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Application Method of CPS (CPS) in Demand Side of New Power System

Genxin XIONG[1], Siyuan CHENG, Wenjuan SHI, Yun LI, Jing MA, Tongle WANG
Beijing China-Power Information Technology Co.,LTD. China

Abstract. The new power system optimizes the energy structure and energy flow mode of the existing power system. On the power demand side, it is manifested by the increase of power generation equipment such as distributed power generation and virtual power plants and the increase of power trading business. This change has a wide impact on the management mode of the power system demand side. By reviewing the development trend of demand side and the concept and model of CPS(CPS), this paper points out the great advantages of CPS(CPS) in solving the complex problems of power system demand side, mainly the interaction problems of equipment, people and cyber system of complex business system composed of multiple equipment, and puts forward the application scheme and basic idea of future CPS in power system demand side management.

Keywords. New power system, CPS

1. Introduction

With the gradual development of society, the problem of energy shortage and global warming has increasingly become the focus of governments, environmental organizations and the public [1-2]. For example, in China, according to the government's plan, it is necessary to achieve the "carbon peak" by2030, that is, the carbon dioxide emissions will not increase and reach the peak. In2060, China would achieve "carbon neutrality", that is, the balance between the carbon dioxide emitted and the carbon dioxide absorbed by the earth, which will help reduce the global carbon dioxide content [3]. These changes would be accompanied by a series of energy reforms and technological updates. This means that new energy and supporting projects for renewable energy would become an important development direction of the energy industry.

Electric energy plays a special role in energy. At present, both fossil energy and renewable energy need to be converted into electricity, carried by electric energy, then transmitted to users, and then converted into various forms of energy for users to utilize [4]. Therefore, in promoting the transformation of the energy industry, electricity is crucial. Building a future-oriented and renewable-energy-oriented intelligent new power system is the focus of the future development of the power industry.

The power demand side refers to the consumer side in the power system, which mainly refers to the power supply to various consumers, including ordinary residential users, commercial users, factories and other power enterprises [5-6]. These consumers are also gradually interested in new distributed energy and virtual power plants [7-8].

[1]Corresponding author: Siyuan Cheng, Beijing China-Power Information Technology Co., LTD;
E-mail: phchengsiyuan@163.com.

This has led to changes in the original single power flow, that is, from the production end to the consumer end. The flow of energy has become diversified, and the trading methods have also become diversified—— These have brought new challenges to equipment interaction, human-computer interaction and system interaction on the demand side of the power system.

The demand side of the power system is a complex system composed of a series of equipment represented by electricity meters, power terminals, transformers, etc., which is distributed in all cities, villages and industrial areas. These devices come from different suppliers, belong to different asset owners, and adapt to different protocols. At the same time, these devices also undertake different business tasks, such as cost calculation, control, operation monitoring, etc. These business tasks increase the difficulty of cyber system design.

In the new power system, the increase of distributed power generation on the power demand side has brought more complex equipment, equipment combination and new business [9-10]. For example, customers with distributed power supply would pay more attention to their household electricity consumption, and new generation methods such as virtual power plants will bring new retail electricity business. More complex equipment has more suppliers, different protocols, different standards and faster update speed.

Generally, the demand-side system is designed with the general software design method and business-oriented. However, in this way, the standards of power equipment are not uniform and it is difficult to manage them uniformly. Often, one equipment needs to develop a system for management. The unity and flexibility of the power side are greatly constrained, resulting in high development costs and operating costs. The root cause of this problem is the lack of a unified model and system that can realize the unified description and management of various equipment on the power side.

Cyber Physical System (CPS) is a system that puts cyber system and physical system together to observe and integration. It is a theory based on these problems at present [11-13]. The CPS generally divides the system with equipment management and business realization into physical layer and cyber layer. The physical layer is a system composed of physical entities such as people and devices that exist in the real world and their interactions [14]. The cyber layer refers to providing efficient business realization support through cyber interaction between software and software. There is an obvious barrier between the cyber layer and the physical layer. That is, entities in the physical layer need to abstract the form, attribute, function and interaction of devices in the complex physical world into businesses and functions that can be realized by software in the cyber layer. There will be "abstract leakage", which is an unavoidable problem in software engineering. In the interaction of tens of millions to hundreds of millions of devices and users, this "abstract disclosure" often brings about more and more complex systems with business changes and cyber increases, and the increase of operation and maintenance costs with equipment upgrading and protocol changes.

