An Experimental Design of Controlling Temperature and Pressure for Coal Fired Fluidized Bed Boiler on DCS

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Abstract

This paper is based on the design and on-line testing of control logics for coal fired fluidized bed boiler-5 of captive power plant of Century Pulp and Paper, Lalkua, Nainital. Because of the rapid load fluctuations, it became difficult to maintain the steam pressure by controlling the bed temperature of the boiler. For this reason boiler bed was divided into four compartments and the control logics has been developed to maintain the steam pressure with in the range of 61.5kg/cm² to 64.5kg/cm² and bed temperature between 800°C to 925°C by using the capabilities of TDC-3000 distributed control system (DCS) supplied by Tata Honeywell, Pune. The experimental study showed that implementation of these logics, and DCS was able to maintain the steam pressure with a deviation of ±1.5kg/cm² from set point and temperature within the normal limits automatically. This has helped in reducing the coal consumption, which has improved the overall productivity.

INTRODUCTION

Steam boilers are used industrially both as a power source and in processing. They consist of a furnace, where air and fuel are combined and burned to produce combustion gases, and a water tube system, the contents of which are heated by these gases. The tubes are connected to the steam drum where the generated water vapour is withdrawn. The steam drum pressure is an indication of the balance between the inflow and the outflow of heat. Therefore by controlling the steam pressure one can establish a balance between the demand for steam (process load) and the supply of the steam (firing rate). A change in steam pressure will result from a change in firing rate only after a delay of a few seconds to a minute, depending on the boiler and load level (1). The use of fluidized bed boiler (FBB) has been increasing in the process and utility industries for generating steam. It is reported in the literature that the FBB will command more than 50% of the new market for industrial boilers. This is due to their advantages, such as, fuel flexibility, efficient sulphur removal, low NOx emission and good turndown. Zaidi et. al. (2) described the current status of the NOx formation and combustion control techniques to reduce NOx emission from industrial boiler. A case study on design and troubleshooting of the boiler has been given in (3). Biggs et al. (4) have developed a model to address optimization of overhauls by identifying the risk of failure associated with maintenance, operation and engineering practices applied to steam turbines for pulp and paper industry.

Over the past 50 years, rising labour costs and increasing global competition have demanded greater industrial efficiency and product quality. These demands fostered the development of complex process that required distributed control system (DCS) to run them because of its fast response, good controllability and capability to handle complex problems (5). Today DCS has achieved the global acceptance and are essential for the success of any plant operation.

The capabilities of TDC-3000 DCS supplied by Tata Honeywell, Pune, is used to develop the control logic to control the bed temperature and steam pressure by limiting the firing of the fuel and air. The process instrumentation (PI) diagram of combustion control for coal fired FBB is shown in the Fig. 1. In the present scheme, if the bed temperature is within the normal bed limits, the entire controlling is done by the pressure controller, while if bed temperature exceeds this limit then temperature controller take care. For this purpose PID controller has been developed in the TDC-3000 DCS. The output of temperature and pressure controllers are going in the selector switch, developed in the DCS. The output of the selector switch controls the speed of the fuel feeder. The boiler is divided into four compartments and each compartment has two fuel feeders. The control logics to achieve the above condition are discussed in proceeding articles.

