Research on Substation Comprehensive Information Automation System Based on Ubiquitous Power Internet of Things Technology

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Abstract. The rapid development of society has made the production and living requirements of electrical energy supply higher and higher. Large-scale data collection and analysis of people's lives and social production, and making corresponding judgments based on the results, are of great significance for optimizing power planning, saving energy and reducing emissions, facilitating residents' lives, and coordinating social production. State Grid Co., Ltd. proposes to build “three types of two networks”, in which the ubiquitous power Internet of Things shoulders the existing power grid and further communicates the tasks of the user side and the generation, transmission and distribution side. In terms of function, the ubiquitous power IoT can be basically divided into four structures: perception layer, network layer, node centre and dispatch layer. According to the role of each structure, the development and construction are targeted. The system coordinates the construction of the ubiquitous power Internet of Things based on the overall structure, so that things are connected and characters interact, and a shared energy interconnection ecosystem is built.

1. Introduction
With the steady progress of the ubiquitous power IoT construction, as a hub-type, platform-type and open-type power IoT, not only will the grid-related information be integrated, but also the multi-source information access and integration of user information and external information will be realized. The unified time base and precise time marking are important requirements for the efficient integration and application of the above information and the guarantee of data quality, which lays a solid foundation for the construction of the platform layer and the application layer and the data realization business. At the same time, the measurement, control and protection of the power system are not limited to on-site, but cross-regional wide-area measurement and wide-area protection. Various advanced applications supporting the smart grid require cross-section data of the entire grid as the application basis, which requires relevant the data collection time corresponding to the primary device is precisely synchronized [1].
In order to improve the operation and maintenance capabilities of the cloud platform, this article explores the construction of a cloud platform monitoring system for containerized platform components and containerized applications. Containers have the characteristics of no fixed IP address, large number, and short operating cycle. Traditional monitoring tools such as Zabbix and Naggio that use Agent or Agentless to collect data cannot meet the requirements. To this end, this article seeks other technical solutions. This article selects a cloud platform monitoring solution that conforms to the technical characteristics of containerized cloud platforms, is simple to deploy, and is an open source technology. It uses Prometheus as the collection service, Grafana as the monitoring display service, and the intelligent inspection platform as the alarm platform.

2. Architecture and function of ubiquitous power Internet of Things
The perception layer and the node centre that constitute the ubiquitous power Internet of Things can efficiently, real-time, and accurately achieve the effect of "interconnection of things" and "interpersonal connection", while the network layer effectively implements data-based monitoring and prediction through edge intelligence algorithms and technologies, To prevent in advance, avoid failures, and improve efficiency. The scheduling layer realizes remote control of various types of devices and different behaviours through a large number of practical applications. Figure 1 shows that the system has strong potential for modularization and system integration, and the scope of implementation can be as small as a single substation, factory or residential area, and as large as a district, urban area and other power consumption areas. Whether it is data integration, system promotion, or intelligent interconnection, convenient management, etc., it has a strong social and urban construction significance.

2.1. Overall architecture
The overall architecture of the integrated application system for the intelligent IoT of the substation is shown in Figure 2. The system adopts a layered and distributed structure design, which can be divided into a perception layer, a network layer, a platform layer and an application layer. The bottom-level subsystems at all levels adopt independent networking and independent calculation methods. Data...
transmission between the back-end system and the sensing-layer equipment is carried out through the wired power private network, 1.8G wireless private network and LoRa wireless network and other communication networks. The system has terminal ubiquitous Access, open platform sharing, cloud computing collaboration, data-driven business, application customization on demand, etc. The entire system uses a combination of central computing and edge computing to improve data processing efficiency and reduce system central server load. Each subsystem and sensing equipment complete the front-end processing of various types of data collection, calculation, analysis, etc., to achieve the edge-side processing of the data; the system back-end centre server completes the fusion, analysis, and processing of panoramic big data, and realizes the centre-side data analysis.

