CHAPTER THREE
METHDOLOGY

3.1 INTRODUCTION

The name MATLAB stands for Matrix Laboratory. MATLAB is a high-performance fourth-generation programming languagedeveloped by Math Works for technical computing. It integrates computation, visualization, and programming environment. Furthermore, a modern programming language environment has sophisticated data structures, contains built-in editing and debugging tools, and supports object-oriented programming. These factors make MATLAB an excellent tool for teaching and research. [22]

MATLAB introduce an additional package, Simulink, which is a graphical programming environment for modeling, simulating and analyzing multidomain dynamic systems. It is widely used in automatic control and digital signal processing for multidomain simulation and Model-Based Design. [23].

We will use MATLAB Simulink toolbox to optimize the response of the heater, which represented with the heater mathematical model and then simulate the system using PROTEUS simulator.

PROTEUS is an execution-driven simulator Which multiplexes a single processor among the various activities in a simulated parallel machine to provide accurate information about the timing and behavior of an application and the underlying simulated architecture, compared with other simulators it is fast, accurate, and flexible, also it is one to two orders of magnitude faster, it can reproduce results from real multiprocessors, and it is easily configured to simulate a wide range of

MIMD architectures , The modular structure provides two very important abilities. First, the structure simplifies customizing the target architecture: very easy to experiment with part of the architecture while keeping the rest unchanged, Second, the modular structure promotes multiple implementations of a given module, which allows users to switch between very accurate versions and very fast version configured to simulate a wide range of MIMD architectures. [24]

The microcontroller that we use will be programmed using CODEV1S1ON programmer, which is the only Integrated Development Environment on the market that features an Automatic Program Generator (CodeWizardAVR) for the new XMEGA chips. there is many versions of it for example V3.28 whichadds support for the ATmega324PB chip, improved code generator C source code style formatting in the editor and bug fixes.

3.2 Heater mathematical model

To control the water heater it is important to choose the right model representation of that non-linear system. The mathematical model of the water heater was establish by applying the principle of energy conservation in the electric water heater system.

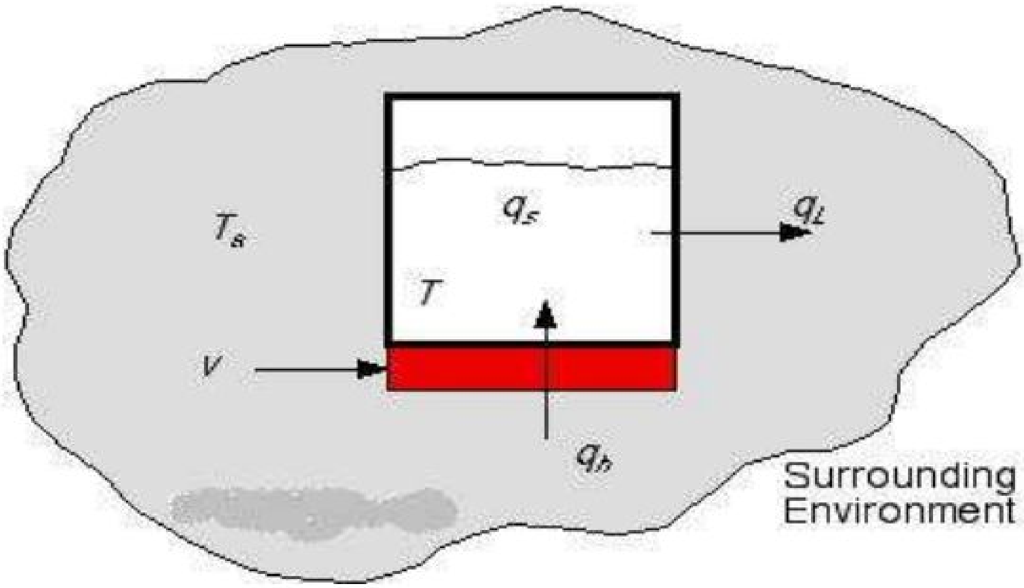

Figure 3-1: electric water heater

- T= Temperature of water (output).
- Ta=ambient temperature.
- Qh=Energy supplied by heater.
- Qs=Energy stored by liquid.
- QL=Energy lost to the surrounding environment by conduction= Voltage applied to the heater (input).