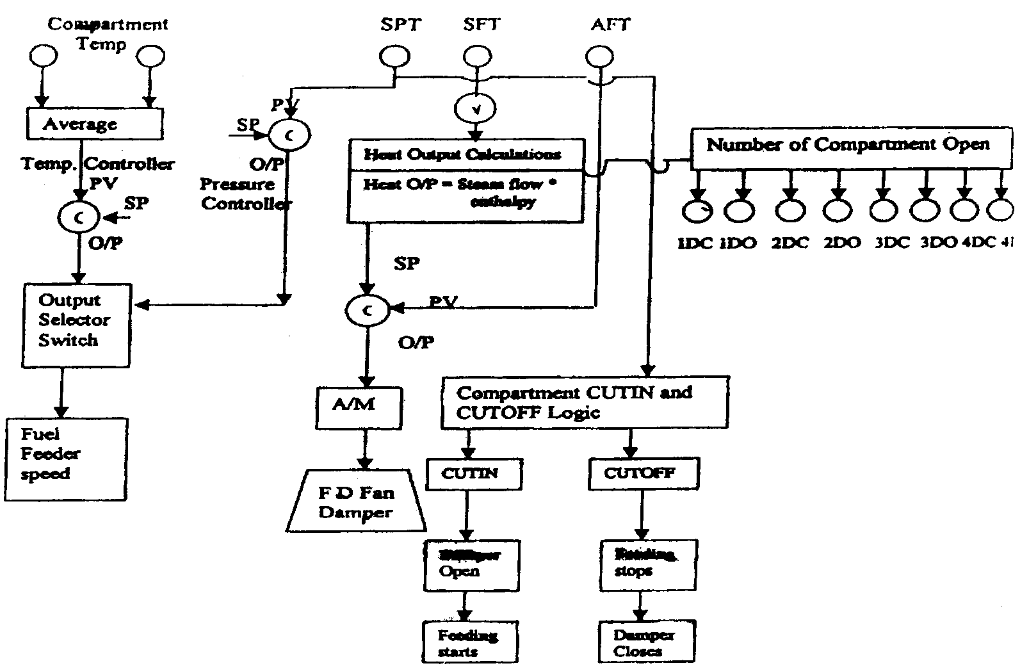
Design of control logics

The control logics for combustion control has been developed for the Boiler No.-5 of the Century Pulp and Paper, Lalkua, Nainital . The boiler was supplied by Cethar Vessels Ltd. Some important parameters of the boilers are :

Evaporation	50t/hr
Super heater outlet pressure	62Kg/cm^2
Super heater outlet temperature	48^{0}C
Feed water temperature	170^{0}C

Conditions for logic design

- The bed temperature of the operating compartment should be in the range of 800^{0}C to 925^{0}C.



Note :

1 DC = Compartment-1 Damper close
1 DO = Compartment-1 Damper open
2 DC = Compartment-2 Damper close
2 DO = Compartment-2 Damper open
3 DC = Compartment-3 Damper close
3 DO = Compartment-3 Damper open
4 DC = Compartment-4 Damper close
4 DO = Compartment-4 Damper open
SPT = Steam Pressure Transmitter
SFT = Steam Flow Transmitter
AFT = Air Flow Transmitter

Fig. 1- Block Diagram of Combustion Control Logic for Fluidized Bed Boiler.

- The combustion control loop should be by passed during following conditions.

(i) During the boiler start-up until all the compartments are heated up to a minimum temperature.

(ii) When the number of compartments in operation are less than or equal to two.

- During the turn down of compartments for the purposes of matching of the steam demand. The combustion control loop should be limited to minimum two-compartment operation.

- For minimum and maximum heat output value (based on steam flow, pressure & temperature) the airflow value required is fixed and the same is taken from the literature supplied by the boiler manufacturer.

- When the boiler heat output varies (between minimum and maximum), accordingly the airflow also varies. The rpm of the feeders is to be adjusted to maintain the bed temperature within the range of 800°C to 925°C, based on the signal from steam pressure controller. The bed temperature readings in the operating compartments may be averaged for this purpose. However, if the temperature difference between the readings of the thermocouple of the same compartment is more than 100°C, the reading of the thermocouple indicating lower temperature is disregarded.

- Conditions of output selector switch:

(i) When the bed temperature is above 950°C, Fuel feeder should trip.

(ii) If bed temperature is less than 800°C, the speed increases by 10rpm repeatedly after every 30 seconds, until a bed temperature of 800°C is attained.

(iii) If bed temperature is above 925°C, the speed decreases by 10rpm repeatedly after time interval of 30 seconds, until a bed temperature of 925°C is attained.

(iv) Output selector switch logic will select the maximum output when demand is high or bed temperature is in the range of 600°C and 830°C or both the conditions exit.

- Under normal conditions steam pressure controller controls fuel feeder and feeder speed depends upon steam pressure deviation.

- Airflow controller accepts signal from the airflow transmitter, which acts as process value and heat output value (depends upon steam flow) as set point. The output of airflow controller is fed to power Cylinder open/close F.D. damper in order to match with required airflow.

