

Research on the architecture and physical end of micro-grid CPS

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Abstract. In view of the trend of intelligent development of future micro-grid, the combined of Information Physics fusion system (CPS) technology with the construction of micro-grid is proposed in this paper. Meanwhile, in this paper, the micro-grid CPS system was established. This paper expounds the reason and necessity of establishing micro-grid CPS, and the schematic diagram was established, and a framework of 6 layer control system for micro-grid CPS was proposed, which are application layer, network layer, connection layer, coordination layer, adjustment layer and physical layer, respectively. Meanwhile, the simulation results shown that the micro-grid system is stability.

1. Introduction

Micro grid is a small distribution power system composed of distributed power supply, power load, power distribution facilities, energy storage devices, and monitoring and protection devices [1]. As an important supplement to the entire power grid system, it can provide economic and security to specific users. Reliable power.

Micro grid is a new generation power grid development model that promotes the coordination between centralized and decentralized systems. It has four basic characteristics: micro, clean, autonomous, and friendly. Micro grid usually combines the development needs of cities, industrial and commercial parks, new towns, new countryside and islands, oasis. Its forms are diversified and the scale is changeable. In view of the above characteristics of the micro grid, the micro grid communication system is obviously different from the traditional substation communication system, and there is no corresponding general standard so far.

Cyber Physical System is a brand-new research field that combines the common computing capabilities, communication capabilities, and autonomous control capabilities with deep integration of information and physical systems. CPS is a control network that integrates computing, communication, and control based on the full awareness of the environment. CPS emphasizes real-time and dynamic information control, information services based on environmental awareness and interconnection between objects can detect or control physical entities in a safe, reliable, efficient, and real-time manner [2]. The significance of CPS lies in connecting physical devices with embedded features to the Internet, and merged technologies such as ubiquitous environmental awareness, embedded computing, network communications, and network control to make physical device systems computational, communication, and precise, which provide five functions of control, remote coordination, and autonomy to achieve human-physical interaction [3].

Advanced information technology is a necessary guarantee for smart grids [4]. In document [5], the CPS concept was introduced into the power system, and power CPS architecture was initially established. This framework can meet certain characteristics of the smart grid to some extent, such as



autonomous behavior and massive data processing. However, this framework is based on the smart grid, and it is the establishment of power CPS architecture for the entire large-scale power system. It is relatively general, and the concept of introducing CPS directly to the unformed smart grid will encounter a lot in terms of operation difficulties.

There are many advantages of CPS systems, such as 1) the high integration of information and physical components; 2) All physical components should have information processing and communication capabilities; 3) Large-scale, networked and complex systems; 4) Multiple complexity in dimensions such as time and space; Can realize the efficient and dynamic organization and coordination of resources allocation; 5) Autonomous system automation to meet real-time robust control; 6) System security, reliability, resistance to destruction, and verification; 7) Self-learning, self-adaptation, dynamic autonomy, autonomous collaboration.

2. The Basic Definition of Cyber-Physical Systems

The concept of CPS was initially pinpointed by the American Natural Science Foundation, which is the combination of computational process and physical process. Because of the high complexity, mixing different technologies of various disciplines the CPS has, it is hard to give an accurate and comprehensive definition. Researchers of different fields currently also do not have a common comprehension regard to the definition of CPS. There are some typical definitions which were pointed out by different scholars. WANG Wei [6] proposed that CPS is a tight integration of a series of computational processes and physical process components. The computational core is used to monitor the operation of physical entities. The physical entities use network and computing components to realize the perception and control of the environment. YUAN Xin-xi believes that CPS is a highly reliable system in which the various computational elements and physical elements in the system are closely coupled and coordinated with each other under the action of dynamic uncertain events [7]. Khan U [8] states from the aspects of computational science and information storage processing, and believes that CPS integrates computing, communication, and storage capabilities, can run in real time, reliably, securely, stably, and efficiently, and is able to monitor the networking of entities in the physical world. computer system. Poovendran R [9] pointed out from the perspective of embedded systems and equipment development that “Cyber” is an integration of computing, communication and control technologies involving physical processes and biological properties. The essence of CPS is the integration of reliable Computation, communication and control capabilities of an intelligent robotic system. Lee I [10] points out that CPS is a controllable, trusted, and scalable networked physical equipment system that integrates computing, communication, and control capabilities based on environmental awareness, and achieves deep integration and real-time integration through feedback loops in which computing processes and physical processes interact with each other. Interactions to add or extend new capabilities to detect or control a physical entity in a safe, reliable, efficient, and real-time manner.

