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Intelligent Prevent the Risk of Carcinoma of the Lung Progression

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Abstract

Smog hanging over cities is the most familiar and obvious form of air pollution. The effects of inhaling particulate matter have been studied in humans and animals and include asthma, lung cancer, cardiovascular issues, and premature death. There are, however, some additional products of the combustion process that include nitrogen oxides and sulfur and some un-combusted hydrocarbons, depending on the operating conditions and the fuel-air ratio. Tuning the fuel to air ratio caused to control the lung cancer. Lung cancers are tumors arising from cells lining the airways of the respiratory system. Design of a robust nonlinear controller for automotive engine can be a challenging work. This research paper focuses on the design and analysis of a high performance PID like fuzzy controller for automotive engine, in certain and uncertain condition. The proposed approach effectively combines of design methods from linear Proportional-Integral-Derivative (PID) controller and fuzzy logic theory to improve the performance, stability and robustness of the automotive engine. To solve system's dynamic nonlinearity, the PID fuzzy logic controller is used as a PID like fuzzy logic controller. The PID like fuzzy logic controller is updated based on gain updating factor. In this methodology, fuzzy logic controller is used to estimate the dynamic uncertainties. In this methodology, PID like fuzzy logic controller is evaluated. PID like fuzzy logic controller has three inputs, Proportional (P), Derivative (D), and Integrator (I), if each inputs have N linguistic variables to defined the dynamic behavior, it has $N \times N \times N$ linguistic variables. To solve this challenge, parallel structure of a PD-like fuzzy controller and PI-like fuzzy controller is evaluated. In the next step, the challenge of design PI and PD fuzzy rule tables are supposed to be solved. To solve this challenge PID like fuzzy controller is replaced by PD-like fuzzy controller with the integral term in output. This method is caused to design only PD type rule table for PD like fuzzy controller and PI like fuzzy controller.

Keywords: *smog hanging, air pollution, lung cancer, IC Engine fuzzy logic theory, fuel-air ratio, PID like fuzzy controller.*

1. Introduction and Background

Smog hanging over cities is the most familiar and obvious form of air pollution. But there are different kinds of pollution—some visible, some invisible—that contribute to global warming. Generally any substance that people introduce into the atmosphere that has damaging effects on living things and the environment is considered air pollution. Carbon dioxide, a greenhouse gas, is the main pollutant that is warming Earth. Though living things emit carbon dioxide when they breathe, carbon dioxide is widely considered to be a pollutant when associated with cars, planes, power plants, and other human activities that involve the burning of fossil fuels such as gasoline and natural gas. In the past 150 years, such activities have pumped enough carbon dioxide into the atmosphere to raise its levels higher than they have been for hundreds of thousands of years. Other greenhouse gases include methane—which comes from such sources as swamps and gas

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emitted by livestock—and chlorofluorocarbons (CFCs), which were used in refrigerants and aerosol propellants until they were banned because of their deteriorating effect on Earth's ozone layer. Another pollutant associated with climate change is sulfur dioxide, a component of smog. Sulfur dioxide and closely related chemicals are known primarily as a cause of acid rain. But they also reflect light when released in the atmosphere, which keeps sunlight out and causes Earth to cool [1-3]. Volcanic eruptions can spew massive amounts of sulfur dioxide into the atmosphere, sometimes causing cooling that lasts for years. In fact, volcanoes used to be the main source of atmospheric sulfur dioxide; today people are. Industrialized countries have worked to reduce levels of sulfur dioxide, smog, and smoke in order to improve people's health. But a result, not predicted until recently, is that the lower sulfur dioxide levels may actually make global warming worse. Just as sulfur dioxide from volcanoes can cool the planet by blocking sunlight, cutting the amount of the compound in the atmosphere lets more sunlight through, warming the Earth. This effect is exaggerated when elevated levels of other greenhouse gases in the atmosphere trap the additional heat. Most people agree that to curb global warming, a variety of measures need to be taken. On a personal level, driving and flying less, recycling, and conservation reduces a person’s "carbon footprint"—the amount of carbon dioxide a person is responsible for putting into the atmosphere. On a larger scale, governments are taking measures to limit emissions of carbon dioxide and other greenhouse gases. One way is through the Kyoto Protocol, an agreement between countries that they will cut back on carbon dioxide emissions. Another method is to put taxes on carbon emissions or higher taxes on gasoline, so that people and companies will have greater incentives to conserve energy and pollute less [4-6]. Fumes from car exhaust contain dangerous gases such as carbon monoxide, oxides of nitrogen, hydrocarbons and particulates. On their own, they cause great harm to people who breathe them. Additionally, they react with environmental gases to create further toxic gases. Figure 1 shows the relationship between air-pollution and cars. Internal combustion engines produce air pollution emissions, due to incomplete combustion of carbonaceous fuel. The effects of inhaling particulate matter have been studied in humans and animals and include asthma, lung cancer, cardiovascular issues, and premature death. There are, however, some additional products of the combustion process that include nitrogen oxides and sulfur and some un-combusted hydrocarbons, depending on the operating conditions and the fuel-air ratio [1-10].

Figure 1. Cars and Air-pollution

Lung cancers are tumors arising from cells lining the airways of the respiratory system. Aden carcinoma of the lung is one of the main types of lung cancers. Aden carcinoma of the lung arises from the secretary (glandular) cells located in the epithelium lining the bronchi. Lung cancer is also deadly: it is the commonest cause of cancer death in Australia, accounting for around 23% of male and 15% of female cancer deaths. Lung cancer is more than twice as common in men as in women. Geographically, the tumor is found worldwide, but it is especially common in countries with high air-pollution consumption. Aden carcinoma of the lung is the commonest type of lung cancer, accounting for 32% of all cases of lung cancer. Air-pollution is the main predisposing factor. In recent years, it has been recognized that passive ait-pollution can also put people at risk. Generally, the risk increases with the increase the number of cars as well air-pollution. The link between air-pollution and adenocarcinoma is weaker than the link between air-pollution and other types of lung cancer, but is still the most significant risk factor identified. Exposure to asbestos increases the risk of developing this tumour. The combination of asbestos exposure plus air-pollution is particularly harmful. Other occupational exposures such as exposure to metals including arsenic, chromium and nickel can also increase risk. Some studies have suggested that diet can play a role in lung cancer risk. However, it is not known how it works, diets high in fruits and vegetables seem to decrease risk. Radiation exposure damages the DNA material within the cells and can also cause lung cancer. Radon (a radioactive gas) exposure from our normal surrounding environment, if higher than normal, can predispose to lung cancer. This evidence is mainly based upon population studies which show that people living in areas with a high radon content are prone to increased incidences of a variety of cancers. Aden carcinomas tend to be slow-growing. Spread of the tumor can occur by the lymphatic vessels to lymph nodes located within the lung, mediastinum and thorax. If spread by the blood stream, it can lead to deposits of tumor in the liver, opposite lung, bone and brain [11-15]. Figure 2 shows the right is that of a cancerous lung post mortem, showing local growth of the tumor.

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Figure 2. Cancerous Lung Post Mortem

To tune the fuel ration, modeling of an entire IC engine is a very important and complicated process because engines are nonlinear, multi inputs-multi outputs and time variant [21-23]. One purpose of accurate modeling is to save development costs of real engines and minimizing the risks of damaging an engine when validating controller designs. Nevertheless, developing a small model, for specific controller design purposes, can be done and then validated on a larger, more complicated model [24]. Analytical dynamic nonlinear modeling of internal combustion engine is carried out using elegant Euler-Lagrange method compromising accuracy and complexity. Belong as IC engine is nonlinear system, to adjust the fuel ratio nonlinear control methodology is the best candidate. A controller (control system) is a device which cans sense information from system (e.g., IC engine) to improve the performance of the system using actuation and computation. According to the control theory, systems' controls are divided into two main groups: conventional control theory and soft computing control theory. Conventional control theories are work based on automotive engine's dynamic model. This technique is highly sensitive to the knowledge of all parameters of nonlinear automotive engine's dynamic equation. Conventional control theory is divided into two main groups [16-20]:

- Linear control theory
- Nonlinear control theory.

Soft computing (intelligent) control theory is free of some challenges associated to conventional control theory. This technique is worked based on intelligent control theory. This theory is divided into the following groups [21-27]:

- Fuzzy logic theory,
- Neural network theory,
- Genetic algorithm
- Neuro-fuzzy theory

In this research, linear control theory is added to control the internal combustion engine. To estimate the performance of fuzzy logic theory is introduced. To improve the fuzzy logic controller, PID like fuzzy controller with minimum rule base is introducing. This paper is organized as follows; section 2 introduces and describes the theory regarding to linear controller and intelligent theory. Part 3 introduces the methodology algorithm. Section 4 presents the simulation results and discussion of this algorithm applied to IC engine and the last part is described as conclusion.

