Parabolic Antenna Control

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***Abstract*—The parabolic antenna is a key component in the information and communication technology (ICT) whose operation is sometimes automated with the aid of servomotors. This paper focused on improving the operation of the antenna system using the Quadratic Optimal Regulator (QOR) approach. The system responses with and without the controller were simulated using SIMULINK/MATLAB software. Results showed that the rise time, peak time, maximum overshoot and settling time were improved without the controller from; 0.7900 seconds, 1.1450 seconds, 14.77% and 2.4900 seconds respectively to; 0.5750 seconds, 0.7600 seconds, 4.14% and 1.0100 seconds respectively with the regulator controller. Therefore, a drastic improvement in the system performance was inferred using the QOR method.**

***Keywords*—Servomotors; parabolic antenna system; information and communication technology; Quadratic Optimal Regulator (QOR); controller**

I. INTRODUCTION

The parabolic dish antenna systems have contributed immensely in the remarkable achievements in the information and communication technology (ICT) sector. The operations of these antennas are sometimes automated with the aid of servomotors. Antennas are transducers that convert electrical signals into electromagnetic waves which are radiated in free space and vice versa [1].

In [2] a controller was proposed for a parabolic dish satellite antenna system used for tracking satellite TV signals using the conventional PID technique and H_∞ controller design methods. The results of their findings were compared and the H_∞ controller showed a superior performance. In [3], the Linear Quadratic Regulator control method was used to develop a controller for a magnetically levitated vehicle (MAGLEV) which was simplified by a single mass system on a rigid guide way. The MAGLEV of course was a system known with stability problems and the results of their research showed that the system was successfully stabilized for both position (magnet gap deviation) and vertical acceleration using the method.

II. METHODOLOGY

The parabolic dish antenna system model used by Ahmed *et al.* [4] was used in this research and it is as shown in equation (1). The control strategy was developed for the system using the Quadratic Optimal Regulator (QOR) method. The system responses were simulated using SIMULINK/MATLAB software environment. The system responses; with and without the controller were then compared.

$$G_A(s) = \frac{136.8}{s^3 + 15s^2 + 50s} \tag{1}$$

A. Quadratic Optimal Regulator System

Consider a control system represented in state space as;

$$\begin{aligned} \dot{x} &= Ax + Bu \\ y &= Cx + Du \end{aligned} \tag{2}$$

Where; x = state vector (m-vector), y = output signal (scalar), u = control signal (scalar), A = m by m constant matrix, B = m by 1 constant matrix, C = 1 by m matrix, D = constant (scalar)
If the control signal is chosen to be;

$$u(t) = -Kx(t) \tag{3}$$

It means that the control signal u is determined by an instantaneous state, and such a scheme is called state feedback. The 1 by m matrix K is called the space feedback gain matrix. Assuming that all the state variables are available for feedback and also u is not constrained. The block of the optimal configuration system is as shown in Fig. 1.

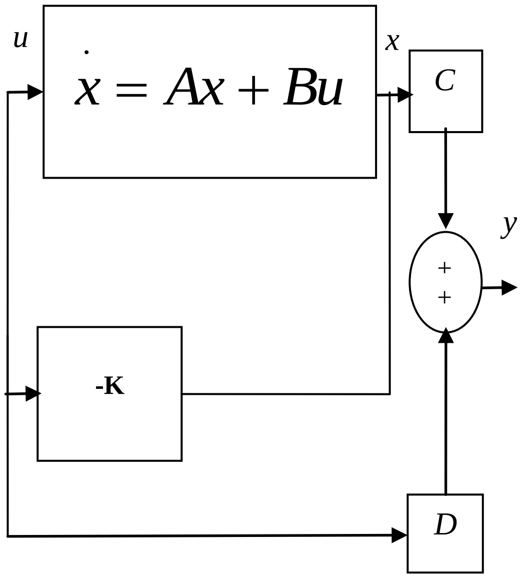

Fig. 1. Illustration of the Quadratic Optimal Regulator system.

