CHAPTER THREE

CIRCUIT IMPLEMENTATION

3.1 Introduction

a servomotor a packaged of several components :a motor ,a gear train to reduce the many rotations of the motor to a higher torque rotation , a position encoder that identifies the position of output shaft and an inbuilt control system .The input control signal to the servo indicates the desired output position .any differences between the position commanded and the position of the encoder gives rise to an error signal that cause the motor gear train to rotate until the encoder reflects a position matching that commanded. a simple low-cost servo of this type is widely used for ratio-controlled model .

3.2 Mathematic model

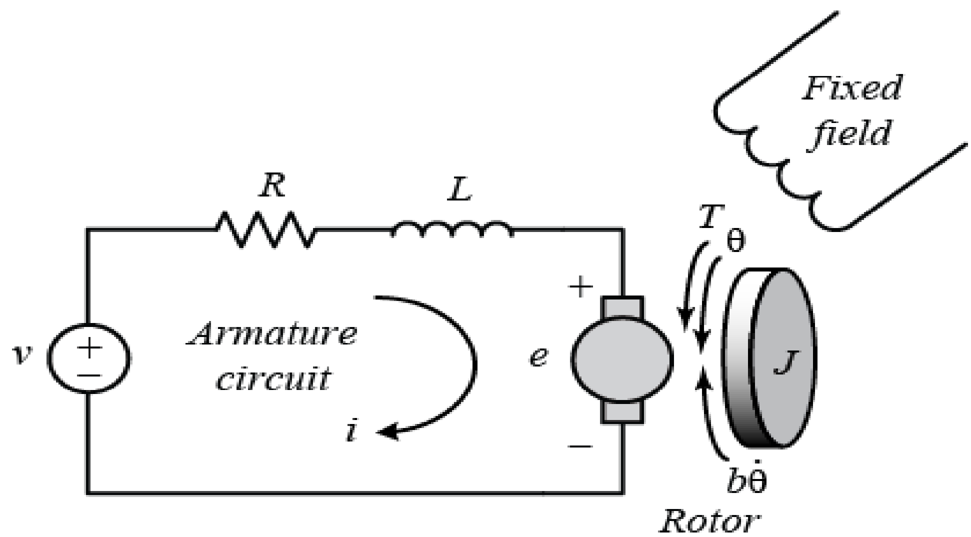


Figure (3.1): Equivalent circuit of DC motor

In general, the torque generated by a DC motor is proportional to the armature current and the strength of the magnetic field. Assume that the magnetic field is constant and, therefore, that the motor torque (T) is proportional to only the armature current (i) by a constant factor (K_t) called torque constant as shown in the Equation (3.1). This is referred to as an armature-controlled motor.

$$T = K_t\, i \quad (3.1)$$

The back electromotive forceemf (e) is proportional to the angular velocity of the shaft ($\dot{\theta}$) by a constant factor (K_b) called electromotive force constant as shown in the Equation (3.2).

$$e = K_b \dot{\theta} \quad (3.2)$$

In system international units, the motor torque and back emf constants are equal, that is, $K_t = K_b$; therefore, (K) will be used to represent both the motor torque constant and the back emf constant.

By using Figure (3.1) to derive the following governing equations based on Newton's 2nd law in Equation(3.3)and Kirchhoff's voltage law in Equation (3.4).

$$J\ddot{\theta} + b\dot{\theta} = Ki \quad (3.3)$$

$$La\frac{di}{dt} + Ra * i = V - K\dot{\theta} * b \quad (3.4)$$

Where (J) is the moment of inertia of the rotor, (b) is the motor viscous friction constant, (La) is the electric inductance, (Ra) is the electric resistance, and (V) is the voltage source.