2. Theory

Internal Combustion Engine*:* Modeling of an entire internal combustion (IC) engine is a very important and complicated process because internal combustion engines are nonlinear, multi inputs-multi outputs (MIMO) and time variant. There have been several engine controller designs over the previous years in which the main goal is to improve the efficiency and exhaust emissions of the automotive engine [15-18]. Specific applications of air to fuel (A/F) ratio control based on observer measurements in the intake manifold were developed by Benninger in 1991 [19]. Another approach was to base the observer on measurements of exhaust gases measured by the oxygen sensor and on the throttle position, which was researched by Onder. These observer ideas used linear observer theory. Hedrick also used the measurements of the oxygen sensor to develop a nonlinear, sliding mode approach to control the A/F ratio [20]. All of the previous control strategies were applied to engines that used only port fuel injections, where fuel was injected in the intake manifold. Current production A/F ratio controllers use closed loop feedback and feed forward control to achieve the desired stoichio metric mixture. These controllers use measurements from the oxygen sensor to control the desired amount of fuel that should be injected over the next engine cycle and have been able to control the A/F very well. In developing a valid engine model, the concept of the combustion process, abnormal combustion, and cylinder pressure must be understood. The combustion process is relatively simple and it begins with fuel and air being mixed together in the intake manifold and cylinder. This air-fuel mixture is trapped inside cylinder after the intake valve(s) is closed and then gets compressed. When the air-fuel mixture is compressed it causes the pressure and temperature to increase inside the cylinder. Unlike normal combustion, the cylinder pressure and temperature can rise so rapidly that it can spontaneously ignite the air-fuel mixture causing high frequency cylinder pressure oscillations. These oscillations cause the metal cylinders to produce sharp noises called knock, which it caused to abnormal combustion. The pressure in the cylinder is a very important physical parameter that can be analyzed from the combustion process. After the flame is developed, the cylinder pressure steadily rises, reaches a maximum point after TDC, and finally decreases during the expansion stroke when the cylinder volume increases. Since cylinder pressure is very important to the combustion event and the engine cycle in spark ignition engines, the development of a model that produces the cylinder pressure for each crank angle degree is necessary. Regarding to IC engine modeling, it is important to design nonlinear model-reference controller. In developing a valid engine model, the concept of the combustion process, abnormal combustion and cylinder pressure must be understood. The combustion process is relatively simple and it begins with fuel and air being mixed together in the intake manifold and cylinder. This air-fuel mixture is trapped inside cylinder after the intake valve(s) is closed and then gets compressed. When the air-fuel mixture is compressed it causes the pressure and temperature to increase inside the cylinder. In abnormal combustion, the cylinder pressure and temperature can rise so rapidly that it can spontaneously ignite the air-fuel mixture causing high frequency cylinder pressure oscillations. These oscillations cause the metal cylinders to produce sharp noises called knock, which it caused to abnormal combustion. The pressure in the cylinder is a very important physical parameter that can be analyzed from the combustion process. Since cylinder pressure is very important to the combustion event and the engine cycle in spark ignition engines, the development of a model that produces the cylinder pressure for each crank angle degree is necessary. The dynamic equations of IC engine can be written as:

$$\begin{bmatrix} \boldsymbol{PFI} \\ \boldsymbol{DI} \end{bmatrix} = \begin{bmatrix} \dot{\boldsymbol{M}}_{\boldsymbol{air}_{11}} & \dot{\boldsymbol{M}}_{\boldsymbol{air}_{12}} \\ \dot{\boldsymbol{M}}_{\boldsymbol{air}_{21}} & \dot{\boldsymbol{M}}_{\boldsymbol{air}_{22}} \end{bmatrix} \begin{bmatrix} \ddot{\boldsymbol{FR}} \\ \ddot{\boldsymbol{\alpha}}_{\boldsymbol{I}} \end{bmatrix} + \begin{bmatrix} \boldsymbol{P}_{\boldsymbol{motor}_1} \\ \boldsymbol{P}_{\boldsymbol{motor}_2} \end{bmatrix} \begin{bmatrix} \dot{\boldsymbol{FR}} & \dot{\boldsymbol{\alpha}}_{\boldsymbol{I}} \end{bmatrix} + \begin{bmatrix} \boldsymbol{N}_{11} & \boldsymbol{N}_{12} \\ \boldsymbol{N}_{21} & \boldsymbol{N}_{22} \end{bmatrix} \times \begin{bmatrix} \dot{\boldsymbol{FR}} \\ \dot{\boldsymbol{\alpha}}_{\boldsymbol{I}} \end{bmatrix}^2 + \begin{bmatrix} \boldsymbol{M}_{\boldsymbol{a}_1} \\ \boldsymbol{M}_{\boldsymbol{a}_2} \end{bmatrix} \quad \textbf{(1)}$$

There for to calculate the fuel ratio and equivalence ratio we can write:

$$\begin{bmatrix} \ddot{\boldsymbol{FR}}_{\boldsymbol{a}} \\ \ddot{\boldsymbol{\alpha}}_{\boldsymbol{I}_{\boldsymbol{a}}} \end{bmatrix} = \begin{bmatrix} \dot{\boldsymbol{M}}_{\boldsymbol{air}_{11}} & \dot{\boldsymbol{M}}_{\boldsymbol{air}_{12}} \\ \dot{\boldsymbol{M}}_{\boldsymbol{air}_{21}} & \dot{\boldsymbol{M}}_{\boldsymbol{air}_{22}} \end{bmatrix}^{-1} \left\{ \begin{bmatrix} \boldsymbol{PFI} \\ \boldsymbol{DI} \end{bmatrix} - \left\{ \begin{bmatrix} \boldsymbol{P}_{\boldsymbol{motor}_1} \\ \boldsymbol{P}_{\boldsymbol{motor}_2} \end{bmatrix} \begin{bmatrix} \dot{\boldsymbol{FR}} & \dot{\boldsymbol{\alpha}}_{\boldsymbol{I}_{\boldsymbol{a}}} \end{bmatrix} + \begin{bmatrix} \boldsymbol{N}_{11} & \boldsymbol{N}_{12} \\ \boldsymbol{N}_{21} & \boldsymbol{N}_{22} \end{bmatrix} \times \begin{bmatrix} \dot{\boldsymbol{FR}}_{\boldsymbol{a}} \\ \dot{\boldsymbol{\alpha}}_{\boldsymbol{I}_{\boldsymbol{a}}} \end{bmatrix}^2 + \begin{bmatrix} \boldsymbol{M}_{\boldsymbol{a}_1} \\ \boldsymbol{M}_{\boldsymbol{a}_2} \end{bmatrix} \right\} \right\} \quad \textbf{(2)}$$

To solve $\dot{\boldsymbol{M}}_{\boldsymbol{air}}$,

$$\dot{\boldsymbol{M}}_{\boldsymbol{air}} = \begin{bmatrix} \dot{\boldsymbol{M}}_{\boldsymbol{air}_{11}} & \dot{\boldsymbol{M}}_{\boldsymbol{air}_{12}} \\ \dot{\boldsymbol{M}}_{\boldsymbol{air}_{21}} & \dot{\boldsymbol{M}}_{\boldsymbol{air}_{22}} \end{bmatrix} \qquad \text{Where } \dot{\boldsymbol{M}}_{\boldsymbol{air}_{12}} = \dot{\boldsymbol{M}}_{\boldsymbol{air}_{21}} \quad \textbf{(3)}$$

Where $\dot{\boldsymbol{M}}_{\boldsymbol{air}}$ is the ratio of the mass of air.
Matrix P_{motor} is a 1×2 matrix:

$$P_{motor} = \begin{bmatrix} \boldsymbol{P}_1 \\ \boldsymbol{P}_2 \end{bmatrix} \quad \textbf{(4)}$$

Matrix engine angular speed matrix(N) is a 2×2 matrix

$$N = \begin{bmatrix} \boldsymbol{N}_{11} & \boldsymbol{N}_{12} \\ \boldsymbol{N}_{21} & \boldsymbol{N}_{22} \end{bmatrix} \quad \textbf{(5)}$$

Where,
Matrix mass of air in cylinder for combustion matrix (M_a) is a 1×2 matrix.

$$M_a = \begin{bmatrix} \boldsymbol{M_{a_1}} \\ \boldsymbol{M_{a_2}} \end{bmatrix} \quad \textbf{(6)}$$

The above target equivalence ratio calculation will be combined with fuel ratio calculation that will be used for controller design purpose. Figure 3 shows the IC engine.