Controlling the system using the optimal regulator technique, the system equation (2) determines the matrix **K** of the optimal control vector in (3), so as to minimize the performance index,

$$J = \int_0^{\infty} (x^* Qx + u^* Ru)dt \tag{4}$$

Where; Q is a positive-definite (or positive-semi-definite) Hermitian or real symmetric matrix and R is a positive-definite Hermitian or real symmetric matrix. The term ($u^* Ru$) accounts for the expenditure of the energy of the control signals. The matrices Q and R determine the relative importance of the error and the expenditure of this energy.

The linear control law given in equation (3) is the optimal control law. Therefore, if the unknown elements of the matrix K are determine so as to determine the performance index, then $u(t) = -Kx(t)$ is optimal for any initial state $x(0)$. Solving equations (2), (3), and (4) using matrix Ricatti method, we have;

$$u(t) = -Kx(t) = -R^{-1}B^* Px(t) \tag{5}$$

$$A^* P + PA - PBR^{-1}B^* P + Q = 0 \tag{6}$$

The system is stable if matrix P is positive definite or matrix $A - BK$ is stable. Equation (6) is called the reduced-matrix Ricatti equation [5].

III. Problem Statement

The transfer function of the plant which is the DC servomotor controlled parabolic dish antenna system from equation (1) in state space becomes;

$$\dot{x} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 0 & -50 & -15 \end{bmatrix} \bar{x} + \begin{bmatrix} 0 \\ 0 \\ 136.8 \end{bmatrix} \bar{u} \tag{7}$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \bar{x} + [0] \bar{u} \tag{8}$$

The problem becomes solving for K such that the performance index as shown in equation (4) is minimal [5, 6].

IV. Results And Discussion

The value of K for the system was obtained as shown in equation (9) after solving equations (4) and (5).

$$K = [1095.4 \quad 265.0 \quad 31.6] \tag{9}$$

Fig. 2 is the unit step responses of the system with and without controller. It can be inferred from the graphs that; the rise time was 0.7900 seconds, peak time, 1.1450 seconds, maximum overshoot 14.77% and a settling time of 2.4900 seconds without the controller and with the controller, they are; 0.5750 seconds, 0.7600 seconds, 4.14% and 1.0100 seconds respectively. It can be seen that the values of the response parameters were highly reduced with the QOR controller and hence a better performance.

Figs. 3, 4, and 5 were the responses of system without and with the controller when the antenna system was positioned at 30, 50 and 70 degrees respectively. It can be clearly seen that regardless of the antenna position the system reaches steady state maintaining the response parameters without and with the controller.

Fig. 6 was a bar chart for the rise, peak and the settling times of the system responses with and without the controller. It clearly portrayed the comparisons of the various response parameters. Hence, it can be seen that the introduction of the controller had reduced the rise time, peak time and the settling time by 27%, 34% and 65% respectively.

Fig. 7 was a bar chart of the maximum overshoots with and without the controller and it can be deduced that it had been reduced by 72% with the controller.

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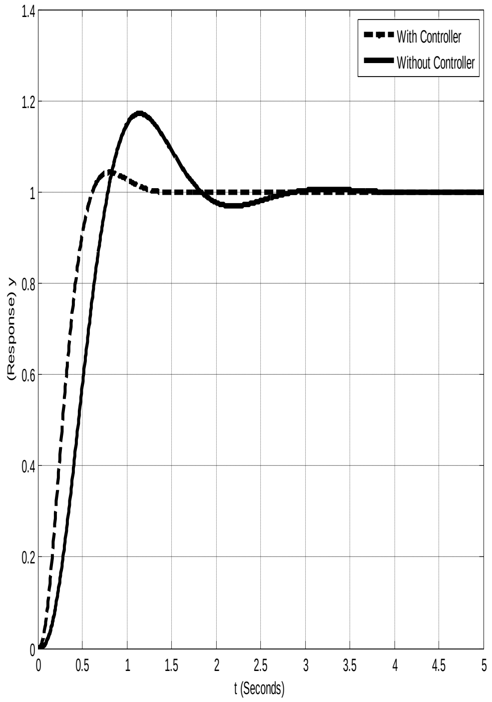

Fig. 2. Unit step response of the system.

