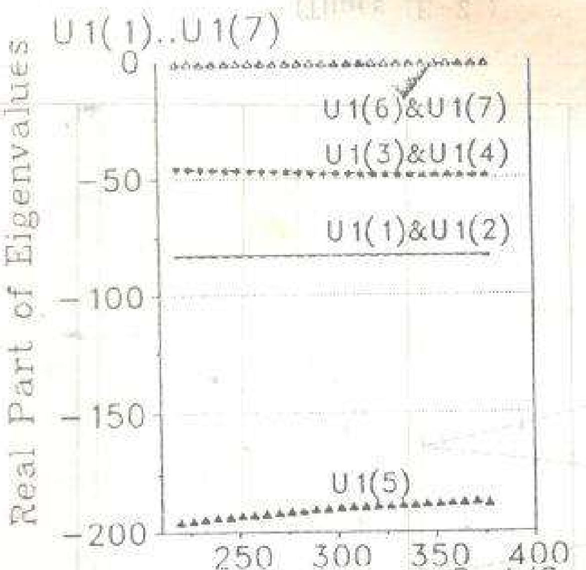

Fig. 6 Eigenvalues Plot of the Closed-Loop System With Q(6,6)=Q(7,7)= 10.

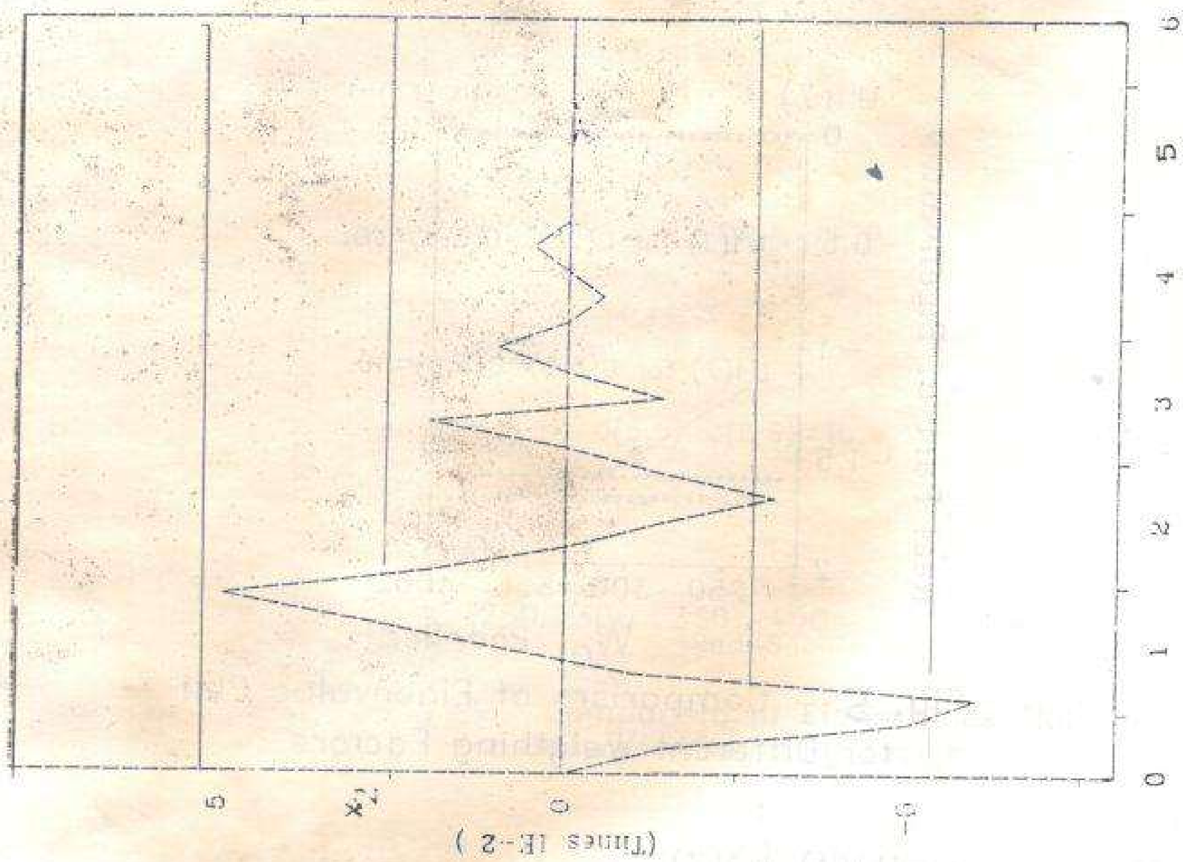

FIG 8 RESPONE OF STATE VARIABLE X_2

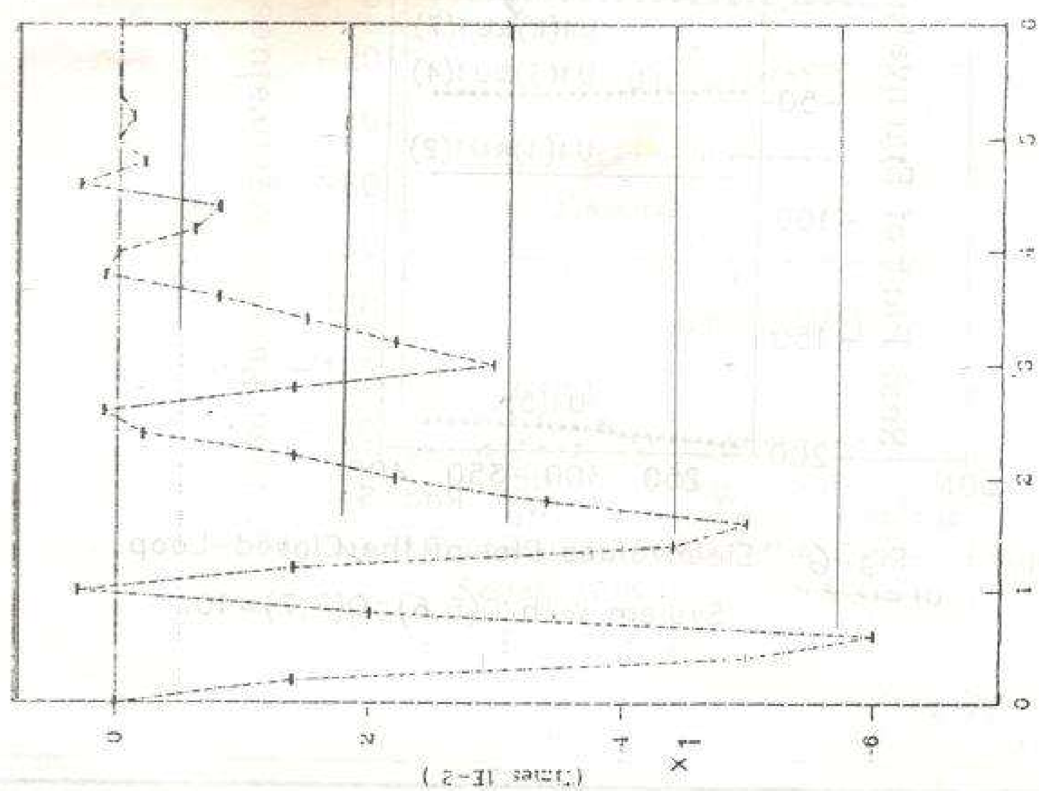

FIG 7 RESPONE OF STATE VARIABLE X_1

