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Speed Control of DC Motor Using Fuzzy Logic Controller Based on Weather Station Data

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ABSTRACT:- *The Astronomical dome has two shutters with three DC motors, Speed control of DC Motor is vital in many applications. In this paper the DC motors of Astronomical Dome and mirror shutters have been controlled by fuzzy logic control based on online homogenous weather station data. Control of motors speed used to open and close the dome and mirror shutters. The environmental weather station data, wind speed, humidity, rain rate, temperature, and dust particle have affected on statues of decision. The weather station data transfer to the fuzzy control system simultaneously to open or close the shutters. A simulation for DC motor fuzzy control system based on SIMULINK/MATLAB for dome and mirror motors done. The motor speed controlled through control the input voltage.*

Keywords*:- DC motor, Fuzzy control systems, Astronomical, weather station.*

I. INTRODUCTION

Fuzzy logic is implemented in a standard microcontroller to regulate the speed of a universal motor by a real time adjustment (every 30 millisecond) of the motor current [1]. This microcontroller directly tunes the motor current by means of a chopper converter. It is found that, fuzzy logic approach can be applied to build a closed speed regulation loop from a very low cost tacho-generator. It is applied to fast "real-time" regulation loop without requiring any specific expertise in conventional methods of regulation. The speed of the DC motor controlled using fuzzy logic control based on LABVIEW program [2]. The position of DC motor is controlled by four methods of PID controlling techniques [3] The fuzzy logic controller designed to apply the required control voltage that sent to DC motor based on fuzzy rule base of motor speed error (e) and change of speed error (Ce). The simulation results demonstrate that the response of DC motor with fuzzy logic control show a satisfactory well damped control performance.. The four methods were, Ziegler-Nichols tuning, hand tuning, soft tuning in built in SIMULINK and fuzzy logic controller. According to the comparison of results of the simulations, it is found that the fuzzy logic controller is better than other methods; overshoot, rise time, and steady state error were reduced by using fuzzy logic controller. The steady state operation and its various torque-speeds, torque-current characteristics of DC motor studied [4]. A fuzzy controller with two inputs and three outputs designed. The results for self-tuning of fuzzy logic control system has better dynamic response curve, shorter response time, small overshoot, small steady state error, and high steady precision compared to the conventional PID controller.

The astronomical telescope dome is one of the important item in astronomical observatory. Not only do they allow you to leave your equipment set up permanently, ready for observing, but also it improves viewing conditions by protecting from the elements and reducing the problem due to the weather conditions. The astronomical telescope dome has some of shutters for the dome and telescope mirror has one shutter. Open and close of shutters done using DC motors.

In the present work, fuzzy logic system based on weather station data has been used to control the speed of DC motor. The dome shutter is presented in section 2. The fuzzy control system is presented in section 4. The discussion and conclusion have been presented in section 10.

II. TELESCOPE SHUTTERS

The mirror shutter (gate) consists of twelve steel triangle parts with turning spindle-chain transfer motion system oprating with 1.5 Kw, 380 v, and 1350 r.p.m. DC gear motor for opening the shutter like flower as shown in **Figure 1**. **[5]**