The differential equation is obtained by applying heat balance equation. Energy supplied by the heater: (Qh) = Energy stored by water (Qs) + Energy lost to the surrounding environment by conduction (QL).

$$Qh = Qs + QL \qquad (3.1)$$

$$K*V=C*(dT/dt) + (T-Ta)/R \qquad (3.2)$$

- K is its thermal conductivity.
- C is a thermal capacitance of the liquid.

- R is the thermal resistance of the tank wall (heat conduction).
- t is the time.

Previews Equation is the differential equation that describes the dynamics of the thermal system. Taking Laplace transform at both the side of the equation and rearranging in the transfer function form

$$k * V(s) = C * s * T(s) + \frac{1}{R} * T(s) \quad (3.3)$$

$$\frac{T(s)}{V(s)} = \frac{k}{C*s+\frac{1}{R}} \quad (3.4)$$

Equation (3.1) is a first order system with the time constant C*R.k*R can be treated as system static gain with a time delay = 0.3s.the second one is the transfer function of the previews equation which represent the relation between the input V(s) and the output T(s). By applying the values of the thermal conductivity of the heater (K=25W/m℃), thermal capacitance of the water (C), and carbon steel heater walls thermal resistance(R=0.6Ω)[25]:

$$\frac{T(s)}{V(s)} = \frac{25}{2400s+1.66} \quad (3.5)$$

3.3 Simulink representation

By using Simulink toolbox library, we will represent the heater mathematical model to obtain the response of the heater. Any system response descriped using the following charactrastics:

- Rise Time defined as the time for the waveform to go from 0.1 to 0.9 of its final value. [25]
- Settling time is defined as the time for the response to reach and stay within 2% of its final value [25]

- Overshoot occurs when the value of the transition is higher than the final value. . [26]
- Undershoot occurs when the transition is from higher to lower, and its value is lower than the final value. [26]
- Steady state: if the variables (called state variables) which define the behavior of the system or the process are unchanging in time [27]
- Steady-state error is defined as the difference between the input (command) and the output of a system in the limit as time goes to infinity [28]
- Set point: the desired value in a closed-loop feedback system, as in regulation of temperature or pressure. [29]

3.3.1 Open loop module of the system response

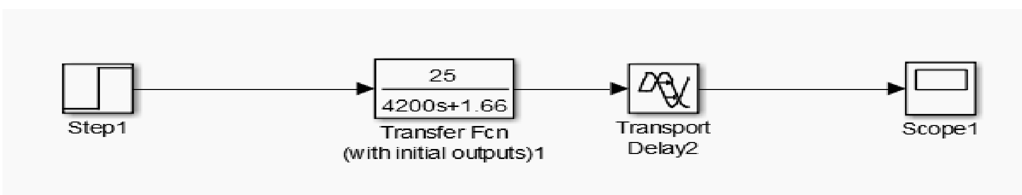

Figure 3-2: open loop system module

Open loop module as the one presented in Figure 3-2, consists only of a forward path that contain the Step signal block as set point which is a discontinuous function whose value is zero for negative argument and one for positive argument, and transfer function block to represent the mathematical model of the heater, and delay block, the response is displayed in the scope block which represent the output as a function of time. The response of the system calculated according to the system input regardless of the system's desired set point.

3.3.2 Closed loop module of the system response:

From the figure 3-3 below, the system, consists of a forward path and a feedback path. The forward path contain Step signal block (set point), Transfer function block to represent the mathematical model of the heater, and delay block. Feedback path returns the output of the heater transfer function and compares it with the set point (step signal block) to automatically achieve and maintain the desired output, the result will be an error signal that fed to the transfer function as an input signal, and then the output response of the transfer function will be represented by the scope block.

