Neural Network based System Identification and PID Tuning for Optimum Adaptive Control

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Abstract- **In this paper the optimization technique is successfully applied to the system and PID controller is tuning for optimum adaptive control. The first part deals with the PID controller tuning and second part deals with the plant optimization. The plant which is constructed as steam boiler which has fuel supply and input. A servo motor control is used for controlling the flow of air and gas and this will be given to the steam boiler. In the disturbance controller where the reference and actual values are compared and error values are generated. This error values are employed to configure as per the reference value, so then going for the adaptive PID control where the gains of K_p ,K_i , and K_d are tuned and the servo motor is adjusted for fuel flow, again the error values are taken and the procedure follows for better optimization. This will result in the constant pressure control of the steam boiler system even though disturbance taking place.**
Here the PID controller tuning by adaptive control in future for better control operation adaptive PID controller tuned by using the Neural Network.The good response of the neural network and Comparison of the adaptive controller best fast response of the neural netwok.

Keywords- Adaptive PID controller; Neural networks; Servo motor;

I. INTRODUCTION

The steam boilers are energy conversion units which transform the combustion energy of fuel into steam heat and mechanical power. High pressure steam boilers are applied in cogeneration plants for steam turbine operation and district central heating. Low pressure steam is utilized for technological needs and for autonomous heating of administrative and manufacturing buildings, like food production enterprises. The main tasks of the steam boiler design, operation and automatic control are as follows: to minimize heat losses from the furnace and boiler room using economizers, increasing the heat resistance and fuel combustion efficiency, as well as optimizing the heat load control; to reduce flue gas emissions using emission reduction facilities and applying burners optimal control according to flue gas analysis; continuous measurement, analysis and control of inner technological parameters steam pressure and temperature, and drum water level and temperature, as well as outer disturbances feed water flow and steam expenditure what directly affect the boiler parameters. Commonly, a steam boiler is characterized by changing sensitivity and inertia factors, highly variable disturbances, large thermal time constants and time delays. Classical PID (proportional-integral-derivative) control is still the current tool for the steam boiler control The main control loop with only PID controller cannot eliminate the effect of disturbances to the transition process of the steam parameters enough effectively because of delayed response on variable steam expenditure and feed water flow. To increase operation stability and the process control quality of the steam boilers and power plants, wide investigations of long-range control methods are made recently The algorithms of the disturbance preemptive compensation (DPC) controller are compiled according to the invariant control principle in strong correlation with the algorithms of steam boiler and power supply unit, as well as the steam flow and feed water flow effect on steam pressure. The transfer functions and operational equations of the steam boiler control system components are composed using mathematical analyses, operator mathematics and Laplace transforms. The transfer coefficients and time constants of the control system components are determined according to their technical parameters and operation conditions.

II. PROBLEMS IN ADAPTIVE PID CONTROLLER

In thermal power plan boiler the ratio of air and fuel can ne constant by the use of Adaptive PID control.

- Slow Response when compare to other controller
- Ratio of air and fuel may be constant.
- Reduce Thermal plant efficiency.

A. System Identification

The plant model was identified the parameters found are used to tune the PID controller. The performance of the system for a first order plant whose dynamic characteristics changes in time are presented. This aim is reached by determination of the optimum set of PID controller parameters: proportional, integral and derivative parameters. As the plant model is identified periodically, the changes in its dynamic characteristics can be observed. If the settling time or the overshoot becomes too large another process of identification and PID tune is fired..

B. Control Algorithm

The system parameter which is the process variable that needs to be controlled is temperature. The controlled signal is given to the process. In this model block gives input to the adjustment mechanism. It is refer the controller output and value.

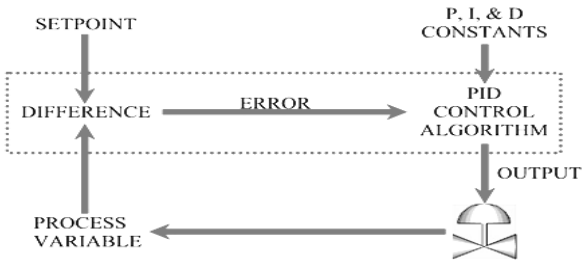


Fig 1 PID Control Loop

If produce the desire value of control this is a closed loop control system, because the process of reading to provide thence tuned the controller by Ziegler-Nichols method a good but not optimum system response will be reached. The transient response can be even worse if the plant dynamics change. It must be noticed that a great amount of plants has its dynamics changed by external/environmental factorsTo assure an environmentally independent good performance, the controller must has the ability to adapt to plant dynamic characteristics changes. This requirement made the adaptive control theory to exist.