This paper proposes a scheme to realize the equipment and human-computer interaction management of the new power system demand side based on the CPS. Starting from the physical entities, the efficiency of equipment management on the power demand side is improved through the analysis of hierarchical relationship and the design of business activities based on physical entities.

2. Understanding and analysis of cyber physics system

One of the biggest obstacles in the development of cyber physics systems is the lack of clear and unified concepts and specific construction plans [15]. Therefore, although the CPS has been given a lot of attention in many countries, such as China, the United States and Europe, these countries take the CPS as a new direction of the next generation of industry, there are still few places where the CPS is really applied. CPS refers to a system that connects physical devices in the real world with computer software by using embedded devices and communication chips to achieve real-time network transmission, control, and other functions. CPS first includes the meanings of cyber and physics, and then can be subdivided into four concepts: physical entity, cyber entity, physical layer, and cyber layer. In the research of related fields, these concepts have the same meaning in different terms. Not only the CPS, but also the digital twins, the Internet of Things and other related research area related to the interaction between network and physical systems have expressed similar concepts.

Physical entities are the general name of the objects which are the thing that could be observed in the real world. For example, when building an electric power billing system, the devices that perform the functions in the system are electricity meters, acquisition terminals, etc. Therefore, the meters and acquisition terminals running in the field are called "physical entities".

Physical layer refers to a collection of physical entities which people focus on. For example, when constituting an electricity billing system, the electricity meters, terminals and their relationships in a distribution network can be collectively referred to as a physical layer.

"Virtual layer" or "Cyber layer" is the mapping of this physical layer in the cyber system. By building relationships, the devices in physical layer and the system formed by relationships are copied into the computer.

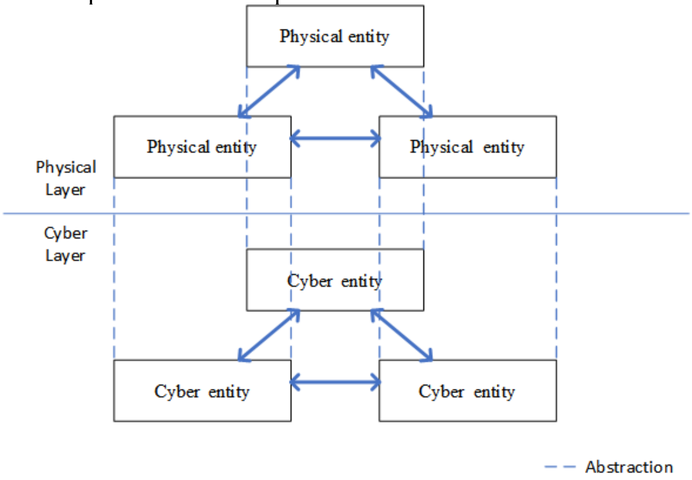

Figure.1 The relationship between the four concepts in CPS

Figure 1 shows the relationship between the four concepts. First, a physical layer is often a system composed of multiple physical entities. Physical entities exchange information and achieve specific functions by establishing links. Moreover, physical entities often have a hierarchical or parallel relationship. The more complex the system, the more complex the relationship between physical entities will be. cyber entity is the mapping of physical entity in cyber layer. Then, as a collection of cyber entities and relationships between cyber entities, cyber layer also needs to accurately map the relationships between physical entities.

For Figure 1:

$$V = \mathbf{f}(R) \qquad (1)$$

$$R = g(V) \qquad (2)$$

$$\| g(V) - R \| < e \qquad (3)$$

Where V represents cyber layer, R represents physical layer, f represents mapping physical layer to cyber layer, g represents reconstructing physical layer according to cyber layer, and formula (3) represents the difference between physical layer reconstructed according to cyber layer and actual physical layer, which should meet the project requirements **e**.

For CPS engineering implementation, on the one hand, it should consider how to realize the bidirectional mapping of V and R, on the other hand, it should be ensured that the error of the bidirectional mapping meets the engineering requirements. This first requires sufficient abstraction and induction of R, and then consider the implementation of f and g.