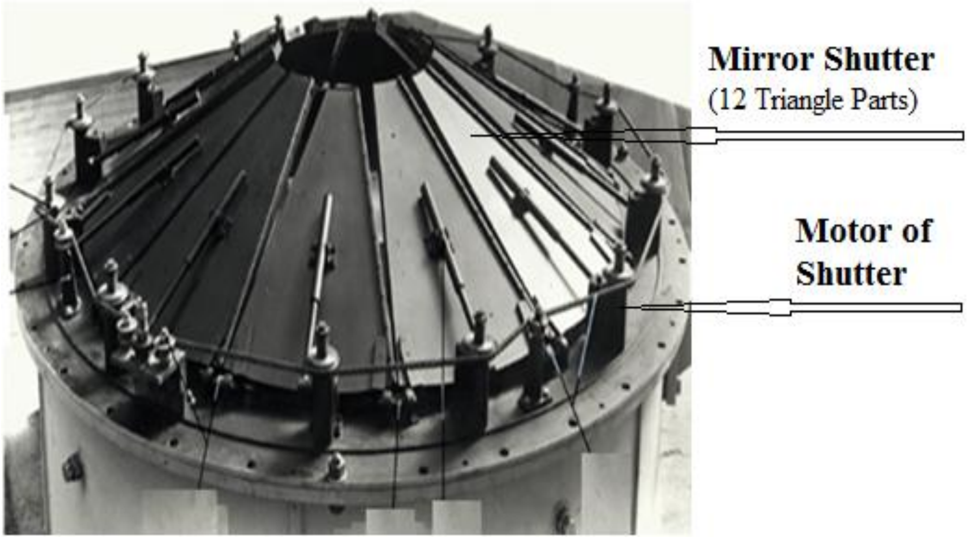


Figure 1: Mirror Shutter

The telescope dome rotated on 26 traveling wheels with 17 r.p.m. speed by 6 three phase DC motors driving 6 pinions into a circular rack. Dome also can be opening of 5m wide and extends 2.5m beyond the zenith. Other shutters (gates) were lower and upper one that moving with 4.5 Kw, 380 V, and 1750 r.p.m. three phase DC gear motors.

Figure 2: The Telescope Dome with Open Shutters

Upper shutter is "up and over" type and lower shutter is in two parts each opening to the side, by DC motors as shown in **Figure 2**. It is a pushbutton for both dome and shutters motions. It runs on rails attached to the main arches of the dome. Similar pushbuttons are also provided at various positions around the periphery of the dome. It is no any electrical control connections between the telescope and the dome. As the telescope tracks the object across the sky, it is necessary to rotate the dome from time to time to allow the light of the object to enter to the telescope.

III. DC MOTOR MATHEMATICAL MODEL

The equivalent circuit of the DC three phase gear motors that used for moving (open and close) the dome and mirror shutters (gates) is shown in **Figure 3**.

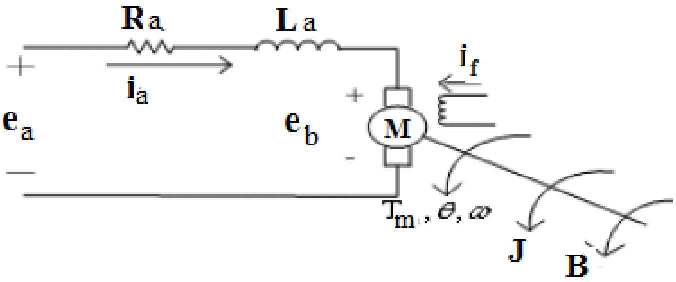


Figure 3: Equivalent Circuit of the DC Motor.

The equation of motion for motor can be explained as following [8];
Using Kirchhoff's circuit voltage law the input voltage (e_a) to the motor can get

$$e_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + e_b(t) \tag{1}$$

Because the back electromotive force (e_b) is directly proportional to speed (ω) hence

$$e_b(t) = K_b \frac{d\theta(t)}{dt} = K_b\, \omega(t) \tag{2}$$

From Newton law the motor torque (T_m) can be obtain

$$T_m(t) = J\frac{d^2\theta(t)}{dt^2} + B\frac{d\theta}{dt} = K_\tau i_a(t) \tag{3}$$

Where;
$R_{a,}$ is the Armature resistance
$L_{a,}$ is the Armature inductance
$I_{a,}$ is the Armature current
$I_{f,}$ is the Field current
$e_{a,}$ is the Input voltage
e_b, is the Back electromotive force (EMF)
$T_{m,}$ is the Motor torque
ω, is the angular velocity of rotor
J, is the Rotor inertia
B, is the Friction constant
K_b , is the EMF constant
$K_{T\,,}$ is the Torque constant
The most comman characteristics of the DC motors used for shutters appeared in **Table 1**.

Table 1: DC Three Phase Gear Motor Performance Characteristics

Parameter	Values for Dome Motor	Values for Mirror Motor
R_a	13.790 Ω	5.441 Ω
L_a	0.146 H	0.0575 H
I_a	12 A	4.734 A
e_a	380 V	380V
ω	138.75 rad/s	55 rad/s
J	0.02658 kg.m^2	0.01048 kg.m^2
B	0.00354 Nms/rad	0.0012 Nms/rad
K_b	0.54 Vs/rad	0.2106 Vs/rad
K_T	1.53 Nm/A	0.598 Nm/A

Taking Laplace transforms for equations (1), (2), and (3) can be formulated as follows;

$$E_a(s) = (R_a + L_a s)I_a(s) + E_b(s) \tag{4}$$

$$E_b(s) = K_b\, \omega\, (s) \tag{5}$$

$$T_m(s) = \omega(s)(B + Js) = K_\tau I_a(s) \tag{6}$$

There are basically three methods of speed control on DC motor.
1- Variation of resistance in armature circuit.
2- Variation of field flux.
3- Variation of armature terminal voltage

From equations (4), (5), and (6) the DC motor armature speed control system (depending on variation of armature voltage) functional block diagram is shown in **Figure 4**.

