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Intelligent System Designing For Losses Control:-
A Proposed Combustion Model on Thermal Power Plant

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The combustion system of the boiler and how efficiently it works, is at the core of operating an efficient boiler. Many significant advances in boiler technology are a direct result of optimizing the combustion system and allowing the boiler to be more fuel efficient. The more fuel efficient the boiler, the lower the cost of operation and the better the energy output

In a boiler, as the excess air is increased, the stack temperature rises and the boiler's efficiency drops. It takes fewer BTU's of input to the burner to get the same number of BTU's out of the boiler if lower excess air can be used. Therefore one of the most important functions of a burner is to burn the fuel at the lowest possible excess air to achieve the greatest overall boiler efficiency

Through paper combining of PID characteristic in fuzzy system in a control action utilise the excellent learning performance and adaption. The basic motto of this proposed controlling model is to reduce the excess oxygen of exist so as to increase the combustion efficiency of a coal fired boiler. It is verified with PID /FUZZY/ PID FUZZY controller and tuned that the proposed FUZZY PID controller builds a good modelling characteristic for this complex non liner system with desired accuracy. Witch can touch the expecting efficiency range in different operating condition and surrounding .Hence this module may be use at different capacity of thermal power generating unit.

INTRODUCTION

The boiler converts the chemical energy available in the fuel (coal) into internal energy of steam, the working fluid. The boiler feed water pumps deliver feed water to the boiler drum from where water is directed into the down comers and the circulating pumps located at the bottom of the boiler. The circulating pumps deliver the feed water to the distribution headers beneath the furnace sections. The water rises in the circuits, which are the vertical enclosing walls of the furnace. During combustion, the water walls absorb radiant heat in the furnace, boiling take place and a water-steam mixture (saturated steam) enters the drum, while the saturated water leaves the drum and enters the down comers.

Combustion takes place when fuel, most commonly a fossil fuel, reacts with the oxygen in the air to produce heat. The heat created by burning the fossil fuel is used in the operation of boilers, furnaces, kilns, and engines. Along with the heat, CO2 (carbon dioxide) and H2O (water) are created as by-products of the exothermic reaction.

By monitoring and regulating some of the gases in the stack or exhaust, it is easy to improve the combustion efficiency, which conserves fuel and lowers operation cost. Combustion efficiency deals with the calculation of how effectively the combustion process takes place. To achieve the highest levels of combustion efficiency, complete combustion should take place. Complete combustion occurs when all the energy in the fuel being burnt is extracted and none of the carbon and hydrogen compounds are left unburnt. Complete combustion will occur when proper amounts of fuel and air (fuel/air ratio) are mixed in correct proportion under the appropriate conditions of turbulence and temperature. Although theoretically stoichiometric combustion provides the perfect air to fuel ratio, which in turn lowers the losses and extracts all the energy from the fuel. In reality, stoichiometric combustion is unattainable due to many factors that are varying with respect to time. Heat losses are inevitable thus making cent percent efficiency impossible. In practice, to achieve complete combustion, it is necessary to increase the amount of air so as to ensure the complete burning of all the fuel. The amount of air that must be added to make the combustion complete is known as excess air. In most of the combustion processes, some additional chemicals are formed during the combustion reactions. Some of the products as a result of combustion process are CO (carbon monoxide), NO (nitric oxide), NO2 (nitrogen dioxide), SO2 (sulphur dioxide), soot, and ash. These flue gas emissions should be minimized and accurately measured. The EPA has set specific standards and regulations for emissions of these products, as they are harmful to the environment. Combustion analysis is a vital step to properly operate and control any combustion process in order to obtain the highest combustion efficiency accompanied by low flue gas emissions.

