Research on the Operation and Monitoring Index of Electric Power System Based on Data Analysis

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Abstract. Based on the model for IoT Sensor data analytic, this paper proposes a business-driven key performance indicator system for the operation and monitoring of multidimensional intelligent power system operation monitoring, and establishes a real-time monitoring and early warning system frame. With the large grid panoramic information platform, by combining and segmenting the performance indicator cube of dispatching process, dispatching service and dispatching management, a business-driven and decision-oriented performance indicator system for smart grid dispatch is formed, which solves the problems of unclear dispatching and lack of decision indicators in current dispatching performance indicator system.

Introduction

The Yunnan Power Grid Panorama Information Visualization Platform, built on the monitoring systems and management systems operated within the master station, is a “one-stop” decision support system that reflects the real-time operation and control, dispatching operation, operation maintenance and coordination management of the power grid. The operation and monitoring module supports the control command and high-level decision-making of the dispatching operation. It displays the key indicators (KPI) of the grid operation by panoramic visualization, in the form of an intuitive image, provides early warning and intelligent decision support for key abnormal events, and evaluates the control performance after a deep analysis in the characteristics of its operation by integrated information mining technology. The construction of a comprehensive, reasonable, flexible and efficient smart grid dispatching key performance indicator system (hereinafter referred to as the operation monitoring KPI system) is a prerequisite for grid operation monitoring.

To conduct research on the operation monitoring KPI system and establish a scientific, reasonable and efficient KPI system is not only vital for power dispatch and operation, but also crucial to build a strong smart grid. At present, domestic and foreign power grid experts’ research on operation KPI mainly focuses on three aspects, namely, the selection of power grid operation indicators, the state division of indicators and the collaborative processing means of indicators in different states, but with different emphases.

The Status Quo at Home and Abroad

Foreign Electricity Grid Operation Monitoring System

Operation indexes of the system in Europe and the U.S. are listed as below:

Voltage Index: includes amplitude, stability, and distribution of electric current, along with other voltage parameters before and after the fault state.

Current Index: analyzes surcharge conditions of power transmission equipment and current transmission load between control fields, along with other parameters involved before and after the fault state.

Frequency Index: ensures safe operation of the adjacent grid, allowable frequency and effective solution to grid malfunctions.

Reserve capacity Index: directly influences the frequency stability as it is related to electricity production and the load of the system.
Electricity Production & Load Index: show the reserve situation of the decision-making system and also impact the natural power flow.

ACE Index: is related to unbalance situation between electricity production and load, and plays a great role in the frequency.

Time Offset: records the warp happening between the actual frequency and rated frequency, and would trigger coping measures if the offset surplus the certain limitation.

Inadvertent Interchange: shows frequency deviation in a control area, especially the deviation between the actual interchange and rated interchange.

Stability Index: is divided into 3 status as follows. Static stability (stable status after variety on energy production capacity till balance with load), transient stability (synchrony capability of generators under suddenly complicated interference) and dynamic stability (Capability of the control system to decrease the vibration of generators under minor interference)

Var Generator Index: includes rotating var generator and static var generator. The sufficiency of var generators decides a controllable variety of voltage.

Network Topology Index: shows topology varieties by analyzing furcation of current transmission and voltage caused by examine and repair, offline equipment, topology addition or other events related to generating and distribution unit.

Weather/Environment Index: helps to estimate the protentional load situation. The gloomy weather and accidents may pose threats against the grid system.

Equipment Index: monitors the running status of SCADA and automatic control system to minimize damages caused by misjudgment, misoperation and other accidents.

Adjoining System Index: ensures the normal operation as connectively-operated power grid system would not work well if the adjoining system broke. When malfunction happens to one subsystem, this index provides solutions to minimize effects on other running subsystems to ensure the stability of the whole power grid system.

Index System for Operation and Monitoring of Domestic Power Grid

Domestically, as different power grids adopt different dispatching automation systems and set different priorities of monitoring, the operation index of each power grid differs with that of another. Index system generally has three layers, namely, primary index (main class), secondary index (subclass), and tertiary index (base class). The index system is constructed on the basis of the overall requirements of power grid intellectualization. This index system features unclear division, indicator redundancy, wide coverage, lack of priority, and unclear correlation among indexes, which lead to the distraction and decreased working efficiency of dispatchers and operators as well as a negative impact on decision results.

Constructing Method of KPI Index System for Operation and Monitoring

Constructing Method

To construct a business-driven indicator system, we first need to establish a six-dimensional indicator system based on our business objectives after analysis on it, and on decisive information and related data sources that need to be provided in the work of related staffs; then combine operational monitoring, operational management, EMS and other advanced application software indicators, and add the required derivative decisive indicators to form the indicator pool; finally, we will connect the indicators in the pool according to the six dimensions, determine the corresponding coordination rules, and build the entire indicator system.

In the construction of indicator system, we start from the process-target-object dimensional and build its basic indicator cube based on the business objectives, and then expand it to the other three dimensions—Time Dimensions—Spatial Dimensions—Business Dimensions—through the integration and cutting of multiple basic indicator cubes.
Construction of KPI System

In order to be available to the flexible integration and segmentation of different staffs, the monitoring KPI system must be scalable, comprehensive, and applicable to support data mining and monitoring for different business purposes. The dimensions of the monitoring KPI system include:

- Time dimension: the time interval of the representation, that is, the history, real-time and future of the indicator state;
- Target dimension: the target area targeted, i.e., the specific business objectives;
- Process dimension: applicable process links, including generation, transmission, distribution, change, usage, and dispatch;
- Space dimension: Applicable management level, including district network, provincial network, and prefecture network;
- Business dimension: applicable business, including scheduling, mode, automation, communication, security, and comprehensive.

