Philosophy and Practice of Classification and Hierarchization of Power Distribution Network Planning and Design Standard System

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Abstract. The integration of distributed power sources and other new-type equipment to power distribution network places higher requirements on the planning of power distribution network. Due to lack of scientific and reasonable classification and hierarchization methods, overlap or even contradiction among China's existing power distribution network planning and design standards is becoming increasingly severe. Based on the principles of standard classification and the existing standard system, a classification and hierarchization method suitable for the power distribution network planning and design standard system is proposed in this paper. The power distribution net-work planning and design standards are classified into five classes. And then, after analysing the content attributes of standards at each level and the relation of inclusion among standards at different levels, two hierarchization methods including Content Evaluation Method and Comparative Analysis Method are proposed to determine the level of a standard. Finally, this paper illustrated the effectiveness of the two methods by examples. These research results provided theoretical guidance and reference for the effective management and efficient application of standards and the establishment of a modern power distribution network planning and design standards system.

Keywords: Distribution network, Planning and Design Standard System, Classification and Hierarchization, management and application of standards.

1. Introduction

The power distribution network standard system is the fundamental basis for planning, design and construction of power distribution network, and is of great importance in the standardization of and guidance for construction of scientific, reasonable, flexible and open modern power distribution net-work [1]. With the increase of standards, the problem of overlap or even contradiction among them is becoming more and more serious. In addition, the energy storage elements, electric vehicles, micro-grids, and etc. have been connected to power distribution network, which brings new challenges to

existing power distribution net-work planning and design standards [2-3]. It is necessary to design and establish a modern power distribution net-work planning and design standard system, further pro-mote standardization work.

Classification and hierarchization are important means for effective management and application of standards. Some research findings on standard classification and hierarchization have been obtained. Reference [4] introduces classification of foreign standards, where, standards are classified into international standards, technical specifications, public specifications, technical reports, and industrial technical reports by development process, maturity, and market demand. In China's standardization work, standards can be classified into national standards, industrial standards, local standards and company standards by the development organization; technical standards, management standards and work standards by the property of standardization objects; compulsory standards and voluntary standards by the binding effect of standards; or standard documents and standard samples by the carrier of standard information [5]. Reference [6] proposes a new philosophy for classification of standards, that is, to classify standards into public ones and private ones by the purpose of developing standards. References [7] and [8] list the main contents of the energy internet standard system, and put forward suggestions on energy internet standardization, providing reference and basis for standardization of power distribution network planning and design.

All the references above made study on standard classification and hierarchization and on standardized system architecture. But still there has been no scientific and reasonable classification and hierarchization method specially for power distribution network planning and design standards for a long time, causing an incomplete standard frame-work and hindering the construction of a standardized system. To this end, this paper aims to provide a scientific and reasonable classification and hierarchization method for power distribution network planning and design standards, and establish a power distribution network planning and design standard system architecture based on this method.

2. Classification of Planning and Design Stand-Ards for Power Distribution Network

2.1. Classification Methods

Based on the principles of systematicness, logicality and openness, this paper proposes three methods for the classification of distribution network planning and design standards, namely, classification by business process, classification by discipline and classification by equipment management.

1). Classification by business process: Classify standards based on their applicable business stages. The distribution network planning and design involve coordination among multiple businesses, including grid status analysis, load forecast, project scheme determination, grid index calculation and investment size estimation. Management of standards by business process is beneficial to division of responsibilities and process management. However, this method may result in uneven distribution of standards, and cannot effectively classify standards across multiple businesses, making the standards system irregular.

2). Classification by discipline: Classify standards based on their applicable disciplines. The distribution network planning involves multiple disciplines such as planning, design and civil. This method is simple in classification, clear in logic and significant in effect. Each standard corresponds to an applicable discipline, and therefore, can be quickly classified. The quantity of standards covered by each discipline is equivalent and the macro system structure is stable. In addition, with high flexibility and extensibility, this classification method is adaptable to transformation and upgrading of power distribution network in the future. However, it does not reflect the procedures and progress; therefore, it is not particularly convenient for process control and business management.

3). Classification by equipment management: Classify standards based on their applicable power equipment. The distribution network planning mainly involves power equipment such as transmission lines, transformers and power supplies. The advantage of this method is that the standards are classified by equipment, which eases the management of standards. However, with this method, many standards

are difficult to classify or even cannot be classified; it is out-dated and rarely used; the classification is too detailed and lacks macro and systematic understanding of the entire standards system.