Figure 2. Schematic diagram of the substation intelligent IoT system structure

Different subsystems of the system must complete specific projects in accordance with the work requirements that have been formulated, especially for the platform layer. Only when all projects are running normally and stably can the system's operational safety be improved [2]. The security technology with the highest frequency of application and the best function is the key technology. Each network interface must be able to carry a randomly generated key, and the other end of the interface must generate a corresponding key database, where the amount of data is determined according to the system's analytical capabilities. The working mode of the data analysis system is to compare the similarities and differences between the key and each string in the database. Only when the corresponding relationship is found, the communication behaviour is allowed to occur.

2.2. Perception layer equipment

The system perception layer mainly includes industrial video cameras in substations, intelligent inspection robots, transformer vibration monitoring, transformer oil chromatography monitoring, wireless temperature and humidity sensors, flame detectors, fire pipe pressure sensors, and conventional auxiliary control system detection and sensing equipment. State-aware devices. Through the use of various types of sensors, cameras, controllers and other equipment, collect the main equipment status data at the front end of the substation, monitor the health status of the main equipment in the substation, and provide a basic data source for advanced applications of the substation intelligent IoT integrated application system.
2.3. Edge computing layer

The edge computing layer is a sensor, intelligent device, intelligent terminal and other devices of the distributed intelligent agent perception layer close to the end perception node at the edge of the network. At the edge computing layer, the sensed data is processed and analysed nearby. After the key data is extracted, it will be further uploaded to the cloud platform for centralized processing. Edge computing is generally performed by the intelligent IoT gateway configured in the ubiquitous power IoT, and has distributed computing capabilities. As a fusion of perceptual extension layer and edge computing layer, the intelligent terminal can also complete edge computing tasks.

Introducing the recursive least squares (RLS) algorithm in edge computing is a fast convergence algorithm. The recursive least squares (RLS) algorithm is based on the decision to directly process the received data to minimize the quadratic performance exponential function. The LMS algorithm is to minimize the expected value of the square error.

The prediction error $e(n)$ is expressed by the following formula

$$e(n) = x(n) - W^T(n-1)X(n) \quad (1)$$

You can change $U(n)$ in formula (1) to

$$W^T(i-1)X(i)X(i) = X(i)X^T(i)W(i-1) \quad (2)$$

Note that $W^T(i-1)X(i)X(i) = X(i)X^T(i)W(i-1)$ and Eq. (2), multiplying Eq. $R^{-1}(n)$ with $q$:

$$W(n) = R^{-1}(n)\sum_{i=1}^{n}X(i)X^T(i)W(i-1) + R^{-1}(n)\sum_{i=1}^{n}X^T(i)e(i) \quad (3)$$

In order to simplify the expression of the first term $W_i(n)$ and establish the relationship between $W(n)$ and $W(n-1)$, a reasonable idea is that the filter parameters at time $n-1$ and the time before it are the same, namely:

$$W(0) = W(1) = ... = W(n-1) \quad (4)$$

On the other hand, in order to simplify the expression of $W_{i}(n)$, a reasonable idea is: think that factor $z = 0$ is forgotten. This is equivalent to that only the results of this moment are memorized, and all the results of the previous moments are forgotten. Thus, there are the following simplified results:

$$W_{i}(n) = R^{-1}(n)\sum_{i=1}^{n}X^T(i)e(i) = R^{-1}(n)X^T(n)e(n) \quad (5)$$

Substituting equations (3) and (4) into (2), then

$$W(n) = W(n-1) + R^{-1}(n)X^T(n)e(n) \quad (6)$$

Equation (5) describes an adaptive filtering algorithm whose filter parameters are controlled by its input error $e(n)$, which is called recursive least squares (RLS).
2.4. Network transport layer
The network transmission layer is a data transmission channel between the sensing extension layer and the platform application layer, which can transmit the sensed information without barriers, high reliability, and high security. To achieve a wider range of interconnection functions. The network transmission layer is composed of a local communication network and a remote communication network. The local communication network uses local short-distance communication technology to realize flexible, high-efficiency, low-power local communication between massive sensing nodes and edge computing nodes. The long-distance communication network relies on wide area communication technologies such as mobile networks, satellite communications, and LTE power wireless private networks, and supports highly reliable, low-latency, and differentiated communications between edge computing nodes and ubiquitous IoT cloud platforms.

