Control Of Boiler Steam Temperature Using Different Control Stratagies

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***Abstract*-The power plant subsystems are generally nonlinear and the operating conditions may vary over a wide range subjected to various disturbances and noise. Control of superheated temperature is one of the widely available control problems in thermal power plants, cause it is highly nonlinear and has a long dead time and time lag. The steam temperature is commonly controlled by adjusting the amount of water that is sprayed into the steam header after the steam has passed through the superheater. Traditional PID Proportional Integral Derivative) controllers are difficult to apply in this application due to significant time delay and changing process dynamics as a function of turbine load. This paper present advanced techniques like IMC(Internal Model Controller) ANFIS ,fuzzy to achieve the goal of controlling the superheater steam temperature and illustrates the robustness of designed control law. The merits of fuzzy and ANFIS(Neuro Fuzzy Inference System) is illustrated.The controllers are designed and simulated. Results indicate that the proposed algorithms significantly improve the performance of thermal power plant subsystem. The thermodynamic modelling was performed and the control algorithm was implemented in MATLAB and simulation results are given and the results are compared.**

***Index Terms*-superheater, Mathematical modeling, COHEN and Coon method tuned control, PID,IMC tuned PID ,Fuzzy Logic Control**

I.INTRODUCTION

Proper control of the superheated steam temperature is extremely important to ensure the overall efficiency and safety of the power plant as the temperature in the superheater is the highest in the plant. It is undesirable that the steam temperature is too high as it can damage the superheater and high pressure turbines, or too low as it will lower the efficiency of the plant. In addition excessive swings in steam temperature can lead to increased fatigue in the turbine blades and increased incidence of leaks in the boiler, therefore the superheater steam is to be controlled by adjusting the flow of spray water to within ±10ºC during the transient states and ±5ºC at the steady state. It is also important to reduce the temperature fluctuations inside the superheater as it helps tominimize the mechanical stress that causes microcracks in the unit, in order to prolong the life of unit and to reduce maintenance costs. So steam temperature must be stable to achieve peak turbine efficiency and reduce fatigue in the turbine blades.

There are three main factors that can affect the superheated steam temperature: load, gas flow, and inlet steam temperature of superheater [7]. Other factors include steam flow, feedwater temperature, enthalpy of steam entering the superheater and combustion gas temperature. Unpredictable disturbances such as dust deposition on the furnace walls and sedimentation in the steam pipe can also affect the heat transfer coefficients and consequently the operation of the superheater. However, it is difficult to control a temperature process with adequate performance point due to its nonlinearities, time-varying properties and sensitivity to small disturbances when working near the equivalence point. The proportional integral (PI) and proportional integral derivative (PID) controllers are widely used in many industrial control systems because of its simple structure and robustness. When it comes to the control of nonlinear and multivariable processes, the controller parameters have to be continuously adjusted.The mathematical modelling [1] of superheater used for reheating the steam available is done with some assumptions to simplify the mathematical manipulations. Therefore, the analysis/ investigations carried out with these approximated models do not serve the purpose of providing accurate and realistic results. With the application of fuzzy logic control concept in the design of controllers for superheated steam temperature, more realistic studies can be carriedout. In this proposed work, FLC is considered as one of the intelligent control concepts[9] for application to superheated steam temperature control. Thus, designing a nonlinear controller which is robust in terms of its performance for different operating conditions is essential. There is also increasing interest in the potential of "intelligent" control methods for process applications.

In this paper, the thermodynamic modeling of a temperature control system is obtained. The Cohen and Coon method tuned cascaded PID controller, IMC tuned cascaded PID .Fuzzy Logic Controller is designed and implemented in MATLAB.

II.MODELLING OF SYSTEM

Black Box Modeling or empirical modeling is considered here. Black-box modeling is usually a trial-and-error process, which estimate the parameters of various structures and compare the results. Typically, start with the simple linear model structure and progress to more complex structures.

The transfer fucntions for superheater [2] and desuperheaterwas dentified. By Cohen Coon method,the parameters Kp,Ki,Kd was estimated. The transfer functions obtained were:-

For superheater:-

$$G_s(s) = \frac{100}{s+1} \qquad (1)$$

For desuperheater:-

$$G_d(s) = \frac{3}{s+2} \qquad (2)$$

The overall transfer function is:-

$$G(s) = \frac{300}{(s+1)^2(s+2)} \qquad (3)$$

III.. COHEN AND COON OPEN LOOP TUNING OF PID

PID controller calculates an "error" value as the difference between a measured process variable and a desired setpoint. The controller attempts to minimize the error by adjusting the control inputs. Types of controller tuning methods include the trial and error method, and process reaction curve methods. The most common classical controller tuning methods are the ZieglerNichols and Cohen-Coon methods. The Cohen-Coon is typically used for open loop systems.PID gain values are obtained using the Cohen and Coon open loop formulae-