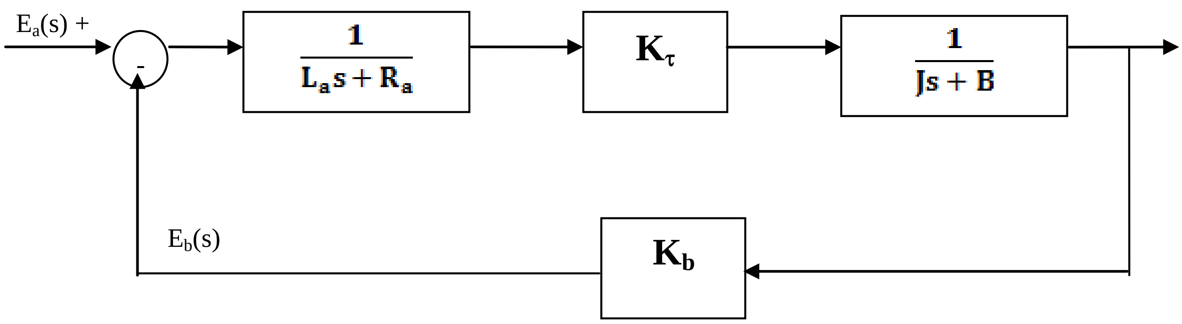


Figure 4: DC Motor Speed Control System Functiona Block Diagram

The transfer function of DC motor speed with respect to input voltage can be written as follows;

$$G(s) = \text{transfer function} = \frac{\omega(s)}{E_a(s)} = \frac{K_\tau}{(L_a s + R_a)(Js + B) + K_b K_\tau} \quad (7)$$

IV. FUZZY CONTROLLER DESCRIPTION AND DESIGN

A fuzzy logic control (FLC) system is a control system in which a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively) **[7]**. Fuzzy Logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. Fuzzy Logic’s approach to control problems mimics how a person makes decisions, only much faster.
Components Characteristic of a Fuzzy Controller;

- Preprocessing
- Fuzzification
- Rule Base
- Defuzzification
- Post processing

Preprocessing: The inputs are most often hard or crisp measurement from some measuring equipment rather than linguistic. A preprocessor block in **Figure 5** shows the conditions of measurements before enter the fuzzy controller.

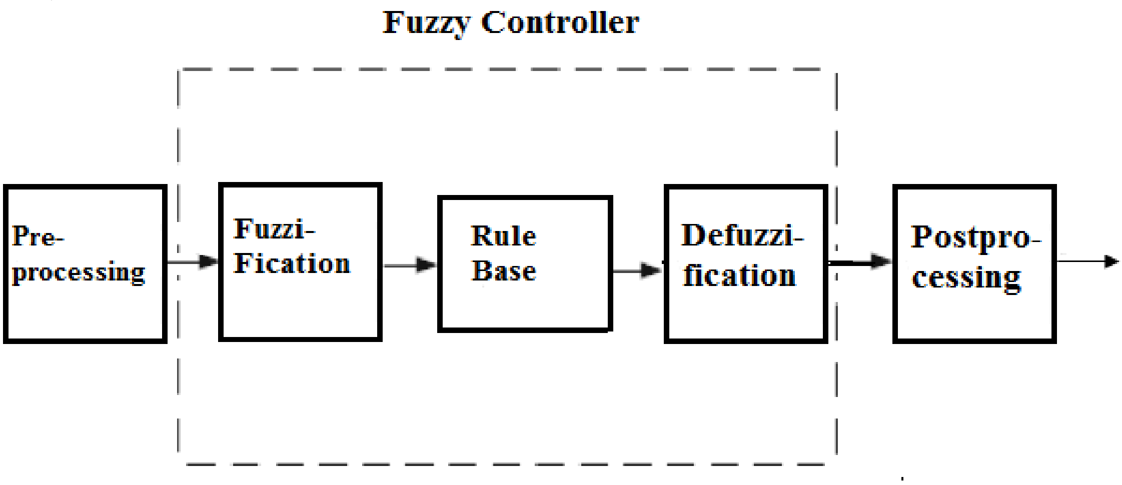


Figure 5: Process Blocks for a Fuzzy Controller

Fuzzification: The first block inside the controller is fuzzification which converts each piece of input data to degrees of membership by a lookup in one or several membership functions.