MOTIVATION FOR RESEARCH

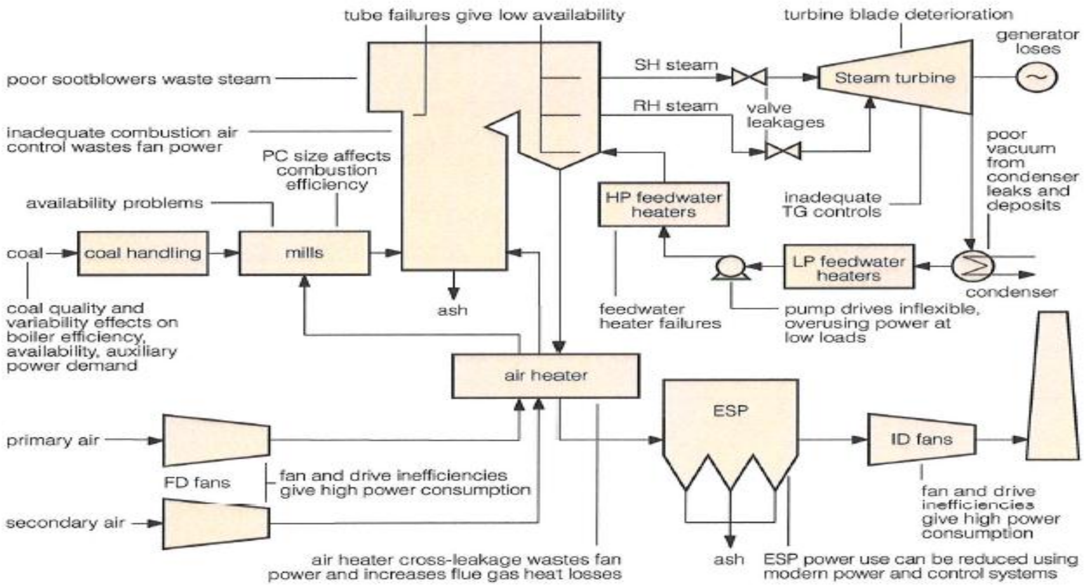
Combustion Efficiency

Heat Losses It is vital to keep heat losses to a minimum so that efficiency is maximized and more energy is conserved. Heat losses are inevitable, especially through the stack, but great amounts of heat losses may be prevented with the proper measurement and control procedures.

Total heat losses are normally tallied by adding the *stack losses*, the *skin/shell losses*, and the *losses due to the un-burned fuel in ash* collection hoppers.

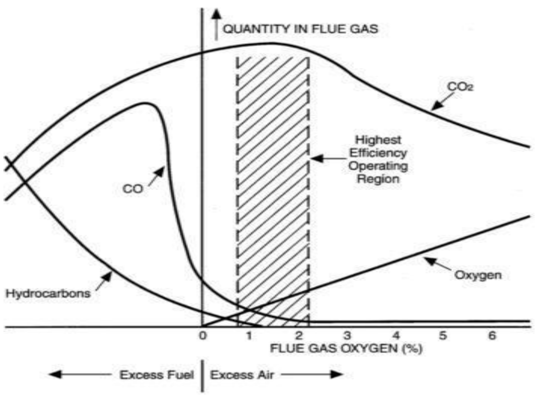
Stack losses will combine the *sensible heat losses or dry gas losses* and the *latent heat losses*. Sensible heat losses relate to the heat used to heat the combustion gases exiting the stack; the higher the volume and temperature of the flue gases the larger the dry gas heat losses. Latent heat losses are due to the water vapor in the flue gases (a large amount of energy is used as water evaporates).

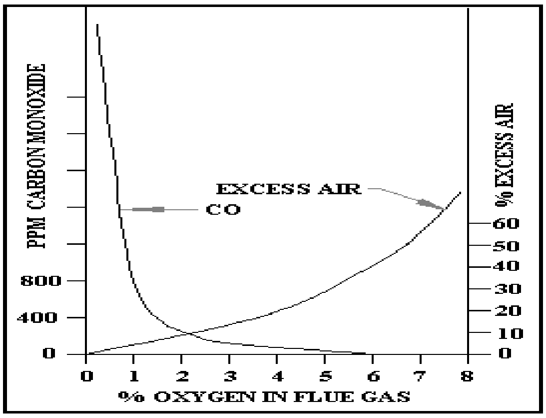
Skin/shell losses, which are the losses due to radiation from the boiler walls can be minimized with proper insulation and in general are relatively small.



OBJECTIVE OF THE WORK

There are complicated models based on finite elements approximation to partial differential equations. These models are in the form of large simulation codes for plant design, simulators and commissioning. However they are not normally used in control design approach because of their complexity. The analytical combustion model can be formulated based on the fundamental laws of physics such as conservation, momentum and energy semi- empirical law for heat transfer and thermodynamic state conversion. To build such analytical models it is necessary to define their parameters with respect to boundaries, inputs and scan be used to can be used to outputs. Generally the developed models need t be tuned by performing tests to validate for steady state and transient response .In addition a mathematical plant model can be developed based on measured data obtained from real performance of the plant. The gather information from experiment can be used to developed test data based models by using system identification techniques. The four main step to determine a test based model from input output data includes collection of data from experiment .Choosing a model structure estimation of model parameter and model validation. Soft computing methods can be used to maximise control model parameters over a full range of input output data. For tanning and adaption of system parameter neuro fuzzy control is use now days. It has many advantages over conversational control as it does not required a complete system model not and can be employed to globally search for optimal solution When the identified model is non linear the parameters using conventional methods will not provide superior results. In this case soft computing methodological are investigated as potential solution to obtain good estimation of the model parameter.





