Research on Information Coding of Smart Substation Facing "Two Networks Convergence"

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Abstract. With the popularization and application of "Internet of Things" technologies such as equipment online monitoring and intelligent inspection in the field of substation operation and maintenance, the number of subsystems in smart substations has increased rapidly, and the types of information and the amount of information have shown explosive growth. However, due to disorder and irregular expression, the potential value of a large amount of information is difficult to be effectively used. This paper proposes a "system code-device code-information code" information coding technology that serves the operation and maintenance of information equipment to make information orderly and standardized. This technology lays the foundation for quickly and accurately finding the required information, fully mining and effectively using the value of information, strengthening information fusion between subsystems, and realizing digital management and control of substation equipment information.

1. Introduction

With the rapid development of technologies such as sensors, communications, and big data, "Internet of Things" technologies such as equipment online monitoring and intelligent inspection have been promoted and applied in the field of substation operation and maintenance [1]-[4]. The number of substations in the substation has nearly doubled in the past ten years. While providing operators with richer real-time monitoring methods and more objective data support, it also brings new challenges. First, the explosive growth of monitoring data has brought about the problem of massive data processing. A 500kV substation has more than 5000 information points, 220kV substations have more than 2500 information points, and 110kV substations have more than 1000 information points. And the number of information points will continue to increase in the next few years. The second is that the data formats of different subsystems are very different, and it is difficult to achieve cross-system data linkage, the information between different systems is relatively isolated, and the value of system information interaction is difficult to mine. How to achieve cross-system linkage and multi-dimensional analysis and display of massive data in multiple systems has become a new problem that needs to be solved urgently.
Information coding technology is one of the brand-new methods to solve the above-mentioned problems. Information coding refers to the formation of a consensus on the information definition mode of the various subsystems in the substation, and the establishment of a unified coding rule to order and regularize the original chaotic and disorderly multi-system information. Through information coding, it is possible to realize the efficient concatenation of data in different subsystems, and to fully explore the intrinsic value of information; to clarify the functional logical relationship between different types of systems, to establish a clear call relationship model; it could dig out the information gathering points between different systems to achieve fast and accurate query. There are already relevant equipment, material coding standards and information naming standards in the power grid, but there is little research on information coding. This paper studies and explores the information coding technology system for the integration of "Internet of Things" and "Smart Grid", analyzed the status quo of substation information architecture and the status quo and requirements of power grid information coding. It proposed object-oriented information coding rules based on "system code-device code-information code" to make information orderly and standardized. So that to lay a foundation for the computer system to quickly and accurately find the required information, fully excavate and effectively use the value of information, improve the degree of information fusion between different subsystems, and realize the digitization of substation equipment information. Finally, several typical application scenarios of information coding are listed to provide reference for the application of information fusion in substations.

2. Analysis of Information Architecture of Substation and Necessity of Information Coding

2.1. Information Architecture and Application Status of Intelligent Substation
The information structure of the smart substation is shown in Figure 1.1-1. The information in the station consists of primary and secondary main equipment information and auxiliary equipment information such as online monitoring and intelligent assistance. The main equipment information can be divided into protection information, monitoring four remote information, metering information, wave recording information, phasor measurement information, etc. Auxiliary equipment information includes equipment online monitoring information, environmental security and image monitoring information, equipment infrared temperature measurement information, fire-fighting HVAC equipment information, etc.

Figure 1  Information architecture diagram of smart substation
The main equipment information is mainly based on the principle of electrical measurement, and the information format is electrical analog or switch value. Auxiliary equipment information is mainly based on non-electrical measurement principles such as various sensors, and the information format...
mostly adopts 4-20mA conversion electrical quantity or video format. With the increasing demand for unattended remote operation and maintenance, the number of traditional electrical quantity signals and new non-electric quantity signals have increased significantly. However, due to the continuous changes in technology and the limited accumulation of operation and maintenance experience, the standardization and standardized management of information is relatively lagging, and the method of sending all the information without difference in engineering construction has led to a substantial increase in the number of cables in substations and information access. Insufficient number of input device interfaces, and significant increase in pressure on background information processing. In addition, due to the large number of subsystems, different information formats, and the lack of a link system for information fusion, the information between different subsystems cannot be effectively integrated, which increases the workload of operation and maintenance personnel and reduces work efficiency.