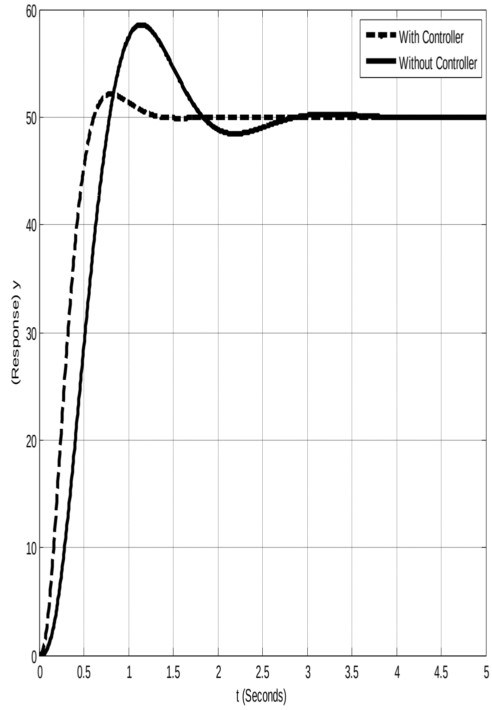

Fig. 4. Step response at 50^0 position.

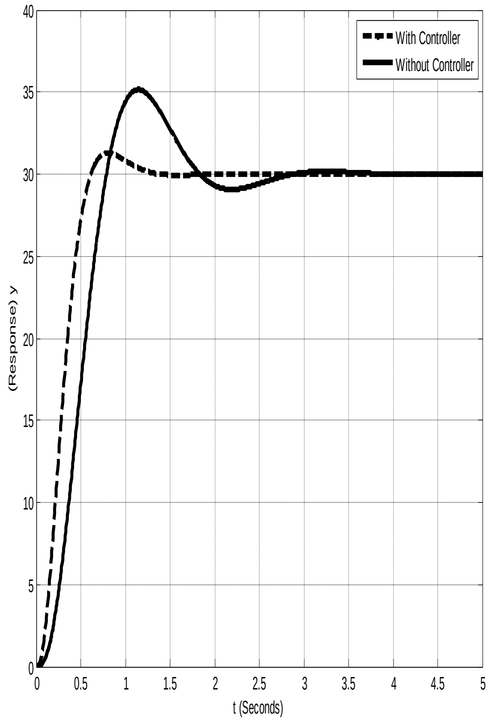

Fig.3. Step response at 30^0 position.

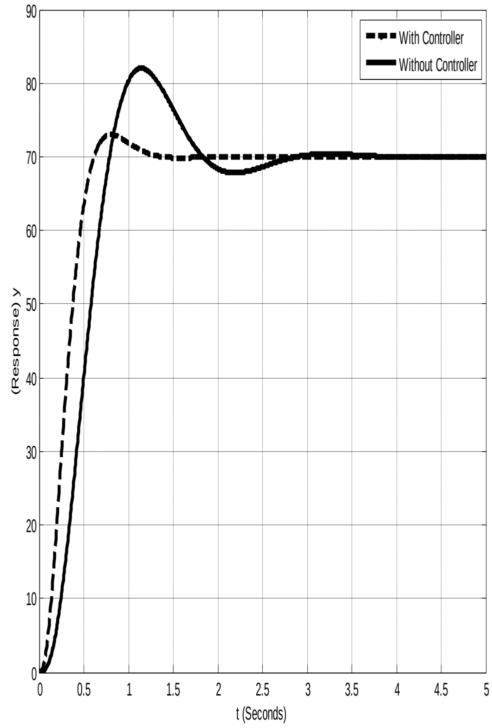

Fig.5. Step response at 70^0 position.