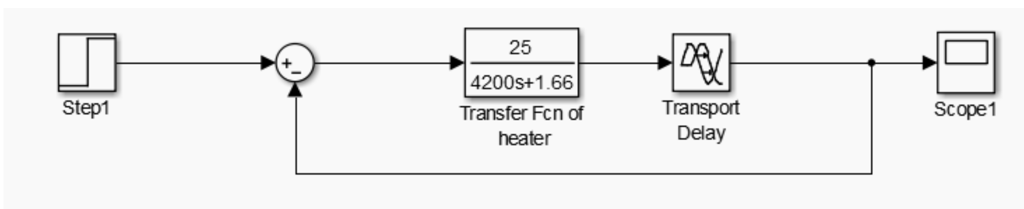

Figure 3-3: Simulink block diagram of the heater transfer function

As we can see from figure3:2 the heater response is far different from the desired response in the matter of the setpinot and the time respone . To improve the response of the system we will use PD controller Defined in pervious chapters.

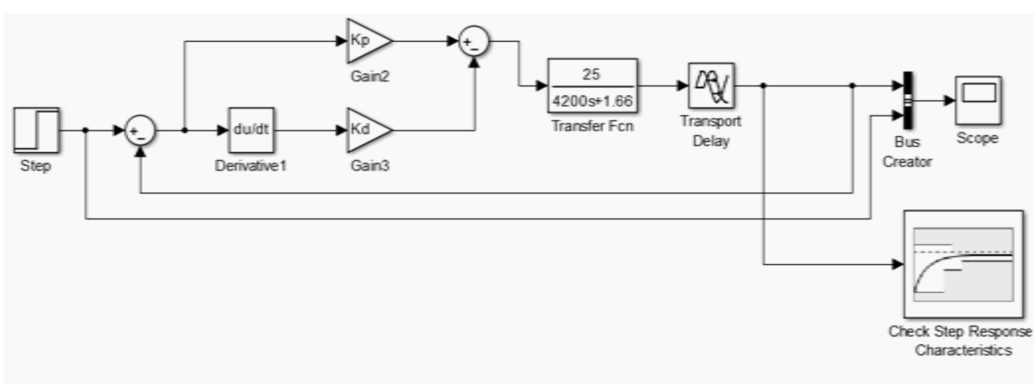

Figure 3-4: Simulink block diagram of PD controller

We will use check step response characteristics block in Simulink to automatically tune the parameters of the PD controller by specifying the desired step response characteristics and given a random values to kd and kp which is in our case kd=1, kp=1and then we insert these values in gain blocks .