2.2. Existing coding standards and application status

The power grid industry has long borrowed a coding system that can be accurately identified and distinguished by computers to realize the physical and logical hierarchical identification of building, equipment and other material resources, and then apply various digital methods to plan, construct, and purchase the coded material resources, operation, maintenance and other automatic management throughout the life cycle. So far, the relevant coding standards of the power grid industry mainly include the "Code for Grid Engineering Identification System" (GB/T 51061—2014), "Uniform Numbering Guidelines for Parts of Power System Equipment" (SD 240—87), and "National Grid The company’s Material Master Data Classification and Coding Specification (Q/GDW 1936—2013) and the “Application Guidelines for Digital Design and Coding of Transmission and Transformation Projects" (Q/GDW 11600—2016), respectively, from equipment identification, scheduling requirements, and material procurement requirements. The coding standards for power grid engineering are defined in other aspects.

The "Code for Grid Engineering Marking System" mainly adopts the structural framework of KKS coding. According to a certain internal logical relationship, a coding and marking system suitable for various systems, equipment and components in power grid projects is developed, which can identify the name of the equipment, installation location and installation location information, and stipulates the coding depth standard in different processes of project construction. Its advantages are large and comprehensive, and it has a certain application foundation in power plants. Its identification system covers all majors in substation and line engineering, including electrical, general drawing, construction, hydraulics, HVAC, communication, etc., and runs through the project. The whole life cycle of the construction has strong practicability.

The "Uniform Numbering Guidelines for Some Equipment in Power System" was compiled by the dispatching department. It is a dispatch naming rule designed to strengthen the management of power system dispatch and operation, mainly for the electrical main equipment that needs to be dispatched and controlled in 500kV transmission and transformation projects. Its main characteristics are that the application object is highly targeted, the coverage is limited, the naming adopts "power system dispatching predicates", the equipment identification is concise and clear, and the semantics is readable.

"State Grid Corporation Material Master Data Classification and Coding Specification" is a material coding system specially formulated by State Grid Corporation for the unified electronic bidding of equipment and materials. It adopts a three-layer and seven-digit structure to classify equipment into large, medium, and small categories. Class codes, each class uses different numbers or letters for identification, covering all equipment, installation materials and accessories that need to be tendered for electronic materials in substations and line projects. In terms of equipment name identification, the difference between it and the KKS coding system is that the KKS coding is intended for practical application, and each actual device needs to be given a certain and uniquely identifiable code, while the material code does not need to distinguish two identical. It is necessary to distinguish...
between different types of equipment and equipment with different characteristics in the same category. Therefore, the "small-type identification" in the code identification is used to identify the characteristic value of the equipment.

The "Guidelines for the Application of Digital Design Coding for Transmission and Transformation Engineering" unify the above three types of specifications from the perspective of application. It does not develop coding standards itself, but separates the dispatch coding system and the material coding system from the equipment standard coding. The KKS system corresponds to one to one, which promotes the unified standardization of different codes in the application.

2.3. Information coding necessity
Through the analysis of the current situation of intelligent station information architecture and power grid-related coding specifications, it can be seen that effective coding is an effective way to achieve orderly management of disordered information. The existing coding system is mainly aimed at the equipment in the power grid engineering or the building itself. The information transmitted between them lacks corresponding coding standards, which is not conducive to the intelligent processing of information, and it is not conducive to the multi-dimensional supplement and fusion application of monitoring data of multiple subsystems of the same monitoring object. It is necessary to effectively expand the original equipment coding system. In order to meet the needs of the development of engineering construction.

