CHAPTER TWO

LETRATURE REVIEW

2.1 Background

Electric heater is any device that changes electrical energy into heat energy. Inside every electric heater is an electrical resistor which is the heating element, and works on the principle of Joule heating: an electric current passing through a resistor will convert that electrical energy into heat energy The measure of electrical energy is called the Joule after its discoverer, James Prescott Joule. [3] Though numerous experiments, Joule determined that the quantity (Q) of heat transferred from electrical energy is proportional to the square of the current (I2) multiplied by the resistance (R) for the period of time (t) through which it passes:

$$Q \propto I^2 * R * t \quad (1)$$

However in modern electric circuits. Instead of joule, the controlling factor becomes that of power (p):

$$P = I^2 * R \quad (2)$$

The only difference between the formula for determining power and that of determining Joules is the time component. The time factor in heating becomes readily apparent in any device that gets hot when an electric current flows through it: its temperature rises as time passes [4]. Electric heaters explode into a myriad of types, sizes, applications, the operating voltage of the heater and designs depending upon what’s being heated, the degree of heating needed, and the method by which the heat is applied. And it includes Common applications such as space heating, water heating and industrial processes. [3]

2.1.1 Space heating

Space heating is used to warm the interiors of buildings. Space heaters are useful in places where air-handling is difficult, such as in laboratories. [3]Several methods of electric space heating are used:

I. Radiant heaters

Electric radiant heating uses heating elements that reach a high temperature. The element is usually packaged inside a glass envelope resembling a light bulb and with a reflector to direct the energy output away from the body of the heater. The element emits infrared radiation that travels through air or space until it hits an absorbing surface, where it is partially converted to heat and partially reflected. This heat directly warms people and objects in the room, rather than warming the air. This style of heater is particularly useful in areas through which unheated air flows. They are also ideal for basements and garages where spot heating is desired. More generally, they are an excellent choice for task-specific heating [3]

II. Convection heaters

In a convection heater, the heating element heats the air in contact with it by thermal conduction. Hot air is less dense than cool air, so it rises due to buoyancy, allowing more cool air to flow in to take its place. This sets up a convection current of hot air that rises from the heater, heats up the surrounding space, cools and then repeats the cycle. These heaters are sometimes filled with oil. They are ideally suited for heating a closed space. They operate silently and have a lower risk of ignition hazard if they make unintended contact with furnishings compared to radiant electric heaters. [3]

III. Fan heaters

A fan heater, also called a forced convection heater, is a variety of convection heater that includes an electric fan to speed up the airflow. They operate with considerable noise caused by the fan. They have a moderate risk of ignition hazard if they make unintended contact with furnishings. Their advantage is that they are more compact than heaters that use natural convection. [3]

IV. Domestic electrical under floor heating

An electric under floor heating system has heating cables embedded in the floor. Current flows through a conductive heating material, supplied either directly from the line voltage (120 or 240 volts) or at low voltage from a transformer. The heated cables warm the flooring until it reaches the right temperature set by the floor thermostat. The flooring then heats the adjacent air, which circulates, heating other objects in the room (tables, chairs, and people) by convection. As it rises, the heated air will warm the room and all its contents up to the ceiling. This form of heating gives the most consistent room temperature from floor to ceiling compared to any other heating system. A variation of this principle uses tubes filled with circulating hot water. [3]

2.1.2 Liquid heaters

I. Immersion heater

An immersion heater has an electrical resistance heating element encased in a tube and directly placed in the water (or other fluid) to be heated. The immersion heater may be placed in an insulated hot water tank. A temperature sensor within the tank triggers a thermostat to control the temperature of the water. Small portable immersion heaters may not have a control thermostat, since they are intended to be used only briefly and under control of an operator. [3]

2.1.3Industrial electric heater

There are several types of Industrial electric heater such as:

I. Immersion Heater

Used in many different industries to heat liquids in large vats, containers and tanks. Immersion heaters use a direct heat transfer to heat liquids (raise the temperature of water and chemicals) .fluids must be contained in an enclosed space such as a tank or a container. It Work well for liquids with vastly different properties, and they usually require little in the way of maintenance. Some of the more common types of immersion heaters include:

- Flanged heaters.
- Screws plug heaters.
- Circulation.
- Over the side heaters.