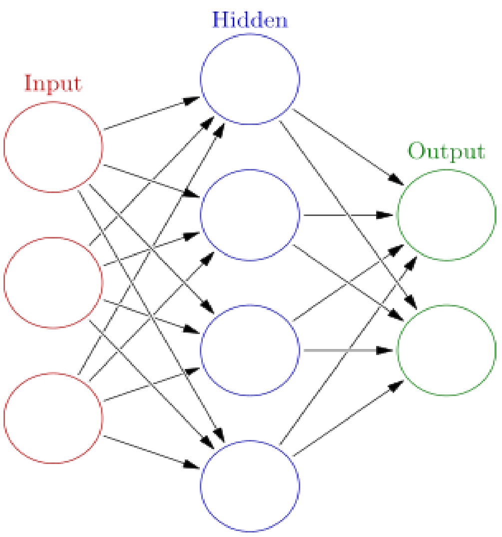


Fig 2 Neural Network .

C. *PID Controller Method*

The PID controller is to maintain the output at a level so that there is no difference (error) between the process variable (PV) and the set point. When there is a "process upset", meaning, when the process variable or these point quickly changes - the PID controller has to quickly change the output to get the process variable back equal to the set point.

D. *Adaptive Control*

Adaptive control is the control method used by a controller which must adapt to a controlled system with parameters which vary, or are initially uncertain. Adaptive control is different from robust control in that it does not need a priori information about the bounds on these uncertain or time-varying parameters; robust control guarantees that if the changes are within given bounds the control law need not be changed, while adaptive control is concerned with control law changing them.

E. *Classification of Adaptive Control*

In general one should distinguish between: Feed forward Adaptive Control, Feedback Adaptive Controls well as between Direct Methods and Indirect Methods. Direct methods are ones wherein the estimated parameters are those directly used in the adaptive controller. In contrast, indirect methods are those in which the estimated parameters are used to calculate required controller parameters. Here are several broad categories of feedback adaptive control (classification can vary):Dual Adaptive Controller

F. *Stability*

If the PID controller parameters are chosen incorrectly, the controlled process input can be unstable, i.e., its output diverges, with or without oscillation, and is limited only by saturation or mechanical breakage. Instability is caused by *excess* gain, particularly in the presence of significant lag. Generally, stabilization of response is required and the process must not oscillate for any combination of process conditions and set points.

G. *PID Tuning Software*

Mathematical PID loop tuning induces an impulse in the system, and then uses the controlled system's frequency response to design the PID loop values. In loops with response times of several minutes, mathematical loop tuning is recommended, because trial and error can take days just to find a stable set of loop values. Optimal values are harder to find. Some digital loop controllers offer a self-tuning feature in which very small setpoint changes are sent to the process, allowing the controller itself to calculate optimal tuning values

H. *Linearity*

Another problem faced with PID controllers is that they are linear, andin particular symmetric. Thus, performance of PID controllers in non-linear systems (such as HVAC systems) is variable. For example, in temperature control, a common use case is active heating (via a heating element) but passive cooling (heating off, but no cooling), so overshoot can only be corrected slowly – it cannot be forced downward. In this case the PID should be tuned to be overdamped, to prevent or reduce overshoot, though this reduces performance (it increases settling time).

I. *MRAC Theory*

The proportional gain, K_p, is either the root locus gain, or the root locus gain is proportional to K_p.The root locus for a first order system will have the form shown below. the idea behind Model Reference Adaptive Control is to create a closed loop controller with parameters that can be updated to change the response of the system to match a desired model.

