Research and analysis of control strategy for dual fuel thermal power unit

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Abstract. It is mainly introduced that the design type of the M701F heavy dual fuel gas turbine unit, the fuel choice and the transformation, five kinds of control mode and the role of each kind of control mode as unit working. The control model design idea, the logical function, the primary control logic structure diagram is researched and analysed, as well as every control model automatic transformation, which should be widely used.

1. Introduction
The combined cycle unit of the first phase of the construction of the Minsk No.5 Thermal Power Station in Belarus uses a "1+1+1+1" single-axis configuration, that is, one gas turbine, one waste heat boiler, one steam turbine and one generator. The gas turbine, steam turbine and generator are arranged on a single shaft and the gas turbine model is M701F heavy. Unlike the domestic pure gas-fired units, the main fuel of the unit is natural gas, and the backup fuel is light diesel. When the main fuel or backup fuel supply is abnormal, it can be automatically switched to another fuel operation by fuel switching, or two fuels. Mixed combustion to ensure long-term stable operation of the unit. Therefore, the control mode is different from the conventional gas-fired unit, and the design is more complicated. The following is a brief analysis of the control mode of the unit.

There are five control modes[1] of the unit: speed control mode, load control mode, blade channel temperature control mode, exhaust temperature control mode and load limit mode.

2. Speed control mode
The speed control mode[2] is mainly applied to the automatic synchronous speed in the empty load mode and the valve position control operation in the load mode. The control mode block diagram is shown in Figure 1.

In the empty load mode, the turbine speed can be changed by the synchronization signal sent by the automatic synchronization request or the GOVERNOR RAISE/GOVERNOR LOWER.

In the ALR ON (automatic load adjustment input, the following abbreviation is the same as above) and the speed control mode, ALR SET (automatic load adjustment set value) is compared with the actual power, and then after the proportional adjustment P, if the difference is greater than 0.15, then Issue SPSET UP (speed set value increase) command; if the difference is less than -0.15, issue SPSET DOWN (speed set value minus) command to change SPSET (speed set value), equivalent to unit load according to ALR SET Closed loop adjustment keeps the actual power of the unit equal to ALR SET.
In the ALR OFF (automatic load adjustment exit) and speed control mode, the gas turbine speed can be changed by the manual operation button (GOVERNOR RAISE/GOVERNOR LOWER), which is equivalent to manually changing the unit load.

In the load control mode, the CSO (main control system command output) plus 5% offset is compared with GVCSO (speed control mode command output). If the difference is greater than 0.15, the SPSET UP command is issued; if the difference is less than -0.15, the SPSET DOWN command is issued to change the SPSET speed setting value.

SPREF (speed reference value) = (SPSET + 100) * 30, when LDON (ignition acceleration phase) is 0, SPSET = 0.266, SPSET plus 100 is 100.266, minus E (actual rotational speed gets the deviation value), The deviation is adjusted for gain.

GVCSO=E * GV GAIN (gain in speed mode) + NO LOAD CSO (empty load main control command output);
GV GAIN=60/4=15 under gas condition and GV GAIN=50.5/4=12.625 under fuel condition;
Under the gas working condition, NO LOAD CSO=20.2, and under the fuel condition, NO LOAD CSO=20.4.

When MD2 (the fixed speed of the gas turbine is not connected to the grid), the Ts (tracking signal) is 0. At this time, the synchronous device is automatically turned on, and the automatic synchronizing device generates the signals of SPEED UP and SPEED DOWN according to the requirements of synchronous grid connection. The SPSET is increased or decreased with a certain slope to match the generator frequency with the grid frequency.

When MD3 (generator outlet breaker GCB is closed), the tracking signal Ts is 1, and after a calculation period (50 ms), Tr (tracking value) is 6.2, but the upper and lower limits of SPSET are +6% and -4%, respectively. Therefore, the SPSET actual output should be the upper limit of 6%. According to the above formula, SPR$(100+6)*30=3180$, which is equivalent to the gas turbine speed at the initial load.

3. Load control mode
The function of the load control mode is to maintain the matching between the load and the frequency by adjusting the output power. The control mode block diagram is shown in Figure 2.

In ALR ON and load control mode, ALR SET is compared with LDSET (load set value). If the difference is greater than 0.2, the LDSET UP command is issued. If the difference is less than -0.2, it is issued. The LDSET DOWN command changes the LDSET (load setpoint), which is equivalent to the closed-loop adjustment of the unit load according to the ALR SET, keeping the actual power of the unit equal to the ALR SET.
In ALR OFF and load control mode, the load of the gas turbine can be changed by the manual operation button (LOAD RAISE / LOAD LOWER).

In the load control mode, when LOAD HOLD = 1, LDREF (load reference value) = ACTLD (actual load); when LOAD HOLD is 0, LDREF = LDSET. LDSET is a process quantity, which is mainly set according to the LOAD LIMIT SET on the CRT. When LDSET is less than the set value on the CRT, it increases; otherwise it decreases.