Once used fuel as their source of power, but rising fuel costs over the past few decades have seen the emergence of electric immersion heaters. Electric heaters are much better for the environment and they are able to transfer heat immediately. The most common applications for electric immersion heaters are heating crude oil, fuel oil and hydraulics oil to maintain its viscosity, maintaining an oil temperature for pipeline transportation, Heating water and Keeping wastewater from freezing. [5]

II. Pipe Heaters

As the name suggests, pipe heaters are designed to fit inside 2 or 3” pipes and provide heat. Pipe heaters work well for applications that require low heat like making waxes, tar, and molasses or with more corrosive materials. They don’t actually touch the liquid that is being heated. Unlike the direct heat of immersion heaters, pipe heaters transfer the heat indirectly. This is done by the element heating the pipe from the inside and the pipe heating the liquid. And they don’t normally require much maintenance, as the containers holding liquids never have to be emptied out if the heaters are changed, because the heater isn’t actually in the liquid.[5]

III. Cartridge heater

is a tube-shaped, heavy-duty, industrial joule heating element (electrical resistance) used in the process heating industry, usually custom manufactured to a specific watt density, based on its intended application Highly compacted they reach a surface watt density of up to 50 W/cm^2,and It Designed to heat up solids by fitting snugly inside a mold or cavity and reaching high temperatures. Cartridge heaters are able to carry thermocouple, which helps to control and maintain the heater’s temperature with a greater degree of accuracy. Some of the more common uses motor oil or hydraulic oil applications, bag sealing, water based applications and gearboxes. Food equipment and laboratory equipment also make use of cartridge heaters regularly. Equipped with lead wire connections that help to transfer the heat. Different connections may be used depending on how high the temperature needs to be. [5]

Advantages of electric heating methods over other forms, include precision control of temperature and distribution of heat energy, combustion not used to develop heat, and the ability to attain temperatures not readily achievable with chemical combustion. Electric heat can be accurately applied at the precise point needed in a process, at high concentration of power per unit area or volume. Electric heating devices can be built in any required size and can be located anywhere within a plant. Electric heating processes are generally clean, quiet, and do not emit much byproduct heat to the surroundings. Electrical heating equipment has a high speed of response, lending it to rapid-cycling mass-production equipment. The limitations and disadvantages of electric heating in industry include the higher cost of electrical energy compared to direct use of fuel, and the capital cost of both the electric heating apparatus itself and the infrastructure required to deliver large quantities of electrical energy to the point of use. This may be somewhat offset by in-plant (on-site) efficiency gains in using less energy overall to achieve the same result. [6]

2.1.4 Electric water heater

Water heating is a thermodynamic process that uses an energy source to heat water above its initial temperature. Typical domestic uses of hot water include cooking, cleaning, bathing, and space heating. In industry, hot water and water heated to steam have many uses. [7] An Electric water heater usually Compose of an electric resistance, a permutation chamber and several sensors used for control and security.

2.2 Thermal systems control

There are many kinds of thermal systems in common industrial, transportation and domestic use that need to be controlled in some manner, and there are many ways in which that can be done. For example heat exchangers, environmental control in buildings, satellites thermal packaging of electronic component s, manufacturing, rapid thermal processing of computer chips, and many others. If precise control is not required, or if the process is very slow, control may simply be manual; otherwise some sort of mechanical or electrical feedback system has to be put in place for it to be automatic. Most thermal systems are generally complex involving diverse physical processes. These include natural and forced convection, radiation, complex geometries, property variation with temperature, nonlinearities and bifurcations, hydrodynamic instability, turbulence, multi-phase flows, or chemical reaction. It is common to have large uncertainties in the values of heat transfer coefficients, approximations due to using lumped parameters instead of distributed temperature fields, or material properties that may not be accurately known. For this reason large, commonly used engineering systems are hard to model exactly from first principles and even when this is possible the dynamic responses of the models are impossible to determine computationally in real time. Most often some degree of approximation has to be made to the mathematical model. The two major reasons for which control systems are needed to enable a thermal system to function as desired are the approximations used during design and the existence of unpredictable external and internal disturbances which was not taken in to account. [8] There are two main methods used for temperature control such as:

2.2.1 Manual control

Manual control done manually for example as shown in Figure 2-1 to keep the temperature of water discharged from an industrial gas-fired heater constant, an operator has to watch a temperature gauge and adjust a fuel gas valve accordingly. If the water temperature becomes too high for some reason, the operator has to close the gas valve a bit just enough to bring the temperature back to the desired value. If the water becomes too cold, he has to open the gas valve. [9]