Mapping is a method of abstracting the attributes, functions, and relationships required for building a system from entities. Based on information physics systems, this method is not advanced. The informatization of equipment is achieved through the digitization of electronic components and sensors of the equipment. Therefore, the mapping of devices can be digitized. This change from continuous physical attributes to discrete values is achieved through devices such as sensors and processors. The device needs to implement certain functions in the system, which are also driven by the internal controller of the device. This drive is the process from receiving discrete digital signals to driving its operation by the controller. Generally speaking, in a system, the existence of an entity should be described as two parts: its attributes and functions. Meanwhile, as the entity is present in the system, it is necessary to define its location within the system. Therefore, the mapping of an entity in the system is the sum of all its attributes, functions, and relationships.

Mapping links physical entity, cyber entity, physical layer and cyber layer.These four concepts constitute four basic conditions for the operation of the CPS. At the same time, these four concepts can form an understanding of the connotation of CPS. This connotation is similar to the concept of most studies, but it is easier to understand [16-18]. Through these four concepts, the CPS (CPS) can be understood as a system that can realize efficient connection and collaborative work between cyber layer and physical layer.

In addition, although the CPS and the Internet of Things express certain similarities, unlike the Internet of Things, which focuses more on the sensor itself, the CPS emphasizes more on the high integration of the cyber system as a system and the physical world to meet the higher accuracy and larger scale of data interaction that the Internet of Things cannot meet. In the specific architecture design, some ideas of the Internet of Things could be combined with the concept of CPS to make the architecture of CPS more easily realized in technology.

3. Design method of cyber physics system model

It can be seen that the CPS is a system that focuses on "entities". Therefore, this paper points out that when designing a cyber physics system, three points need to be focused on:

1) The definition of entities needs to follow certain rules. For example, an electricity meter could be seen as an entity. If the communication chip in an electricity meter is also an entity, and it appears at the same time as the electricity meter. Is the message sent by the communication system interacting with the meter or with the chip in the meter? Based on this, a hierarchical rule should be designed to distinguish entities and their components.

At present, when designing systems, system designers rely on experience to design entities or objects. It will cause a certain degree of design redundancy. Therefore, certain rules need to be followed when designing information physics systems. For example, when designing a new type of power system, a natural person should be taken as an entity, rather than dividing it into customers, users and staff to establish objects. When designing equipment, only those that can independently complete certain operations are called an entity. For example, the communication chip of an electricity meter can only accept signals and cannot operate, so it cannot be counted as an entity. Such abstract rules are a way to avoid design redundancy and abstract disclosure.

Therefore, consider designing a system with three to four levels. The smallest unit is a component, that is, a function block that realizes some functions. Components are the basic units to complete these tasks. Entities form relationships through the connections of various components to complete the one-way or two-way transmission, transmission, transfer and other actions of information, energy, material, capital, etc. An entity refers to an individual that can exist independently and complete business functions independently. For example, a distributed photovoltaic device is an individual. An entity often has multiple components, such as control components, communication components, nameplates, processors, etc. These components are interconnected to form an individual. A subsystem is a system that undertakes a certain part of business according to business requirements. The system is the largest description range of all subsystems in the whole business domain. This system can be composed of systems, subsystems, entities and components. Considering the size of the CPS, multiple layers can also be performed. System, subsystem and entity are the subject and object that complete the one-way or two-way transmission, transmission, transfer and other actions of information, energy, material, capital, etc. Systems, subsystems and entities are the subjects and objects that complete the one-way or two-way transmission, transmission and transfer of information, energy, material, capital and other behaviors; For a system, its behavior is accomplished through subsystems or entities; For subsystems, subsystem behavior is completed by individuals; For entities, their actions are completed through components; A component is an actuator or basic unit used to complete all actions.

Each level is closed internally and externally. That is, the internal components of a level are externally represented as the attributes and behaviors of this level. For example, the communication between systems only exists between systems, not between individuals in a system and other systems. As shown in Figure2, the communication between entities in a subsystem only exists between individuals, not between components of individuals and other individuals, even though the communication of individuals is actually completed by communication components.