Rule Base: The collection of rules is called a rule base. The rules are in "*If Then* "format and formally the *If side* is called the *conditions* and the *Then side* is called the *conclusion*. The computer is able to execute the rules and compute a control signal depending on the measured inputs *error* (e) and *change in error* (Ce).

Defuzzification: Defuzzification is when all the actions that have been activated are combined and converted into a single non-fuzzy output signal which is the control signal of the system. The output levels are depending on the rules that the systems have and the positions depending on the non-linearity's existing to the systems.

Post processing: The post processing block often contains an output gain that can be tuned and also become as an integrator.

V. DEFINING INPUT AND OUTPUT

The goal of designed FLC in this study is to open and close the dome and mirror shutters related to weather station values, it done by control the speed of the DC gear motor of this shutters through changing the motor armature voltage value. The cycle of dome and mirror DC motor control system can be simplified as shown in **Figure 6.**

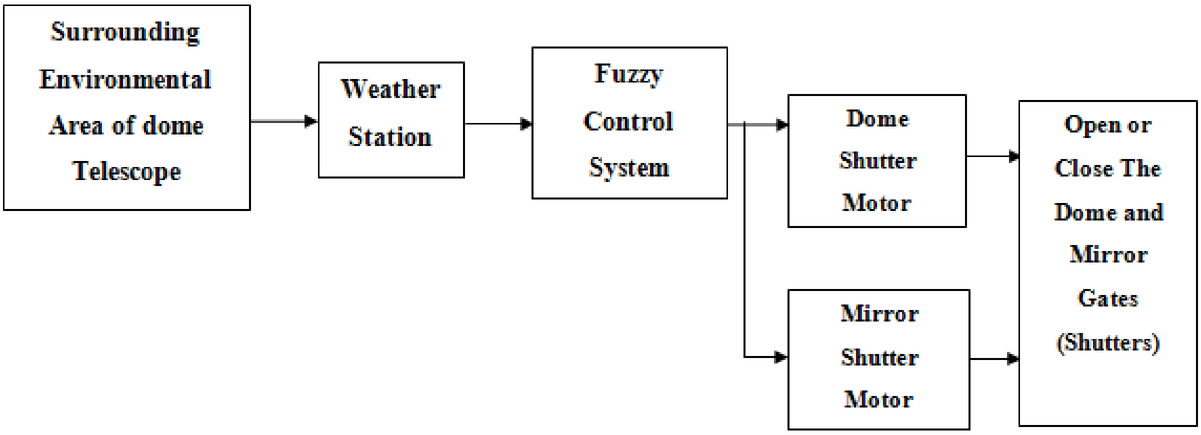


Figure 6: Scheme of Control System Used

VI . WEATHER STATION

The weather station used to measure weather parameters like temperature, rain rate, and wind speed, humidity, and dust particles. Several measuring sensors used for this purpose. At a certain level of these parameters the mirror shutter must be closed. On the other side, the rain rate, and humidity levels have the main decision on opening or closed the dome shutter. The range of the measuring values for each parameter's sensor shown in **Table 2**.

Table 2: Measuring Values Range for Weather Station Sensors

Parameter	Value
Temperature	(-3-50) ^{o}C
Rain rate	(0.25-50) mm/hr
Wind speed	(0-15) km/hr
Humidity	(0-80) %
Dust particles	(0-1.5) %

VII. FUZZY CONTROL SYSTEM

To protect telescope from the weather changes, it must be control the open or closed of dome and mirror shutters. We define the membership function (m_{Ai}) for each (x), in the each stage (*Si)* a fuzzy subset fuzzy model as follows:

$$m_{Ai}(x) \quad = \quad \begin{Bmatrix} 1 \quad if \quad \frac{4n}{5} < nix \leq n \\ 0.75 \quad if \quad \frac{3n}{5} < nix \leq \frac{4n}{5} \\ 0.5 \quad if \quad \frac{2n}{5} < nix \leq \frac{3n}{5} \\ 0.25 \quad if \quad \frac{n}{5} < nix \leq \frac{2n}{5} \\ 0 \quad if \quad 0 < nix \leq \frac{n}{5} \end{Bmatrix} \qquad (8)$$