When LDON (ignition acceleration phase) is 0, LDSET=20MW, LDCSO (load control mode command output) is 45. After the unit is connected to the grid with load to the initial load, it is controlled by LDCSO. At this time, LDSET is based on certain as the rate of increase continues to increase, the control unit continues to load up to the selected LOAD LIMIT SET value.

![Figure 2. Load control mode logic diagram.](image)

4. Temperature control mode

The main function of the temperature control mode[3] is to limit the maximum fuel output to ensure that the inlet flue gas temperature of the turbine blade is at a safe value during the start-up phase and the load phase, preventing the temperature from overheating and damaging the blade.

The temperature control of the M701F is divided into two cases: blade channel temperature control and exhaust temperature control. The corresponding temperature measurement points are: the blade channel temperature measurement point (20) and the exhaust gas temperature measurement point (6), which are all arranged in a ring shape.

In general, the higher the turbine inlet air temperature T3 have, the higher the power and efficiency of the turbine obtain, so it is desirable to operate safely at the highest possible T3 temperature[4]. However, if the T3 is beyond the reasonable range, it will pose a threat to the safety of the gas turbine. Therefore, the temperature change must be monitored during the operation of the gas turbine to ensure that the T3 does not exceed the specified limit. However, the temperature of T3 is very high, and the M701F class is about 1 400 °C. It is very difficult to measure and control directly. However, under steady-state conditions with constant atmospheric temperature, the trend of T3 and EXT TEMP (exhaust temperature T4) is the same, while T4 is much lower than the temperature before turbine T3, and the temperature field of T4 is also passed by the gas. The turbine is mixed and evenly distributed, so the T4 is easy to measure and control[5]. Therefore, the magnitude of the pre-turbine temperature T3 can be indirectly reflected by measuring the exhaust gas temperature T4 of the gas turbine. In order to respond to changing atmospheric temperatures, parameters such as COMP INLET AIR TEMP[6] or COMB SHELL PRESS (compressor outlet pressure) are required to correct T4. When the atmospheric temperature is increased, the compressor outlet pressure is lowered, and in order to make T3 constant,
T4 is increased. On the contrary, in order to maintain T3 as a constant, when the atmospheric temperature is lowered, the compressor outlet pressure is increased, and T4 is lowered. In order to make T3 constant, there is a relationship between the exhaust gas temperature T4 and the compressor outlet pressure. This is the temperature control reference line, and the output of the temperature control reference function is used as EXREF (reference reference value of exhaust gas temperature T4).

\[ T4 = \frac{T3(P4/P3)^n}{n-1} \]

- T3: turbine turbine inlet air temperature
- T4: exhaust temperature
- P3: intake pressure
- P4: exhaust pressure
- n: multi-square constant

Temperature control is based on this curve. Because BPT TEMP (blade channel temperature) is upstream of exhaust temperature, BPREF (blade temperature reference) should be higher than EXREF, so EXREF plus BPT BIAS (BPT deviation) is used as BPREF, BPT bias logic control block diagram as shown in Figure 3.

![Figure 3. BPT bias control mode logic diagram.](image)

The temperature control system compares the reference reference values EXREF and BPREF with the corresponding measured actual deviation values, and inputs them into the PIQ regulator with high and low value limits, and the respective outputs are BPCS0 and EXCS0, respectively. The temperature control mode block diagram is shown in figure 4 and figure 5.

![Figure 4. Blade temperature control mode logic diagram.](image)
5. Fuel limit control mode
The FX function is calculated based on the measured values of the gas turbine speed and the compressor outlet pressure, and is selected as the output of the FLCSO (Fuel Limit Mode Control Command) by high selection[7]. The fuel limit control mode block diagram is shown in figure 6.

When MDO-INV (fuel input) is 0, the output of FLCSO is -5%.

When the ACC (acceleration state) is 1 (at 500 rpm to 2,500 rpm), the FLCSO linearly increases as the number of revolutions increases. When the rated speed is reached, the FLCSO is 30. After the grid is loaded, the FLCSO is gradually increased, and it is impossible to exit the actual control by the minimum selection.

Therefore, the fuel limit control[8] is only used to initiate the fuel open loop control during the speed increase process.

Figure 5. Exhaust gas temperature control mode logic diagram.

Figure 6. Fuel limit control mode logic diagram.
6. Conclusion

Through the analysis of the above five control modes, it is known that in the initial ignition phase, the speed increase control mode is used to control the speed increase process, and at the no-load fixed speed, the speed control mode is used to adjust the matching between the gas turbine and the grid frequency; In the process of lifting the load, the expected load power is achieved through the load control mode; in the process of approaching the full load, the temperature control mode is switched to prevent the gas turbine from overheating. During the commissioning and operation of the unit, the five control modes are automatically switched according to the changes of the working conditions, which satisfies the self-adjustment of the unit according to the changes of the environment, and has great reference for the debugging of the dual fuel unit.

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