AN ADAPTIVE IDENTIFICATION ALGORITHM FOR ELECTRO-MECHANICAL SYSTEMS

طريقة مقترحة للتقدير التوافقى لمتغيرات منظومة كهروميكانيكية

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ملخص البحث

فى هذا البحث تمت دراسه لدوال الحساسيه فى المنظومات الكهروميكانيكية . وهذه الدراسة تاخذ فى الاعتبار تاثير تغير معاملات الوحدة المتحكم فيها وكذلك تاثير الاضطرابات الخارجية الغير مقاسة .وقد تمت دراسة امكانية التقدير التوافقى لمتغيرات المنظومة الكهروميكانيكية باستخدام قانون تحكم توافقى مناسب .

واقترحت طريقة لتصميم مراقب توافقى لمثل هذه المنظومات.ونتائج المحاكاة تبين ملائمة مثل هذا المراقب التوافقى للاستعمال فى المنظومات الكهروميكانيكية حيث يتم تقدير معامل التكبير (الانتقال للمنظومة) تحت تاثير المعاملات المتغيرة والاضطرابات الخارجية بطريقة مرضية . ويساعد المراقب التوافقى المقترح فى استقرار الخصائص الديناميكية للمنظومات الكهروميكانيكية .

ABSTRACT

In the present paper a study on the sensitivity functions in electro-mechanical systems is introduced .This study takes into account the effect of parameters variation of the controlled plant . Also , the effect of the unmeasurable disturbance are studied . The possibility of identifying the unstationary parameters of an electro-mechanical system is viewed , using the suitable adaptive control law .

A new algorithm for designing an adaptive observer is introduced . The designed observer insures the possibility of evaluating the transfer co-efficient of the controlled electro-mechanical plant , under the effect of unmeasurable disturbances on the load side . The suggested adaptive observer helps in stabilizing the dynamic behaviour of electro-mechanical systems .

INTRODUCTION

Adaptive identification of transfer co-efficient in electro-mechanical systems represents one of the most significant problems . This transfer co-efficient is the most important parameter that must be identified in electro-mechanical systems . The previous identification algorithms suggested in [1],[2] & [3] are effective only, when the external disturbance is either small or it is possible to be measured . In case of large or unmeasurable disturbances , these previously mentioned algorithms become ineffective as identification algorithms . The well known identification algorithms introduced in [4] ,[5] are used only for single input systems and are not suitable for electro-mchanical systems.
From another point of view , the algorithm introduced in [6] can not stand effective in case of identifying parameters of an unstationary electro-mechanical system . Identification of dynamic systems , using sensitivity functions [7] , can be illustrated as shown in fig .(1) .

The identification process can be defined as a construction of a mathematical model of the real system, capable for observing and measuring the output signals [8] . In other words , it provides the designer with information about the variable parameters of the real system .

Considering the system shown in fig.(1), the output Y can be obtained form the input X through a system transfer co-efficient A . In the identification process, the system transfer co-efficient A is not estimated, but another co-efficient A_o belonging to the system model . The co-efficient A is known as the estimation of A . The best chosen model is that having a co-efficient A_o closely near to the transfer co-efficient A_o. In real systems, this closeness is achieved through a performance index (PI) , which must be minimized . The error signal ε , which represents the differene between the outputs of model $\tilde{Y}(t)$ and real system $Y(t)$ respectively , is given by :

$$\varepsilon = \tilde{Y}(t) - Y(t) \qquad (1)$$

This error signal is used to formulate the performance index (PI) . The optimum estimation A_o is obtained when (PI) is minimized .

SENSITIVITY FUNCTIONS IN ELECTRO-MECHANICAL SYSTEMS .