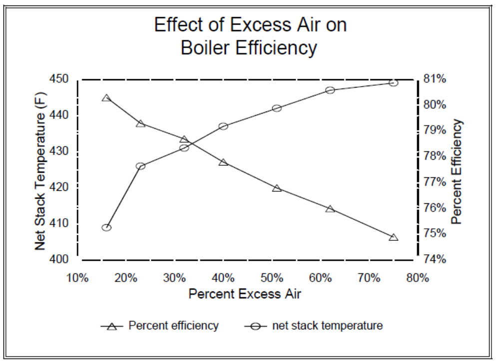
LITERATURE SURVEY

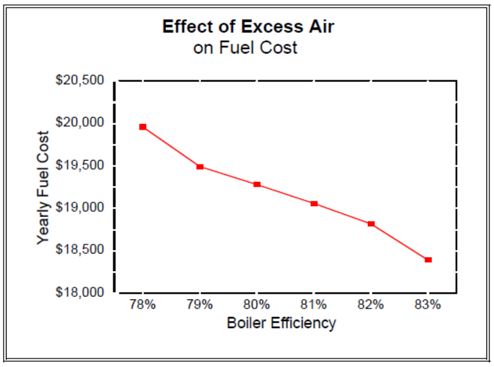
Figure 2 shows a simplified burner head. The air is brought into the head by means of a forced draft blower or fan. The gas is metered into the head through a series of valves. In order to get proper combustion, the air molecules must be thoroughly mixed with the gas molecules before they actually burn.

The mixing is achieved by burner parts designed to create high turbulence. If insufficient turbulence is produced by the burner, the combustion will be incomplete and samples taken at the stack will reveal carbon monoxide as evidence.

Since the velocity of air affects the turbulence, it becomes harder and harder to get good fuel and air mixing at higher turndown ratios since the air amount is reduced. Towards the highest turndown ratios of any burner, it becomes necessary to increase the excess air amounts to obtain enough turbulence to get proper mixing. The better burner design will be one that is able to properly mix the air and fuel at the lowest possible air flow or excess air.

Figure 3 shows graphically how excess air affects the efficiency and operating cost of a boiler. The data was compiled on an actual boiler and is not just some theoretical mumo-jumbo.





Excess Air – In order to ensure complete combustion, combustion chambers are fired with excess air. Excess air increases the amount of oxygen and nitrogen entering the flame increasing the probability that oxygen will find and react with the fuel. The addition of excess air also increases turbulence, which increases mixing in the combustion chamber. Increased mixing of the air and fuel will further improve combustion efficiency by giving these components a better chance to react. As more excess air enters the combustion chamber, more of the fuel is burned until it finally reaches complete combustion. Greater amounts of excess air create lower amounts of CO but also cause more heat losses. Because the levels of both CO and heat losses affect the combustion efficiency, it is important to control and monitor excess air and the CO levels to ensure the highest combustion efficiency

Calculating Excess Air - As discussed earlier, under stoichiometric (theoretical) conditions, the amount of oxygen in the air used for combustion is completely depleted in the combustion process. Therefore, by measuring the amount of oxygen in the exhaust gases leaving the stack we should be able to calculate the percentage of excess air being supplied to the process.

