

Condition Assessment of A 360MW Turbine

Li Chongsheng

Information & Supervision Research Dept.
Xi'an Thermal Power Research Institute Co., Ltd.
Xi'an, China

Bu Jianwei

Yueqing Power Plant
Zhejiang Provincial Energy Group Company Ltd.
Wenzhou, China

Abstract— An opening HIP (high and intermediate pressure) casing overhaul of a 360MW turbine should be taken in 2012 on schedule. And this kind of overhaul wasn't taken on the turbine during the past 12 years from startup. But the overhaul needs to be delayed for some reasons. A comprehensive condition assessment of the turbine is taken. By the full investigation, calculation and assessment, the actual condition of the turbine is obtained. According to the result of the comprehensive assessment, the overhaul is delayed and a considerable benefit is brought to the owner.

Keywords— turbine state assessment, risk assessment, maintenance period optimization

I. INTRODUCTION

A 360MW turbine was manufactured by GEC ALSTOM. It is a subcritical pressure, single-reheat, single-extraction, two-casing, double-exhaust, and condensing steam turbine. Based on suggestion proposed by ALSTOM, the opening coverage overhaul cycle of LP (low pressure) casing is defined as 6 years, which is called major overhaul by ASLTOM. The opening coverage overhaul cycle of HIP casing is defined as 12 years. Until 2012, it is the opportune moment of opening coverage overhaul of HIP casing.

The project duration of the opening coverage overhaul of HIP casing is at least 40 days. In compliance with plan, the denitration project of the unit will be carried out in 2013, which the project would last about sixty days shutdown. And a full overhaul of the unit must be taken in the recent three years. So the owner wants to know if the planning opening coverage overhaul of HIP casing could be delayed in 2012 to year 2013, and the overhaul would be planned to be taken during denitration project construction period. As a precondition of satisfying the safety requirement, the postponement of the overhaul will bring some advantages as follows:

- Combining the two overhauls to one will reduce shutdown time (the duration of opening coverage overhaul cycle of HIP casing) and power loss, advance availability coefficient of unit.
- Combining the two overhauls to one will save one overhaul and the corresponding considerable maintenance cost.

Thus, a comprehensive assessment for the turbine was taken by TPRI (Xi'an Thermal Power Research Institute Co., Ltd). The conclusion of assessment will be a basis to make strategic decision on the board meeting about the feasibility to postpone the planning opening coverage overhaul of HIP casing to year 2013.

According to basic program of condition assessment, the result of the turbine risk is obtained: the turbine risk is medium, prolonging the overhaul cycle shortly and appropriately is feasible.

II. PRINCIPLE, METHOD AND PROCEDURE

The key works of this project include three aspects: comprehensive assessment and analysis to determine turbine condition, quantifying the assessment result according to scientific scoring mechanism, maintenance cycle recommendation of turbine will be put forward.

A. Assessment Principle

According to general risk assessment method, the comprehensive condition assessment of turbine can be taken from two aspects: safety and reliability factors and economic factors. On the basis of documents of design, manufacture, installation, commissioning, operation, maintenance and experiment of the turbine and actual monitoring data, these two aspect factors assessment are accomplished, and then the comprehensive condition assessment result of turbine is obtained. Then the relevance between comprehensive condition assessment results with overhaul cycle eventually is established. This is thought to be an entire closed loop process from condition to maintenance. In which, safety and reliability of turbine can be obtained by safety condition monitoring, statistics and assessment, economics of turbine can be obtained by efficiency monitoring, statistics and calculation.

The condition assessment result in any aspect of turbine is defined as four levels: excellent, good, medium and poor. In which, good is reference level and its value is one. If there is any latent danger or risk with influencing safety, stability and economy of turbine, few scores will be added to the assessment value based on reference value according to severity and consequence of hazards. Otherwise, if the plant has adopted some measures such as technical reform work to improve running condition of turbine, few scores will be subtracted from the assessment value based on reference value according to actual effect. The overall principle of scoring of turbine condition is the worse the condition or the greater the risk, the higher the score. In the principle of this scoring criterion, combined with the actual situation of steam turbine, it is feasible to realize quantitative risk assessment for turbine.

B. Safety and Reliability Assessment

Safety and reliability factor of turbine is determined by turbine failure possibility and impact factor together, thus, the

task of this stage is assessing failure possibility and impact factor of turbine.

Failure possibility, also known as damage coefficient, includes vibration characteristics, casing body and shaft expansion characteristics, casing temperature and thermal deformation characteristics, bearing characteristic, running oil management assessment and life consumption etc.

Impact factor, also known as failure consequence, including any related facts associated with turbine state and life variation in every design, manufacturing, installation, commissioning, operation and maintenance stage. The determination basis of impact factor is shown in table I.