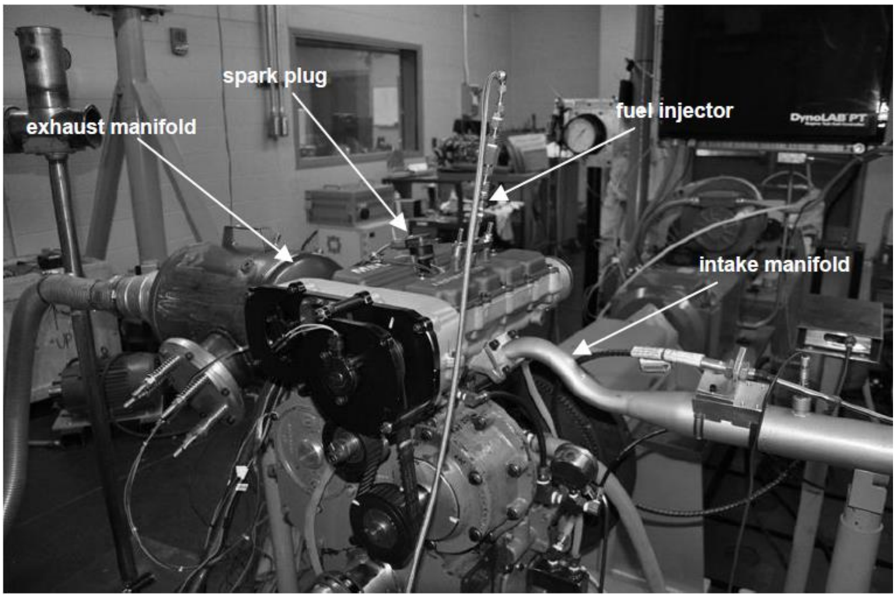

Figure 3. Test Engine

Linear Control Technique (LCT): Linear control theory is used in linear and nonlinear systems. This type of theory is used in industries, because design of this type of controller is simple than nonlinear controller. However this type of controller used in many applications but it cannot guarantee performance in complex systems. Proportional (P) control is used to responds immediately to difference of control input variables by immediately changing its influences variables, but this type of control is unable to eliminate the control input difference. Figure 4 shows the block diagram of proportional controller with application to IC engine.

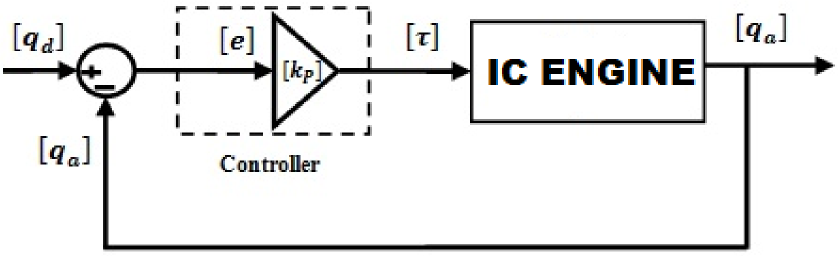

Figure 4. Block Diagram of Proportional Controller

Proportional plus Derivative (PD) controller is widely used in control process where the results are sensitive to exceeded of set point. This controller, like Proportional controller, has permanent variation in presence of self-limitation control. In mathematically, the formulation of Proportional-Derivative part calculated as follows;

$$\boldsymbol{U_{PD} = K_p \times e + K_v(\frac{de}{dt}) = K_p \times e + K_v\dot{e}} \quad \textbf{(7)}$$

The Derivative component in this type of methodology is used to cancel outs the change process variables change in presence of quick change in controllers input. Figure 5 shows the block diagram of Proportional-Derivative (PD) control of IC engine. Figure 6 shows the ramp response of PD controller.

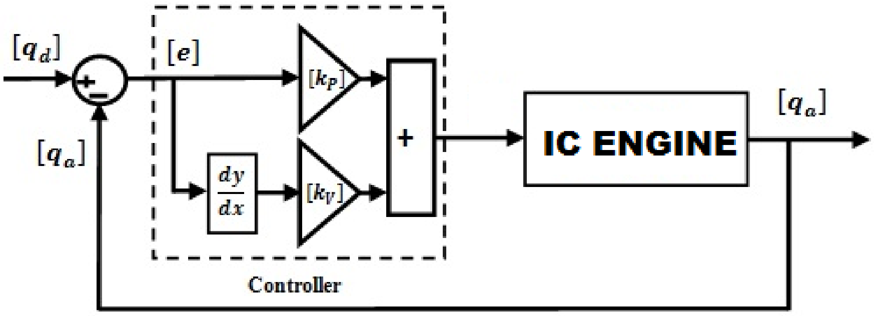

Figure 5. Block Diagram of PD Control of IC Engine

Integral (I) control, integrate the input signal deviation over a period of time. This part of controller is used to system stability after a long period of time. Figure 7 shows the block diagram of Integral (I) controller with application to IC engine. In contrast of Proportional type of controller, this type of controller used to eliminate the deviation [6-7].

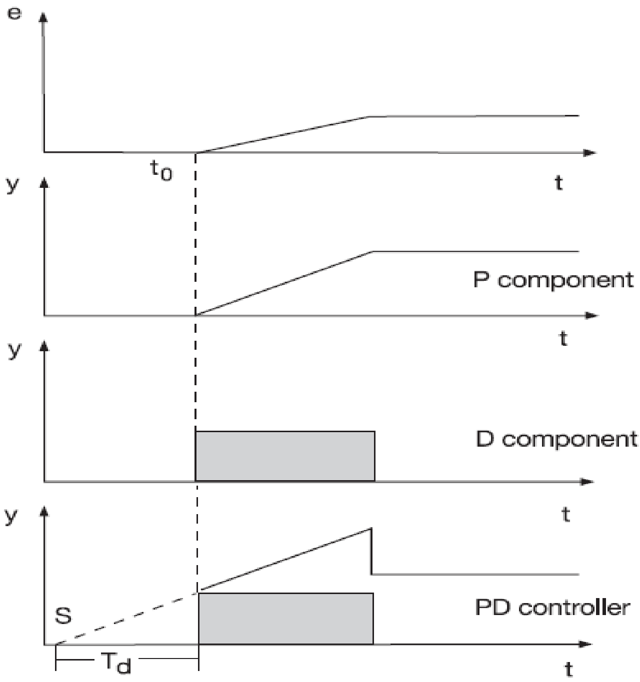

Figure 6. Ramp Response of a PD Controller

In mathematically, the formulation of integral part calculated as follows;

$$I = \frac{1}{T}\int e.dt = \sum e \tag{8}$$

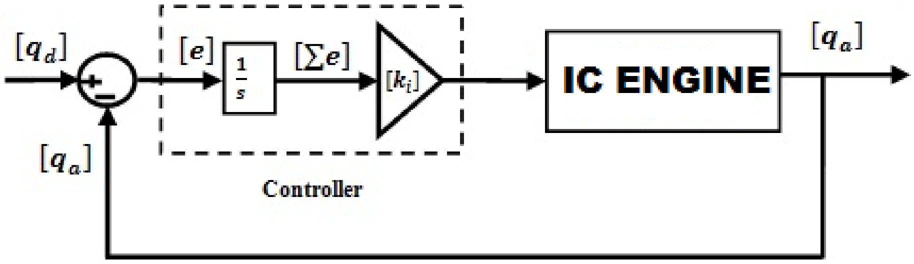

Figure 7. Block Diagram of Integral Control of IC Engine

Figure 8 shows the step response of integral controller.

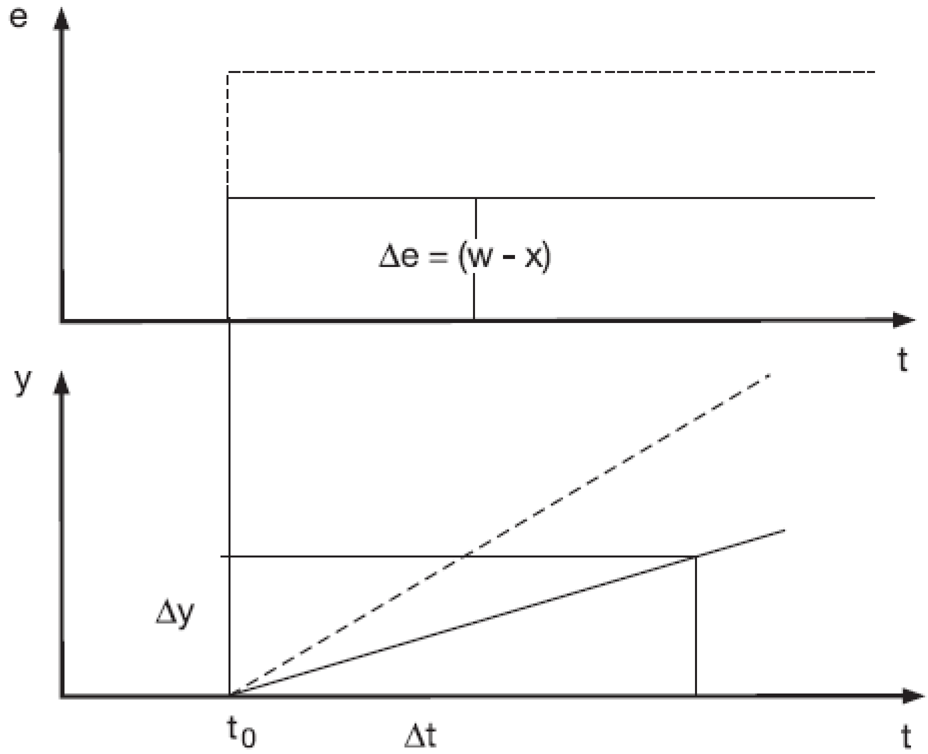

Figure 8. Step Response of an Integral (I) Controller

According to integral type of controller, it takes relatively long time. The proportional type controller used to immediately response to the input variations [8]. The proportional-integral (PI) controller has the advantages of both proportional and integral controller; it is rapid response to the input deviation as well as the exact control at the desired input. Figure 9 shows the block diagram of PI control of IC engine.

