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Boiler Drum Level Control In Thermal Power Plant

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Abstract: The boiler is a fundamental part of almost all industries. It varies in application from low pressure to high pressure. The proper and safe control of the steam drum water level is the most crucial operation of the boiler. The boiler may get damaged due to overheating, if the level is too low, and also, due to overflow of water, if the level is too high. Therefore, there exists an optimum interface level between steam and water within the boiler drum. The steam boiler drum level is characterized by a high extent of nonlinearity, uncertainty, disturbance and overshoot.. The cascade-three parameters water level control system includes boiler drum water level, steam flow and water supply. Boiler drum water level is controlled by using cascaded Proportional Integral Derivative(PID) controller technique and then optimization is done by using Model Predictive Controller(MPC).Simulations are done in 210MW thermal power plant. The comparative analysis shows the better result when an advanced controller such as MPC is used. MPC has a comparatively less overshoot than PID controller and much faster settling occurs for an MPC , which shows the superiority of MPC.

Keywords: PID Controller, MPC Controller, Process Variables (PV)

I. INTRODUCTION

The water level of boiler drum is one of the crucial control parameters for any process industries, which reflects the control of mainly boiler load and feed water indirectly. If the water level is critically high it results in low drum pressure causing swelling and results in water carryover into the steam piping.. If the water is low then results in high drum pressure causing shrinkage which is severe enough to trip the boiler. The feedwater control system is a three element type, designed to monitor changes in steam flow, water flow and drum level. Steam flow is the rate of steam leaving the boiler - the demand. Water flow is the rate of feedwater flow into the boiler - the supply.

Drum level reflects the amount of water in the boiler - the inventory. With changes in boiler load (steam flow), steam and water flow become unbalanced and water level consequently deviates from the normal position. In such an event, the level controller will adjust the boiler feed water valve position to restore the flow to its set point before the boiler drum liquid level is even affected. The level controller is the primary controller, (sometimes referred to as the master controller) in this cascade, adjusting the set point of the flow controller, which is the secondary controller (sometimes identified as the slave controller).
For measurement of drum level following points must be taken care of:-

(a)Elimination of errors which are attributed in measurement due to fluctuating water level or changing rate of water inflow and steam outflow.

(b)Thermodynamics of pressure and temperature, geometry of the steam drum, and equation of continuity are the parameters to define transmitter calibration.
(c)The zero elevation and span against transmitter specifications must be checked to ensure proper calibration of selected transmitter.

Boiler operating conditions that alter the total volume of water in the boiler cannot be corrected by feed forward control strategy. For example, forced circulation boilers may have steam generating sections that are placed out of service or in service intermittently. The level controller itself must be correct for these unmeasured disturbances using the normal feedback control algorithm. Feedwater flow and steam output flow transmitters are required to find out the difference between the two flows. A drum level transmitter reference is used to control the boiler feed water control valve.

II. TYPES OF BOILER FEED WATER CONTROL

There are different types of control techniques for a boiler feed water control.

A. Single Element Control
Single Element Drum Level Control is the simplest and least effective method to regulate the water level. It is mainly used for boilers with modest change requirement and start-up operation. The process variable coming out from the drum level transmitter is compared to the set

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point and a deviation value is produced. This signal is fed into the controller and make corrective action.

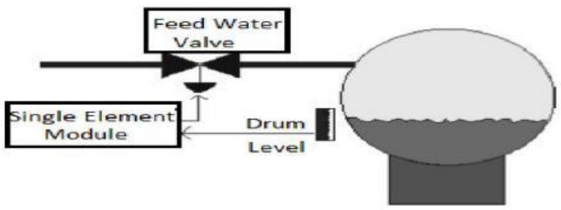

Fig1: Single Element Control

B. Two Element Control

Two Element Drum Level Control includes steam flow as a feed forward element Two element control system has two variables, drum level and steam flow to manipulate the feed water control valve. This strategy compensate the imbalance between feed water mass flow and steam mass flow out into the drum. It is adequate for load changes of moderate speed and magnitude. It has some drawbacks i.e. it can use on a single boiler with a single feed water pump using a constant feed water pressure, it cannot adjust for pressure or load disturbances in the feed water system and it cannot eliminate phasing interaction between various portions of the process.