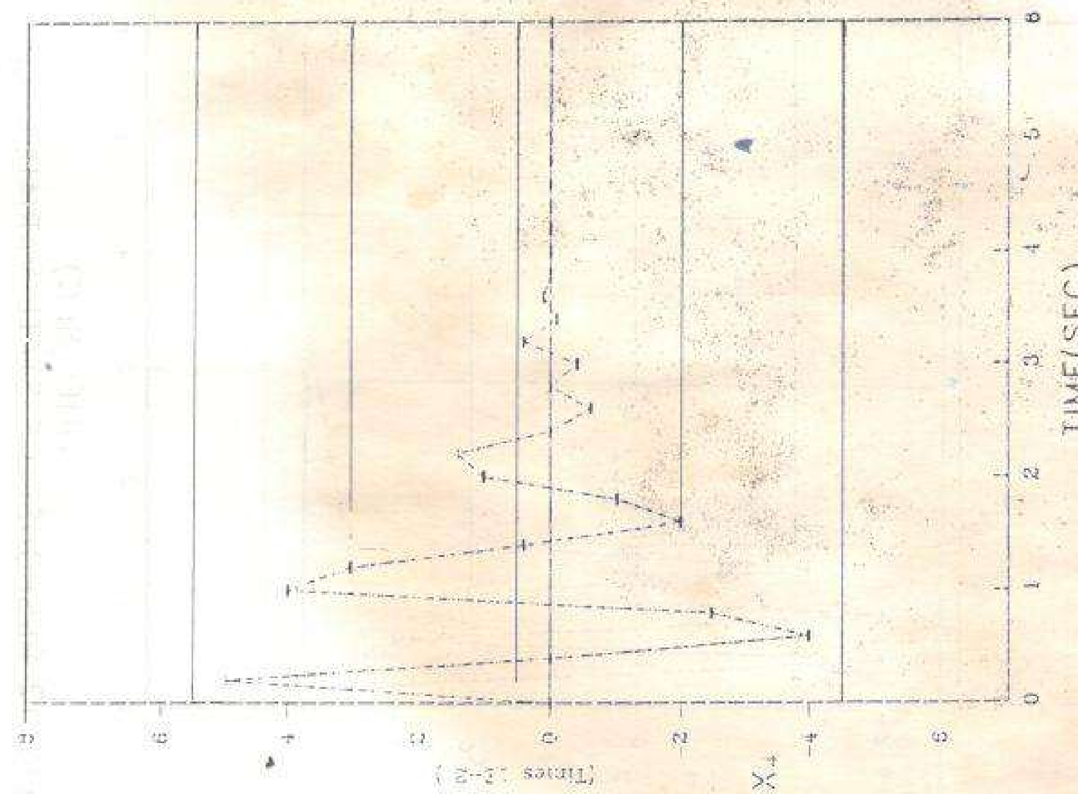

FIG 10 RESPONEE OF STATE VARIABLE X_4

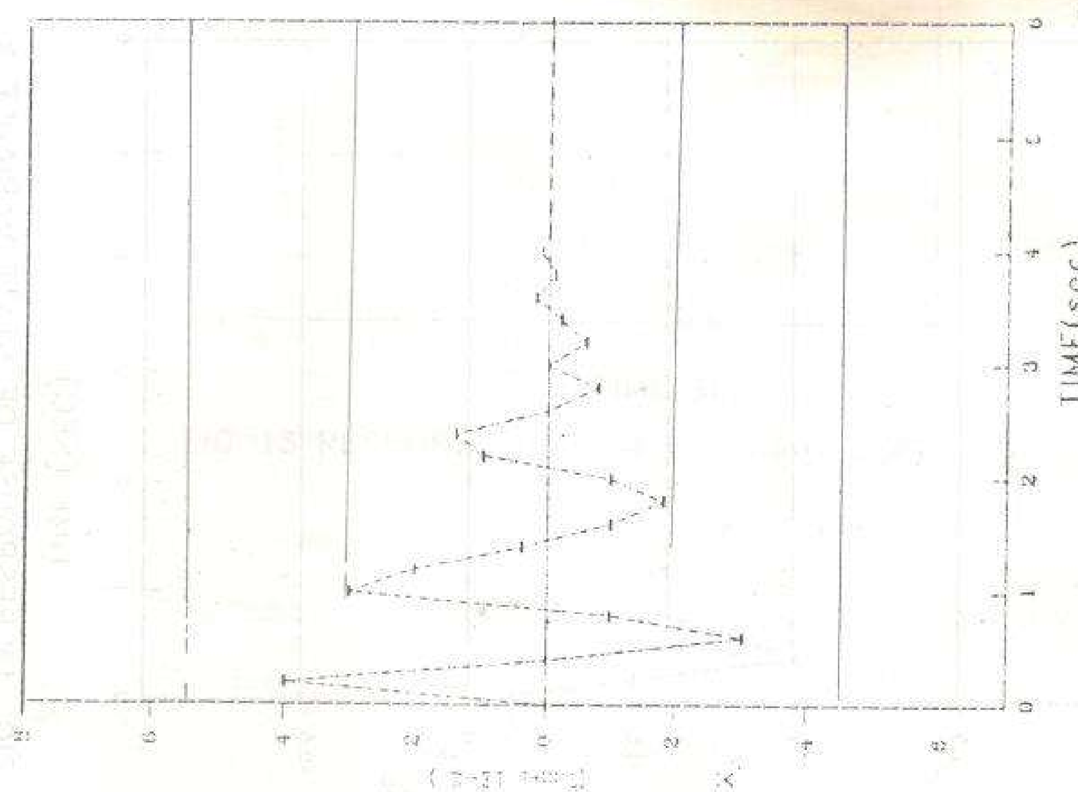

