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Research on Electric Power Monitoring System Based on Wireless Big Data Platform

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Abstract. This paper discusses the design idea of wireless big data platform from the aspects of data acquisition, data transmission, data network construction and business coordination operation mechanism of big data system. By setting some examples of the monitoring business of key cross-section transmits limit capacity for power grid, the concept of the relevant features and choice of ideas are given, and the related calculation and the coordination & operation process from the big data system related to the monitoring business that key cross-section transmission limit capacity are shown completely. The simulation experiment shows that the choose of the relevant feature variables and the evaluation method of the performance index that are given can support the need of the whole wireless big data network to monitor the power system with high precision.

Keywords: big data platform, distributed node, electric power monitoring system, transmission capacity, wireless network

1 Introduction

At present, China's power transmission and distribution system exists the problem that equipment investment efficiency is low and the phenomenon of capacity being idle is serious, and the average load utilization rate is less than 50%, resulting in serious waste of investment and resources [1-2]. The root cause of this problem is the lack of accurate and synchronous detection in the entire grid from the power generation, substation, transmission and distribution, electricity using and other aspects, and then the system is difficult to do effective coordination and control. Therefore the stability of the system and where the boundary is can not be given. The power generation equipment and the electricity load can not do scientific and timely scheduling, resulting in waste of resources, and affect the stability and reliability of the system operation seriously.

Smart grid construction also brings in more severe challenges to the power grid system. Given that the smart grid needs to accept a variety of new distributed power generation, such as wind power, solar power etc, if the interference caused by these distributed power supply is not dealt well, it will seriously affect the power quality, and even lead to the unstability of power grid. On the other hand, the core technology of smart grid construction is the need to provide menu-oriented services for users, which is how much power users need, how the power quality is, on-demand orders, and to provide users with seamless energy needs according to user needs. If the smart grid is to achieve the menu-oriented service, precise control and fine deployment capabilities is unthinkable without real-time and accurate detection to the grid.

Thus, a real-time and accurate power monitoring system is compulsory whether it is focused on improving the efficiency of the grid, or focused on the construction of smart grid.

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However, the current status of the power system is far from accurate and real-time detection, so it can not achieve precise control. The current power system detection is far from full network coverage usually in a number of key nodes to detect; on the other hand, currently the power parameter detection, transmission and the processing of the timeliness can not meet the requirements of the real-time and accurate detection and control from the power grid system because the transition time of dynamic process in the power system is very short (milliseconds).

To achieve system-wide, synchronous and accurate monitoring to the whole power network, the current traditional mechanism modeling, and the reanalysis research method has clearly failed to solve the fundamental problem, because for such a big and full coverage real-time detection network, its construction cost will be an astronomical figure. In addition, by analysis method of traditional detection modeling, real-time accurate detection and monitoring to the power grid can not be achieved when faced with a variety of interference and non-linear.

The concept and technology of big data in electric power system can support the integration of multi-data source, multi-area, and cross-time data in the power system. It can do data collection and analysis for the whole power system dynamically and realistically from the perspective of more macroscopic view and whole network, achieving a full range of information access [3-4, 7-8]. So it is possible to achieve real-time, accurate and simultaneous detection and monitoring to the entire power grid, in order to maximize the efficiency of the grid and lay a solid technical foundation to smart grid construction.

This paper is organized as follows: In section 2, the idea to detect the regional power equipment operating status, energy consumption condition and power quality by signal expansion functions is discussed, and a kind of distributed structure is provided for big data power monitoring system. In section 3, the topological structure for big data power monitoring system is presented, which consist of distributed regional wireless sensor networks with the Beidou satellite communication modules as main nodes and the big data center as the master node for the power wireless network systems. In addition, the monitor system work program is also given. In section 4, The division of labor of big data platform system supported by wireless data monitoring system is discussed, in which, the algorithm for selection of feature variable on a single computing node and evaluation of regional grid transmission capacity is described, and the idea to determinate the limit transmission capacity of the distributed node in the big data center is stated. In section 5, A simulation experiment is carried out, it can prove the feasibility of the method provided in this paper which is the core support for the wireless big data platform to realize the on-line monitoring system of power grid. Finally, in section 6, we summarize and draw the key issues need to be solved in the practical application of big data in power networks in the future, and suggest some theoretical problems should be paid attention and solved.