3. Information coding rules and ideas

3.1. demand analysis

3.1.1. Information coding object
Information coding is based on the classification of information, using a combination of agreed letters or numbers to represent different types and characteristics of information. The amount of information of different types of equipment and different types of systems in the substation is very large. It is very difficult to encode all the information, and the internal interaction information between many equipment has no effect on external systems and operation and maintenance personnel, and there is no coding. Therefore, the information coding described in this article is mainly for the information that the regulation or operation and maintenance personnel need to monitor, as well as the information that needs to interact between different systems, including the monitoring information in the station, phasor measurement, wave recording, electric energy measurement, Information about equipment online monitoring, image monitoring, environmental monitoring, and process related equipment monitoring.

3.1.2. Functional Requirements
(1) Unique identification of information
   The unique identification of a certain piece of information or a certain type of information, through this code, can realize the rapid identification and processing function of the computer, and can agree on a common and dedicated meaning to it to avoid semantic conflicts.

   (2) As a communication link between different participants in substation construction
   The design, construction, operation and maintenance of substations belong to different personnel, and the information sources are not symmetrical with each other, resulting in constant program changes in the construction of substations. Equipment information coding reflects the characteristics of equipment products to a large extent, and directly serves as the support basis for later equipment operation and maintenance. Therefore, the information coding of the equipment can become an effective communication link for different participants in the construction of the project, aiming at the realization of the terminal demand, and then feeding it back to the design source, so that the system
and equipment can meet the terminal operation and maintenance needs from the beginning of production and reduce repeated changes, improve the overall efficiency of project construction.

(3) As a medium for the linkage and call of information of different subsystems in the station

The information sources in the substation belong to different systems. In order to realize the multi-dimensional monitoring and information mutual calibration of the same equipment object, different sub-systems need to call each other data and system linkage, and the information code with uniquely definite and clear classification identification is the best effective method.

3.2. Coding scheme

3.2.1. Information coding overall format framework

According to the analysis of the objects and functional requirements of the information coding, the information coding mainly involves all the electrical equipment in the substation and the information of the main hydraulic HVAC equipment. Therefore, the information coding can be defined in the following format:

**System code-device code-information code**

(1) System code

The system code indicates the system type to which the equipment object belongs, and is identified by a letter. According to the information content in the substation, the following three system types can be set:

| System code | System type          | Number of digits | Serial number | Character code | System type          |
|-------------|----------------------|------------------|---------------|----------------|----------------------|
| 1           | A                    | 1                | 1             | A              | Electrical System    |
| 2           | B                    | 2                | 2             | B              | Water supply and drainage system |
| 3           | C                    | 3                | 3             | C              | HVAC system          |

(2) Device code

For different systems, the format of the device code is different. For electrical systems, equipment is generally divided and managed according to electrical intervals. Therefore, the electrical system can be defined in the format of "interval type - equipment type". The equipment type includes both primary and secondary equipment. The specific definition is as follows:

| Electrical system equipment code | Number of digits | Voltage level | Interval type | Interval serial number | Delimiter |
|---------------------------------|------------------|---------------|---------------|------------------------|-----------|
|                                 | 1                | A            | line          | 01                     |           |
|                                 | 2                | B            | breaker       | 02                     |           |
|                                 | 3                | C            | Busbar        | ...                    |           |
|                                 | 4                | D            | transformer   | 11                     |           |
|                                 | 5                | E            | Reactor       | 12                     |           |
|                                 | 6                | F            | Capacitor     | 13                     |           |
| Number of digits | 6  | 7 | 8 | 9  | 10 | 11 | 12 | 13  | 14 |
|------------------|----|---|---|----|----|----|----|-----|----|
| Serial number    |    |   |   |    |    |    |    |     |    |
| 1                | X  | breaker |     |     |    |    |    |     |    |
| 2                | G  | Isolation switch |     |     |    |    |    |     |    |
| 3                | GD | Earthing switch |     |     |    |    |    |     |    |
| 4                | CT | Current Transformer | default | no |    |    |    |     |    |
| 5                | PT | Voltage transformer |    |    |    |    |    |     |    |
| 6                | BLQ | lightning arrester |    |    |    |    |    |     |    |
| 7                | LB | Line protection |    |    |    |    |    |     |    |
| 8                | CK | measurement and control |    |    |    |    |    |     |    |
| 9                |    |    |    |    |    |    |    |     |    |

