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Operational Practices To Mitigate Pre-Synchronization and Post-Synchronization Risk of Damage to Boiler In Supercritical Thermal Power Units

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Abstract:
The proliferation of Supercritical Technology based thermal power units is indicative of a progressive shift toward a reduced carbon emission epoch. These units exhibit superior operational efficiency compared to earlier technologies, thereby contributing to the mitigation of carbon footprint. While original equipment manufacturers (OEMs) typically furnish documentation detailing the start-up procedures tailored to the specific condition of the unit following a designated duration of shutdown, certain startup practices andpost-synchronization operational precautions remain unaddressed. Overlooking these intricacies could precipitate inadvertent tripping events or damage to boiler pressure parts by reducing its life. Notably, such intricacies may not find comprehensive coverage in the OEM-provided start-up guidelines.Drawing on extensive operational experience and root cause analyses of multiple instances of tripping in Supercritical Units subsequent to synchronization, this study elucidates critical operational nuances that warrant vigilance from DCS operational engineers to forestall spurious tripping. This paper underscores key ambiguities that necessitate careful consideration and offers practical insights to enhance the understanding of essential operational intricacies, thereby bolstering the reliability of supercritical technology unit operations.

Keywords: supercritical technology, thermal power units, carbon footprint, operational efficiency, start-up procedures, synchronization, tripping events, root cause analysis, operational nuances, reliability enhancement, unit start up, boiler light up, swelling, pressure vessel, feed water

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I. Introduction

For Supercritical unit start up it is of utmost importance to understand the flow path of Feed water and Steam in the circuit. As shown in Figure – 1, the feed water stored in the Deaerator is pumped with the help of electric or steam driven boiler feed pumps via Feed regulating station (consisting of 30% feed water flow control valve and 100% feed water flow motorized valve). After the feed regulating station the water flows to the suction of the boiler circulation pump and the discharge of the boiler circulation pump is controlled by the discharged flow control valve which maintains the feed water flow to the economizer as per the set point of feed water flow. OEM provides tripping due to low feed water flow and it is one of the most vital parameters to monitor during unit start up as well as during normal running at full load. The 30% feed water flow control valve monitors the separator vessel level as per the set point provided by the desk operator. After the unit attains 30% load the desk operator changes over the feed water flow from 30% feed water flow control valve (nomenclature is so give as the capacity of the pipe can only cater 30% of feed water flow of unit full load) to 100% motorized valve (nomenclature is so given as the line is so designed to cater 100% of feed water flow of the unit full load). Boiler circulation pump remains in service right from the beginning of unit start up till there is a wet mode to dry mode change over occurs based on the fulfillment of certain set of conditions and logics as provided by the OEM. "Wet mode" basically means that the separator vessel is partially filled up with feed water coming from the riser tubes and water wall and partially with steam while on the other hand "Dry mode" means that the separator or leveling vessel does not have feed wateri.e.,the total feed water inlet to the Separator is equal to steam outlet from it.

There are certain emergencies that can be created during the transient load rising post synchronization which can lead to various emergencies in the unit as for example turbine exhaust pressure ratio low to Turbine trip, low feed water flow to MFT, drastic increase in feed water flow to wet steam carry over in super heater circuit causing low main steam temperature, higher rate of change in main steam temperature and pressure than permissible due to increase of coal flow, operational error in bypass system or mal operation of valves. This paper deals with major operational lapses or errors during pressure and temperature raising phase of Boiler and post synchronization that the operator can create because OEM does not address these issues in their manual. This paper includes all the practical hands-on tipsfor the following phases and practical issues faced:

A. Impact of non-uniformity of the Superheater metal temperatures during pressure and temperature raising phase in Supercritical Boilers
B. Separator Level fluctuation during steam blow phase
C. Impact of Separator Pressure drop post synchronization
D. Effects of Post-Synchronization Delay in Closing HP-LP Bypass Valve
E. Implications of Load Set Point Modulation Post-Synchronization in Supercritical Boiler Operations
F. Effects of Fast Increase of Coal Flow Following Transition from 30% to 100% Feed Water Flow Valve Changeover

