A REAL TIME APPLICATION OF THE DUAL CONTROLLER BY CORRECTIONS VECTOR

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INTRODUCTION

The dual controller by corrections vector (DCCV) (Luzardo and Padilla, (1)) is a sub-optimal dual control strategy. This controller has shown its efficiency in computer simulations. The efficiency is measured through the transient response of the controlled system. In the transient response, the controller must provide the control signals to follow the reference and to assure a good estimation of the parameters.

The algorithm of the DCCV presents the disadvantage of requiring a search procedure to find the real roots of a fifth order polynomial. This drawback may eventually be a limitation in a real time application of the controller. This paper investigates such an application.

DESCRIPTION OF THE SYSTEM AND ITS MATHEMATICAL MODEL.

Fig. 1 shows a schematic representation of the controlled system. It has two interacting tanks. The tank number two (T2) is a closed tank. The level of the tank number one (T1) was controlled manipulating the output flow (Q3) of the second tank (T2). The flow Q1 is a perturbation variable.

The instrumentation used was:

a. Level transducer based on ultrasound techniques. This transducer converts linearly the level of the first tank (T1) (range: 0-40 cms) to a binary number between 255 and 0.
b. Current to pressure transmitter (4-20 mA to 3-15 psi linearly).
c. Pneumatic control valve. The relation between the output flow (Q3) and the input pressure (3-15 psi) is non linear.

The system is non-linear, however a linearization can be pursued around an operation point. The choice of the model structure was determined by previous identifications which suggested the model:

$$\frac{Y(s)}{U(s)} = \frac{Ke^{-sT}}{(1+sT_1)(1+sT_2)} \qquad (1)$$

where

Y(s): Laplace transform of the level variations of T1 around the operation point.
U(s): Laplace transform of the variations of the transmitter input current around the operation point.
T: System delay.

The discretization of the model described by eq.(1), taking into account zero order sample-hold, is:

$$y(t)+a_1y(t-1)+a_2y(t-2)=bo\ u(t-k)+b_1u(t-k-1) \qquad (2)$$

where k is the system delay expressed as a multiple integer of the sample time.

CONTROL STRATEGIES

The equation (2) can be written as:

$$A(q^{-1})y(t)=B(q^{-1})u(t-k)+e(t) \qquad (3)$$

where the q operator is defined as:

$$q^{-1}x(t) = x(t-1)$$

and

$$A(q^{-1}) = 1 + a_1q^{-1} + a_2q^{-2}$$

$$B(q^{-1}) = b_o + b_1q^{-1}$$

e(t): white gaussian noise (measurement errors)

Previous identifications determined that the system was a non-minimum phase one and that the value of k was 2.

It's necessary to find an auxiliar predictive equation for the model described by eq.(3) in order to apply the self-tuning controller (Clarke and Gawthrop, (2)) and the DCCV (see (1))

Using the identity (Astrom (3)):

$$1 = A(q^{-1})\ F(q^{-1}) + q^{-2}\ G(q^{-1}) \qquad (4)$$

where

$$F(q^{-1}) = 1 + f_1q^{-1}$$

$$G(q^{-1}) = g_o + g_1q^{-1}$$

the equation (3) yields to a two step predictor:

$$y(t+2) = F(q^{-1})e(t+2) + G(q^{-1})\ y\ (t) + B(q^{-1})\ F(q^{-1})\ u(t) \qquad (5)$$

the equation (5) can be written as:

$$y(t) = \varepsilon(t) + \phi(t)\ \theta \qquad (6)$$

where:

$$\varepsilon(t) = F(q^{-1})\ e(t)$$

$$\phi(t) = [u(t-2)u(t-3)u(t-4)y(t-2)y(t-3)]$$

$$\theta = [\beta_o \beta_1\ \ \beta_2\ g_o\ g_1]^T$$

$$BF(q^{-1}) = \beta_o + \beta_1q^{-1} + \beta_2q^{-2}$$

The system described by eq.(3) can be controlled using eq.(5) with a self-tuning controller in order to minimize the criterion (see (2)):

$$J_1 = \underset{u(t-2)}{E} \{ [y(t)-y_R(t)]^2 + \lambda [u(t-2)-u(t-3)]^2 \}$$

By the other hand, the proposed controller minimizes the criterion:

$$J_2 = \underset{u(t-2)}{E} \{ [\phi(t)\theta - y_R(t)]^2 + \lambda_1 ||V(t)||^2 + \lambda_2 [u(t-2)-u(t-3)]^2 \}$$

where:

$||V(t)||$: module of the stimated parameters corrections vector.