- If the boiler bed temperature exceeds 925°C, the airflow controller gets isolated and airflow selects the maximum flow in order to cool the bed.

- The slumping or reactivation of a compartment is done on the basis of airflow and steam flow. The reactivation of compartment is done automatically only if the temperature of the compartment to be reactivated is more then 600°C else the reactivation of compartment should be done manually.

- The slumping sequence of the compartments are:

(i) Reduce fuel feeder rpm to zero.

(ii) After one minute, close fluidizing air damper of the compartment to be slumped.

- Reactivation of the compartment.

(i) Open the fluidizing air dampers.

(ii) The coal feeders shall be switched on only after the bed temperature reaches 600°C in the compartment during the compartment cut in logic. The feeder should be started from starter.

- On the basis of above conditions control logics has been developed and implemented on DCS.

Control Logic-1

The control logic (Fig. 2) for compartment-1 has been developed to control the speed of the fuel

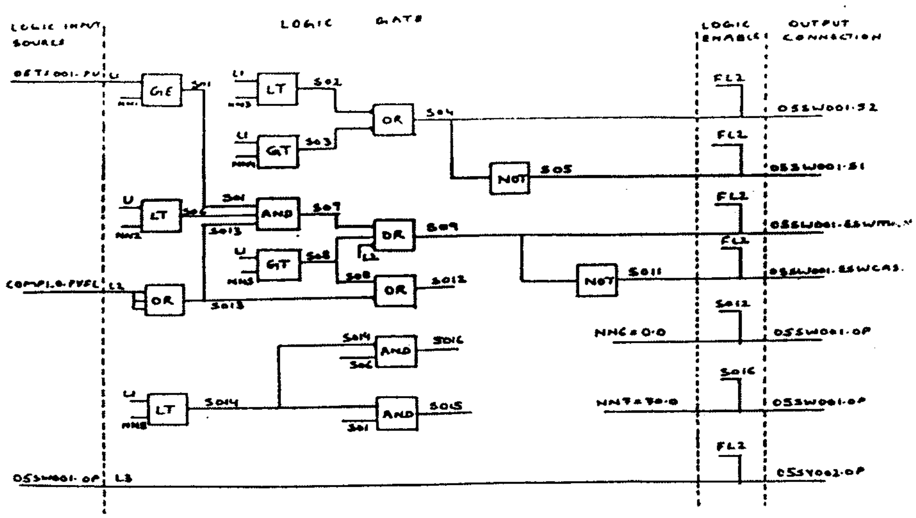


Fig. 2- Compartment-1 fuel feeder speed control logic.

feeder according to varition in temperature and pressure conditions. After implementation of the logic-1, it has been observed that:

- If the temperature of the compartment is greater than or equal to 650°C, but less then 785°C and compartment[1] is open then SO_7 will be high, this will put selector switch in mannual mode.
- If the temperature is greater than 925°C then SO_8 will be high this will put selector switch is in manual mode. This means fuel feeding will be minimum i.e. 200 rpm.
- If the temperature is less than 800°C or greater than 910°C then SO_4 will be high, which means that temperature controller (05SW001.S2) controls the fuel feeding.
- If compartment temperature falls below 785°C then SO_6 will be high the speed of the fuel feeder (05SW001.OP) will become maximum i.e. 70%.
- If compartment temperature is between 800°C and 925°C then SO_5 will be high, then pressure controller controls the fuel feeding.

The various input and output sources and numeric values defined in the Fig. 2 are:

Input source

L1: 05TX001.PV (Maximum of two bed temperature of the compartment-1.

L2: COMP1_O.PVFL (Compartment-1 open flag)

L3: 05SW00I.OP (Selector switch for fuel feeder)

Output source

05SW001.S2 (Output of the selector switch of compartment-1 in temperature controller mode).

05SW001.S1 (Output of the selector switch of compartment-1 in pressure controller mode).

05SW001.ESWMAN (Selector switch in manual mode).

05SW001.OP (Output of selector switch for fuel feeder)

05SW001.ESWCAS (Selector switch in cascade mode).

05SY002.OP (Selector switch output to fuel feeder)

05SW001.OP (Output to selector switch).