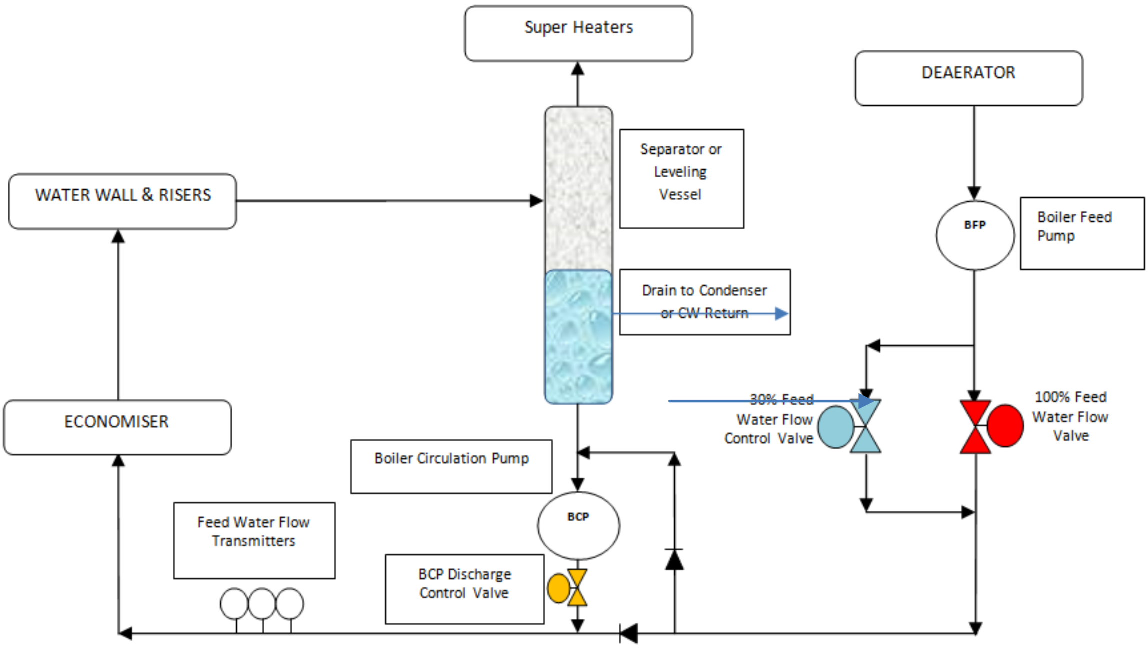

Figure 1 - Typical Feed Water System of 660 MW Supercritical Thermal Power Plants

A. Impact of Non-Uniformity of Superheater Metal Temperatures during Pressure and Temperature Raising Phase in Supercritical Boilers

Supercritical boilers play a pivotal role in power generation, operating under high pressures and temperatures to achieve optimal efficiency. However, the non-uniformity of superheater metal temperatures during the pressure and temperature raising phase can have significant consequences on the boiler life and reliable operation in long run.

One primary consequence of non-uniform superheater metal temperatures is the potential for thermal stresses and material fatigue. As certain sections of the superheater experience higher temperatures compared to others during the pressure and temperature raising phase due to uneven flow of steam through the superheater tubes and flue gas flow difference, differential expansion and contraction occur. This non-uniform expansion can result in thermal stresses that compromise the integrity of the superheater tubes, increasing the likelihood of tube failures and leaks. Such failures contribute to unplanned downtime and maintenance costs. Operators should optimize the start-up pressure and temperature rise in the boiler uniformly and gradually to ensure uniform flow establishment through all the tubes.

Furthermore, operators play a crucial role in averting wet steam carryover by comparing metal temperatures of the roof superheater, platen, and final superheaters with the saturation temperature corresponding to the boiler pressure. This step is essential to ensure that no tube is subjected to wet steam conditions, which could lead to tube life degradation. Implementing a careful temperature-raising sequence, intricately coordinated with fuel and airflow rates, serves as a preventive measure. This approach not only minimizes the risk of non-uniform superheater metal temperatures but also safeguards against potential issues associated with wet steam carryover. In case there if any tube metal temperature is not having degree of superheat (actual tube metal temperature – saturation temperature of steam at given boiler pressure prevalent at the moment), at least more than five to seven degrees centigrade, then further load raising should be withheld. In such instances, it is advisable to maintain a constant steam flow until all the metal temperatures of the superheater tubes attain the necessary degree of superheat. This precautionary measure ensures that the superheater components uniformly reach the desired operating temperatures before proceeding with additional load, mitigating the risk of thermal stresses and associated complications of wet steam carry over. Integrating this practice into the operational procedures contributes to the overall reliability and safety of supercritical boilers during the critical phases of pressure and temperature elevation.