Applying the Laplace transform, the modeling equations can be expressed in terms of the Laplace variable*s* as shown inEquation (3.5) and Equation (3.6).

$$s(Js + b)\theta(s) = KI(s) \quad (3.5)$$

$$(Las + Ra)I(s) = V(s) - Ks\theta(s) \quad (3.6)$$

Following open-loop transfer function had arrived by eliminating I(s) in Equations (3.7), where the rotational speed is considered the output and the armature voltage is considered the input.

$$G(s) = \frac{\dot{\theta}(s)}{V(s)} = \frac{K}{(Js+b)(Las+Ra)+K^2} \quad [\frac{rad/sec}{V}] \quad (3.7)$$

Table (3.1): DC servo motor parameter

Kt	0.01 N.m/A
Kb	0.01V/rad/s
Ra	1Ω
B	0.1N.m/rad/s

However, during this model continue looking at the position as the output. The position has been obtained by integrating the speed; therefore, it needed to divide the transfer function in Equation (3.8).

$$\frac{\theta(s)}{V(s)} = \frac{K}{s((Js+b)(Las+Ra)+K^2)} \quad [\frac{rad}{V}] \tag{3.8}$$

The position θ(s) in Equation (3.8) is the rotational displacement which produced on the motor's shaft but there are gears between shaft and load with ratio known as gears ratio (K_g) , so the transfer function becomes as shown in Equation (3.9).

$$\frac{\theta(s)}{V(s)} = \frac{K*Kg}{s((Js+b)(Las+Ra)+K^2)} \left[\frac{rad}{V}\right] \tag{3.9}$$

The physical parameters of the servo motor used for simulation testing are given in table (3.1) .

Substitute there parameters in equation (3.9) , the transfer function becomes as follow :

$$\frac{\theta m(s)}{Ea(s)} = \frac{3.839}{0.004s2 + 0.34s + 1}$$

3.3 PID Controller Design

By substituting the parameters of equation (3.9) in MATLAB Simulink techniques to obtain three –term control:the integral –proportional, and derivative values , of PID controller that will meet the transient and steady–state specifications of the closed loop system.

3.4 Fuzzy logic Controller Design

A fuzzy logic controller input variables involves receiving the error signal and change of error. These variables evaluate the fuzzy control rules using the compositional rules of inference and the appropriately computed control action is determined by using the defuzzification.

3.4.1 Fuzzy basic FIS editor

The FIS editor displays high–level information about a fuzzy inference system shown as in Figure .At the top is a diagram of the system with each input and output clearly labelled. The membership function editor can be brought by double-clicking on the input or output boxes , also the rule editor will be brought by double-clicking on the fuzzy rule box in the center of the diagram .Just below the diagram is a text field that displays the name of current FIS .The various functions used in the fuzzy implication process was allowed by series of popup menus in the lower left of the window .In the lower right are field that provide information about the current variable .The current variable is determined by clicking once on one of the input or output boxes.

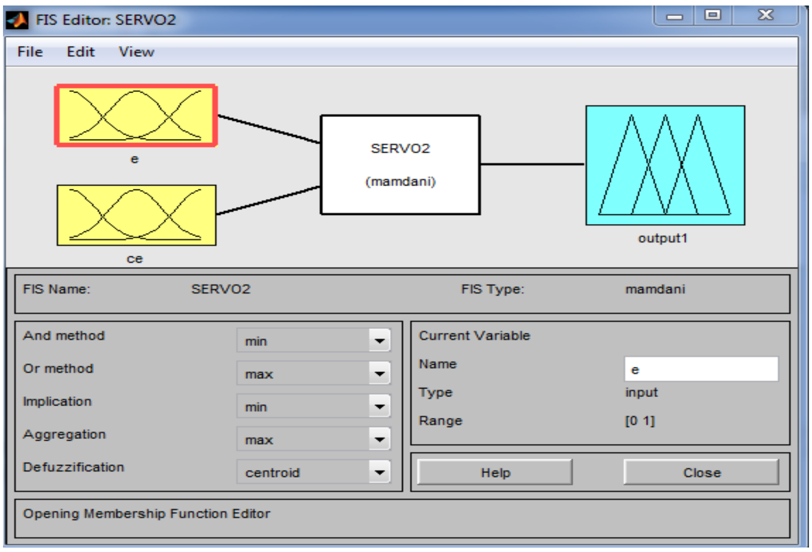


Figure (3.2):FIS editor

By adding INPUT variable from edit menu then FIS give two inputs variable which one is error(e) and another is change of error (ce) etch one consist of five membership functions rules to give 25 rules.

3.4.2 MF Editor of FLC

All the membership functions for the FIS stored in the file a.FIS were modified by The mf edit ('SERVO2') that generates a membership function editor shown figure(3.2) .

All the MFs for the current variable . It could select any of these by clicking once on the line or name of the MF .Once selected , could modify the properties of the MF using the controls in lower right.

