หอสมุดกลาง จุฬาลงกรณ์มหาวิทยาลัย

Chapter II

PRELIMINARY DESIGN OF SOLAR TRACKING SYSTEM

2.1 Introduction

In the design of any engineering system, the prime objective is to achieve optimization. This chapter describes the descriptions of the solar tracking system and the criteria employed to optimise the system.

2.2 Descriptions of Servomechanism

The system descriptions may be summarized as follows :

2.2.1 The system would be designed such that it can be installed and operated outdoor. The power supply is to be designed to operate on both A.C. (220 V, 50 HZ) and D.C. (battery) input. The detected range of operated voltage is $\pm$15 V (two units of 12 V battery and one unit of 6 V battery). If the input is an A.C.. the regulated power supply unit converts it to D.C. voltage in the range $\pm$15 V.

2.2.2 In order to use a motor of a larger size with the maximum power of 30 W, the regulated power supply must be designed to operate at the rated current of at least 2.5 A.

2.2.3 The lever in the moving part of the system must be operatable in both directions. The D.C. motor is selected because it can change the direction of rotation by reversing the input polarity.

2.2.4 To obtain a high precision in tracking, the speed of lever rotation is kept as low as possible. The selected speed of motor is 1 rpm.

2.2.5 To amplify the D.C. error signal, it is advantageous to use an operational amplifier because of its high gain and low cost.

2.2.6 The servo-amplifier or power amplifier used is a complementary type since it can operate for both positive and negative D.C. signal and can operate in the active region.

2.2.7 The control unit can be placed in any convenient location and connected to the moving part by means of wires for the east of moving and installation of the system.

2.2.8 In a cloudy day, the detector may not detect correctly. It is necessary, in this case, to design a manual switch which directs lever to the position perpen - dicular to the solar radiation to start the tracking.

2.2.9 To prevent the lever striking the base of the stands, two limit switches in both directions, East and West, must be added to the system.

2.3 Preliminary Design

The solar tracking system is a type of feedback control system (closed-loop control system). The block diagram of the system is shown in Figure 2.1. The characteristic of each block diagram is assumed to be linear.

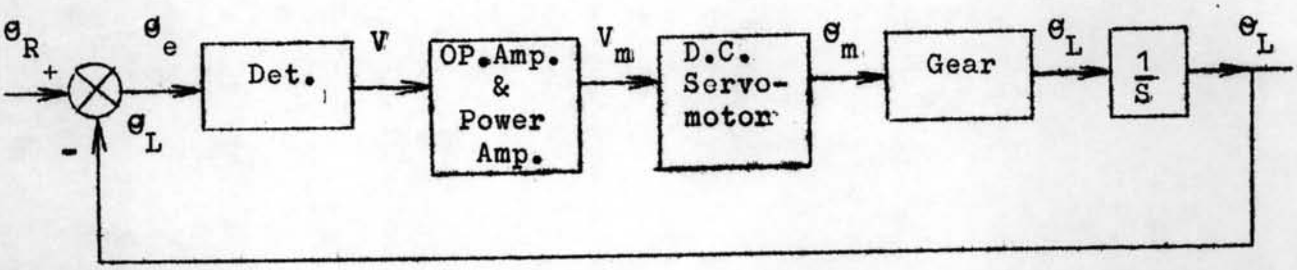

Figure 2.1. Block Diagram of the Tracking System.

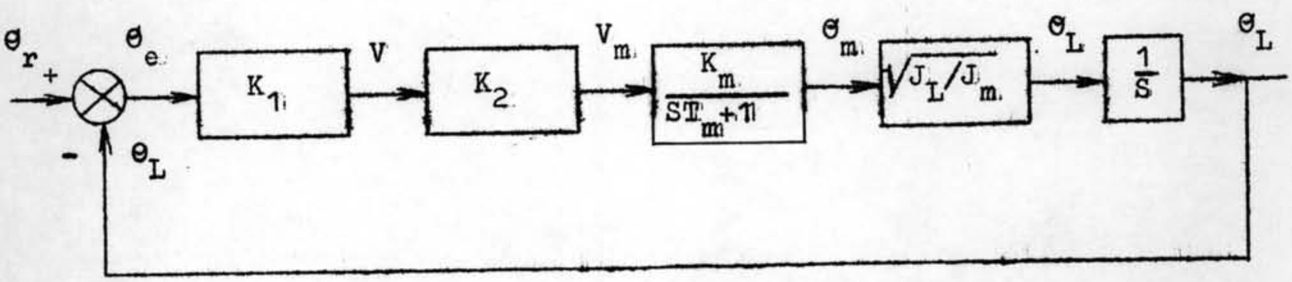

Figure 2.2. Block Diagram with Transfer Functions for Tracking System.

Consider the block diagram in Figure 2.1 and 2.2 . The transfer function of each block diagram is as follows :

1. Detector gain $= \frac{V}{\theta_e}(S) = K_1$.

2. Operational amplifier and power amplifier gain

$$= \frac{V_m}{V}(S) = K_2 .$$

3. D.C. Servomotor gain $= \frac{\dot{\theta}_m}{V_m}(S)$,

$$= \frac{K_m}{ST_m+1}$$ (The proof is shown in chapter III).

4. Transfer function of gear train = the optimum gear ratio

$$= \frac{\dot{\theta}}{\theta_m}(S) = M = \sqrt{J_L/J_m}$$

(The proof is shown in chapter III).

The closed-loop transfer function of the system is :

$$\frac{\theta_L}{\theta_R}(S) = \frac{K_1 . K_2 . \frac{K_m}{ST_m+1} . M . \frac{1}{S}}{1+K_1 . K_2 . \frac{K_m}{ST_m+1} . M . \frac{1}{S}} ,$$

$$= \frac{K_1K_2K_mM}{S^2T_m+S+K_1K_2K_mM} ,$$

$$= \frac{K_1K_2K_mM/T_M}{S^2+S/T_m+K_1K_2K_mM/T_M} ,$$

$$\frac{\theta_L}{\theta_R}(S) = \frac{\omega_m^2}{S^2+2\zeta\omega_n S+\omega_m^2};$$

where $\omega_m = \sqrt{K_1K_2K_m/MT_m}$ = undamped natural frequency,

and $\zeta = \frac{1}{2\omega_m} \cdot \frac{1}{T_m}$ = damping ratio.

The closed loop transfer function represents the characteristic of the system. The response of the system depends on the damping ratio ζ which is a measure of the amount of damping. If the system is critically damped, i.e., $\zeta = 1$, it returns to equilibrium with no overshoots. If the damping ratio is greater than 1, overdamping permits a slow return to equilibrium with no overshoots. Under - damping permits a rapid return to equilibrium with overshoots, this results in a settling out period required to reach steady state equilibrium, and is represented with a damping ratio less than 1. If the damping ratio is zero, oscillation occurs and this makes the system unstable.

From the above consideration, the constants K_1, K_2, K_m and T_m are designed to make the system overdamped. To optimized the system components and materials, the optimum gear ratio, minimum size of motor and low power consumption of circuit components will be considered.