Discussion on RB technology and the application in 330MW unit

Yuanyuan Li, Qing Yan, Yingkun Han, Song Gao, Qingbin Yu, Kelei Li, Enren Liu, Xiangrong Meng

1 State Grid Shandong Electric Power Research Institute, Jinan, Shandong, China.

Abstract: The RB function can automatically reduce the unit to a specified value after the main auxiliary equipment of the power plant is tripped to reduce the number of unit outages, which is beneficial to the stability of the power system. Based on the experiments of RB test on different types of power units, this paper makes research of RB technical problem, analyzes the characteristics of RB rapid load reduction and RB plan and test results in detail.

1. Introduction
The Run Back (RB) function is a function that automatically handles accidents and automatically reduces load when the main auxiliary machine fails. The reliability of the RB function is important to prevent the fire extinguishing of the unit and improve the stability of the power grid. In particular, the new units, according to the “Rules for the initiation and completion acceptance of basic construction projects of thermal power plants (1996 edition) and related regulations” of the Ministry of Power Industry, after the completion of commissioning 168h, RB test must be carried out during the six months trial production, in order to ensure safe operation of the unit. In addition, the power plant has strong requirements for the realization of the RB function during the production operation due to its own safety and economy.

2. Characteristics of the RB test
After the occurrence of RB, the pressure of the fourth extraction drops, and the water in the small machine is difficult to get water. The contradiction between the heat generation requirements of the unit and the stability of combustion. The contradiction between the requirement for rapid evaporation of the unit and the heat storage of the boiler. As the capacity of the unit increases, the volume of the drum is relatively reduced, which is not conducive to the stability of the drum water level. In the case of drastic changes in the operating conditions of the unit, the technical difficulties such as complete automatic control of the unit are realized. The above reasons lead to the rare success of RB test.

After the occurrence of RB, the main control system of the unit should be completed in the automatic control state, so the RB test is not only a protection function of CCS from the control point of view. The RB test, while protecting the unit, is also a process of optimizing and verifying the quality of the CCS control. If the automatic control system does not have good dynamic and static adjustment quality, the RB test is unlikely to achieve satisfactory results.
3. Case Analysis
The RB test involves all aspects of the thermal control of the unit, such as CCS, MCS, FSSS, SCS, DEH, MEH. Here, only the core technology of the RB test is discussed.

3.1 Condition of RB occurrence
When the unit load is greater than a certain value, the unit is in coordinated control mode, and one auxiliary unit trips at the same time.

The confirmation of the unit load setting should consider the maximum output of the single-side auxiliary machine and the minimum steady combustion load of the boiler. If conditions are met, it is best to perform the maximum output test of the single-sided auxiliary machine before the RB test. In addition, considering that RB caused by different auxiliary machine fault trips may occur at the same time, it is necessary to determine the priority according to the maximum output of the single-sided auxiliary machine, the number of fuels to be cut, the time interval and other issues caused by the problem.

After the Steam feed pump trips for a certain period of time, the feed pump RB occurs when the electric pump is not started up. This time is set to 5s according to our experience.

3.2 Coordinated control
After RB occurs, the unit is automatically switched to the TF mode by the original CCS mode. The load of the unit is controlled by the boiler side, while the turbine side controls the main steam pressure of the unit.

3.3 Load reduction rate
According to the energy balance, the 330MW unit is used as the object to linearly analyze the process and establish.

Main steam pressure function: \( P = P_e - [KP] \cdot t \)
Target pressure: \( P_{mb} = 14 \text{MPa} \).
Load function: \( N = N_e - kN \cdot t \).
Target load: \( N_{mb} = 150 \text{MW} \).

\( P_e, N_e \) is Rated pressure and rated load.
\( P_e = 16.5 \text{MPa}, N_e = 330 \text{MW} \).
[\( KP \)] is allowable main steam pressure drop rate \( \leq 1 \text{MPa/min} \).
kN is Load rate.
t is Process time.

According to the initial rated parameters, the RB target parameter, and the two equations are obtained, the minimum load rate of RB is 43MW/min.

3.4 Main steam pressure control
For the control of the main steam pressure of the unit after the occurrence of RB, there are generally two ways: onstant pressure operation, sliding pressure operation. The constant pressure operation unit can resume working condition quickly, but the constant pressure operation is likely to cause the unit load and pressure to be mismatched, and the turbine door opening to be too small.

