Research and Implementation of Generator Unit’s Load Drop Under Over-frequency

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Abstract. In the case of power interconnection faults such as power lockout, the large-scale power transfer will have a great impact on the stability of the sending end and receiving end power grid. According to the load regulation demand under the large-scale power gap of the power grid, combined with the adjustment capacity of the thermal power unit, the load target value and the load adjustment rate of the unit are real-time dynamically adjusted with the amplitude change of the grid frequency. The frequency difference is used to reduce the peak frequency of the grid and avoid the occurrence of high-frequency generator-shedding.

1. Introduction

Under the new situation of interconnection between UHV power grid and regional power grid, the connections between power grids at all levels are increasingly close, and the requirements for cooperation between power grids and power units are also increasingly high. Due to the high voltage grade, long transmission distance and large capacity, the UHVDC project will greatly affect the stability of the power grid at the sending end and the receiving end in the event of failure of phase change, restart of line fault and power lock. The scholars have made in-depth research on the safety and stability characteristics and stability control measures[1, 2] of the receiving power grid after UHVDC feeding, and the influence of DC blocking on the stability of the transmission network[3-5]. The setting of the over-speed protection of the generator set and the high frequency optimization research of the cutting machine coordination has been carried out[6]. The literature[7] grasped the analytic formula of the regional network frequency deviation, grasped the frequency variation characteristics, and proposes a method based on the single machine model to quickly configure the high frequency cutting machine scheme. In order to deepen the regional power grid, the coordination of the over-speed protection setting between units is studied. The above literature is worthy of reference for the configuration method of high frequency cutting machine and the coordination principle of each parameter, but the high frequency generator set under the grid caused by large-scale DC power blocking. The problem of load drop has not been studied.

For the power grid, it is required to have fast and accurate power adjustment capability in the generator unit to ensure the stability of the grid frequency and voltage, thus ensuring the safety and stability of social production. When there is a large power gap in the power grid, such as a DC blocking accident, the grid frequency will suddenly change, and the load on the grid-connected unit needs to be quickly adjusted to ensure that the grid frequency is maintained within a safe range. Especially for the transmission end grid, a considerable part of the unit load output is output to the
receiving grid system through the DC line. When a DC blocking occurs, the output of the unit to the end grid must be rapidly reduced. According to the grid requirements, in severe cases, the power supply system needs to automatically cut off part of the generator unit, otherwise the grid frequency will be too high, causing the system to collapse. At the same time, when the scale power fluctuation occurs in the power grid, the current power grid regulation department mainly relies on manually setting the target value or telephone to notify the running unit to perform load adjustment, and the cycle is long and the effect is poor. Therefore, it is necessary to adjust the load of the generator unit quickly and accurately according to the frequency change of the power grid. According to the frequency change of the power grid, the generator unit’s load drop can reduce the peak frequency of the power grid and avoid the occurrence under over-frequency.

2. AGC and Unit Load Control

The grid frequency is determined by the value of electricity consumption and generated energy. If the value of electricity consumption is equal to the generated energy, the grid frequency is stably. If the value of electricity consumption is greater than the generated energy, the grid frequency will increase. If the value of electricity consumption is less than the generated energy, the grid frequency will reduce. The power grid’s energy adjustment is mainly realized by automatic generation control (AGC). Emergency control of power system means that in the event of grid accidents, the system frequency and voltage will change greatly due to the imbalance of power and load power in the system, especially in the absence of active power, lack of power. In the event of a crash in the system, the load shedding, cutting and disengagement control are performed to ensure the safe operation of the main system and the uninterrupted power supply to important users. Because the load control performance of the unit in the control area directly determines its rapid compensation and adjustment capability to the interconnected power grid in the frequency sudden accident, it is necessary to optimize the load optimization of the network source in the grid operation. Even if a high-frequency reciprocating unit is required, it is generally preferred to reserve a unit that has undergone a coordinated test of the machine network and has a good AGC performance as the regulating unit.

2.1. Characteristic of AGC Control

AGC is one of the important measures to regulate the frequency and active power of power grid and ensure its security and economic operation. The primary frequency control (PFC) is a kind of important way of the frequency control system, but, because of its attenuation characteristic and differ regulation, can't to control the system frequency depending solely on it. To realize zero error output adjustment of frequency, it must rely on the frequency of the AGC. The schematic of PFC is shown in Figure 1.

\[
\Delta P_{l0} = \Delta P_{G0} + BC + AB = \Delta P_{G0} + K_s \Delta f
\]

If \(\Delta P_{l0} = \Delta P_{G0}\), namely generators increase \(\Delta P_{l0}\) load power as assumed, then \(\Delta f = 0\), that is, to achieve a so-called no droop. No droop in dashed lines in Figure 1.

![Figure 1. Schematic of AGC control](image)
The adjustment of AGC for power grid system frequency has no deviation. Because of the energy conversion process time limit, it's much slower that PFC on system load change response than PFC in the thermal power unit, and its response time general need a few minutes. Based on the characteristics of the AGC, it can effectively adjust the minutes level and longer cycle load fluctuation.

2.2. Unit Load Control

When big power grid frequency fluctuation occurs, AGC should adjust the unit’s active power as soon as possible to return to 50Hz according to the size of the area control error (ACE), in order to quickly make up the power shortfall.

