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Maximizing Performance and Sustainability in Thermal Power Generation with DCS Control

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Abstract

The Thermal Power Plant relies on the initial heating of feed water to produce steam, which in turn propels the turbine. This turbine is linked to a generator, generating electricity for various applications. Any residual steam is then condensed and cycled back into the boiler, a fundamental process commonly referred to as the Rankine cycle. The central objective of this initiative is to devise an automated control system catering to critical components like the boiler, furnace, deaerator, cooling tower, turbine, feed water tank, economizer, and superheater. This system is geared towards delivering prompt responses to variations in load demands. Emphasis is also placed on improving boiler efficiency through the real-time monitoring and regulation of dynamic parameters including temperature, pressure, level, and flow. The primary goal of managing the thermal power plant is to enhance overall steam production, ensuring that efficiency and safety integrity levels are maintained at all times. The execution of this project relies on the utilization of a Distributed Control System (DCS). The creation of the Piping and Instrumentation diagram is facilitated through the application Edraw Max. This comprehensive software tool aids in the visualization and development of the project, ensuring accuracy and clarity in the planning and implementation process.

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

1. Introduction

The augmentation of an automated control system for a thermal power plant relies on the adept utilization of a Distributed Control System (DCS).[1] This approach embodies a unique characteristic wherein control functions are systematically distributed, while the monitoring aspect remains centralized. The overarching goal of this project encompasses multiple facets, with a central focus on strengthening boiler efficiency and optimizing steam production, all while minimizing fuel consumption [1]. To achieve these objectives, various innovative techniques and mechanisms have been seamlessly integrated into the plant's operations.

Traditionally, single-element control was employed to maintain the boiler drum level. However, this project takes a progressive step by implementing a more intricate three-element control system. It takes into account not just the drum level but also the characteristics of the inlet feed water and outlet steam. This sophisticated control system ensures a more precise regulation of the boiler's pivotal parameters [2].

Furthermore, to address the issue of running pumps unnecessarily when there's no demand for steam in the condenser, the proposed system introduces the use of liquid fuel as a more efficient alternative to coal. This strategic shift in fuel source significantly reduces ash production. A specialized process is employed, involving the controlled combustion of coal for a limited duration to create a fireball, mitigating ash generation and conserving coal resources.

In the pursuit of energy efficiency, forced draft and induced draft mechanisms are deployed to optimize energy consumption within the plant. These measures lead to a more sustainable and eco-friendly operation, minimizing the environmental impact of the power plant [3].

Moreover, to extend the longevity of the boiler, a deaerator is introduced into the system. Its primary function is the elimination of dissolved oxygen from the feed water, mitigating the corrosive effects of oxygen and ensuring the endurance of boiler components.

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A critical aspect of this project revolves around the meticulous maintenance of water levels within the boiler. A reduction in water level can lead to a surge in pressure within the boiler, posing the potential for catastrophic explosions. Conversely, a sudden increase in water level can disrupt the production of steam and result in damage to the turbine blades. Hence, the vigilance and precision in maintaining water levels are pivotal to the safe and efficient operation of the thermal power plant [4-6]. This comprehensive approach seamlessly integrates numerous elements of control, automation, and energy management to enhance both the performance and sustainability of the thermal power plant.

2. Methodology

The fundamental constituents of a thermal power plant encompass essential elements such as the boiler, economizer, deaerator, superheater, reheater, and attemperator. Furthermore, the intricate operational framework is fortified by the inclusion of meticulous control systems. These systems play a pivotal role in monitoring critical parameters, including the flow of water and steam, fuel flow, and air flow, ensuring the seamless operation of the power plant.

3.2 Feed water system

The water supplied to the boiler to generate steam is referred to as feed water. This feed water can originate from two primary sources: condensed steam collected from the condenser and treated raw water sourced from natural bodies of water like rivers and canals. Utilizing condensed water serves to enhance the boiler's efficiency. To achieve this, the heat extracted from the furnace, subsequent to the boiler's operation, is harnessed to preheat the feedwater before its introduction into the boiler. The heating process is accomplished through shell and tube heat exchangers, with the feedwater flowing through the tubes and the steam enveloping the shell. Notably, the heater located clo'est to the boiler receives the highest heat input for the steam generation process.