$$U_{PI} = K_p \times e + K_i(\frac{1}{T}\int e.dt) = K_p \times e + K_i \sum e \quad \textbf{(9)}$$

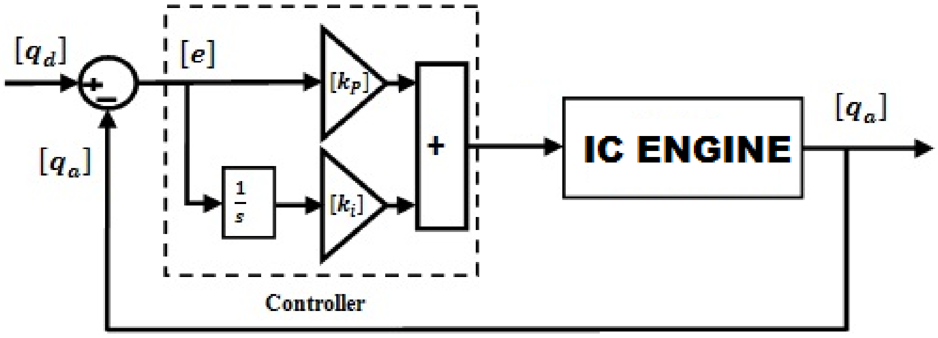

Figure 9. Block Diagram of PI Control of IC Engine

Figure 10 shows the step response of PI controller.

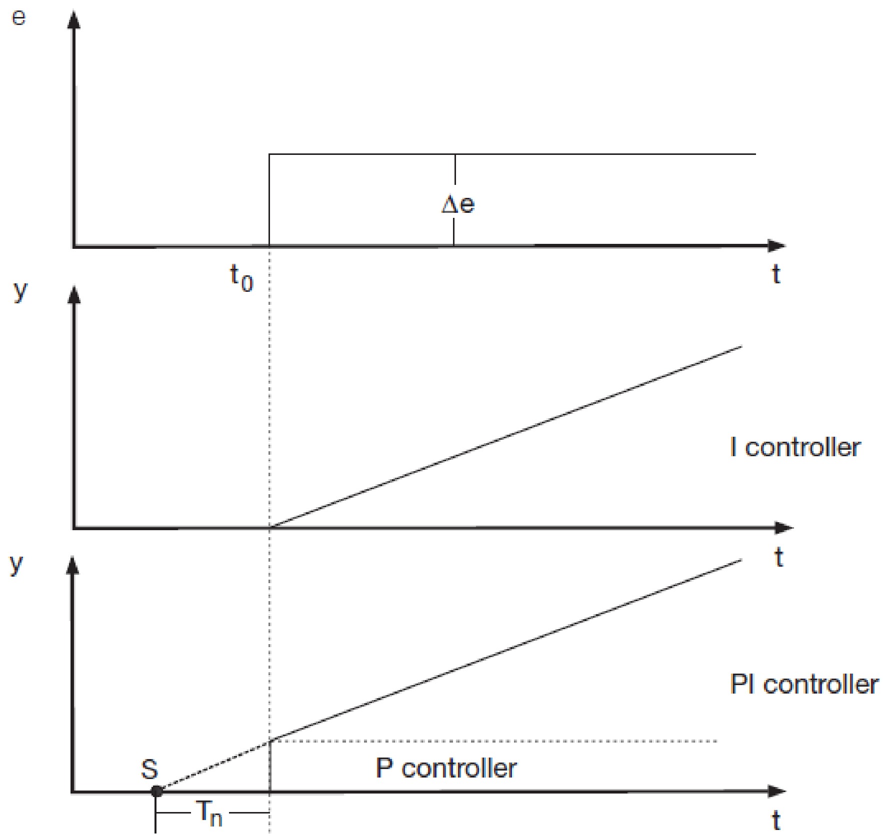

Figure 10. Step Response of a Proportional-Integral (PI) Controller

The combination of proportional (P) component, integral (I) component with a derivative (D) controller offered advantages in each case. Proportional-Integral-Derivative (PID) controller has rapid response to the input deviation, the exact control at the desired input as well as fast response to the disturbances. The PID controller takes the error between the desired joint variables and the actual joint variables to control the IC engine. A proportional-derivative integral control system can easily be implemented. This method does not provide sufficient control for systems with time-varying parameters or highly nonlinear systems. Figure 9 shows the block diagram of PID control of IC engine. The formulation of PID controller calculated as follows;

$$\boldsymbol{U_{PID} = K_p \times e + K_i(\frac{1}{T}\int e.dt) + K_v(\frac{de}{dt}) = K_p \times e + K_i \sum e + K_v \dot{e}} \quad \textbf{(10)}$$

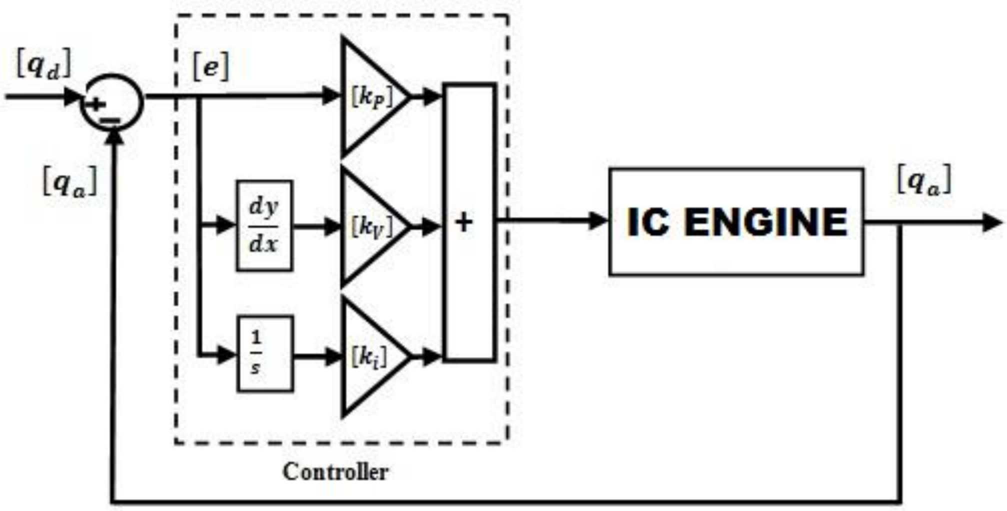

Figure 11. Block Diagram of PID Control of IC Engine

Figure 12 shows the step response of PID controller.