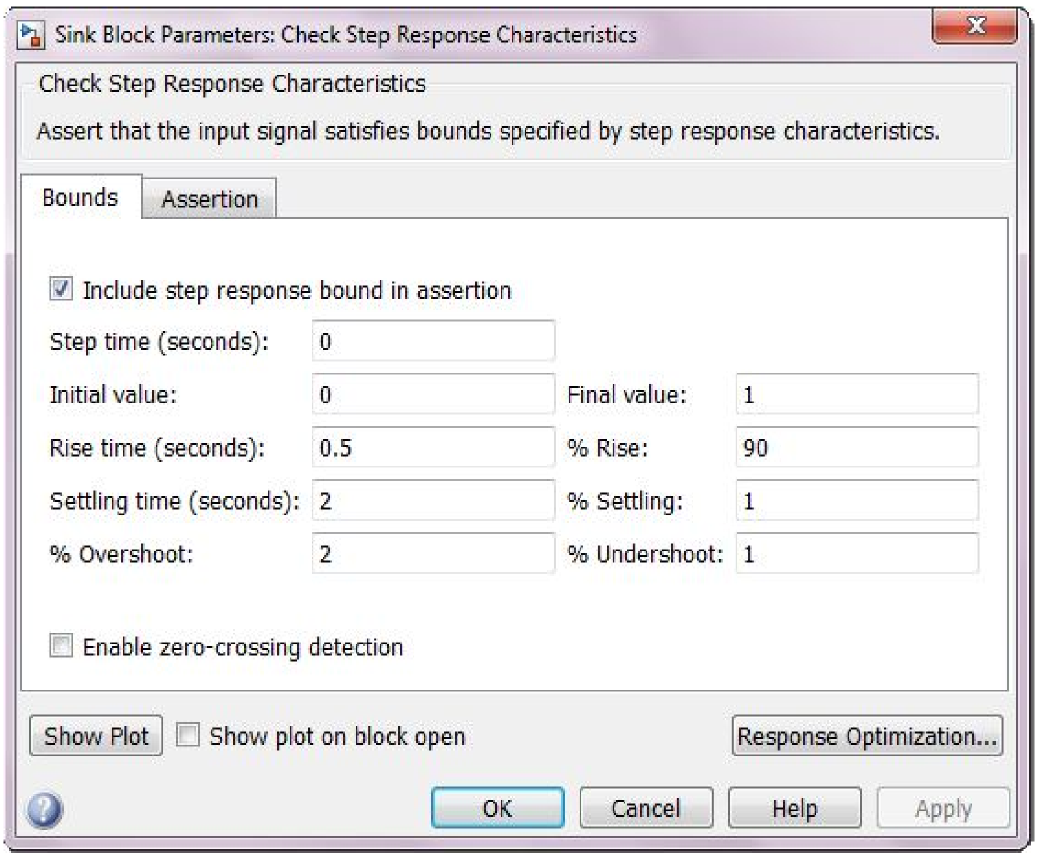

Figure 3-5: check step response characteristics window

And start optimization which illusrated in figure 3-6 .

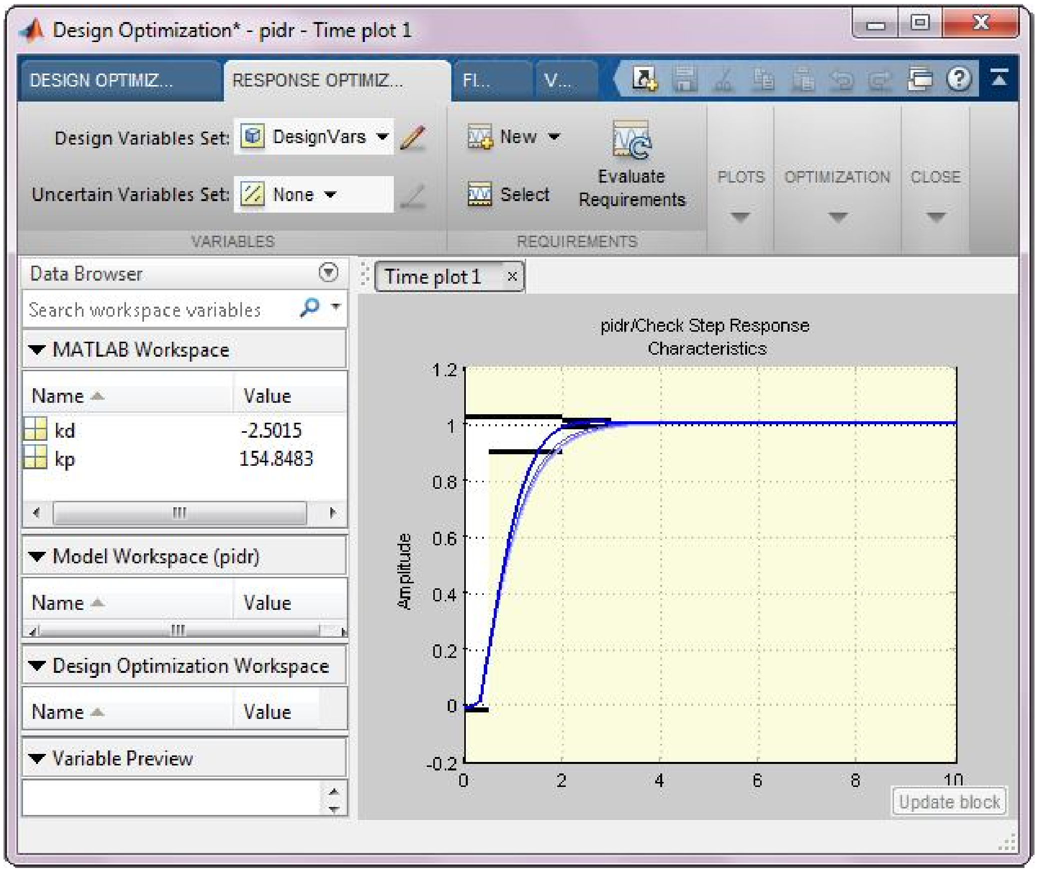

Figure 3-6: design optimization window

After tuning finish the optimized values of kd = -2.5015 and kp = 1.5484 saved into the gain blocks, The error from the difference between the set point and the actual output is multiplied by the proportional factor (kp), the change in error is calculated by the derivative block to obtain change in error which is the difference between error in time t and error in time t+1, and the result fed into the heater transfer function.