For primary controller,

K_P=0.049490, K_i=0.059770, K_d=0.0077612

For secondary controller,

K_p= 83.0959, K_i = 0.010285, K_d= 0.10588

IV.DIFFERENT CONTROL STRATAGIES

4.1 IMC TUNED CASCADED PID

Internal model control tuning also referred as Lambda tuning method offers a robust alternative tuning aiming for speed. The tuning is very robust meaning that the closed loop will remain stable even if the process characteristics change dramatically. Lambda tuning is a form of internal model control (IMC) that endows a PI controller with the ability to generate smooth, non-oscillatory control efforts when responding to changes in the set point. The IMC based tuning parameters for PID controller can be obtained by determining the controller equation.

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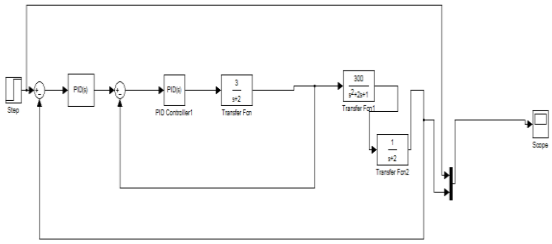

Fig.1Simulink using controlling steam temperature using IMC based PID

A setpoint of 490 is given and the results are observed.

4.2 THE PROPOSED FUZZY LOGIC CONTROL

With the aim of compensating system nonlinearities, the use of fuzzy controllers might be a proper solution to control nonlinear industrial plants. This work proposes a fuzzy system to control the boiler steam temperature process. The controller structure has a feedback loop and a single inputs: error. The fuzzy output is the control signal to operate the spray value of water flow.

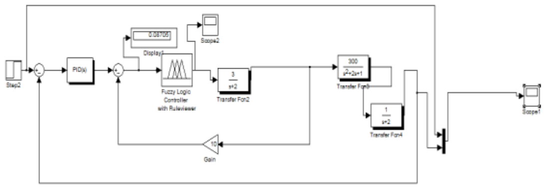

Fig.2 Simulink using fuzzy for temperature control

A setpoint of 490 is given and the results are observed.

4.3 FUZZY VARIABLES AND INFERENCE SYSTEM

The input fuzzy variable is error (Err) have five triangular membership functions.-

VS(Verysmall),S(Small),M(Medium),L(Large),VL(VeryLarge).The output*(controller output)* has 5 linear membership functions named *VS(Very small),S(Small),M(Medium),L(Large),VL(VeryLarge)*.

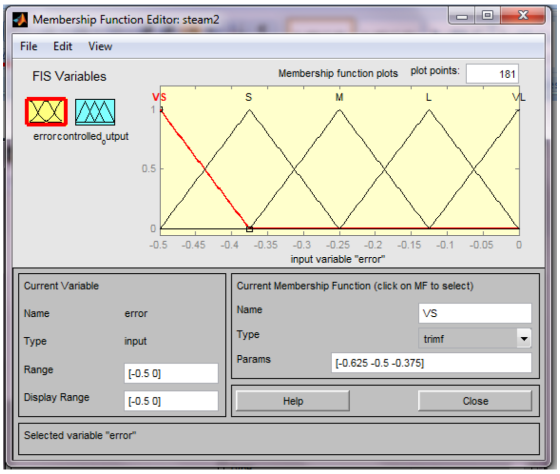

Fig.3-Input membership functions

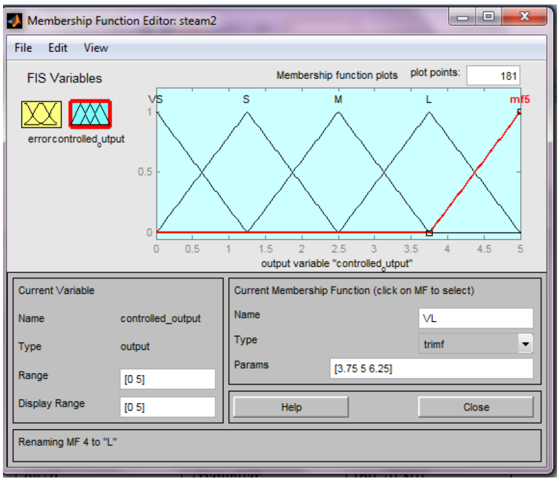

Fig. 4-Output membership functions

Table 1-Rules of FIS

If (error is VS) then (output1 is VS)
If (error is S) then (output1 is S)
If (error is M) then (output1 is M)
If (error is L) then (output1 is L)
If (error is VL)then(output is VL)