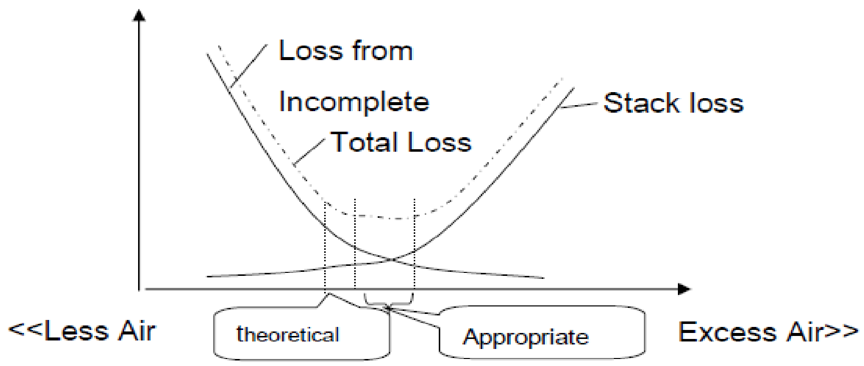
The following formula is normally used to calculate the excess air:

%O2 measured % Excess Air = x 100 20.9-%O2 measured

Efficiency:- Although combustion efficiency can not be measured directly, it can be calculated by identifying all of the losses that occur during combustion. It is important to consider all factors including sensible heat losses, unburned gases, radiation, and unburned particles. In most instances, the values of the skin losses and latent heat losses are not taken into account. The following equation can be used to calculate combustion efficiency: Total Heat losses

%Efficiency = 100% - x 100 Fuel heating value

METHODOLOGY



Since boiler system can be decomposed into smaller components that can be analyzed and models saperately.The behaviour of combustion system and sub system can be captured in terms of balance equations and constitutive equations, variable that account for storage of mass energy and momentum have to be introduced as well as parameters.

The combustion model can be developed based on the chemical reaction. However such a model is not directly used in all of the proposed models but it would be useful for designating the fuel to air control system .In dealings with chemical reacting system. The concept of absolute enthalpies is very important. The absolute enthalpy is the sum of enthalpies that takes into account the energy associated with the chemical bonds.

$$\Delta \acute{h}(T) = \acute{h}\ (T) - \acute{h}^{o}\ (T_{ref})$$

A balance relationship for any fuel air system is written as

$$C_aH_b + \gamma(a + \frac{b}{4})\ (O_2 + 3.76N_2)\ aCO_2 + \frac{b}{2}\ H_2O + dN_2 + eO_2 + f\ NO_x + gCO + \ldots.$$

The definition of the enthalpy of reaction or the enthalpy of combustion (heating value)

$$\Delta h_R = H_{prod} - H_{reac}$$

This value can be adjusted for per mass of fuel basis , so

$$\Delta h_R \text{ (kJ/kg}_{fuel}) = \Delta h_R / m_{fuel}$$

Also ,it is in turn converted to a per unit mass of mixture basis as.

$$\Delta h_R \text{ (kJ/kg}_{max}) = \left(\frac{m_{fuel}}{m_{mix}}\right) \Delta h_R \text{ (kJ/kg}_{fuel}) = \frac{m_{mix+m_{air}}}{m_{fuel}} \Delta h_R = \left(\frac{1}{\frac{A}{F}+1}\right) \Delta h_R$$

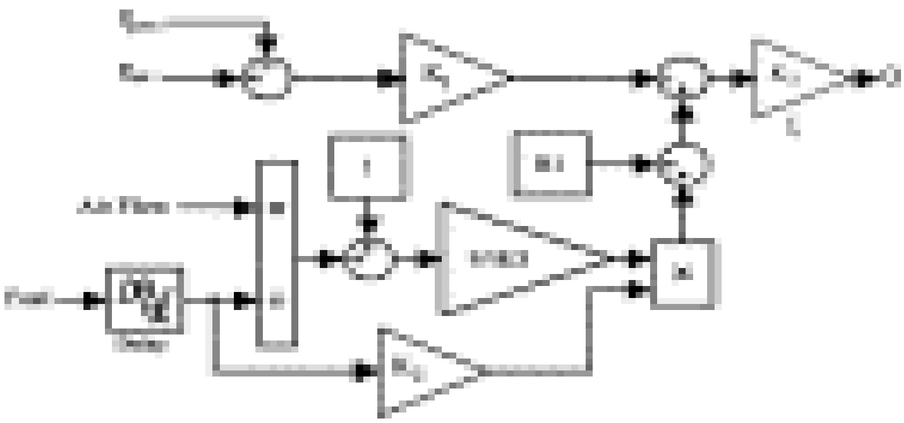
The combustion heat is calculated by assuming that all of the water in the products has converted to gas it called the lower heating value of fuel.