To enhance the response of the PD controller it will be combined with the fuzzy logic controller.

3.3.3 Fuzzy-PD controller

The fuzzy controller have two inputs (E, ED) and one output (Y). The inputs are the error multiply by optimized value of kp and change in error multiply by optimized value of kd , each inputs divided into seven ranges, each range indicate by name according to values of both inputs E, DE, illustrated in figure3-7:

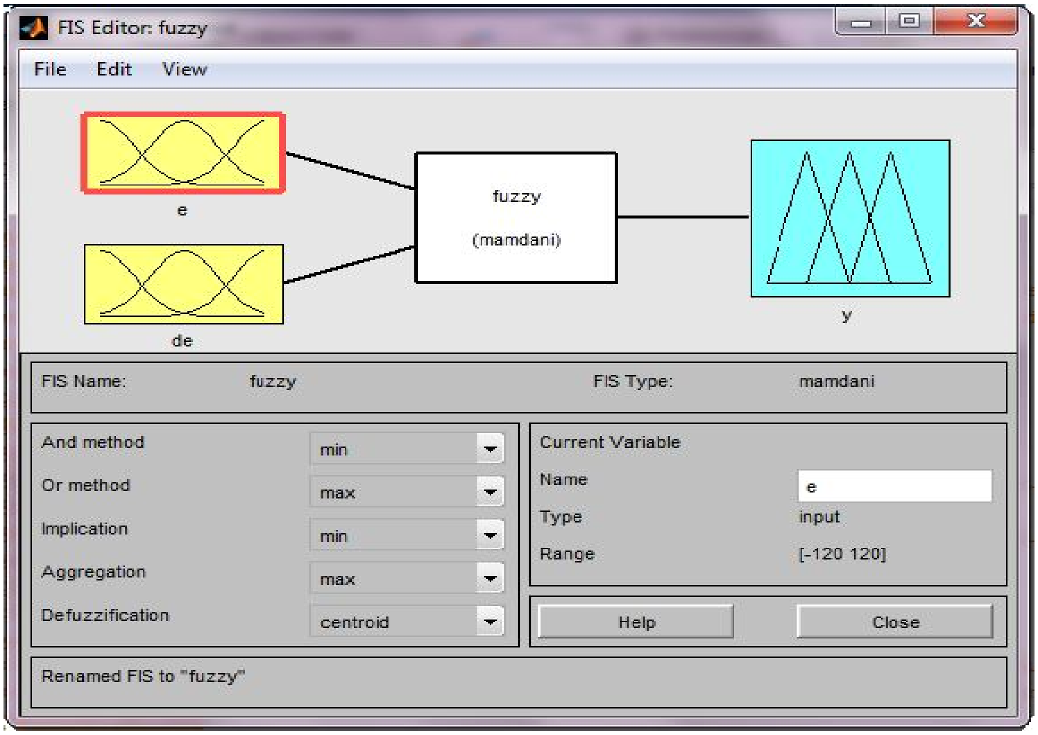

Figure 3-7: F1S editor window

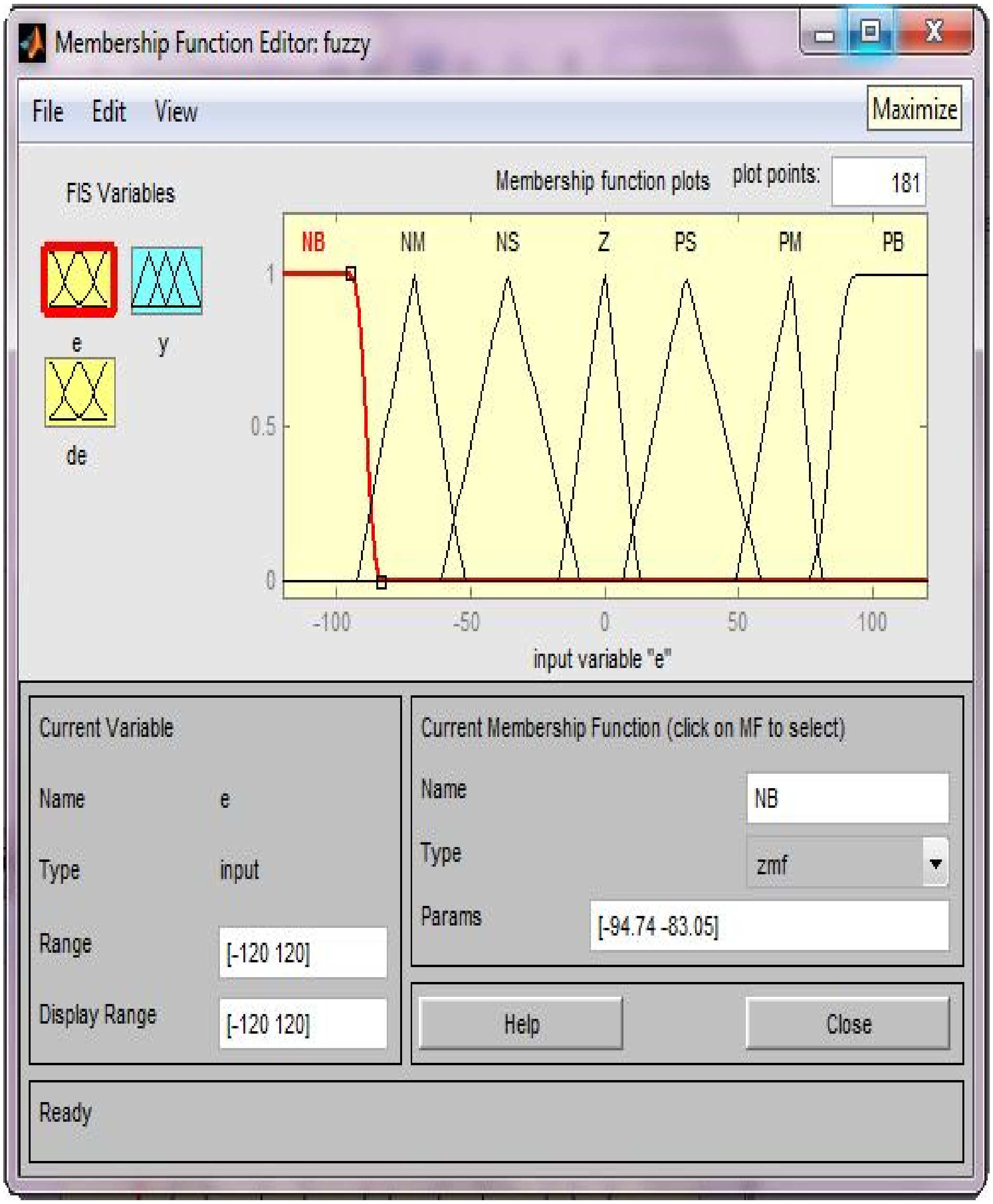

Figure 3-8: membership function editor window

Then we will write the fuzzy rules obtained from table 3-1:

Table 3-1: PD control rule matrix

E / DE	NB	NM	NS	ZO	PS	PM	PB
PB	ZO	PS	PM	PB	PB	PB	PB
PM	NS	ZO	PS	PM	PB	PB	PB
PS	NM	NS	ZO	PS	PM	PB	PB
ZO	NB	NM	NS	ZO	PS	PB	PB
NS	NB	NB	NM	NS	ZO	PS	PM
NM	NB	NB	NB	NM	NS	ZO	PS
NB	NB	NB	NB	NB	NM	NS	ZO

The output of each compensation of E and DE is obtained logically in a form of if then statement as shown in figure 3-9 for example: if E is negative big (NB) and DE is positive, big (PB) the output is zero (ZO).