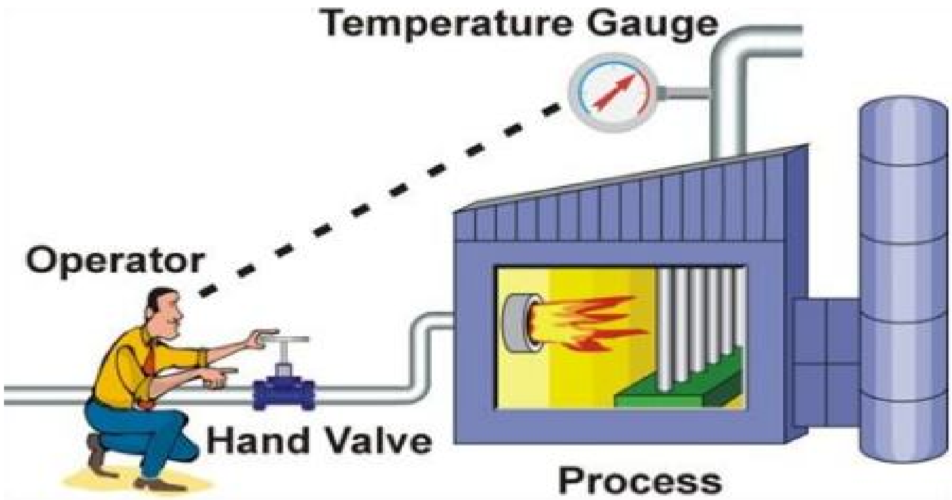

Figure 2-1: An Operator Performing Manual Control

The control task done by the operator is called feedback control, because the operator changes the firing rate based on feedback that he gets from the process via the temperature gauge. Feedback control can be done manually as described here, but it is commonly done automatically, as will be explained in the next section. The operator, valve, process, and temperature gauge form a control loop. Any change the operator makes to the gas valve affects the temperature, which is fed back to the operator, thereby closing the loop. [9]

2.2.2 Automatic control

The control function can be automated with several methods such as

I. PID control.
II. Artificial intelligence techniques (AI).

I. PID control

PID controllers are used in most automatic process control applications in industry. They can regulate flow, temperature, pressure, level, and many other industrial process variables. Closed loop PID control, often called feedback control, is the control mode most often associated with temperature controllers. In this mode the controller attempts to keep the load at exactly the user enter set point, which can be entered in sensor units or temperature. To do this, it uses feedback from the control sensor to calculate and actively adjust the control (heater) output. The control algorithm used is called PID. From previews example (1) A PID controller has a Set Point (SP) that the operator can set to the desired temperature. The Controller's Output (CO) sets the position of the control valve. And the temperature measurement, called the Process Variable (PV), gives the controller its much-needed feedback. The process variable and controller output are transmitted via current, voltage, or digital signals (Figure 2-2). [9].

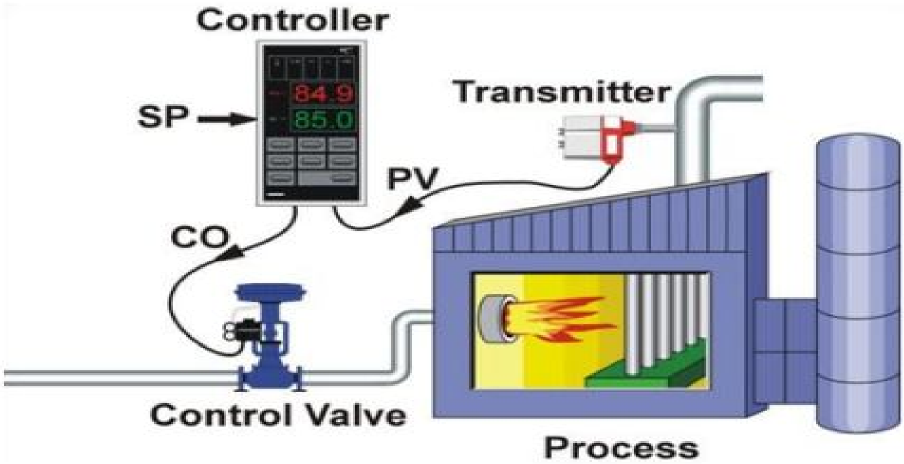

Figure 2-2: A PID Controller Performing Automatic Control

When everything is up and running, the PID controller receives the process variable signal, compares it to the set point, and calculates the difference between the two signals, also called the Error (E). Then, based on the error and the PID controller's tuning constants, the controller calculates an appropriate controller output that sets the control valve to the right position for keeping the temperature at the set point. If the temperature should rise above its set point, the controller will reduce the valve position and vice versa. [9]

PID controllers have three control modes:

I. Proportional Control.
II. Integral Control.
III. Derivative Control.

Each of the three modes reacts differently to the error. The amount of response produced by each control mode is adjustable by changing the controller's tuning settings. [9]

I. Proportional Control Mode

The proportional factor is easiest to understand: The output of the proportional factor is the product of gain and measured error ε. Hence, larger proportional gain or error makes for greater output from the proportional factor. Setting the proportional gain too high causes a controller to repeatedly overshoot the set point, leading to oscillation. (Introduction to PID).[9]

II. Integral Control Mode

The function of the integral control mode is to increment or decrement the controller's output over time to reduce the error. Given enough time, the integral action will drive the controller output until the error is zero. [9] Integral mode sums the error term over time. The integral response will continually increase over time unless the error is zero, so the effect is to drive the Steady-State error to zero.(Steady-State error is the final difference between the process variable and set point). [10].If the error is large, the integral mode will increment/ decrement the controller output at a fast rate; if the error is small, the changes will be slow. For a given error, the speed of the integral action is set by the controller's integral time setting (Ti). A large value of Ti (long integral time) results in a slow integral action, and a small value of Ti (short integral time) results in a fast integral action. If the integral time is set too long, the controller will be sluggish; if it is set too short, the control loop will oscillate and become unstable. [9]