The furnace pressure P fur which corresponds to combustion air pressure can be taken part by eq $\Delta h = \Delta u + v\Delta P_{fur}$

The kinetic energy of air flow has not a considerable role and can be neglected. The important feature is the furnace pressure control which affords additional energy saving. In the best condition, the air pressure should be close to the product pressure. Operating under –ve pressure or at high +ve pressure significant fuel wasting and damaging the boiler. The amount of absorbed heat in a boiler from burners depends on the type of the boiler and its subsystems. Besides the thermal efficiencies of these sections are different. The effect of these aspects can be introduced by a coefficient as follow

$$Q = K_3\left(m_{fuel}.K_2\left(\frac{\left(\frac{A}{F}\right)_{com}+1}{\left(\frac{A}{F}\right)_{sto}+1}\right)\right) - K1\,(P_{air} - P_{por}) + B_1$$ (where b1 k1 k2 k3 are the parameter of model

The proposed model for the combustion system is presented



PID Controller

Proportional –Integral – derivative PID controller , which have relatively simple structure and robust performance are the most common controller in industry by taking the time derivative of the both side of the continuous time PID equation and disserting the resulting equation are easily gets the PID equation in the incremental form as below

$$U(K) = U(K-1) + K_P e(K) - e(K-1) + \frac{K1T}{2}\left[e[e(k)+e(k-1)] + \frac{K_0}{T}[e(k)-2e(k-1)+e(k-2)]\right]$$

Where kp kd ki are gain and Tis the sampling period U is the discrete time index. The difference between the reference input (r) and the actual plant output (y) is error E=r-y

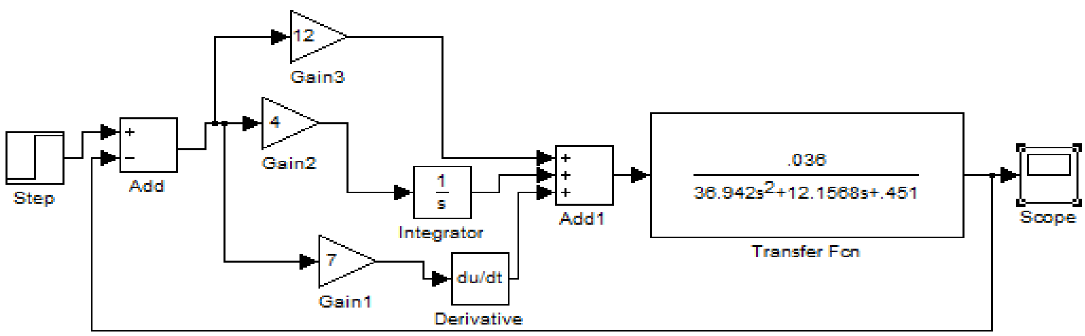
SoΔ U(K) = K_P e_P (K)+ $K_i e_I$(K)+ K_P e_P(K)

$U(K) = U(K-1) + \Delta U(K)$

Where $e_P(K) = e(K) - e(K-1)$, $e_I(K) = \frac{T}{2}[e(K) + e(K-1)]$

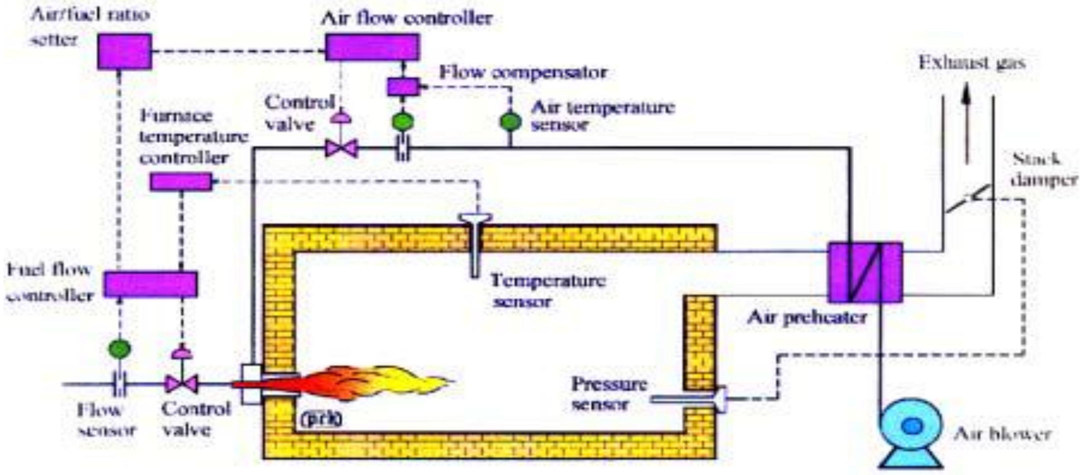
$e_P(K) = \frac{1}{T}[e(K) - 2e(K-1) + e(K-2)]$ with e(K) = 0 for K<0

