

Review Article

Thinking and Prospect of Power Chip Specificity

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The contradiction between the demand of massive intelligent scene caused by the interconnection of things in power system and the bottleneck of the chip itself is becoming more and more serious. How to realize the self-controllable and domestic substitution of power chips has been widely concerned in the power field. Therefore, this paper analyzes the demand for power chips in power system and discusses the scene specificity of power chips. Then, it combs the design architecture of power chips and discusses the application scenarios and research focuses of power chips. Finally, the key scientific problems and major technical bottlenecks of power chips are prospected.

1. Introduction

Chip is the leading foundation of national economic and social development. The development of chip industry is not only an inevitable development trend facing external competitive pressure but also meets the urgent “neck” demand of various industries in China [1]. Now, it has risen to the level of national strategy [2]. Since 2014, the state has successively promulgated such strategic plans and policies, such as the outline for promoting the development of the national integrated circuit industry, the 13th five-year development plan for the national high tech industrial development zone, and several policies for promoting the high-quality development of the integrated circuit industry and software industry [3]. It is aimed at promoting the innovation and breakthrough of integrated circuit and improving the technology level of Chinese chip industry [4]. It can be seen that independent research and development of chips and accelerating the industrialization of chips are the urgent needs and major strategic planning of the country [5].

As the basic energy industry of industrial development, the power industry is closely related to the use of chips in all aspects of power production [6]. In 2010, the State Grid comprehensively promoted the construction of smart grid. At that time, the demand for chips was expected to reach 20 billion pieces. In 2019, State Grid and China Southern Power Grid have put forward strategic measures to build the power Internet of Things (IoT) and digital grid, aiming to realize the coordinated interconnection of all production links of power system [7]. Comprehensive perception of system operation status and efficient processing of massive power information by using new modern information technologies such as advanced sensors, intelligent equipment, artificial intelligence and edge computing [8–10]. In this context, all intelligent scenarios need to use power chips for efficient data analysis and intelligent processing, and the demand for power chips in the power system is growing exponentially.

Under the important national strategic planning and the urgent demand of power system, the research and

development of domestic power chip with self-control have been widely concerned in related fields. Many power chip enterprises, such as Beijing Smart Chip, Fudan Microelectronics, and Datang Microelectronics, have emerged in China, which can realize the localization substitution of some security chips, master chips, and RF chips. However, at present, the high-end chips in the electric power field are still mainly imported chips. Due to the technical bottlenecks in technology, materials, and performance testing system, there is still a big gap between domestic power chip enterprises and foreign enterprises [11]. Relevant scholars have also studied the key technologies involved in power chips, including energy consumption optimization technology based on multicore chips [12], modeling customization for power chips [13], and device development and system integration based on power chips [14]. It is thus clear that the current theoretical research on the chip is mainly based on the general chip architecture and the demand integration and performance optimization of power application scenarios are carried out [15].

However, with the intellectualization and ubiquity of power grid application scenarios under the power IoT, the power system presents an urgent demand trend for diversified power chips [16]. The contradiction between the increasing demand for intelligent scenarios in power system and the technology bottleneck of power chips and the power chip integration mode based on the general chip architecture is intensified. Power core is urgently needed in power application scenarios. The bottleneck technology breakthrough can realize the customization of various application scenarios. For these purposes, this paper analyzes the power chip architecture and the application of power chip and discusses the key problems of power system chip from the perspective of power chip classification and application. The main contributions in this paper can be summarized as follows:

- (i) Analyzing the demand for power chips in the power system and discuss the specifics of their scene
- (ii) Combining the architecture design of power chips and discussing their application scenarios and research focus
- (iii) Exploration of major scientific problems and major technical bottlenecks for power chips

2. Preliminary

2.1. The Particularity of Power Scene. With the development of power system in the direction of digitalization, automation, and interaction, a series of intelligent power equipment, such as intelligent meter and intelligent distribution terminal, are widely used in the power system [17]. These intelligent power devices need to use a large number of power chips. These chips are not only directly related to the demand of intelligent analysis scenarios but also an important link between the user side and the smart grid information exchange. Power chip has become the core force of smart grid development, which is of great significance to the construc-

tion of power IoT and the realization of digital transformation of power grid.

At present, power chips have penetrated into all aspects of intelligent power system, such as power generation, transmission, transformation, distribution, power consumption, and dispatching, providing the underlying material support for the development of the power industry [18–20]. There are many intelligent scenarios in the power system inseparable from the use of power chips, but each scenario needs different types of power chips. Power grid data analysis, processing, and control need the master chip to complete; field data acquisition needs sensor chip support; key data protection needs specific security chip; information transmission and interaction rely on communication chip. Identification and storage management of power equipment need radio frequency identification chip; massive intelligent inspection and monitoring terminal need artificial intelligence chip. A large number of intelligent acquisition devices and small and micro sensors are needed for the collection of user electricity information and environmental state perception, as well as corresponding intelligent processing chips [21]. Therefore, diversified scenes, huge volume, and fragmented application are the characteristics of the demand for chips in power system.