III. Derivative Control Mode

You can think of derivative control as a crude prediction of the error in future. Based on the current slope of the error. How far into the future? That's what the derivative time (Td) is for. Once the derivative mode has predicted the future error, it adds an additional control action equal to Controller Gain * Future Error. For example, if the error changes at a rate of 2% per minute, and the derivative time Td = 3 minutes, the predicted error is 6%. If the Controller Gain, Kc = 0.2, then the derivative control mode will add an additional 0.2 * 6% = 1.2% to the controller output, D mode is used when prediction of the error can improve control or when it necessary to stabilize the system. The ideal version of the PID controller is given by the formula and shown in figure 2-3 :

$$u(t) = Kp\left(e(t) + \frac{1}{Ti}\int_0^t e(t)d\tau + Td\frac{de(t)}{dt}\right) \qquad (3)$$

Where Ti is the integral time constant and Td the derivative time constant. The proportional part acts on the present value of the error, the integral represents an average of past errors and the derivative can be interpreted as a prediction of future errors based on linear extrapolation. [11]

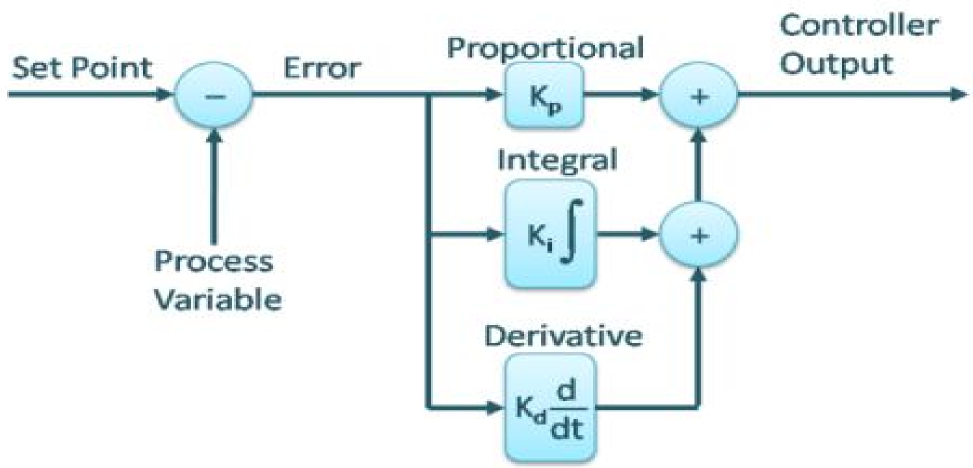

Figure 2-4: The Parallel PID Controller Algorithm

There are three types of PID controller:

- P controller.
- PI controller.
- PD controller.

- **P controller**

PID controller can be configured to produce only a proportional action by turning off the integral and derivative modes Proportional controllers are simple to understand and easy to tune it's the main driving force in a controller. The adjustable setting for proportional control is called the Controller Gain (Kc). A higher controller gain will increase the amount of proportional control action for a given error. If the controller gain is set too high the control loop will begin oscillating and become unstable. If the controller gain is set too low, it will not respond adequately to disturbances or set point changes. [9]

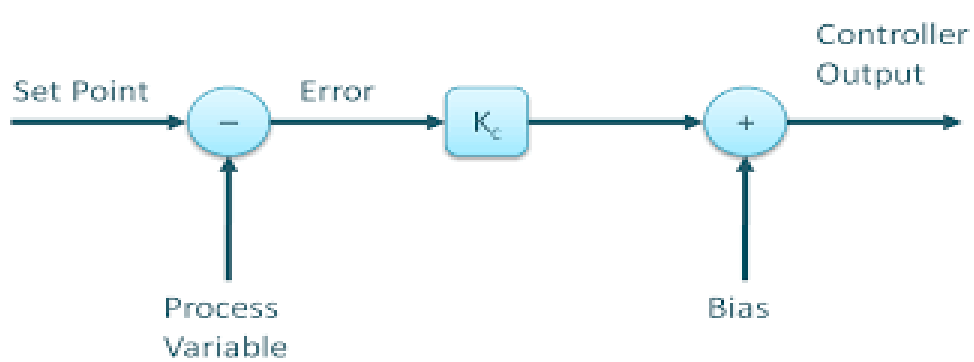

Figure 2-5: A Proportional-Only Controller Algorithm

- **PI controller**

As the name suggests it is a combination of proportional and an integral controller the output (also called the actuating signal) is equal to the summation of proportional and integral of the error signal. Now let us analyze proportional and integral controller mathematically. As we know in a proportional and integral controller output is directly proportional to the summation of proportional of error and integration of the error signal, writing this mathematically we have:

$$A(t) = Ki\int_0^t e(t)\,dt + Kp * e(t) \qquad (4)$$

Where K_i and k_p proportional constant and integral constant respectively.

