Boiler Instrumentation, Control and Optimization in Modern Power Plants

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Steam boilers are used industrially both as a power source and in processing operations. Varying demands of steam and power loads tend to destabilize the process when controlling the various parameters manually. Hence, the role of various levels of instrumentation comes into picture. The paper explains basic configuration of the boiler control loops and the role of various alterations through Distributed Control System (DCS) to compensate the effect of variables. The discussions have led to the conclusion that optimum instrumentation certainly makes a boiler capable of satisfying the rapid changes in load with greater "Turndown" compared to other segments of a plant.

INTRODUCTION

The boiler optimization for improving the load-following capability of power plant units has been gaining considerable importance in modern power plants. An optimized instrumentation and control system regards all major design and operational characteristics and therefore plays a major role in the profitable operation of a power plant by achieving availability, flexibility, reliability and efficiency. Distributed Control System (DCS) and Programmable Logic Control (PLC) are two main control systems used in view above, an optimization in modern power plants.

Boiler Controls

Fig. 1 describes a well-design scheme of a boiler control loops and the tie up points for optimization. The various boiler controls have been described in the subsequent sections.

Boiler pressure control/combustion control

This can be subdivided into 2 sections:

1. Fuel Control and
2. Combustion air control system

The inter-relationship between the above 2 sub-sytems necessitates the use of air-fuel ratio controls. Balance between the inflow and outflow of heat from the boiler drum is indicative of the steam drum pressure. A change in steam pressure will result from a change in firing rate only after a delay, depending upon the boiler load level and therefore feed forward control, is incorporated.

Feed Forward Control of Steam Pressure

A feed forward control is effected in single boiler or in boilers when total steam flow is measured with the biggest contributor. Fig. 2 demonstrates such a loop using feed forward loop with back trim, where loops 101 and 102 measure the flow and pressure of steam generated where FT-102 is a high rangeability and linear Transmitter. Firing rate demand signal is generated in a feed back manner by the pressure controller PIC-101. A feed forward trim is added to speed up the response of this loop to load changes. Therefore, as soon as the demand for steam changes, FY-102 will trim the firing signal demand, without waiting for the steam pressure to change. The dynamics of FY102 are adjusted to reflect the time constants of the boiler, recognizing the time displacement between a change in firing rate and the resulting change in the rate of steam generation sometime later.

Fuel Control (Measurable Fuels)

Major fuels used in the boiler are Coal, Oil & Gas. But other non-conventional fuels like waste gases, waste sludges & waste products like saw dust & bark etc. are also being used. However, the scope of this paper has been restricted to commonly used fuels. Oil and gas are the simplest type of fuel that are easily measurable and require only a control valve with accessories to control the quantity. Coriolis mass flow sensors are commonly used for such measurements in place of orifice plate. Fig.3 an Fig.4 show the loops for a single fuel and dual fuel controls, which are self-explanatory. In dual fuel system a manual split requirement is possible via 2 Nos.

