Assess and Optimization of Automatic Generation Control Performances for Thermal Power Generation Units

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Abstract. Automatic generation control (AGC) plays an important role to maintain real time power generation and load balance, and to ensure the quality of power supply. Power system requires each power generation unit to have satisfactory AGC performance. In addition to the design of AGC control strategy, the characteristics of power generation equipment also affect its performance in AGC control. This paper introduces the assess index of AGC performance of power unit, and analyzes the reasons for the poor AGC performance. Based on the AGC control strategy of thermal power units, the paper proposes an optimization method to improve assess index of AGC performance. Through the implementation of typical industrial case studies, the effectiveness of the proposed method is validated.

1. Introduction

The technology of automatic generation control (AGC) is important for safe and economical operation of power grid [1-3]. A balance of required powers from users and the generated powers is crucial to achieve a stable grid frequency and a good quality of power supply. Hence, power generation units must regulate their actual power according to the required power demand distributed by electric dispatching automation systems from power dispatching center [4-7]. For the aim of assessing the contribution of each power generation unit, an index of AGC performance have been proposed by North China Electric Power Supervision Bureau.

Current research focuses on the establishment of AGC control model and the design of corresponding control scheme for thermal power units [8-13]. In these studies, thermal power units are often regarded as an ideal mathematical model. 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 introduces the assess index of automatic power generation control, and analyzes the reasons for the poor AGC performance of thermal power units. Based on the AGC control strategy of thermal power units, the paper proposes a new optimization method to improve assess index of AGC performance. Through the implementation of typical industrial case studies, the effectiveness of the proposed method is validated.

The rest of this paper is organized as follows. Section 2 introduces the assess index of AGC performance. Section 3 presents the optimization method to improve the 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 form \( P_1 \) 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. An optimization method to improve AGC performance

3.1. Cause analysis of poor AGC performance

The speed and accuracy of load control for thermal power units operating in AGC mode are strictly required. However, in practical application, due to the inertia and hysteresis of the equipment itself, the action of the actuator such as the turbine regulating valve often lags behind the change of the load instructions, which can not meet the requirements of fast and accurate load response under AGC mode.

As shown in Figure 2, it is obvious that when the AGC command changes, the change of the actual power always lags behind the change of the actual command, which is determined by the characteristics of the device itself. In this case, the adjustment of the parameters of the controller itself can not eliminate the influence.
3.2. Optimization method of AGC

In summary, when the AGC instructions change, the passive receiving of AGC instructions and adjusting them through feedback loop can no longer meet the requirements of response speed and control accuracy of AGC. It is necessary to add advanced control to load instructions to compensate for the influence of the lag of equipment on control quality. At the same time, in order to satisfy the requirement of repetitive control, it is necessary to add advanced control to load instructions. The control robustness under miscellaneous conditions requires dynamic adjustment of the parameters of the lead controller. A new optimization method of AGC design is shown in Figure 3.

Figure 3. Optimization method of AGC

The control strategy is to add a dynamic parameter adjustment link based on load instruction change to the PID control loop of conventional steam turbine main control system. It is easy to realize in engineering. In steady state, the original controller parameters are maintained to maintain the original control quality. When the speed of load change is fast, the controller parameters are dynamically adjusted. The problem that the response speed and control precision can not meet the requirement due to the hysteresis of compensation equipment itself.

4. Industrial case studies

An industrial case of 330 MW thermal power unit is shown in this section. The AGC control quality of the generating unit can not meet the requirements of the power grid, and 5 days index of AGC performance is shown in Table 1.
Table 1. Index of AGC performance before optimization.

|            | Regulation speed ($K_1$) | Adjustment accuracy ($K_2$) | Response time ($K_3$) |
|------------|--------------------------|----------------------------|-----------------------|
| 2018-11-5  | 1.14                     | 0.99                       | 1.68                  |
| 2018-11-6  | 1.15                     | 0.96                       | 1.64                  |
| 2018-11-7  | 1.13                     | 0.97                       | 1.66                  |
| 2018-11-8  | 1.12                     | 0.96                       | 1.65                  |
| 2018-11-9  | 1.13                     | 0.98                       | 1.67                  |
| **Average**| **1.134**                | **0.972**                  | **1.66**              |

After optimization with the method of Section 3, the 5 days index of AGC performance is shown in Table 2.

Table 2. Index of AGC performance after optimization.

|            | Regulation speed ($K_1$) | Adjustment accuracy ($K_2$) | Response time ($K_3$) |
|------------|--------------------------|----------------------------|-----------------------|
| 2018-11-21 | 1.2                      | 1.12                       | 1.72                  |
| 2018-11-22 | 1.2                      | 1.08                       | 1.71                  |
| 2018-11-23 | 1.2                      | 1.13                       | 1.72                  |
| 2018-11-24 | 1.2                      | 1.09                       | 1.72                  |
| 2018-11-25 | 1.2                      | 1.12                       | 1.73                  |
| **Average**| **1.2**                  | **1.108**                  | **1.72**              |

The index of AGC performance, especially the adjustment accuracy, has been significantly improved. The average index $K_1$ increased by 5.8%, average index $K_2$ increased by 14.0%, and average index $K_3$ increased by 3.6%. The AGC performance after optimization is shown in Figure 4.

![Figure 4. AGC performance after optimization](image)

**5. Conclusion**

This paper focuses on the influence of the characteristics of power generation equipment on the AGC control, introduces the assess index of AGC performance of power unit, and analyzes the reasons for the poor AGC performance. Based on the AGC control strategy of thermal power units, the paper proposes an optimization method to improve assess index of AGC performance. Through the implementation of typical industrial case studies, the effectiveness of the proposed method is validated.

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