2 Data Layer Construction of Wireless Big Data Power Monitoring System

The detection of various parameters in the power system, which is generally derived from direct sensor detection, provides some basic parameters such as current, voltage, power and others. Towards this power parameter detection method relying on traditional sensor network, construction costs are huge, and the efficiency is low. The research of this paper is supported by the Innovation Foundation Project of Shenzhen Technology & Creation Branch (Project: “Research on fine calculation and analysis for power signals in power system”; project number: JCYJ20160429112213821). The study obtained regional power equipment operating status, energy consumption condition and power quality, through signal sampling for the voltage and current on a point, refined calculation and analysis. The idea is that the power system signal can be generally expressed as a linear combination of a set of expansion functions. Let us set gm as a set of expansion functions for the power signal space X, and for any power signal x $\in$ X can be expressed as: $\theta(t) = \frac{1}{\sqrt{2\Pi}} \ell^{-\frac{t^2}{2}}$ where a_m is the coefficient of the expansion function and M is the number of expansion functions.

The signal expansion function g_m in the equation can actually represent the main characteristic of the power disturbance signal. These expansion function that can be expressed as the main characteristic of the power disturbance signal expansion function is the electrical signal disturbance characteristic function. By extracting these characteristic signals, it is possible to analyze the energy consumption and power quality of the area by analyzing what equipment is running and how they are running.

According to this idea, the big data system system of the power system can be built according to the distributed structure, the entire power system is divided by region, each region sets up a calculation node, and fine analysis and calculation is done in each area of the current and voltage sensor ‘s sampling signal to obtain the relevant feature variable of the power signal in the region. The relevant characteristics of the amount of data are calculated by the calculation of the node, constituting the entire power system’s data sources.

3 Wireless Network System Construction of Big Data Power Monitoring System

About the entire grid geographical area coverage, the project construction and its cost is unacceptable if we build data transmission network according to the conventional means of communication. Given that the RFID radio frequency communication technology is with a very low cost and of easy installation, also, based on wireless technology, achieving the relevant detected power signal transmission through the combination of RFID and sensors is an economical and feasible way.

Through RFID, the full coverage of the power system can be achieved, but to let the RFID node of the power signal information sent to the monitoring center of the big data computing center, a higher layer of technology should be used.

So far, the Beidou satellite communication technology has been very mature. Beidou satellite communication device can not only provide accurate location information, but also provide accurate time synchronization information. More importantly, it can transmit the power system information to anywhere on earth through the satellite system. Therefore, it is possible to solve the sampling synchronization problem and the location problem of the power grid by adopting the wireless network model combining Beidou satellite communication and RFID. Based on this, we can establish a three-dimensional power network information monitoring system with three-dimensional coordinates of time-space-power sampling numerical.

The program using RFID + Beidou satellite communication technology to achieve wireless big data power monitoring system is:

(1) Construct a regional wireless sensor network with the Beidou satellite communication module as the communication trunk node, and in the trunk node, the distributed big data computing node is equipped with.

The working process for the construction of the wireless sensor network in the region is:

(a) In the center of a power network area, set the Beidou satellite communication module as the communication backbone node;

(b) Regarding the Beidou satellite communication node as the center again, in the Beidou satellite communication node surrounding area of each test center, the RFID node with the electrical parameter detection sensor is installed according to the needs of the grid detection signal.

(c) RFID nodes with electrical parameter detection transmit the detected grid parameters to the Beidou satellite communications node at a set frequency;

(d) The Beidou satellite communication node adds its own geographic data and the current time information to the numbered RFID information when receiving the numbered RFID information;

(e) A big data calculation operation is carried out by the RFID to the regional grid parameters by the distributed big data computing center equipped with the Beidou satellite communication node to obtain the relevant power parameter characteristic variable of the regional network;

(f) The Beidou satellite communication node transmits the regional electrical parameter feature variable calculated by the distributed big data to the big data computing center of the grid through satellite communication. It is clear that these feature quantities are very clear about the location of the power network corresponding to these feature quantities due to the presence of accurate geographic location data.

The entire area of the wireless sensor network is shown in Fig. 1.