Equation (6) is the output equation of the Kalman filter. This equation presents coulored noise ($\varepsilon(t)$) because the delay is equal to two sample times. $\varepsilon(t)$ is statiscally independent of $\phi(t)$. There are sub-optimal techniques which allow to design a Kalman filter for systems with coulored noise in the autput equation (Anderson and Moore, (4)). However, under the assumption of θ beeing a constant, the used Kalman filter did not consider $\varepsilon(t)$ as coulored noise in this application.

The main problem in the real time application of the DCCV is the minimization of J_2. In this case, the u-axis was divided into intervals where on each of them a local minimum exists. The global minimum was obtained by comparing the local minumums. It was observed that one local minumum existed in stacionary conditios.

EXPERIMENTAL RESULTS

The experimental tests were two-fold:
a. Changes in the reference values
b. Changes in the perturbation values

The sample time was 15 seconds in all the tests. The initial values were:

Case 1, self-tuning controller:

$$\hat{\theta}(0) = [-0.04, -0.01, 0.6, 0.4]^T$$

$$\phi(0) = [\ 0,\ 0,\ 0,\ 0\ ]$$

$$\beta_o = -0.05 \text{(fixed, perfectly known)}$$

$$P(0) = 200\ I$$

In this case, the estimated parameters $\hat{\theta}(0)$ were close to the true parameters in order to improve the transient response.

Case 2, DCCV:

$$\hat{\theta}(0) = [10^{-4}, 10^{-4}, 10^{-4}, 10^{-4}, 10^{-4}]^T$$

$$\phi(0) = [\ 0,\ 0,\ 0,\ 0,\ 0\ ]$$

$$P(0) = 200\ I$$

The comparison of the controllers is made on the basis of two indexes:

$$V(N) = \sum_{n=o}^{N} [y(n)-y_R(n)]^2$$

$$C(N) = \sum_{n=o}^{N} u(n)^2$$

The results are shown in figures 2, 3, 4, 5, 6, 7, 8 and 9.

CONCLUSIONS

The DCCV was implemented for a slow response system. The system delay was aproximately two sample periods. The DCCV could be implemented under the assumption of θ (system parameters) beeing a constant vector. The DCCV shown a better perfomance for deficient initial values ($\theta(0)$, $P(0)$) than the self-tuning controller. This result allows to conclude that the dual control and in particular the DCCV, represents a new control alternative in industrial applications.

REFERENCES

1. Luzardo, J.A. and Padilla P.A., 1985, "Dual Controller by corrections vector and its extension to systems with coloured noise". Paper submitted to International Conference Control 85. University of Cambridge, U.K.