As illustrated above, this system regards the process, object, and target cube as the basic indicator cubes. Through these cube combinations and extensions, you can monitor, analyze, and evaluate the operation situation of different services, in different times, different processes, different objects, different aims, and different space. Such an indicator system makes the indicators more refined.

Indicator Status and Related Correlation

The indicator status in the indicator pool has three states: normal state, alarm state, fault state, corresponding to the power system running state, and the visual display color: green, yellow, and red. The relationship between indicators can be clarified through formulas.

For the dispatching service of the provincial dispatch center, the grid reliability index is an important indicator.

1) PHS (Probability of Healthy State)

\[ PHS = \sum_{s_k \in D_H} P_{s_k}(t) \]  

In the formula, \( P_{s_k}(t) \) represents the probability of system state \( s_k \) at a moment \( t \); \( D_H \) is the set of the healthy state of the system.

2) PFS (Probability of Power Flow Security)

\[ PFS = \sum_{s_k \in D_{s,ls}} P_{s_k}(t) \]  

In the formula, \( P_{s_k}(t) \) represents the probability of system state \( s_k \) at a moment \( t \); \( D_{s,ls} \) is the set of the state of all the power flow security of all lines in the system.

3) The Analysis of Relationship of Load Characteristic Indicators

The magnitude of the correlation coefficient of the load characteristic index data cannot determine the causality and linkage relationship between the load characteristic indicators, nor can it determine the long-term synchronous movement trend between the indicators, nor can it determine the linkage of the load characteristic indicators, and instead it can only explain the strength of relevance in statistical data. The theory of linkage analysis in economics is mainly based on the calculation method and theory of one variable of regression analysis on another or some variable dependence.

The load characteristic correlation index analysis method is to explore the inherent regular relationship hidden in the massive statistical data indicators through data mining. In the current situation, we first conduct correlation analysis between two groups (each group with two indicators) of indicators, and secondly, we will use a correlation analysis method of binary variables. According to different types of variable data, different correlation analysis methods are adopted. When the grid load statistical indicators are correlated, the load characteristic indicators are usually
numerical variables, and the Pearson correlation coefficient analysis method is selected to obtain the correlation coefficient between the load characteristic indicators. 
First set two random variables, X and y, and the correlation coefficient of the X and Y is:

$$
\rho = \frac{\text{cov}(X,Y)}{\sqrt{\text{var}(X)} \sqrt{\text{var}(Y)}} \tag{3}
$$

Secondly, cov(X,y) is the covariance of two random variables; \(\text{var}(X)\), \(\text{var}(y)\) are the variances of the variables X and Y, and the overall correlation coefficient is a measure of the correlation coefficient between the two variables.

4) Analysis of Algorithm\[^{[5]}\]

The algorithm analysis uses the example of “safety”—“frequency stability”—“emergency reserve for generation” indicator. Firstly, the surface characteristics of the indicator can be adjusted within 10 minutes, and the power generation rotary standby on the grid-connected unit and the adjustable standby of the standby water turbine unit can be calculated as follows:

$$
V_{\text{EPI}} = \min \left( \frac{P_i}{L_i} \right) \tag{4}
$$

\(V_{\text{EPI}}\) represents the calculated value of index, \(P_i\) represents the emergency reserve of area \(i\), \(L_i\) represents the adjust the load of area \(i\), \(i = 0,1,\ldots,5\), respectively representing the areas in the regional power network, Guangdong, Guangxi, Yunnan, Guizhou, and Hainan.

$$
V_{\text{pos}} = \begin{cases} 
0, & V_{\text{EPI}} \leq V_0 \\
\frac{V_{\text{EPI}} - V_0}{V_1 - V_0}, & V_0 < V_{\text{EPI}} \leq V_1 \\
\frac{V_2 - V_{\text{EPI}}}{V_2 - V_1}, & V_1 < V_{\text{EPI}} \leq V_2 \\
1, & V_2 \leq V_{\text{EPI}} 
\end{cases} \tag{5}
$$

(2) provides normalization algorithm, adopting the piecewise linear model. \(V_{\text{pos}}\) is the normalized value between 0-1; \(V_0, V_3\) are the lower and upper limit settings respectively; \(V_2, V_3\) are the threshold setting, which form three sections characterized by normal, early warning, and alarm status.

Conclusion

Yunnan Power Grid is one of China's complex and large UHVAC/DC power grids. Amid the massive data and information on dispatching and operation monitoring, the intelligent dispatching key performance indicator system, business-oriented and decision-oriented, can quickly transform massive data into an efficient indicator system to meet the scheduling requirements of a refinement and smart grid, and support dispatchers for real-time monitoring of modern power grids, online security analysis, and decision-making. Based on the research on a decision-oriented and business-driven dispatching operation index system of Yunnan power grid intelligent construction, a lightweight, extensible and decision-supporting key performance index system is constructively proposed from the perspective of large-scale power grid security dispatching, presenting a great practical significance for the research on the integration of intelligent dispatching and control systems.

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