The PID controller is traditionally suitable for second and lower order system .It can also be used for higher order plant as here with dominant 2nd order behaviour. For PID controller in combustion cycle monitoring and control value of tuning parameter .Usually initially design value of PID controller obtained by all means needs to be adjusted repeatedly through computer simulation until the close loop system perform or compromise as desired .This simulates the development of intelligent tools that can assist the engineers to achieve the best overall PID control for entire operation envelops



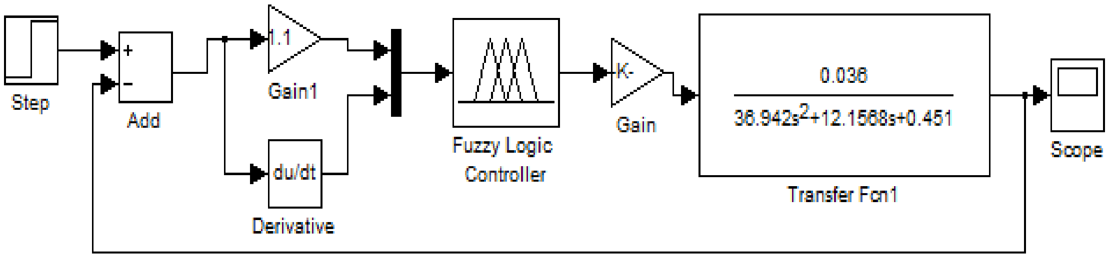
Existing setup

Most Furnaces have control systems which measure furnace Temperature and throttle fuel valves to keep furnace temperature at the setpoint. At the same time the controllers will adjust air dampers to achieve preset air to fuel ratio.Besides combustion, the controllers also control Furnace Pressures by sensing the pressure and manipulating exhaust air dampers



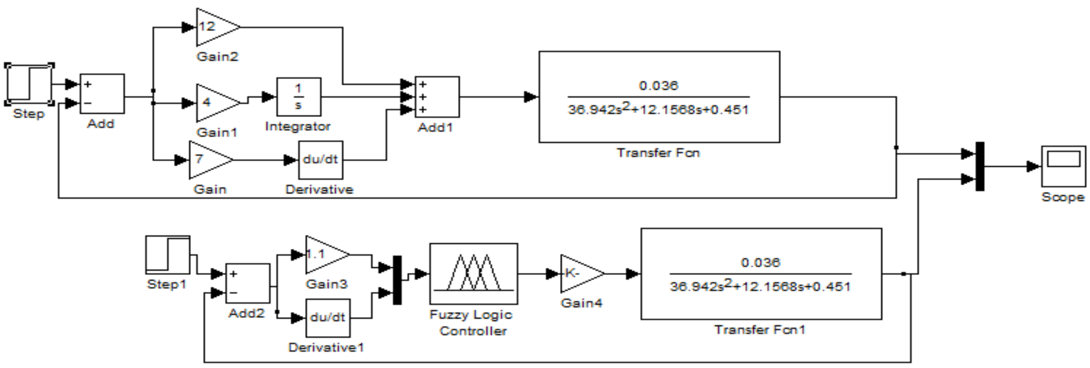
Fuzzy Controller

Fuzzy control is used when the process follows some general operating characteristic and a detailed process understanding is unknown or process model become very complex. The capability to qualitatively capture the attributes of a control system based on observable phenomena and the capability to model the nonlinearities for the process are the main features of fuzzy control. The ability of fuzzy loge c to capture system dynamics qualitative sachem in a real time situation .The essential part of FLC is a set of linguistic control rules related to the dual concepts. OF FUZZY implication and the compositional rule of inference. Essentially the fuzzy controller provides an algorithm that can convert the linguistic control strategy, based on expert knowledge into an automatic control strategy. In general the basic configuration of a fuzzy controller has five main models as it is shown In this first module a quantization module converts to discrete value and normalised the universal manipulated variable(input). Then a numerical fuzzy converter maps crisp data to fuzzy numbers characterized by a fuzzy set and a linguistic label (fuzzy fiction).In the next module the inference engine applied the composition rule of the inference to the rule base in order to derive fuzzy value of the control signal from the input, facts of the controller .Finally a symbolic numerical interface know as de fuzzy faction module provides a numerical value of the control signal or increment in the control action. This is integrated by fuzzy numerical converter and a de quantization module (output)Thus the necessary steps to builds fuzzy control system has a) input output variable representation in linguistic terms within a discourse universe, b)definition of membership function that will convert the process into variables to fuzzy sets c) knowledge based configuration d) design of the inference unit that will relate input data to fuzzy rules of the knowledge based e) design of the module that will convert the fuzzy control action into physical control action.



