

Design and Development of Generators-Power Grid Dynamic Performance Online Monitoring System Based on WAMS data

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Abstract. Generator set and its control system are the most important dynamic components in power system. It has a vital effect on the safety and stability of power system. In order to ensure the safe and stable operation of power system, we must strengthen the monitoring of power generation units and control system. This paper introduces the hardware structure and software structure of Generators-Power Grid Dynamic Performance Online Monitoring System based on WAMS data, and the main functions and performance. The practical operation of system in the provincial power grid network is introduced in this paper, which fully demonstrates the practicability and accuracy of the system, the operation of the system provides the powerful tool and means for the safety and stability of the power grid.

1 Introduction

Generator set and its control system are the most important dynamic components of power system, having a crucial impact on stability and safety of power system. With the development of China power grid, a rapid increase in grid-scale, sources type and number can be seen and power system dynamic characteristics is becoming more complicated. In order to guarantee the safe and stable operation of power system, it's necessary to focus more on power generation units and control system monitoring. For conventional hydraulic or thermal engine group, the main task is to conduct a comprehensive monitoring on the key variables of generator excitation and governor control system, giving a full play to its continuous and controllable characteristics, which will play a supporting role to power system stability and safety.

The widespread deployment of WAMS provides a strong support for the monitoring of generator and its control system. By connecting critical internal variables of the conventional generator set control system into WAMS system, comprehensive monitoring of the conventional unit control performance can be achieved and fast and accurate recognition can be conducted as soon as power grid disturbance or oscillation occurs, then we can evaluate the performance of generation units in power system depending on its response to disturbance.

In view of power network situation, the proposed source network dynamic performance monitoring and evaluation online system based on the WAMS information can make full use of the real-time data from WAMS, analyzing the unit control system internal key variables in-depth, detecting power grid disturbance and oscillation effectively and quickly, identifying the abnormal running state of unit, examining whether the response of unit to disturbance and oscillatory meet the requirements of power grid or not, evaluating the dynamic performance of generator set as well as providing technical support for the safety and stability of power grid.

2 System Design

The application subsystem of the D5000 platform is based on the source network dynamic performance online monitoring and evaluation system, which aims to achieve generator condition online monitoring, network generation unit performance online monitoring and assessment,

database services, human-computer interface display function, generator set dynamic performance online monitoring and evaluation function.

2.1 System hardware structure

The system hardware structure mainly includes data server, on-line application server, advanced application function display workstation, maintenance work station etc., system platform architecture diagram is shown in figure 1.

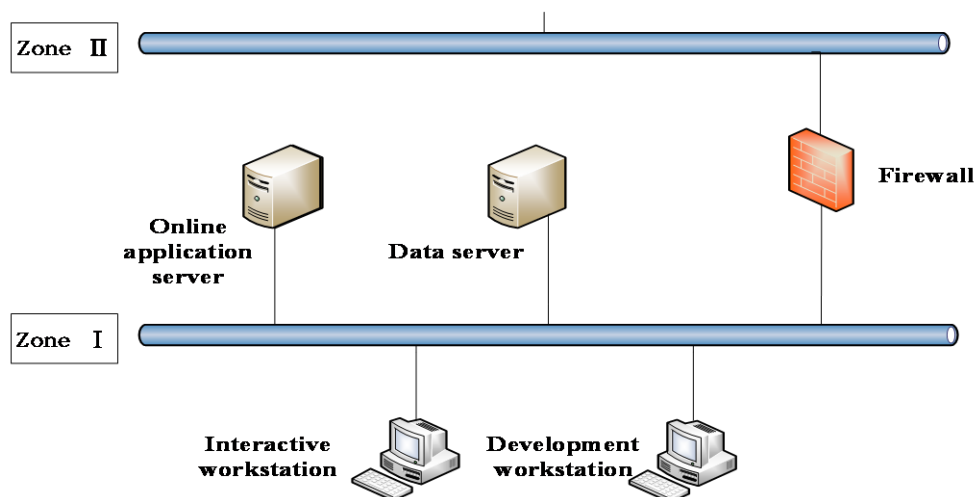


Figure 1. Architecture diagram of the system platform

2.2 System software structure

2.2.1 Software service configuration

Basic services that system software platform provides including real-time library services, historical library services, event library service, file service aiming for providing related services for dataapplication system and software. The services and programs which are deployed and configured on each node are shown in table1.

Table 1. Node service configuration

Safety zone I		
Nodes Number	Node machine	Services and programs deployment
4	Online application server	Generator set operation performance online monitoring
		Excitation system performance online monitoring and evaluation
		Speed control system performance online monitoring and assessment services
		Real-time D5000 database & Time series database services
	Data server	Disturbance data service
		Real-time D5000 database & Time series database services
	Interface workstation	Interface program of source network dynamic performance online monitoring and evaluation system
		D5000 database services
		Off-line auxiliary analysis tool
	Maintenance and development work station	D5000 database services
		System configuration utilization program
		Qt/other applications development tools

2.2.2 Software functions structure

Software functions mainly include data fusion and dynamic monitoring, AVR and PSS performance evaluation, governor performance evaluation, AGC and AVC performance evaluation, generator dynamic performance evaluation and other functional modules and software functions structure is as shown in figure 2.