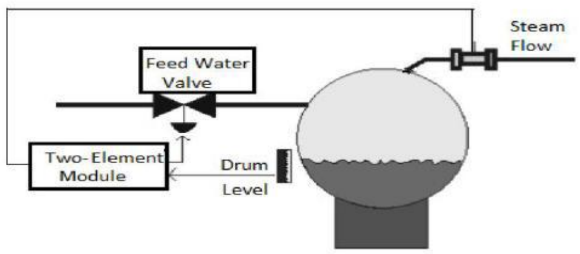

Fig 2: Two Element Control

C. Three Element Control

Three element control strategy is the commonly used method to control the drum water level. This method is ideally suited for a boiler plant, which consists of multiple boilers with multiple feed water pumps. By using cascade control mechanism, level element act as primary loop, flow element acts as the secondary loop and steam flow acts as the feed forward controller. This strategy attempts to compensate the changes or disturbance in steam flow and feed water flow.

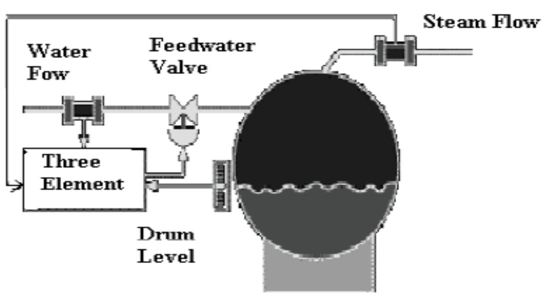

Fig3: Three Element Control

III. PROBLEM FORMULATION

A boiler of a thermal power plant is taken and the drum level control of the boiler is achieved using conventional PID controller and compared with MPC. The comparison of both the controller performance is analyzed

IV.MATHEMATICAL MODELLING OF BOILER DRUM

Mass and energy conservation equations are written for the drum in its entirety. The entire contents of the drum are assumed to be in the saturation state.

A. Mass and Energy Balance

The boiler drum level ld responds in an integrating manner to the steam flow Fd and feed water flow Few . Basically, the drum model describes the dynamics of drum water volume Vdw in terms of the mass and energy conversion equations. A separate relationship between Vdw and ld is derived then from the geometry of the drum and this equation is solved using the Newton-Raphson method to obtain ld. The mass and energy balance equations for the boiler drum are derived as follows :

Mass Balance:

Rate of change of mass of steam and water in the drum = Feed water flow to the drum – steam flow from the drum

$$\frac{d}{dt}[(V_d - V_{dw})\rho_d + V_{dw}\rho_{dw}] = F_{ew} - F_d \qquad (1)$$

Energy Balance:

Rate of change of energy of steam and water in the drum = Total energy of steam and water mixture after leaving the water walls - Energy of drum water - Energy of drum steam

$$\frac{d}{dt}[(V_d - V_{dw})\rho_d h_d + V_{dw}\rho_{dw}h_{dw}] = F_D h_w - (F_D - F_{ew})h_{dw} - F_D h_d \qquad (2)$$

The differential equations obtained are

$$\frac{d\rho_d}{dt} = \frac{1}{q_2 q_4 \rho_{dw}}\{\rho_d F_{ew} - \rho_{dw} F_d + X_q F_D(\rho_{dw} - \rho_d)\} \qquad (3)$$

$$\frac{dV_{dw}}{dt} = \frac{1}{q_4 \rho_{dw}}\{(1 + q_3)F_{ew} - q_3 F_d + X_q F_D\} \qquad (4)$$

where Xq is the steam quality.

The drum level ld is computed using Newton-Raphson Method. [3]

$$l_d(k+1) = l_d(k) - \frac{f(l_d(k))}{f'(l_d(k))} \qquad (5)$$

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V. BOILER DRUM LEVEL MODEL WITH CONVENTIONAL CONTROL SYSTEM

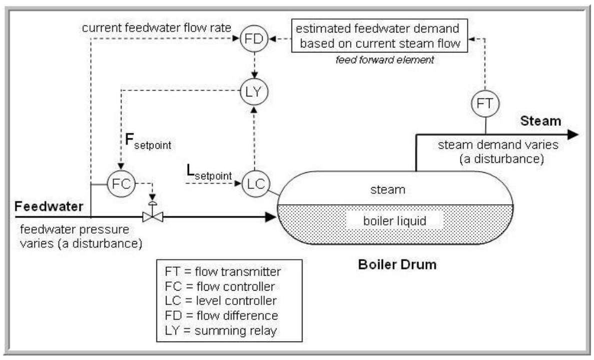

Fig4: Feed Water Flow Control System

Most of the medium and high pressure boilers today use a "3-element" boiler control strategy. The term "3-element control" refers to the three process variables(PV's) that are measured to effect control of the boiler feed water control valve. These measured PVs are:

-Liquid level in the boiler drum
-Flow of feed water to the boiler drum
-Flow of steam leaving the boiler drum
Fig 4 shows a cascaded control for 3-element boiler drum level control.

