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The effect on cold-end improvement of a 330 MW turbine unit after capacity expansion and efficiency improvement

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Abstract. Taking a 330 MW steam turbine after capacity expansion and efficiency improvement as the object, the problems of the cold-end system of the unit after capacity expansion and efficiency improvement are concluded. In addition, the cold-end system was improved, and the efficient arrangement of tube bundles of condenser was adopted to increase the heat exchange areas. The cooling water flow also can be increased by adopting advanced technology to improve the profile of the cooling water pump. The results show that the exhaust pressure of the turbine decreases by 1.22 kPa after the improvement of the cold-end system, compared with before. This kind of the improvement has obvious energy- saving benefits.

1. Introduction

The capacity expansion and efficiency improvement of 300 MW and 600 MW steam turbine generating units can be carried out with advanced through-flow transformation technology, and the capacity of the units can reach 330 MW and 660 MW [1]. From the perspective of the unit after the efficiency improvement, with the advanced through-flow transformation technology and the improvement of manufacturing installation level, the heat consumption rate of the unit can be reduced by 2-4% [2]. However, after the capacity expansion of the unit, if the cold-end system is not synchronously upgraded, a series of problems will occur in operation, which will inevitably lead to the increase of exhaust pressure [3]. This will also inevitably reduce the economic benefits of through-flow transformation technology. Therefore, it is necessary to improve the cold-end of steam turbine unit after capacity expansion and efficiency improvement, which can reduce the exhaust pressure. It is of great significance to save energy and improve economic efficiency.

In this paper, taking a 330 MW steam turbine after capacity expansion and efficiency improvement as an example, the problems of the cold-end system of the unit after capacity expansion and efficiency improvement are concluded. In addition, the cold-end system was improved. Through adopting some measures such as the replacement of material of cooling pipes, adopting the efficient arrangement of tube bundles, that can increase the heat transfer areas of the condenser, improve the flow of cooling water, and improve the performance of cold-end system. The improvement of cold-end system has the purpose of energy-saving.

2. The design description of unit

The output power of a 300 MW unit reached 330 MW after the through-flow transformation. The output power under THA is 330 MW, and that is 353 MW under TMCR. After the capacity improvement of the unit, the condenser and cooling pumps of the cold-end system have not been improved. Design parameters of original condenser and cooling pumps are shown in table 1. The type of condenser is N-17000-2, single shell, double flow, surface type and copper tube. The model of the cooling pumps is 72lkxe-24.

Table 1. Design parameters of condenser and cooling pumps before the improvement.

content	unit	parameter
design parameters of condenser		
model	/	N-17000-2
type	/	Single shell, dual flow
cooling area	m^2	17000
condenser pressure	kPa	4.9
design pressure on the steam side condenser	MPa	0.098
design pressure of water side	MPa	0.35
design heat load of cooling water	kW	389400
design flow of cooling water	m^3/s	9.5
design inlet temperature of cooling water	℃	20
average cooling water velocity	m/s	2.0
The temperature rise of cooling water	℃	9.28
design parameters of cooling pumps		
model	/	72LKXE-24
water flow	m^3/s	5.46
pump head	m	24.1
motor speed	r/min	270
shaft power	kW	1479
efficiency	%	87.2

3. The performance test results before improvement

In order to accurately evaluate the performance index of the condenser before the improvement of cold-end system of the unit, the performance test of condenser was carried out. The test results are shown in table 2. Under the test condition, the pressure of condenser is 10.72 kPa and that is 5.55 kPa, which is 0.65 kPa higher than the design pressure 4.9 kPa after the correction of inlet temperature and flow of cooling water.

Table 2. The performance test results of the condenser.

content	unit	test data
The unit load	MW	332.64
the operation of cooling pumps	/	double pump
the flow of cooling water	m3/s	9.23
inlet temperature of cooling water	℃	33.545
outlet temperature of cooling water	℃	43.23
the pressure of condenser	kPa	10.72
saturation temperature at condenser pressure	℃	47.19
temperature rise of cooling water	℃	9.69
heat transfer end difference	℃	3.96
super-cooling degree	℃	0.93
the pressure of condenser corrected to design condition	kPa	5.55

Through the condenser performance test, the following problems can be found in the cold-end system of the unit:

3.1. The heat transfer areas of the condenser do not meet the requirement

The turbine after capacity expansion and efficiency improvement can not meet the corresponding requirement of the condenser described in this article, the heat exchange areas of original condenser are 17000 m^2, can't meet the capacity of TMCR condition of the unit, the heat exchange areas of the condenser are insufficient margin.

3.2. The arrangement of the tube bundles of condenser is unreasonable

The arrangement of the tube bundles of condenser in the unit described in this paper does not adopt calculation optimization and flow field simulation, but only adopted the traditional experience to arrange tube bundles. The large steam resistance of the tube bundles and local eddy current phenomenon have resulted in uneven distribution of the heat load of the whole bundle. The overall heat transfer coefficient is low [4,5].

3.3. The heat transfer performance of the condenser decreases gradually

According to the test results, the condenser pressure which is corrected to the design cooling water temperature and water flow rate at the rated load condition is 5.55 kPa, higher than the design pressure, the heat transfer performance of the original condenser decreases gradually.

3.4. The flow of the cooling water is insufficient

The cooling water system of the unit is operated by unit system. The maximum output of cooling water pump is operated by double pumps. The operating flow is 9.23 m^3/s, lower than the design flow of 9.5 m^3/s. The original cooling water pump cannot meet the demand of the cooling water under THA and TMCR conditions after the capacity expansion and efficiency improvement of unit.

