Optimization and Application of Primary Frequency System for Real-Time Communication Using PMU Data

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Abstract. By integrating the network-related parameters of the electrical and thermal control specialty in the network-related system, communicating with the Pi real-time database in the power plant Area II, and further realizing the Web application function in the Production Information Area III. Secondly, using these real-time big data, it analyzes the operation of primary frequency regulation and optimizes it accordingly, establishes the standard table, carries out monthly analysis and daily index supervision, so as to make the pass rate of primary frequency regulation close to or reach 100%, and increase the compensation cost, so that the unit is not only in energy-saving operation but also not assessed by the power grid.

Keywords: real time data production, WinPcap, primary frequency, temperature control mode, locking, optimization and adjustment.

1. Introduction
In the core business system of power plant, including DCS, PMU(Phase Measurement Unit), NCS, AGC, AVC, and many other network-related systems, the network-related parameters in each system are independent, even unreasonable and contradictory. By integrating the grid-related parameters of the electrical and thermal control specialty in each grid-related system and communicating to the Pi real-time database of the power plant Area II, the centralized monitoring of the parameters, on-line tracking, multi-dimensional calling and intelligent alarm are further realized, and according to the running data custom data report and log report and other functions. The data system of PMU and PI database guarantees accuracy and synchronism. Effective primary frequency actions are screened from collected data for analysis on line. Contribution electric quantity and contribution rate of primary frequency are selected as indexes for evaluating and calculating primary frequency, which can truly reflect the operation of unit, analyze the primary frequency actions and optimize them accordingly, and establish a standard table. Monthly analysis and daily index supervision are carried out so that the qualified rate of primary frequency is close to or up to 100%, and compensation cost is increased, so that the unit can operate in energy-saving without being assessed by power grid.
2. Method

2.1. Data Communication
The new communication server in power plant production control area I is used for data acquisition of PMU, the data of DCS system, AGC/AVC system and NCS system are communicated to the Pi Database Server of Production Control Zone II through the firewall with the original OPC server, after the data is consolidated in Zone II of production control, it is stored in the Pi Database Mirror server of Zone III of production information by horizontal isolation device. Using application servers and Web servers in Zone III of production information to deploy the online monitoring platform of Web-related parameter information, in which real-time computation and relational databases are deployed to application servers, web Applications and other applications that invoke the system's data are deployed on the Web server.

![Production Information Zone I](image)

Figure 1. Hardware system architecture design diagram

2.2. Data Collection
Since the data in the PMU are sent directly to the dispatch center, independent of other control systems in the power plant, taking into account the need for information security protection, winpcap dynamic link library is used to detect and capture the corresponding packets on the data link from the PMU substations to the main stations. The communication between the PMU substations and the main stations is based on TCP/IP protocol. After analyzing the data according to the TCP/IP protocol, the data are decomposed twice, and the data block in the data packet is analyzed according to the real-time dynamic transmission protocol of the power system, the phasor and analog data of frequency and primary frequency modulation are stored in SQL database of PMU.

3. Problems in primary frequency

3.1. Temperature control of gas turbine
When the gas turbine enters the temperature control mode, it is unable to respond to the primary frequency regulation command, which affects the primary frequency regulation qualification rate. When FSRN (speed load control mode) > FSRT (temperature control mode), at this time, the minimum value selection gate selects FSRT output, it is unable to select FSRN, and the primary frequency regulation loop action is invalid. Because the sign of temperature control of gas turbine is not the value of load, but
the value of temperature. When the unit enters the temperature control mode, the load of the unit will not be controlled by the load loop, which will lead to the failure of load increase in low cycle of power grid, which is easy to make primary frequency regulation assessment. Therefore, when the unit is in the pre selected load control mode of gas turbine, in order to ensure the high load rate of the unit and reserve the space for primary frequency regulation, it is difficult to ensure that the gas turbine operates at a high load rate all the time.

3.2. The speed accuracy of gas turbine is not high
The speed of gas turbine participating in primary frequency regulation calculation comes from the speed signal of gas turbine speed control loop. The eddy current measurement principle is adopted for speed measurement, with three speed probes in total. According to the relationship between the action point of primary frequency regulation issued by the power grid and the dead zone of gas turbine speed 2R/ min, it is found that the gas turbine often fails to act during the operation. The deviation of gas turbine speed measurement results in inaccurate primary frequency regulation and low pass rate of primary frequency regulation.

3.3. The logic is unreasonable
According to the speed deviation control circuit, with the change of system speed (grid frequency), the load can be increased or decreased by directly controlling the fuel quantity by adjusting the fuel benchmark. Since there is no dead zone in the speed signal circuit of the system, the load regulation is easily affected by the system speed, and the stability of the control valve is affected by the long-term load fluctuation.

According to the load control loop, when the grid frequency and 3000r/ min deviation exceeds 2R/ min, the load deviation of primary frequency regulation is planned according to the speed inequality rate, which is superimposed on the load target value, so that the tnrl (speed travel reference) is changed, and the load is increased or decreased by changing the fuel reference through the subsequent logic. When the load deviation of primary frequency regulation is small, the output of load control loop changes little or even remains unchanged, and after subsequent logic processing, the dead zone set in the fuel reference circuit cannot be "exceeded", resulting in the failure of primary frequency regulation.