Combining the above viewpoints, this paper believes that CPS emphasizes the interaction of “Cyber-physical” and involves the integration of massive heterogeneous data in the future network environment, the real-time reliable processing and communication of uncertain information signals, the organic coordination of dynamic resources and capabilities and adaptive control, which is a next-generation intelligent system that is highly autonomous, and capable of interconnecting and synergizing virtual and physical worlds.

In practical applications, CPS aims to improve the quality of human life and promote the harmonious development of humans and the environment. In terms of system implementation, CPS aims at ensuring both “real-time performance” and “high-performance” of the system. It is autonomous, interactive, and with the features of precision, resistance to destruction, coordination, and high efficiency, it is possible to realize the monitoring and management of large-scale, dynamic, heterogeneous resources between Cyber and Physical Compared to existing smart technologies, CPS has the following major features in terms of structure and performance. [11].

Figure 1 shows the hierarchical structure of the micro grid CPS, which is 6-tier control architecture. From the bottom to the top, there are the physical layer, the adjustment layer, the coordination layer, the connection layer, the network layer, and the application layer. Each layer has its own application

and Network structure. Between layers, information is not one-way flow. Mutual interaction and control exist, and the uploaded information is varied. Besides, the decentralized control instructions are also different. The physical layer is the lowest layer of the micro grid CPS, which is mainly the power equipment device of the micro grid. As the bottom layer of the micro grid CPS, they are one of the perceived objects, and are also subject to execution control. They can be independently addressed to the Internet, have higher autonomy, and can be networked, dynamically reassembled. In addition, it can also be identified in multiple levels and on multiple scales. Various distributed power generation devices, energy storage devices, power electronics, protection devices, and various types of loads have been IPized.

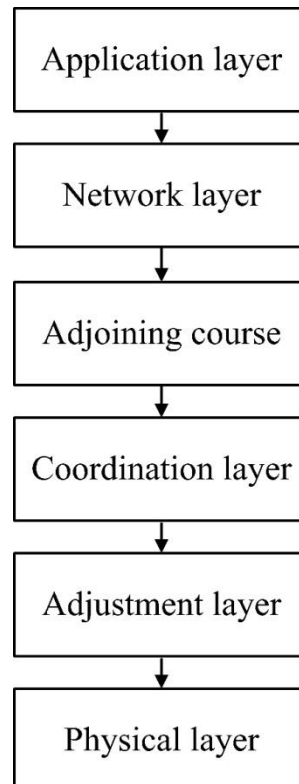


Figure 1. CPS hierarchical structure of micro grid

The adjustment layer is a domain composed of sensors and actuators. It directly acts on the environment of the power devices and surrounding objects of the micro grid and controls them. The conditioning layer is the area of direct contact with the micro grid electrical installation and its surrounding environment. This layer passes the collected information upwards and sends down control commands. In addition to basic data acquisition, these sensors should also have basic data processing functions to optimize the uploading of data.

The coordination layer is on the third floor. Sensors and actuator nodes will form a network autonomously. Layers may be based on proprietary protocols to ensure that nodes can also communicate with each other and deliver information.

The connection layer is located between the coordination layer and the network layer. The sensor collects the necessary data for each physical entity in the micro grid, and the amount of data generated will be huge and of various types. It is necessary to filter the information through some degree of gateway optimization, protocol loading or compression to reduce the network's Transmission pressures are transmitted over the CPS network with optimized information.

The main task of the network layer is to provide the specifications required for transmission between different types of network systems, so that nodes can perform addressing and path selection among different types of network nodes, and provide horizontal communications between different networks and vertical communication between different networks.

The application layer is the level of face-to-face contact with the user, providing the user with an operating interface to communicate with the network.