Consider the electro-mechanical system shown in fig.(2) . The system transfer function (T.F.) $\omega_u(s)$ for a given input u is given by

$$\omega_u(s) = \frac{G_S(s)\ G_C(s)\ G_R(s)\ G_{\omega}(s)\ G_M(s)}{D(s)} \qquad (2)$$

while the system transfer function due to a disturbance F on the load side is given by :

$$\omega_F(s) = \frac{[(G_S(s)\ G_T(s)\ G_R(s)\ G_{\omega}(s) + 1\ ]\ G_M(s)}{D(s)} \qquad (3)$$

where :

$G_S(s)$ = (T.F.) of the speed regulator of first order

$G_C(s)$ = (T.F.) of the current regulator of first order

$G_R(s)$ = (T.F.) of the rectifying element feeding the d.c.motor of first order

$G_a(s)$ = (T.F.) of the armature circuit (electrical side), of first order

$G_M(s)$ = (T.F.) of the mechanical side of the system of first order

$G_T(s)$ = (T.F.) of the feed-back transducer of First order

D (s) = a combination of the above T.F.^{s} and can be obtained easily .

In the given system we shall assume that electrical time constant T_a and the mechanical time constant T_M in addition to the gain factor of the rectifier element K_R , are varying with time . The sensitivity function for each of these parameters can be determined , [9] , as follows :

For any variable parameter α , the sensitivity function in the logarithmic form can be written as :

$$S_\alpha = \frac{\partial \ln \omega(s,\alpha)}{\partial \ln \alpha}$$

$$= \frac{\partial \ln \omega(s,\alpha)}{\partial \ln G(s,\alpha)} * \frac{\partial \ln G(s,\alpha)}{\partial \ln \alpha} \qquad (4)$$

then , the sensitivity function for K_R under the effect of an input u is given by

$$S_R^u = \frac{\partial \ln \omega_u(s,K_R)}{\partial \ln G_R(s,K)} \cdot \frac{\partial \ln G_R(s,K_R)}{\partial \ln K_R} \qquad (5)$$

for an external disturbance (F) on the load side the F will be

$$S_{K_R}^F = \frac{G_C(s)\ G_R(s)\ G_M(s)\ G_T(s)\ G_S(s) - G_S(s)}{D_9(s)} \qquad (6)$$

for a unit step input the input signal to the current regulator is given by :

$$U_C(s) = \frac{G_S(s)\ [\ 1 + G_a(s)\ G_M(s)\ ]}{D_4(s)} \qquad (7)$$

Using equations (5) and (7) we get :

$$S_{K_R}^u = M_z\ U_C(s) \qquad (8)$$

where M_2 is the sensitivity model connected to the input point of current regulator

$$M_S = [\, G_S(s)\,]^{-1} = \beta_S^{-1}\,(\tau_S(s) + 1\,)^{-1} \qquad (9)$$

where : β_S^{-1} is the reciprocal of gain co-efficient β_S and τ_S is the time constant of the regulator . From equtions (3) and (6) we have :

$$S^F_{K_R} = M_\sigma\, E_F \qquad (10)$$

where : E_F is the system output for a unit step input .

$$M_\sigma = \frac{G_T(s)\; G_a(s) \; - \; G_S(s)}{D_\sigma(s)} \qquad (11)$$

i.e., for a unit step input , the outputs of sensitivity models will have the character : $S^{u_c}_{K_R}$ & $S^F_{K_R}$. The sensitivity models due to the variation of the two parameters T_a and T_M have the form :

$$M_4 = \frac{T_a\; G_a(s)\; [\, 1 + G_S(s)\; G_C(s)\; G_R(s)\,]}{T_M\; G_S(s)\; G_R(s)\; [\, 1 + G_T(s)\; G_C(s)\; G_a(s)\; G_R(s)\,]} \qquad (12)$$

The sensitivity functions of the system can be calculated , using equations (8,10) .