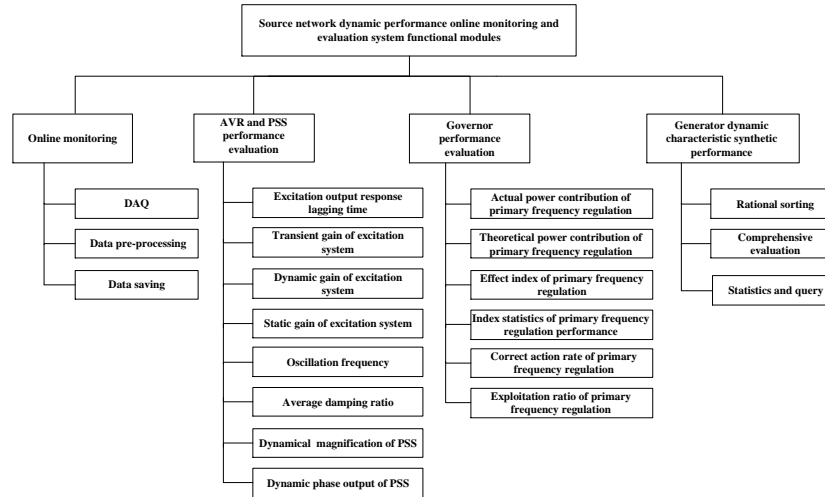


Figure 2. Software architecture diagram

3 System function and performance

3.1 Data fusion and dynamic monitoring modules

By building up data interface with D5000 system or PSASP we acquired model parameters and operation data in order to achieve the function of data fusion. For the uneven quality of different types of real-time data in distribution network, the data to be analyzed should be pro-processed. The data quality should be evaluated and unqualified data should be eliminated to avoid the interference of bad data to monitoring analysis, realizing the automatic verification of various types of data.

3.2 AVR and PSS performance evaluation

The functional module monitors and evaluates the dynamic performance of excitation system, using the actual response data of different units after power grid disturbance, combining the basic parameters of the excitation system settings, such as magnification and excitation limits, to calculate the per unit value of units' controlled volumes and controlled variables. For the effective voltage disturbance, it would extract excitation output response lagging time, transient magnification of excitation system, dynamic magnification ratio, static magnification, etc. to evaluate the performance of generator excitation system. For grid oscillation, the system extracts oscillation frequency, oscillation damping ratio, PSS dynamic magnification, PSS dynamic phase output and other indexes to evaluate the performance of generator excitation system.

3.3 Governor performance monitoring module

This module monitors and evaluates the governor dynamic characteristics, basing on units' speed regulation system instruction, speed deviation, power deviation and other responses, combining the basic operation mode and parameter setting of speed regulation system, to derive the per unit value of units' controlled volumes and controlled variables. The system extracts actual power contribution, theoretical power contribution, effect index, index statistics of performance, correct action rate, exploitation ratio, etc. of the primary frequency regulation.

3.4 AGC/AVC performance monitoring module

This module makes use of AGC/AVC monitoring data to record AGC/AVC commissioning and ceasing data as well as their action situation and then calculate AGC/AVC regulation performance index.

AGC performance index includes:

- (1) AGC Availability ratio
- (2) AGC regulation performance
 - 1) Regulation rate
 - 2) Regulation precision
 - 3) Response time
- (3) AGC regulation performance comprehensive index

AVC performance index includes:

- (1) Units' AVC commissioning rate
- (2) Units' AVC regulation pass rate
- (3) Bus bar voltage pass rate

3.5 Unit dynamic characteristics evaluation module

- (1) Propose rational sorting algorithm taking disturbance difference
The response of unit control system to disturbance will vary with the situation changes, which will influence the evaluation rationality of unit dynamic characteristic.
 - 1) Analysis effects that different disturbance scenarios would have on dynamic performance index of generators;
 - 2) Compare and manage the different dynamic performances of unit.
- (2) Comprehensive evaluation of unit characteristic
 - 1) quantify the importance of each single dynamic performance index and derive the weight of each single performance index of unit.
 - 2) Obtain the comprehensive evaluation of the dynamic performance of the generator according to the synthesis of several performance indexes of the unit.
- (3) Statistics and query
Display the results of unit dynamic characteristic evaluation, taking the results as the guideline of system operation.
 - 1) Tally, query and analyze the calculation results according to different indicators monthly, quarterly and yearly.
 - 2) Automatically generate unit dynamic performance index report monthly, quarterly, yearly or in custom date range.
 - 3) Automatically generate synthesis evaluation of generator dynamic characteristic report.

4 System application

4.1 Excitation system performance evaluation

After the excitation system performance online monitoring and evaluation module putting into operation, several unconventional dynamic processes were detected. By processing and analyzing the data of excitation system, the performance monitoring and evaluation can be achieved based on the response characteristics.

- (1) On January 6, 2016, 04:34:58, 440 #1 generator occurred voltage sag, as shown in figure 3. The system detected this event accurately and fast, then it finished online evaluation. And the result shows that the dynamic response performance of excitation system operates well.