4. The improvement of cold-end system

4.1. The improvement of condenser

The original condenser was improved as follows:

- First of all, because the arrangement of tube bundles, the material of pipe, the calculation of exhaust steam resistance, the heat load distribution of the original condenser are not reasonable, the study of the above problems of the condenser is done, advanced arrangement technology of the tube bundles is adopted. The arrangement technology named bionic double-connected tree was adopted. As shown in figures 1 and 2.

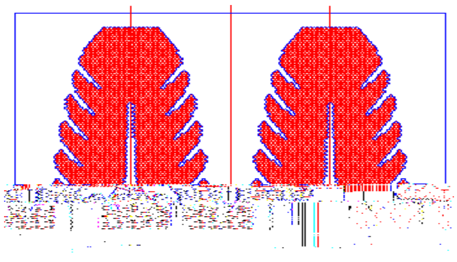

Figure 1. The schematic diagram of bionic double-connected tree tube bundles.

Figure 2. Engineering field.

- Redesigning and changing the tube bundles and water chambers, the original brass are all replacement for Φ 25 x 0.5/0.7 mm TP316L stainless steel pipes, the effective length is10840 mm.

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- The end pipes plate adopt TP316L stainless steel composite pipes, with a thickness of 40 (35+5) mm, the connection between the pipes and the water chambers is maintained in the original design.
- The expansion between the joint and argon is connected to the cooling pipes and the tube plate, so as to ensure the tension and sealing of the connection.
- Replacing all intermediate baffles and their internal connectors and that can ensure vibration resistance is qualified.
- Redesigning the water chambers.
- The latest technology was used to improve the arrangement of tube bundles to improve the heat exchange efficiency. The heat transfer areas are improved by HEI standard.

The technical specifications after the improvement are shown in table 3.

Table 3. The design specifications of improved condenser.

content	unit	THA
the unit load	MW	330
steam load	t/h	630.2
water speed in cooling tubes	m/s	2.19
inlet temperature of cooling water	℃	20
outside diameter of cooling pipes	mm	25
cleanness coefficient	/	0.9
the wall thickness of the cooling pipes	mm	0.5/0.7
total number of cooling pipes	/	22000
effective length of cooling pipes	mm	10840
heat transfer areas	m^2	18730

4.2. The improved scheme of cooling water pump

The original cooling pumps were improved as follows:

Replacing the impellers of the cooling pumps to improve the efficiency. There is no need to change the original inlet and outlet water pipes, foundation and so on. By improving the blade profile, the flow of the cooling water pumps can be increased as much as possible without increasing the power of original motor. The design flow of the original cooling water pump is 19656 m^3/h, the head is 24 m, the efficiency of the cooling water pump is 84.5%, the power of the motor is 1800 kW, the design flow of the cooling water pump after improvement is 22000 m^3/h, and the head is 22 m, the power of the motor is still 1800 kW.

Table 4. The design specifications of cooling water pump after improvement.

content	data
flow	22000m^3/h
pump head	22
motor speed	370r/min
pump shaft power	≦1515kW
pump efficiency	≥87%
vibration	≦0.05mm
noise	85db

The drive motor of the original cooling pump was keep without any modification. The connection pipes between the cooling water pumps and other related equipments is remain unchanged, the stand shall of cooling water pump is remain unchanged, and the pump housing shall is remain unchanged. According to the above improvement, the main shaft, axle sleeve, sleeve, shaft seal and other supporting parts are redesigned. The performance parameters of the reformed cooling water pumps must ensure that the motors do not exceed the rated power. Because the original system and the original motors are not changed, the electricity consumption does not increase. In order to improve the strength of the blades, the composite impeller structure was changed to the integral casting impeller structure.

The technical specifications after modification are shown in table 4.

5. The effect of the improvement of the cold-end system

After the improvement of the cold-end system of the unit, performance tests of the condenser were carried out, and the results were shown in table 5. It can be seen from tables 5 and 2, the maximum flow rate of cooling water pumps rises from 9.23 m^3/s to 11.25 m^3/s. The condenser pressure which is corrected to the design inlet temperature and the design water flow of cooling water was reduced from 5.55 kPa to 4.33 kPa under 330 MW condition. The vacuum of the unit was increased by 1.22 kPa.

Table 5. The test results of condenser after the improvement of cold-end system.

content	unit	The test data
the operation of cooling pumps	/	double pumps
unit load	MW	330.75
cooling water flow	m^3/s	11.25
inlet temperature of cooling water	℃	29.75
outlet temperature of cooling water	℃	39.84
the pressure condenser	kPa	8.31
saturation temperature at condenser pressure	℃	2.31
temperature rise of cooling water	℃	10.08
heat transfer end difference	℃	2.42
super-cooling degree	℃	0.19
the pressure of condenser corrected to design condition	kPa	4.33

6. Conclusions

The pressure of condenser of a 300MW steam turbine unit is higher than the design value after the capacity expansion and efficiency improvement, which is caused by the performance decline of the condenser, the insufficient heat exchange areas of the condenser and the insufficient flow of cooling water. The maximum flow of cooling water increased by 2.02 m^3/s after the improvement of the cold-end system was adopted. The performance test results of the improved condenser show that the pressure of the condenser is 4.33 kPa, which is 1.22 kpa lower than that before the improvement. The energy -saving efficiency is remarkable and this kind of the improvement has certain engineering application value.

Acknowledgments

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