For the feed RB, the effect of the two methods on the test results is not obvious, but for the feed pump RB, the constant pressure mode will cause the unit to be difficult to water up, and the sliding mode will cause the unit to reduce the load too slowly. After repeated argumentation, using the constant-sliding pressure method was finally adopted, it means that fix the pressure first then reduce pressure and load. The test proves the method is a better solution. In order to ensure the implementation of the constant-sliding pressure mode, the prohibition logic of the turbine door and the buck rate limitation of the sliding pressure are indispensable. The theory proves that when the rate of change of the drum pressure exceeds 1MPa/min, a false water level phenomenon may occur. Generally, the rate of change of the main steam pressure is set to 0.2-0.4MPa/min which is suitable.
3.5 FSSS function
After the occurrence of RB, the boiler side controls the load of the unit. In order to quickly reduce the load on the unit, it is required to realize the function of rapidly reducing the heat generation after the occurrence of RB in the control scheme. To this end, after the occurrence of RB, the FSSS cuts off part of the fuel in turn from top to bottom at regular intervals. For poor coal quality or fuel compartment operation, the automatic fueling function should be added to the FSSS logic. When determining the interval, you should pay attention to the contradiction between balancing the requirements of the unit for rapidly reducing load and preventing the drastic changes of the unit's combustion conditions. If the minimum steady combustion load > the maximum output of the unit's single auxiliary machine, the FSSS also needs to increase the automatic oil-injection function.

3.6 DEH function
It is also crucial for the success of the RB test to prohibit switching to manual control when the deviation is large, close desuperheated water regulating valve override, and the actuator to prevent the overcurrent and the upper limit.

3.7 Balance of output
After the occurrence of RB, the output of auxiliary machine must be Increased opened quickly, that is, part of the output of the tripping auxiliary machine should be transferred to the running auxiliary machine as soon as possible. The auxiliary machine must be operated with a high limit to prevent overcurrent.

For the auxiliary machine with the output balance function in its control loop, its PID must be subjoined less than 50 high-limit to prevent over-saturation, affecting the quality of reverse regulation.

4. Case Analysis
In this paper, the RB test of the #2 unit (330MW) of Lubei Power Plant is taken as an example. The process and results of the test are analyzed as follows.

4.1 Test range
Design The main purpose of the RB logic is to maintain the boiler's allowable output when the main auxiliary machine fails. The unit must be quickly and automatically reduced in load, while ensuring that the main regulating system is working properly and maintaining the main parameters of the unit within the allowable range. The unit is designed with the following RB functions:
- One of the two parallel force draft fans trips
- One of two parallel induced draft fans trips
- One of the two parallel primary air fans trips
- One of the three parallel feed pumps trips

4.2 Test conditions
- The single-system RB cold test of CCS and FSSS has been successfully performed, the RB cold test of two systems combined has been successfully performed; the cold and hot tests of the other systems of thermal engineering and related majors such as machine, furnace and electricity have been successfully performed, and the test data is complete.
- The main automatic adjustment system of CCS has been running for more than 12 hours when the unit is fully loaded.
- DEH operates normally in coordinated control mode.
- The FSSS machine boiler large interlock test was successful, and the action logic of RB was normal.
- The adjustment of the TF mode meets the requirements.
- The “Unit Load Change Test” has been completed and the control performance meets the unit operation requirements.
There are no major defects in the main and auxiliary equipment

4.3 Static test

4.3.1 Auxiliary machine output test
Run single-side fan and single-stage steam pump, gradually increasing the opening degree or speed of the single auxiliary machine to check whether it is over current. Record the maximum output of a single auxiliary machine as the target value of the unit load after RB occurs. After the force draft fan RB, induced draft fan RB and primary air fan RB occur, the unit’s target load is 180MW; After the feed pump RB occurs, the unit’s target load is 180MW.

4.3.2 RB Logic Test
Force the logical condition of the boiler and the steam turbine main controller in the automatic mode; Simulate the RUN BACK test in a coordinated control mode; There are four types of test content: force draft fan RB and induced draft fan RB, Primary air fan RB, feedwater pump RB. Taking the feed pump RB as an example, the static test is as follows: When three small machines are running parallely, forcing one of the small machines to trip, that is RUN BACK, after RUN BACK action, check whether the following commands are normal:
The unit control mode is switched from coordinated control to TF control mode; The boiler side controls the unit load and setting the load command to 180MW at a certain load reduction rate;
After a small machine trips, the command of the other small machine instantaneously opens up, and does not exceed a certain high limit. The water supply control should be in the automatic state during the whole RB process. In order to prevent the decrease of the steam flow resulting the three-flush water supply adjustment reversed, the output of the three-flush water supply is automatically limited, or automatic water supply is switched to the single impulse adjustment by the three-pulse control.