4.4 ANFIS BASED DESIGN OF CONTROLLER

Adaptive Network based Fuzzy Inference System (ANFIS) can play a particularly important role in the induction of rules from observations. powerful alternative strategy to fuzzy systems[3], since it is capable of learning. It provides If-Then fuzzy rules in linguistic and explicit forms. Measurements were made on the process variables of the superheated steam temperature control process. The readings were taken at every second. The 120 readings corresponding to the data set for one day were used as the training data for the ANFIS[4]. The data set was normalized before being utilized. By considering the number of membership functions to be three, for each process variable and by choosing back propagation algorithm in combination with a least squares type of method, the ANFIS system was trained. The performances of error and trained epochs of ANFIS for different types membership functions are illustrated.

V. RESULT ANALYSIS

5.1 CASCADED PID CONTROLLER

The cascaded PID is designed and simulated .A temperature value of 490 given as setpoint for which the response was obtained.The PID parameters were tuned by using Cohen and Coon method.

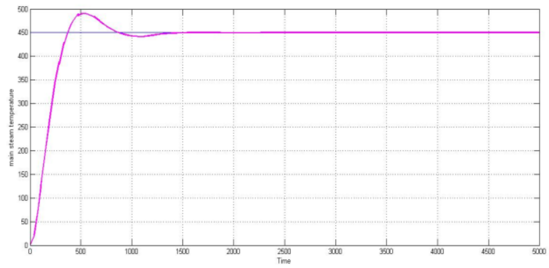

Fig.5- Cascaded PID response for temperature

5.2 IMC BASED CASCADED PID CONTROLLER

The primary and secondary controllers were tuned using IMC based tuning method [6] to achieve robustnesss .A setpoint of 490 was given and the responses are obtained.

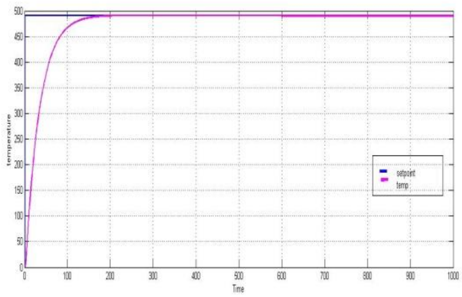

Fig 6- IMC based cascaded PID response for temperature

5.3 *Fuzzy Logic Controller*

A fuzzy logic controller was designed with the necessaru input and output membership functions and rules.A setpoint of 490 was given for steam temperature for which the responses was obtained.

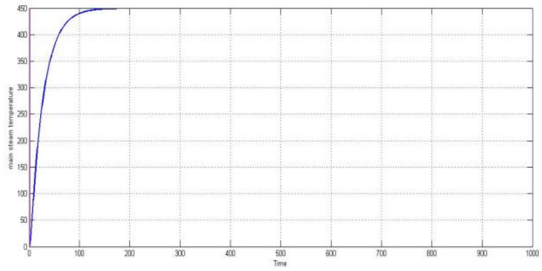

Fig.7- fuzzy response for controlling water flow

5.4 *ANFIS*

A ANFIS was designed with the training data obtained from real time.120 samples of data was taken as training data for the spray water flow values for steam temperature. ANFIS can be used in place of fuzzy controller for automatic updating of membership functions. The output data versus training data was observed in the following responses. The error rate is also reduced.