Impact factor is determined by defect properties or failure accident founded through scientific scoring mechanism. The base value of every factor is defined as 1 under good condition of equipment, the actual value of every factor is determined by defect properties or failure accident.

TABLE I THE DETERMINATION BASIS OF IMPACT FACTOR.

| Design and manufacturing factor | | Installation and commission factor | |
|--|--|---|--|
| Whether the device has design and manufacturing drawbacks? ✓ Design specifications; ✓ Design structure; ✓ Design strength; ✓ Manufacturing process; ✓ Manufacturing defects; ✓ Factory management; ✓ Manufacturing supervision. | | Whether the device installation has significant defects, which affect operation? ✓ Installation process; ✓ Installation quality; ✓ Pre-installation inspection; ✓ Installation supervision; ✓ Commission quality; ✓ Installation supervision. | |
| Performance factor | Maintenance factor | Assessment description | |
| Whether the device is running at rated conditions? ✓ Operation indicators; ✓ Operating conditions and mode change; ✓ Reliability; ✓ Economy; ✓ Running time; ✓ Start and stop times. | Whether there has been a serious accident but not been improved? Whether there are serious defects but not being found out during infection course? ✓ Serious defect ✓ Repair quality; ✓ Test reliability; ✓ Maintenance management. | Recommendations on whether the device can be used anymore? | |

C. Economic Assessment

Analysis of heat consumption rate and variation of HIP casing efficiency is taken to assess economic of turbine according to operation and maintenance history data and test report etc.

D. Comprehensive Condition Assessment

Comprehensive condition assessment program of turbine is shown in fig. I.

As mentioned above, the safety and reliability factors of turbine are determined by failure possibility and impact factor together. Thus, this section depicts these two aspects specifically.

For failure possibility, assessment was taken from analysis of vibration characteristics, casing and shaft expansion

characteristics, casing temperature difference and thermal deformation characteristics, bearing characteristics, life loss, running oil and steam quality management, turbine reliability etc.

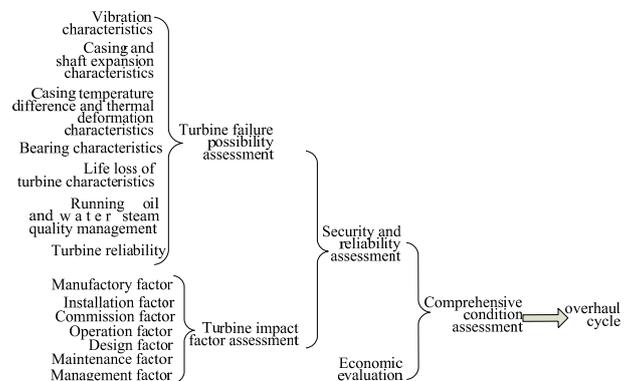


Fig. I. Comprehensive condition assessment program of turbine.

For impact factors, assessment was taken from analysis of any related facts associated with turbine state and life variation in every design, manufacturing, installation, commission, operation and maintenance stage.

E. Assessment Process

The project workflow of this project is as follows:

- 1) On-site survey
 - Professionals' visit
 - Information collection
- 2) Date extraction and analysis
- 3) Equipment condition assessment
 - Safety and reliability assessment
 - Economic assessment
 - Risk assessment
 - Overhaul cycle analysis
- 4) Come to a decision

III. ASSESSMENT AND CONCLUSION

According to the information collected during investigation, the turbine has been running for nearly 12 years, over 80,000 hours. During this period, there is no major accident occurred, which reflect that the level of design, manufacture, installation and commission of turbine is excellent.

A. Safety and reliability assessment and conclusion

1) Life loss of turbine characteristics

Till Dec. 31, 2011, the unit1 turbine-generator set have been put in service about 82611 hours, the total start up is 555 times. The data is listed in table II.

After correction, the whole life loss of unit 1 turbine is about 14.80%.

TABLE II THE DESIGN VALUES OF LIFETIME CONSUMPTION PER EVENT AND THE ACTUAL NUMBER

| Transient events | Number of transient | Actual number of transient | Lifetime consumption per transient(%) | Sub-total actual lifetime consumption(%) |
|--------------------------------------|---------------------|----------------------------|---------------------------------------|--|
| Very hot start-up | 150 | 94 | 0.002 | 0.188 |
| Hot start-up | 2850 | 299 | 0.009 | 2.691 |
| Warm start-up | 1000 | 94 | 0.01 | 0.94 |
| Cold start-up | 200 | 68 | 0.025 | 1.7 |
| Load transient | 4000 | 10 | 0.001 | 0.01 |
| Total actual lifetime consumption(%) | | | | 5.529 |

2) Vibration characteristics

According to the monitoring data of turbine bearings vibrations, as shown in Fig. II, from Oct.4 2008 to Feb.6 2012, totaled up to 37 groups, it is obvious that the whole trend is smooth and there is no violent fluctuation.