FIG 9 RESPONEE OF STATE VARIABLE X_3

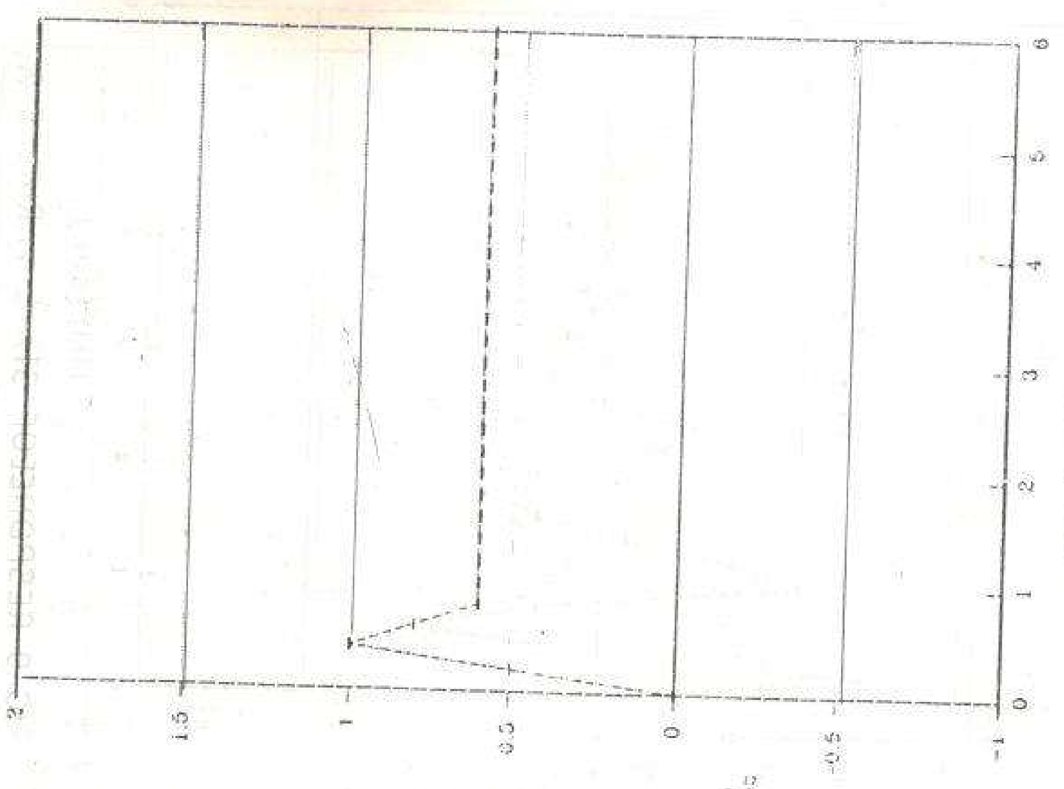

FIG. 11 RESPONSE OF STATE VARIABLE X_5

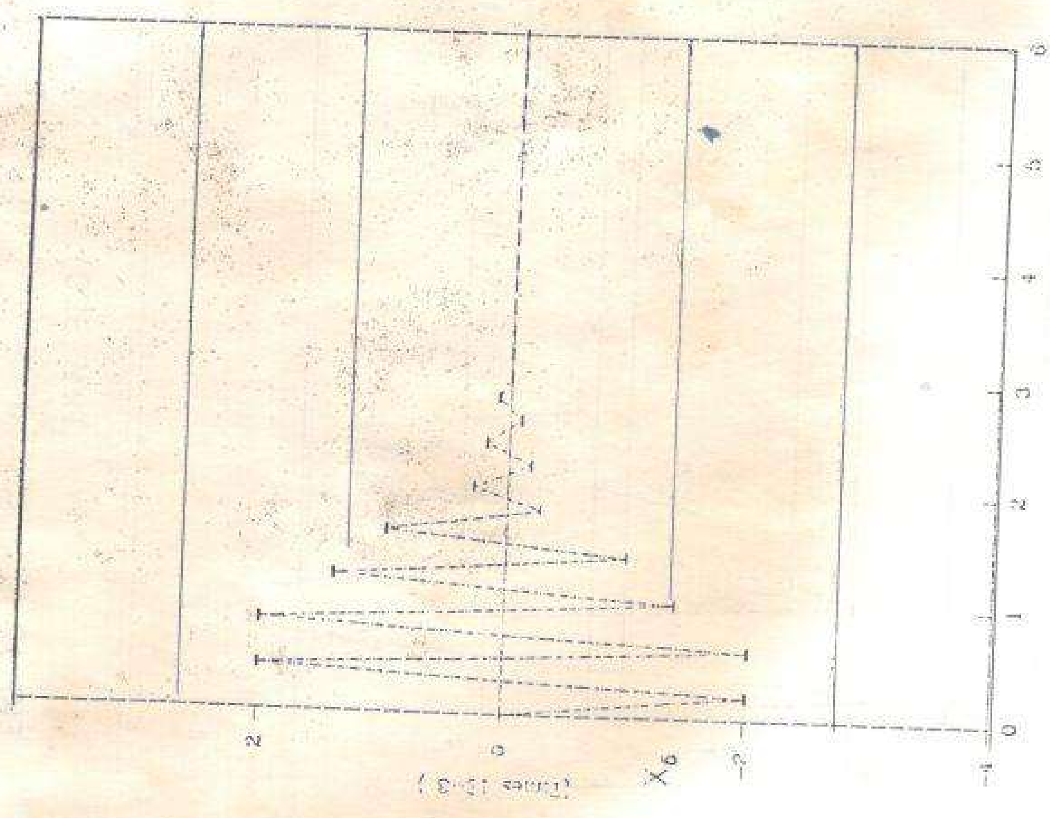