MFs are added and removed using the edit menu.

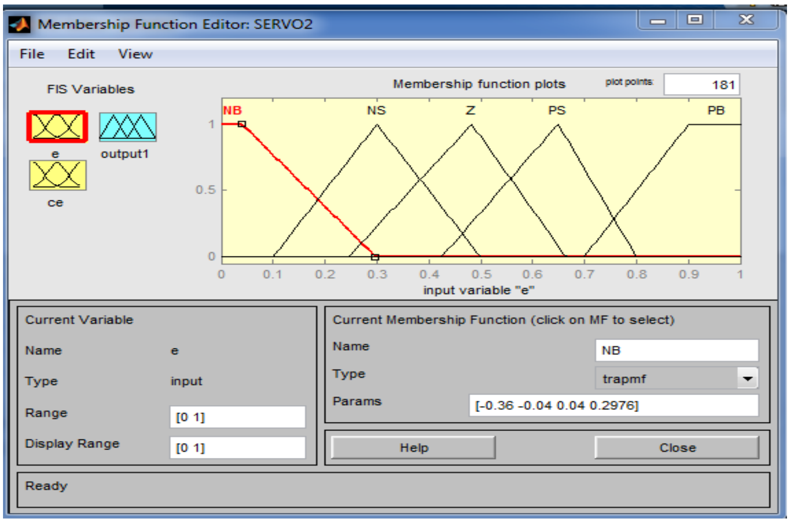


Figure (3.3):Membership function

3.4.3 Rule editor

The rule editor shown in Figure (3.4) , when invoked using ruled it ('SERVO2'),is used to modify the rules of a FIS structure stored in a file , It can also be used to inspect the rules being used by a fuzzy inference system.

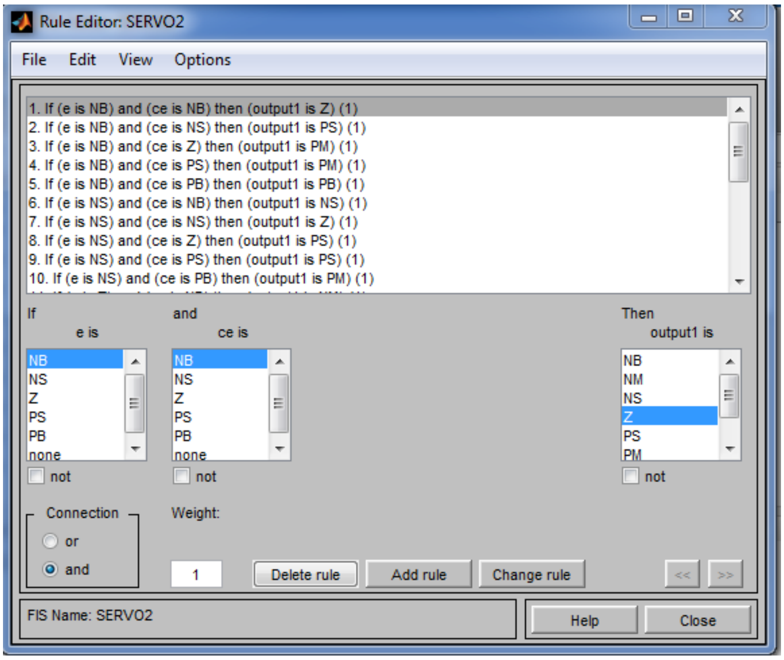


Figure (3.4): Rule editor

Table (3.2):Rule base for Five membership functions

Rate(t) / Error(t)	PB(de)	PS(de)	Z(de)	NS(de)	NB (de)
PB(de)	Z	NS	NM	NM	NB
PS(de)	PS	Z	NS	NS	NM
Z(de)	PM	PS	Z	NS	NM
NS(de)	PM	PS	PS	Z	NS
NB(de)	PB	PM	PM	PS	Z

3.4.4 Rule viewer

The rule viewer displays shown in figure (3.5), in one screen, all parts of the fuzzy inference process from inputs to outputs. Each row of plots corresponds to one rule ,and each column of plots corresponds to either an input variable (yellow ,on the left) or an output variable (blue, on the right).