ILLUSTRATIVE EXAMPLE :

For the electro-mechanical system shown in fig.(2) let :
T_M= 0.04 sec., T_a= 0.05 sec., T_T= 0.01 sec., T_R= 0.01 sec., K_R = 10, K_T = 0.5 and K_a= 10 .
The sesitivity function due to the variation of parameters K_R , T_a and T_M are determined for the model in the following two cases :

1- The input to the system is a unit-step function .
2- The external disturbance on the load side is a unit-step disturbance

Fig. (3-a) illustrates the sensitivity functions for the above two cases due to the variation of K_R. Fig. (3-b) shown the sensitivity function for the above two cases due to the variation of T_a . While fig.(3-c) illustrates the sensitivity functions due to the variation of T_M .

The following notes can be deduced from the above figures :

1- From Fig.(3-a), $S^{u_c}_{K_R}$ has a large initial value and tends to zero very quickly , while $S^F_{K_R}$ becomes less than unity when the transient oscillations die-out .
2- From Fig.(3-b) $S^{u_c}_{Ta}$ and S^F_{Ta} also have large initial values and tend to zero as time passes.

3- Fig.(3-c) illustrates that S^{uc}_{Tm} and S^{r}_{Tm} have the same initial value and also both tends to zero.

A comparative study of the shown figures leads to the following conclusion . The main parameters affecting to dynamic behaviour of an electromechanical system are the transfer-co-efficient K_R and the mechanical time constant T_M .Thus, in adaptive control system design, it can be recommended to identify the unstationary gain (transfer) co-efficient, which strongly affects the system dynamics.

A NEW ALGORITHM FOR DESIGNING AN ADAPTIVE OBSERVER FOR, AN ELECTRO-MECHANICAL SYSTEM.

The problem can be formulated as follows . For the given electro-mechanical system the unstationary transfer co-efficient b - relating current to speed will be under consideration. This co-efficient relates the excitation flux of the motor and moment of inertia J. Thus, it is required to design an adaptive observer, which produces an asymptotic estimation $\dot{b}$ for the unstationary co-efficient b In this case, it is assumed that an unmeasurable external disturbance F, is impressed on the system . In this case , we have to variants for designing such observer :-

1.FIRST VARIANT :

The differential equations describing the observer,required for an electro-mechanical system can be written as :

$$\dot{\tilde{Y}} = - \lambda \tilde{Y} + (u - F)\tilde{b} - \tilde{b}F - b\tilde{F} \qquad (13)$$

$$\dot{\tilde{b}} = \sigma (u - F) \tilde{Y} + \sigma YF \qquad (14)$$

$$\dot{\tilde{F}} = K\tilde{Y} \qquad (15)$$

Where :

$$\tilde{Y} = \dot{Y} - Y \quad , \quad \tilde{b} = \hat{b} - b$$

$$\tilde{F} = \hat{F} - F$$

$\tilde{y}$, $\tilde{b}$ and $\tilde{F}$ are the errors in the estimations., u , y and b are the input current, output speed and the unknown parameter of the plant respectively. F is the external disturbance on the interval (t, ∞); $\hat{y}$, $\hat{b}$ and $\hat{F}$ are the estimations of y , b and F respectively; λ , σ and K are paremeters of the designed observer.

To illustrate the hyper-stability behaviour of the system [10], we suggest to represent that system into two parts. One of these parts is linear and represented as :

$$\dot{\tilde{Y}} = -\lambda\tilde{y} + \mu \qquad \text{with a T.F.}$$

$$\phi(s) = \frac{1}{S+\lambda} \tag{16}$$

The second part of the system is nonlinear and represented as :

$$\rho = -\mu = -w(t)\,\tilde{b} + b\tilde{F} + \tilde{b}\,F \tag{17}$$

where $\tilde{w}(t) = u - F$

$$\dot{\tilde{b}} = -\sigma w(t)\,\tilde{Y} + \sigma\,\tilde{y}\,\tilde{F} \tag{18}$$

$$\dot{\tilde{F}} = K\tilde{y} \qquad > 0 \tag{19}$$

since

$$R\,(\phi(s))\big|_{s=j\omega} = \frac{\lambda}{\lambda^2 + w^2} > 0 \qquad \text{and}$$

$$\int_0^T \rho\,(t).\tilde{y}\,(t)dt = \frac{b}{2K}\tilde{F}^2 + \frac{1}{2\sigma}\tilde{b}^2 - \gamma_o^2 \geq \gamma_b^2$$