2.5. Platform application layer
The system application layer development is guided by the actual needs of operation and maintenance operations, and has the functions of one-time equipment intelligent inspection, comprehensive perception of equipment status, and intelligent linkage of equipment operation.

2.5.1. Intelligent inspection function. The system mainly conducts daily inspections of primary equipment such as circuit breakers, disconnectors, transformers, reactors, capacitors, etc. through video surveillance, inspection robots and other equipment, and daily operation and maintenance patrols such as meter reading, oil level monitoring, and identification of opening and closing positions work, and automatically analyse and process the inspection results and intelligent alarms. The system can automatically generate the operation and maintenance inspection report according to the professional requirements of the operation and maintenance of the substation, so that the operation and maintenance personnel can browse and judge remotely.

2.5.2. Comprehensive awareness of device status. The system uses the main transformer online monitoring sensors, video monitoring, temperature and humidity sensors and other equipment to realize the full-range self-real-time perception of the status of the transformer equipment, and initially judges whether the data is normal according to thresholds and other criteria. When the device data is abnormal, all the information of the device can be obtained in real time through the system to realize the longitudinal analysis of historical data, the horizontal comparison of each phase device and the same type of similar equipment, and the preliminary diagnosis of the device status, so as to realize the independent rapid perception and early warning of the device status. For abnormal equipment, timely push warning information to the operating personnel, adjust the status monitoring strategy, and upload to the platform layer for more accurate diagnosis and analysis [3].

2.5.3. Device operation linkage. The substation intelligent IoT integrated application system communicates with the substation station control layer SCADA system through the forward isolation device. The SCADA system uses UDP (User Datagram Protocol) messages to control the operation and alarm information of primary equipment such as remote control, remote signalling, and telemetry. Transmission to the Internet of Things system. When the device is operated once in the SCADA system, the IoT system server intelligently links the video camera to read the corresponding video picture after receiving the corresponding UDP message. When important information such as SF6 alarm and protection trip occurs in the primary equipment of the SCADA system, the IoT system automatically starts the corresponding inspection tasks to provide detailed inspection results for the operation and maintenance personnel.
3. Substation monitoring function under the background of ubiquitous power Internet of Things

This article combines the monitoring tool Prometheus, the visualization tool Grafana and the intelligent inspection platform as the unified monitoring system of the State Grid Cloud, which realizes the full coverage of the monitoring of the OpenStack and K8s platform clusters and meets the three-dimensional monitoring requirements [4].

3.1. Three-dimensional monitoring

In order to collect OpenStack platform host machine and cluster operation data, the research uses node-exporter agent to collect host machine's resource operation index, OpenStack-exporter agent collection platform operation index, ceph-exporter agent to collect back-end distributed storage operation index Collection of main operating indicators at both the host and the platform. The functions and deployment methods of several OpenStack instance monitoring agents are shown in Table 1.

Table 1. OpenStack instance monitoring agent

| Serial number | Agent name        | Effect                                                                 | Deployment method                        |
|---------------|-------------------|------------------------------------------------------------------------|------------------------------------------|
| 1             | node exports      | The host monitors the agent and obtains the running status of the host. | Deploy node-exporter agent on each host  |
|               |                   | CPU, memory, storage, and network resources enable                     |                                           |
| 2             | OpenStack-exporter| Use case                                                               | Run on the control node                  |
| 3             | ceph-exporter     | OpenStack platform monitoring agent to obtain platform service operation status, number | Run on the control node                  |
|               |                   | and resource allocation status                                         |                                           |

In order to collect K8s platform host machine, cluster and hosted IoT application container operation data, the research uses node-exporter to collect resource operation indicators of host machine, cAdvisor to collect all container operation indicators, kube-state-metrics to collect all Pod container operation status, kube-metrics collects platform and other information to realize the collection of main operating indicators at three levels of host, platform, and container applications. The functions and deployment methods of several K8s instance monitoring agents are shown in Table 2.