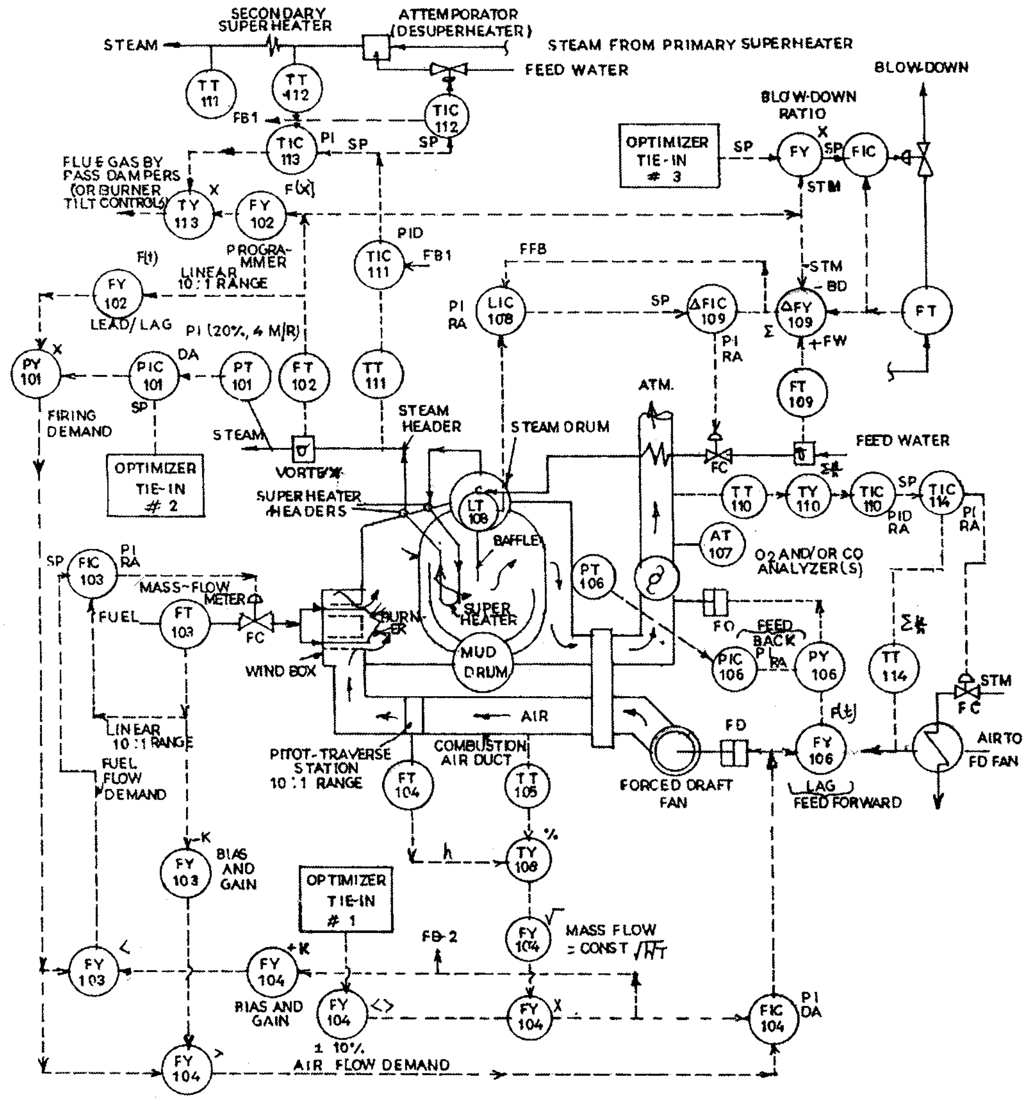

Fig. 1 : Good Boiler Controls without Optimization

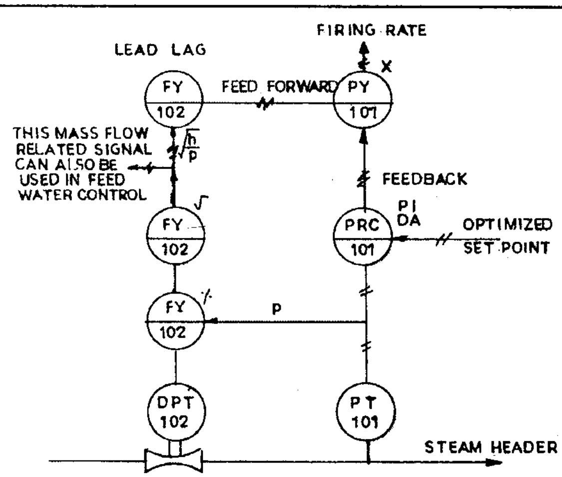

Fig 2. : Firing Rate Determination using Feed Forward Loop with Feed Back Trim

Bias and manual control function relays.