Thus, the identification algorithm is asymptotically hyperstable, where:

$$\gamma_o^2 = \frac{b}{2K}\tilde{F}^2(0) + \frac{1}{2\sigma}\tilde{b}^2$$

2. SECOND VARIANT :

A suggested structure for the adaptive observer is illustrated in Fig.(4) . Digital simulation results of the observer behaviour are illustrated , for two different cases , in Fig.(5-a) and (5-b). In Fig.(5-a), the excitation flux of the motor is decreased to 0.25 of its initial value. In this case, the difference between the estimation $\hat{b}$ of the transfer co-efficient b does not exceed 5% when, b reaches its maximum value. When b is decreased to its minimum value the difference ranges between 10 & 50% depending upon the rate of decrease. Fig.(5-b) illustrates the estimation $\hat{b}$ compared with the transfer co-efficient b when the load torque is varied suddenly . It is clear that the estimation $\hat{b}$ has the same character as that of Fig.(5-a). This leads to a result that the observer output (estimation) has a stable character . Thus, the suggested new observer can be used in the adaptive control of electro-mechanical systems. The required speed of adaptation depends mainly on the proper choice of the observer parameters σ , λ and K.

CONCLUSIONS

In the present paper, an analyticcal study about the effect of parameters variation on the dynamic behaviour of electro-mechanical systems is introduced. The study is based on the sensitivity functions approach, taking into account the effect of an unmeasurable external disturbance. It has been deduced that the transfer-co-efficient stands as the main effective variable parameter on the dynamic behaviour of electro-mechanical systems.

According to the above conclusion, the design of an adaptive observer for estimating this co-efficient became available. Two variants for designing such observer are suggested. The designed adaptive observers based on these two variants provide a stable estimation of the system transfer co-efficient.

Thus, it is possible to use one of the two suggested designs in the adaptive control of electro-mechanical systems. The speed of adaptation depends mainly on the proper choice of the observer parameters .

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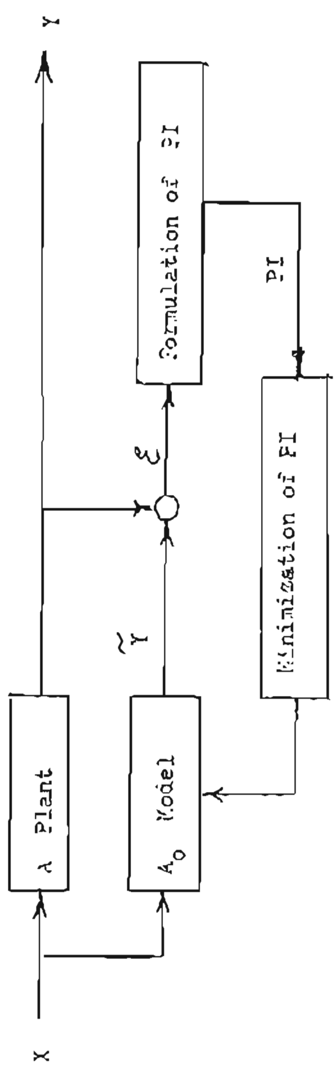

Figure (1)