2. Clarke, D.W. and Gawthrop P.J., 1975, Proc. IEE, Vol 12, N°9, 929-934.

3. Aström, K.J., 1970, "Introduction to Stochastic Control Theory", Academic Press, New York.

4. Anderson, B.D.O. and Moore, J.B., 1979, "Optimal Filtering", Prentice-Hall, New York.

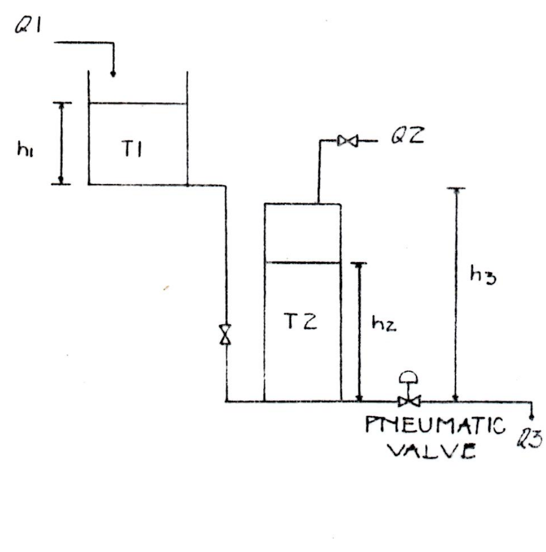

Fig. 1 Hydraulic system

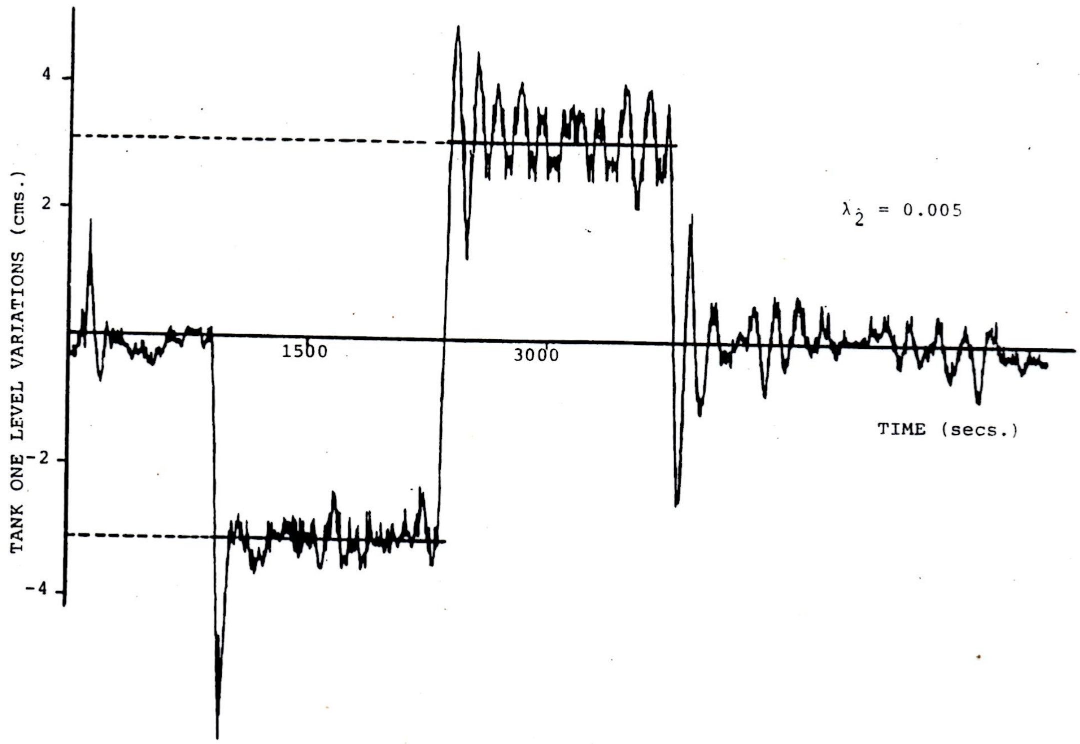

Fig. 2 System controlled by the self-tuning controller (reference changes)