3. Micro-Grid System Security Investment

Since the electrical and physical equipment in the micro grid CPS should have a very strong function, this article will construct the Agent system on the physical equipment node based on the Agent technology. Agent technology has two main directions: one is to build a single-agent system with complex structure, rich knowledge, and powerful functions; the other is to form a multi-agent system (MAS) with multiple agents with simple structure and functions. Through the cooperation between them, the entire system can also have rich knowledge and powerful functions. The single agent system mainly emphasizes its ability to perceive, observe, summarize, infer, learn, predict, plan, and respond. It constantly strengthens its intelligence level and self-control ability, enriches domain knowledge, and optimizes solutions to problems. The MAS highlights the ability of Agents to solve problems through cooperation and clearly reflects the structure and relationship of each unit's Agent model.

According to the foregoing description, the constructed electrical and physical equipment Agent is operated in the cloud computing environment of the micro grid CPS. Each Agent is a unit structure with extremely strong self-discipline, and can meet the five functional requirements of the CPS for physical equipment. At the same time, it can act on itself and the environment and respond to changes in the environment.

The performance and purpose of the electrical and physical equipment in the micro grid are different. Agents residing on its nodes will be composed of a group of agents, and there will inevitably be great differences between them. Therefore, this paper uses the abstract model to define the agent of the end-node of the CPS electrical and physical equipment in the cloud computing environment. The physical model in the CPS environment of micro grid can be described as a three tuple:

$$PhyNode ::= \langle ENV, GOAL, MA \rangle$$

The state of the environment is ENV, $ENV = \{e_1, e_2, \dots, e_n\}$, and the Goal represents a set of target descriptions, $GOAL = \{g_1, g_2, \dots, g_n\}$.

g_i represents the two tuples, comprised of a target description function G_d and the target constraint function G_c , and it expressed as: $g_i = \{G_d, G_c\}$, $G_c = \{g_{c1}, g_{c2}, \dots, g_{cn}\}$.

MA represents a set of Agents with independent and mutual sensing characteristics, located on end nodes of electrical physics, and it can be described as: $MA = \{C_{Agent1}, C_{Agent2}, \dots, C_{Agentn}\}$.

A_{cti} represents the intension based on the current circumstances.

$$A_{cti} = \{a_{ct1}, a_{ct2}, \dots, a_{ctn}\}$$

In Figure 1, the double-headed arrows indicate the power flow of the micro grid CPS, and the single-headed arrows indicate the flow of information. The entire micro grid CPS includes two parts: the power network and the information network. The physical equipment is mainly the power equipment in the micro grid, such as distributed power supply, power electronics, energy storage devices, and various types of loads. Since the interruptible load here is a movable charging device such as an electric vehicle, the load has bidirectional flow of energy, which is one of the characteristics of the micro grid. Information devices include various sensing devices, distributed computing devices, servers, CPS real-time networks, and more.

The electrical and physical equipment are connected through power lines to form a controllable small system, which is incorporated into the distribution network end of the power system. In emergency situations, the static switch can be disconnected to operate independently, forming a local power island. Information network devices such as sensors, servers, CPS real-time networks are connected by a communication network. The micro grid CPS can be one of the future power CPS, connected to the power CPS network via a CPS router. The CPS router should be able to conveniently implement IP address addressing and conversion between heterogeneous data formats. The local information and control center of the micro grid CPS is set in the distribution network. The center can integrate all the data of the nearby micro grid CPS, then analyzing and simulating it. It can process the

uploaded node data in real time, check the validity of the user identity, and accept the local user's Data search and analysis request issue or forward control instructions to the control node where the actuator is located.