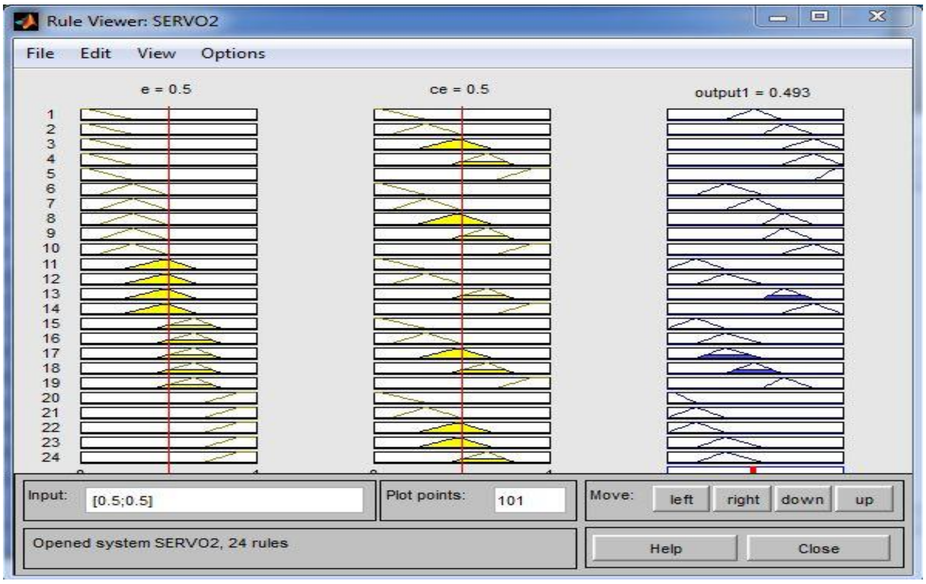


Figure (3.5): Rule viewer

3.4.5 Surface viewer

The output surface of a FIS, a fis , for any one or two inputs was examined by the surface viewer shown in Figure (3.6) invoked using surf view ('a')is a GUI tool. since it does not alter the fuzzy system or its associated FIS matrix in any way , it is a read only editor .the two input variables you want assigned to the two input axes (X and Y), as well the output variable you want assigned to the output (or Z) axis was selected by using the pop-up menus.

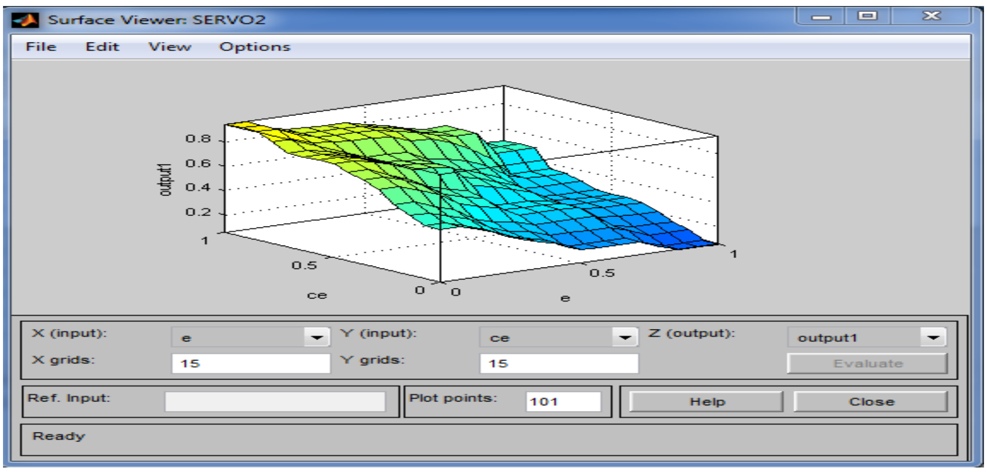


Figure (3.6):Surface viewer

3.5 System electrical parts

The Electrical circuit consists of Arduino Uno, Dc servo motor and ultrasonic sensor.

- **Arduino Uno**

Arduino Uno as shown in Figure (3.7) is a microcontroller board based on ATmega328P microcontroller. It has 14 digital input/output pins (of which 6 can be used as pulse width modulation (PWM) outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, header and a reset button. Using PID library in Arduino Uno code (See Appendix A) as a PID controller has many benefits such as:

- There are many ways to write the PID algorithm. A lot of time was spent making the algorithm in this library as solid as any found in industry.
- When using the library all the PID code is self-contained. This makes your code easier to understand. It also lets you do more complex stuff, like having 8 PIDs in the same program.