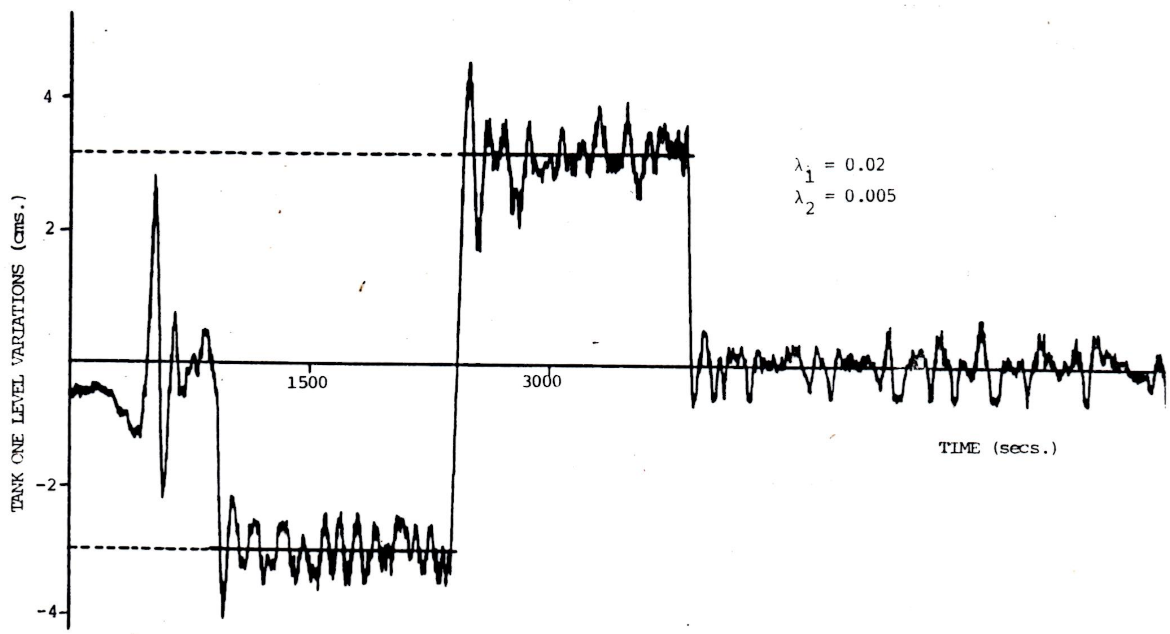

Fig. 3 System controlled by the DCCV (reference changes)

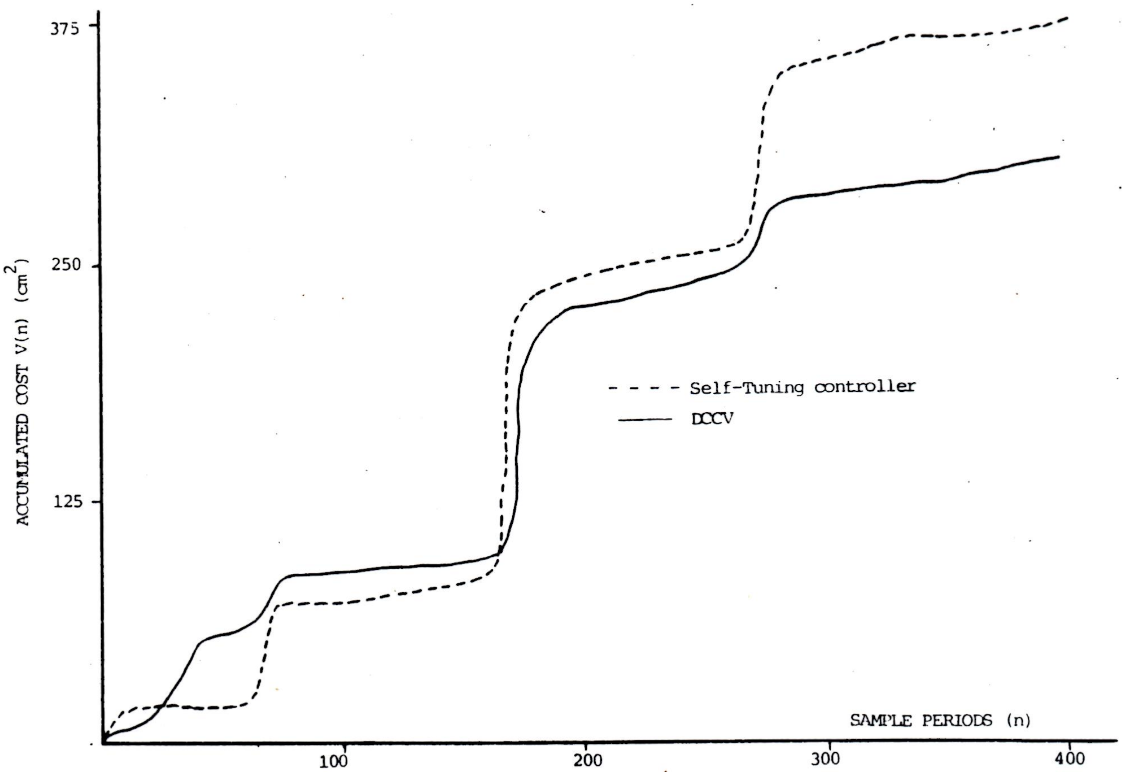

Fig. 4 Comparison of V(n) (reference changes)

