Analysis on Application Examples of Unit No.0 High Pressure Heater

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Abstract. Because of excess power capacity, most of the thermal power units often in low load operation and poor economic efficiency, the addition of 0 high pressure heater is a new energy-saving emission reduction technology. This paper summarizes the characteristics of the program and the influence on the steam turbine and the boiler by analyzing the application of the No.0 high pressure heater in the energy saving technological transformation of the unit from the aspects of steam source selection and installation.

1. Introduction
In accordance with the requirements of the action plan for energy conservation, emission reduction, upgrading and transformation of coal power (2014-2020) jointly formulated by the national development and reform commission, the ministry of environmental protection and the energy bureau on September 12, 2014 [1] and the current situation that the unit is operating under low load regularly, the application of new energy saving technologies is paid more attention when building and reconstructing thermal power units by companies. In order to improve the operating efficiency of the unit under low load condition, regenerative system optimization is an important direction to be concerned. The regenerative heater series is one of the main factors affecting the thermal economy of regenerative system. With the increase of regenerative heater series, the temperature of feed water increases and the unit's cycle thermal efficiency also increases. No.0 high pressure heater is one of the measures which can save energy and reduce emission under low load, improve operation economy of unit and in service rate of denitration device.

The application status of No.0 high addition is discussed in this paper from two aspects of steam source selection and installation mode. Analysis is also given on the effect of energy saving, the effect of environmental protection and the impact of the original system.

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2. No.0 High Pressure Heater and Its Application Status
No.0 high pressure heater technology is only applied to some ultra-supercritical units at the present stage. In the following part, the application status of No.0 high pressure heater is analyzed from two aspects of steam source selection and installation mode taking the ultra-supercritical units for examples.

2.1. No.0 high pressure heater
In the reheat system, a high pressure heater is added to heat the feed water between the No.1 high pressure heater and the boiler economizer. The steam source of the high pressure heater comes from a stage of high pressure cylinder before 1-stage extraction. The steam trap of the high pressure heater flows by itself to the No.1 high pressure heater or desecrator step by step. The high pressure heater that meets the above conditions is called No.0 high pressure heater.

2.2. Source selection of No.0 high pressure heater
It is very important to select high pressure steam source of No.0 high pressure heater with suitable parameters without affecting the safety of the unit. According to the different structure of the unit, the selection of the steam source of 0 is introduced from the following two aspects.

2.2.1. The selection of steam source of 0-stage. Extraction to the unit with supplementary steam valve.
The technology of the steam supplementary valve in the ultra-supercritical unit is that a new steam pipeline equipped an external steam supplementary valve is added between the main steam valve and the regulating valve and the new steam throttles into the space after the fifth rotor blade of the high-pressure cylinder by means of the steam supplementary valve. The steam supplementary valve technology is only used when overloading or rapid responding to the primary frequency modulation requirements. The unit often operates in the sliding pressure operation mode with the main steam regulating valve fully open at low load, without using the steam supplementary valve technology [2]. No.0 high pressure heater is fed with the help of the steam turbine existing steam valve, under low load. The steam supplementary valve and No.0 high pressure heater shares the same steam inlet switched by the fast valve, as shown in Figure 1.

![Figure 1. Selection of steam source for stage 0 extraction to the unit with supplementary steam valve](image)

The advantages for the unit with the supplementary steam valve to select steam source of 0-stage extraction are as follows:
The supplementary steam valve isn’t in service under low load and the efficiency of the turbine is improved by means of adopting No.0 high pressure heater.
High safety performance, low cost of equipment investment, simple installation, quick operation and simple maintenance.
The disadvantage is that throttling loss reduces the economy of the unit.
This scheme is adopted by Huaneng Weihai power plant, Tongshan Huarun power co., LTD., Zhejiang Zheneng Taizhou second power generation co. LTD and Shanghai Waigaoqiao third power generation co. LTD.

2.2.2. The selection of steam source with 0-stage extraction to the unit without supplementary steam valve. For the kind of units without the supplementary steam valve, there is a problem of how to optimize the steam source of 0-stage extraction. Relevant studies of domestic turbine manufacturers, indicate that the best steam source should be selected after the dynamic blade of the high-pressure cylinder of stage 7 according to the principle of maximum reduction of weighted average heat consumption under various load conditions. After the 9 of the high-pressure cylinder finally serves as the steam source of stage 0 extraction through optimization calculation [3]. As shown in figure 2.

![Figure 2. Selection of steam source for stage 0 extraction to the unit without the supplementary steam valve](image)

The advantages for the unit without the supplementary steam valve to select steam source of 0-stage extraction are as follows (compared with a unit with supplementary steam valve):

1. The steam source is the best steam source through optimization calculation. No pressure reduction or enthalpy reduction is required.
2. The strength, rigidity and safety performance of the external cylinder shall be verified.