Where the system's *(n)* entities (objects), $n \geq 2$, during a process involving vagueness and/or uncertainty. Denote by , *i=1,2,3*. A MATLAB fuzzy logic control system designed to control this operation. The inputs of the fuzzy control system are the output of the weather station. The FLC has 5 inputs, 1 output, and 6 membership functions. The inputs were the output of the weather station (measuring sensors values of temperature, rain rate, wind speed, humidity, and dust particles). The output of the fuzzy system (1 or 0) interred to the motor transfer function control equation to control the speed of dome motor (decision of open or closed the shutter). The FLC control system structure shown in **Figure 7** with membership functions explained as shown in **Figure 8** , and the fuzzy system rules shown in **Figure 9**.

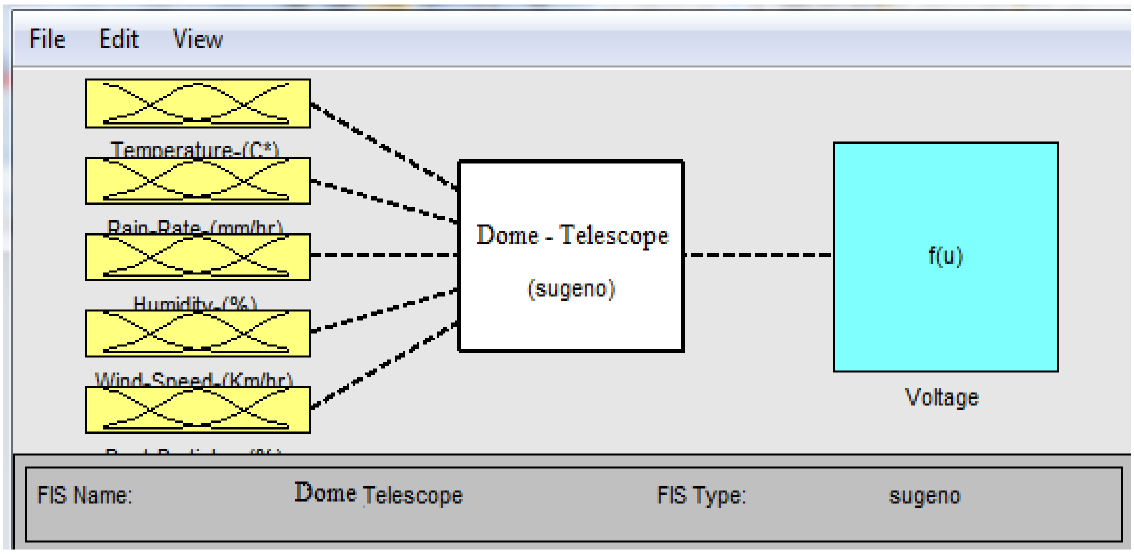
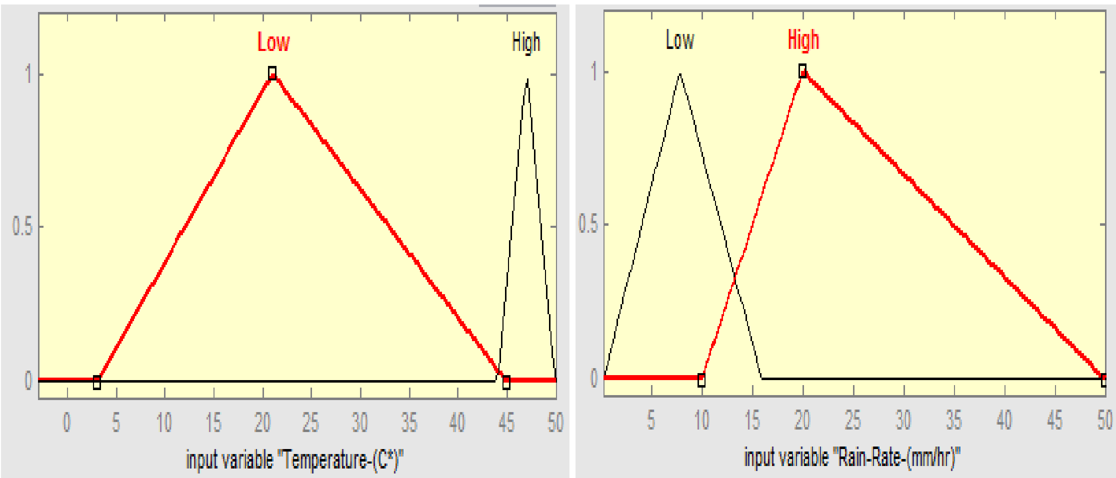
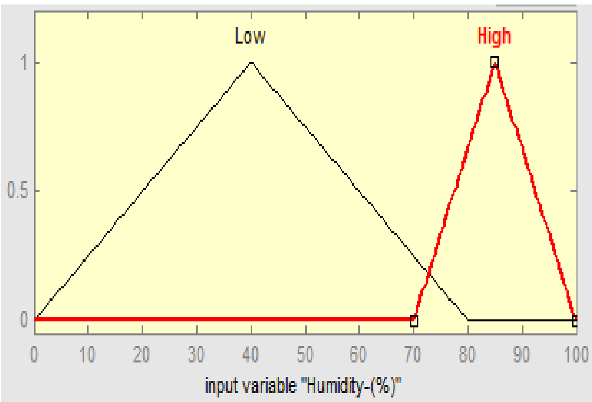


