Maestría en Ingeniería en Automatización de Procesos Industriales

Title

Design and implementation of a position servo-mechanic on a cylindrical-parabolic concentrator

Author

Erikssen Aquino Díaz

Contributor

F.O González Manzanilla

C. Muñiz Montero

J.A. Arizaga Silva

September-December 2016

Design and implementation of a position servo-mechanism on a cilindric-parabolic concentrator

E. Aquino-Diaz, F. O. González-Manzanilla, C. Muñiz-Montero, J.A. Arizaga-Silva
Master's degree on engineering of control and automation of Industrial Processes
eriksen.aquino@uppuebla.edu.mx
3er. Carril del Ejido Serrano S/N, San Mateo Cuanalá, Juan C. Bonilla, Puebla, Mexico

1. Introduction.

A Cylinder-parabolic concentrator(CPC) its a thermosolar device, its energy can be used in several ways, rather than just produce electricity as the photovoltaic panels do. At this time are found three types of this machines, the tower concentrator, the CPC, and the parabolic dish. Countries like Spain, USA and France just to mention, are producing from 48MWatts to 1.98 GWatts of electricity, with this devices, but in Mexico this technology is only for research sources.

So this job is about building a servomechanism such as the sun will be tracked with an acceptable precision, this aplying discrete control estrategies over the UPP CPC device, Figure 1, founded in its Renewable Energies Laboratory.

Figure 1. CCP Device in the "Universidad politecnica de puebla".

2. Objectives

2.1 General Objective

To Implement a robust position servomechanism on a cilindryc-parabolic concentrator for a precise solar tracking.

2.2 Specific Objectives

- To design a servomechanism for the fine tuninng of the position of the reflecting surface of the CPC.
- To design the control system for having an error of 0.2 degree according to cordal speed.
- To Implement the servo system for the CPC correct working.

3. Methodology

Mechanism Parametrics — **Theoretical design of Prototype**, **CAD design of the device.**

2. Prototype Instrumentation — **Open loop Tryouts**, **Adjustment integration**

3. Control System Design — **Theoretical design of control**, **GEDA design of the device.**, **Build up Control**

4. Control Implementation — **Closed loop tryouts**, **Adjustment Integration**, **Device Setup**

4. Mathematical Development

4.1 Discrete PID controller

The CPC integrates three diferent types of systems, the one present on the modeling of position is like Equation 1 [1].

$$\frac{\Theta(s)}{E_a(s)} = \frac{K}{JLs^3 + (JR + LB)s^2 + (K^2 + RB)s} \quad \text{Eq. 1}$$

Previous model can be discretized by aplyng a control estructure as shown in Figure 2, by adding a sampler in the output of the plant.

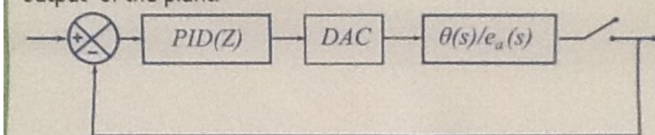

Figure 2. Implementation of a discrete PID into a CCP system. Own source

$$\frac{\theta(Z)}{E(Z)} = \frac{0.0428z^4 + 0.1262z^2 + 0.1262z + 0.0428}{z^3 + 0.5163z^2 + 0.6931z + 0.546} \quad \text{Eq. 2}$$

$$U(z) - z^{-1}U(z) = [K_1 + K_2z^{-2} + K_3z^{-2}]E(z) \quad \text{Eq. 3}$$

$$u[k] = u[k-1] + K_1e[k] + K_2e[k-1] + \cdots + K_3e[k-2] \quad \text{Eq. 4}$$

4.2 H infinite optimal controller

By augmenting the CCP dynamics model with equations 5 and 6 will give the expected initial conditions, and therefore the aproximated desired behavior.

$$w_1 = \frac{110 * (0.005 * s + 1)^2}{(0.2 * s + 1)^2} \quad \text{Eq. 5}$$

$$w_2 = \frac{(0.2 * s + 1)^2}{36000} \quad \text{Eq. 6}$$

By applying a round of optimization such as the error over the position is minimal, it is obtained the control law expressed by equation 7.

$$\frac{1.1318e06(s + 48.42)(s^2 + 1.429s + 257.1)}{(s + 9617)(s + 216.4)(s + 5)^2} \quad \text{Eq. 7}$$

4.3 LQR controller

$$A = \begin{bmatrix} -7.2222 & 0 & -0.008611 \\ 0 & 0 & 1 \\ 0.856826 & 0 & -4.809286 \end{bmatrix} \quad \text{Eq. 8}$$

$$\hat{B} = \begin{bmatrix} 0.555555 \\ 0 \\ 0 \end{bmatrix} \quad \text{Eq. 9}$$

$$Qlqr = \begin{bmatrix} 6 & 0 & 0 \\ 0 & 9 & 0 \\ 0 & 0 & 6 \end{bmatrix} \quad \text{Eq. 10}$$

$$K^T = [2.352904 \;\; 9.486832 \;\; 2.175883] \quad \text{Eq. 11}$$

$$\begin{cases} \dot{x}_1 = & -\frac{1}{L}(R \cdot x_1(t) + K \cdot x_3(t) - V(t)) \\ \dot{x}_2 = & x_3(t) \\ \dot{x}_3 = & \frac{1}{J}(K \cdot x_1(t) - b \cdot x_3(t)) \\ \theta(t) = & x_2(t) \\ V(t) = & -2.352905 \cdot x_1(t) - 9.486833 \cdot x_2(t) + 9.486833 \cdot u(t) - 2.175884 \cdot x_3(t) \end{cases} \quad \text{Eq. 12}$$