Air Flow Measurement / Control

For air fuel ratio control combustion air flow measurement is important (Table 1). Normal differential pressure range of these measurement are between one inch water column to six inches water column for conventional sensors and as low as 0.1 inches water column for area averaging pitted stations.

Dampers have been normally used for air controls in the boiler. But of late, variable frequency drives are taking their place. But it has been experienced that at low speeds and loads, the variable drives do not function satisfactorily and therefore a combination of dampers and variable drives are being preferred.

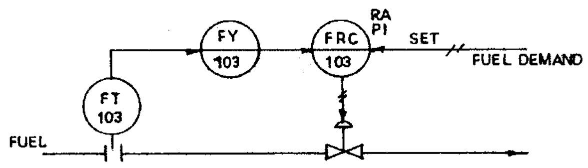

Fig. 3 : Fuel Controller to Keep Demand and Flow in Linear Reletionship

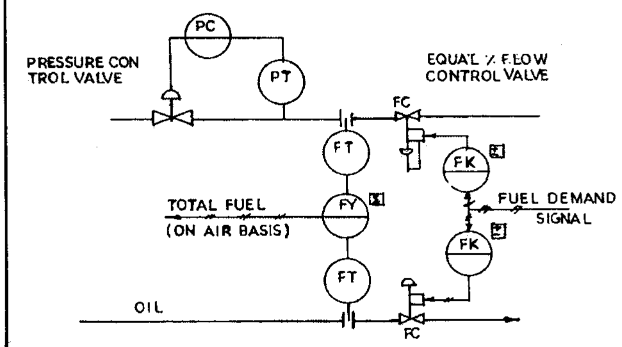

Fig 4. : Manual Splitting of Fuel Demand Between two Fuels on an Open-Loop Basis

Furnace Draft Controls

In case of a balanced draft boiler the maintenance of constant furnace pressure keeps the forced and induced draft in balance, the purpose of which is to avoid positive pressure in the furnace and provide combustion-air suitably. The measurement of furnace draft produces a noisy signal limiting the loop and air to low values. Force draft fan is normally used as air flow adjuster and the induced draft as the furnace draft controller. However, air demand signal is also given to induced draft fan control as fuel based signal. Air flow is a function of both induced draft fan and forced draft fan.

Table 1 : Flow Sensor Errors on Boilers

Flow Streams Measured	Type of Flow Meter	Inaccuracy (% of flow) at 10%	33%	100%	Rangeability	Limitation
Fuel (Oil)	Coriolis mass flow	0.5	0.5	0.5	20:1	Not of gases
Steam and Water	Vortex shedding steam	1-1.5	1-1.5	1-1.5	10:1	Min R=20,000 Max. Temp.= 750°F(400°C)
	Water	0.5-1	0.5-1	-.5-1	10:1	
	Orifice	NG*	2-5	0.5	3:1	Rangeability can be increased if using two conventional d/p cells or a "Smart" d/p cell
Air	Area averaging Pilot traverse Station	NG	2-10	0.5-2	3:1	Rangeability can be increased if using two conventional d/p cells or a "Smart" d/p cell.
	Multipoint thermal	5-20	2-5	1-2	10:1	Dual-range unit required
	Piezometer ring Orifice segment Venture section Airfoil section	NG	3-20	2-3	3:1	Can't be used below 25% of maximum flow.

* NG = Not good

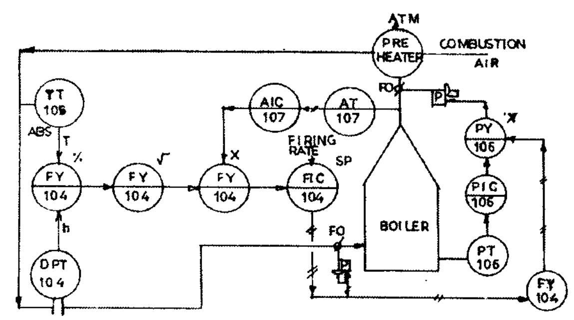

Fig. 5 : Parallel Control of Inlet and Outlet Dampers

The common rule is that air flow should be measured and controlled on the same side of the furnace to minimize interaction between flow and pressure loops. One might also reduce interaction by connecting the two dampers/fans in parallel and using the furnace pressure as a trimming signal as shown in Fig.5. Fuel: air ratio is maintained with the help of gas analyzers lke O_2, CO_2, CO etc.