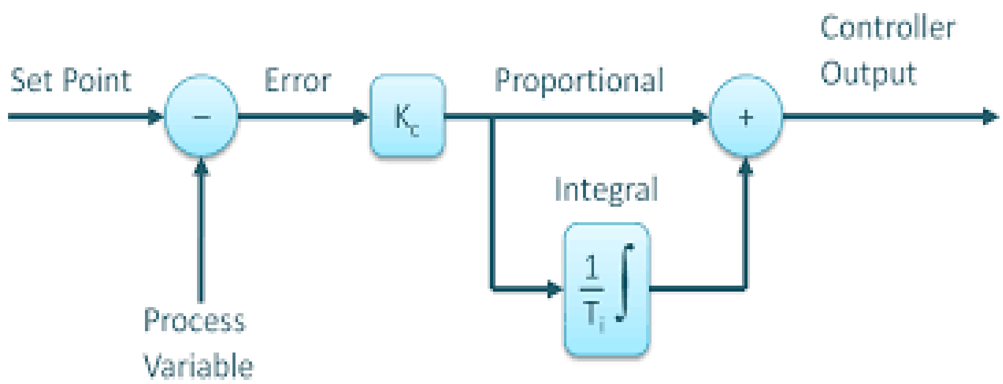

Figure 2-6: The PI Controller Algorithm [9]

- **PD controller**

It is a combination of proportional and a derivative controller the output (also called the actuating signal) is equals to the summation of proportional and derivative of the error signal. Now let us analyze proportional and derivative controller mathematically. As we know in a proportional and derivative controller output is directly proportional to summation of proportional of error and differentiation of the error signal, writing this mathematically we have.

$$A(t) = Kd * \frac{de(t)}{dt} + Kp * e(t) \qquad (5)$$

Where K_d and k_p proportional constant and derivative constant respectively. [9]

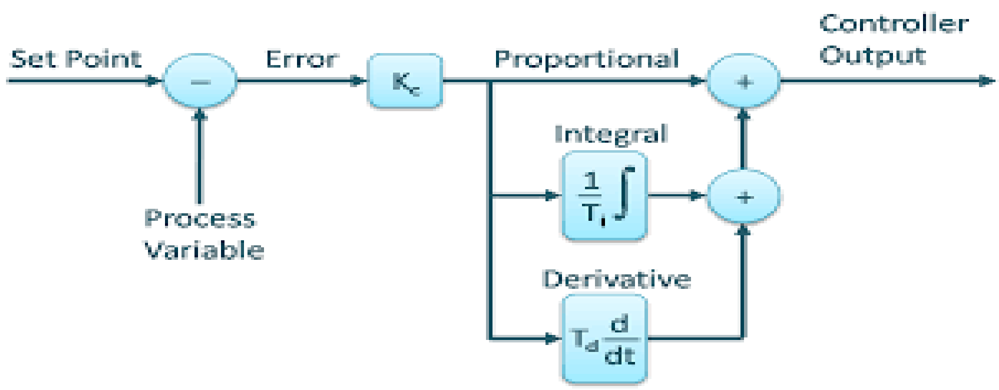

Figure 2-7: The PI Controller Algorithm [9]

II. Artificial intelligence control techniques (AI)

Intelligent control is a class of control techniques that use various artificial intelligence computing approaches like neural network, BAYESIAN probability, fuzzy logic, machine learning, evolutionary computation and algorithms. [6] And we are going to describe fuzzy control only in details since it is used in our study.

- **Fuzzy control**

On late fuzzy logic control (FLC) has become very popular over the conventional control logic (CCL), mainly the process of FLC is simply to put the realization of human control strategy, where CCL heavily relies on the mathematical formulations Fuzzy controllers are very simple conceptually. They consist of an input stage, a processing stage, and an output stage. The input stage maps sensor or other inputs, such as switches, thumbwheels, and so on, to the appropriate membership functions and truth values. The processing stage invokes each appropriate rule and generates a result for each, then combines the results of the rules. Finally value. [9], the output stage converts the combined result back into a specific control output Fuzzy logic controller is made up of four components: rule-base, inference mechanism, fuzzification and defuzzification, whose basic architecture figure is as (Figure 2-7). [12]

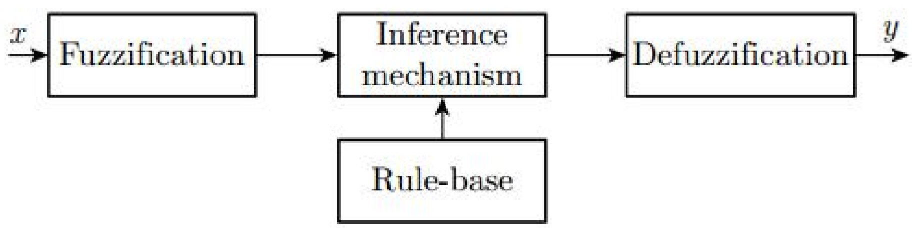

Figure 2-8: Fuzzy controller architecture

Fuzzy rules which makes PID controller reliable for the industrial process having different degrees of non-linearity’s & variation in parameters.