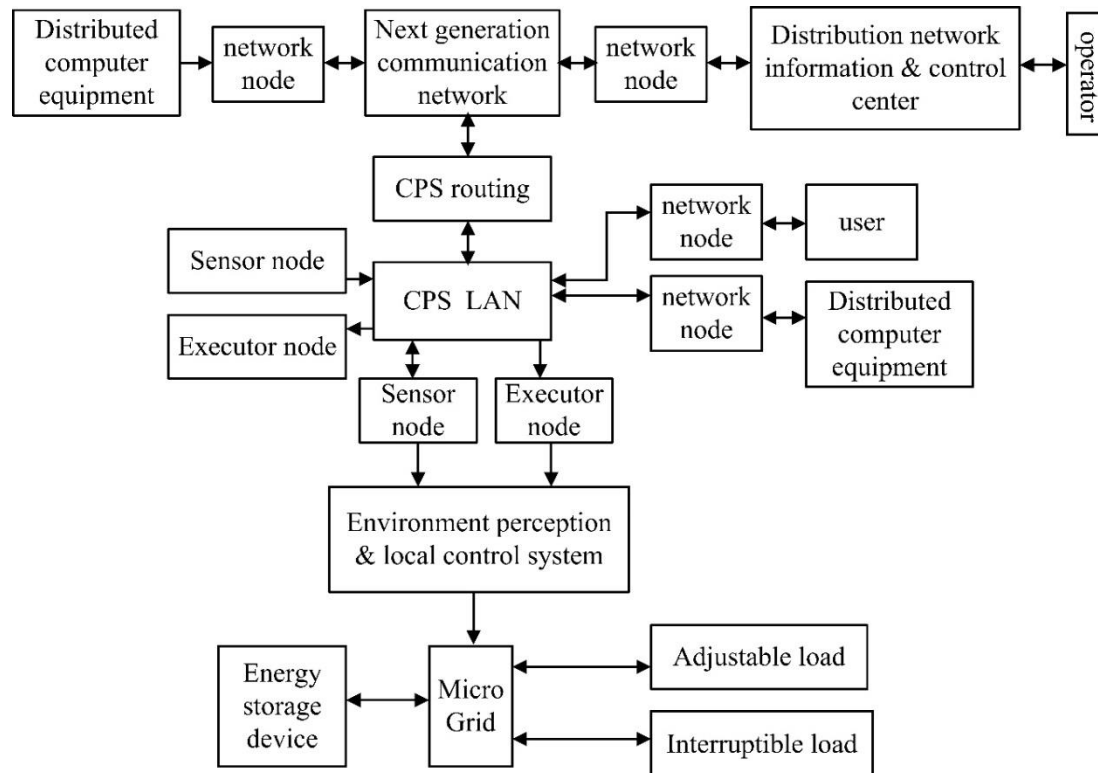


Figure 2. CPS architecture of micro grid

We request to afford a statistical sample to clarify the presentation of upper system. And we adopt the demo jumps at time 1 and echo jumps at time 11. As shown in Fig. 3. It concluded that the uncovering nosedives when there is no disruption. And a superior disruption can raise the presentation of the indicator.

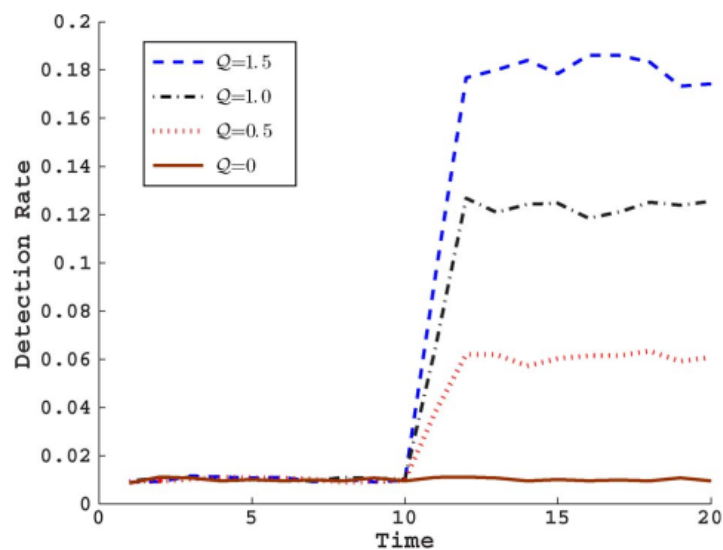


Figure 3. Different detection rate under over time situation

4. Conclusion

In this paper, the concept of CPS is introduced in the field of micro-grid, and the basic framework of micro-grid CPS is set up, and 6 layer control architecture of micro-grid CPS is proposed. In view of the functional requirements of CPS for physical equipment, an abstract model of the end node of power physical equipment in the computing environment of micro-grid CPS cloud end is established by using Agent technology. Meanwhile, the reason for using cloud computing to replace cloud computing in micro-grid CPS is expounded.

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