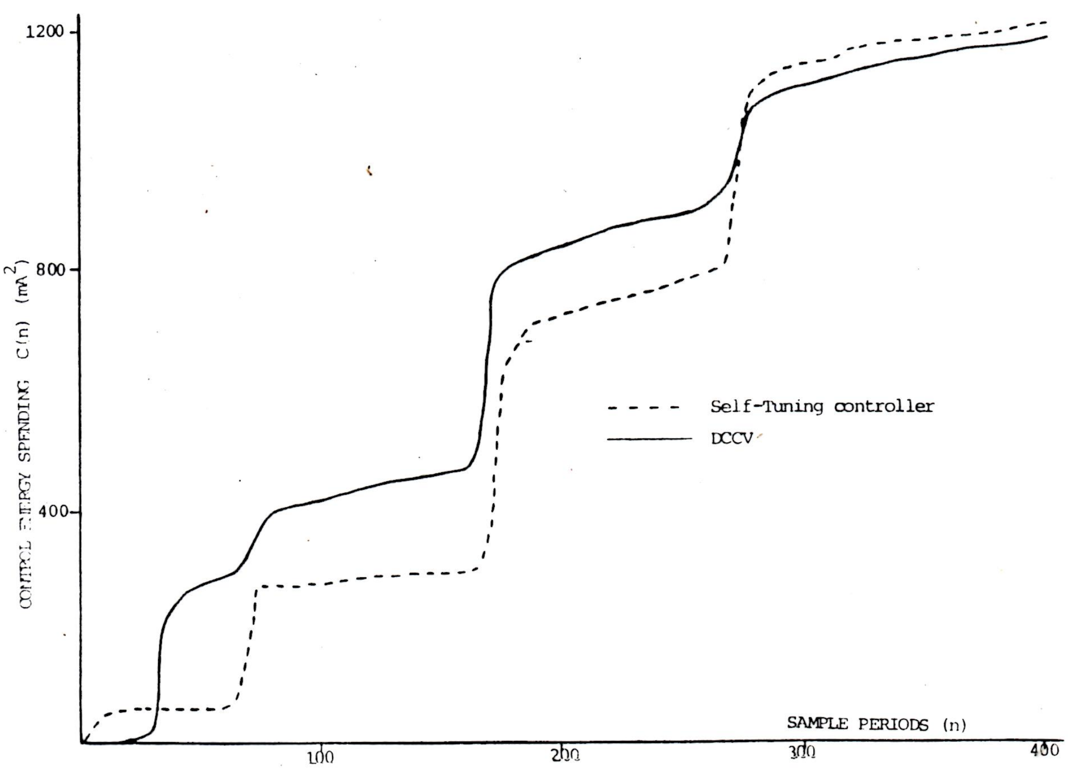

Fig. 5 Comparison of C(n) (reference changes)