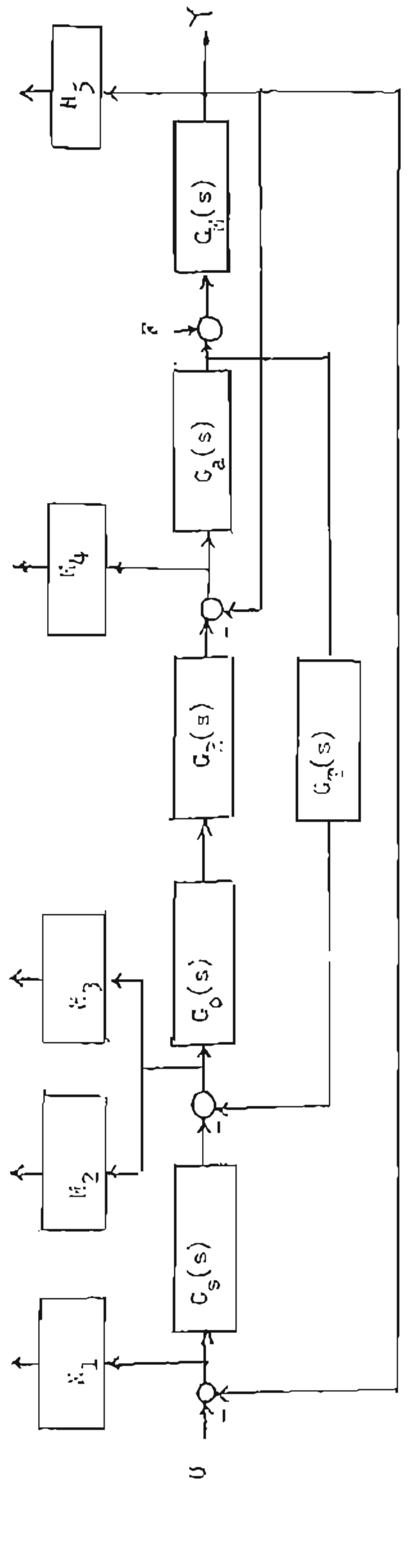

Figure (2)

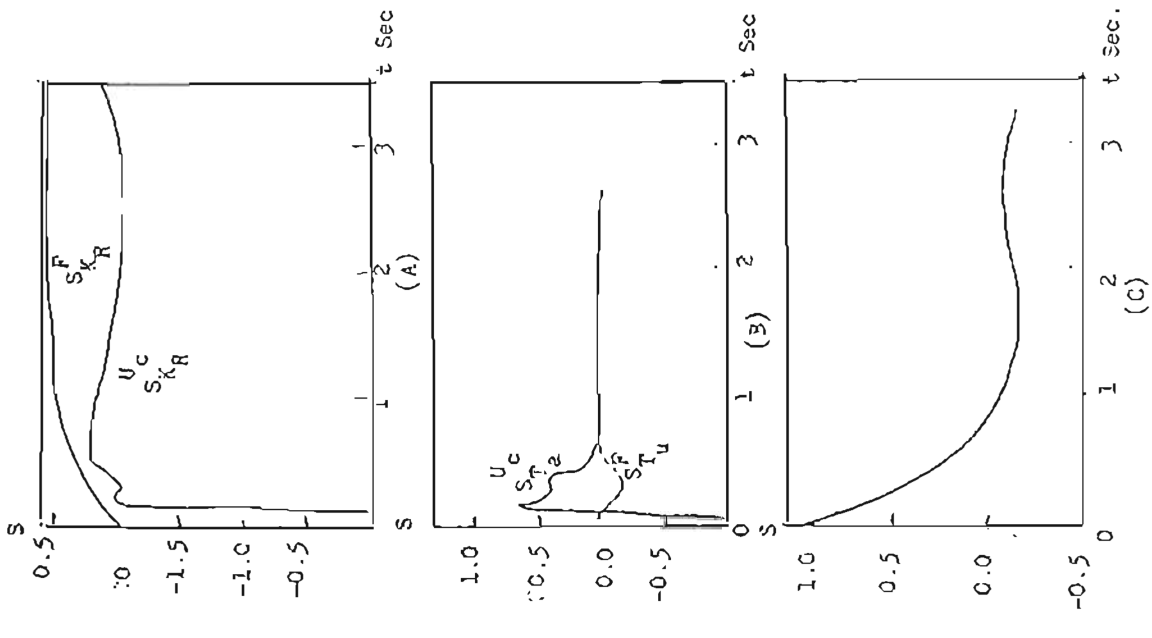

Figure (3)