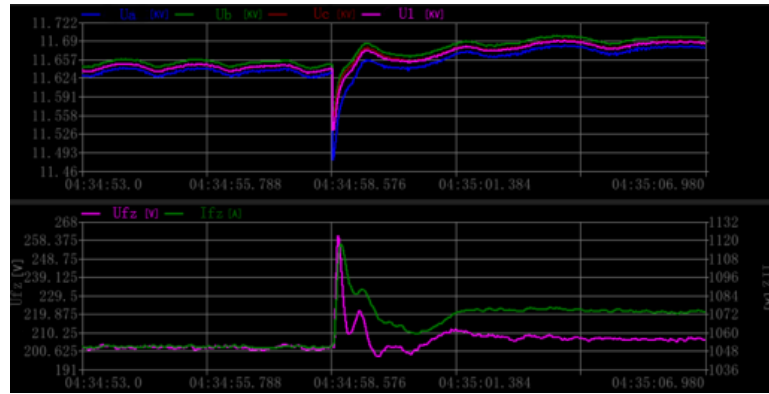


Figure 3. Dynamic response process of voltage sag

- (2) In September 24, 2015, 11:55:00, the 160 electric power plant's #5 generator shut down and the Dynamic Performance Online Monitoring System accurately monitored the accident. Meanwhile, the system made online analysis and evaluation. Based on the analysis result, we can found that the generator set's excitation system had good dynamic performance during the process of shutting down. As shown in figure 4.

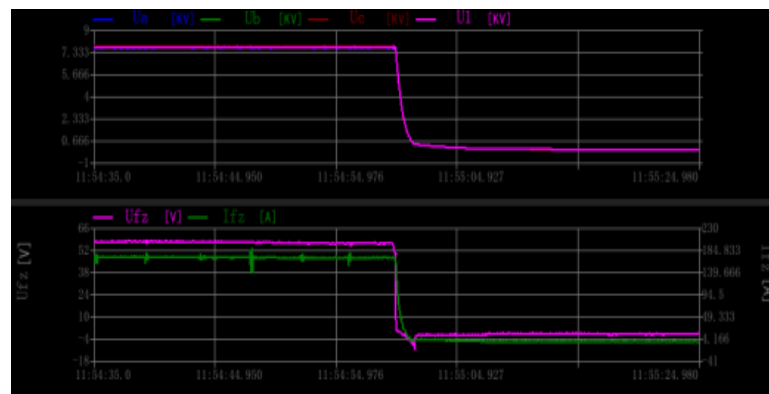


Figure 4. Dynamic response process of down

4.2 Application of the governor characteristics evaluation module

After the online governor dynamic characteristics monitor and evaluation module putting into operation, it detected the process of power system frequency crossing the dead zone many times. Based on the processing and analysis of governor's dynamic process data, the module succeeded to calculate the parameter of governor's characteristics, realizing the function to monitor and evaluate the governor's characteristics.

- (1) In December 23, 2015, 16:01:10, the 840 electric power plant's #1 generator's frequency fluctuated then primary frequency modulation module worked. The online governor dynamic characteristics monitor and evaluation module accurately recorded the whole process of primary frequency modulation. Meanwhile, it analyzed and evaluated the process. Based on the result, we found that the governor's dynamic response performance is well. Shown as figure 5.

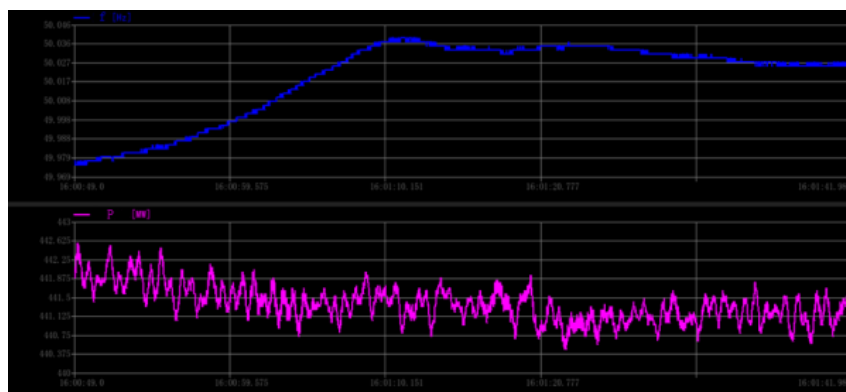


Figure 5. Operation process of primary frequency regulation

5 Conclusion and discussion

Generators-Power Grid Dynamic Performance Online Monitoring System Based on WAMS data has been put into operation in many provincial power grid, the system can quickly detect all kinds of disturbance, oscillation in network and it can also identify the abnormal operation of the unit online. By calculating and analyzing key variables of unit internal control system, we can evaluate network dynamic performance online, and assess whether the response of the unit in disturbance and oscillation conform to the requirements of the grid based on evaluation results; The system can monitor and evaluate the dynamic performance of grid connected power plants at all levels online, providing a powerful technical guarantee for the safe and stable operation of the power grid.

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