AGC Performance Analysis of Thermal Power Unit Based on Characteristics of Steam Turbine Valve

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Abstract. Maintaining the balance between real-time generation and load is one of the important tasks of power system. Automatic generation control (AGC) is an important part of power grid frequency control, so grid-connected thermal power units must have good AGC performance. Many factors may cause the AGC regulation performance of generating units to fail to meet the requirements, such as unreasonable system design, imperfect control strategy, poor equipment characteristics and so on. This paper introduces the performance index of thermal power units participating in AGC regulation and analyses the influence of flow characteristics of steam turbine valves on AGC performance. By optimizing the steam turbine valve management function, the performance can be effectively improved. The effectiveness of this method is verified by its implementation on a typical 300 MW thermal power unit.

1. Introduction
Maintaining the balance between real-time generation and load is one of the important tasks of power system. Automatic generation control (AGC) is an important part of power grid frequency control, so grid-connected thermal power units must have good AGC performance [1-4]. For the aim of assessing the contribution of each power generation unit, an index of AGC performance has been proposed by North China Electric Power Supervision Bureau.

Many factors may cause the AGC regulation performance of generating units to fail to meet the requirements, such as unreasonable system design, imperfect control strategy, poor equipment characteristics and so on. Current research mainly focuses on the design and optimization of AGC control strategy [5-9]. However, the characteristics of power generation equipment also have a great impact on the quality of AGC control, and there are few studies in this area.

This paper focuses on the influence of flow characteristics of steam turbine valves on AGC performance. The rest of this paper is organized as follows. Section 2 introduces the assess index of AGC performance. Section 3 analyses the influence of flow characteristics of steam turbine valves on AGC performance. Section 4 provides industrial case studies to illustrate the effectiveness of the proposed method. Section 5 makes concluding remarks.

2. Assess index of AGC performance
An official document titled “Detail operation and management rules for North China regional power plants” was proposed by North China Electric Power Supervision Bureau.
A standard AGC response of a power generation unit is illustrated in Figure 1. At the time instant $T_0$, the unit receives an AGC command to raise the unit output from $P_1$ to $P_2$. The generated active power starts the response to the command at the time instant $T_1$.

![Figure 1. The standard AGC response.](image)

Based on the above AGC response, three performance indices have been defined, namely, the regulation speed, adjustment accuracy and response time, denoted respectively by $K_1$, $K_2$ and $K_3$. The mathematical definitions and computing methods for these performance indices are introduced in the following three subsections.

2.1. Regulation speed
Regulation speed is defined as the speed of power generation unit making response to the AGC command.

2.2. Adjustment accuracy
Adjustment accuracy is the difference between the actual generated power and the AGC command when the AGC response completes.

2.3. Response time
Response time refers to the time between a power generation unit receiving an AGC command and starting the response.

3. Influence of flow characteristics of steam turbine valves on AGC performance

3.1. Cause analysis
Thermal power unit changes the steam flow into the turbine by changing the opening of the steam turbine valve, and then changes the actual generating power of the unit. Therefore, in the ideal steam turbine valve control model, the relationship between the valve opening and the active power of the generating unit is linear, so as to ensure that the regulation of active power is linear. The poor linearity of flow characteristics of steam turbine valves will lead to over-regulation or under-regulation of active power under certain valve opening positions, which will affect the speed and accuracy of AGC performance.

The flow characteristic of steam turbine valve can be fitted through the corresponding data relationship between valve position and active power for a period (e.g. 10 days). Figure 2 shows the flow characteristic of steam turbine valve of a typical 300 MW power unit. The linearity of the flow characteristic of the steam turbine valve of this unit is poor.
Figure 2. Flow characteristics of steam turbine valves
Figure 3 shows the AGC performance of this 300 MW power unit. It is obvious that when the AGC command changes, the change of the actual power always lags from the change of the actual command, which is determined by the characteristics of the device itself.

3.2. Optimization method
Typical 300 MW thermal power units usually have four regulating valves: GV1/GV2/GV3/GV4. Their valve position setting corresponds to the general valve position demand of the steam turbine as shown in Figure 4. The poor linearity of flow characteristics is often caused by inappropriate setting parameters of some of the regulating valves. According to the AGC performance of the 300 MW power unit, it is found that poor AGC performance often appears in the range of 82%-88% of the general valve position demand of the steam turbine.
According to Figure 4, the valve management function of GV3 is inappropriate. Adjust the valve management function of GV3 as shown in Figure 5.

4. Application case
An industrial case of 330 MW thermal power unit is shown in this section. The AGC control quality of the generating unit cannot meet the requirements of the power grid as shown in Figure 3, and the index of AGC performance is shown in Table 1.
Table 1. Index of AGC performance before optimization.

| Date       | Regulation speed($K_1$) | Adjustment accuracy($K_2$) | Response time($K_3$) |
|------------|--------------------------|-----------------------------|----------------------|
| 2019-4-3   | 1.2                      | 0.99                        | 1.7                  |
| 2019-4-4   | 1.2                      | 0.96                        | 1.67                 |
| 2019-4-5   | 1.2                      | 0.97                        | 1.7                  |
| 2019-4-6   | 1.2                      | 0.96                        | 1.7                  |
| 2019-4-7   | 1.2                      | 0.98                        | 1.68                 |
| Average    | 1.2                      | 0.972                       | 1.69                 |

After optimization with the adjustment the valve management function of GV3 in Section 3, the index of AGC performance is shown in Table 2.

Table 2. Index of AGC performance after optimization.

| Date       | Regulation speed($K_1$) | Adjustment accuracy($K_2$) | Response time($K_3$) |
|------------|--------------------------|-----------------------------|----------------------|
| 2019-4-12  | 1.2                      | 1.12                        | 1.76                 |
| 2019-4-13  | 1.2                      | 1.15                        | 1.77                 |
| 2019-4-14  | 1.2                      | 1.08                        | 1.73                 |
| 2019-4-15  | 1.2                      | 1.1                         | 1.76                 |
| 2019-4-16  | 1.2                      | 1.1                         | 1.74                 |
| Average    | 1.2                      | 1.11                        | 1.752                |

The index of AGC performance, especially the adjustment accuracy, has been significantly improved. The average index $K_2$ increased by 14.2% and average index $K_3$ increased by 3.7%.

The flow characteristics of steam turbine valves after optimization is shown in Figure 6, and the linearity has improved significantly.

Figure 6. Flow characteristics of steam turbine valves after optimization

5. Conclusion

This paper mainly focuses on the influence of flow characteristics of steam turbine valves on AGC performance. This paper introduces the performance index of thermal power units participating in AGC regulation and analyses the influence of flow characteristics of steam turbine valves on AGC performance. By optimizing the steam turbine valve management function, the performance can be effectively improved. The effectiveness of this method is verified by its implementation on a typical 300 MW thermal power unit.
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