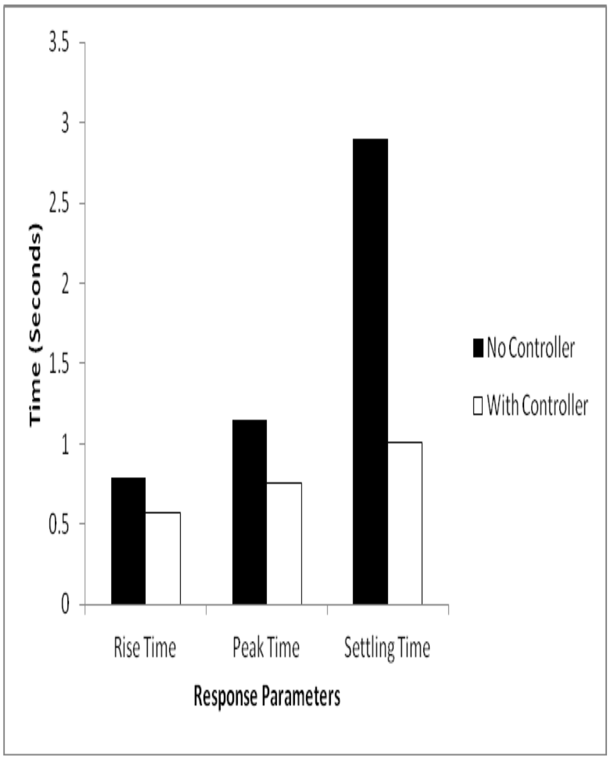

Fig. 6. Bar chart of the rise, peak and settling times.

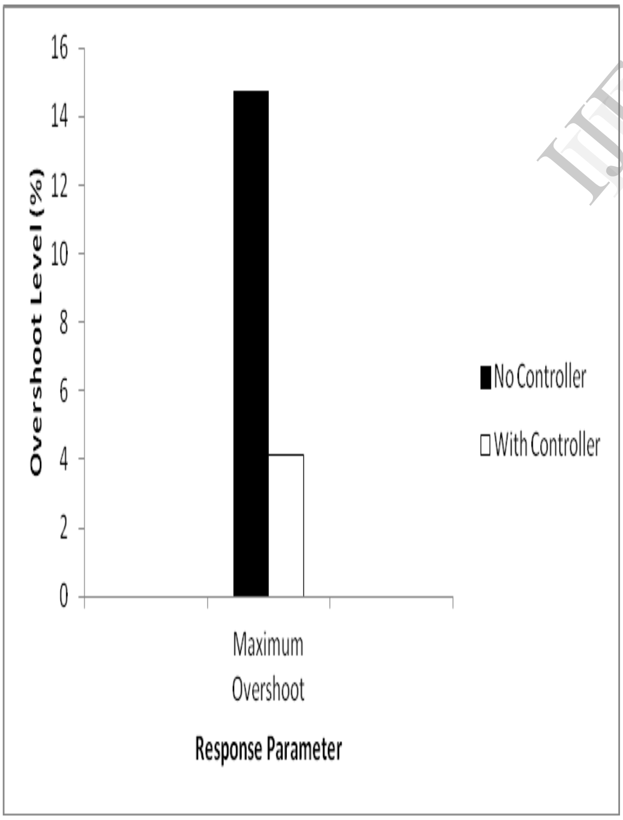

Fig. 7. Bar chart of the maximum overshoot.

V. CONCLUSION

In this paper, the Quadratic Optimal Regulator control scheme was successfully applied for the position control of the servomotor actuated antenna system. The simulation and testing of the system with and without the controller was also a success, which was performed using the SIMULINK/MATLAB software flat-form. It was also discovered that the introduction of QOR controller to the system had made its performance better in terms of the rise time, peak time, maximum overshoot and settling time. Therefore, a position controller has been designed successfully for the antenna system for its smooth and improved operation.

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