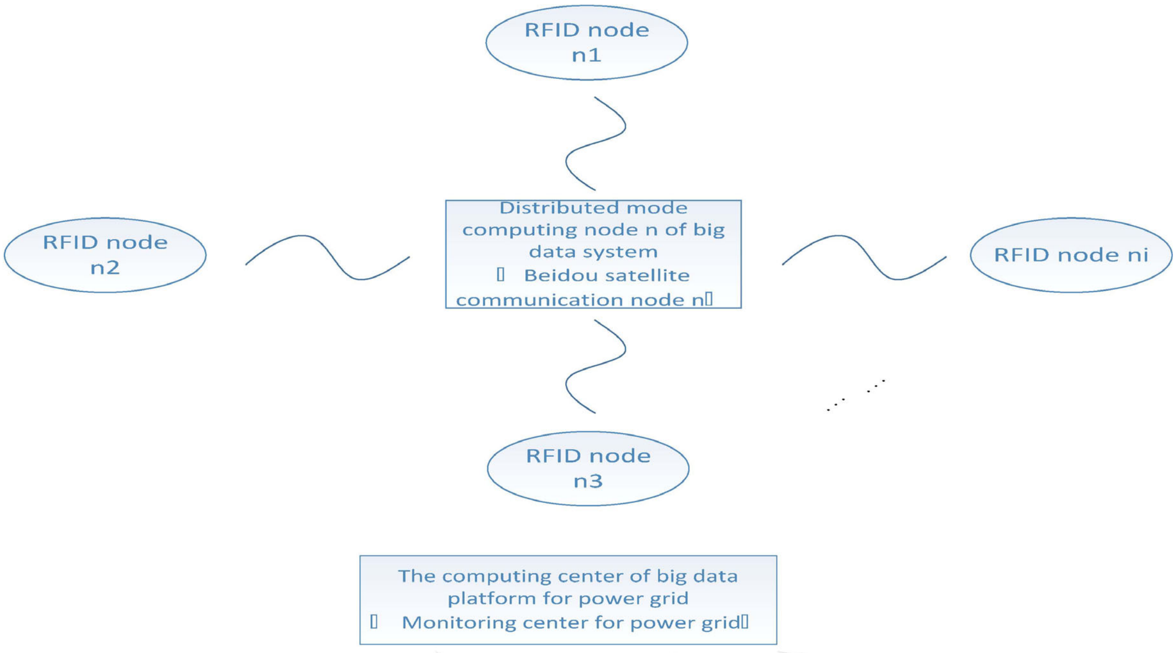

Fig. 1. Schematic diagram of a regional wireless sensor network with the Beidou satellite communication module as the main node

No matter the Beidou satellite communication node or the RFID node data, all nodes are all three-dimensional data of geo-temporal-power sampling data.

Building the power wireless network system with a power system big data center as the main node

On the basis of the regional wireless sensor network that is based on the Beidou satellite communication module, it is easy to construct the power wireless network with the main data center of the power system as the main node. As the Beidou satellite communication has satellite communication functions as the main node, the distance of the transmission data can basically reach any given location. Therefore, no matter in which geographical location the power system data center is set, each wireless sensor network's power parameter feature with the Beidou satellite communication module as the backbone can be transmitted directly to the Big Data Computing Center of the Power System with the Beidou satellite communication node via satellite communications.

The power wireless network with big data calculation center as the main node of shown in Fig. 2.

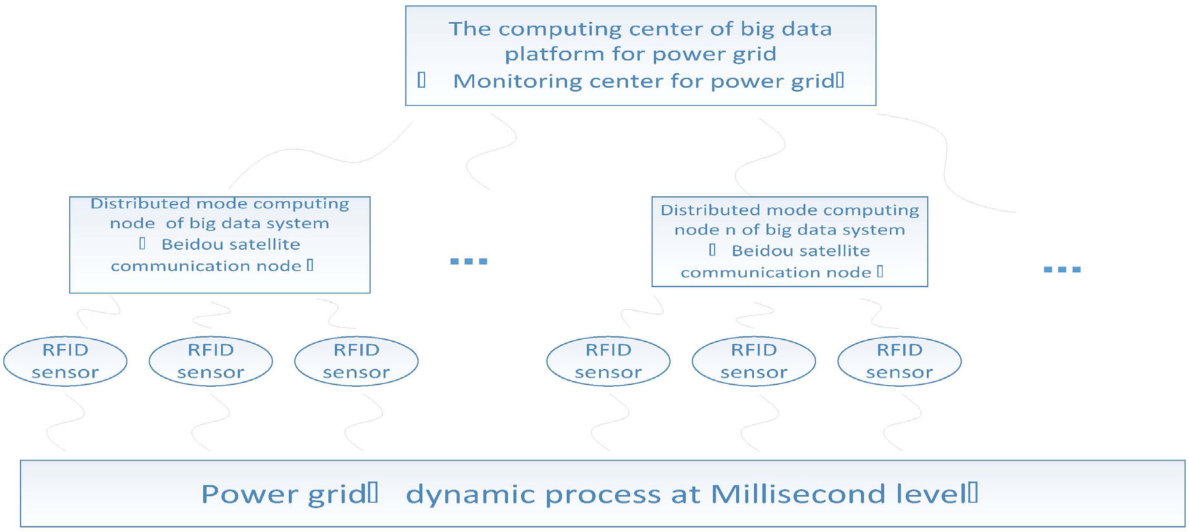

Fig. 2. Schematic diagram of a power wireless network with a big data center of the power system as the master node