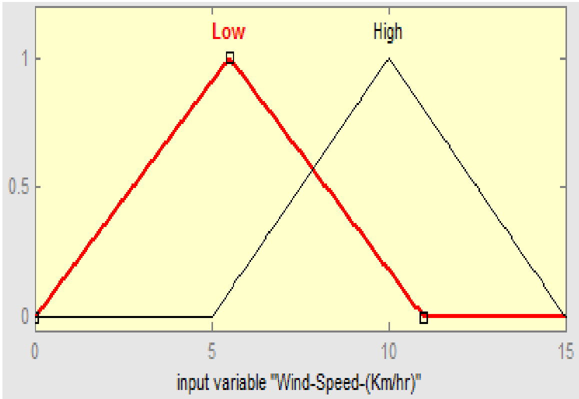
Figure 7: FLC Control System Structure



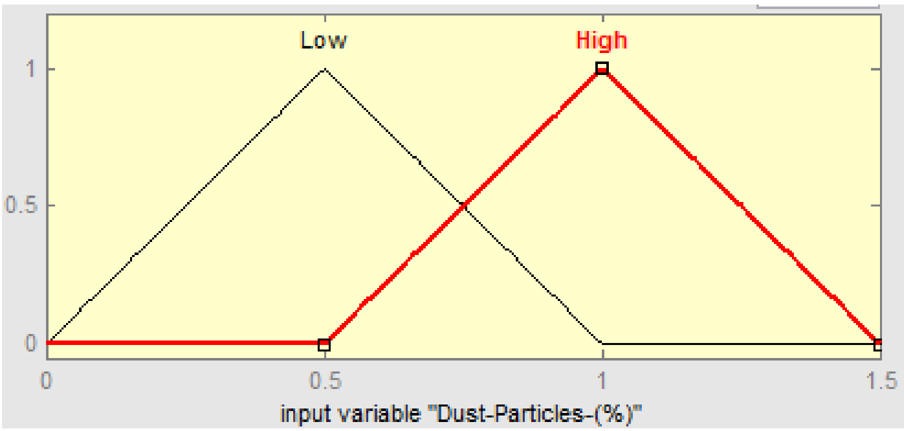
(a) **(b)**



(c)



(d)



(e)

Figure 8: Membership Functions for (a) Temperature, (b) Rain Rate, (c) Humidity, (d) Wind Speed, and (e) Dust Particles

