ANALYSIS OF FRONT END CONTROL SCHEME APPLIED TO SECOND ORDER PLANTS+

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Abstract

In this paper , a control scheme for second order plant which is used to improve the quality of response of this plant is suggested. The suggested front end control scheme is applied to both known and unknown plants . Application of this scheme to unknown plant is carried out using the principle of model reference adaptive control (MRAC).The response of this plant reaches the steady state value as quickly as possible without overshoot and oscillations . The time at which the plant response reaches the desired output is constant . This scheme is applied to second order plants by using analog computer simulation techniques.

المستخلص

يتناول هذا البحث اقتراح مخطط للتحكم في بعض أنظمة الدرجة الثانية الذي يكون ذا كفاءة عالية في تحسين الاستجابة لهذه الأنظمة. يستخدم مخطط التحكم بالنهاية الأمامية المقترح للأنظمة ذات العناصر المعلومة والمجهولة. إن استخدام هذا المخطط ذات العناصر المجهولة تم بالتحكم بطريقة النموذج المرجعي المتكيف. تصل استجابة المنظومة إلى الحالة المستقرة سريعا دون حدوث تجاوز للهدف وحدوث تذبذباً. إن الزمن المستغرق لوصول الاستجابة إلى الإخراج المحدد ثابت. تم استخدام الحاسب التناظري في تحليل هذه الأنظمة .

Introduction

Several industrial automata, such as robots, perform their task cycle by changing the position of their elements from point to point.

Many types of optimum control systems are used and found useful in practical applications, such as:

1) the optimal performance criterias are used to perform this task in a most effective manner [1, 2].
2) the time optimal control systems are used to drive the state of the controlled system to desired state in the possible minimum time [3, 4].
3) the dead beat control systems are used to force the state of a linear discrete-time system in such a way that it leads to the fastest response with zero steady state error at the sampling instants [5,6,7] .

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4) the posicast control systems are a well technique used for obtaining a finite time setting response without oscillations [8, 9].

5) the front end (F.E) control system having an initial control sequence of varied levels, optimizes a performance [10] .This strategy, is used to improve the response of the plant for first –order and second - order plants.

The (F-E) control scheme is proposed to deal with second order inputs which consist of underdamped plants of two levels.

F.E control scheme is simulated in analog computer [11].

The procedure used to determine the F.E. control levelsis if the input switching from b to c is made to occur when a switching function S (t) reaches zero at time (t_m) the switching is

$$S(t) = Y(t) - Y_{ss} - \alpha \dot{Y}(t)$$

The last term ensures a correct switching time at (t_m).

F.E Control for second order plant

The general form of the input r(t) is shown in Fig (1) .

The input is maintained at (b) which makes the maximum overshoot in the plant output to occur at $y(t) = y_{ss}$ and at $t=t_m$.

At this instant the input is switched from b to c which corresponds to a value that gives a steady state output $y(t) = y_{ss}$.

The use of this type of two level input makes the response of a second order underdamped plant to reach the output without overshoot and oscillation.

The parameters which are used in the second order underdamped plant are w_n & ζ

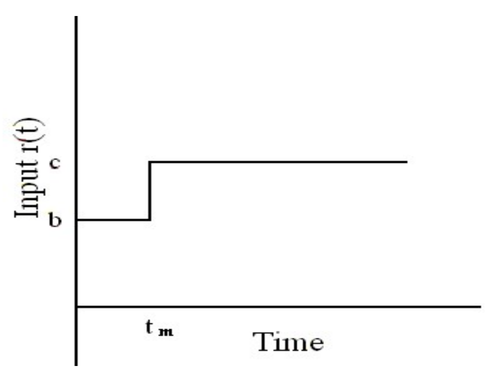

Fig. (1): General form of F.E control for a second order plant

Analysis of the control switching

The following differential equation describes a second order, under damped, time-invariant plant.

$$\ddot{y}(t) + 2\xi w_n \dot{y}(t) + w_n^{\ 2} y(t) = w_n^{\ 2} r(t) \qquad (1)$$

where : w_n is undamped natural frequency, $0< \xi <1$ represents damping ratio of the plant.

