Research on operation of low-pressure cylinder zero output heat supply retrofit unit

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Abstract: This paper introduces the technical route of the zero output heat supply transformation of low pressure cylinders in Shandong Province, the operation after the transformation, the impact on power grid dispatching, and the constraints on the normal operation of some units after the transformation, providing technical support for power generation enterprises to accurately implement the "three transformation linkage" transformation scheme and the accurate dispatching of the power dispatching center

Keywords: Zero output of low-pressure cylinder, Heating, Peak shaving

1. Background

As of August 2022, a total of 28 low pressure cylinder zero output retrofits [1-3] have been completed for direct thermal power generation units in Shandong Province, including 6 in 2019, 10 in 2020, 10 in 2021, and 2 in the first half of 2022; The rated capacity is 9265MW, accounting for 17.91% of the total capacity of direct thermal power units in Shandong Province. There are 4, 22 and 2 units below 300MW, 300MW and 600MW, respectively. The rated capacity is 600MW, 7335MW and 1330MW, respectively, and the capacity accounts for 6.48%, 79.17% and 14.36% respectively.

In 2021~2022 heating season, there are a total of 23 units with normal cylinder cutting, and no abnormal conditions affecting the normal operation of cylinder cutting are found. In order to meet the requirements of heat supply or peak load regulation [4-6], 19 units have been put into normal cylinder cutting operation, and 4 units have been put into operation for a short time; There are 5 units not put into cylinder cutting operation.

2. Low pressure cylinder zero output heat supply transformation

2.1 Low pressure cylinder zero output heating technology

The zero output heat supply technology of the low pressure cylinder is that under the high vacuum operation condition of the low pressure cylinder, the original steam inlet pipe of the low pressure cylinder is cut off with a fully sealed hydraulic butterfly valve, and a small amount of cooling steam is introduced through the newly added bypass pipe to take away the air blast heat generated by the low pressure rotor after the zero output transformation of the low pressure cylinder. Compared with conventional heating methods, low pressure cylinder zero output heating technology has the following advantages:

1) Compared with that before transformation, the zero output heating technology of low pressure cylinder uses the steam made by the original low pressure cylinder for heating, reducing the loss of cold source of the unit, and reducing the coal consumption rate of generating unit; Under the same boiler heat load, the heat supply capacity of the unit can be improved; Under the condition of constant heat supply, the generating power of the unit can be reduced to a certain extent to achieve deep peak shaving.

2) Compared with optical shaft heating [7], high back pressure heating [8] and other heating technologies, low pressure cylinder zero output heating technology can realize the flexible switching between the condensing operation mode and the high back pressure operation mode of the heating unit, making the unit have the characteristics of high back pressure unit with large heating capacity and flexible operation mode of the condensing heating unit, The problem of replacing the low pressure cylinder rotor twice during the heating period and the problem of storing and maintaining the spare rotor in the high back pressure heat supply transformation (double rotors) and smooth axis transformation scheme are avoided, and the maintenance cost during unit operation is greatly reduced.

2.2 Main technical route of transformation

1) Transformation of medium and low pressure connecting pipe and butterfly valve at the inlet of low pressure cylinder;

2) Add LP cylinder cooling steam system;

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3) Supporting transformation of monitoring and measuring points for turbine proper operation;
4) Check the operation safety of the low pressure secondary and final stage blades and spray the anti water corrosion metal wear-resistant coating;
5) Improvement of exhaust cylinder spray desuperheating system;
6) Supporting transformation of heating system, air extraction system, condensate system, etc;
7) Reconstruction of supporting automatic control system.
The transformation of the supporting automatic control system mainly includes sorting out the control logic related to heating and steam extraction in the original control system, and canceling all the locking control logic corresponding to the closing of the low-pressure butterfly valve; Cancel the protection logic of low load input of heat supply; Cancel relevant control logic that conflicts with zero output heat supply of low pressure cylinder. Sort out the protection settings related to the operation of low pressure cylinder in the original control system, and confirm that each control logic is consistent with the requirements for zero output heating and heating operation of low pressure cylinder. Add zero output heat supply input/removal control logic of low pressure cylinder. In the transformation scheme, monitoring and measuring points are added to connect to the DCS control system.
There are three different design methods for the additional LP cylinder cooling steam system. First, small flow cooling steam pipeline is equipped, and the adjustable range of cooling steam flow is small; Second, large flow cooling steam pipe is equipped as "auxiliary connecting pipe", and the cooling steam flow can be adjusted in a wide range. When the low pressure cylinder operates at zero output, adjust the steam regulating valve of the cooling bypass of the low pressure cylinder to make the unit "flexible cylinder cutting operation"; Third, on the basis of the first design method, the cooling steam is desuperheated and depressurized, and the steam and water are separated, reducing the demand for cooling steam, but the steam temperature at the outlet of the steam water separator must be controlled, increasing the preparation time for cylinder cutting.