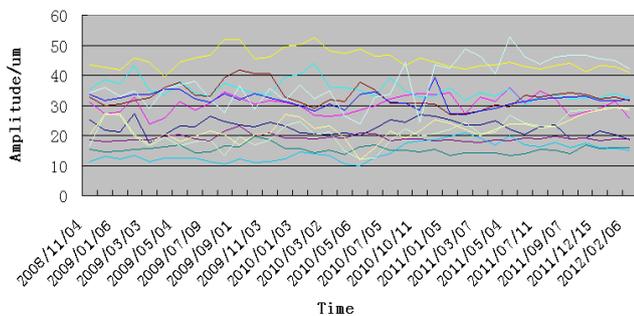


Fig. II. Bearing vibration (Peak-Peak) form Oct.4 2008 to Feb.6 2012

According to the monitoring data of bearing vibration and the record of dealing with the abnormality, the whole assessment of vibration characteristic is good.

3) Casing and shaft expansion characteristics

According to the monitoring data and the history record, the whole assessment of casing and shaft expansion characteristic is good.

4) Casing temperature difference and thermal deformation characteristics

According to the data mentioned above, the thermal deformation state of HIP casing and IP casing is good, and the casing temperature difference and thermal deformation characteristics is good.

5) Bearing characteristics

According to the investigation and accessing record, the oil film oscillation and lubrication oil out of supply haven't occurred, the control liquid and lubrication oil haven't been mixed with water.

According to the monitoring data and the history record, the whole assessment of bearing characteristic is good.

6) Running oil and water steam quality management

The turbine was imported wholly, so was its auxiliary water treatment equipment. All these imported equipments are

with highly reliability, since there was no major accident which can influence safety production occurred after twelve years operation. The water treatment plant operated well and has never been overhauled.

The water treatment system and oil system are with high reliability and stability. The operating and maintenance level is good.

7) Turbine reliability

Compared with the reliability data of the unit and nationwide average, the reliability of the unit is all greater than the nationwide average.

The utilization hours of the unit in 2011 is 6402.9 hours and the corresponding nationwide average is 5446.63 hours.

The service hours of the unit in 2011 is 7591.83 hours and the corresponding nationwide average is 7149.12 hours.

The equivalent available factor of the unit are 98.66% (in 2007), 90.67% (in 2008), 94.57% (in 2009) and 98.99% (in 2011). The corresponding nationwide average are 91.29%, 91.96%, 85.06 and 92.53 respectively.

8) Management factor assessment

The operation management company who provides operation and maintenance services to the owner obtained three certificates for ISO 9001 (quality), ISO 14001 (environment), OHSAS 18001 (safety & health) of French AFAQ company and Beijing Fangyuan certification company.

The company adjusts and optimizes the management manner during decade's operation and maintenance according to the domestic actual situation. In the course of major overhaul, experts from ALSTOM and domestic specialist provided professional support and service. The work reports are written in English, and also the inner files.

According the investigation results, the management factor of the power plant is assessed well.

9) Abnormal record

a) Bearing characteristics

In 2009, the unit 1 generator front bearing (#5) temperature is higher than rear (#6) bearing (about 5.5°C), the maximal temperature for #5 bearing is 100.34°C and average temperature is 96.89°C. According to the GGR system operation instructions "OI", the generator bearing metal temperature should be 70~85°C, the upper alarm 95°C, the operation limit 110°C (turbine manual trip). The root cause is not clear till now. And the action to be put in practice was keeping monitor. No impact is on the unit operation.

b) Vibration characteristics

Since Dec.27 2009, unit 1 No.2 bearing vibrations are fluctuated each about eight hours. The vertical vibration of No.2 bearing from 52.6um to 79.4um (maximal), the horizontal vibration from 39.2um to 68.3um (maximal) at unit full load (347MW). The fluctuation last about one hour and it would recover to normal level. The root cause of defect is not clear till now; it needs further action to find out the root cause. After 2009 outage, the periodical fluctuation disappeared, but the root cause is not clear till now. The pending problem is a

hidden trouble. And it would affect the score of vibration characteristic.

On oct.25 2009, high vibration and then recovering of No.1 and No.2 bearing occurred. And on Nov.13 2009, similar event occurred. The root cause of first event is: During unit hot start, the steam temperature did not match the turbine casing temperature. The reheat steam temperature was less than IP casing metal temperature. The main steam temperature dropped greatly caused the turbine casing and rotor was cooled. It led to turbine casing and flange metal stress varied. The hot impulsion caused the turbine high vibration. The root cause of the second event is: During unit operation with load, the temperature of main steams and reheat steam dropped fast, and the IP and HP casing metal was cooled. The instant contracted rotor caused the turbine high vibration. The variety of vibration is only a phenomenon of the root cause. The impact will be mentioned in casing temperature difference and thermal deformation characteristic.

c) Casing temperature difference and thermal deformation characteristics

On oct.25 2009 and Nov.13 2009, during unit operation with load, the temperature of main steams and reheat steam dropped fast, and the IP and HP casing metal was cooled. The instant contracted rotor caused the turbine high vibration of No.1 and No.2 bearing.