- **Fuzzy PID control**

In the 1990s, scientists and researchers were trying to use intelligent techniques, such as, fuzzy logic, to enhance the capabilities of classical PID controllers and their family Fuzzy PID controller method is better method of controlling to the complex and unclear model systems. Fuzzy rules can be evaluated from the human experience and knowledge about the system which set fuzzy rules that makes PID controller reliable for the industrial process having different degrees of non-linearity's & variation in parameters. [13]

2.3 Comparison between different types of controllers

In general it can be said that P controller cannot stabilize higher order processes. For the 1st order processes, meaning the processes with one energy storage, a large increase in gain can be tolerated. Proportional controller can stabilize only 1st order unstable process. [14] PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. . [14], but PID controllers in the other hand have all the necessary dynamics: fast reaction on change of the controller input (D mode), increase in control signal to lead error towards zero (I mode) and suitable action inside control error area to eliminate oscillations (P mode).

(Farhad Aslam and Gaga deep Kaur 2011) feature In This paper the influence of different controllers like P, PI, PID and Fuzzy logic controller upon the process of Concentration in CSTR [15]and they concluded that, by using P controller there is not much effect to the output response as compared to uncontrolled process.

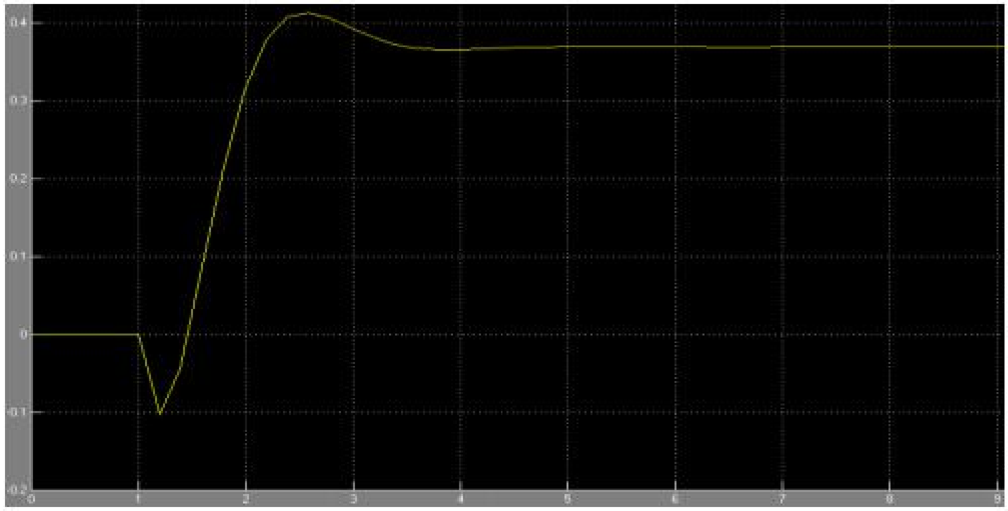

Figure 2-8: Time response of uncontrolled Process

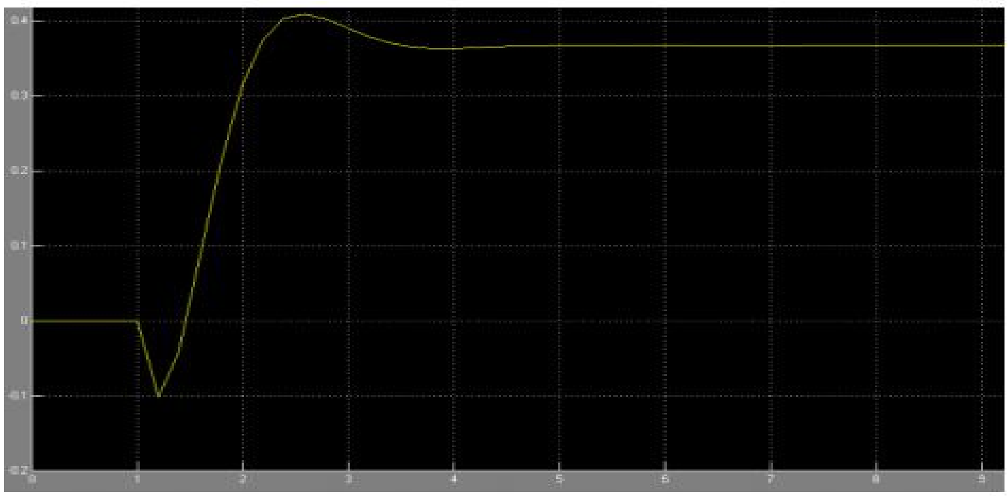

Figure 2-9: Time response with P Controller

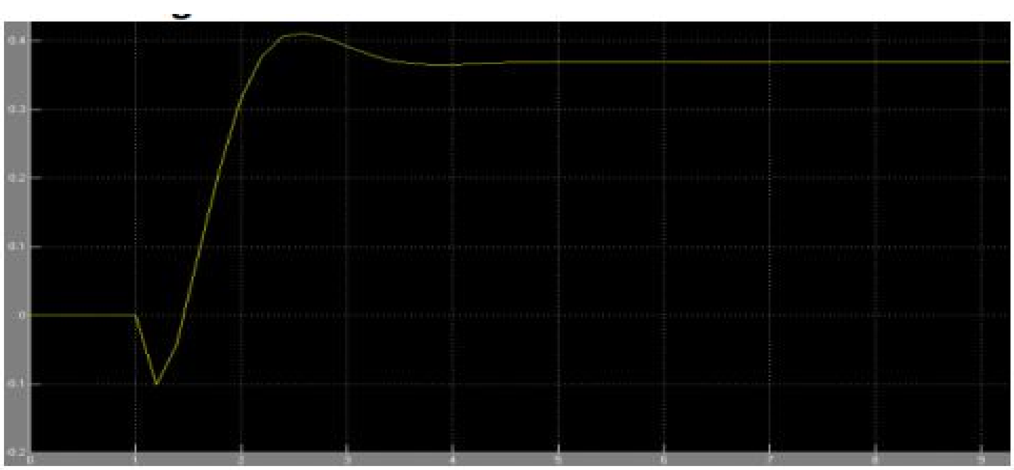

Figure 2-10: Time response with PI Controller

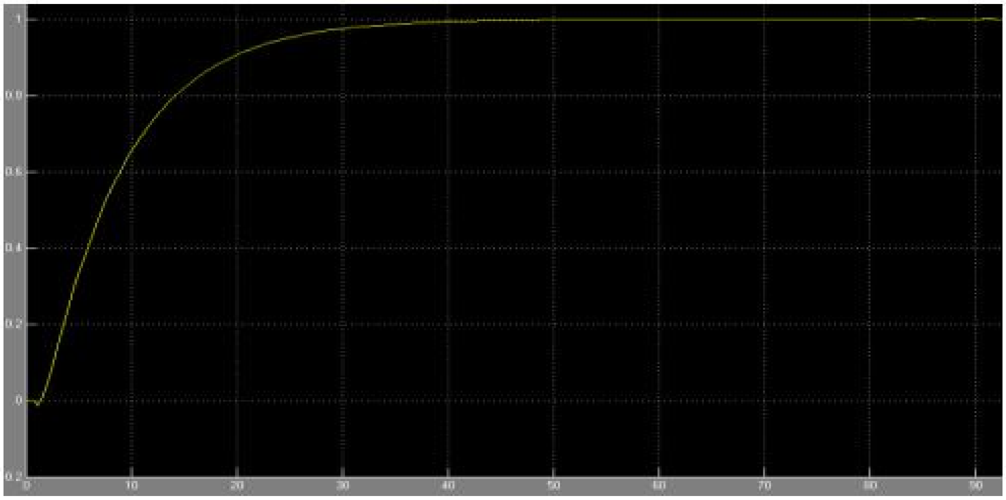

Figure 2-11: Time response with PID Controller

As can be seen from the figure below there is almost negligible time delay and inverted response. When PID controller is used. But when using fuzzy controller there is no any time delay and also no any inverted response. All the limitations are reduced as compared to the PID controller.