3. Enable/disenable technical parameters

3.1 Several operation modes of cylinder cutting

1) Conventional cylinder cutting operation. The butterfly valve opening of the connecting pipe of the middle and low pressure cylinder is 0, and the cooling bypass steam just takes away the blast heat generated by the rotation of the low-pressure rotor.
2) Flexible cylinder cutting operation. As the "auxiliary connecting pipe", the cooling bypass steam pipe has a wide adjustable range of cooling steam flow. When the butterfly valve opening of the connecting pipe of the middle and low pressure cylinder is 0, adjust the cooling bypass steam flow to enable the flexible cylinder cutting operation of the unit.
3) Half cutting cylinder operation. The butterfly valve opening of the connecting pipe of the middle and low pressure cylinder shall be maintained at 5%~14%, and the low pressure cylinder shall retain a certain amount of steam. In this state, the operation shall still be carried out in the manner of cylinder cutting.
4) Switch to single cylinder/double cylinder operation. For 600MW units and above, there are generally two low-pressure cylinders. After cylinder cutting, there are two operation modes: single cylinder cutting and double cylinder cutting.

3.2 Preparation for cylinder cutting

1) The heat supply input is normal, whether the exhaust parameters and heating pressure of the intermediate pressure cylinder are within the safe range, and whether the opening of the steam supply regulating valve is within the required range;
2) Fully open the bypass cooling steam regulating valve of LP casing, and check that the bypass cooling steam flow reaches the required value;
3) Gradually reduce the opening of butterfly valve of connecting pipe to 15% or a certain limit, and check that the heating pressure and flow are normal;
4) Some units need to cut off the steam inlet at the steam side of #5 and #6 low pressure heaters;
Fully open the desuperheating water regulating valve of low pressure cylinder.

3.3 Control of main parameters of cylinder cutting

1) During the normal operation of the unit, the boiler load is basically more than 50%, and can be switched at any time except for the restriction of people's livelihood heating;
2) Parameters such as on/off time (excluding heating of cooling bypass) and cooling water volume change are shown in Table 1.

Table 1 Parameters such as startup/shutdown time and cooling water volume change of some units

Unit No	Cylinder cutting input time (min)	Cylinder cutting exit time (min)	Cooling steam flow（t/h）	Low pressure cylinder spray water flow（t/h）	Maximum temperature limit of last stage and next last stage（℃）	Actual operating last stage and next last stage temperature（℃）
1	5 ~ 7	5 ~ 7	20	7 ~ 10	100/175	33/70
2	1 ~ 2	1	8+Desuperheating water below 1t/h	2 ~ 4	140/140	40/50
3	5	2	20	10	60/80	60/70
4	4	8 ~ 9	26 ~ 27	6 ~ 7	110/150	23/62
5	30 ~ 40	10	10+Desuperheating water below 2t/h	0.5 ~ 2	50/110	50/110
6	15	5	10（including desuperheating water）	11 ~ 13	140/140	40/100

As shown in the above table, the operation time of the unit under normal cylinder cutting operation is generally within 10 minutes, and some units need to be cooled and depressurized before cylinder cutting. The operation time is long, about 30-40 minutes; The exit time is generally within 10 minutes.

