Economic and safety analysis of unconventional peak regulation on power unit of peak shifting start-stop

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Abstract. The capacity difference of peak regulation between the power grid and the actual demand has become a serious problem considering the growth in the difference between electricity supply and demand. Therefore, peak regulation of power grid needs to be deeply studied. Unconventional peak regulation on unit of peak shifting start-stop is a way that can broaden the range of power regulation, as well as benefit safe operation of the power grid. However, it requires frequent and fast unit start-stop, complex operation, and more staff labor. By carrying out unconventional thermal power unit load test, the start-stop mode of peak auxiliary equipment is studied in this paper, indicating that it has a positive effect on safety and economic of load-peaking operation. The best working conditions of the peak units is found by analysing consumption cost, safety specifications, and life lost of the start-stop peak regulation mode.

Keywords: unconventional peak regulation tests, the start-stop mode, economic and security analysis.

1. Introduction

The capacity of heating unit accounted for more than 80% of the capacity of thermal power units in Jilin Province by the end of 2011 [1]. Unit-load adjustment range is limited during the heating phase due to the characteristics of heating units. In addition to this, it is indispensable for extra thermal power unit’s capacity to maintain power balance with the growth of wind power capacity [2].

For large units in Jilin Province, the safety and economy of the peak load regulation is an important issue in electric power production [3]. Unconventional start-stop peaking regulation research and application has been carried out. In order to achieve the purpose of energy saving, the paper analyzes
the economic and safety for the unconventional start-stop equipment and provides reference for the
same type of unit in the economic regulation

2. Unit overview
In Shuangliao power plant, No.2 and No.3 steam turbine is subcritical steam turbine produced by
Harbin steam turbine plant.
The model is N300-16.7/537/537.
The rated power is 314.4MW.
The main steam flow rate is 963.91t/h.
The main steam pressure is 16.67MPa.
The main steam temperature is 537 ℃.
The No.2 and No.3 boiler with 6 sets of fan mill pulverizing system are produced by Harbin boiler
factory production. The main design parameters are as follows.
The superheated steam flow is 1025t/h.
The superheated steam outlet pressure (gauge) is 17.5MPa.
The superheated steam outlet temperature is 540 ℃.
The reheat steam flow rate of is 835 t/h.

3. Operation safety analysis of peak regulation

3.1. Water circulation reliability
Water circulation reliability of natural circulation drum problems attracts attention when the thermal
power unit is at a low load peaking operation [4]. Due to the large circulation rate in Shuangliao power
plant, it can be estimated by using the circulation rate of K when the boiler is in the low load
operation.

\[ k = \frac{k_e}{0.15 + 0.85D/D_e} \]

\( k_e \) —The circulation ratio of K at rated load

\( D_e \) —The main steam flow at rated load, t/h

\( D \) —The main steam flow under low load, t/h

The mass flow rate of the water-cooled wall is about 1000 ~ 1200kg/ (m²·s) when the 300MW unit
is in 160WM load. The boiler is 30% under the rated load condition with the minimum flow rate being
larger than the limit value of 0.4m/s. The circulation ratio of K is 5.8, which is within the
recommended value rage of 4-6.

3.2. Safety of thick wall parts of the drum
The main risk associated with the boiler operation process is the changing stresses of the boiler drum
during the repeated starting processes [5]. The boiler drum will bear more mechanical and thermal
stress due to the periodical change of the pressure, temperature of the working medium, and the
thickness of the wall of the boiler drum. If the control of start and stop is unsuitable, it will lead to larger stress change and reduce the drum’s life. The temperature differences of inner and outer walls are the primary parameters of drum stress. Straight through type feed water-piping structure in the interior of the drum is adopted in order to reduce the temperature differences between the drum of water and steam and improve upon the boiler’s ability to adapt to the rapidly changing load. When appearing in the middle of the drum, the drum wall has a temperature difference of 10°C.

It is noticed in Figure 1 that the temperature difference between the inside and outside wall of the drum is within the range of 14-20 °C, with the maximum changing rate of the temperature being 1.52 °C /min. When units work in the range of 300-160MW, 9769 is the useful service life of the drum.

![Figure 1](image)

**Figure 1.** The temperature difference between the inside and outside wall of the drum.

### 3.3. The safety of steam turbine

The steam turbine was designed with a general life of 30 years. Part of steam turbine life is retained as general life loss distribution is only about 80% and the remaining 20% is for sudden accident. The Mechanical Engineering Handbook gives the team turbine life distribution table. Table 1 shows a life loss rate of 0.01%.

**Table 1.** The life distribution data recommended Mechanical Engineering Handbook.

| Operation model                  | Loss rate% | The number of years of operation | The cumulative running times | The cumulative loss of life% |
|----------------------------------|------------|---------------------------------|------------------------------|------------------------------|
| Cold start                       | 0.05       | 4                               | 120                          | 6                            |
| Warm start                       | 0.01       | 1                               | 30                           | 0.3                          |
| Hot start                        | 0.01       | 200                             | 6000                         | 60                           |
| Overhaul before shutdown         | 0.05       | 1 times in 3 years              | 10                           | 0.5                          |
Load rejection with auxiliary power

| Load rejection with auxiliary power | 0.1 | 2 times in 3 years | 20 | 2 |
|-----------------------------------|-----|--------------------|----|---|
| Large amplitude variable negative40% | 0.005 | 50 | 1500 | 7.5 |
| Small amplitude variable load40% | 0.00025 | ~530 | ~16500 | 4 |

\[ \sum \]

\[ 80.3 \]

4. Economic analysis for unconventional peaking regulation

If a single unit stopped running in Shuangliang power plant, it could create a 150MW capacity every hour for wind power in the Jilin power grid. According to that wind turbine generator working with 150MW load operation, each kW·h can save 327.07g of standard coal. Also, during units stop of 33.75 hours, 1655.792t of standard coal can be saved. In other words, if the price of per ton of coal is 650 Yuan, one million Yuan can be saved.

In the process of unconventional peaking regulation, the cost of the power consumption of non-artificial fuel, oil, coal, water, and electricity is about 28.5982 million Yuan. After deducting start-stop loss units, the total economy benefits by 790281 Yuan. The twenty running process can save 158056 Yuan during the five winter months [6].

It can be seen that great loss is caused to power plants with unconventional peak regulation on power unit of peaking shifting start-stop, but it can also greatly improve the entire economy.

References

[1] Yuan Y and Zhang J W 1974 Test Method for Boiler Combustion Adjustment (Beijing: Hydraulic and Electric Power Press) pp 111-137
[2] Yuan Z F and Tian Z P 2002 Principle of Boiler in Power Plant (Beijing: Chinese Power Press) pp 85-110
[3] Huang X Y 2007 Running on the Boiler Combustion Adjustment (Beijing: Chinese Power Press) pp 55-62
[4] Mohan M R, Paranjothi S R and Israel S Prince 2007 Use of pumped-hydro as peak-load management plant in optimal scheduling of power systems Electric Machines & Power Systems 25(10) 1047-1061
[5] Bogachev A F, Kirillina A V and Kozlov Y V 2008 Behavior of phosphates in a high pressure drum boiler with frequent loading Power Technology and Engineering 42(4) 247-251
[6] Zheng H Q and Fang D B 2007 Interconnection electricity prices of peak regulation and frequency regulation on power plants in regional electricity market East China Electric Power 35(2) 107-109