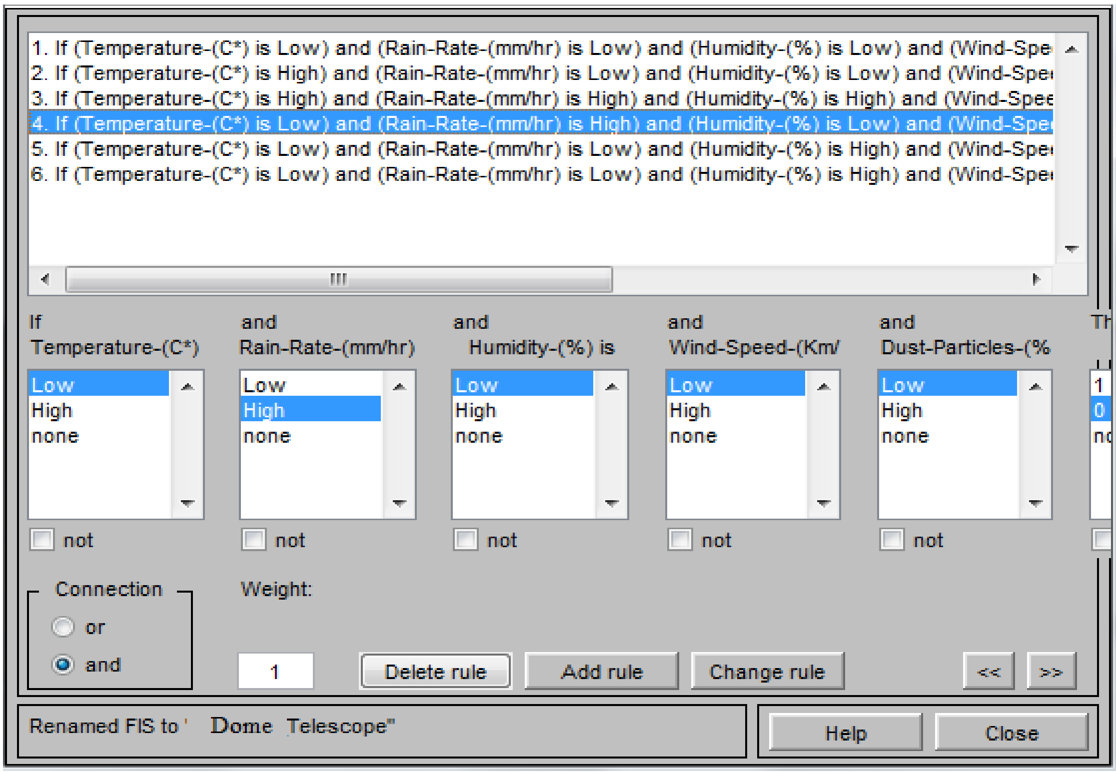


Figure 9: FLC Control System Rules Editor

The rule base represented as If-Then statements governing the relationship between the inputs and outputs variables in terms of membership functions. There were 6 rules depending on weather station parameters values as shown in **Table 3**.

Table 3: Rule Base Parameters

Parameters	Temperature	Rain rate	Wind speed	Humidity	Dust particles	Output value
Case 1	Low	Low	Low	Low	Low	1
Case 2	High	Low	High	Low	Low	1
Case 3	High	High	High	High	High	0
Case 4	Low	High	Low	Low	Low	0
Case 5	Low	Low	Low	Low	High	0
Case 6	Low	Low	Low	High	Low	0