The disadvantage is that it is difficult to drill holes on high pressure cylinders and difficult to operate and maintain with.

This scheme is still in the stage of theoretical research because of high investment and complex processing.

2.3. Installation of No.0 high pressure heater

For energy saving, the added No.0 high pressure heater is different from other ordinary high pressure heating systems. Firstly feed water for water side of No.0 high pressure heater is adopted in two ways: full water feed and partial water feed. For ultra-supercritical units, the way of full water feed requests complex processing, high investment cost, the way of partial water feed is the better choice. Secondly high pressure is classified in two ways for 1000MW units: single row and double row. At present, there are several installation methods summarized as follows.

2.3.1. Installation of single row high pressure heater. No.0 high pressure heater is used as the last stage of high pressure heater, which is often arranged on the water feed pipeline before entering the economizer. Most of the 660MW and above ultra-supercritical units are equipped with No.3 high-addition external steam cooler (steam cooler). Usually, there are three schemes of installation for No.0 high pressure heater.
Scheme 1: for the unit with the steam cooler, No.0 high pressure heater is connected with the steam cooler in parallel. One part of the feed water flow into No.0 high pressure heater, the other part is fed by the steam cooler, and the two parts of the feed water are mixed to the coal saver as shown in figure 3. No.0 high pressure heater and No.1-3 high pressure heater can share a set of high-pressure feed water bypass system which can save investment cost. Step by step self-draining can be adopted as the normal drain of No.0 high pressure heater. That is No.0 high pressure heater can drain to No.1, but the system of step by step flow mode is relatively complicated and the drain flow capacity of No.1-3 should also be tested. It can also be drained to deaerator or condenser neglecting of economic loss. And it can drain to the expansion vessel in case of accident. When the unit is under high load in normal operation, No.0 high pressure heater will not put into operation acting as a feed water channel, the unit efficiency will be less due to pressure loss; When the load is low, No.0 high pressure heater will put into operation and the opening of regulating valve of 0-stage extraction will be governed to control steam extraction capacity from overpressure.

Scheme 2: for the unit with the steam cooler, No.0 high pressure heater is connected with the steam cooler in series. One part of the feed water flows into No.0 high pressure heater and the steam cooler, and the other part of the feed water flows into the coal saver through the added pipeline as shown in figure 4. No.0 high pressure heater and No.1-3 high pressure heaters can share a set of high-pressure feed water bypass system which can save investment cost, with the same method in the first scheme. Step by step self-draining can be adopted as the normal drain of No.0 high pressure heater. That is No.0 high pressure heater can drain to No.1, it can also be drained to deaerator or condenser. A bypass pipeline equipped with a regulating valve is set up on the water feed pipeline, the feed water capacity flowing through No.0 high pressure heater and steam cooler can be governing by means of the regulating valve.
Scheme 3: To some units without steam cooler, No.0 high pressure heater is installed after No.1 high pressure heater as shown in figure 5. No.0 high pressure heater and other high pressure heaters can share a set of high-pressure feed water bypass system which can save investment cost, with the same method in the first scheme. Step by step self-draining can be adopted as the normal drain of No.0 high pressure heater. That is No.0 high pressure heater can drain to No.1, it can also be drained to deaerator or condense. A bypass pipeline equipped with a regulating valve is set up on the water feed pipeline, the feed water capacity flowing through No.0 high pressure heater and steam cooler can be governing by means of the regulating valve.

![Figure 5. Scheme 3: Installatin of No.0 high pressure heater to the unit without the steam cooler](image)

By contrast, the 3 schemes above have characteristics as follows:

- **Investment:** similar cost;
- **Economy:** for a unit with steam cooler, as to that the two strands of feed water are mixed, the greater the temperature difference, the greater the irreversible loss theoretically, scheme 1 can not only maximize the steam cooler and No.0 high pressure heater efficiency, at the same time can guarantee the increase of feed water temperature, so scheme 1 is a relatively optimal.
- **Unit operation control:** No.0 high pressure heater participates in the frequency modulation of the unit in these schemes above, the corresponding operation methods should be developed according to the operation parameters of No. 0 high pressure heater.
- Scheme 1 was adopted in the second Taizhou power plant in Zhejiang province and scheme 3 is applied in Huaneng Weihai power plant.

### 2.3.2. Installation of double high pressure heater

For 1000 MW unit with double row high pressure heater, No.0 high pressure heater is installed in one row of water feed pipeline of high pressure heater(A row), feed water regulating valve is installed in another row(B row) as shown in figure 6. Feed water flow can be governed by feed water regulator in B row to improve the unit’s economy and safety while raising the feed water temperature with variable load.