Feed Water Control

Three-Element Control

Economic considerations make it highly desirable to reduce the size and increase velocities in the water and steam systems therefore generating a need for 3-element control for large boilers. In this, the two flow meters i.e. steam and water shall have identical ranges and their signals are subtracted. If the two flows are identical, the subtractor sends a 50% signal to flow difference controller. Any error in steam water balance will cause a falling or rising level.

Therfore, the level controller must readjust the set point of the difference controller to strike a steady state balance. An external feed back from the flow difference measurement is also applied to the level controller. In this manner, incorrect action caused by the shrink, swell and inverse response are reduced. To regulate feed water, pump-speed can also be regulated if the pump is driven by steam turbine or variable speed drives. This can be used in place of control valves to save power.

Steam Temperature Control

Mostly, boiler steam is used to run steam turbines and the thermal efficiency of turbine is dependent on the steam temperature control on the boilers. The temperature of steam can be controlled by adjustment of the amount of recirculation of the flue gas or an attemperator and also by passing partial steam through

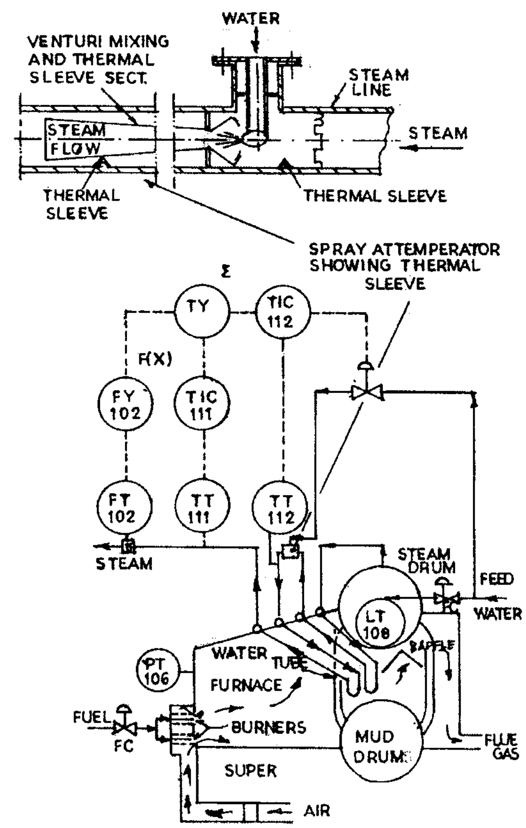

Fig. 6 : Cascade Configuration for controlling the Desuper Heater Control Valve

boiler drum. Although use of attemperator is an energy wasting method, but at the same time, this is the most common and precise method. ABC paper Mill in its new 6MW power plant boiler has adopted desuperheater by attemperator in primary superheated steam location. Temperature is sensed before primary superheater, after spray and then in the final steam. This saves energy to some extent i.e. it does not allow the temperature to up to a level more than required and then desuperheat. Fig.6 shows a smple loop adopted in ABC Paper.

Application of Boiler Instrumentation in 6 MW Power Plant :

A case Study in ABC Paper

M/s ABC have invested nearly Rs. 95.00 lacs on the automation/instrumentation for new 6 MW Power Plant. i.e. 2x28 TPH, 410°C & 35 kg/cm^2 Boilers with 2 Nos. Turbines, 2x1.5 MW i.e. 2 Generators mounted on the same Turbine.