FIG 12 RESPONSE OF STATE VARIABLE X_6

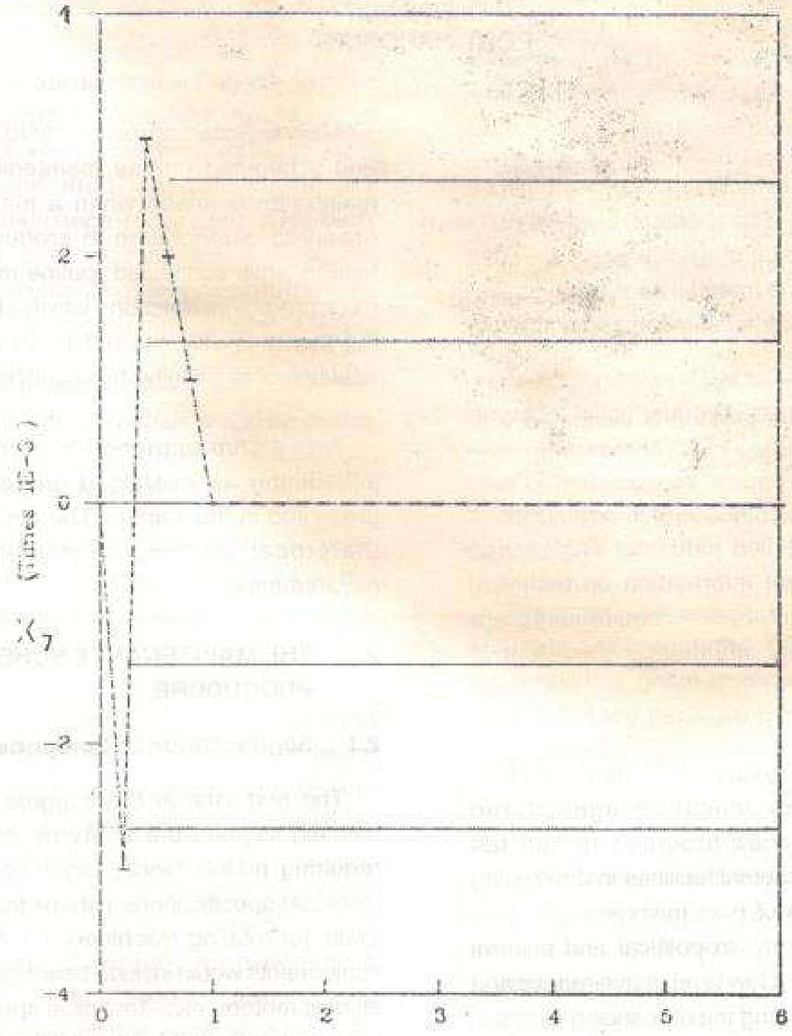

FIG 13 RESPONSE OF STATE VARIABLE X_7