3.2 Deaerator

The feed water typically contains dissolved oxygen, leading to internal corrosion within the boiler and a subsequent reduction in its overall lifespan. This phenomenon arises from the principle that the solubility of water diminishes as the temperature increases, a consequence of the steam extracted from the turbine and circulated back to the feed water. To effectively manage Deaerators, it is crucial to maintain a sufficient temperature disparity between the incoming feed water and the stripping steam. When the temperature proximity is too close, there might not be enough steam to adequately remove the oxygen content from the treated raw water.

3.2 Economiser

The Economiser serves as the final stage in the feed water system's preheating process, typically comprising finned tube heat exchangers that are a common fixture in water tube boilers. Its primary function is twofold: to harness waste heat from the exhaust gases within the furnace and to preheat the feed water. By accomplishing these objectives, the Economiser significantly enhances the overall efficiency of the boiler. This efficiency boost is reflected in reduced fuel consumption, as heat is efficiently transferred to the incoming feed water. Additionally, the Economiser has the capacity to recover excess heat, potentially resulting in a fuel usage reduction ranging from 5% to 10%.

3.2 Superheaters

The primary objective of the superheater is to eliminate any residual moisture from the steam, achieved by elevating its temperature beyond the saturation point. When steam exits the boiler, it is in a saturated state, meaning it is in equilibrium with liquid water at its boiling temperature. The superheater's role is to impart additional energy to this departing steam. Superheaters can take the form of single or multiple tubes, oriented horizontally or vertically, and are suspended within the convective or radiation zone of the boiler. Hot flue gases emitted from the furnace play a crucial role in raising the temperature and heat content of the steam beyond its saturation point.

In the context of a turbine, excessive moisture in the steam above its saturation point can have detrimental effects on both efficiency and turbine integrity. Thus, it is imperative that the steam maintains high purity and low moisture content to prevent the accumulation of non-volatile substances inside the superheater.

3.2 Attemperators

The attemperator assumes the critical role of regulating the degree of superheat emanating from the boiler. This process involves the de-superheating of steam through the injection of high-purity water into the superheated steam. Typically positioned downstream of the superheater, the extent of superheat is primarily contingent on the steam load and the heat capacity of the turbine. The design of downstream processes tends to ensure that the degree of superheat in the outlet steam from the superheater remains relatively stable. The implementation of an attemperator is instrumental in achieving

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precise control over the superheat temperature and steam moisture, ensuring optimal operating conditions within the system.

3.2 Condenser

The condenser plays a pivotal role in the process by transforming the steam discharged from the turbine into a condensed state. Its secondary function involves converting the steam into purified water, rendering it suitable for use as feed water in the boiler. The condenser comprises essential components such as a heat exchanger, cooling well, and a chiller plant. In this operation, superheated steam is introduced into the heat exchanger, with the specific conditions and heat exchanger load guiding the process. Subsequently, the steam undergoes a phase change, transitioning into a liquid state. The heat transfer from the steam elevates the temperature of the incoming cooling water, which then proceeds to the chiller plant for effective cooling, ensuring optimal performance within the system.

3.2 Digital Control System

In a digital control system, the microprocessor is responsible for the control function. Transmitters measure the parameters, generating a 4 to 20 mA current signal corresponding to the process value measured. Signal converters transform this current signal into a voltage signal, which is then converted into a digital signal by analog-to-digital converters. This digital signal is subsequently processed by the microprocessor. Digital control systems are preferred over analog counterparts due to their ease of interfacing with computers for data diagnostics.

Two types of digital control systems exist: the Centralized Control System and the Distributed Control System (DCS). In a Centralized Control System, all field inputs are directed to a single CPU, with relevant set points also assigned to the same CPU. All outputs are derived from this central CPU, effectively allowing it to manage the entire process. However, should this singular CPU fail, the entire plant would be affected, as redundancy is not available in this setup.