2.2. Classification of Planning and Design Standards for Power Distribution Network

This paper adopts the classification by discipline as stated in 2.1. Depending on the applicable discipline, the distribution network planning and de-sign standards are classified into distribution net-work planning standards, power source and load connection standards, engineering design and re-view standards, equipment selection standards, comprehensive standards, and data model and analysis & calculation standards.

The distribution network planning standards mainly specify the basic principles, layout of electric power facilities, evaluation and assessment for the preliminary planning of the power distribution network. Therefore, they can be further divided into three categories: basic technical principles, layout of electric power facilities, and evaluation and assessment.

The basic technical principles mainly specify the pro-grammatic principles for the preliminary planning of power distribution network. They cover the development principles of planning, principles for planning of urban power network, and principles for planning of rural power net-work.

The layout of electric power facilities involves the sites and corridors required for distribution net-work planning. They can promote the effective connection between the distribution network planning and the local government's urban and rural planning and land use planning.

The evaluation and assessment standards aim to objectively and comprehensively evaluate the performance and power supply capacity of the power distribution network. They specify the evaluation index system, evaluation method and evaluation process for the power distribution network.

The power source and load connection standards mainly cover all requirements for connecting power generation and consumption equipment of the distribution network to the system.

The load connection standards specify the technical requirements and access/exit conditions for connection of general users and special users (electric vehicle, energy storage system and micro-grid) to the power distribution network.

The power source connection standards specify the technical requirements and design guide for the connection of PV, wind turbine and other new energies to the power grid. The power source and load connection standards can be subdivided into standards for distributed sources, electric vehicles, PV stations, wind farms, energy storage systems and etc.

The distribution network design standards make provisions on the design of several disciplines such as lines, substations, and civil. The comprehensive design standards cover the general provisions and overall requirements for each discipline. The substation design standards mainly cover the design standards for primary substation, secondary substation, and distribution automation. The line design standards mainly make provisions on the de-sign of overhead lines and cable lines. The civil design standards cover the design of firefighting, water supply and drainage, and buildings. In addition, the equipment selection standards cover the technical standards and technical specifications for the selection of power equipment during the design stage, mainly including the standards for substation equipment, line equipment, secondary equipment and equipment evaluation.

In addition, there are some standards applicable to distribution network planning, power source and load connection, and design. These standards can be divided into comprehensive standards and standards for data and calculation. The former mainly includes the construction land standards and safety standards for the planning and design of distribution network, and the technical principles to be followed during construction and modification. The latter mainly covers the requirements for data model application, data management, and data integration as well as the calculation methods and contents of power flow, short-circuit current, reliability, and reactive power optimization analysis during the planning and design of power distribution network.

The resulting structure of distribution network planning and design standards system is shown in Figure 1.

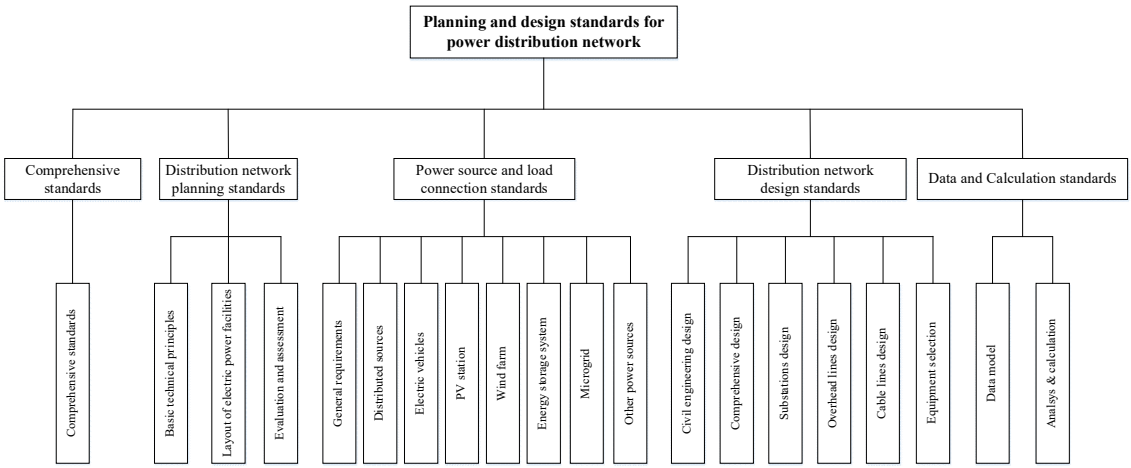

Figure 1. Structure of distribution network planning and design standards system.

