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Study Of Designing Regulator Systems By Using The Different Observer Approach.

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Abstract: *State space regulators are not as well known by many of the engineers either they are a little bit more complicated to understand either a modeling of a system is needed to design a robust and stable feedback loop however, there is a variety of plants, where a use of state space regulators can be used. Especially if regulators of multiple in & multiple out systems need to be designed is not so complicated regulator structure causes very often very robust stable system, which never could be reached by PID regulators. The paper helps in view of control feedback and simplifies the decision weather to choose a conventional structure or state space regulators.*

Keywords: *Regulator, state observer , state space, pole placement, LQR, LTR*

I. INTRODUCTION

The state-space model and dynamic characteristics is to be investigated. In order to stabilize and gain full control of the plant, a state feedback controller using the Linear Quadratic Regulator (LQR) method is required the states can be reconstructed using an OBSERVER if the system satisfies a property observability state observer is used and it will be designed based on the pole placement method. All the above investigations will be carried out or simulated by MATLAB and Simulink. The complete controller is then given as the observer in cascade with the SVFB. In effect, the observer functions as a dynamic compensator for the system. A crucial property of LQR controller design is that this closed-loop is asymptotically stable(i.e., all the eigenvalues of A BK have negative real part) as long as the following two conditions hold: Sidebar 5. The definitions 1. The system is controllable. And tests for controllability and observability are reviewed in The system is observable when we ignore y and regard z as the sole output.

II. Regulator design:

It is possible to stabilize a controllable system by state feedback with(static) gain K.K can be designed e.g. by pole placement. This results in a stable closed loop system if the poles are chosen in the left half plane. K can be designed more sophistically, e.g. using the LQR method. a stabled closed-loop system results. Moreover, there are some robustness guarantees in form of phase and gain margin. Observer design: For an observable system, it is possible to build an observer with an estimated state vector ˆx converging towards the true state vector x. The gain H used in the observer can be designed e.g. by pole placement. The observer is stable if the poles are chosen in the left half plane. H can be designed more sophistically, e.g. using the LQG method and a stable closed-loop system results. Moreover, there are some robustness guarantees in form of phase and gain margin. Design of observers and increasing the robustness of state regulators with observers.

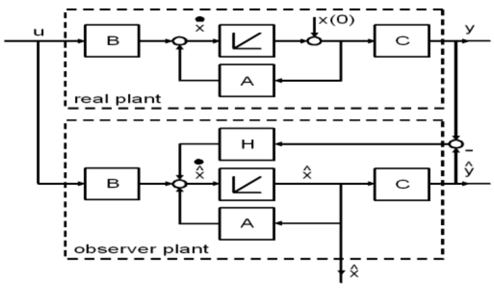


Figure 1: Observer design

The dynamics of ˜x are described by the system matrix A. If it is unstable, then the estimation error diverges. If A is stable then ˜x converges towards zero however, probably very slowly. Furthermore, effects like noise or errors in the system description (A, B) might cause the estimate to diverge from the true state. We now introduce feedback in the observer, to enforce stability of the error dynamics and/or for faster convergence. The difference between the measured and the estimated outputs are used to correct the estimated state, see Fig. 1. The LQ-regulator design assumed that all the state variables are available for feedback. In practice, not all state variables are measured. The reasons are that this is not physically feasible or that the sensors required are probably too expensive. In this section we demonstrate how to reconstruct the complete state information based on the measured output y. The assumption is that we know the system description (A, B, C) and that (A, C) is observable. One method of estimating the state x in an observer is to construct a full order model of the plant dynamics

2.1 State space representation of dynamic systems

A dynamic system consisting of a finite number of lumped elements may be described by ordinary differential equations in which time is the independent variable, by use of vector matrix notation, an n-th order differential equation may be expressed by a first order vector matrix differential equation .if n- elements of the vector are a set of state variables, then the vector matrix differential equation is a state equation. State-space Representation of n-th order systems of linear differential equations in which the forcing function does not involve Derivative Terms. Consider the following n-th order system:

$$y^n + a_1 y^{n-1} + \cdots \dots\dots\dots a_{n-1}\dot{y} + a_n y = u \text{..............Eq (2-1)}$$

Noting that the knowledge of $y(0), \dot{y}(0), \dots\dots y^{n-1}(0)$,together with input u(t) for $t \geq 0$,determines completely the future behavior of the system, we may take $y(t), \dot{y}(t), \dots\dots\dots y^{n-1}(t)$as a set of n-state variables. Let us Define

Then equation can be written as .

$\dot{x_1} = x_2$

$\dot{x_2} = x_3$

$\dot{x_n} = a_n x_1 \dots\dots -a_1 x_1 + u$...... (2-2)

y= C **x** ………………………….. (2-3)

2.2 State-space of linear differential forcing function is in Derivative terms.

$x_1 = y - \beta_{0u}$

$x_2 = \dot{y} - \beta_{0\dot{u}} - \beta_{1u} = \dot{x}_1 - \beta_{1u}$

$\dot{x_2} = \ddot{y} - \beta_{0\ddot{u}} - \beta_{1\dot{u}} = \dot{x}_1 - \beta_{1u}$ …………………….. (1-5).