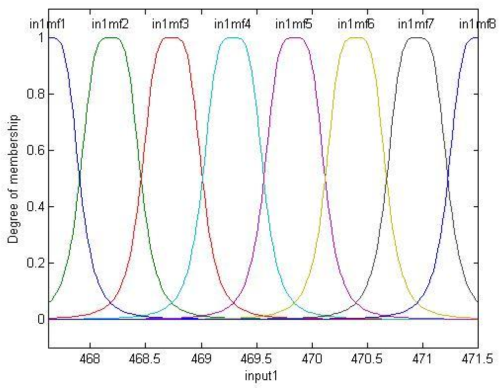

Fig.8-Degree of membership function for input

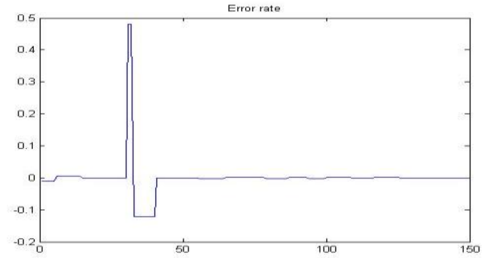

Fig.9- Rate of error

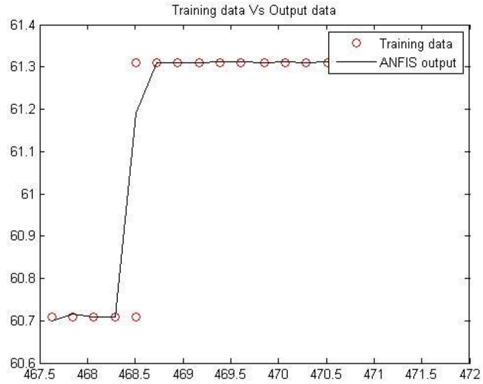

Fig.10- Output data Versus Training data

VI. COMPARISON OF RESULTS

Table 2 -Comparison of results for set point=490 for boiler steam temperature control process.

S.No	**Parameters**	**PID controller**	**IMC based PID**	**Fuzzy logic controller**
1	Settling Time(sec)	1000	300	120
2	Rise time(sec)	190	75	60
3	Overshoot (%)	8	3.8	2
4	Integral Absolute Error (IAE)	63.05	40.5	20.36

The comparative studies between different controllers in terms of settling time, rise time, peak overshoot and integral absolute error for steam temperature is performed. According to the studies after experimentation fuzzy performs faster with less error where fuzzy has best performance for the particular process.

VII. CONCLUSION AND FUTURE WORK

The modeling and control of the superheated steam temperature control process of a boiler has been attempted. The process that has been taken up as case study is the superheated steam temperature control process. Real time data sets were obtained by measurements of the process variables of the process. These data sets form the basis of the various schemes reported in this thesis. PID, ,IMC based cascaded PID, fuzzy and ANFIS[9] was designed for the controlling of steam temperature. The results were analyzed. Fuzzy provides better results than cascaded PID..Fuzzy controller can be replaced by ANFIS for control of spray water flow for automatic updating membership functions. The output data of ANFIS is compared with training data. A hybrid scheme using GA with SA, for the determination of the PID controller can be developed. The procedure can be applied for the optimization of the PID controller parameters for the various transfer function models of the superheated steam temperature control process. Wiener Hammerstein Cascade process model or ANN(artificial neural networks) models can also be developed for the superheating process. The developed models can be realizable in real world.Due to the presence of dead time and inverse response, the system is affected. Hence smith predictor and gain scheduling can be implemented to get better responses.

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BIBLIOGRAPHY

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REFERENCES

[1] Jaya S. Lahane and Meera A.Khandekar," System Identification and Controller Design for Boiler and Heat Exchanger Set-Up", International Journal of Advanced Research in Electrical,Electronics and Instrumentation Engineering, Vol. 3, Issue 7,2014.

[2] Orosun Rapheal and Adamu Sunusi Sani," Modeling And Controller Design Of An Industrial Oil-Fired Boiler Plant", International Journal of Advances in Engineering & Technology, Vol. 3, Issue 1, pp. 534-541,2012.

[3] Subhash Gupta, L. Rajaji, Kalika S.," ANFIS Based Design of Controller for Superheated Steam Temperature Non Linear Control Process",International Journal of Engineering and Innovative Technology, Vol.2, Issue 6, 2012.

[4] Subodh Panda, Ajit Kumar Patro, Dr. (Mrs.) Sarada Baboo, "Adaptive Neuro-Fuzzy Controller For Thermal Power Plant Optimization", International Journal Of Emerging Trends & Technology In Computer Science , Vol.2, Issue 6, 2013.

[5] Imre Benyó, Jenő Kovács, Jari Mononen and Urpo Kortela,," Modelling Of Steam Temperature Dynamics Of A Superheater ",Proceedings 16th European Simulation Symposium,2004

[6] Ali Reza Mehrabian *and* Morteza Mohammad-Zaheri, "Design of a Genetic Algorithm-Based Steam Temperature Controller in Thermal Power

Plants", *International Journal of Computational Intelligence*, Vol. 2, No. 1, pp. 48-52, 2005
[7] S.Vijayalakshmi, D.Manamalli, T.Narayani," Model Identification for Industrial Coal Fired Boiler Based on Linear Parameter Varying Method",International Journal of Engineering and Technology , Vol 5 No 5,2013.
[8] D.Aditya,Dr M Sivakumar," Optimal Stabilizing Controller for Boiler Flow Control using Soft Computing Technique",International Journal of Engineering Research & Technology , Vol. 3 Issue 12, 2014
[9] P. Hari Krishnan, Prathyusha S," Optimization Of Main Boiler Parameters Using Soft Computing Techniques" , International Journal of Research in Engineering and Technology , Vol 03,2014