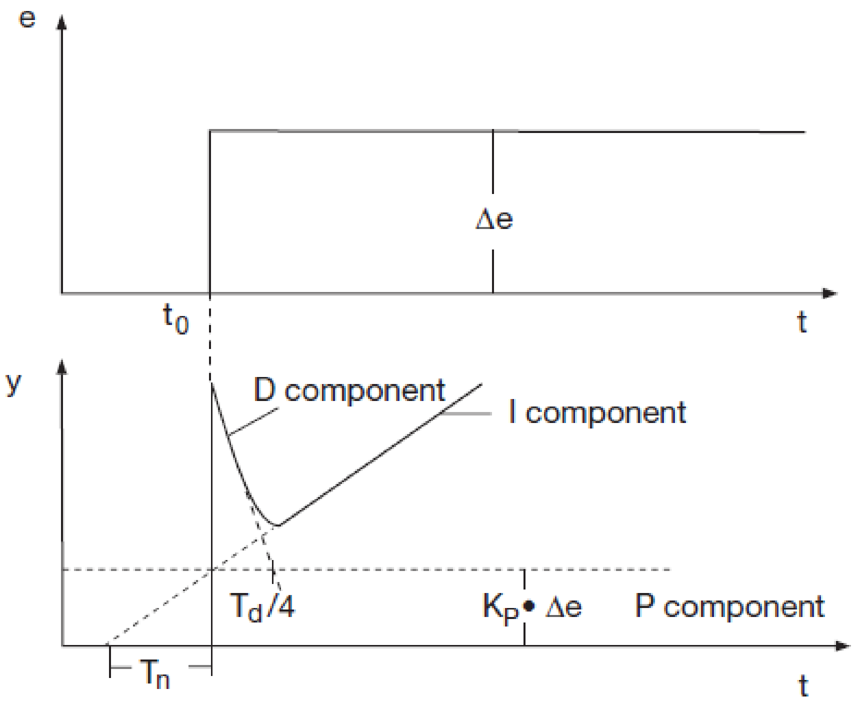

Figure 12. Step Response of a Proportional-Integral-Derivative (PID) Controller

Fuzzy Logic Theory (FLT): Zadeh [7-11] introduced fuzzy sets in 1965. After 40 years, fuzzy systems have been widely used in different fields, especially on control problems. Fuzzy systems transfer expert knowledge to mathematical models. Fuzzy systems used fuzzy logic to estimate the dynamics of proposed systems. Fuzzy controllers, including fuzzy if-then rules are used to control proposed systems. Conventional control methods use mathematical models to control systems. Fuzzy control methods replace the mathematical models with fuzzy if then-rules and fuzzy membership function to control systems. Both fuzzy and conventional control methods are designed to meet system requirements of stability and convergence. When mathematical models are unknown or partially unknown, fuzzy control models can use fuzzy systems to estimate the unknown models. This is called the model-free approach. Conventional control models can use adaptive control methods to achieve the model-free approach. When system dynamics become more complex, nonlinear systems are difficult to handle by conventional control methods. From the universal approximation theorem, fuzzy systems can approximate arbitrary nonlinear systems. In practical problems, systems can be controlled perfectly by experts. Experts provide linguistic description about systems. Conventional control methods cannot design controllers combined with linguistic information. When linguistic information is important for designing controllers, we need to design fuzzy controllers for our systems. Fuzzy control methods are easy to understand for designers. The design process of fuzzy controllers can be simplified with simple mathematical models. Research on applied fuzzy logic methodology in inverse dynamic controller (FIDLC) to compensate the unknown system dynamics considerably improves the IC engine control process. The foundation and introduction of fuzzy logic theory is discussed in this section [10-11]. Supposed that U is the universe of discourse for example in this research error, change of error and torque are the sample of universe of discourse and x is the element of U it means that if error is positive and small or if change of error to be defined as positive and small, all these part of the elements of error and change of error. A crisp set to be defined as a set such as error or change of error which consists of different elements (x) such as negative and small in error will all or no membership in a defined set. In crisp set the membership degree is zero or one such as logical systems. A crisp set (C) in a universe of discourse U is defined by a following membership function $(\boldsymbol{\mu_C})$;

$$\boldsymbol{\mu_C}: \boldsymbol{U} \rightarrow \{\mathbf{0}, \mathbf{1}\} \tag{11}$$

A fuzzy set is a set such as error or change of error that different element has different membership grade between zero to one. A fuzzy set (F) in a universe of discourse U is defined by a following membership function $(\boldsymbol{\mu_F})$;

$$\boldsymbol{\mu_F}: \boldsymbol{U} \rightarrow [\mathbf{0}, \mathbf{1}] \tag{12}$$

The membership function $(\mu_F(x))$ of fuzzy set F has value between zero to one which each element of universe of discourse$\boldsymbol{U}$ mapped a values between zero to one and this value is called membership degree**.** Figure 13 shows the fuzzy membership function.

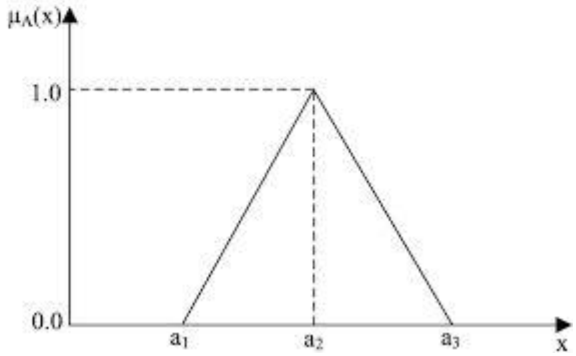

Figure 13. Fuzzy Membership Functions

If the membership functions value $\mu_C(x)$ equal to zero or one it is a crisp set. Based on literature numerical membership function and functional membership function are two important technique to define fuzzy membership function. In numerical membership function the numerator of fraction shows the degrees of membership function and the denominator of fraction shows the universe of discourses point. In functional membership function standard functions in fuzzy sets is used to define membership function and membership degrees. According to the literature the famous functional membership function in practical applications are:

- triangular function

t
- rapezoidal form

G
- aussian form

According to the literature the formulation of Trapezoidal membership function is;

$$\boldsymbol{\mu_{F(x)}} = \begin{cases} \mathbf{0} \quad , & (x < a) or\ (x > d) \\ \dfrac{\boldsymbol{x-a}}{\boldsymbol{b-a}}, & a \leq x < b \\ \dfrac{\boldsymbol{d-x}}{\boldsymbol{d-c}}, & c \leq x < d \\ \mathbf{1} \quad , & b \leq x \leq c \end{cases} \tag{13}$$

Figure 14shows the Trapezoidal membership function.

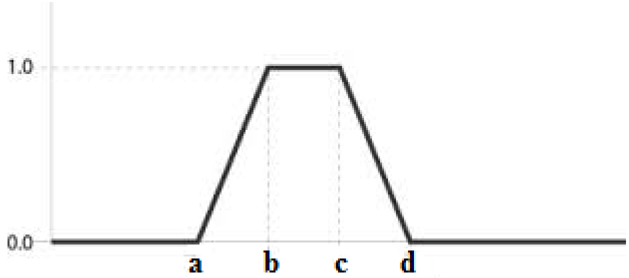

Figure 14. Trapezoidal Membership Functions

The formulation of Triangular membership function is;

$$\boldsymbol{\mu_{F(x)}} = \begin{cases} \mathbf{0} \quad , & x < a \\ \dfrac{\boldsymbol{x-a}}{\boldsymbol{m-a}}, & a \leq x < m \\ \dfrac{\boldsymbol{b-x}}{\boldsymbol{b-m}}, & m \leq x \leq b \\ \mathbf{0} \quad , & x > c \end{cases} \tag{14}$$

Figure 15 shows the Triangular membership function.

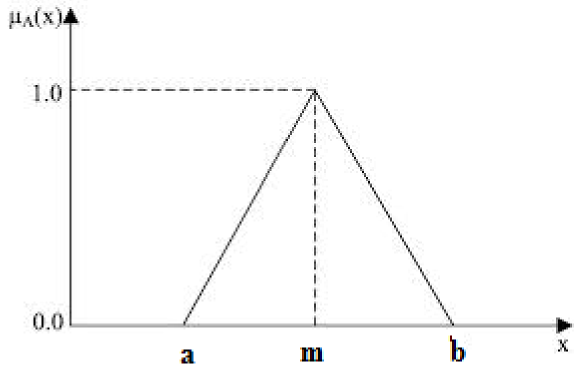

Figure 15. Triangular Membership Functions

Based on literature the Gaussian membership function is formulated by:

$$\boldsymbol{\mu_{F(x)}} = \boldsymbol{e}^{\frac{\boldsymbol{-(x-m)^2}}{\boldsymbol{2K^2}}} \tag{15}$$

Figure 16 shows the Gaussian membership function.

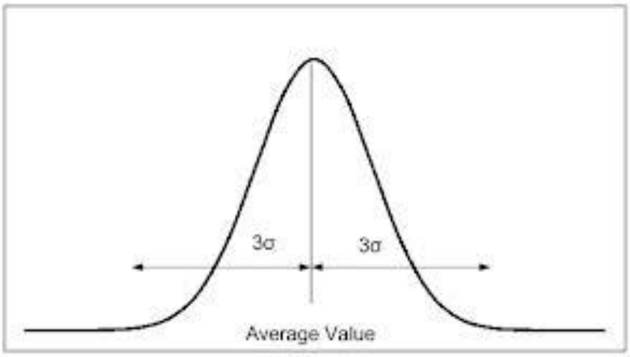

Figure 16. Gaussian Membership Functions

The variable in crisp set is numerical variable but in fuzzy logic theory the variables are linguistic variable. This item is used to describe the values of universe of discourse such as error by any words and sentences. Linguistic variable opens a window to application of fuzzy logic theory in many applications. In a fuzzy logic theory all numerical variables are replaced by words or sentences. For example various words of linguistic variables for any inputs or outputs are: Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (ZE), Positive Small (PS), Positive Medium (PM), Positive Big (PB). Figure 17 shows the membership function and linguistic variables in this graph the universe of discourse is error, the membership function is triangular and the linguistic variables are Negative Big (NB), Negative Small (NS), Zero (ZE), Positive Small (PS), Positive Big (PB).