J. Boiler

The basic working principle of boiler is very very simple and easy to understand. The boiler is essentially a closed vessel inside which water is stored. Fuel (generally coal) is bunt in a furnace and hot gasses are produced. These hot gasses come in contact with water vessel where the heat of these hot gases transfer to the water and consequently steam is produced in the boiler. Then this steam is piped to the turbine of thermal power plant. There are many different types of boiler utilized for different purposes like running a production unit, sanitizing some area, sterilizing equipment.

J. High Pressure Steam Locomotive

A high-pressure steam locomotive is a steam locomotive with a boiler that operates at pressures well above what would be considered normal. In the later years of steam, boiler pressures were typically 200 to 250 psi. High-pressure locomotives can be considered to start at 350 psi, when special construction techniques become necessary, but some had boilers that operated at over 1,500 psi.

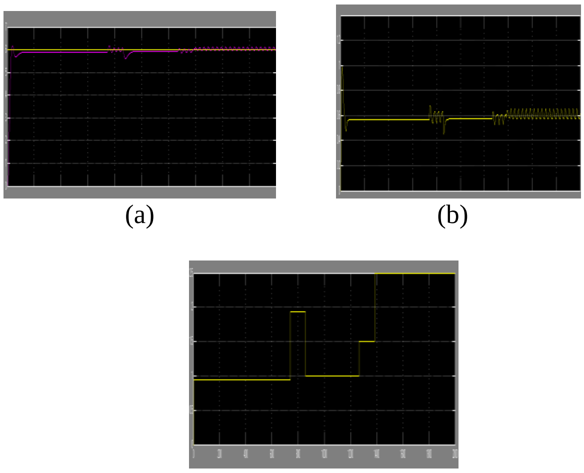
K. Interpreting a histogram

A symmetric distribution is one in which the 2 "shares" of the histogram perform as mirror-images of one another. A skewed distribution is a distribution in which there is no such mirror-imaging. For skewed distribution; it is quite common to have one tail of the distribution significantly longer .A "skewed right" distribution is one in which the tail on the right side. A "skewed left" distribution is single in which the tail is on the left side. The histogram is for a distribution that is skewed right.

Skewed distributions fetch a certain philosophical difficulty to the very process of reckoning a "typical value" for the distribution. To be definite, suppose that the analyst has a collection of 100 values arbitrarily drawn from a distribution, and wishes to summarize these 100 observations by a "typical value". If the distribution is symmetric, the archetypal value is unambiguous-- it is a well-defined center of the distribution. For example, for bell-shaped symmetric distribution, a center point is identical to that value at the peak of the distribution.

II. NEURAL NETWORK

An Artificial Neural Network (ANN) is an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information. The key element of this paradigm is the novel structure of the information processing system. It is composed of a large number of highly interconnected processing elements (neurons) Neural networks process information in a similar way the human brain does. The network is composed of a large number of highly interconnected processing elements working in parallel to solve a specific problem. Neural networks learn by example. They cannot be programmed to perform a specific task. The examples must be selected carefully otherwise useful time is wasted or even worse the network might be functioning incorrectly. The disadvantage is that because the network finds out how to solve the problem by itself, its operation can be unpredictable



(a) (b)

(c)

Fig 6 Neural Network
(a). Steam Boiler , (b). Gas and Air valve output
(c). Disturbance output control.

A. Servo motors

Servo Motors are DC motors equipped with a servo mechanism for precise control of angular position. The RC servo motors have a rotation limit from 90° to 180°.But servomotors do not rotate continually. The rotation is restricted in between the fixed angles. Servomotors are used in robotic arms and legs, sensor scanners and in Remote Control toys like Remote control helicopter, airplanes and cars The Servo Motors originate with three wires to provide ground supply, positive supply and control signal. These wires of a servo motor are color coded where the red wire is the DC supply lead and must be connected to a DC voltage supply in the range of 4.8 V to 6V. The black wire is to provide ground. The colour for the control signal wire differs for different manufacturers. Futaba delivers a J-type plug with an additional flange for proper connection of the servo. Hitec has an S-type connector. A Futaba connector can be used with a Hitec servo by clipping of the extra flange. Also a Hitec connector can be used with a Futaba servo just by filing off the extra width so that it fits in well. Hitec splines have 24 teeth while Futaba splines are of 25 teeth. it is essential to correctly account for the order of wires in a servo motor. A pulse width modulated signal is served through the control wire. The pulse width is changed into an correspondent voltage that is associated with that of signal from the potentiometer in an error amplifier. The servo motor can be moved to a preferred angular position by sending PWM (pulse width modulated) signals on the control wire. The servo knows the language of pulse position modulation. The width of the pulse defines the angular position. A servomotor consumes power as it rotates to the commanded position but then the servomotor rests. Stepper motors run warm to the touch because they continue to consume power to lock in and hold the commanded position. Servomotors are generally used as a high performance alternative to the stepper motor. Stepper motors have some inherent ability to control position, as they have built-in output steps

III. SIMULATION AND OUTPUT RESPONSES

The performance of the block diagram is, when the set point is given then the wave form initiated and then the rules are connected to the next block for the loading purpose.

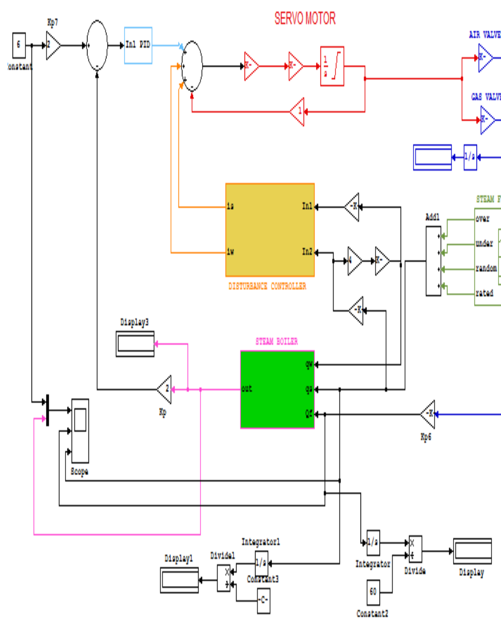
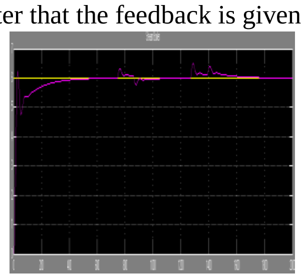
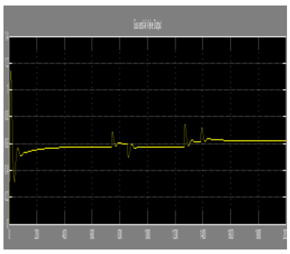


Fig 4. Simulation and Output Response For Adaptive Control

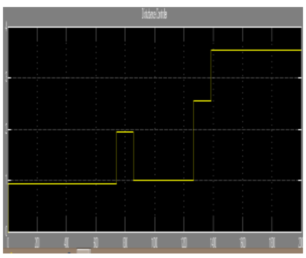
Then the adaptive controller performs the operation, with the help of the transfer function the temperature is obtained .after that the feedback is given to the subtract block



(a)



(b)



(c)

Fig 5. Adaptive Control
(a) Steam Boiler output (b) Gas and Air valve output
(c) Disturbance Controller output

IV. SUMMARY AND CONCLUSION

Thus the pressure can be controlled by adaptive PID controller. Adaptive PID controller technique is magnificently applied in steam boiler. Steam pressure plays an important role in power plant boiler. A PID controller is a control loop feedback mechanism widely used in industrial control systems. Using PID Ziegler Nicholas method to tune the PID parameter and generally PID controller controls the number of oscillation and pressure can be controlled continuously. Generally servo motor is a rotary actuator that allows for precise control of angular position, velocity and acceleration. A PID controller calculates an error value as the difference between a measured pressure variable and a desired set point and it fed to servo motor monitors and regulates both the gas variable and air variable based on desired value. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable. Pressure can be controlled by Adaptive PID controller in steam boiler and it given to servo motor. The comparison to the conventional PID controller shows the best response in Adaptive PID controller. Adaptive PID controller it eliminates the disturbances. A servo motor is a controls both air and gas but based on controller output it regulates the gas and air variable. Here the PID controller tuning by adaptive control in future for better control operation adaptive PID controller tuned by using the Neural Network.The good response of the neural network and Comparison of the adaptive controller best fast response of the neural netwok.

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