The plant has a unity gain, and its response to step input r (t) = r is [12]

$$Y(t) = r[1 - \frac{e^{-\xi w_n t}}{\sqrt{1-\xi^2}} \sin(w_\circ t + \theta)] \qquad (2)$$

where :

$$\theta = \tan^{-1}\frac{\sqrt{1-\xi^2}}{\xi} \quad and \quad w_\circ = w_n\sqrt{1-\xi^2} \qquad (3)$$

The input C is

$C=Y_{ss}$

The plant output is considered for three different instants:

i) For $t < t_m$, then

$r(t) = bu(t)$

where u(t) is a unit step input . The output is

$$Y(t) = b[1 - \frac{e^{-\xi w_n t}}{\sqrt{1-\xi^2}} \sin[w_\circ t + \theta] \qquad (5)$$

The maximum overshoot occurs at t_m [12]

$$t_m = \frac{\pi}{w_n\sqrt{1-\xi^2}} \qquad (6)$$

ii) For t=tm , The plant output becomes

$$y(t_m) = b[1 + e^{-\xi w_n t_m}] = y_{ss} \qquad (7)$$

It can be rewritten as

$$e^{-\xi w_n t_m} = \frac{y_{ss} - b}{b} \qquad (8)$$

eqn. (1) can be reduced to

$$\ddot{Y}(t) + w_n^{\ 2} Y_{ss} = w_n^{\ 2} bu(t) \qquad (9)$$

because $\dot{Y}(t_m) = zero$

Then eqn. (9) at $t = t_m$ results in

$$\ddot{Y}(t) = 0 \qquad (10)$$

iii) For $t \rangle t_m$, the input is

$$r(t) = bu(t) + (c-b)u(t - t_m) \qquad (11)$$

The output becomes

$$Y(t) = b[1 - \frac{e^{-\xi w_n t}}{\sqrt{1-\xi^2}} \sin(w_\circ t + \theta)] + (c-b)[u(t-t_m) - \frac{e^{-\xi w_n (t-t_m)}}{\sqrt{1-\xi^2}} \sin(w_\circ (t-t_m) + \theta)] ...(12)$$

Let $t = \hat{t} + t_m$ ، the eqn (12) becomes

$$Y(t) = b[1 - \frac{e^{-\xi w_n (\hat{t}+t_m)}}{\sqrt{1-\xi^2}} \sin(w_\circ (\hat{t}+t_m) + \theta)] + (c-b)[1 - \frac{e^{-\xi w_n \hat{t}}}{\sqrt{1-\xi^2}} \sin(w_\circ \hat{t} + \theta)] ....(13)$$

Since

$$\sin(w_\circ (\hat{t} + t_m) + \theta) = \sin(w_\circ \hat{t} + \pi + \theta)$$

$$= -\sin(w_\circ \hat{t} + \theta) ....(14)$$

Substituting eqn (14) and (8) in (13), yields

$$Y(t) = Y_{ss} ....(15)$$

In case of under - damped plant with F.E control, the switching circuit is shown in Fig (2).

The input switching from b to c is made to occur when a switching function s (t) reaches zero. The switching function is

$$S(t) = Y(t) - Y_{ss} - \alpha \dot{Y}(t) ....(16)$$

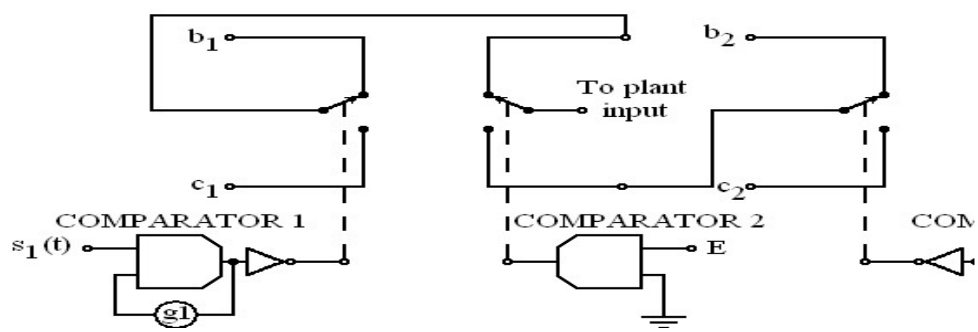

Fig. (2): F.E control switching circuit for second order plant

The proposed two step F.E control scheme forces the output of the under - damped plant to reach the steady state value without overshoot and oscillation at time $t = t_m$.

The response of a second order plant is

$$\frac{Y(s)}{R(s)} = \frac{Kw_n^2}{S^2 + 2\zeta w_n s + w_n^2} ....(17)$$

where $w_n = 4$ and k = 0.5.

The responses of this plant are observed for the following four cases:

i) Critically damped plant with $\zeta = 1$, steady state output $Y_{SS} = 2v$ and with step control.
ii) Under damped plant with $\zeta = 0.3$, $Y_{SS} = 2v$ and with step control.
iii) Under damped plant with $\zeta = 0.3$, $Y_{SS} = 2v$ and with F.E control.
iv) Under damped plant with $\zeta = 0.3$, $Y_{SS} = 5v$ and with F.E control.