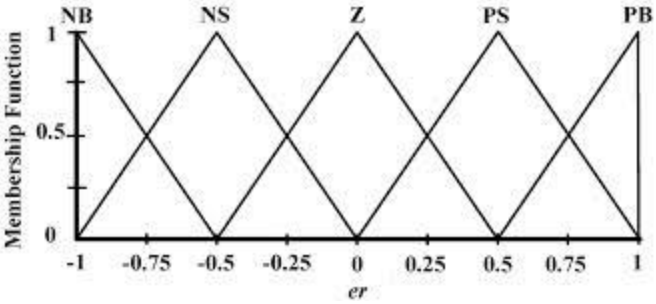

Figure 17. Membership Function and Linguistic Variables

According above discussion, fuzzy set used a membership function to support the membership value of its elements. Universe of discourse is defined by several linguistic variable and different membership functions. To define the behaviour of fuzzy logic set rule base is played important role. If-then rule is the main part to design rule base and rule table. If-then rule statements are used to formulate the condition statements in fuzzy logic theory. A fuzzy if-then rule is divided into two main groups:

- single fuzzy if-then rule
- Multiple fuzzy if-then rule

According to the literature if-then rule has two main parts:

- Antecedent part
- Consequent part

In single fuzzy if-then rule the antecedent part has one variable and it has only one part, following rule shows the single fuzzy if-then rule:

$$\boldsymbol{FR}: \boldsymbol{If\ e\ is\ NB\ Then\ U\ is\ PB} \tag{16}$$

In (2.89) e is input variable which in design controllers defined by fuzzy logic input, U is output variable, NB and PB are the Linguistic variables that can be defined by fuzzy set, the part of "$e\ is\ NB$" is called the antecedent part and the part of "$U\ is\ PB$" is called the Consequent or Conclusion part. In most of fuzzy controllers antecedent part has multiple parts; the following rule shows the multiple antecedent parts:

$$\boldsymbol{FR}: \boldsymbol{If\ e\ is\ NB\ and\ \dot{e}\ is\ ML\ then\ T\ is\ PB} \tag{17}$$

In (2.90) $e\ and\ \dot{e}$ are inputs, T is output, Negative Big (NB), Medium Left (ML) and Positive Big (PB) are the linguistic variables, the part of "$\boldsymbol{If\ e\ is\ NB\ and\ \dot{e}\ is\ ML}$" is antecedent part and it multiple, in this state the fuzzy operations (AND/OR) is used and the part of "$\boldsymbol{then\ T\ is\ PB}$" is the consequent part. In most of fuzzy logic controllers, fuzzy controller inputs are used in antecedent part and the output of controller defined by consequent part.

3. Methodology

The nonlinear dynamic formulation problem in highly nonlinear system can be solved by fuzzy logic theorem. Fuzzy logic theory is used to estimate the system dynamics. This type of controller is free of mathematical dynamic parameters of plant. To solve the challenge of system's dynamic especially in uncertain system, fuzzy controller is recommended.

$$\boldsymbol{\tau_{fuzzy}} = \boldsymbol{U_{PID-fuzzy}} \tag{18}$$

PID like fuzzy logic controller has three inputs, Proportional (P), Derivative (D), and Integrator (I), if each input defined by N linguistic variables to estimate the dynamic behavior, it has $N \times N \times N$ linguistic variables. Design fuzzy controller based on N^3 rule base for each input caused to creation lots of challenges in real timing application. To reduce the number of rule base in PID like fuzzy logic controller, parallel PD and PI strategy is recommended. According to this algorithm to design the same PID controller the number of rule base for each input is $2N^2$. According to this technique, the number of rule base is reduced with respect to have PID like fuzzy logic controller. After solve the first challenge about the number of rule base in PID like fuzzy logic controller, the second challenge is appears. To design parallel PD and PI like fuzzy controller, two types fuzzy rule table should be design. Design two types rule tables are very difficult and need to have much experience. Therefore in this research PI-like fuzzy controller is replaced by PD-like fuzzy controller with the integral term in the output. Due to this method, researcher can design PID like fuzzy logic controller based on PD rule table and $2N^2$ rule base.

According to fuzzy logic methodology definition;

$$\boldsymbol{U_{fuzzy}} = \left(\sum_{l=1}^{M} \boldsymbol{\theta^T}\, \boldsymbol{\zeta(x)}\right)_{e,\sum e,\dot{e}} \tag{19}$$

where $\boldsymbol{\theta^T}$ is gain updating factor and $\boldsymbol{\zeta(x)}$ is defined by;

$$\boldsymbol{\zeta(x)} = \frac{\sum_i \boldsymbol{\mu(x_i)x_i}}{\sum_i \boldsymbol{\mu(x_i)}} \tag{20}$$

and the $\boldsymbol{\mu(x_i)}$ parameter is membership function.

Fuzzy logic controller (FLC) is one of the most important applications of fuzzy logic theory. This controller can be used to control of nonlinear, uncertain, and noisy systems. However the application of fuzzy logic controller is really wide, all types of fuzzy logic controllers consists of the following parts;

- Choosing inputs
- Scaling inputs
- Input fuzzification (binary-to-fuzzy[B/F] conversion)
- Fuzzy rule base (knowledge base)
- Inference engine
- Output defuzzification (fuzzy-to-binary[F/B] conversion)
- Scaling output

Define the Inputs and Control Variables: In most of industrial controllers error and the functional of error are used as inputs to design controller. According to design the PD-like fuzzy controller, error and change of error are used to define as controllers' inputs. Therefore the antecedent part of rule base is comprised of two parts. In this part fuzzy controller's inputs are error (e) and change of error $(\dot{e})$ and the fuzzy controller output is PD fuzzy output $\left(U_{PD-fuzzy}\right)$

Scaling Inputs/Outputs: in fuzzy logic controller to define membership function, scaling the universe of discourse for all parts of rule base (consequent and antecedent part) is very important. The role of a right choice of scaling factors is obviously shown by the fact that if your choice is bad, the actual operating area of the inputs/outputs will be transformed into a saturation or narrow situation. Input scaling factors have played important role to basic sensitivity of the controller with respect to the optimal choice of the operating areas of the input signals moreover when the scale output is scaled, the gain updating factor of the controller is scaled which it is caused to modify the stability and oscillation tendency. Because of its strong impact on stability and reduce the oscillation, this factor is important factor to design fuzzy controller. In this research the scaling factor for error is $[-0.1\ to\ 0.1]$ and divided into eleven levels as follows:

$e = \{-0.1, -0.08, -0.06, -0.04, -0.02, 0, 0.02, 0.04, 0.06, 0.08, 0.1\}$ and the scaling factor of change of error is $[-1\ to\ 1]$ and divided into eleven levels as follows:

$\dot{e} = \{-1, -0.8, -0.6, -0.4, -0.2, 0, 0.2, 0.4, 0.6, 0.8, 1\}$ and at last the scaling factor of PD fuzzy output are between $[-1.5\ to\ 1.5]$.

Input Fuzzification (binary-to-fuzzy [B/F] conversion):

This part is divided into three main parts;

- Linguistic variables
- Scaling factor (normalization factor)
- Inputs membership function

In this research a linguistic variable is defined by;

- Symbolic name of inputs/outputs variables: $error, change\ of\ error$ and $PD\ fuzzy\ output$.
- Set of linguistic values that for error can take on: Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), Positive Big (PB). The linguistic values for change of error are: Negative (N), Zero (Z) and Positive (P) and the linguistic variables for PD fuzzy output are: Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), Positive Big (PB).
- Scaling factor as actual physical domain over which the meaning of the linguistic value, based on experience knowledge this range for error is $[-0.1\ to\ 0.1]$, for change of error is $[-1\ to\ 1]$ and finally for PD fuzzy output is $-1.5\ to\ 1.5]$.

According to experience knowledge in this research, triangular membership function is selected for inputs and output. This controller has two inputs (error and change of error) and one output (PD fuzzy output), the first input (error) is described with seven linguistic values; Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), Positive Big (PB) and it is quantized into eleven levels as follows: $e = \{-0.1, -0.08, -0.06, -0.04, -0.02, 0, 0.02, 0.04, 0.06, 0.08, 0.1\}$, the second input (change of error) is described with three linguistic values; Negative (N), Zero (Z) and Positive (P) and it is quantized into eleven levels as: $\dot{e} = \{-1, -0.8, -0.6, -0.4, -0.2, 0, 0.2, 0.4, 0.6, 0.8, 1\}$ and the output (PD fuzzy output) is described with seven linguistic values; Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), Positive Big (PB) and triangular membership functions are used for inputs and output.

Fuzzy Rule Base: the role of the rules in fuzzy logic controller is extremely significant and the main approaches and source of fuzzy logic controller rules are;

- Expert experience and knowledge base
- Learning based on operators' control action
- Identification of fuzzy model system under control action
- The application of learning technique

According to above, the main approach comes from an expert knowledge of system because any fuzzy controller is expert system to solve the control problem. According to fuzzification the error has seven linguistic variables, the change of error has three linguistic variables and the PD fuzzy output has seven linguistic variables. Therefore PD like fuzzy controller has 21 rule-bases in five parts as follows:

Part 1:

$$FR^1: IF\ e\ is\ PS\ and\ \dot{e}\ is\ Z\ then\ U_{PD}\ is\ NS$$
$$FR^2: IF\ e\ is\ Z\ and\ \dot{e}\ is\ Z\ then\ U_{PD}\ is\ Z$$
$$FR^3: IF\ e\ is\ NS\ and\ \dot{e}\ is\ Z\ then\ U_{PD}\ is\ PS$$

According to first three rule-base error is positive or negative small or zero and change of error is zero. In this case the system's output (U_{PD}) has close deviation around the desired level. Therefore these three rules are related to steady state system's output behavior. In this case if error is positive small to estimate it, the controllers output needs to change the direction with the same power.

Part 2:

$$FR^4: IF\ e\ is\ PB\ and\ \dot{e}\ is\ N\ then\ U_{PD}\ is\ Z$$
$$FR^5: IF\ e\ is\ PM\ and\ \dot{e}\ is\ N\ then\ U_{PD}\ is\ PS$$

In this part the error is Positive Big or medium, therefore based on error formulation $(e = q_d - q_a)$ the desired input is considerably above the actual input. In this time the rate of error is negative, it means that actual input is moving towards to the desired input and caused to reduce the error towards to zero. The control action should to tune the rate of reduce the error. For example when error is Positive Big and change of error is Negative, no control action is recommended because the actual input will be estimate by the speed of change of error due to the desired input.