Table 2. K8s instance monitoring agent

| Serial number | Agent name   | Effect                                                                 | Deployment method                        |
|---------------|--------------|------------------------------------------------------------------------|------------------------------------------|
| 1             | node-exported| Host monitoring agent, you can get the running status of the host, cpu, | Deploy node-exporter agent on each host  |
|               |              | memory, storage, network resource usage                               |                                           |
| 2             | cAdvisor     | Container monitoring agent to get resource usage of docker container   | Each host is deployed with a cAdvisor, running as a daemon of k8s |
| 3             | kube-state   | K8s application monitoring agent, you can get the running status of    | Deployed as a k8s service and run in a k8s cluster |
|               |              | deployment, pod and other k8s resources                                 |                                           |
3.2. Operation analysis
In order to fully grasp the operation of the State Grid Cloud, this article based on the original indicators collected by the monitoring system, combined with the actual needs of the business, carried out operational analysis, designed the indicator analysis formula, mastered the OpenStack cloud platform resource allocation, K8s platform resource allocation, and application container operation. In this situation, the visual display tool Grafana can be used to visualize the operating indicators, which improves the convenience of platform operation analysis. Taking the operation analysis of the OpenStack platform as an example, the OpenStack platform mainly integrates hardware server resources to provide virtual machine computing resources to the outside world. Therefore, real-time information such as the number of created virtual machines, the allocated virtual machine CPU and the proportion of memory resources, etc. Resource allocation and resource expansion have important help significance.

3.3. Space-based time synchronization network management system
The space-based time synchronization network management system uses the network management method to remotely manage the parameters, status, logs and other information of satellite common-view time service devices and time synchronization devices in the network. The system can remotely configure the parameters of the managed equipment, and perform statistical analysis and processing on the summary information such as working conditions, functions, performance, and logs, and store the data [5].

The management system and the existing dispatching automation master station software adopt an integrated design, which runs as a function module of the master station software, and the communication protocol adopts a method conforming to the existing telecontrol communication protocol. The management system should have powerful statistical analysis functions to support horizontal comparison and vertical comparison. Statistical analysis and trend graph drawing can be performed on the local time, GPS time, Baidoo time and ground time of the device. Through the monitoring of the equipment status, the operation management personnel can find the problem and solve the problem in time, thereby improving the correctness and stability of the function of the equipment in the time synchronization network, and ensuring the normal operation of the equipment to the greatest extent.

4. Performance evaluation
Assuming that each sub-unit in the system reported 500 network security vulnerabilities at the same time, the audit efficiency of the certification centre or bookkeeper is 50 per day. According to the scheme of this article, when the number of vulnerabilities exceeds k1, a new vulnerability auditor needs to be added. Assuming k1 = 50 and a total of 3 system members including the accountant participated in the vulnerability audit. Through simulation calculations, the comparison of the distributed vulnerability processing scheme based on blockchain and the traditional centralized processing scheme in time overhead is shown in Figure 3.
As can be seen from Figure 3, under the premise of an audit efficiency of 50 per day, when the number of vulnerabilities is less than 100, the time overhead of the two schemes is basically the same. As the number of vulnerabilities increases, the time overhead of distributed processing based on blockchain is significantly lower than that of centralized processing. Therefore, in terms of audit efficiency, the scheme in this paper has more advantages [6].

5. Conclusion
Starting from the function and purpose of the ubiquitous power Internet of Things, the decomposition of the network can more effectively achieve the unified function of different hierarchical structures. The functions of the same hierarchical structure are independent, which can not only strengthen the reliability and stability of the network, but also improve Work efficiency. According to the process of data collection, data analysis, instruction issuance, and overall planning, the ubiquitous power Internet of Things can be divided into four parts: perception layer, network layer, node centre, and dispatch layer. According to the different main tasks undertaken by different structures, its technical key points and breakthroughs also have their own emphasis. Drawing on the existing construction of the Internet of Things and the Smart Grid, to better build the ubiquitous power Internet of Things will have tremendous social benefits for the construction of an energy interconnected ecosystem, energy saving and emission reduction, convenience for people's lives, and optimization of social production.

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