Fig (3) shows the input of the plant and the responses for (i ,ii) cases. Figs (4) and (5) give the input and the response for (iii , iv) cases.

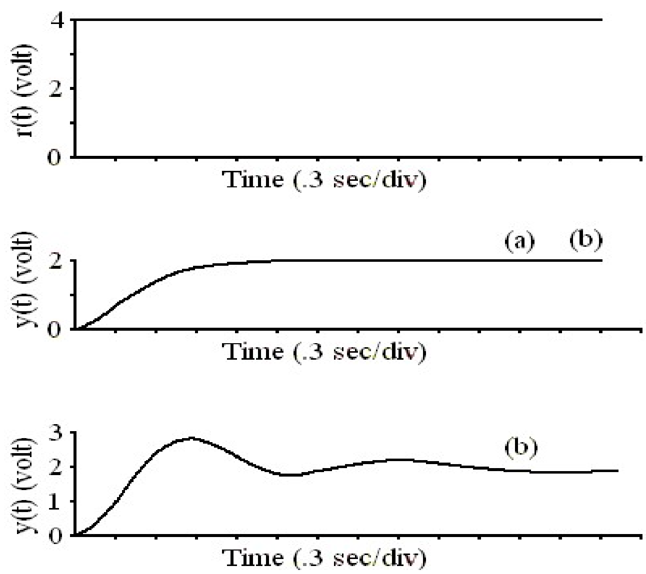

Fig. (3): Input r(t) and response y(t) for (a) case (i) (b) case (ii) – conventional step control

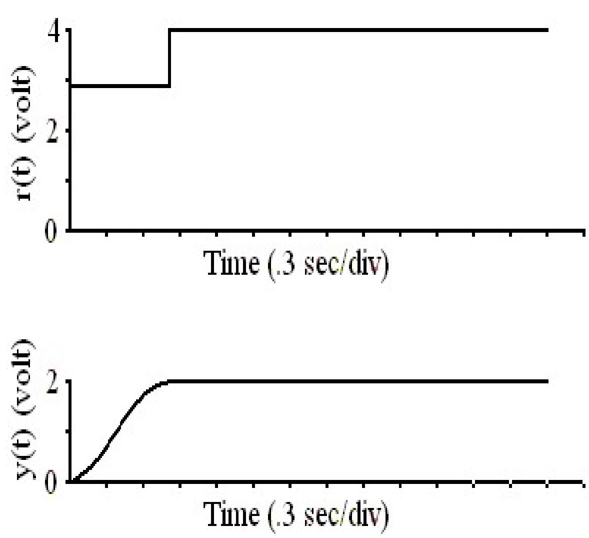

Fig. (4) Input r(t) and response y(t) for case c(iii) – F.E control

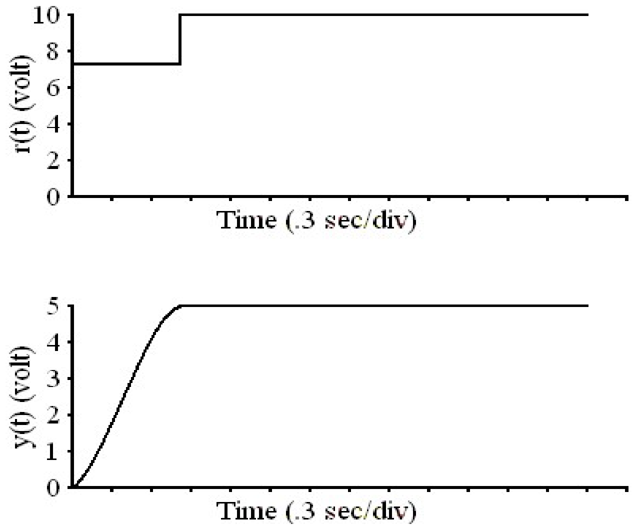

Fig. (5): Input r(t) and response y(t) for case (iv) – F.E control

Discussion and Conclusions :

From the figures , it is evident that:

1) the F.E control can be used with an advantage of obtaining faster responses than those obtained by conventional step control.
2) it is also observed that the time, at which the output of an under - damped second order plant with F.E control reaches its steady state value Y_{SS} , which is constant irrespective of the values of Y_{SS} .

In this paper, the F.E control scheme for second order plant is observed. The theoretical analysis and the analog computer simulation results lead to the following conclusions:

1) This scheme can be applied to a second order under damped plant. If the plant is over - damped, it should be made under - damped using state variable (s. v) feedback.
2) The time at which the plant response reaches the desired output, Y_{SS} , is constant irrespective of the value Y_{SS} .
3) The F.E control consists of different levels. These levels can be calculated and the input can be applied to the plant by using suitable switching circuits.
4) This scheme is also can be applied to the unknown plants.

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