Part 3:

$$FR^6: IF\ e\ is\ PS\ and\ \dot{e}\ is\ N\ then\ U_{PD}\ is\ PM$$
$$FR^7: IF\ e\ is\ Z\ and\ \dot{e}\ is\ N\ then\ U_{PD}\ is\ PB$$
$$FR^8: IF\ e\ is\ NS\ and\ \dot{e}\ is\ N\ then\ U_{PD}\ is\ PB$$
$$FR^9: IF\ e\ is\ NM\ and\ \dot{e}\ is\ N\ then\ U_{PD}\ is\ PB$$
$$FR^{10}: IF\ e\ is\ NB\ and\ \dot{e}\ is\ N\ then\ U_{PD}\ is\ PB$$

In this part the actual input is near the desired input (e(t) is Positive Small, Zero or Negative Small) or the actual input is drastically above it (e(t) is Negative Medium or Negative Big) and at this time the rate of error is negative, it means the rate of actual input is greater than desired input and caused to actual input moving away from desired input. In this time, the role of controller is to reverse this trend and caused actual input start to moving toward to the desired input. According to part 3 rule bases the trend of error will be reduces.

Part 4:

$$FR^{11}: IF\ e\ is\ NM\ and\ \dot{e}\ is\ P\ then\ U_{PD}\ is\ NS$$
$$FR^{12}: IF\ e\ is\ NB\ and\ \dot{e}\ is\ P\ then\ U_{PD}\ is\ Z$$
$$FR^{13}: IF\ e\ is\ NM\ and\ \dot{e}\ is\ Z\ then\ U_{PD}\ is\ PM$$
$$FR^{14}: IF\ e\ is\ NB\ and\ \dot{e}\ is\ Z\ then\ U_{PD}\ is\ PB$$

For this group the actual input is drastically below the desired input (e(t) is Negative Medium or Negative Big) and at this time the rate of error is Positive or Zero, it means the rate of actual input is lower than desired input and caused to actual input moving toward to desired input. In this time, the role of controller is to speed control to reduce the error.

Part 5:

FR^{15}: $IF\ e\ is\ NS\ and\ \dot{e}\ is\ P\ then\ U_{PD}\ is\ NM$
FR^{16}: $IF\ e\ is\ Z\ and\ \dot{e}\ is\ P\ then\ U_{PD}\ is\ NB$
FR^{17}: $IF\ e\ is\ PS\ and\ \dot{e}\ is\ P\ then\ U_{PD}\ is\ NB$
FR^{18}: $IF\ e\ is\ PM\ and\ \dot{e}\ is\ P\ then\ U_{PD}\ is\ NB$
FR^{19}: $IF\ e\ is\ PB\ and\ \dot{e}\ is\ P\ then\ U_{PD}\ is\ NB$
FR^{20}: $IF\ e\ is\ PM\ and\ \dot{e}\ is\ Z\ then\ U_{PD}\ is\ NM$
FR^{21}: $IF\ e\ is\ PB\ and\ \dot{e}\ is\ Z\ then\ U_{PD}\ is\ NB$

This part is very similar to part 3. In this group, the actual input is near the desired input (e(t) is Negative Small, Zero or Positive Small) or the actual input is drastically below it (e(t) is Positive Medium or Positive Big) and at this time the rate of error is positive or Zero, it means the rate of actual input is lower than desired input and caused to actual input moving away from desired input. In this time, the role of controller is to reverse this trend and caused actual input start to moving toward to the desired input.

The PD like fuzzy rule table shows in Table 1.

Table 1. Rule Table in PD like Fuzzy Logic Controller

$\dot{e}$ \ e	**PB**	**PM**	**PS**	**Z**	**NS**	**NM**	**NB**
P	NB	NB	NB	NB	NM	NS	Z
Z	NB	NM	NS	Z	PS	PM	PB
N	Z	PS	PM	PB	PB	PB	PB

Inference Engine (Fuzzy rule processing): The fuzzy inference engine recommends a fuzzy method to transfer the fuzzy rule base to fuzzy set. Mamdani and Sugeno methods are two main techniques of fuzzy rule processing. In this research Mamdani fuzzy inference engine is used as fuzzy rule processing.

Defuzzification: defuzzification is the last step to design fuzzy logic controller and it is used to transform fuzzy set to crisp set. Consequently, defuzzification's input is the aggregate output and the defuzzification's output is a crisp number. Centre of gravity method (COG) and Centre of area method (COA) are two types method to calculate the defuzzifications.

According to design fuzzy logic controller, Figure 18 shows PD like fuzzy logic controller.

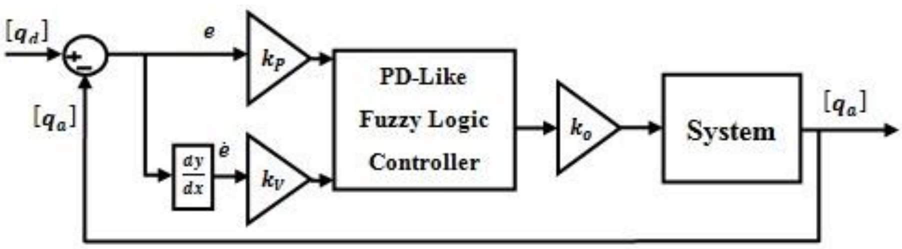

Figure 18. PD-like Fuzzy Logic Controller

In this research PI-like fuzzy logic controller is design based on PD-like fuzzy to reduce the time to design fuzzy rule base. Due to previous discussion, fuzzy rule bases are the controller's behavior and design two types of fuzzy rule bases are difficulties. Therefore design PI like fuzzy logic controller based on PD like fuzzy logic controller is introduced in this part. To design PI like fuzzy logic controller based on PD like fuzzy logic controller integral term is added to the PD controller's output. The formulation of PI controller is;

$$U_{PI} = K_p \times e + K_i(\frac{1}{T}\int e.dt) = K_p \times e + K_i \sum e \quad (21)$$

If the derivative, with respect to time is taken for (21);

$$\frac{dU_{PI}}{dt} = K_p \times \frac{de}{dt} + K_i e(t) = K_p \times \dot{e} + K_i e \quad (22)$$

According to (22) to calculate the output control system integral term is used as follows;

$$\int \frac{dU_{PI}}{dt} = [K_p \times \int \left(\frac{de}{dt}\right) dt + K_i \int (e(t)dt)] = K_p \times e + K_i \times \sum e \quad (23)$$

Figure 20 shows PI controller based on PD controller. According to Figure 19 PI like fuzzy logic controller is design based on PD like fuzzy logic controller. Figure 20 shows PI like fuzzy logic controller based on PD like fuzzy logic controller.

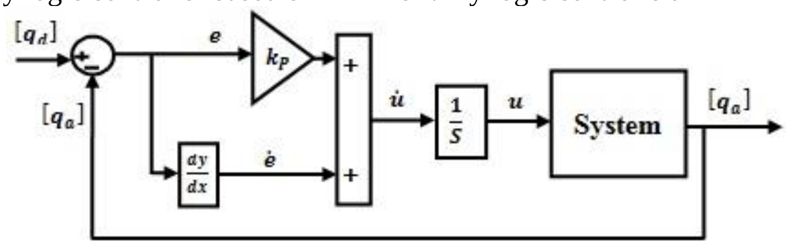

Figure 19. Design PI Controller Based on PD Controller

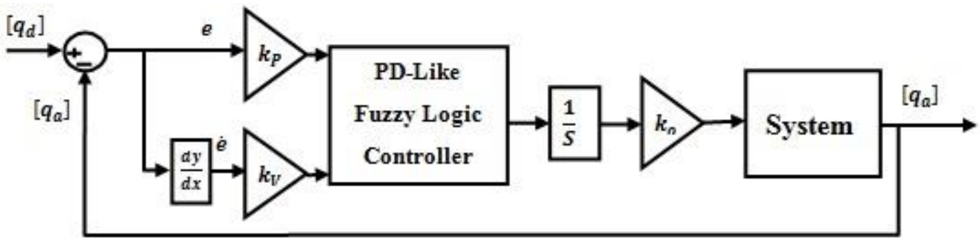

Figure 20. Design PI like Fuzzy Controller Based on PD like Fuzzy Controller

To design PI like fuzzy logic controller based on PD fuzzy logic controller following seven steps are recommended as well as design PD like fuzzy logic controller.