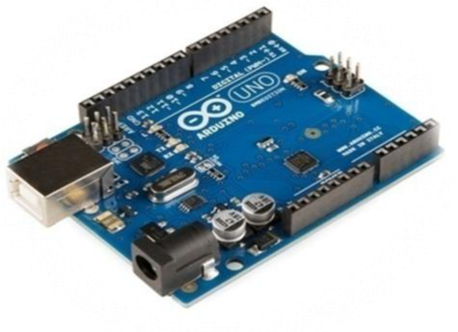


Figure (3.7): Arduino Uno

- **DC servo motor (DSS-M15)**

DSS-M15 as shown in Figure (3.8) is a heavy-duty metal gear digital servo with 180°wide angle, high torque power, improved stability and durability.

Servo is able to work with 6V and deliver a strong torque power of over 15Kg. This DSS-M15 servo demonstrates a maximum torque of 18Kg without much vibration or heat.

Figure (3.8): DSS-M15 servo motor

- **Ultrasonic sensor**

Ultrasonic Sensor as shown in Figure (3.9) are self-contained solid-state devices designed for non-contact sensing of solid and liquid objects. For many applications, such as monitoring the level of water in a tank, ultrasonic technology lets a single device to do a job that would otherwise require multiple sensors.

Active ultrasonic sensors generate high-frequency sound waves and evaluate the echo which is received back by the sensor, measuring the time interval between sending the signal and receiving the echo to determine the distance to an object.

Figure (3.9): Ultrasonic sensor

- **IRF sensor**

The IR Sensor-Single is a general purpose proximity sensor. Here we use it for frequency detection. The module consist of a IR emitter and IR receiver pair. The high precision IR receiver always detects a IR signal. The output of sensor is high whenever it IR frequency and low otherwise. The on-board LED indicator helps user to check status of the sensor without using any additional hardware. The power consumption of this module is low. It gives a digital output. IR sensor showing in fig (3.10) below:

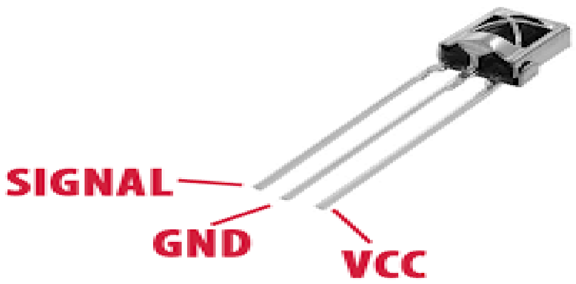


Figure (3.10) : Infrared (IR) sensor

IR detectors are little microchips with a photocell that are tuned to listen to infrared light. They are almost always used for remote control detection - every TV and DVD player has one of these in the front to listen for the IR signal from the clicker. Inside the remote control is amatching IR LED, which emits IR pulses to tell the TV to turn on, off or change channels. IR light is not visible to the human eye, which means it takes a little more work to test a setup, the (IR) sensor (detector / Recever) Unit for Remote control as showing in fig (3.11).