The feed controller will immediately sense any variations in the supply conditions which produce a change in feed water flow. The flow controller will adjust the boiler feed water valve position to restore the flow to its set point before the boiler drum liquid level is even affected.

The level controller is the primary controller also known as master controller in this cascade, adjusting the set point of the flow controller, which is the secondary controller, referred as slave controller.

The third element is the flow of steam leaving the steam drum. The variation in demand from the steam header is the most common disturbance to the boiler level control system in an industrial steam system.

The boiler level control scheme do not feed the steam flow signal directly. Instead, the difference between the outlet steam flow and the inlet water flow is calculated. The difference value is directly added to the set point signal to the feed water flow controller. Therefore, if the steam flow out of the boiler is suddenly increased by the startup of a turbine, for example, the set point to the feed water flow controller is increased by exactly the amount of the measured steam flow increase.

VI. MODEL DEVELOPMENT AND SIMULATION USING MATLAB / SIMULINK

The differential equations (3) and (4) are solved and simulation studies are carried out with the help of the nominal values of the boiler drum variables and parameters collected from the 210 MW thermal power plant boiler during the study. The data pertaining to these drum variables and parameters are represented in Table1. Open loop step response tests are conducted on the model in order to determine its suitability to control application.

Table 1 Nominal values of Boiler Drum variables

Variables	Description	Value	Unit
ρ_d	Density of drum steam	8.221 x 10^{-5}	Kg/cm3
ρ_{dw}	Density of water in drum	63.097 x 10^{-5}	Kg/sec
Few	Feedwater flow	163.5023	Kcal/kg
hew	Enthalpy of feedwater	131.97	Kg/sec
Fd	Steam flow from drum	175.014	Kg/sec
ld	Drum level	88.90	Cm
pd	Steam pressure in the drum	176.8	Kg/cm2
Td	Saturated steam temperature	354	^oC
Xq	Steam quality	0.95	-
δ hd	Gradient of drum steam enthalpy	-657954.52	Kcal-cm3/Kg2
δ hdw	Gradient of water enthalpy at drum Conditions	1128547.11	Kcal-cm3 /Kg2
$\delta_{\rho dw}$	Gradient of drum steam density	-2.0132	-
Vd	Volume of drum	40185469.46	cm^3
Vdw	Drum water volume	20092734.73	cm^3
l	Length of drum	1500	cm
r	Radius of drum	88.9	cm

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Input, output and state variables of the boiler drum model is represented in Figure 5

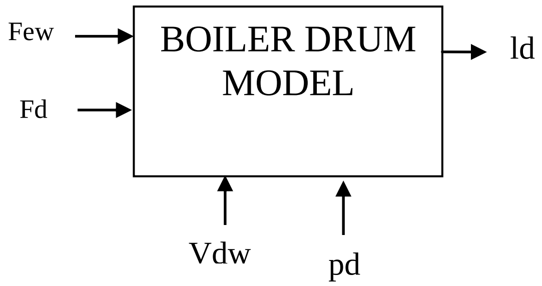

Fig 5: Block diagram of boiler drum model screen and on a black-and-white hardcopy

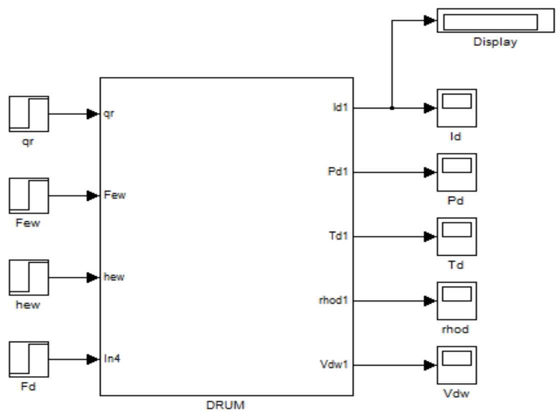

Fig 6: Boiler Drum Model Simulink

VII. SIMULATION RESULTS

The Boiler Drum water level control system is modeled in this paper, and is simulated with conventional PID controller and an advanced control technique such as MPC using MATLAB/SIMULINK environment. The simulations are carried out with the nominal values of a 210MW thermal power plant. In both cases feed water flow and steam flow is considered and the corresponding variations in drum level and drum water volume is analyzed.