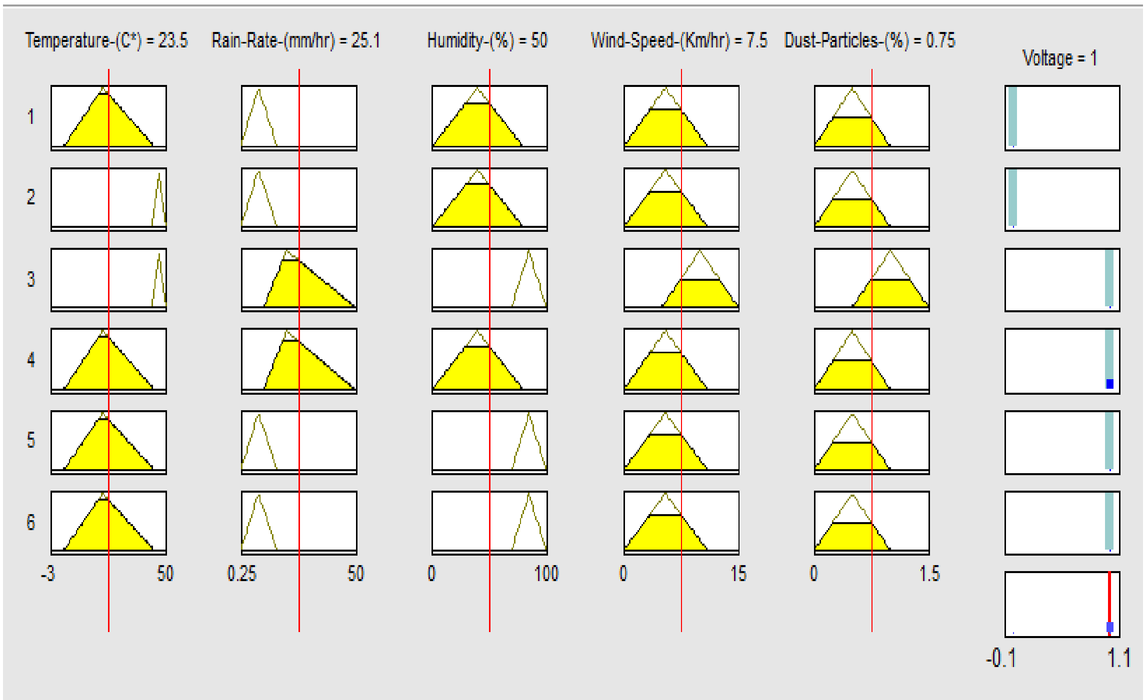


Figure 8: Rules of Inputs and Outputs of FLC

VIII. TRANSFER FUNCTION FOR SHUTTER MOTORS

The input to transfer functions of dome shutter and mirror shutter motors is the armature voltage as shown in **Figure 6**, and the output is the motor speed which effect on open and close of the shutter as explained in equation (7).

IX. SIMULINKE IMPLEMENTATION

Below the **Figure 9** shows the DC motor model built in SIMULINK/MATLAB. Sensors used in weather station measure the Environmental conditions which input to the FLC system. The output of the FLC entered to motors transfer functions to control motor speed for making the open and close shutter easy and accurate.

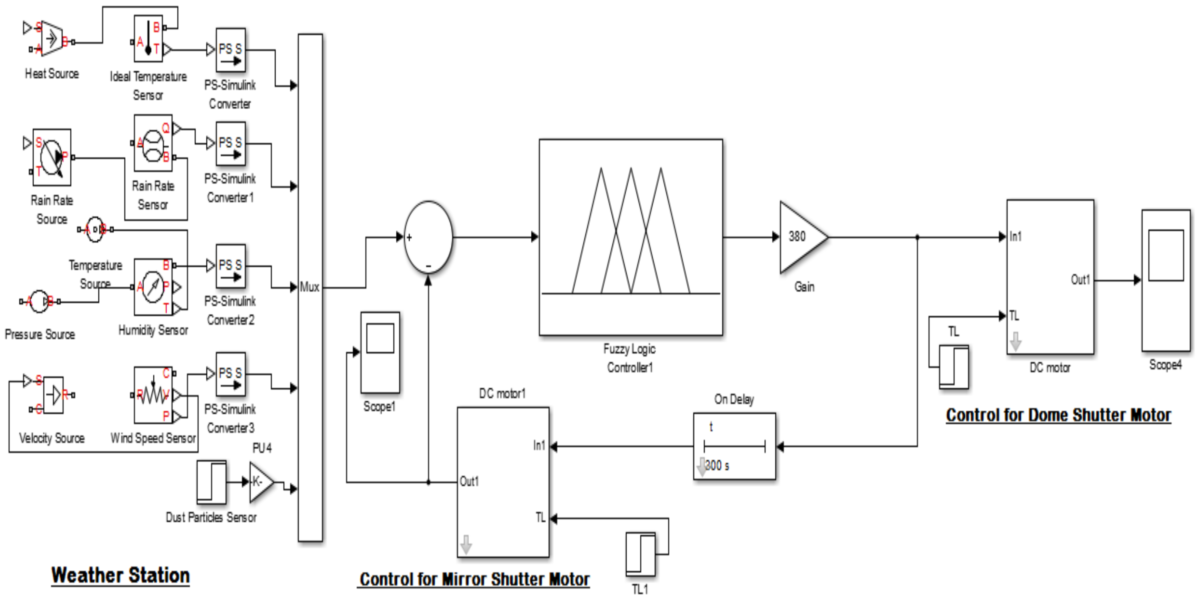


Figure 9: SIMULINK Model of Fuzzy Controlling of DC Motor

X. CONCLUSION

Nowadays the automatic control has played a vital role in the advance of engineering and science. The control of direct current (DC) motor is a common practice thus the implementation of DC motor of controller speed is important. In this paper fuzzy logic control have been used to control the speed of a DC motor of astronomical dome and mirror shutters to open and close the dome and mirror shutters based on simultaneously weather station data, wind speed, humidity, rain rate, temperature, and dust particle. The proposed fuzzy Logic controller for control the astronomical dome has more advantages, such as higher flexibility, control, better dynamic and static performance. The results fuzzy logic response show that the overshoot, settling time, peak time and control performance are greatly by using a fuzzy Logic controller. The simulation results are obtained using MATLAB/SIMULINK. Hence, fuzzy logic controller design was proposed and implemented.

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