- Choosing inputs
- Scaling inputs
- Input fuzzification (binary-to-fuzzy[B/F] conversion)
- Fuzzy rule base (knowledge base)
- Inference engine
- Output defuzzification (fuzzy-to-binary[F/B] conversion)
- Scaling output

Figure 21 illustrates the general structure of the PID like fuzzy logic controller, which consists of two main components. The PID like fuzzy logic controller is built using PD like fuzzy logic controller and PI like fuzzy logic controller. According to design PD like fuzzy controller and PI like fuzzy controller based on PD fuzzy rule base, design PID like fuzzy controller is introduced based on the following formulation;

$$U_{PID} = U_{PI} + U_{PD} = \left(\frac{K_p}{2}\right) \times e + K_i\left(\frac{1}{T}\int e.dt\right) + (\frac{K_p}{2}) \times e + K_v \dot{e} \quad (24)$$

$$U_{PIDlike\,fuzzy} = [(\sum_{l=1}^{M} \theta^T \zeta(x))_{e,\sum e} + (\sum_{l=1}^{M} \theta^T \zeta(x))_{e,\dot{e}}\,] \quad (25)$$

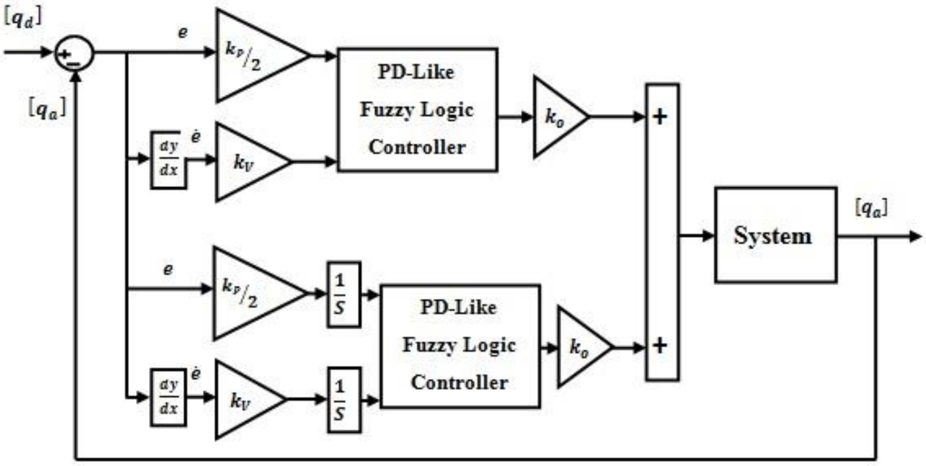

Figure 21. Design PID like Fuzzy Controller

4. Result and Discussion

PID like fuzzy controller and conventional PID controller are compare in this research. These controller are tested in certain and uncertain situation. These tests are very important to improve the air pollution reduction, which is very important factor to reduce risk of carcinoma of the lung progression.

Comparison of the Tracking Data and Information: the trajectory following for PID like fuzzy controller and PID controller are compared in this section. According to Figure 22, the rise time in PID controller is better than PID like fuzzy controller but conventional PID controller has error in certain condition. In error point of view, PID like fuzzy controller is better than PID controller. This test is important to test the fuel consumption. This item is fuel consumption optimization. In this research the reference data is 5 for fuel-ratio.

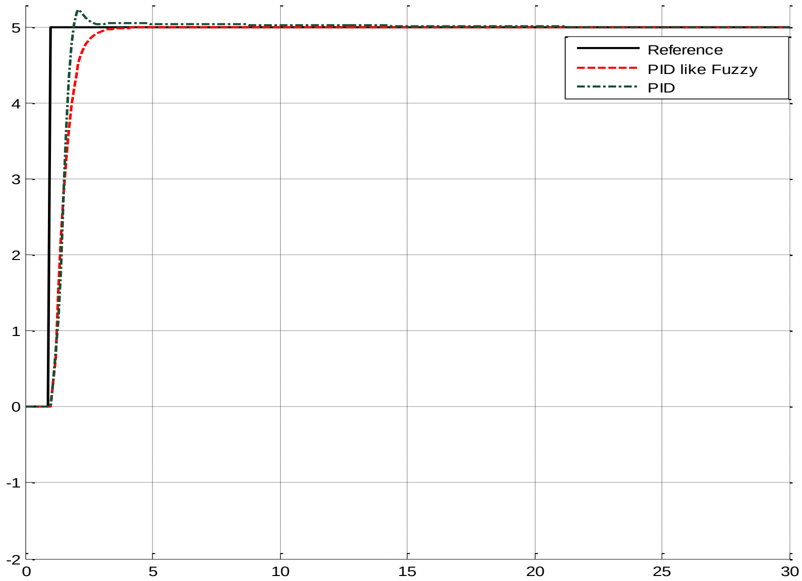

Figure 22. Tracking Data: PID like Fuzzy Controller and PID Controller

Comparison the Disturbance Rejection: the power of disturbance rejection is very important to robust checking in any controllers. In this section trajectory accuracy is test under uncertainty condition. To test the disturbance rejection band limited white noise with 30% amplitude is applied PID like fuzzy controller and PID controller. In Figures 23, trajectory accuracy is shown. This test is very important to stability and robust checking related to fuel consumption.

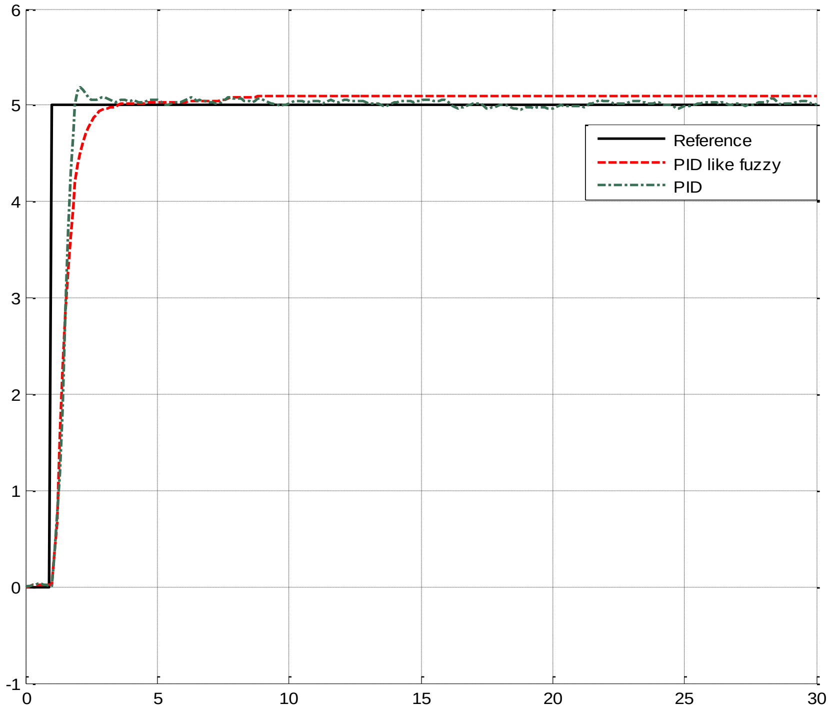

Figure 23. Tracking Data: PID like Fuzzy Controller and PID Controller in Presence of Uncertainty

According to above graph, however PID like controller has suitable oscillation in presence of uncertainty but it is more robust than PID controller. PID controller has very much fluctuation in presence of external disturbance.

5. Conclusion

Conventional nonlinear controllers are worked based on automotives dynamic model. Based on equivalent part in conventional nonlinear controllers, in complex and highly nonlinear systems these controllers have many problems for accurate responses because these type of controllers need to have accurate knowledge of dynamic formulation of system. The nonlinear dynamic formulation problem in highly nonlinear system (e.g., automotive engine) can be solved by fuzzy logic theorem. Fuzzy logic theory is used to estimate the system dynamics. This type of controller is free of mathematical dynamic parameters of plant. When system works in uncertainty, the nonlinearity term of automotive engine will be different. To reduce the role of nonlinearity term PID like fuzzy logic controller is used in this research. To design minimum rule base PID like fuzzy logic controller, parallel PD and PI strategy is recommended. According to this technique, the number of rule base is reduced with respect to have PID like fuzzy logic controller. To avoid of design two types fuzzy rule base in proposed PID like fuzzy logic controller, integral term of PI like fuzzy logic controller is replaced by PD like fuzzy logic controller. According to above algorithm to design the same PID controller the number of rule base for each link is $\mathbf{2} \times \boldsymbol{N} \times \boldsymbol{M}$. Where $\boldsymbol{N}$ is the number of linguistic variables for error and $\boldsymbol{M}$ is the number of linguistic variables for change of error. Regarding to this research, the risk of carcinoma of the lung progression is controlled by intelligent PID technique.

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Iranian center of Advance Science and Technology (IRAN SSP) is one of the independent research centers specializing in research and training across of Control and Automation, Electrical and Electronic Engineering, and Mechatronics & Robotics in Iran. At IRAN SSP research center, we are united and energized by one mission to discover and develop innovative engineering methodology that solve the most important challenges in field of advance science and technology. The IRAN SSP Center is instead to fill a long standing void in applied engineering by linking the training a development function one side and policy research on the other. This center divided into two main units:

- Education unit
- Research and Development unit

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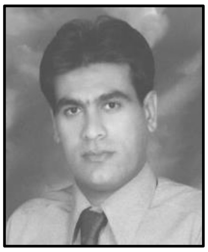

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