B. Separator level fluctuation during steam blow practice during steam parameters achieving phase prior synchronization in supercritical units

Observations indicate that, during the steam parameter (pressure and temperature) elevation phase through modulation of the High-Pressure (HP) and Low-Pressure (LP) bypass systems, a steam blow practice might be occasionally implemented to achieve steam quality early. This practice aims to preemptively address challenges such as the accumulation of iron dust in boiler tubes to expedite the achievement of desired parameters with desired steam quality. Before synchronization, the steam blow involves the fast opening of HP Bypass valves by 10% to 15%, causing a sudden surge in steam flow through the boiler tubes giving a sudden pressure drop of approximately 10 bar to 15 bar. This abrupt flow aims to dislodge surface iron particles that may have accumulated in the tubes.Typically, three to five such blows are administered, and subsequent measurements of iron (Fe) concentration in parts per billion (ppb) at a sampling point near the condenser confirm the removal of loose iron particles. This preventative measure helps mitigate the risk of tube failure due to exfoliation by maintaining proper steam quality prior synchronization, helps to bring all the superheater and reheater tubes' metal temperature uniform and also reduce the time for machine synchronization with grid.

It is important to note that these sudden blows, coupled with the subsequent steam pressure drop in the boiler, result in swelling in the separator. This phenomenon requires meticulous monitoring by the operation desk engineer to ensure the system's integrity and prevent undesirable consequences by closely monitoring the feedwater flow (ensure that the 30% feed water flow control valve, whether in Auto or Manual mode, must not get closed by false increase in separator level due to transient swell) during the swell phase and regulate the high separator level through operation of the drain valves from separator to condenser or to cooling water return line (as shown in the Figure – 1).

C. Impact Of Separator Pressure DropPost Synchronization

In the realm of Supercritical Unit operations, meticulous monitoring of separator pressure assumes a critical role during Wet Mode operations to avert any potential drop in feed water flow. An imperative consideration lies in the fact that the temperature of the separator water consistently aligns with the saturation temperature corresponding to the prevailing separator pressure. Any sudden decrease in the separator pressure triggers an anomalous expansion of the water of the separator tank, inducingswelling of water of the Boiler Circulation Pump's (BCP) suction line. This expansion manifests as the formation of vapor bubbles within the water, consequently leading to a significant decline in the feed water flow by BCP due to the presence of vapor. Such a decline may cause inadvertent tripping of the boiler as a consequence of perceived low feed water flow. Additionally, this occurrence is often reflected by an abrupt reduction in the current drawn by the Boiler Circulation Pump at the instant of sharp reduction of separator pressure due to more steam drawn by turbine cycle from Boiler.

The operating desk personnel must remain aware that the phenomenon of swelling or expansion due to reduction of separator pressure will manifest as a falsely elevated separator level, despite the actual mass of water within the separator being significantly lower. Consequently, the function of the 30% control valve, entrusted with the task of maintaining the separator water level, will be compromised, as it fails to activate owing to the falsely inflated separator water level. The likelihood of this phenomenon is particularly heightened immediately following the synchronization process, concurrent with the introduction of steam into the turbine and the subsequent closure of the High-Pressure (HP) and Low-Pressure (LP) bypass. Additionally, it's important to slowly increase the separator pressure based on the operational needs post synchronization in Wet Mode. Operators can control the process better by carefully watching the coal flow increase at the moment of gradual pressure rising post syncing the machine with grid as coal increase manifests in the pressure and temperature dynamics, typically with a lag of one to three minutes, contingent upon the behavior of the boiler. The key guiding principlethe separator pressure should have an upward pressure increase trend after synchronization**.**

D. Effects of Post-Synchronization Delay in Closing HP-LP Bypass Valve

Within thermal power industry practices for Supercritical (SC) units, a critical operational procedure post synchronization involves load ramp-up. This necessitates the closure of both the High-Pressure (HP) and Low-Pressure (LP) Bypass valves, which are typically opened between 25% to 50% based on specific unit requirements or Original Equipment Manufacturer (OEM) recommendations. Any delay in the closure of these valves following synchronization can yield precarious consequences during the transient operational phase.

Specifically, if the HP Bypass is fastclosed while the LP Bypass remains open due to delayed closure or sluggish valve operation, the likelihood of spurious tripping of the unit via Reverse Power Protection is imminent for the turbines where IPT Rolling is done only. The steam through HRH (hot reheat) line following the path of least resistance moves towards the condenser, thus depriving the Intermediate Pressure (IP) and Low Pressure (LP) cylinders of High-Pressure Reheat (HRH) steam, consequently impeding their ability to generate the requisite power post synchronization. Compounding this issue, the partially opened LP Bypass exacerbates the decline in power output below the reverse power flow tripping set point, leading to inadvertent tripping.