Numeric values

NN1=650°C, NN2=785°C, NN3=800°C, NN4=910°C, NN5=925°C, NN6=0.0, NN7=70.0, NN8=700°C.

Similarly logic has been developed for the fuel feeding in the compartment-2.

Control Logic-2

The control logic (Fig. 3) for compartment-3 has been developed to control the fuel feeding according to varition in temperature and pressure conditions. After implementation of the logic-2, it has been observed that:

- If the temperature of the compartment-3 is between 790°C and 925°C than fuel feeding is controlled by the pressure controller (05SW003.S1).
- When the temperature of the compartment-3 (L1) is greater than 925°C or when total air flow (L4) falls below 40.4m^3/hr and compartment-3 is open than SO_{10} will be high, this will put selector switch in manual mode i.e. fuel feeding is done manually by the process engineer.
- When the temperature of the compartment-3 is between 650°C and 790°C then SO_4 will be high i.e. temperature controller (05SW003.S2) will control fuel feeding in the compartment.
- If the temperature of the compartment-3 is between 650°C and 740°C then SO_{10} will be high this will put selector switch in manual mode means speed of the fuel feeder will be maximum i.e. 70%.

The various input and output sources and numeric values defined in the Fig. 3 are:

Input source

The various inputs used in this logic are:

L1: 05TX003.PV (Higher of the two bed temperature of the compartment-3).

L3: COMP_O.PVEL (Compartment-3 open flag)

L4: 05FT003.OP (Selector switch for fuel feeder)

L5: 05SW003.PV (Total airflow)

Output source

05SW003.S2 (Output of selector switch is dependent on the temperature controller).

05SW002.S1 (Output of selector switch is dependent on pressure controller_

05SW003.ESWMAN (Selector switch in manual mode).

05SW003.OP (Output of selector switch for fuel feeder)

05SW003.ESWCAS (Selector switch in cascade mode).

05SY003.OP (Fuel feeder output)

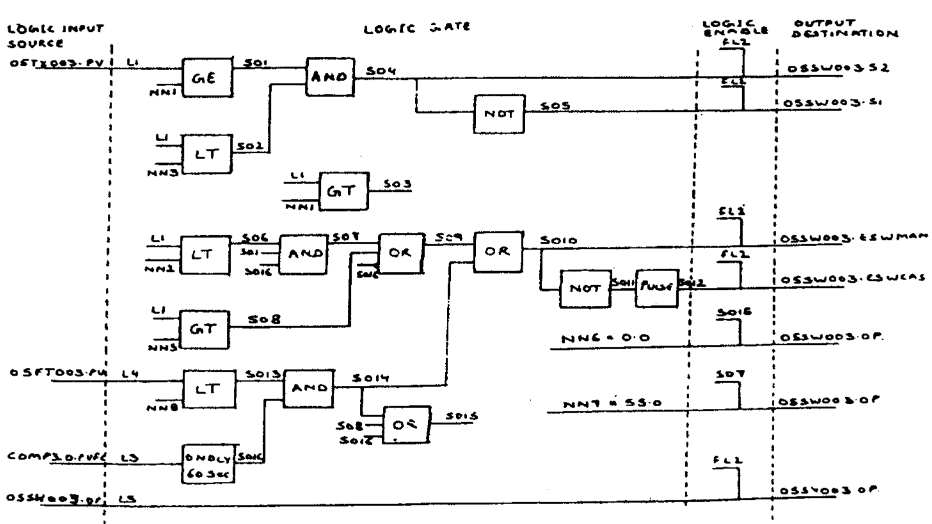


Fig. 3- Compartment-3 fuel feeder speed control logic.

Numeric values

NN1=650°C, NN2=740°C, NN3=790°C, NN4=920°C, NN5=925°C, NN6=0.0, NN7=55.0, NN8=40.4m³/hr.