5. Computer Design of prototype

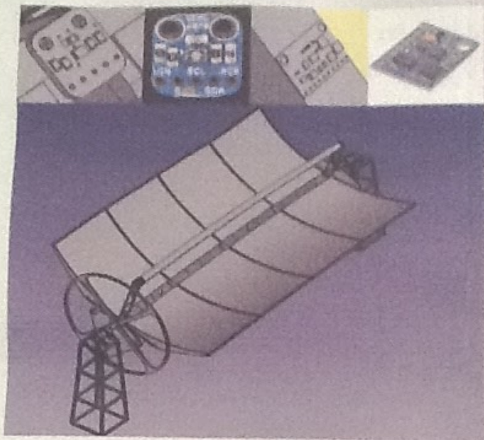

Figure 3. CAD design of an ideal CCP [3]. Own Source

6. Results

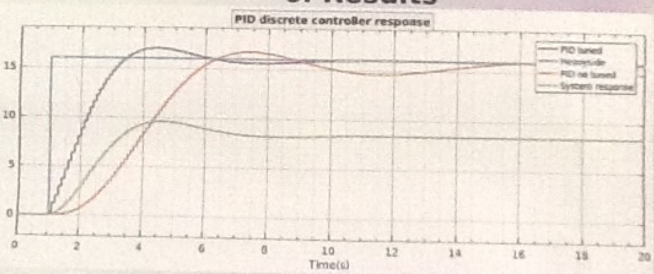

Figure 4.Response of the discrete PID controller.

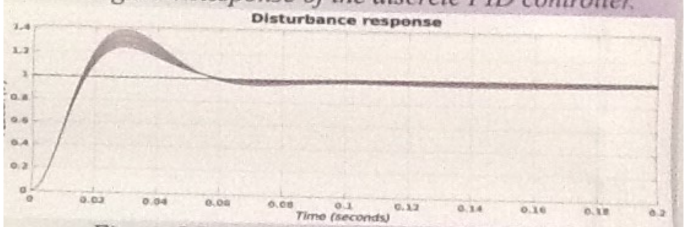

Figure 5.Response obtained by applying a posistion disturbance.

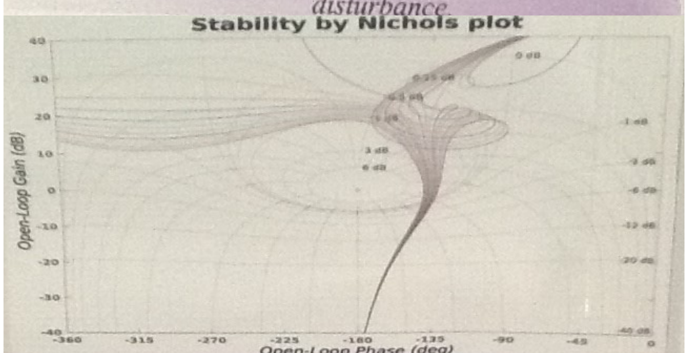

Figure 6. Robustness of the H infinite controller . Own source.

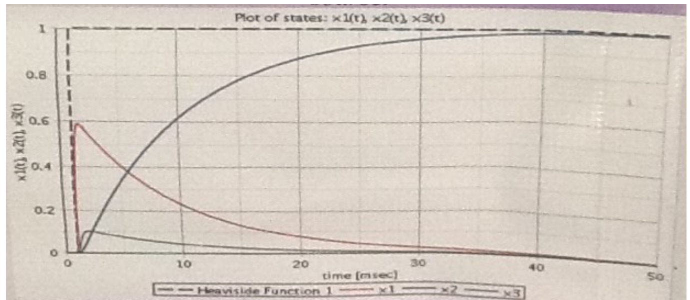

Figure 7. LQR controller response

7. Conclusion

In this job it's designed a mathematical model, from wich its obtained an aproximiate trajectory of a CCP, this behavior has been applied on a previous designed CAD model, also obtained as part of the project, this fullfilled the first objective of the work.

From this point were calculated three diferent controllers in order to be implement in the plattform with the planned instrumentation, so the project is ready to be deployed.

8. Referencias

[1] B. Kuo, Sistemas automáticos de control, 7 Ed. México: Pearson Educación, 2010.

[2] N. Nise, Sistemas de control para ingeniería, 3 Ed. México: CECSA, 2002.

[3] R. L. Mott, Diseño de elementos de máquinas, 4a Ed. México: Pearson Educación, 2006.

[4] Vishay Semiconductors, "www.vishay.com," 7 Enero 2016. [Online]. Available: www.vishay.com/docs/842 veml6070.pdf. [Accessed 5 Noviembre 2016].

[5] dipmicro, «https://www.dipmicro.com/,» dipmicro, 25 Enero 2007. [En línea]. Available: https://www.dipmicro.com/store/GY521-MOD. [Último acceso: 18 Noviembre 2016].

9. Acknowledgments

To Conacyt for the scolarship #72710 of Engineer Erikssen Aquino Diaz, and to GRABCAD community that shares several models and CAD designs, finally to open source community for their iniciative to make knowledge free and worldwide.

2016