$x_n = y^{n-1} - \beta_{0u} - \beta_{1u} - \cdots \dots\dots\dots - \beta_{0n-2\dot{u}} - \beta_{n-1u} = \dot{x}_{n-1} - \beta_{n-1u}$.

Where $\beta_0, \beta_1, \beta_2 \dots\dots \beta_n$ are determined from

$\beta_0 = b_0$

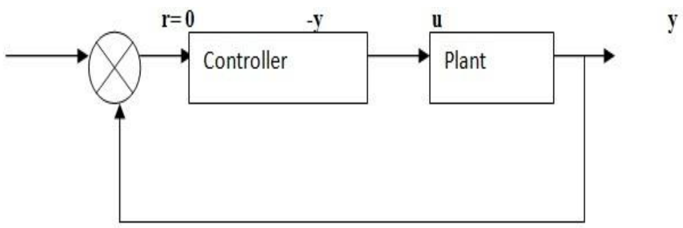
$\beta_1 = b_1 - a_1\beta_0$

$\beta_2 = b_2 - a_1\beta_1 - a_2\beta_0$

$\beta_n = b_n - a_1\beta_{n-1} \text{ ------- } a_{n-1}\beta_1 - a_n\beta_0$ …… (1-6)

With this choice of state variables the existence and uniqueness of the solution of the state equation is guaranteed. In this state –space representation, matrices A and C are exactly the same as those for the system. the derivatives on the right-hand side of equation affect only the elements of the B matrix. Matlab can be used to obtain state-space representation.

III. The regulator system by Observer Design with Dual Methods



In the case of the regulator design we discussed the method of pole placement: Given are A and B — determine K such that the eigenvalues of A − BK coincide with some predefined poles. For the observer design, the problem occurs in its dual form. Given are A and C — determine H such that the eigenvalues of A − HC coincide with some predefined poles. Note that A−HC and its transpose, AT −CTHT, have the same eigenvalues. So, for the pole placement, we add a new entry to the list of correspondences K the reference input is zero the plant transfer function is

$G(s) = \frac{4(s+2)}{s(s+4)(s+6)}$…………..(3.1)

using the pole-placement approach, design a controller such that when the system is subjected to the following initial condition:

$x(0) = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}, e(0) = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$

Where x is the state vector for the plant and e is the observer error vector, the maximum undershoot of y(t) is 25 to 35% and the settling time is about 4 sec. Assume that we use the minimum-order observer.

3.1 Design procedure

1. Derive a state space model of the plant.
2. Choose the desired closed-loop poles for pole placement. Choose the desired observer poles.
3. Determine the state feedback gain matrix K and the observer gain matrix $K_{e.}$
4. Using the gain matrices K and ke, obtained in step-3,derive the transfer function of the observer controller. If it is a stable controller, check the response to the given initial condition. If the response is not acceptable, adjust the closed loop pole location and/or observer pole location until an acceptable response is obtained.

3.2 Design step 1:

We shall derive the state-space representation of the plant. Since the plant transfer function is

,$\frac{y(s)}{u(s)} = \frac{4(s+2)}{s(s+4)(s+6)}$

The corresponding differential equation

,$\dddot{y} + 10\ddot{y} + 24\dot{y} = 4\dot{u} + 8u$

From the above define the state variables $x_1, x_2 \& x_3$ as follows:

$x_1 = y - \beta_{0u}$

$x_1 = \dot{x_1} - \beta_{1u}$

$x_3 = \dot{x_2} - \beta_{2u}$

From above (1-6) equation derive B value

From that u got state model.

3.3 Design step 2:

As the first trial, let us choose the desired closed-loop poles at

,$s = -1 + 2j, \quad s = -1 - 2j, \quad s = -5$

And choose the desired observer poles at $s = -10, \quad s = -20$

3.4 Design step 3:

Now compute the state feedback gain matrix K and the observer gain matrix K_e

Ke = $\begin{bmatrix} 20 \\ -24 \end{bmatrix}$

3.5 Design step 4:

We shall determine the transfer function of the observer controller.

Define the minimum –order observer-based controller. By considering u as the output and –y as the input, U(s) can be written as,

U(s)=$[\tilde{c}(sI - \tilde{A})^{-1}\tilde{B} + \tilde{D}]Y(s)]$

From that calculate the transfer function of the observer controller.

The result is,$Gc(s) = \frac{21.60s^2 + 164.50s + 250}{s^2 + 27s - 85}$

IV. System with this observer controller as system1.

The observer controller has a pole in the right-half s-plane. The existence of an open loop right half s-plane pole in the observer controller means that the systems is open loop unstable, although the closed loop system is stable. Calculate characteristic equation for the system.