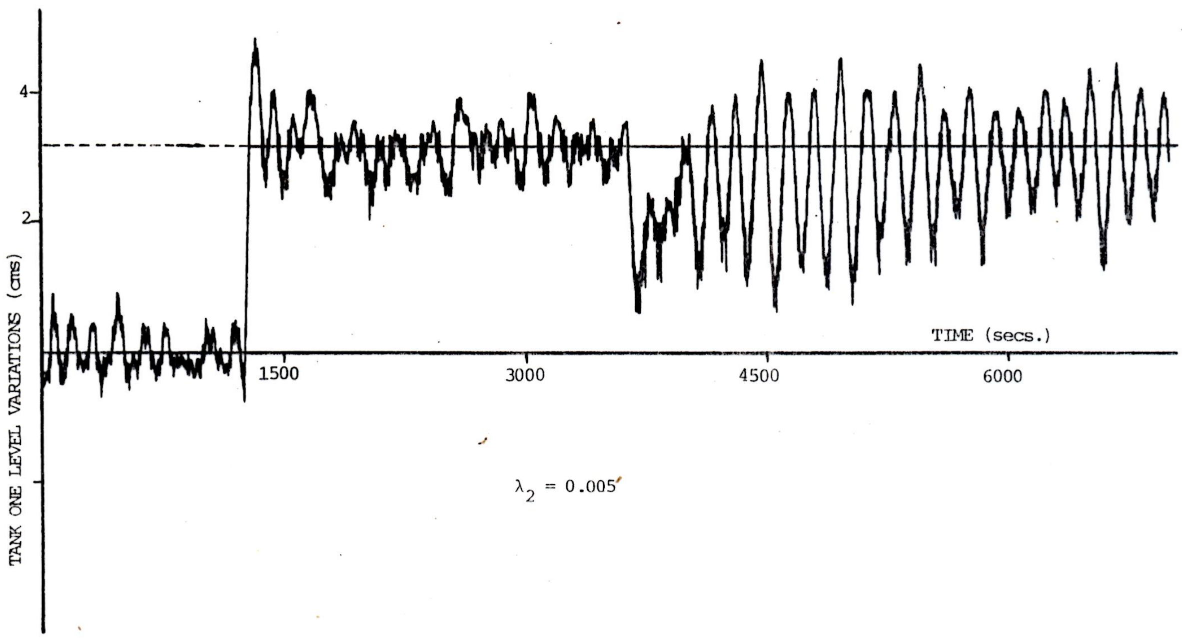

Fig. 6 System controlled by the self-tuning controller (perturbation)

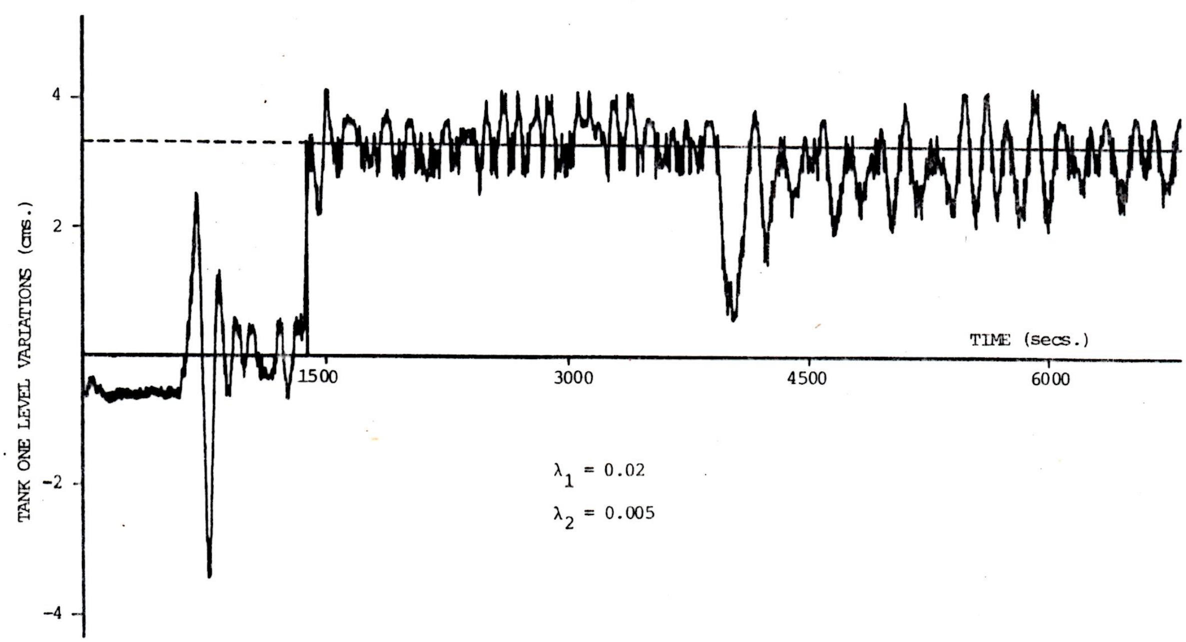

Fig. 7 System controlled by the DCCV (perturbation)