Control Logic-3

The control logic-3 (Fig. 4) for compartment-4 has been developed to control the fuel feeding according to varition in temperature and pressure conditions. After implementation of the logic-3, it has been observed that:

- Whenever the temperature of the compartment-4 exceeds 925°C than speed of the fuel feeder automatically reduces to minimum i.e. 20%.
- When the temperature of the compartment-4 is between 600°C and 770°C also compartment-4 (L3) is open than SO_7 will be high, which will put selector switch in manual mode which increases the speed of the fuel feeder to maximum level i.e. to 60%.
- If the temperature of the compartment-4 is greater than 800°C but less than 920°C than SO_5 will be high i.e. pressure controller (05SW004.S1) controls the fuel else it is controlled by the temperature controller.

If total airflow sensed by flow transmitter falls below 60m³/hr and compartment-4 is open or when the temperature of the compartment-4 is greater than 925°C than SO_{15} will be high that will reduce the fuel feeding to compartment-4 to minimum level i.e. to 20%.

The various input and output sources and numeric values defined in the Fig. 4 are:

Input source

L1: 05TX004.PV (Higher of two bed temperature of the compartment-4)

L3: COMP3_O.PVEL (Compartment-4 open flag)

L4: 05FT003.PV (Total air flow)

L5: 05SW004.OP (Output of selector switch to fuel feeder)

Output source

05SW004.S2 (Output of the selector switch controlled by the temperature controller).

05SW004.S1 (Output of the selector switch controlled by the pressure controller).

05SW004.ESWMAN (Selector switch in manual mode).

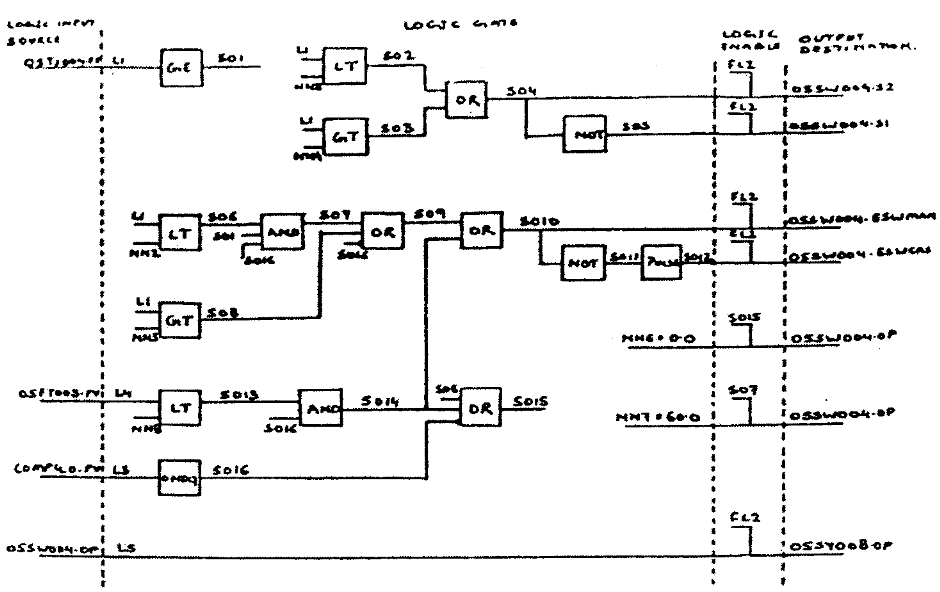
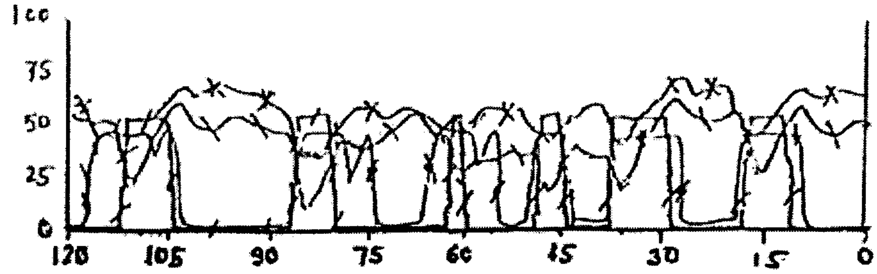


Fig. 4- Compartment-4 fuel feeder speed control logic.



