AUTOMATED CONTROL DESIGN FOR THERMAL POWER PLANT USING DCS

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Abstract

The Thermal Power Plant uses feed water which is initially heated and steam is produced. This steam produced rotates the turbine. The turbine is connected to a generator for the production of electricity. The left-over steam is condensed and recycled to the boiler. This process of condensing and recycling the left-over steam to the boiler is known as Rankine cycle. The main aim of this project is to design an automatic control system for boiler, furnace, deaerator, cooling tower, turbine, feed water tank, economizer and superheater which is capable of providing instant response for load demand variations. It also focuses to increase efficiency of the boiler by monitoring and controlling dynamic parameters such as temperature, pressure, level and flow. The main objective of controlling the thermal power plant is to increase the overall production of steam. During this process it should be made sure that efficiency and safety integrity levels are maintained. This project is implemented using Distributed Control System (DCS). For the creation of Piping and Instrumentation diagram Edraw Max is used.

Keywords: Distributed Control system, Boiler, Thermal power plant, Temperature control.

I. INTRODUCTION

Additive Automated control design for thermal power plant is done with the aid of Distributed Control System (DCS). In DCS the control function is distributed, But the monitoring is still centralized. The main objective of this project is to increase the boiler efficiency and the production of steam by using less fuel. The use of single element control to maintain the boiler drum level is replaced by three element control by considering inlet feed water, drum level, outlet steam. To reduce the wastage of running pump without the presence of steam in the condenser our proposed system uses liquid fuel instead of coal as a result of which a large amount of ash is produced. The process of burning the coal for a limited time to create a fire ball is performed to reduce the ash that is being produced and also the reduce the amount of coal being used. In addition to this forced draft and Induced draft are used to reduce energy consumption. To increase the life time of the boiler deaerator is used to remove dissolved oxygen in feed water. It is very essential to maintain the water level in the boiler, When the level of the water decreases the pressure inside the boiler increase leading to an explosion within the boiler. Similarly, when there is a sudden increase in water level the production of steam is reduced and also decrease in water level will cause a relentless damage in the turbine blades.

II. METHODOLOGY

The main components of Thermal power plant are Boiler, Economiser, Deaerator, superheater, Reheater, Attemperator. In addition, there are control systems for monitoring water and steam flow, fuel flow and air flow.

2.1Feed water system

The water which is supplied to the boiler for the production of steam is known as feed water. The sources of feed water are condensed steam from the condenser and treated raw water from water bodies like rivers and canals. Condensed water is used to improve the efficiency of boiler. Heat is extracted from the furnace after the boiler is used to preheat the feedwater before entering the boiler. Heaters are made up of shell and tube heat exchangers with the feedwater on tube side and the steam on shell side. Heater closest to boiler receive the maximum heat for the steam. The condensate

steam is recovered in condenser and immediately pump to boiler for reuse.

2.2 Deaerator

Feed water contains dissolved oxygen as a result of which corrosion takes place within the boiler and its lifespan gets reduced.It is based upon the principle that the oxygen dissolved will gradually decrease the solubility of water when temperature is increased. This Increased temperature is because of the steam that is extracted from turbine and passed to the feed water.One vital reason in controlling the Deaerators is to ensure adequate temperature difference between incoming feed water and the stripping steam. If the temperature is too close, there is not enough steam to strip the oxygen from the treated raw water.

2.3 Economiser

Economiser is the last preheating process for feed water system and they are made up of finned tube heat exchangers commonly found in water tube boilers. It is used to extract waste heat from exhaust gases in furnace and to preheat feed water to increase the efficiency of the boiler.It reduces the fuel requirement by transferring heat to incoming feed water and by recovering left over heat it can reduce the usage of fuel by 5% to 10%.

2.4 Boiler

A boiler is a closed vessel which provides combustion by transferring the heat to water from furnace until it becomes steam. The production of steam is known as evaporation state. The steam exerted from boiler has high pressure and it is used for rotating the turbine wheels. Mainly water is used as medium because it is very cheap and easily available. When water is converted into steam its volume increases and steam produced from boiler is explosive as gun powder.

2.4.1 Types of boiler

There are two different types of boiler. They are water tube and fire tube boiler. In our project we consider water tube boilers.

In water tube boiler water flow inside tube and the tubes are surrounded by hot gases outside as shown in the figure. Here the feedwater enters the tube and to boiler drum. Feed water circulates through the tubes connected external to drums. These water tubes are heated and it is converted into steam and the steam remains in the same boiler drum. Due to the convectional flow movement of water is faster in water tube boiler. These types of boiler have high efficiency.