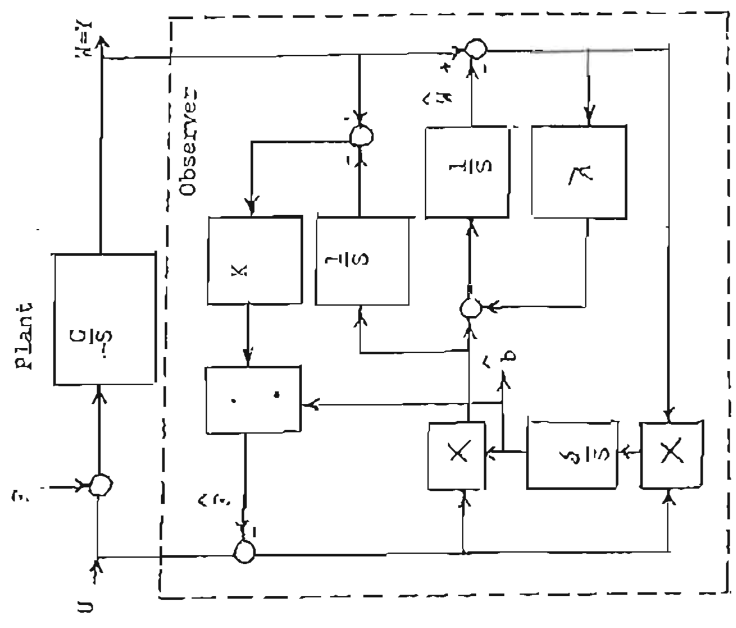

Figure (4)

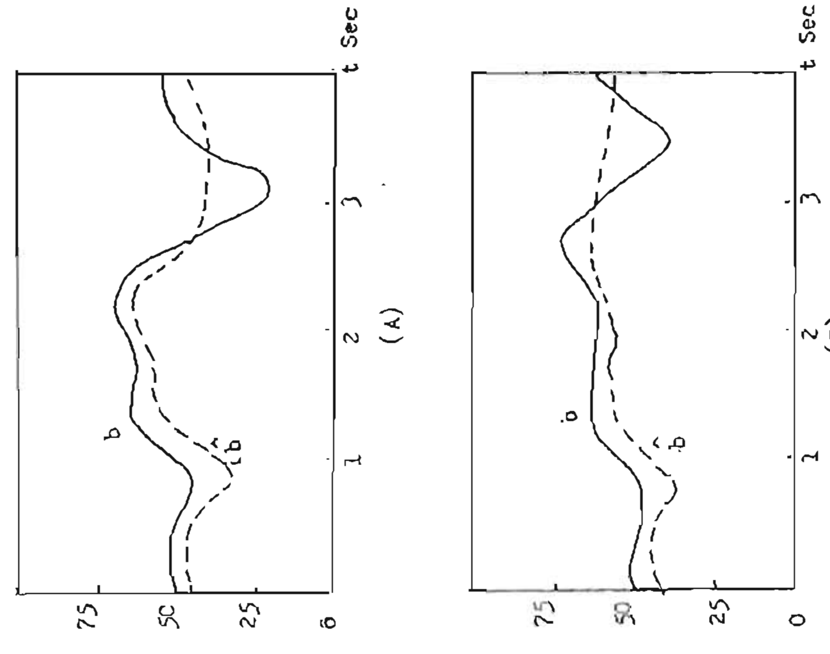

Figure (5)