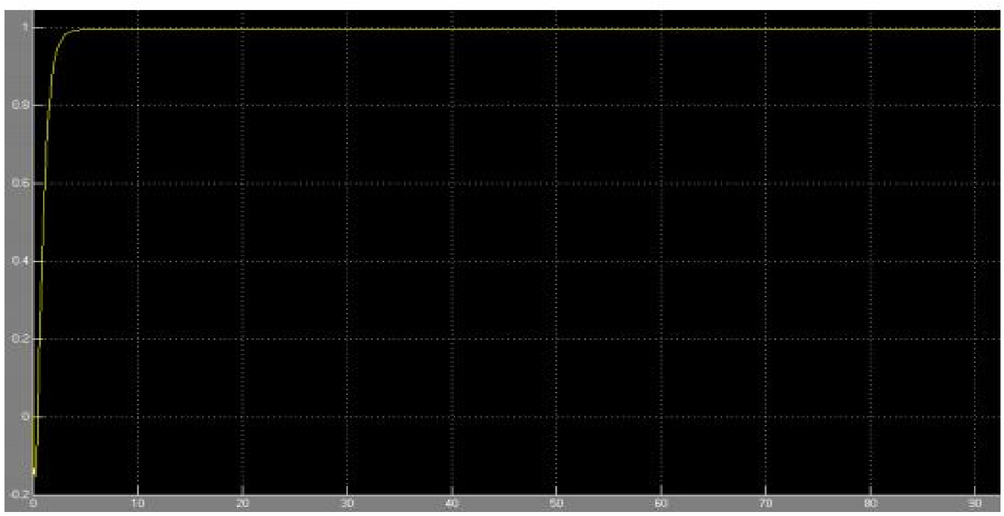

Figure 2-12: Time response with fuzzy controller (Farhad Aslam, Gaga deep Kaur 2011)

When there is no control to the process, it generates an inverse response together with an overshoot and considerable delay time. But when the PID control is implemented to the process, the problems of inverse response, overshoot and delay time are controlled in the ongoing process and are removed considerably but then it was showing instability in terms of rise time and settling time. To overcome this instability in rise time & in settling time a fuzzy logic controller has been used. The fuzzy control scheme helps to remove those delay times and the inverted response shown in graphs. Rise time and settling time are also reduced. [15]

(Zaid Amin Abdul-Jabbar 2011) department of Computer Science College of Education designed a heating and cooling system using fuzzy controller and concluded that ;The fuzzy control system determines a required water ratio precisely to regulate the temperature instead of using trials for adjusting the water ratio when applying conventional control. It is an important factor of the given control system eventually reaches an equilibrium state, after which the temperature barely needs to be adjusted anymore. A conventional control method causes the waste of hot or cold water, which means not optimal utilization of energy. The fuzzy logic control means: accuracy of temperature control and saves energy by rationing the cold or hot water streaming. Thus fuzzy logic is more efficiently used in temperature control system. [16].

(Jelena Godjevac). [17] compared between PID and fuzzy controllers and ended to these conclusions; Fuzzy controllers have the advantage that can deal with nonlinear systems and use the human operator knowledge, fuzzy controller has a lot of parameters when those parameters and rules are well chosen the response of the system has Avery good time domain characteristics, but the computing time compared to the PID controllers is much more. [17]

(Om Prakash Verma, Rajesh Single, Rajesh Kumar 2012) controlled a water bath system using intelligent control Neural Network (NN), Fuzzy Inference System (FIS) and Adaptive Neuron Fuzzy Inference system (ANFIS)) and their Results show that the ANFIS and Fuzzy logic Controller method results in a quicker response with no overshoot than the conventional PID Controller. It also improves the settling time of the process. Moreover, it has strong temperature tracking capability and the absolute error (ASE) performance criteria also shows that ANFIS has better performance, another example of preferring intelligent control over conventional controllers is(Rahul Malhotra1, Rajinder Sodhi 2011) from the Department of Electronics & Communication Engineering they controlled A boiler of a chemical plant by using fuzzy PID logic controller and they noticed that when using PID controller alone gives a very high overshoot and high settling time. So they implemented a fuzzy logic control and then optimized the step response parameter using genetic algorithm. [18], also in this paper (Shoubin Wang 2012) presented a kind of optimal fuzzy PID controller was. It is applied to resistance furnace temperature control system which has large inertia, time-varying and uncertain characteristics. From the results of simulation example, it is concluded that this kind of fuzzy PID controller is very effective. It has better performance than a conventional PID controller. It can be widely used to control different kinds of objects and processes [19]. (SHI Dequan*, GAO Guili, and others 2012) Also used fuzzy PID controller but with the aid of expert system to control heating furnace and they found that this controller has many advantages of high precision of fuzzy control and fast response of expert control. Simulation results show that the expert fuzzy PID controller is superior to conventional PID controller in the overshoot, rise time and response speed. The practical experiments on heating furnace also show that the temperature control effect is better and the temperature can quickly reach stable. [20], (Abdullah I. Al-Odienat, Ayman A. Al-Lawama 2008) compared between fuzzy PID and conventional types and concluded that Fuzzy logic provides a certain level of artificial intelligence to the conventional controllers, leading to the effective fuzzy controllers. Process loops that can benefit from a non-linear control response are excellent candidates for fuzzy control. Since fuzzy logic provides fast response times with virtually no overshoot. Loops with noisy process signals have better stability and tighter control when fuzzy logic control is applied. P Fuzzy controller has smaller sensitivity to the change in the input voltage, however, more sensitivity is observed to load changes. PI-Fuzzy controller has less sensitivity to load changes, where, higher sensitivity to the change of the input voltage is observed. Analysis of transient and static error of regulation has shown advantage of an indistinct PI- controller forth output voltage over the P-type fuzzy controller. P Fuzzy controller has faster transient as compared to PI controller, while, transient for PI Fuzzy controller is almost periodic. [21]