Fire tube boiler is the reverse of water tube Boiler in which the fire is passed through the tube and it is surrounded by water. These fire tubes heated up the water and convert them into steam. It cannot produce steam at high pressure because the water and steam are in same vessel.

2.5 Boiler Drums

Boiler drum is used to separate water and steam. Feed water enters the boiler drum from the economizer or from the feed water heater train if there is no economizer. Incoming feed water provides a circulation in the boiler.

2.6 Superheaters

Main purpose of superheater is to eliminate moisture content from steam by raising their temperature above its saturation point. Steam which is leaving from boiler is saturated, it is an equilibrium with liquid water at their boiling temperature. It adds energy to the leaving steam from boiler. It may be a single or multiple tube either in horizontal or vertical alignment which is suspended in the convective or radiation zone of the boiler. Hot flue gases from furnace raises the temperature and heat content of the steam above its saturation point. In case of turbine, if there is excessive moisture in steam above their saturation point can adversely affect the efficiency and integrity of the turbine. It is important that the steam should have high purity and low moisture content so that non-volatile substances do not build up inside the superheater.

2.7 Attemperators

Attemperator is used to control degree of superheat emitted from the boiler. It is the process of de-superheating steam by the injection of high purity water into the superheated steam. It usually located on the downstream of superheater. Degree of superheat mainly depends on the steam load and heat capacity of turbine. The degree of superheat of outlet steam from superheater is generally not subject to wide variation because of their design of the downstream processes. In order to achieve the proper control of superheat temperature and moisture of the steam, attemperator is used

2.8 Turbine

Turbine is a rotary mechanical device which converts flow to rotational motion. Fluid flow must contain high pressure and high

temperature. It works on simple construction of energy from fluid flow turns the rotor which is connected to the propeller. It is connected to the main shaft that spin the generator to generate electricity. There are two types of turbine. They are Impulse turbine and Reaction turbine.in our project we use Impulse turbine.

In Impulse turbine, high pressure steam strikes on turbine blades at high speed as shown in the figure which produces kinetic energy as well as pressure energy which cause turbine to rotate.

In Reaction turbine, high pressure steam is passed through the rotor vent. Due to Newton's third law of motion action and reaction of steam are equal and opposite. Pressure of steam changes when it is passes through turbine blades and it cause the turbine to rotate.

2.9 Condenser

Condenser is used to condensate the steam existing from the turbine. It is also used to convert steam into pure water so that it can be used in Boiler as feed water. It includes heat exchanger, cooling well and chiller plant. Here superheated steam enters the heat exchanger depending upon the initial steam conditions and design load of heat exchangers and then it is converted into liquid state as shown in the figure. The inlet cooling water for heat exchanger get heated due to the transformation of heat from steam. Then the water is again subjected to chiller plant for cooling.

2.10 Fuel supply system

Fuel system plays a critical role in performance of boiler. Their primary functions include transferring the fuel to into furnace and distributing the fuel within the furnace to promote uniform and complete combustion. Initially liquid fuel is used in furnace to achieve maximum heat to promote complete combustion. Atomization by air and tiny droplets of pressurized liquid fuel is made to pass through the furnace to achieve initial heat and after attaining standard temperature solid fuels are given to furnace. Solid fuels are more difficult to handle than gaseous and liquid fuels. Preparing the fuel is generally necessary and may involve techniques such as crushing or shredding. Here coal is used as a fuel which is crushed by pulverizer. It is transported along with hot air to remove moisture content in coal for transient burning for ventilation of heat throughout the boiler system.

2.11 Furnace

The ability of furnace is to mix combustion air with fuel is the measure of its performance. A good furnace mixes pulverized coal and emits a maximum amount of heat from it. The best burners are engineered for the emission of maximum amount of heat from the fuel and limit the amount of pollutants. Burners with these capabilities are now used in boilers that must comply mandated emission limitations.

2.12 Digital Control System

In Digital control system control function is done by microprocessor. In digital control system, the parameters are measured by the transmitter. 4 to 20 mA current signal is generated by transmitter corresponding to 0 to 100% of the process value measured. This signal is converted by signal converters into a voltage signal. Analog to digital converters are used to convert this analog signal to digital signal. This digital signal is given to the microprocessor for further processing. digital control system is preferred over analog control systems since it is easy to interface with computers for data diagnostics.