3. Hierarchization of Power Distribution Network Planning and Design Standards

3.1. Hierarchy of Standards

China's standards features a three-level hierarchical structure, as shown in Figure 2. The three levels, from top down, are national, industrial standards, and company standards.

National standards have great importance for the national economic and technological development and therefore have to be developed at the national level. They are applicable to all industries and regions across the country. Industrial standards are a set a criteria within an industry. Company standards refer to product standards developed by a company and standards that specify uniform technical, management and work requirements that should be followed within a company. Company standards are usually mandatory within the company.

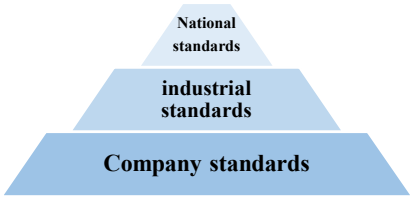

Figure 2. Relation of inclusion among standards in terms of their scope of application.

In addition, there are association standards, which are established by associations or organizations of the electric power industry according to their standards development procedure, and are issued for use on a voluntary basis. In terms of their development organizations, the level of as-sociation standards is between industrial standards and company standards [9].

3.2. Methods for Determining the Level of Standards

When determining the level of a standard, it is usually necessary to consider the content of the standard, its development organization, the promotion and implementation of it, etc. Given below are some methods that may be used to determine the level of a standard.

1). Content Evaluation Method: In this method, the level of a standard is determined based on the content of the standard or the technical approach described by it. This paper proposes three aspects may be taken into account, including applicability, technical advancement, and importance. Generally, the content of national standards has the highest applicability, followed by the industrial standards and the association, company standards. National standards usually specify methods and technologies from a macro perspective, while company standards often deal with specific issues and detailed technical specifications. From the perspective of importance, the content of national standards is the most

important, and it specifies the fundamental and core requirements that need to be unified across the country. The content of company standards is relatively less important, and it specifies the technical and management requirements that need to be followed within the company. The importance of industrial standards lies between the national standards and the company standards. In terms of the technical advancement, company standards come first, followed by the industrial standards and the national standards. This is because companies are usually pioneers in innovation for the purpose of gaining market share. When this method is used to determine the level of a standard, these three aspects may be considered, as shown in Table 1.

Table 1. Content evaluation methods.

Aspects	National Standard	Industrial Standard	Association &Company Standard
Applicability	Cross-industry	Intra-industry	Company
Importance	Most important	Very important	Important
Technical advancement	Low	Medium	High

When determining the level of a standard from these three aspects, if the content of the standard ranks high in two or more aspects, then its level can be easily deter-mined. However, if a standard does not rank high or low in any aspect or ranks high in one aspect but low in another, then its level may be determined by sequencing these aspects in the order of applicability, importance and technical advancement.

2). Comparative Analysis Method:In this method, the level of a standard is deter-mined by comparing its content with the content of other standards of the same class based on the principles that the content of industrial, association and company standards usually has to be developed within the framework of national standards.

National standards specify the basic requirements, and industrial, association, and company standards make more specific and detailed description of these basic requirements. In another word, national standards are basic, common standards, while industrial, association and company standards are more professional and specific. Therefore, in terms of content comparison and reference, it can be approximated that the applicable scope of national standards covers that of the industrial standards, and the applicable scope of industrial standards covers that of the association & company standards, as shown in Figure 3.

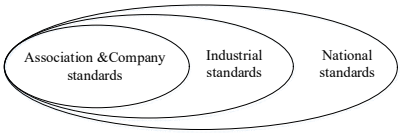

Figure 3. Hierarchy of China's standards.

The specific procedure for using the Comparative Analysis Method is as follows: (a) Classify the standard according to the framework of standards system based on its content; (b) Compare the standard's content with other standards of the same class. If the standard is a complement and supplement to an existing standard, then it shall be at the same level as the latter. If the standard references an existing standard (i.e. it is based on the latter), the standard shall be one level lower than the referenced standard.

It can be seen from the above that the Comparative Analysis Method may be adopted when the level of a standard cannot be accurately determined using the Content Evaluation Method. The Comparative Analysis Method can be used as a supplement and complement to the Content Evaluation Method. Also, the Comparative Analysis Method offers a method to quickly determine the level of a standard. Instead of understanding and evaluating all the content of a standard, it is only necessary to classify it and then make a comparative analysis.