The operation time for cylinder cutting of some units is relatively long, and the reasons are analyzed as follows:

1）The exhaust parameters of intermediate pressure cylinder are high. The steam exhaust of the intermediate pressure cylinder is four extraction, which is higher than the steam exhaust parameters of the unit with five extraction in the middle. Before cylinder cutting, it is necessary to reduce the temperature and pressure, which leads to a long preparation time before cylinder cutting.

2）The outlet temperature of steam separator is high. Temperature and pressure reduction and steam separator are added to the cooling steam bypass of some units. Before cylinder cutting, the outlet temperature of steam separator needs to be lowered, which leads to a long preparation time before cylinder cutting (the operation mode of some units is to cut the cylinder first and then lower the outlet temperature of steam separator, which shortens the time for cylinder cutting).

3.4 Change of main parameters during cylinder cutting

For 300MW units, the electrical load after cylinder cutting is about 10MW~20MW lower than that before cylinder cutting, and the thermal load is about 120t/h higher when the main steam flow is unchanged. Under the condition of constant external heat load, cylinder cutting can reduce the power generation by about 30% compared with no cylinder cutting.

3.5 Main risks or problems in cylinder cutting adjustment

3.5.1 The butterfly valve of connecting pipe of middle and low pressure cylinder is jammed or not tight.

When the butterfly valve of the connecting pipe of the middle and low pressure cylinder fails, the original steam extraction heating operation mode shall be restored immediately. The maintenance personnel and technicians of the butterfly valve manufacturer shall analyze the cause of the failure, and the cylinder cutting operation shall be carried out after the relevant failure is completely eliminated.

3.5.2 After cylinder cutting, when the external heat load is low, there is a risk of intermediate exhaust overpressure.

When the high exhaust pressure alarm of the intermediate pressure cylinder occurs, the exhaust pressure of the intermediate pressure cylinder can be reduced by increasing the opening of the quick closing regulating valve for heating and steam extraction, and appropriately reducing the boiler load or the circulating water supply temperature of the heating network; If none of the above measures can restore the exhaust pressure of the intermediate pressure cylinder to the normal operating range, quickly open the butterfly valve of the intermediate and low-pressure connecting pipe until the exhaust pressure of the intermediate pressure cylinder returns to the normal operating range.

3.5.3 TSI monitoring parameters may be abnormal.

3.5.4 The water spray of the rear cylinder of the low pressure cylinder is blocked or the linearity difference of the adjustment valve causes the high temperature of the last stage and the second last stage blades.

It is recommended to control the last stage temperature of the low pressure cylinder and the exhaust temperature of the low pressure cylinder not to exceed 80 ℃ during operation, especially during the zero output operation of the low pressure cylinder. When the unit is shut down, check the water spray blockage of the rear cylinder through the manhole of the low pressure cylinder and deal with it. Check the water spray blockage of the rear low-pressure cylinder before starting as a routine inspection item for unit startup.

When the temperature of the last stage and the second last stage blades is too high, the desuperheating water flow of the low pressure cylinder can be increased by increasing the opening of the desuperheating water regulating valve of the low pressure cylinder and the outlet pressure of the condensate pump, and the opening of the bypass regulating valve of the connecting pipe of the middle and low pressure cylinders can be appropriately increased to increase the steam inlet flow of the low pressure cylinder until the temperature of the second last stage of the low pressure cylinder returns to the normal level.

3.5.5 The rear cylinder spray opening is too large, and the last stage blades of the low pressure cylinder are at risk of water erosion.

As the opening of the water injection regulating valve of the low-pressure cylinder decreases, the water injection flow decreases accordingly. When the exhaust temperature of the low-pressure cylinder is stabilized at the saturation temperature corresponding to the exhaust pressure+5 ℃, stop reducing the water injection flow of the low-pressure cylinder. In the process of adjusting the water spray control valve of the low pressure cylinder, the opening change each time is not more than 5%. When the opening of the water spray control valve of the low pressure cylinder is less than 50%, the opening change each time is reduced to 2%. After the adjustment of the opening of the control valve each time, the next operation can be started after the final stage and exhaust temperature of the low pressure cylinder are stable.