Conversely, in a Distributed Control System, the control function is decentralized, while the monitoring remains centralized. Field inputs are distributed among multiple CPUs, also known as Field Control Stations in DCS terminology. In this arrangement, the autonomous controller benefits from redundancy at various levels, ensuring continued operation even in the event of component failure.

3. Design and Execution

3.1 Regulation of the Air-to-Fuel Ratio in the Furnace

The combustion chamber primarily relies on the optimal mixture of air and fuel (coal). Proper heating and proportional blending of air and fuel are crucial, with the air-to-fuel ratio typically maintained within the range of 1.0 to 1.5. This value may require adjustments during the initial setup phase. The Temperature Indicating Controller (TIC) functions as the primary controller, while FIC101 and FIC102 operate as secondary controllers. FIC (Fuel Flow Controller) regulates fuel flow to maintain the desired furnace temperature. On the other hand, the objective of the air flow controller FIC is to regulate the overall combustion air flow (FD and SA) based on load demands, achieved by adjusting the inlet guide vane of the FD fan or modulating the speed of the FD fan.

3.2 Feed water tank

LIC201 is responsible for maintaining a constant flow and level in the feed water tank. The tank level is monitored by the level transmitter LT201. If the tank level is low, a start command is activated to engage the Inlet pump (PUMP1) to draw water and fill the tank. Similarly, when the deaerator level is low, a start command is issued to the Outlet pump (PUMP2) to transfer water from the feed water tank to the Deaerator tank. In instances where the feed water tank level becomes excessively high, an open command is executed to activate the feedwater tank overflow valve. The feed water level is monitored by LT201, while the action of the overflow valve UCV201 is of the air-to-open type, with its fail-safe position set to close.

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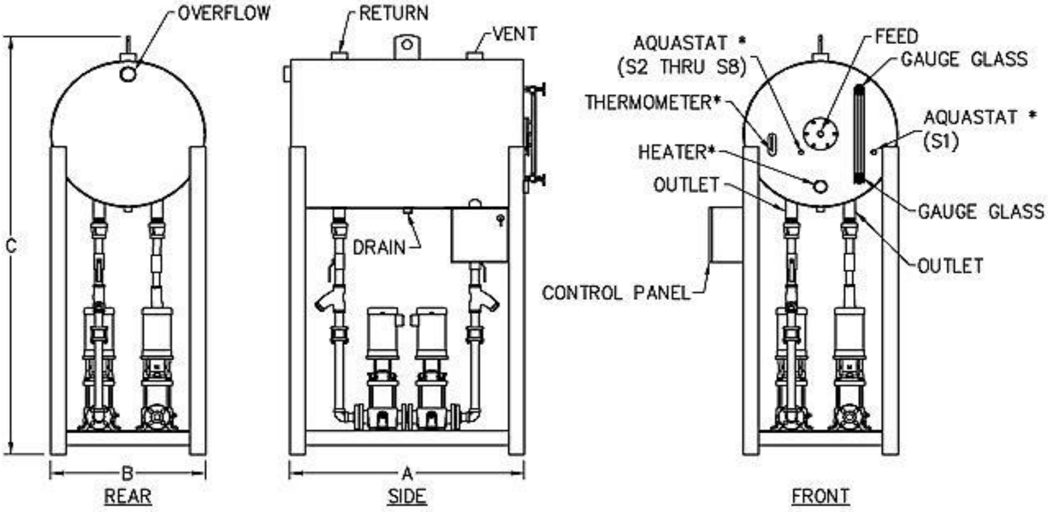

Figure 1.Feed Water Tank

3.3 Drum level Compensation Loop

The control system for regulating the feed water quantity into the boiler, which is essential for maintaining the required water level in the steam drum, is equipped with both single and three-element control mechanisms, as illustrated in the diagram. The water level is continuously monitored by three independent transmitters, namely LT501A, LT501B, and LT501C. To ensure accurate control, all three level signals undergo density correction, which relies on input from the pressure transmitter PT501.