4 The Division of Labor of Big Data Platform System Supported by Wireless Data Monitoring System

In the constructed wireless power data network monitoring system, many key technical problems that is difficult to be solved by the traditional mechanism modeling research method can be solved, such as the accurate estimation of the transmission capacity of the power system, the real-time monitoring of the power quality etc.

This paper, setting the whole power grid security monitoring as an example, describes the calculation and evaluation of the division of labor to solve the problem of grid capacity based on big data platform.

(1) The algorithm for selection of feature variable on a single computing node and evaluation of regional grid transmission capacity

Assuming that predicted value that the power grid's key cross-section transmits limit capacity in the power grid is Q_0: u is the candidate variable of the candidate Q_0, r is the relevant feature variable of the candidate, and R is the selected grid feature set. The choice of the feature variable can refer to R. Battiti proposed the prototype of the relevant information evaluation criteria the prototype [7], getting the equation (1) after integrating.

Select the relevant feature variable according to equation (1):

$$J = COV(Q_0;u) - \lambda \sum_{r \in R} COV(r,u) \tag{1}$$

In the above equation, COV represents a function to obtain the relevant information. Obviously, in the process of selecting the feature variable, two factors are considered into (1). One is the correlation between the candidate feature variable u and the transmission capacity of the critical section of the power grid, and the greater the correlation value, the more the variable is inclined to be selected. The second is the correlation value between the candidate feature variable u and all the selected candidate feature variable r. The bigger the value is, it indicates that the candidate feature is a redundant amount that affects the transmission capacity of the critical cross-section of the power grid, and is not inclined to be selected. $\lambda \in (0,1)$, determine how much the value J is the time for u to be selected as transmission capacity predictive value of Q_0 influencing the key cross-section of power grid according to the actual situation, which means $u \in R$.

Taking into account that the power grid is in the normal operation of the state and in a short time it will not be drastic changes, the linear knowledge description method can be used to describe the safety and stability characteristics of nonlinear power system in a short time [8]. Therefore, the critical transmission capacity Q_0 of the critical section of the regional grid can be calculated as follows:

$$Q_0 = Q_s + a_1 \Delta r_1 + a_2 \Delta r_2 + \cdots + a_m \Delta r_m \tag{2}$$

In this equation, Q_s is the basic value of limit transmission capacity of regional key sections when the power grid is normal, Q_0 is the predicted value of limit transmission capacity of regional key sections, Δr_i (i = 1, 2, ..., m) is the characteristic variable of the critical section transmission capacity forecast value, a_i (i = 1, 2, ..., m) is the sensitivity that the relevant feature variable influence Q_0.

(2) The determination of the limit transmission capacity Q_s of the distributed node in the big data center and the on-line monitoring of the grid capacity.

Big data center can calculate the critical section limit transmission Capacity basic values Q_s when the regional power grid is in normal condition and be transmitted to the distributed nodes through the wireless network according to the condition of the grid line and network transformation, as well as the operation of the power grid because of the more comprehensive materials of the entire network and the grid operation information.

The selection process of the feature variable that affects Q_s can refer to (1), and for the calculation process of Q_s, we can refer to (2).

At the same time, the big data center obtains the relevant critical cross-section transmission limit capacity prediction value of power grid area through the wireless network from the distributed computing nodes.

The entire wireless big data monitoring can do real-time monitoring for the entire network to monitor the online transmission capacity for the power system system through the big data center and distributed node division of labor, providing an important guarantee of security.

5 Simulation Experiment

In this paper, the simulation experiment is carried out for IEEE 9-node system. The modified IEEE 9 node system is shown in Fig. 3.