3.3. Hierarchization of Power Distribution Network Planning and Design Standards

In hierarchization of the planning and design standards for power distribution network, the two methods described in 3.2 are usually combined and used together. Firstly, classify the standard according to

proper classification methods, and then make a quick determination of the standard's level using the Comparative Analysis Method. Secondly, the standard may be hierarchized using the Content Evaluation Method following the priority sequence of applicability, importance and technical advancement. Alternatively, evaluate whether a standard is only for internal use by a few companies for the purpose of collaborative innovation and whether its content is very flexible and does not involve any trade secret of these companies. If yes, the standard may be recommended to be developed into an association standard. Finally, the standard's level could be recommended as the company standard and would be upgraded gradually in the future if the standard's level is difficult to be determined. Figure 4 shows a flow chart of the hierarchization of power distribution network planning and design standards.

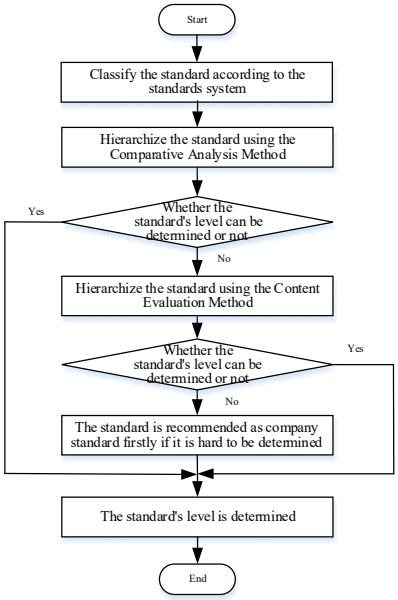

Figure 4. Flow chart of standards hierarchization.

4. Examples of Classification and Hierarchization of Power Distribution Network Planning and Design Standards

This section illustrates the classification and hierarchization of power distribution network planning and design standards using the methods proposed in section 2 and section 3.

4.1. Examples of Classification

In order to specify the principles, methods and pro-cesses for evaluating the technical and economic intended effects of the design scheme for connecting electric vehicle charging/discharging infrastructure to the power distribution network, and guide the evaluation of the design scheme, the Techno-economic Evaluation Guidelines of electric vehicles charging equipment interconnected to distribution network is proposed.

The Guidelines mainly address the issues of power source and load connection. So, according to the content of the Guidelines and the structure of the power distribution network planning and design standards system shown in Figure 1, this standard may be classified as a power source and load connection standard. More specifically, it mainly deals with the electric vehicles which are new power generation and consumption equipment, and there-fore the Guidelines is classified into electric vehicle standards under the power source and load connection class.

4.2. Examples of Hierarchization

As for the hierarchization of the Guidelines, it is classified as an electric vehicle standard under the power source and load connection class.

The Guidelines specify the techno-economic evaluation of the design scheme for connecting electric vehicle charging/battery swap equipment to power distribution network. Another standard of the electric vehicles class, the technology guide for EV charging equipment inter-connected to power grid, mainly establishes the technical specifications for connection of charging/battery swap infrastructure to power grid, and it is a company standard [10]. Technical specifications are the basis for techno-economic evaluation which usually requires reference to and quotation of the technical specifications. So according to the Comparative Analysis Method, the proposed Guide-lines may be determined as a company standard.

5. Conclusion

This paper makes a comprehensive and multi-dimensional comparative analysis of the standards classification and hierarchization methods used at home and abroad, and proposes suitable classification and hierarchization methods for the power distribution network planning and design standards. First, this paper compares three common methods for classifying power distribution network planning and design standards, and proposes the method of classification by discipline. With this method, the power distribution network planning and design standards are classified into five classes which constitute the structure of the power distribution network planning and design standards system. Then, according to the existing standards hierarchization methods used in China, two hierarchization methods including Content Evaluation Method, and Comparative Analysis Method are proposed after analysing the content attributes of standards at each level and the relation of inclusion among standards at different levels. These two methods may be combined and used together for determining the level of a standard. Finally, this paper illustrates the effectiveness of the two methods by examples. These research results provide theoretical guidance and reference for the effective management and efficient application of standards and the establishment of a modern power distribution network planning and design standards system.

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