The water supply and drainage system equipment in the substation mainly includes three types of equipment for water supply, drainage and fire protection, which can be defined in the format of "function type. equipment type", as follows:

Table 3 Equipment code identification of water supply and drainage system

| Number of digits | 1 | 2 | 3  | 4 | 5 | 6  | 7 |
|------------------|---|---|----|---|---|----|---|
| Serial number    |   |   |    |   |   |    |   |
| Function type    |   |   |    |   |   |    |   |
| Delimiter        |   |   |    |   |   |    |   |
| Equipment type   |   |   |    |   |   |    |   |
| Equipment serial |   |   |    |   |   |    |   |
The HVAC system equipment in the substation mainly includes two types of equipment, ventilation and air-conditioning, which are defined directly according to the type of equipment, as follows:

| HVAC equipment code | Number of digits | Equipment type | Equipment serial number |
|---------------------|-----------------|----------------|------------------------|
| G Water supply      | 1               | SJB Deep well pump | 01 Device 1            |
| P drain             | 2               | SSX Life water tank | 02 Device 2            |
| X Fire fighting     | 3               | QSB Submersible pump | 03 Device 3            |
| JSB Sump            | 4               |                |                        |
| XFB Fire Pump       | 5               |                |                        |
| WYB Regulators      | 6               |                |                        |
| XSX Fire water tank | 7               |                |                        |
|                     | 8               |                |                        |

The function of the information code is to provide an index to quickly and effectively locate the specified information. Therefore, the basic format of the information code can be defined as "classification code + identification code". The classification code is to classify the information type. The information types in the substation include telemetry, phasor measurement, broadband, wave recording, and other information. The identification code can be expressed in specific characters according to different information types, or it can be directly used as a serial number. Means that for some important remote signals, such as the total signal of interval accidents, a fixed serial number can be assigned for easy reference. In addition, for some application functions, it is not enough to find the information alone. It is necessary to be able to describe the typical characteristics of the information through coding, and because the characteristics of different types of information are different, the purpose of the application is also different. It cannot be expressed by a unified code. At this time, it can be realized by the information feature code that can be expanded independently, and the information feature code is uniformly added with the "()" mark to show the difference. The details are shown in the following table:

| Information code | Number of digits | Information System Code | Delimiter | Information code or serial number | Information feature code |
|------------------|------------------|-------------------------|-----------|----------------------------------|--------------------------|
| A telemetry      | 1                | A                       | .         | la A phase current effective value | Suitable for current     |
| B Phasor measurement | 2 | B                       | .         | lb B phase current effective value |                          |
| C Broadband      | 3                | C                       | .         | lc Effective value of            |                          |
Take remote messaging information as an example, to define and explain the information feature code. Remote signal can be divided into position signal, hard contact signal and soft message signal. In order to regulate and control applications, signals are generally divided into four types: displacement, notification, abnormality, and accident. While individual signals also need to be inverted in the background, the key signals need to be specially monitored by the glazing plate, some signals also need to participate in the execution of specific functions such as AVC. In view of the above characteristics, the characteristic codes of the remote signaling hard contact signal can be defined as follows:

| Number of digits | Serial number | Signal level | Whether to reverse | Whether AVC block signal | Whether to glaze the nameplate |
|------------------|---------------|--------------|--------------------|--------------------------|-------------------------------|
| 1                | 1 Variable Bit | F1 Yes       | B1 Yes             | G1 Yes                   |                               |