$chara_{eq} = \quad 1.0e + 003 *, 0.0010 \quad 0.0370 \quad 0.4250 \quad 1.8750 \quad 3.7500 \quad 5.0000$

A disadvantage of using an unstable controller is that the system becomes small. Such a control system is neither desirable nor acceptable. Hence to get a satisfactory system, we need to modify the closed loop pole location and observer pole location.

Take L = [-3.5 -3.5]

Find the new feedback gain, from that obtain transfer function. Define this observer controller as system 2.

$$Ke = \begin{bmatrix} -3.000 \\ 18.25 \end{bmatrix} ; Gc(s) = \frac{1.0359s^2 + 8.0125s + 15.3125}{s^2 + 4s + 1.8906}$$

Obtain the response of the system 2 to the initial condition.

$x(0) = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}, e(0) = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$, By substituting $u = -Kx$, for the plant

The error equation is for the minimum-order observer is $\dot{e} = (Abb - K_e Aab)e$

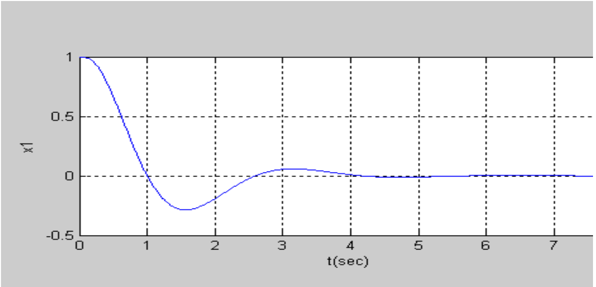


Fig.1 Initial condition response $x_1(0) = 1$

After drawing the diagram with the observer controller as a series controller in the feed forward path,

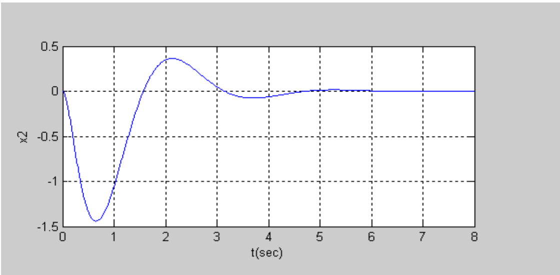


Fig.3 Initial condition $x_3(0) = 0$

Finally obtain the response of the system to the following different condition`

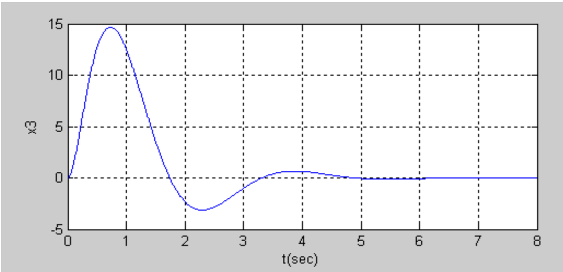


Fig.2 Initial condition $x_2(0) = 0$

After putting the initial condition in the characteristic equation error goes to zero after changing the poles for observer

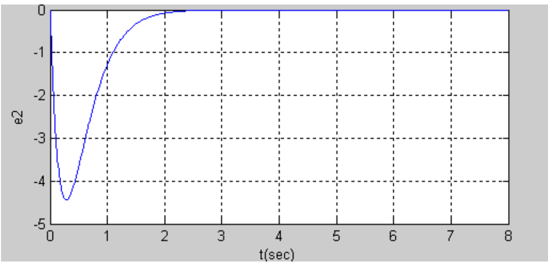


Fig.4 Error initial response $e_1(0) = 1$

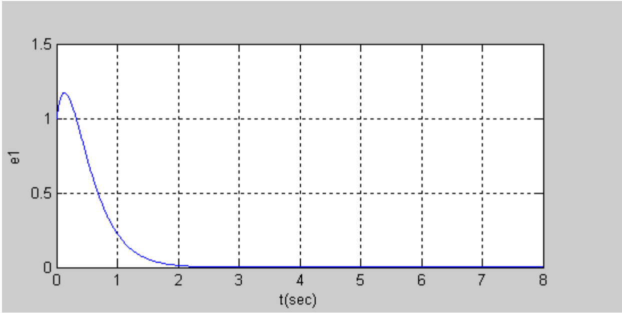


Fig.5 Error e_2 (0) = 0

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V. CONCLUSION

In given paper input single output (SISO) plant is converted from a transfer function expression into the state-space representation. The plant's open loop dynamics is analyzed and simulated. Results show that it is neither asymptotically stable nor BIBO stable. Thus, state feedback is needed to stabilize the system. We assume that all state variables are measurable. State feedback control using the LQR method is implemented and the error is changing next case when the state variables are not measurable. A full order state observer controller is designed based on the pole placement method. The relationship between the observer pole location and system performance.

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