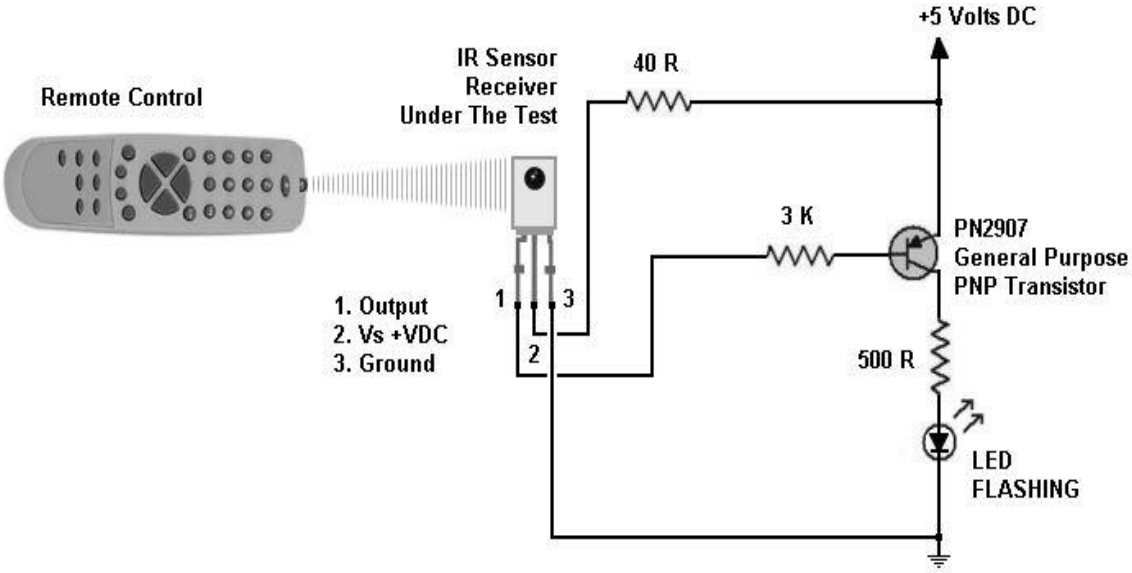


Figure (3.11) :Infrared (IR) sensor (detector/Recever) Unit for Remote control

- **The Antenna Azimuth control system**

The Antenna Azimuth control system in fig (3.12). The potentiometer the operator controls is at the very top. The signal is sent to the preamplifier then to the power amplifier. The result is sent to a motor (gyrator) then to a gear, which is connected to another gear to change the position of the antenna. Finally the antenna's signal is connected to another gear and apotentiometer. The feedback is going back from the potentiometer into the differential preamplifier. The feedback is crucial in determining whether our antenna is in the correct position.

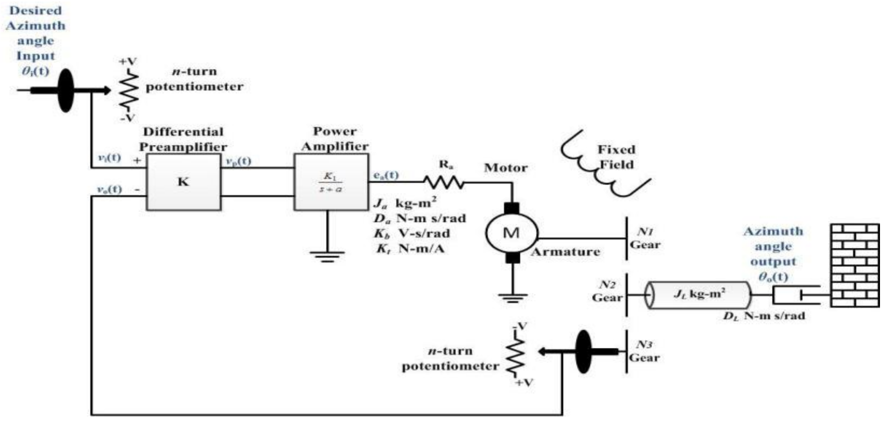
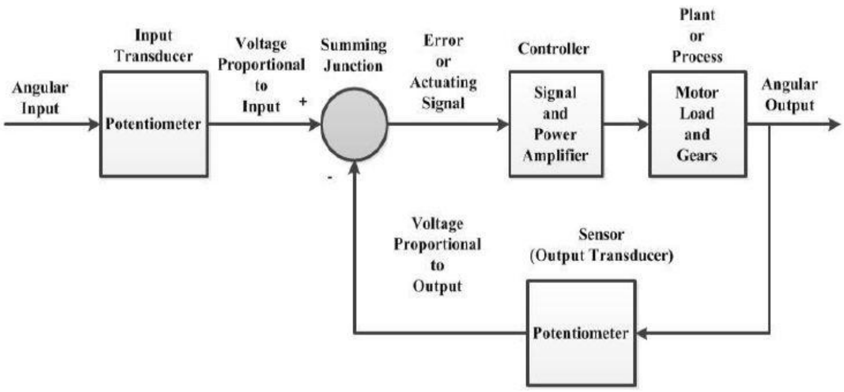


Figure (3.12) Schematic of the Antenna Azimuth control system

This schematic was used to derive the block diagram of the system Figure (3.13) , this block diagram will be used in the design and simulation for the control system [9].



Figure(3.13):Block diagram of control system for antenna azimuth position