Table 6 Schematic of the feature code of hard contact remote signaling information
4. Typical application of information coding

4.1. Multi-system data linkage standardized modular application

At present, substation operation and maintenance personnel can monitor equipment objects from multiple angles and dimensions through a variety of systems, and the realization of multi-system data fusion analysis and image linkage display are important requirements for further improving the level of operation and maintenance. The existing system linkage design scheme has many problems, such as opacity of information between subsystems, point-to-point docking of different manufacturers to realize linkage function, difficulty in standardization of program development, and easy to miss and incomplete linkage information. Information coding enables the signal of the device to have a unique and clear identification, which can effectively solve the aforementioned problems and provide a new solution for the display and analysis of data linkage between multiple systems.

Take the image linkage of circuit breaker tripping as an example. In some projects, when a circuit breaker in a certain interval performs remote opening and closing operations or a fault trip, the corresponding equipment images can be linked to the control operation and maintenance personnel for analysis and confirmation. In order to realize the trip image linkage, the image system developer needs to request all the action requirements that need to be linked from the monitoring manufacturer, and correspond to the camera points in its own system one-to-one. Due to the random order of various information, the monitoring manufacturer must manually find out the important points from the thousands of points in the monitoring point table and submit them to the image manufacturer. If the equipment information is uniquely coded based on uniform rules, both manufacturers can quickly and efficiently find out information such as equipment remote control, displacement, protection actions, equipment critical alarms, etc., without the need for point-to-point docking. In addition, by adopting similar information coding logic in different projects, the reusability of the program is significantly improved.

4.2. Application of multiple system data mutual correction bad data elimination mechanism

With the rapid increase in the amount of information, the probability of errors in the monitoring system itself and the appearance of bad data has also increased rapidly. When a device object monitored by a system has abnormal data, it is necessary to determine whether the device is really abnormal or a false alarm caused by bad data. Data mutual correction between systems based on information coding is an effective means to identify bad data. When there is a data abnormality, based on the device code in the information code, send a letter to other systems for verification. If multiple systems report the same abnormality simultaneously, it can be judged that the monitored object has a problem; if there is only a single If the data of the system is abnormal, there may be a problem with the system itself. Information coding helps to form a "correct answer" mutual correction mechanism between different systems, which can significantly reduce the false alarm rate of information and improve the quality of information.

4.3. Point table automatic matching mechanism based on automatic coding

The information point table is the main basis for the control and operation and maintenance departments to grasp the on-site operation of the current substation, and the explosive growth of information in the substation has caused great difficulties in the compilation of the information point table. At present, the workload of manual design and review in the point table is very large. Taking the remote signaling point table as an example, it is necessary to confirm the naming norms of each signal one by one, determine the alarm level of each signal, whether it needs to be reversed, and whether it is glazing. Plaques and so on. As the amount of semaphore increases, the time-consuming and error rate
of the point table will continue to increase. If the information can be encoded and the aforementioned information can be reflected by the feature code, the point table can be automatically, quickly and accurately identified and compiled by the computer system.

5. Conclusion

Information coding is the basis for realizing the digital management and control of equipment information, and an effective way to speed up and deepen intelligent operation and maintenance. This paper discusses the information coding design of smart substations from the perspective of standardizing the information planning of smart substations, eliminating the information barriers of different project participants, and reducing the communication costs between different equipment developers. The main results and conclusions are as follows:

(1) A "system code-equipment code-information code" information coding technology for the operation and maintenance of information equipment is proposed.

(2) Establishing a unified information coding rule helps to improve the standardized management level of substation information, improve the identifiability of information in computer systems, and avoid semantic conflicts in information from multiple systems. Information coding can be used in many aspects such as the development of advanced application functions of various intelligent substations, and the digital management of substations, and has a wide range of application prospects.

(3) Information coding should be implemented from the equipment production and engineering design stages, and run through the entire life cycle of the equipment.

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