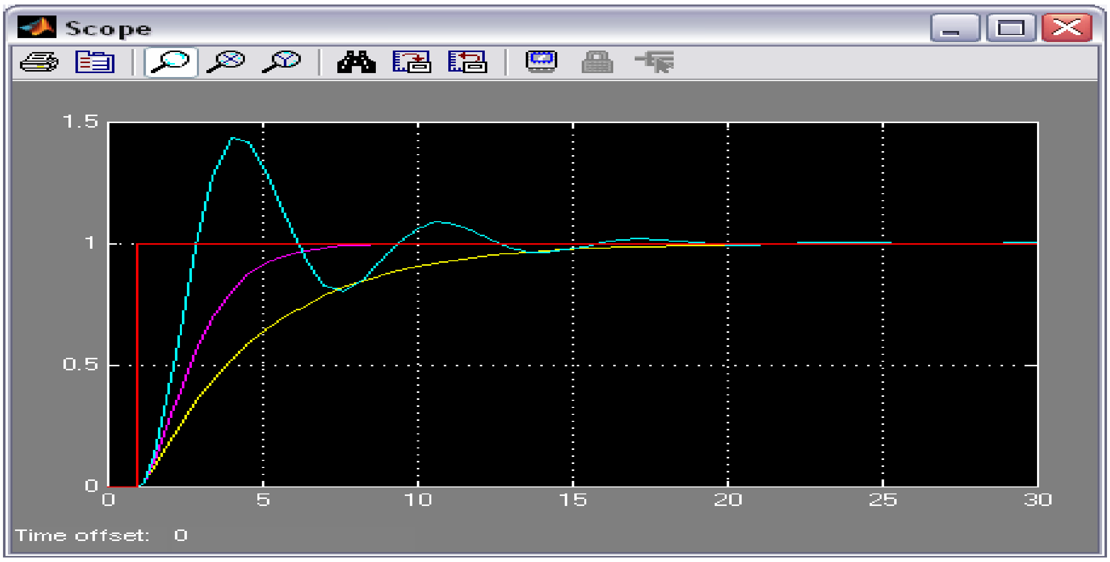
c)FuzzyPID

The fuzzy PID controller is the natural extension of this conventional version which preserves their linear structure of PID CONTROLLER. The fuzzy PID are designed using fuzzy logic control principle in order to obtain a new controller that possesses analytical formulas very similar to digital PID controller. Fuzzy PID controller has variable control ain in their linear structure. These variable gains are non liner function of the error and changing rates of error signal. The main contribution of this variable gain in improving the control performance is that they are self tuned gain and can adapted to rapid changes of the error and rate of changes of error caused by time delay effects, nonlinearities and uncertainties of the underling process.



SIMULATION

The simulation result clearly shows that the fuzzy controller gives a much better control of temperature rather than ANN or PID controller .To evaluate the performance of the different controller we have considered two parameter of the step responses of the system .The first parameter is the maximum overshoot and the second parameter is the settling time .In all the three controller two parameter are evaluate and comparative study of their performance has been shown in fig



CONCLUSION

This paper present a novel approach to constructing systematically a self organizing and self learning multivariable intelligent PID controller ,a combination of a conventional PID controller with knowledge based fuzzy control technology. It has been observed that fuzzy PID produced an comparable or even better control performance then the traditional PID controller or fuzzy control alone. As intelligent PID is capable of learning and extracting required control rules automatically from the controller environment. The fuzzy over come fixed gain of PID and take the support nonlinear mapping of fuzzy which make it more suitable for complex process. The theoretical study and practical application indicate that the application of intelligent PID controller in thermal power plant process monitoring and control is profitable, effective and acceptable by control engineering system This design controller used for air to fuel ratio optimisation in the combustion process of a power plant boiler and this optimization of air to fuel ratio through this controller reduce the excess air level and improve the combustion efficiency

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