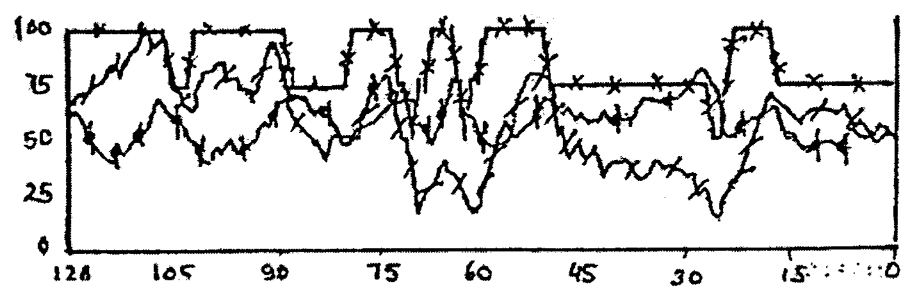
Graph 1. Compartment-3-4 temperature Vs Compartment 3-4 feeder speed.

Indicates compartment-3 temperature

Indicates compartment-4 temperature

Indicates compartment-3 feeder speed (0-1500 RPM)

Indicates compartment-4 feeder speed (0-1500 RPM)



Graph 2. Number of Compartment OPEN Vs Steam Pressure Vs Steam Flow

Indicates number of compartment open

Indicates Steam Pressure (58 to 66 kg/cm^2)

Indicates Steam Flow (28 to 50T/hr)

Fig-5

05SW004.OP (Output of the selector switch for fuel feeder)

05SW004.ESWCAS (Selector switch in cascade mode).

05SY004.OP (Selector switch output to fuel feeder)

Numeric values

NN1=600°C, NN2=770°C, NN3=800°C,

NN4=920°C, NN5=925°C, NN6=0.0°,

NN7=60.0, NN8=60.631m^3/hr.

RESULTS AND DISCUSSION

For efficient operation of the process and longer life of the boiler and turbine the bed temperature and steam pressure is to be maintained. To achieve this, different logics have been designed, implemented and tested online using DCS. It has been observed that the control logic-1 is able to maintain the bed temperature in the range of 800°C and 925°C by controlling the fuel feeding in the compartment-1 Further it is seen that if the bed temperature of compartment-3 is greater than 925°C or airflow is below 40.4 m^3/hr then feeding is done manually to prevent clinker formation (control logic-2). Also if the bed temperature is below 740°C but greater then 650°C and compartment is open then fuel feeding in the compartment is maximum, in order to increase the temperature of the bed (control logic-2). If the airflow to compartment-4 is below 60m^3/hr and compartment-4 is open or when the temperature of the compartment-4 is above 925°C then fuel feeding reduces to minimum level and is controlled manually (control logic-3). If the temperature of the bed is between 800°C and 920°C the temperature controller takes care of fuel feeding else pressure controller does this function.

Online testing of these control logics showed that, when the compartment-3 & 4 are open and the temperature of the compartment-3 & 4 is between 750°C and 800°C then fuel feeding is maximum (750 rpm), so that temperature starts increasing. When only two compartments are running then the feeding in the compartment-3 & 4 is not taking place (Graph 1). Further it has been observed that whenever the demand (steam flow) of the plant increases the steam pressure decreases. When the pressure falls below 62.5kg/cm^2 the compartment-3 opens and if pressure falls to 62kg/cm^2 then to increases the pressure compartment-4 also opens as a result of it both steam flow as well as steam pressure increases. Compartment-4 remains open till the steam pressure is below 63kg/cm^2 as soon as the steam pressure exceeds 63kg/cm^2 the compartment-4 closes. Further if the steam pressure exceeds 64.5 kg/cm^2 then compartment-3 also closes (Graph-2). This represents successful implementation of the control logics-1, 2 and 3.

CONCLUSION

The control logic-1 2 and 3 was able to maintain the bed temperature within 800°C to 925°C so that optimum combustion can take place. The developed logics were not only able to maintain the bed temperature but also the airflow so that the optimum utilization of the fuel can be done, thereby reducing the fuel consumption. These control logics have helped in reducing the down time of boiler by maintaining the bed temperature within the desired limits because at higher temperature within the desired limits because at higher temperature (1000°C) clinker formation takes place, which forces to shutdown the boiler to clean the bed.

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