Figure 2. Unit AGC control structure

The active power of the unit is the load, which can be increased or decreased by changing the load target value of the unit and then changing the output of the relevant auxiliary system. For example, the thermal power unit that occupies the main part of the power grid at present, its conventional load control scheme is shown in Figure 2. ≮ is no less than judgment, receive lower limit load. ≯ is no greater than judgment, receive upper limit load. V≽ is speed limiter, receiving qualified rate of load adjusting, to control the rate of change of input. When the AGC function is put into operation in CCS mode, the value of load demand is the instruction issued by the power grid scheduling, otherwise it is the instruction set by the power plant operator.

3. Project Design and Application

In order to solve the above problems, the research on the control strategy of generator unit load speed drop under over-frequency is carried out, and an control device is designed to increase the interaction of power and frequency signals between network sources and accelerate grid frequency recovery. The device can adjust the load target value and the load adjustment rate of the unit in real time according to the amplitude change of the grid frequency, so as to achieve a rapid drop of the generator unit load.

3.1. Control Design

As shown in Figure 3, it is the design of the unit over-frequency load drop structure. The first analog quantity generator A1 is the over-frequency upper limit setting value, and is set according to the value specified in the technical standard such as GB/T 31464 'The Grid Operation Code', generally not exceeding 50.5Hz. The second analog quantity generator A2 is the standard load regulation rate value of the unit. It is set according to the requirements of the grid.
source coordination management regulations of the grid area. Take the management regulations of the power plant operation management regulationas an example, requiring the thermal power unit of the drum furnace of the direct-blowing pulverizing system is 1.5% of the rated active power of the unit. The general thermal power unit with the intermediate storage type pulverizing system is 2% of the rated active power of the unit.

The second input terminal X2 of the maximum value selector MAX receives the load lower limit and the value is the lowest load value that the unit can reach the power grid, and the thermal power unit is taken as an example, and the range is generally 30%-50% rated active power.

The function of the digital three-to-two selector THRSEL is, the output D is 1 when two or more of the three digital inputs are 1, and D is 0 in other cases. Table 1 is the algorithm truth table.

| D1 | D2 | D3 | D |
|----|----|----|---|
| 0  | 0  | 0  | 0 |
| 0  | 0  | 1  | 0 |
| 0  | 1  | 0  | 0 |
| 0  | 1  | 1  | 1 |
| 1  | 0  | 0  | 0 |
| 1  | 0  | 1  | 1 |
| 1  | 1  | 0  | 1 |
| 1  | 1  | 1  | 1 |

The device can calculate three digital signals according to the grid frequency measurement value, the unit speed measurement value and the high frequency load speed drop issued by the power grid. The three signals are independent of each other and perform three-to-two logic judgments, which can effectively ensure the accuracy of the signal. Reliable, ultimately determines whether the unit is carrying down the load. The unit selects the minimum value of the unit load deviation value obtained by the function generator after the over-frequency load drop deviation value and the grid frequency measurement value issued by the power grid, and the selected value is superimposed with the original load demand value, and then the maximum load value of the unit is selected as the maximum value.
On the one hand, the load corresponding to the unit at the over-frequency of the system can be reduced as much as possible, and on the other hand, the minimum stable operation of the unit can be ensured.

3.2. Engineering Application

Take one 300MW direct-pressure direct-blowing thermal power unit in the northeast regional power grid as an example, the set value of A1 in the unit is less than 50.5Hz, and the unit is set as 50.2. Correspondingly, the second input end X2 of CMP1 is 50.2, and the second input end X2 of CMP2 is $50.2 \times 60 = 3012$ rpm. The load regulation rate set in A2 is $300 \times 1.5\% = 4.5$ MW/min. Its minimum stable combustion load is 35%Pe, so the second input end of MAX is $300 \times 35\% = 105$ MW. Function settings in function generator F(x) are shown in the Table 2.

| Grid frequency measurement value | Unit load deviation value |
|----------------------------------|---------------------------|
| 50.00                            | 0                         |
| 50.033                           | 0                         |
| 50.10                            | -12                       |
| 50.20                            | -20                       |
| 50.30                            | -40                       |
| 50.40                            | -50                       |
| 50.50                            | -70                       |

At one time, the unit is running at 190 MW. The power grid suddenly has a DC blocking fault, and the grid frequency rapidly rises to 50.3Hz. The grid-regulated EMS system issues the over-frequency load drop digital high-level signal 1 to the unit. The deviation value -50MW of over-frequency load drop is issued. At this time, the unit load deviation value corresponding to the frequency is -40MW, so MIN outputs -50 to the adder ADD for calculation, that is, the first input value of MAX is 140. This value is greater than 105 of the second input, so the output of MAX is 140. For CMP1, the value of X1 is 50.3 is greater than 50.2 of X2, and its output is digital high level signal 1. The unit speed measurement is 3018 rpm, because 3018 is greater than 3012, so the output of CMP2 is the digital high level signal 1. Since the three inputs of THRSEL are all digital high level signals 1, the output thereof is the digital high level signal 1, that is, the set end of AXSEL1, AXSEL2 S is a digital high-level signal 1, both output the value of the first input, that is, the load drop demand of the unit is 140, and the load regulation rate of the unit is 4.5MW/min.

4. Conclusion

With the rapid development of electric industry, the relationship between the power grid and the power supply is closer, and the coordinated action of them is needed to ensure the balance between supply and demand. By analyzing the load regulation demand under the large-scale power gap of the power grid, combined with the adjustment capacity of the thermal power unit, the load target value and the load adjustment rate of the unit are real-time dynamically adjusted according to the amplitude change of the grid frequency. The frequency difference is used to reduce the peak frequency of the grid and avoid the occurrence of high-frequency generator-shedding.

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