There are two types of Digital control system. They are,

1.Centralized Control System

2.Distributed Control System

In Centralized Control System all filed inputs are fed to single CPU, relevant set points are given to same CPU and all the outputs are taken from the same CPU. In this type of autonomous controller single CPU controls whole process. If it fails entire plant will get affected. Redundancy is also not available in Centralized Control System.

In Distributed Control System, the control function is distributed but monitoring is still centralized. All field inputs are not fed to single CPU instead they are distributed among multiple CPU's. In DCS terminology CPU is referred as Field Control Station. In this type the autonomous controller has redundancy at various levels.

III. DESIGN AND IMPLEMENTATION

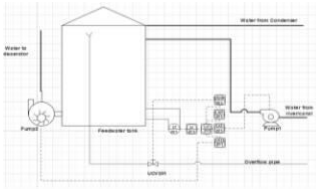
3.1 Air to fuel ratio control loop in furnace

Air and fuel (coal) are the main ingredients for the combustion chamber. Air and fuel are heated and mixed in proper

proportion. Air to fuel ratio shall be 1.0 to 1.5. This value may be changed during commissioning. Here TIC is the primary controller and FIC101 and FIC102 are the secondary controller. Fuel flow control loop FIC is to allow fuel flow for maintain desired temperature in furnace. The objective of air flow controller FIC is to regulate total combustion (FD & SA) air flow based on load demand by regulating FD fan inlet guide vane or by regulating the speed of FD fan.

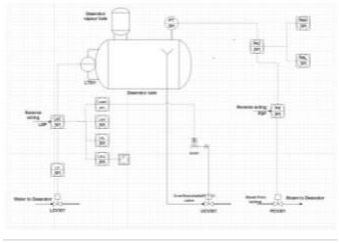
3.2 Feed water tank

LIC201 is to maintain the constant flow and level in the feed water tank. Level of the tank is measured by the level transmitter LT201. When the level is low, start command is initiated to Inlet pump - PUMP1 to suck the water to fill the tank. When deaerator level is low, start command is initiated to Outlet pump-PUMP2 to transfer the water from feed water tank to Deaerator tank. When the level of feed water tank is very high, open command will be initiated to open the feedwater tank overflow valve. Feed water level will be measured by LT201 Action of overflow valve UCV201 is air to open type and fail-safe position is close.



3.3 Deaerator

LIC301 loop is used to make up the deaerator level by regulating the de-mineralized water inlet control valve. When the level is below the set point, controller LIC301 will further increase the level further by opening the de-mineralized water inlet control valve LCV301.PIC301 loop is used for maintaining the backed temperature for Boiler feed water. It is necessary to maintain constant deaerator pressure for proper deaeration of water. When the pressure is below the set point, controller PIC301 will further increase the pressure by opening the steam from low pressure turbine. When deaerator level is very high, open command will be initiated to open the deaerator overflow valve UCV301. deaerator level will be measured by



3.4 Economizer

This loop is used to indicate the temperature of feed water in economizer. Temperature transmitter TT401 is used to measure feed water temperature before entering economizer and temperature transmitter TT402 is used to measure feed water temperature leaving economizer.

3.5 Boiler

3.5.1 Drum level Compensation Loop

Single /Three element feed water control system is provided to regulate the quantity of feed water flowing into the boiler to maintain the required water level in the steam drum as shown in the figure. The level is measured by three independent transmitters LT501A, LT501B, LT501C. All the three level signals are corrected for density using the drum pressure signal from pressure transmitter PT501.

The following equation is implemented in density compensation,

$$\Delta P = HP - LP = (Hm \times Dw) + ((H - Hm) \times Ds) = \{\Delta P + H(Da - Ds)\} / (Dw - Ds)$$

Where,

Hm – Compensated level of the drum

Dw – Density of water in gm/cm3

Da – Density of water at ambient temperature (34°C) = 0.994 m/cm3

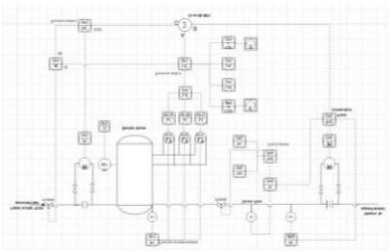
Ds-Density of steam in gm/cm3

H-Distance between tapping points / water head on LP side = 600 mm

Pressure acting on HP side = (Hm × Dw) + ((H - Hm) × Ds)
Pressure acting on LP side = H × Da

Compensated drum level is derived from the above equation. This value shall be scaled to 0 -100% range for display and alarms in Human Interface Station. Δ P is the

differential pressure value from drum level transmitters LT501A, LT501B, LT501C. The values of Dw and Ds are depending upon the current drum pressure signal from PT501. After density compensation, middle value of the transmitters value is used for further control. If there is a maximum deviation in their indication of level, then the deviated value is eliminated and other two transmitters take part in control and it will indicate to operator about the status of the operator. The average value is used for indication, control & alarms.