Conversely, should the LP Bypass be closed prematurely with the HP Bypass remaining open, there exists a risk of the unit tripping due to low HP Exhaust Pressure ratio(Pressure of first stage divided by the pressure of HP exhaust should not go below1.7, otherwise turbine will have the chance of tripping on high HP exhaust temperature because of churning). Notably, Desk operator must immediately close the ventilation valve of HP turbine (i.e.,valve from the HP turbine to Condenser) as a standard SOP (standard operating practice) to increase the load and establishing HP exhaust to Reheater.This mechanism serves to maintain optimal flow through the turbine thus preventing escalation of the blade metal temperatures due to churning of steam. Subsequent closure of the LP Bypass post synchronization leads to an increase in CRH pressure, thus diminishing the HP Exhaust pressure ratio, potentially triggering unwarranted unit tripping on low HP exhaust pressure ratio.

Above rational is based on specific design of rolling procedure of Turbine. However, reader has to take care of HP Bypass, LP Bypass and Ventilation Valve operation specific to their OEM Turbine Rolling procedure.

E. Implications of Load Set Point Modulation Post-Synchronization in Supercritical Boiler Operations

Following unit synchronization, the Distributed Control System (DCS) autonomously generates a block load set point based on the turbine Governing Valve (GV) opening and the turbine Throttle Valve (TV) upstream pressure. Operating personnel possess the flexibility to adjust the load set point, considering the rate of ascent or descent of the main steam pressure based on operational acumen. A surge in coal input results in increasedmain steam pressure, correspondingly escalating the load for a consistent GV opening. Conversely, maintaining a steady coal flow results in a near-constant main steam pressure. Should the operator choose to increase theload set point from the DCS, thereby increasing the GV opening, the main steam pressure would drop, potentially inducing swelling in the separator. Consequently, this would cause a decline in the Boiler Circulating Pump (BCP) feed water flow, ultimately leading to the possibility of a trip in the event of insufficient and delayed corrective action by the operator. Conversely, neglecting to enhance the load set point in the DCS while ramping up coal flow without adjusting the feed water flow can trigger a rapid and critical escalation in main steam pressure and temperature, potentially giving rise to a unit-wide emergency situation.

F. Effects of Fast Increase ofCoal Flow Following Transition from 30% to 100% Feed Water Flow Valve Changeover

Observations reveal that, subsequent to the transition from wet to dry mode operators sometimes escalate coal flow to facilitate the premature termination of oil gun usage to reduce costly secondary fuel consumption. In the event of increase in pressure and temperature, operators may respond by increasing feed water flow or adjusting the load via Governing Valves (GV) manipulation. Post-transition, the differential pressure across the 100% motorized feed water valve (as shown in the Figure 1) diminishes, aligning with the separator pressure. Prior to the 30%-to-100%-line transition, it is advisable, based on operational experience, to maintain this differential pressure within the range of 10 to 20 bar).Under circumstances where the boiler feed pump pressure is elevated in the upstream side of the motorized 100% valve and lower in the downstream as per the separator pressure, even a slight opening of the motorized valve can induce an upsurge in feed water flow. If this flow surpasses a critical threshold, it can result in the conveyance of moisture-laden steam from the separator or leveling vessel to the superheaters, thereby resulting in asharp decline in main steam temperature, possibly leading to an emergency situation. Conversely, if the operator opts to elevate coal flow post 30% to counterbalance the increased feed water flow stemming from the heightened differential pressure across the valve, it may inadvertently trigger another emergency by intensifying main steam temperature and pressure.

To mitigate the impacts of high steam temperature and pressure, the operator may adjust the feed water flow or increase the load through GV manipulation. However, considering the transient operational phase, this can trigger wet steam carryover in the superheaters, potentially culminating in tube failures at a later stage.

II. Conclusion

In conclusion, the thorough understanding of the feed water system and the steam flow paths through the boiler along with the controlled operation of valves in the turbine and auxiliary equipment section during the start-up of a supercritical unit is crucial for its successful operation. This paper has delved into various operational challenges and potential errors that operators may encounter during the pressure and temperature raising phase, particularly post-synchronization. The identified issues encompass the impact of sudden separator pressure drop, the consequences of delayed closure of HP-LP bypass valves, the implications of load set point modulation, the effects of increased coal flow during the transition from 30% to 100% feed water flow valve changeover, the significance of non-uniform superheater metal temperatures, and the separator level fluctuation during steam blow practice to ensure faster steam quality achievement in pre-synchronization period.

The examination of these issues reveals the need for meticulous monitoring and operator intervention to ensure reliable and safe supercritical boiler operation. The consequences of these operational lapses include potential tripping, tube failures, and emergencies, underscoring the critical role of operators in mitigating risks and maintaining optimal performance.Addressing these challenges requires a combination of adherence to operational procedures, and the application of operational acumen. Operators must be vigilant during critical phasesand exercise caution in decision-making to prevent unwarranted tripping and potential damage to boiler components.