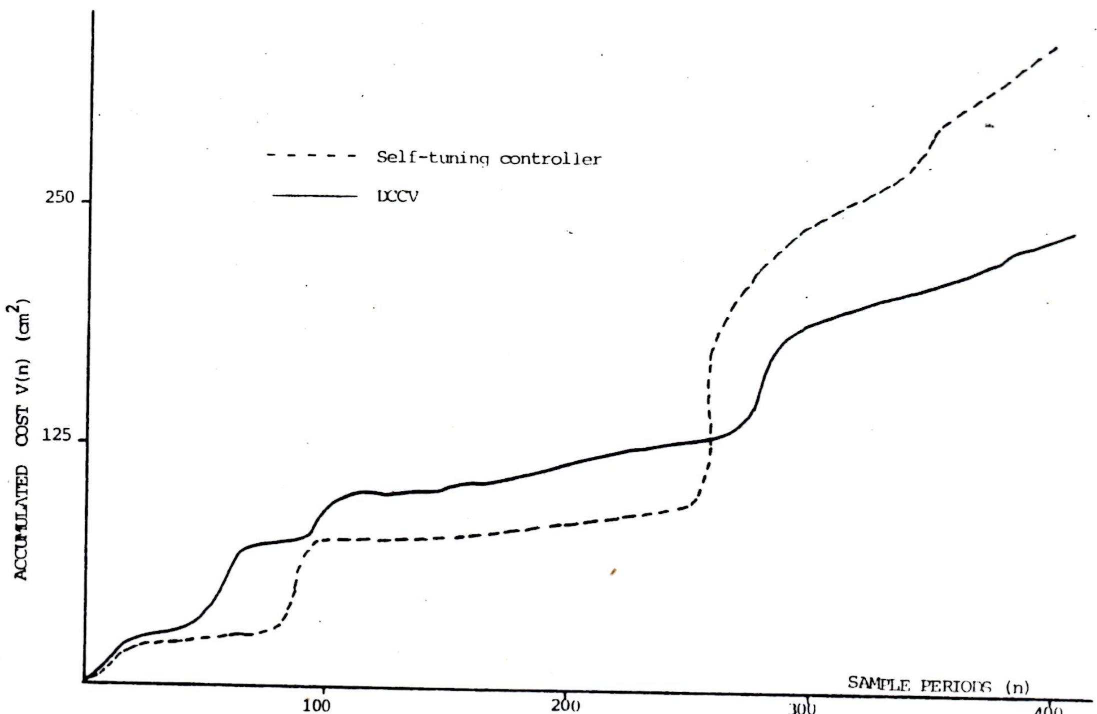

Fig. 8 Comparison of V(n) (perturbation)

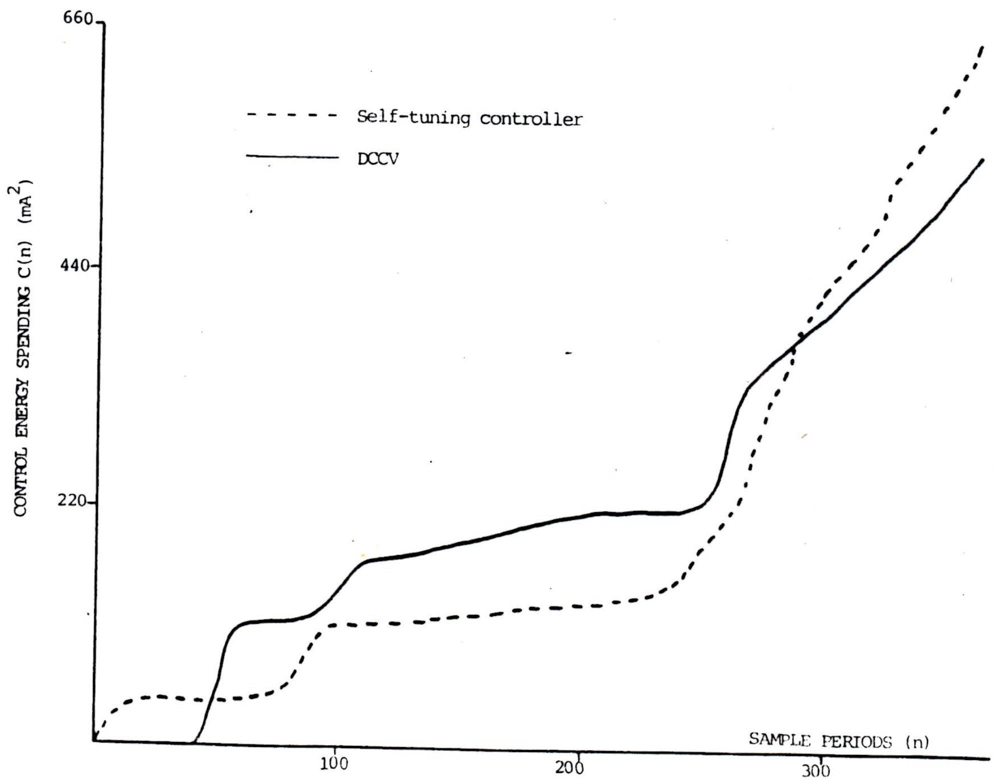

Fig. 9 Comparison of C(n) (perturbation)