![Figure 6. Installatin of double row high pressure heater](image)
The scheme has characteristics as follows:

1. Economy: the heat consumption rate is shown in FIG 7 while No. 0 high pressure heater added. (Without considering the boiler efficiency) [4].

![Figure 7. Turbine heat rate reduction after adding No. 0 high pressure heater](image)

2. Unit operation control: Feed water flow into No. 0 high pressure heater can be governed by feed water regulator in B row to improve the unit’s economy and safety while raising the feed water temperature with variable load. The regulation lower limit should be set for the outlet regulating valve of B row must set in order to guarantee the heat transfer capacity of B row.

3. Consideration of drainage system: a unit operation data shows that: No.0 high pressure heater control logic can meet the requirements of normal operation when the load is above 60%, it cannot satisfy the requirements on condition that No.0 high pressure heater drain water comes up to 150 t/h, A row feed water flow increases, A row steam extraction increases and drainage valves are fully open when the load under 60%, then the steam extraction pressure of No.0 high pressure heater should be contained and the efficiency of No.0 high pressure heater decreases. To deal with this problem, No.0 high pressure heater can drain to No.1 in A row and No.1 in B row at the same time to ensure the adjustment tolerance of A row high pressure heater water and performance ability of B row high pressure heater and economy of full load operation under variable conditions with added No.0 high pressure heater as shown in FIG 6. This scheme is applied in Tongshan Huarun power co. LTD.

3. Influence of No.0 High Pressure Heater on Unit Performance

3.1. Influence of No.0 high pressure heater on energy saving

No.0 high-pressure heater is a comprehensive new technology for energy conservation and emission reduction, which can be implemented in the construction of new units or the renovation of existing units.

1. It can increase the feed water temperature under low load of the unit, the average temperature of cycle heat absorption process is raised with an additional stage of steam extraction, and thereby the circulation efficiency of the whole heat cycle is improved;

2. Steam extraction flowing into the feed water system reduces the amount of steam entering turbine condenser, decreases loss of cold end of steam turbine and lets the steam consumption of the steam turbine cut down;

3. It improves the steady burning performance of boiler under low load;

4. The regulating valve installed on the 0-stage extraction pipeline has certain frequency modulation ability, which can reduce the throttling loss of the turbine regulating valve and further reduce energy consumption when it is combined with the condensate water throttling.
3.2. The influence of No.0 high pressure heater on environmental protection
No.0 high pressure heater increases the final feed water temperature, reduces the heat absorbed by the feed water in the economizer, and increases the smoke temperature at the outlet of the economizer. Therefore, under low load, the feed water temperature of the coal economizer is increased, and the inlet smoke temperature of the denitration equipment is correspondingly increased, which not only improves the SCR denitration efficiency and reduces the denitration cost, but also slows down the aging speed of the catalyst.

3.3. Influence of No.0 high pressure heater on original unit
(1) Influence on the flow passage of high pressure cylinder. The inlet of supplementary steam valve is located at after a certain stage of the high pressure cylinder (such as high pressure cylinder stage 5). If the valve is changed to extraction steam, the pressure after supplementary steam valve should be adjusted according to the inlet steam parameter of No.0 high pressure heater, the pressure will be reduced, resulting in the increase of the front and rear pressure difference of unit blade to increase, which has an impact on the blade strength. Therefore, the strength of the through-flow blade of the high pressure cylinder needs to be re-checked or designed.

(2) Influence on axial thrust and axial vibration of steam turbine. Compared with the original design, the pressure in front of the high-pressure balancing piston decreases due to steam extraction, thus reducing the balance capacity. This requires a re-check or modification of the design to meet thrust requirements by raising the height of the rotor balance piston to ensure the unit's safe operation.

(3) Influence on the safety of the original steam turbine. It is a great test for the strength of the high pressure outer cylinder to add a 0-stage extraction to the high pressure cylinder before the first stage of extraction for the unit with no supplementary steam valve.

4. Conclusion
(1) No.0 high pressure heater can improve the feed water temperature, reduce steam turbine thermal consumption, improve the utilization rate of denitration device at low load, and realize energy saving and emission reduction effectively.

(2) The influence on steam turbine, boiler and denitration facility after adding No.0 high pressure heater should be paid more attention, especially the strength of the through-flow blade of the high pressure cylinder needs to be re-checked or designed.

(3) All the steam turbines with supplementary steam valve are qualified to adopt No.0 high pressure heater technology; for units without supplementary steam valve, the reconstruction is not recommended.

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