To run the Power Plant more efficiently & smoothly, we decided to make use of the flexibilities & features of a distributed control system keeping a margin for extension of the same in future to cater the needs of Recovery/Evaporator Plant also. Optimizing loops like those of three element controls, (incorporating feed forward control for combustion & drum level/feed water), attemperator controls with cascade loops by mentioning pre/post primary superheater and final steam temperature have also been introduced.

All the fuel feeders and induced draft fans have been equipped with variable frequency drives for energy conservation keeping in mind. With the above, we are experiencing better thermal efficiency at Turbines, precise Boiler pressure controls, better combustion efficiency of fuel, Less manual labour deployment, better safety of the equipments because of various safety interlocks provided through distributed control system etc.

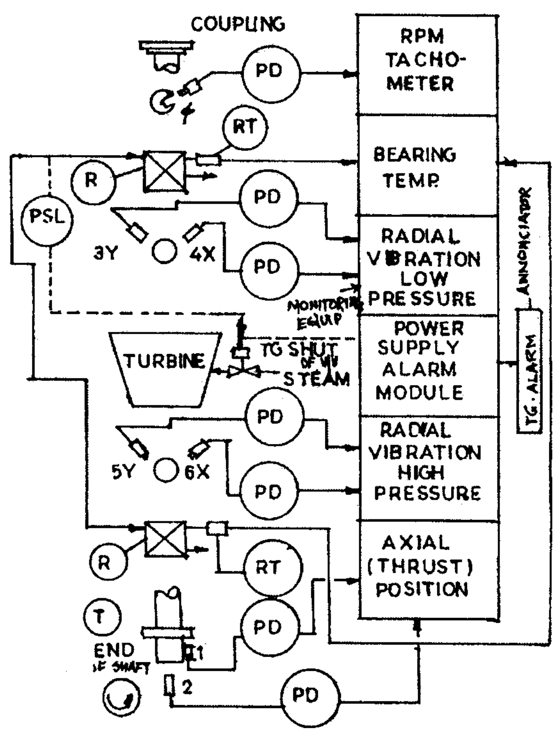

Fig. 7 : Turbine "HEALTH MONITORING" System

Steam Turbine Controls

Turbines are popular drives for rotary equipment and are energy conservation machines. Energy from steam is converted to Shaft-Work. Now, very high-speed turbine even upto 12000 rpm are available. Higher the speeds, higher the accurate & precise controls and Safety supervisory instrumentation. Fig. 7 shows a typical health monitoring system of a modern turbine.

CONCLUSION

The conclusion drawn from the above discussion is that boiler performance in power plants can be improved significantly by implementing proper instrumentation and optimizing the boiler controls. The optimization in boilers should be concentrated to achieve the following goals:

- Minimize flue gas temperature and excess air.
- Minimize blow down.
- Minimize steam pressure level i.e. reduced feed pump discharge and heat loss through pipe walls
- Efficiency Measurement
- Minimize transportation costs (use variable speed fans, eliminate condensate pumps, consider variable drives for feed water pumps)

If the potential of all aspects of boiler instrumentation, control and optimization are exploited, the steam generation costs can certainly be lowered with improved efficiency that ultimately compensates the optimization costs.

ACKNOWLEDGEMENT

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Nomenclature

AT	Analyser Transmitter
BD	Blow Down
DPT	Differential Pressure Transmitter
FB	Feed Back
FIC	Flow Indicating Controller
FO	Fan damper Operator
FT	Flow Transmitter
LT	Level Transmitter
P	Proportional
PD	Proportional plus Derivative
PIC	Pressure Indicating Controller
PID	Proportional+Integral+Derivative
PRC	Pressure Recording Controller
PT	Pressure Transmitter
RT	Resistance Temperature detector
SP	Set Point
TIC	Temperature Indicating Controller
TIE	Temperature Element
TT	Temperature Transmitter