B. Evaluation of turbine economic

The initial performance test in 2000 and performance test report after overhaul in 2006 are listed in Table III.

TABLE III THE INITIAL PERFORMANCE TEST IN 2000 AND PERFORMANCE TEST REPORT AFTER OVERHAUL IN 2006.

| Year | Item | | TMCR 370MW | 75% | 50% |
|---|--|-----------|---------------|---------|---------|
| 2000.12 | Turbine test heat consumption rate | kJ/(kW.h) | 7729.22 | 7844.88 | 8011.33 |
| | Turbine test heat consumption rate corrected | kJ/(kW.h) | 7705.31 | 7823.82 | 7978.42 |
| 2007.04 | Turbine test heat consumption rate | kJ/(kW.h) | 7820.4 | 7939.2 | 8138.2 |
| | Turbine test heat consumption rate corrected | kJ/(kW.h) | 7724.5 | 7888.4 | 8078.7 |
| Rate of change of turbine heat rate corrected | | % | 0.25 | 0.83 | 1.26 |

Compared with the performance test results in 2000 and 2007, under TMCR (370MW), 75% load and 50% load, turbine test heat consumption rate increases 0.25%, 0.83% and 1.26% respectively. And average value increases 0.78%. This is the normal heat rate transform.

But the reheat steam temperature deviation from the design value is too large. Under TMCR, 75% load and 50% load, the reheat steam temperatures are 518.4°C, 511.2°C and 501.0°C respectively, which are 21.6°C, 28.8°C, 39°C lower than the design value of 540°C. These are negative for safety and economy. If the reheat steam temperature can reach the design value, the turbine heat consumption rate will reduce about

0.55%. The transform of turbine performance is in the normal range.

IV. CONCLUSION

The weighting of corresponding factor is listed in the table IV. The reference listing of risk result and advice is shown in table V.

TABLE IV THE STANDARD OF RISK.

| Risk result | Risk grade | Advice |
|---------------------|------------|---|
| $R \leq 0.2$ | low | Consider delaying the overhaul cycle actively |
| $0.2 < R \leq 0.35$ | mid | Follow the now overhaul cycle, to delay the overhaul reasonably |
| $0.35 < R \leq 0.5$ | high | Follow the now overhaul cycle, to shorten the overhaul reasonably |
| $R \geq 0.5$ | very high | Consider shortening the overhaul cycle actively |

In accordance with comprehensive assessment solution of turbine operation condition, collected document, and related standard, integrated assessment score of each subsystem, the following conclusions are obtained: Till the end of the year 2011, comprehensive condition score of the turbine is 0.249. Compared to risk rating table, the risk level of turbine is II. Its risk is medium, thus we recommend that it is feasible to prolong the overhaul cycle shortly and appropriately.

TABLE V THE SCORE OF THE TURBINE

| Failure probability | Design, manufactory, installation, commission factor | Operation, maintenance factor | Management factor | Risk result | Integrative result |
|---------------------|--|-------------------------------|-------------------|-------------|--------------------|
| 0.148 | 1 | 1.95 | 1.15 | 0.235 | 0.249 |

REFERENCES

- [1] Li Chongsheng, Resaerch of Analysis Technology of large Boiler Maintenance Period in Power Plant, Postdoctoral Report, 2010.
- [2] DL/T 302.2-2011 Equipment maintenance analysis guideline for power plant, Part2: risk-based maintenance (RBM) analysis.
- [3] GB/T 12145-2008 Quality criterion of water and steam for generating unit and steam power equipment.
- [4] GB/T 14541-2005 Guide for maintenance and supervision of in-service mineral turbine oil used for power plants.
- [5] DL/T 571-2007 Guide for operation and maintenance of phosphate ester fire-resistant fluid used in power plant.
- [6] DL/T 302.1-2011 Equipment maintenance analysis guideline for power plant, Part1: reliability centered maintenance (RCM) analysis.
- [7] DL/T 438-2009 the technical supervision codes for metal in fossil-fuel power plant.
- [8] GB/T 11348.2-2007 Mechanical vibration - Evaluation of machine vibration by measurements on rotating shafts - Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1500 r/min, 1800 r/min, 3000 r/min and 3600 r/min.
- [9] DL/T 654-2009 The technical guide for the life assessment of units in fossil-fuel power plant.
- [10] DL/T 904-2004 Calculating method of economical and technical index for thermal power plant.