3.5.2 Steam Flow compensation Loop

This loop is used for compensation of flow on the basis of pressure and temperature. Steam flow is affected by both pressure and temperature. When temperature measured by TT502 increases flow of steam gets decreased and when pressure measured by PT502 increases steam flow gets increased. This loop is used to correct flow rate measured by differential pressure flow meter FT502.

The following equation is implemented in density compensation,

$$F0 = \frac{}{0 = \sqrt{\left(\frac{P + 1.01325 * 100}{* 100 + 273.15}\right) * \frac{}{+ 273.15 + 1.01325}}}$$

Pressure: kpa

Where

F1 – Measured flow rate

F0-corrected flow rate

P-Measured pressure (KPa)

Pb-Reference pressure (KPa)

T-Measured temperature(℃)
Tb-Reference temperature(℃)

Boiler drum Level Control Loop

3.5.3 Single element control

In single element control, boiler drum level by regulated by feed water inlet valve FCV501 by measuring drum level alone. When boiler level is below the set point, controller FIC501 will further increase level by opening feed water inlet valve FCV501. When level is high reverse action will be taken. This loop can be selected by using a switch.

3.5.4 Three element control

In three element control, boiler drum level is regulated by feed water inlet valve FCV501 by measuring drum level, feedwater inlet and steam outlet Steam flow rate is sensed by flow transmitter FT502 and it acts as a feed forward control. LIC501 is the primary controller when level is below the set point, controller FIC501 will further increase level by opening feed water inlet valve FCV501. Manipulated value of LIC501 is added with the compensated steam flow for further calculation. FIC501 is the secondary controller in three element control, when the feed water flow is below the setpoint, controller FIC501 further increase the flow by opening FCV501. This loop can be selected by another switch.

3.5.5 Steam Temperature Control Loop

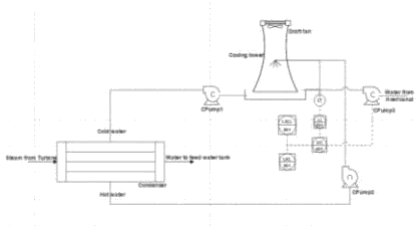
In order to control the temperature of the steam that is been generated in the boiler drum, this loop TIC501 generates an alarm when it exceeds the normal operating range

3.6 Attemperator

The control loop TIC601 is used to control the addition of moisture content in dry steam. Temperature transmitter TT601 measures the temperature of dry steam after superheater. If temperature of dry steam is below set point controller TIC601 regulates addition of water by controlling the inlet valve TCV601. If the temperature reaches high direct action will be taken.

3.7 Condenser

This loop is to maintain the proper flow of water during condensation. When steam flow is detected inside the tube through flow transmitter FT502, inlet flow pump CPUMP1and outlet flow pump CPUMP2 get started. When there is no flow, pump is tripped. This loop is to maintain level in the cooling well. Level of the well is measured by the level transmitter LT801 When the tank level is low, start command is initiated to Inlet pump – CPUMP3 to suck the water to fill the tank. This pump is controlled to maintain desired level.



IV. RESULT AND DISCUSSION

We have spoken about the implementation of DCS in Thermal power Plant where the safety integrity levels are maintained. The simulation Thermal power Plant using DCS software and the simulation is done on the basis of the information gathered and perceptions accumulated from the writing overview just as from the modern Experts. All the physical parameters associated with the procedure are observed and controlled automatically.

.V. CONCLUSION

DCS has made the process monitoring and controlling in plants simple as it is an easy to handle powerful system without compromising safety. This project fulfilled the purpose of designing an automatic control design for thermal power plant which is capable of giving immediate response to the load demand variations. It increases efficiency of boiler, saves energy without affecting the safety integrity levels. This serves the purpose to increase the production of thermal energy.

This has resulted in reduction of man power without affecting the safe operation of thermal power plant. the process is monitored by operating station. In case of emergency, alarm, messages and faults are given to both field and operating stations and the process is brought to safe state by shutting down the faulty part

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