4.4 Unit dynamic test process
The #2 unit of Lubei Power Plant conducted four RB tests, including RB test of the force draft fan, RB test of the induced draft fan, RB test of the Primary air fan and RB test of the feed pump. In the above test, the feed pump RB test is the most difficult.
The system sets three electric feed pumps, sets the standby pump interlock start, and enters the RB logic when the start fails. The feed pump RB has a great influence on the water level of the unit. If the automatic adjustment is not timely, the steam level will be too low, triggering the boiler MFT protection action, the unit is out of service. After the pump C trips, it directly enters the RB control logic. The lowest steam drum water level is -290mm (the low steam drum water level is -330mm). After the unit load is reduced, the steam flow rate is reduced and the drum water level is gradually restored. The main control system of the test process is working normally, and other main parameters are also within the safe range. In the whole process, the main parameters of the unit are shown in Table 1, and the test curve is shown in Figure 1.

| Table 1. #2 Unit feed pump RB working condition unit main parameter record. |
|-----------------------------------------------|-----------------|-----------------|---------------|
| Unit load | Before the experiment | After stabilization | Unit |
| main steam pressure | 17.11 | 15.347 | MPa |
| Main steam temperature | 533.15 | 520.38 | °C |
| Reheat steam temperature | 513.74 | 482.12 | °C |
| Running coal mills | A B C D | A B C | |
| Furnace negative pressure | -92.00 | -81.71 | Pa |
| Water supply flow | 842.92 | 630.32 | t/h |
In the RB test of the force draft fan, the unit load is about 220MW, four sets of mills are running, force draft fan B is tripped, RB occurs, and Interlock trip induced draft fan B, and the fuel is blocked. Furnace pressure change: up to 358Pa, minimum to -208Pa, far below the unit safety protection rating (±3300Pa). In the whole process, the main parameters of the unit are shown in Table 2, and the test curve is shown in Figure 2.

Table 2. #2 Unit force draft fan RB working condition unit main parameter record.

|                              | Before the experiment | After stabilization | Unit |
|------------------------------|-----------------------|---------------------|------|
| Unit load                    | 219.52                | 194.11              | MW   |
| main steam pressure          | 113.44                | 12.54               | MPa  |
| Main steam temperature       | 539.06                | 536.96              | ℃    |
| Reheat steam temperature     | 506.92                | 503.06              | ℃    |
| Running coal mills           | A B C D               | A B C               |      |
| Furnace negative pressure    | -76.28                | -54.13              | Pa   |
| Water supply flow            | 677.46                | 603.17              | t/h  |
In the Primary air fan RB test, the unit load is around 275MW, four sets of mills are running, Primary air fan B trips, RB occurs, Trip C and D mills, and After the Primary air fan B trips, the wind pressure reaches 3.8Kpa. After the shutdown of #2 inlet baffle, the wind pressure is restored to meet the safe operation requirements of the unit. In the whole process, the main parameters of the unit are shown in Table 3, and the test curve is shown in Figure 3.

**Table 3. #2 Unit Primary air fan RB working condition unit main parameter record.**

| Parameter                        | Before the experiment | After stabilization | Unit |
|----------------------------------|-----------------------|---------------------|------|
| Unit load                        | 247.39                | 235.01              | MW   |
| main steam pressure              | 16.77                 | 15.28               | MPa  |
| Main steam temperature           | 533.14                | 529.76              | ℃    |
| Reheat steam temperature         | 500.32                | 493.89              | ℃    |
| Running coal mills               | A B C D               | A B                 |      |
| Furnace negative pressure        | -86.044               | -184.64             | Pa   |
| Water supply flow                | 824.97                | 757.42              | t/h  |
In the RB test of the induced draft fan, the unit load is about 280MW, four sets of mills are running.

A induced draft fan trips, RB occurs, Interlock trip force draft fan A. Furnace pressure change: up to 773Pa, minimum to -57.99Pa, far below the unit safety protection rating (±3300 Pa). In the whole process, the main parameters of the unit are shown in Table 4, and the test curve is shown in Figure 4.

| Table 4. #2 Unit induced draft fan RB working condition unit main parameter record. |
|----------------------------------|-------------------|-----------------|
|                                  | Before the experiment | After stabilization | Unit   |
| Unit load                        | 278.51             | 216.97           | MW     |
| main steam pressure              | 15.072             | 14.498           | MPa    |
| Main steam temperature           | 530.89             | 535.80           | ℃      |
| Reheat steam temperature         | 501.95             | 507.18           | ℃      |
| Running coal mills               | A B C D             | A B C            |       |
| Furnace negative pressure        | -86.98             | 186.62           | Pa     |
| Water supply flow                | 848.31             | 674.89           | t/h    |

Figure 3. Primary air fan RB test curve.
4.5 Test quality
Since the coordinated control system load swing test has been completed before the RB test, it is ensured that the adjustment quality is good. Repeatedly negotiated with Lubei Power Plant on the relevant content of the RB test, and proposed detailed test plans and measures. The relevant leaders of Lubei Power Plant attached great importance to it and all departments actively cooperated to ensure the successful RB test of Lushan Power Plant #2 unit.

5. Reviews
The results of the RB test show that when the main auxiliary machines of the unit, such as: Primary air fan, force draft fan, induced draft fan, and feed pump unilaterally trip, relying on the RB function of the automatic adjustment system, the main parameters of the unit can be controlled within the allowable range, completely can ensure the safe operation of the unit under accident conditions.

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