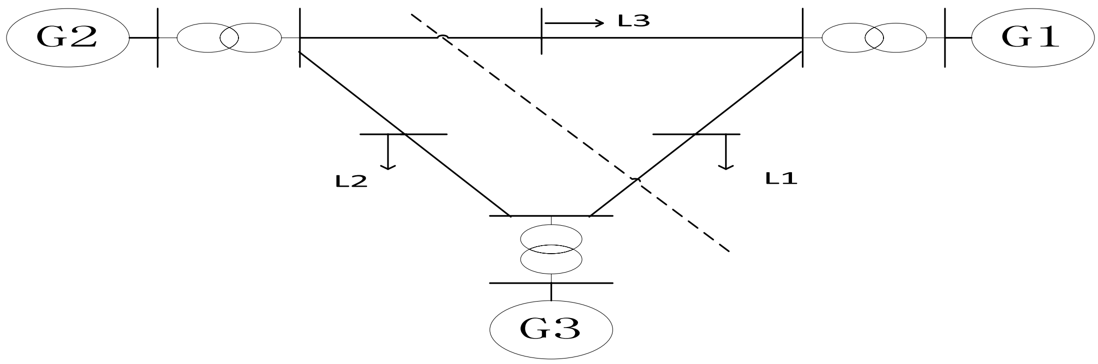

Fig. 3. IEEE 9-bus power system

The initial operating state of the system is shown in Table 1 and Table 2. The electrical data in the simulation system are all unitary values, in which the power basic value is 100 MW and the thermal stability limit for all transmission lines in the grid is assumed to be 100 MW. The output of the IEEE 9-node system generator and the terminal voltage are shown in Table 1, and the node load power is shown in Table 2.

Table 1. Active power and terminal voltage of generators in IEEE 9-bus system

Generator No.	Active Power Output	Generator Terminal Voltage
1	0.91	1.026
2	1.35	1.026
3	1.01	1.032

Table 2. Active and reactive power of loads in IEEE 9-bus system

Load No.	Active Power	Reactive Power
1	1.26	0.51
2	1.01	0.36
3	0.91	0.31

In this mode of operation, the transmission channel cut by the black straight dashed line in Fig. 3 is the transmission channel of the overloaded system. The load rate of the channel is high and the safety margin is small, which reflects the weak link in the power grid, is the key section that should be focused on. Set the prediction value of critical section on-line limit transmission capacity is Q_0, and the basic value Q_s = 2.15. Online monitoring through experiment simulation is expected.

This paper focuses on the critical factors that affect the limit transmission capacity of critical sections from the power flow characteristics in many power grids (such as generator voltage, generator output, etc.) in a short time when the operation status of the grid does not have much change. So we use active power output of the generator voltage P_{G1} - P_{G3}, and the bus voltage U_{G1} - U_{G3} and U_{L1} - U_{L3} as the initial grid-related feature variable.

By using (1) to do simulation calculation and related mathematical processing ($\lambda = 0.4$), we select the relevant feature quantities as: P_{G1}, P_{G2}, and U_{L2} ($J \geq 0.2$), and P_{G3} U_{L1}, U_{L3}, U_{G1} - U_{G3} is the irrelevant feature variable ($J \prec 0.02$).

Finally, the optimal and least square algorithm is used to identify the sensitivity parameter of (2), and then the formula for predicting the online limit transmission capacity of virtual straight line is obtained as follows:

$$Q_0 = 2.15 - 0.75\Delta P_{G1} - 0.38\Delta P_{G2} + 0.31\Delta U_{L2} \quad \textbf{(3)}$$

According to (3), comparing calculation results with the actual system settings, we can find that the calculation accuracy can reach 99.85%.

The simulation experiment is simple, but it can prove the feasibility of the method to calculate and monitor the transmission limit capacity of the power transmission section by selecting the relevant feature variable. This method is the core support for the wireless big data platform to realize the on-line monitoring system of power grid capacity. The method is easy to apply the wireless big data platform proposed in this article to the on-line monitoring system of power grid capacity through borrowing the wireless network system.

6 Summary

The application of big data technology in power system is still in the concept research stage, but it plays an important role in promoting the intelligent grid to be an information network for power grid, achieve comprehensive data sharing and panoramic state perception. In this paper, some problems are proposed, such as, the wireless network sensor system to solve real-time detection problems, the use of big data platform to solve the real-time capacity assessment problems or real-time monitoring problems of power quality that the traditional mechanism analysis is difficult to solve. These should be the the key issues need to be solved in the practical application of big data in power networks in the future.

In order to solve the key technical problems in the practical application of above big data, theoretically, the theoretical problems that need to be paid attention to and need to be solved are: (1) more theoretical research and algorithm research of more efficient feature selection; (2) distributed computing coordination mechanisms and algorithms, such as variable allocation, etc; (3) learn theory knowledge and algorithms deeply and systematically.

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