When AGC and primary frequency regulation act in reverse, the load bias of primary frequency regulation will be cancelled after superposition, even invalid, so it is easy to make a reverse action and be tested.

4. Optimization in primary frequency

4.1. Improvement of temperature control mode for gas turbine
During the full load operation of the unit, in order to ensure that the unit can normally respond to the primary frequency modulation signal, and the unit needs to operate economically under relatively stable load, reduce the gas consumption of gas turbine (natural gas) as far as possible, and improve the operation efficiency of the unit. By adopting a reserved load control method of gas turbine according to the fixed deviation of FSRT and FSRN, the load rate of gas turbine and the action space of primary frequency regulation can be ensured. By setting a smaller reserved setting value, the gas turbine can be at a higher load rate all the time.

According to the principle, the relationship between FSRT and FSRN of gas turbine is modified logically, as shown in the figure below.
4.2. Improvement of speed signal source deviation
According to the initial time and duration of primary frequency regulation action of provincial regulation, and combined with turbine speed, the accuracy of primary frequency regulation action time is analyzed. It is found that the speed of the two gas turbines deviates from the grid frequency. Through comparison, it is found that the DEH speed of the steam turbine has the smallest deviation from the grid frequency, so it should be used as the primary frequency modulation signal source.

4.3. The control circuits

4.3.1. Speed control circuit. ① When there is no primary frequency regulation action, the load does not change. ② When the primary frequency regulation acts, the speed is optimized according to the specific parameters to control the FSRN, which makes the FSRN change accordingly, thus reducing the effect of speed feed-forward, so that the load control of the unit can be relatively stable without the action of primary frequency regulation.

Figure 2. Control principle of reserved load of gas turbine

Figure 3. Speed control circuit
4.3.2. The load control circuit. Reserve the original circuit and switch through the selected mode (selection condition: DCS is allowed to put primary frequency regulation into operation and DEH speed is not bad point), increase the primary frequency modulation offset (primary frequency regulation load deviation after conversion of DEH speed) from DCS to TCS circuit, and switch back to the original circuit if the variable is bad.

Figure 4. The load control circuit

5. Summary
When AGC and primary frequency regulation have reverse action, priority shall be given to primary frequency regulation action reverse. By adding blocking AGC load command mode, primary frequency regulation action can be ensured in place.

After the load function of reserving primary frequency regulation space of gas turbine is put into operation, the primary frequency regulation has not been assessed due to entering the temperature control mode.

The operator does not need to manually intervene the gas turbine load under the pre selected load mode of the gas turbine, so as to avoid entering the temperature control due to neglecting the temperature change, or increasing the gas consumption caused by the reserved large space load.

Through the overall control optimization of load and primary frequency regulation of DCS and TCS system, the qualified rate of primary frequency regulation action has been greatly increased, from about 90% to 98%. After the transformation, the primary frequency regulation has achieved zero assessment.

References
[1] Shi leijian, zhang li, zhang qian. Design and implementation of on-line monitoring system for primary FM of power plant [J]. Software guide, 209, 18(1): 108 -- 111.
[2] Chen J, Li F, Fan L, et al. Review of PMU. Based Online Applications for Dynamic Simulation, Fault Detection, and Cascading Failure Prevention [C] //Proceedings of the 8th WSEAS International Conference on Electric Power Systems, High Voltages, Electric Machines (Power '08). 2008: 212-216.
[3] Ma Qinfeng. Study on evaluation index of primary regulating performance of generator set [J]. Dalian: Dalian university of technology, 2007.
[4] YanXiaoMing. "Two detailed rules" trial operation assessment management and equipment function improvement [J]. Small hydropower, 2011(4): 108-109.
[5] Zheng tao, gao fuying. On-line monitoring of primary frequency modulation characteristic parameters of the unit based on PMU [J]. Power system automation, 2009, 33 (11): 57 -- 61.

[6] Aminifar F, Khodaei A, Fotuhi A, Firuzabad M, et al. Contingency-constrained PMU placement in power networks [J]. Power Systems, IEEE Transactions on, 2010, 25 (1): 516-523.

[7] Luo congkai, sui yuantao, zhang daoli. Control strategy and realization of primary frequency modulation for large power generating turbo sets [J]. Journal of sichuan engineering vocational and technical college, 2013, 27 (2): 18-24.

[8] Design and implementation of primary FM assessment system in wang qibin power plant [D] zhengzhou university, 2014

[9] Yang jianhua, research and development of primary frequency modulation assessment system in central China power grid, power system automation, 2008, 32 (9): 96299

[10] Zhao min, Chen zhiping, zhang juyong. [C] proceedings of the 29th annual conference of automation society of six provinces (regions), 2011:230-232

[11] Yang qing, Yang yan, zheng shiyu database technology and application basics tutorial [M]. Tsinghua university press, 2013.