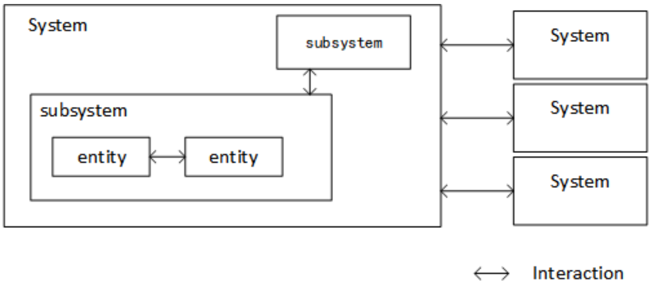

Figure.2 Hierarchical relationship of CPS

This regulation clarifies the boundary of the system and reduces the complexity of the system. It describes the relationship between all levels of the system in a concise and clear way. It provides a good foundation for subsequent modeling and establishment of management control system. Therefore, this paper believes that this way should be taken as the basic criterion for the establishment of CPS.

2) When designing the system, the attributes, functions and interactions between entities should be valued rather than business processes. Business is presented through interaction between entities. The business will change, and a transformer may exist for 40 years. Therefore, if the system is designed based on business, it will lead to more and more bloated problems. Therefore, when designing the CPS, it could refer to the concept of digital twins and regard the physical entity and its mapped virtual entity as an interactive subject. Design other business support externally. Such isolation can ensure that business changes do not affect the internal composition.

Business applications should be isolated from the CPS. The CPS should consider more comprehensively abstracting the functions that can be realized by the current equipment to help the business system run. However, the CPS itself should be a system running independently.

As shown in Figure 3, design an CPS like this. The cyber layer and the physical layer are connected by the gateway, front-end processor and security gateway. This is the common practice of connecting physical devices and cyber systems. The monitoring system, control system and data collection system, which are closely related to the cyber layer, are isolated as part of the business system and interact with the cyber layer. These data interact with the business system. This design is based on the demand side of the power system, but it also has a certain universality.

3) The design of the CPS should be configurable considering the upgrading of equipment and the changes of customers. The first is the configurability of the equipment. When a new type of equipment is added to the system, it can be added without modifying the program to reduce the cost of later operation and maintenance. Consider the establishment of public libraries and other schemes to classify the properties and functions commonly possessed by the equipment. When the new equipment model is

connected to the system, it can speed up the configuration speed and reduce the operation and maintenance workload.

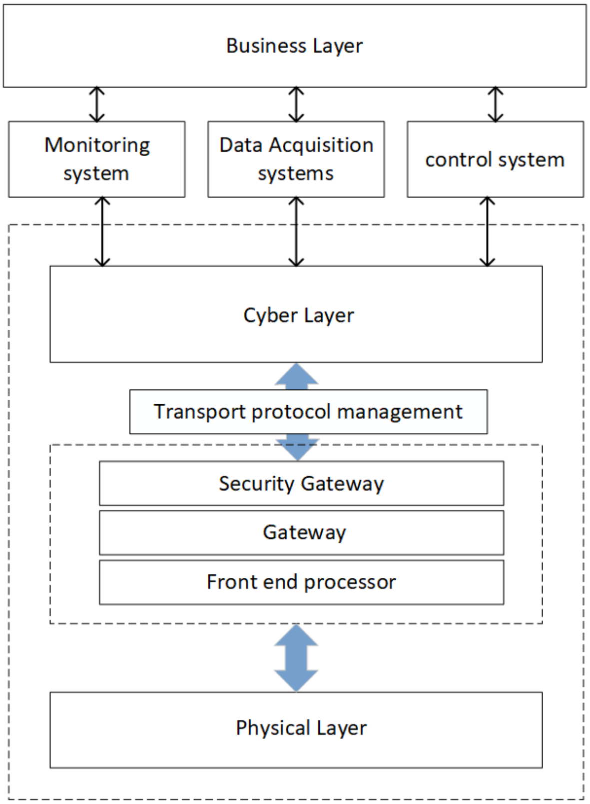

Figure.3 System Design Block

4. Conclusion

This work takes the demand side of the new power system as the starting point, and mainly summarizes the development challenges of the demand side of the power system in the context of new energy. It is mainly distributed generation that joins the demand side, which challenges the traditional power system mode from power plant to transmission to users. The demand-side cyber system also needs further research and improvement with the addition of distributed power. Through the explanation and consideration of the cyber physics system, an application idea of the cyber physics system suitable for the new power system is proposed. This application approach solves some practical problems in applying CPS to a real existing system, such as abstract redundancy issues, hierarchical interaction issues, etc.It has promoted the application of CPS in information system design by addressing these issues and developing solutions.

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