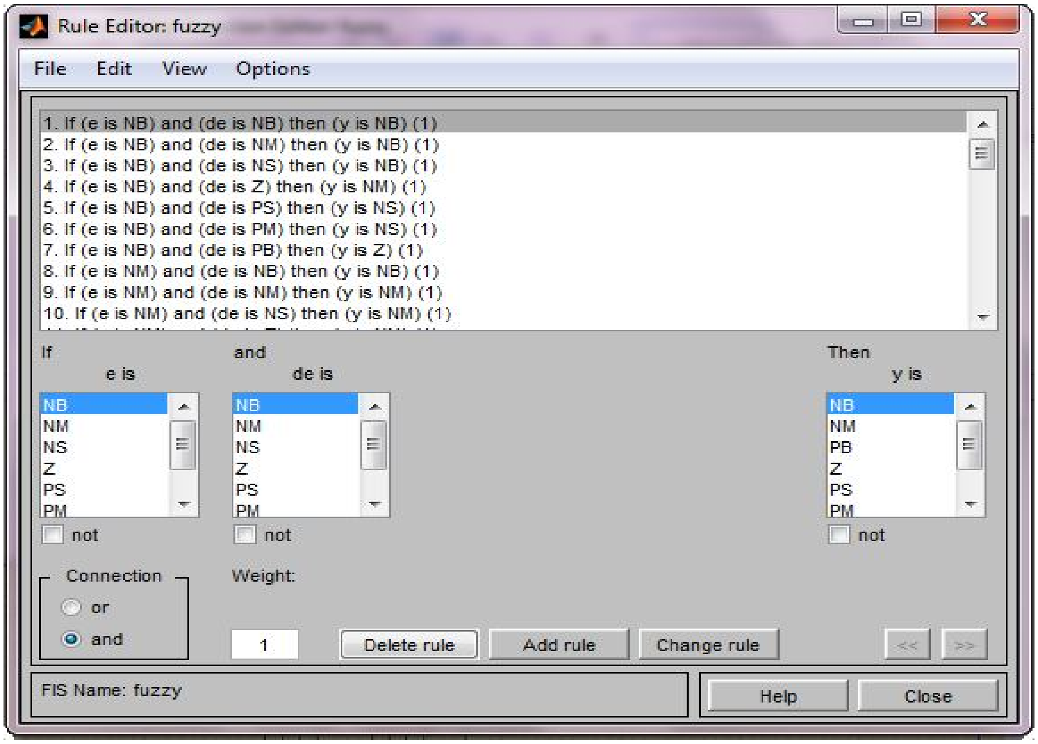

Figure 3-9: rule editor window

Then the fuzzy logic control block will generate a control signal to the transfer function to obtain the desired response as shown in figure 3-10.