3.5.6 The water level of deaerator and low-pressure heater may fluctuate when the cylinder cutting is on or off.

When the deaerator water level alarm is high, open the deaerator overflow valve, close the stage by stage drainage of No. 3 high-pressure heater, and close the deaerator water feeding main control valve; Close the deaerator steam inlet valve and open the deaerator emergency drain valve.

3.5.7 The thermal logic control problem causes a sudden change of a parameter or the cylinder cutting cannot be switched on or off normally.

If the butterfly valve opening is not put into manual operation control when the low pressure cylinder zero output operation mode is exited, the butterfly valve opening is automatically tracked to calculate the butterfly valve opening of the automatic control circuit for heating and steam extraction pressure, which may lead to sudden change of the hydraulic butterfly valve opening when the low pressure cylinder zero output operation mode is exited, causing certain disturbance to the unit operation. Considering that the unit is in operation, there are certain safety risks in online modification and downloading of control logic. It is recommended that the thermal engineering discipline forcibly exit the zero output exit button of the low pressure cylinder.

3.5.8 The cooling tower freezes during cylinder cutting operation.

Measures such as closing the water pouring in the cooling tower, switching the main bypass and covering the canvas are mainly taken.
During actual operation, the operating personnel shall closely monitor and timely adjust the main steam pressure, water level of steam drum, water level of deaerator and condenser, etc., and monitor and record the vibration, differential expansion, axial displacement, secondary and final stage blade temperature, low pressure cylinder exhaust temperature and other parameters of the turbine shaft system. If the parameters change abnormally, suspend the operation in time and analyze the reasons. If the parameter exceeds the limit, the emergency response measures shall be followed.

4. Conclusion

This paper mainly introduces the zero output heat supply transformation of low pressure cylinder in Shandong Province, the basic route and operation of the transformation, as well as three different low pressure cylinder cooling steam systems, and introduces in detail the main risks and solutions in the cylinder cutting adjustment process for reference by power generation enterprises.

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References

1. Ronghe Hao, Zhuang Li, Liping Wang, et al. Economic Analysis of Smooth Shaft Operation of Low Pressure Cylinder in 210 MW Unit[J]. Journal of Shenyang Institute of Engineering (Natural Science), 2020,16(02):25-28+44.
2. Jianxun Wang. Analysis of Flexible Peak-Load R egulation Capability and Economy on the Zero Output Technology of Low-Pressure Cylinder for 650 MW Supercritical Unit[J].Journal of Engineering for Thermal Energy and Power,2021,36(02):18-23.
3. Tianfu Liang, Weiyang Xie, Fei Wang, et al.The key technique research of removing the low pressure cylinder of steam turbine[J].Turbine Technology, 2019, 61(6): 471–472.
4. Haisheng Yang, Tuo Zhang , GuangTong Tang, et al. Influence of Zero-Output Technology of Low-Pressure Cylinder on Deep Peak Regulation Performance of Heating Unit and Compensation Standard for Peak Regulation[J].Journal of Engineering for Thermal Energy and Power, 2020, 35(06):268-273.T
5. Qinpeng Zhang, Xuedong Wang, Feng Li, et al. Analysis of Heating Capacity and Peak-regulating Capacity of 330 MW Steam Turbine Unit With Low-pressure Cylinder off Operation[J]. Shandong Electric Power, 2020,47(12):72-76.
6. Puxin Shi, Peiran Shi, Peiwen Wang, et al.Analysis and Operation Evaluation of Power Peak-shaving Ancillary Service Market in North China[J]. Automation of Electric Power Systems, 2021,45(20):175-184.
7. Xuhui Zhang, Zhonghua Zhao, Fuxing Cui, et al. Experimental Research on Deep Peak Regulation Characteristics of 1030 MW Ultra Supercritical Unit[J]. Shandong Electric Power, 2021,48(02):58-62.
8. Lingkai Zhu, Wei Zheng, Junshan Guo , et al. Application of Heat Load Distribution in Improving Peak-shaving Ability of Plant[J].Power System Engineering, 2019,35(06):43-46+49.