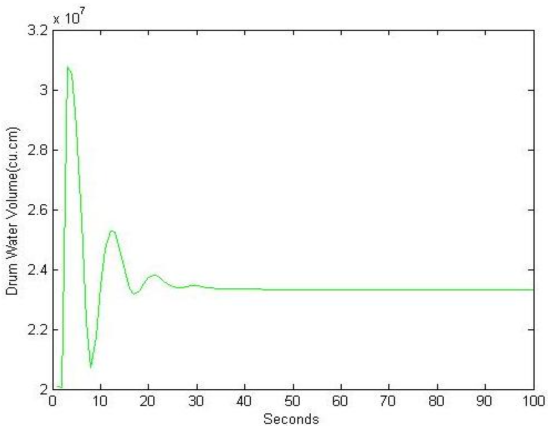

Fig 7: Regulation of boiler drum water volume using PID controller

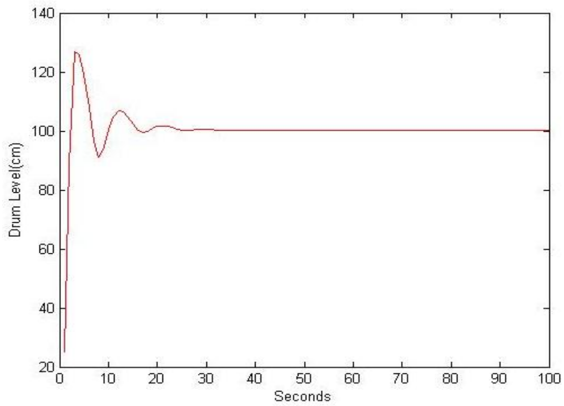

Fig 8: Regulation of boiler drum level using PID controller

Using the described controller design, boiler drum water level control of boiler drum is implemented using SIMULINK. We get the output response shown in fig 7, and fig.8. From the response of PID Control, it is found out that the settling time and overshoot is high. To improve the response of PID controller, here we use an advanced controller MPC.

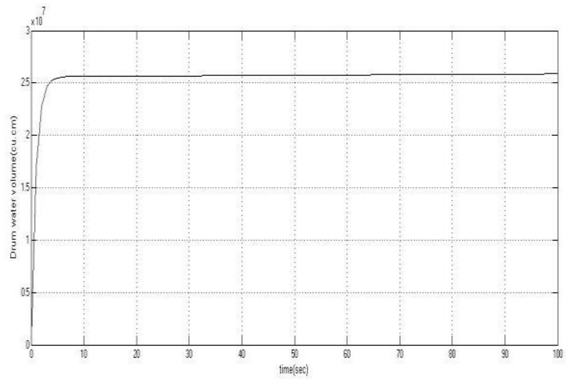

Fig:9 Regulation of boiler drum drum water volume using MPC

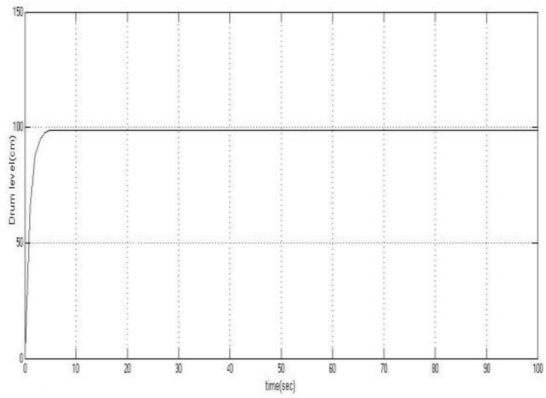

Fig:10 Regulation of boiler drum level using MPC

Above fig 9 and Fig 8 shows the simulation of boiler drum level and volume using MPC. A better response is obtained with reduced settling time and overshoot compared to PID controller.

VIII. CONCLUSION

In this paper, PID controller and MPC are designed for the regulation of boiler drum level. This work basically evaluate the performance of PID and MPC for boiler drum level control system. The simulation result shows the performance of proposed control system and the comparison between both the control strategies are studied. From Simulation response the performance of MPC is more accurate and better than PID controller. With MPC a faster settling time is obtained without any overshoot.

REFERENCES

[1] Damian Flynn: Thermal Power Plant Simulation and control, The Institution of Electrical Engineers (2003).

[2] Rominus Valsalam S: Modelling, simulation and adaptive optimal control of a boiler, PhD thesis (2003)

[3] David, A. C: An introduction to genetic algorithms for scientists and engineers, World Scientific Publishing Co. Pte. Ltd (1999).

[4] Wei, J. L. Wang, J. H. and Wu, Q. H.: Coal mill modelling using evolutionary computation technique and its on-line implementation, Control 2004,University of Bath U.K,ID-080 (2004).

[5] Astrom K.J and Bell R.D: Drum boiler Dynamics, Automatica, No.36, pp. 363-378, (2000)

[6] Flymn ME and Malley M.J.O: A drum boiler model for long term power system dynamic simulation, IEEE transactions on Power Systems, Vol 14, No.1 (1999)