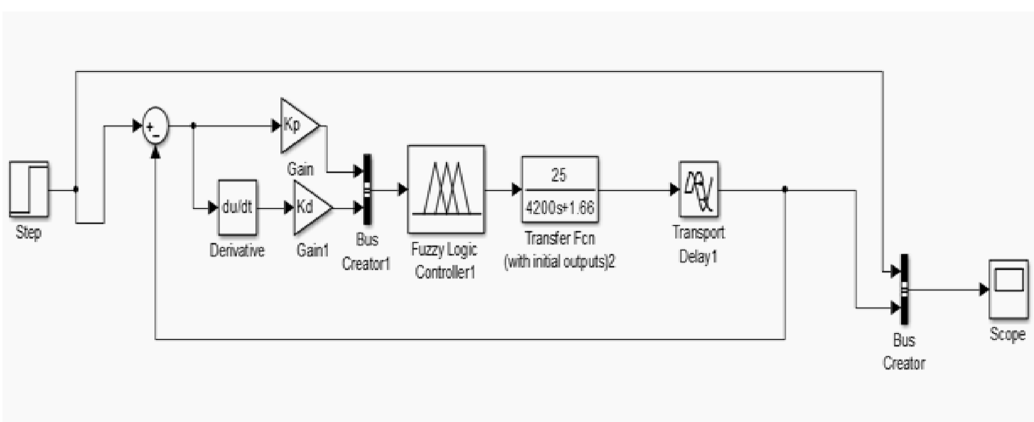

Figure 3-10: Simulink block diagram of fuzzy PD controller

3. 4 System PROTEUS simulation

Heater Temperature is being measured using an integrated circuit temperature internal sensor, which have an analog output voltage. The output voltage of sensor is linearly proportional to temperature with a gradient of 1V/ºC and able to operate in the range +25ºC to +200ºC with an accuracy of ± 0.5ºC[]. The analog output of sensor is given to on-chip Analog to Digital Converter (ADC) of microcontroller. ADC converts an analog voltage into corresponding digital word, which is processed to get the actual physical parameter and then displayed on two 7-segment display modules interfaced to the ports of microcontroller. Circuit diagram of the fuzzy logic PD temperature control system is depicted in Figure3-11.

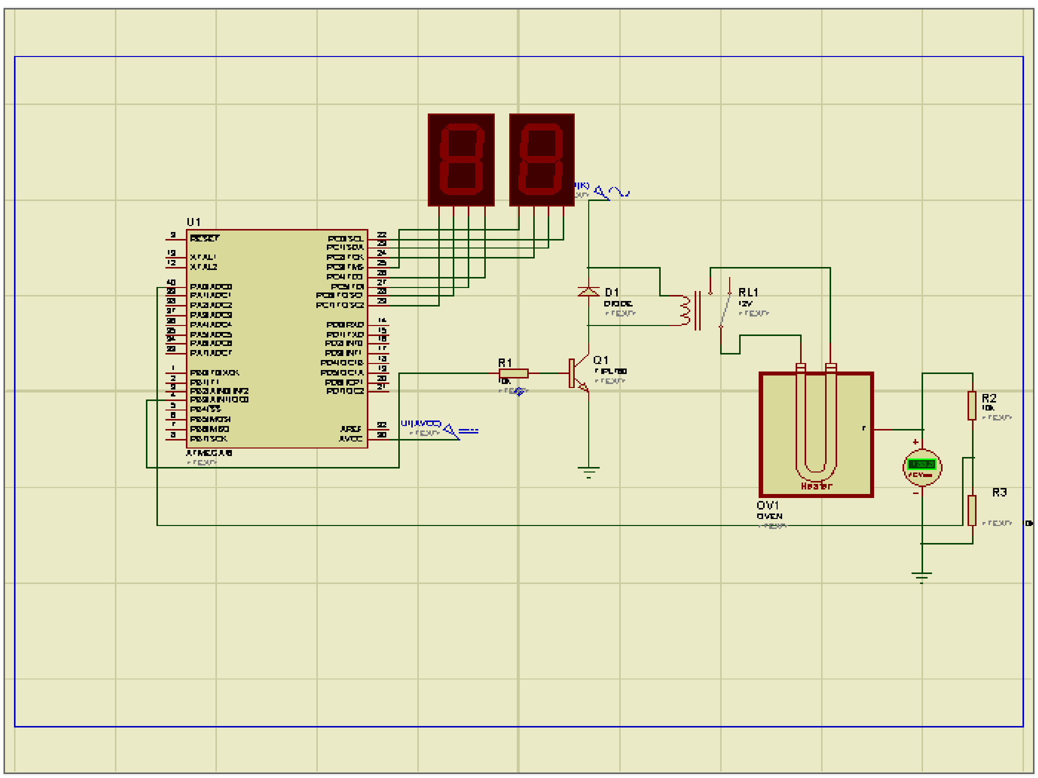

Figure 3-11: heating system PROTUES simulation

The timer 0 output pin (OC0) of Atmega16 microcontroller is fed to the heater interface circuit, which works as protection circuit to isolate the component with high power from the one with lower power. Timer 0 is configured as Fast PWM, mode and its duty cycle adjusted according to the Fuzzy control module. To display the current temperature of the heater, two 7-segment display elements are used. The ATMEGA16 microcontroller is programmed using code vision programing tool code illustrated in a form of flowchart in figure 3-12: