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Hybrid Fuzzy-PID Application in Boilers to Obtain Optimum Efficiency

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Abstract

Many real time processes have complex, uncertain and nonlinear dynamics. Boilers are nonlinear, time varying, multi-input multi-output (MIMO) systems, whose states generally vary with operating conditions. The major problem in controlling that system is that its drum water pressure and steam flow dynamics include an integrator that results a critically stable behavior. Conventional controller previously used have a set of limitations, e.g. empirical tuning of their parameters when the operating conditions of the controlled process are changed. The application of fuzzy control scheme which is compounded with classic controller (PID) may provide more effective and flexible control of boilers in power stations. This research employing fuzzy logic systems due to their transparency and nonlinear features for controlling dynamics, uncertain and highly nonlinear boiler systems and PID controller due to its fast response.

Keywords: Fuzzy controller, PID controller, boiler.

1. Introduction

The dynamic behaviour of industrial plants heavily depends on disturbances and in particular on changes in operating point. This is particularly the case for large coal fired power plants. Such plants represent from the control engineering point of view a time-variant and nonlinear multivariable process with strong interactions. Therefore, they are very difficult to control. Power plants have some inputs and outputs.

The main input variables of a thermal power plant are fuel flow, feed water, injection water and air. The outputs of the system are electrical power, steam pressure, steam temperature, and combustion gas. Some of the inputs and outputs are more important than the others since these are adequate for modelling the power plant. These are coal feed (Heat) and feed water flow as the inputs and the Drum pressure and steam enthalpy as the outputs. Power plant is a multivariable dynamic system. Most of the thermal power plants have been controlled by conventional controller techniques, especially conventional PID controller for many years since these controllers are easy to implement on systems due to their simple structures.

However, changing the power demands, quality differences of the coal and contamination of the boiler heating surfaces are problem for controlling the system outputs with conventional controllers. In addition, although there is a reduced mathematical model of a power plant, it usually non- linear, time-variant and governed by strong cross coupling of the input variables.

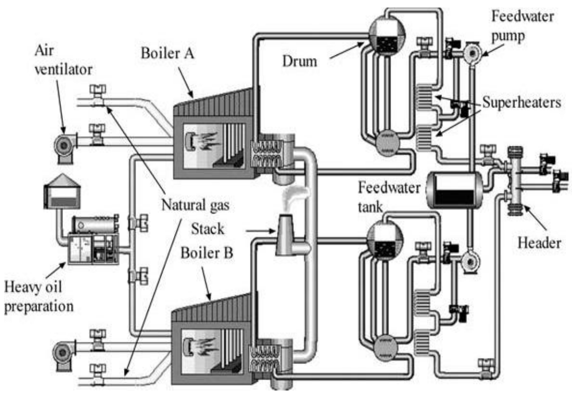
All these problems are removed by using advanced control techniques. One of the major techniques is fuzzy logic control. There have been many improvements in the theory of this controller design during the last decades. Consequently, this technique has been widely used on power plants.

In power generation, an essential requirement is to achieve optimal operation in terms of variant objectives, such as minimization of load-tracking errors, minimization of fuel consumption and heat rate, maximization of duty life, and minimization of pollutant emissions.

Load tracking, voltage, and frequency stability have been the basic issues of more effective control design. This requires boiler turbine modelling and a wide application of simulation tools in power plant control and process study. The dynamics of most power plants is highly nonlinear with numerous uncertainties.

However, no mathematical model can exactly describe such a complicated physical process, and there will always be modelling errors due to un-modelled dynamics and parametric uncertainties. Besides, detailed modelling of plant dynamics is often not efficient for control synthesis.

Modelling of boiler room and boiler turbine control systems is still of substantial interest, especially with new turbulences on fuels market, new energy field paradigms and direct influence on overall production.



All this, move forwards with additional pressure on users for more effectiveness; fewer unplanned and deliberate shutdown and greater ability to respond to rapid changes in production demands – more availability. Researchers developed several linear and nonlinear models representing the dynamics of boiler systems. Some of them are suitable for control design and have also been considered in papers; among them, the more recent ones are. In literature dealing with application of fuzzy logic in boiler room control, problems are solved by using fuzzy logic as a helping tool for PID algorithm parameters determination in different observed situations. This approach asks for understanding of both process and mathematics behind PID algorithm from the source of fuzzy rules, something we cannot expect in case of common human operator. Some other approaches are based on different variant of adaptive auto-tuning controllers.

2. System control model:

2.1. Boiler:

First, proposed boiler control model is presented Where the focus is on boiler water drum because of large number of boiler emergency shutdowns, over 30 % of all recorded shutdowns is result of poor pressure control .The second subject evolved is the burning quality control as representative of fuel consumption optimization. Fig.1 shows the observed boiler with two identical boilers. Boilers have shared feed-water tank, output steam header, secondary fuel preparation installation and stack. Every boiler has its own feeding for air, fuel and water. Heat input produced by burning of fuel in the presence of air causes boiling of water in boiler tubes. Real boilers are much more complicated than those shown in Fig.1 and have complex geometry of risers and down comers tubes, reheaters, preheaters, economizers. Water drum is critical component for drum type boilers because it maintains an adequate water level in the whole water-steam system and serves as steam separator for steam produced in risers.

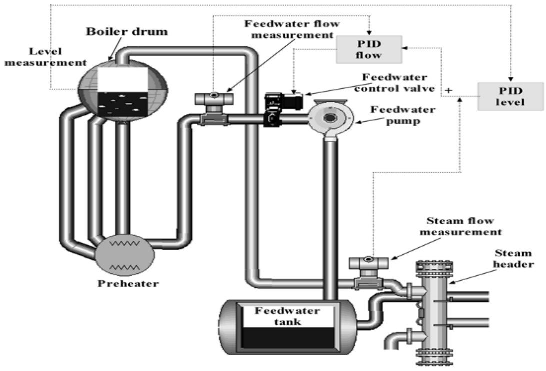
The second control loop observed was combustion control. From the angle of costs the burners control is most valued optimization candidate. Even a small fuel consumption reduction produces significant saving especially if calculated on yearly basis. All conventional controllers used for boiler controls were tuned according to the same criteria according to which the bandwidth was to be maximized without unnecessary wear of the drives and without introducing greater instability in control loops.

2.2. Drum pressure:

Conventional control model usually consists of one component for simpler and smaller boiler to tri-component control for medium to bigger drum type boilers. From the control point of view, start-up problems of conventional tri-component control schema shown on Fig 2 can be solved by the use of a pressure controller in start-up and shutdown conditions and transfer to tri-component control when production of steam and flow of feed-water gets stable. In the presented expert fuzzy control model, same variables are used with addition of an extra variable: steam demand. This variable is connected with pressure just before steam header and in normal work conditions; it is the same as the pressure at steam header. Drag force of boiler steam and fire demand is the change of pressure at steam header.

When pressure is dropping consumers are spending more steam and the response of boiler is the following: fire is increasing with increased air and fuel input, more bubbles of steam are formed inside of boiler drum and false presentation of real situation if we look only level of water in drum. There is less water than is presented through at the level measurement.

Inverse situation is when steam demand is dropping: decreased fire is producing less steam in steam tubes and drum is automatically showing lower level of water that logically should be.



3. Modeling in Simulink :

First of all we could try to prepare a base model of the boiler with special set point. These are heat quantity and feed water flow as the inputs, and the Drum pressure and Steam flow rate as the outputs and subsequently we can observe the situation of outputs and their features as instance response time.

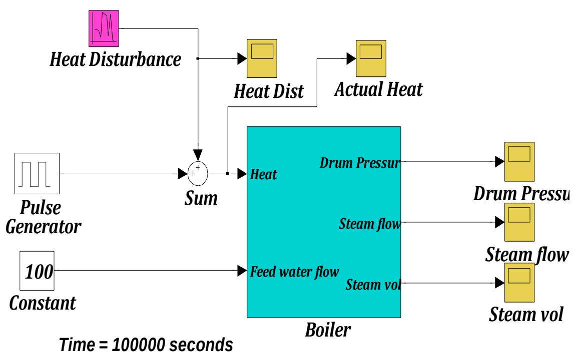


Fig.3. Basic Model

We have defined a heat disturbance at 2000kj rate as a compounded input to achieve a real model. After running, the response time is very high and it is considerable. Response time is approximately 10000 seconds.

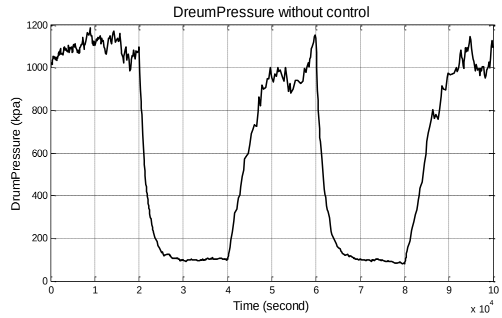


Fig.5. Drum Pressure step response without control

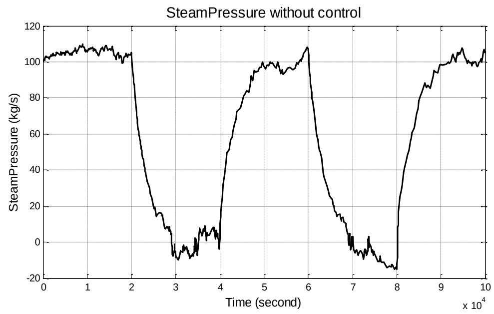


Fig.6. Steam Pressure step response without control

At second step we have examined a model with PID controller and we except all of the features of the model such as response time and set point tracking would be improved.

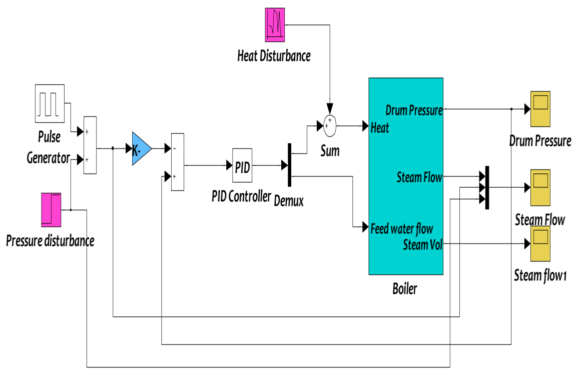


Fig.7. PID controller

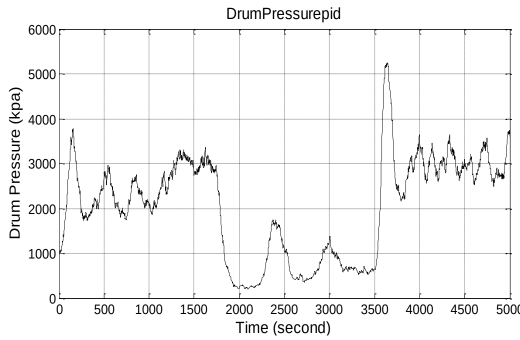


Fig.8. Drum pressure response

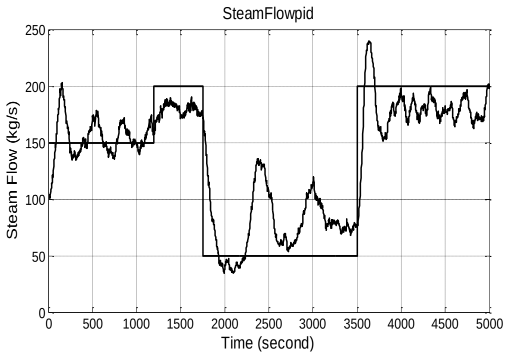


Fig.9. Steam flow response

As shown in figures a quick response time and acceptable set point tracking can be predicted but some features such as steady-state error, overshoot and distortion do not satisfy us to define this model as improved practical model.

Design of a simple fuzzy control unit with error-steam flow as input and heat quantity and drum pressure as outputs can be first step to achieve optimum practical model.

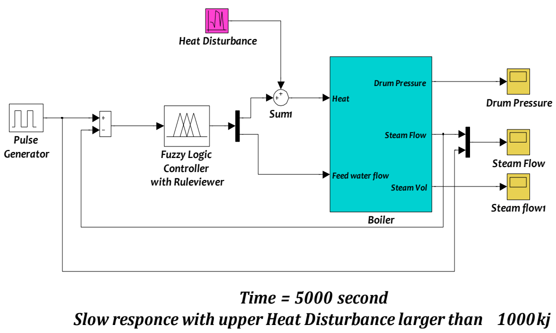


Fig.10. Simple fuzzy control model

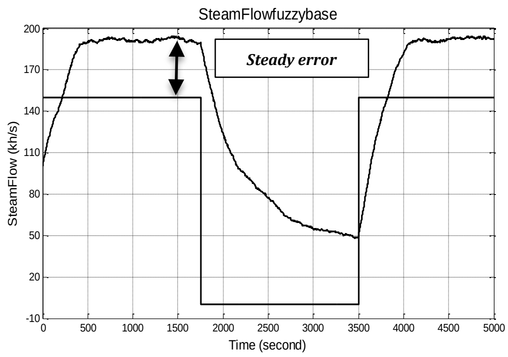


Fig.11. Steam flow fuzzy base response

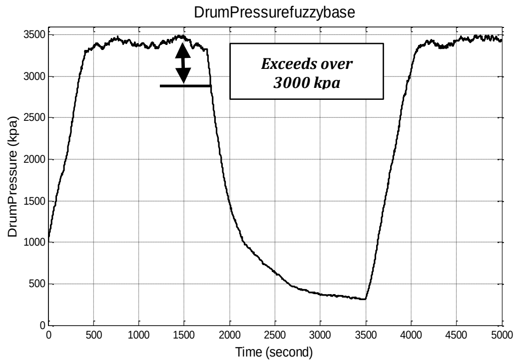


Fig.12. Drum pressure fuzzy base response

We have some problems such as steady-state error response, and drum pressure exceeds over 3000 *kpa* which we cannot control it.

Some features for instance response time and not having the distortion and overshoot are appropriate.

Also along defining of rule bases we could not specify a wide range of control rule bases, due to we have just defined one input as error-steam pressure in this section.

To overcome of these problems we have surveyed other comprehensive fuzzy unit with three inputs such as error-steam, derivate error-steam and drum pressure and the two outputs such as heat quantity and feed water flow rate. This model implicates further accomplishments that we want. In other side we can resolve our objectives problems with control of a new parameter such as Drum pressure consequently we are able to control it.

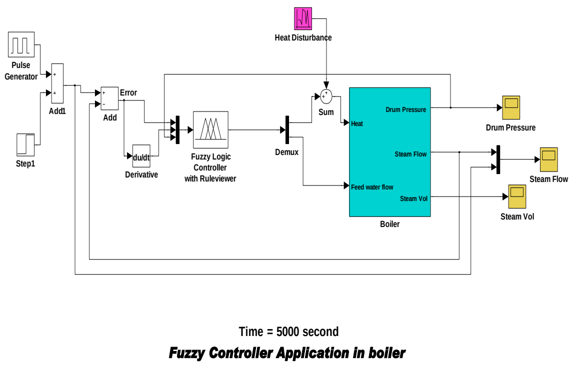


Fig.13. Completed fuzzy controller

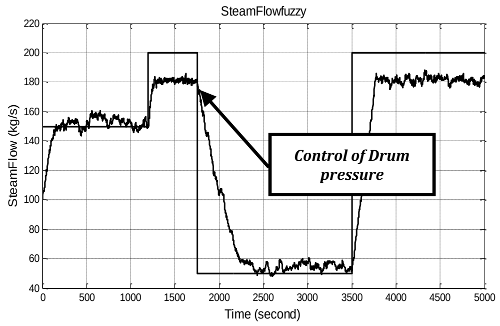


Fig.14. Steam flow fuzzy response

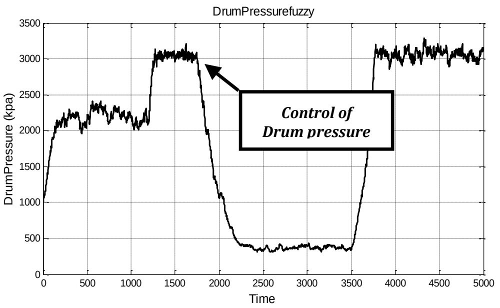


Fig.15. Drum pressure fuzzy response

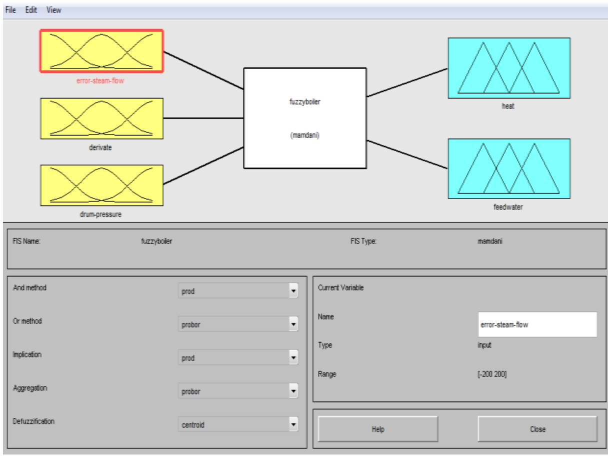


Fig.16. Fuzzy controller schematic

In the last part we have designed and simulated a compound ideal model that is comprised of two original completed controllers as hybrid fuzzy-PID application. In the previous section that was mentioned about fuzzy controller we had observed the reaction of system to the every disturbances or steps is not appropriate perfectly due to its time response.

In the other hand the time approximately takes 200 seconds for tracking step pulse and configures own self to compensate the difference between step pulse and reaction of system.

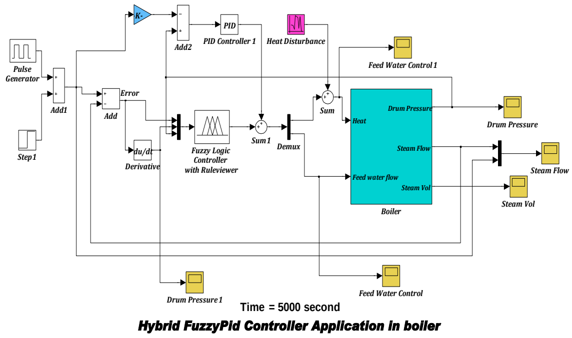


Fig.17. Fuzzy-PID controller schematic

But in this ideal mode we can compensate the rising time and reduce it with using of fuzzy-PID compound controller so we can obtain rising time at least 100 seconds. We have just slight quantity overshoot which can be omitted by changing coefficients of PID controller.

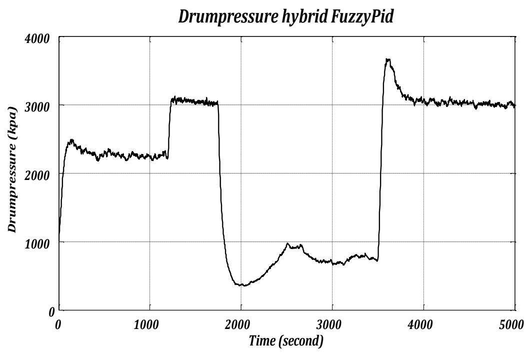


Fig.8. Hybrid fuzzy-PID of drum pressure

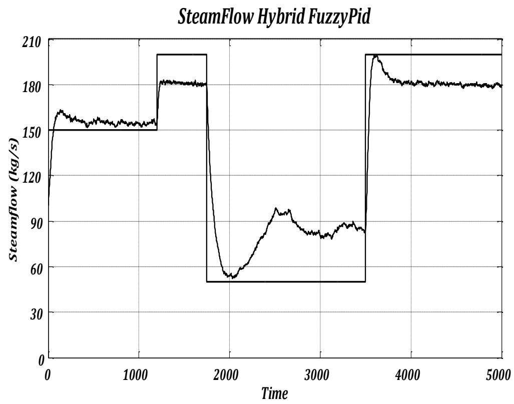


Fig.19. Hybrid fuzzy-PID of steam flow

4. Conclusion

In conclusion the responses had showed to us that the designed PID with adaptive Fuzzy Controller has much faster response than using the classical method. The classical method is good for giving us as the starting point of what are the PID values. However the approached in you can narrow down in getting close to the "optimized" values. An optimized algorithm was implemented in the system to see and study how the system response is.

Rise time, maximum of overshoot, settling time and tracking set points are significant interest measuring factors to achieve an ideal response.

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