The density compensation process follows the equation:
$\Delta P = HP - LP$
$= (Hm \times Dw) + ((H - Hm) \times Ds) - (H \times Da / Hm)$
$= \{\Delta P + H(Da - Ds)\} / (Dw - Ds)$
In this equation:
- Hm represents the compensated drum level.
- Dw stands for the density of water in gm/cm³.
- Da signifies the density of water at ambient temperature (34°C), equivalent to 0.994 gm/cm³.
- Ds corresponds to the density of steam in gm/cm³.
- H represents the distance between tapping points or water head on the LP side, measuring 600 mm.
- Pressure acting on the HP side is calculated as $(Hm \times Dw) + ((H - Hm) \times Ds)$.
- Pressure acting on the LP side is computed as $H \times Da$.

3.3.1 Steam Flow compensation Loop

This control loop is instrumental in compensating for flow variations based on changes in both pressure and temperature. Steam flow is influenced by alterations in pressure and temperature. Specifically, when the temperature, as measured by TT502, increases, the flow of steam decreases, and conversely, when the pressure, as measured by PT502, increases, the steam flow rate is elevated. The primary purpose of this loop is to rectify the flow rate, which is initially measured by the differential pressure flow meter FT502.

The density compensation equation used in this context is as follows:
$F0 = \sqrt{}(P + 1.01325 * 100) * (T + 273.15) / (Pb + 1.01325 * 100 + 273.15)$
Where:
- F1 represents the measured flow rate.
- F0 stands for the corrected flow rate.
- P signifies the measured pressure (KPa).
- Pb corresponds to the reference pressure (KPa).
- T denotes the measured temperature (°C).
- Tb represents the reference temperature (°C).

3.4 Attemperator

The TIC601 control loop is dedicated to managing the moisture content in the dry steam. This entails the utilization of the temperature transmitter TT601, responsible for gauging the temperature of the dry steam following the superheater. If the temperature of the dry steam falls below the predefined set point, the TIC601 controller intervenes to regulate the addition of water, primarily by controlling the inlet valve TCV601. Conversely, if the temperature exceeds the upper limit, prompt action is taken to rectify the situation.

3. Conclusion

The utilization of the Distributed Control System (DCS) has transformed the realm of process monitoring and control in industrial plants, providing a user-friendly and robust system that places safety at the forefront. This project has effectively accomplished its objectives by implementing an automated control design for a thermal power plant, allowing for swift responses to fluctuations in load demand. Additionally, it has significantly improved boiler efficiency while conserving energy resources, all the while ensuring the integrity of safety measures.

This development serves the overarching goal of enhancing thermal energy production, resulting in a reduced need for manpower without compromising the safety protocols of the thermal power plant. The entire process is meticulously monitored from the central operating station. Should an emergency arise, alarms, messages, and fault notifications are swiftly relayed to both the field and operating stations, enabling the prompt shutdown of any malfunctioning components to ensure the overall safety of the system.

Reference

1. K.N. Subrahmanyam, “Study of sub critical, supercritical and ultra super critical thermal power plant,” International Journal of Advance Engineering and Research Development.
2. Bill Gough, “Advanced control of steam superheat temperature on a utility boiler,” 4th international colloquium on signal processing and its applications
3. Orosun raphel and Adamu sunusi sani, “Modelling and controller design of an industrial oil-fired boiler plant,” International Journal for Advances in Engineering and Technology.
4. P. Kiruthika, P. Navaseelan, “Automated control system design for ultra supercritical thermal power plant,” IEEE International conference on Technological Innovations in ICT for agriculture and rural development (TIAR 2015).
5. Xiao wu, Jiong shen, Yiguo lil and Kwang Y. Lee, “steam power plant configuration, design, and control,” Wires Energy Environ 2015.
6. Khyati B Charadaval, “ Simulating and controlling of power plant super heaters,” in National Conference on Emerging trends in computer, electrical and electronics (ETCEE2015) and international journal of Advance Engineering and Research Development (IJAERD).

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