In addition, the power chip used in the current power system is highly dependent on foreign imports and the safe and stable operation of the power system is faced with potential risks such as information security and algorithm constraints. Therefore, speeding up the research and replacement of chips needed for power system intellectualization and realizing the security of power grid chips independently and controllable are the fundamental requirements to ensure the security of power grid. At the same time, the power grid integrated with blockchain and other technologies will become an important security technology [22–24].

2.2. Definition and Classification of Power Chips. Chip is the general designation of semiconductor component products, also known as integrated circuit, microcircuit, etc., which is a kind of micro electronic device or component [25]. There are many classification methods for general chips. According to application scenarios, chips can be divided into four categories: civil, industrial, automotive, and military. According to the use or function, chips can be divided into GPU, CPU, FPGA, DSP, ASIC, and SOC. According to the manufacturing process, chips can be divided into 7 nm and 14 nm ac [26].

At present, power chip mainly refers to the chip used in power system. The power chip is classified according to its application function. The commonly used chip mainly includes main control chip, communication chip, security chip, radio frequency identification chip, and sensor chip. However, with the development of the power IoT and the digital transformation of power grid, the new power system not only needs the basic functions of traditional chip such as sensing, measurement, control, and communication but also needs the intelligent chip to realize intelligent perception, analysis, and identification at the terminal and equipment side. Therefore, the meaning and classification of

traditional power chip cannot meet the special needs of power system development and power scene. Therefore, this paper puts forward the concept of power dedicated chip, which is defined as a customized industrial chip that meets the requirements of power system measurement, control, protection, intelligent perception, analysis, and identification. It is the basic device for new energy access and smart grid upgrade and development. In addition to the traditional master control and communication chips, the power dedicated chips should also include power distribution terminal intelligent chips, visual edge intelligent chips, sensor and edge computing fusion chips, and blockchain chips for IoT applications. Figure 1 shows the classification of power dedicated chips.

The intelligent chip of power distribution terminal is mainly used for terminal equipment of power distribution and power consumption. Intelligent integrated distribution terminal (TTU), feeder terminal device (FTU), and station control terminal (DTU) equipped with smart chip of distribution terminal not only can collect and monitor distribution data but also can analyze and identify fault and power types on line, so as to achieve timely fault isolation recovery, voltage, and reactive power adjustment on the distribution terminal side. The intelligent meter and intelligent charging pile equipped with intelligent chip of power distribution terminal can not only complete the measurement, collection, communication, and accounting of power consumption data but also realize the analysis and identification, prediction, and identification of power consumption load.

The vision edge intelligent chip is mainly used in power transmission and transformation link inspection equipment and power operation monitoring system. The inspection unmanned aerial vehicles (UAV) and transmission line online monitoring equipment equipped with video monitoring edge intelligent chip can not only monitor the changes of temperature, inclination, phase, vibration, and wind deflection of transmission lines but also analyze and identify the transmission line fault and transmission channel environment in real time [27]. The electric power operation monitoring equipment equipped with video monitoring edge intelligent chip can identify the behavior and posture of operators on line and timely warn the poor operation, missing operation, and nonoperation according to the specified sequence, so as to realize the safe production of electric power.

The fusion chip of sensor and edge computing is used in sensor terminals of power system. The temperature sensor, photoelectric sensor, vibration sensor, displacement sensor, and other sensor terminals equipped with sensor and edge computing fusion chip can not only realize online monitoring of the operation status of power equipment but also analyze the fault type of equipment according to the data collected by the sensor and assist the operation and maintenance personnel.

The blockchain chip for the application of the IoT is used for all kinds of terminal devices of the power IoT, providing a basic environment for data exchange for the unified management, security identification, and interconnection of all things of the power equipment, realizing the full traceability

of the power grid data, and ensuring the safe and stable operation of the smart grid. The combination of blockchain technology and power IoT is conducive to the formation of a new form of decentralized power IoT security protection based on blockchain, which plays an important role in power system security detection, distributed trust mechanism, and power grid data privacy protection.

3. Architecture Systematization of Power Chip

3.1. Power Chip Architecture. There are numerous chip products used in the power industry, but there is no systematic technical standard and architecture for chips in the power industry. The national standards issued by the national integrated circuit standardization subcommittee mainly focus on the basic general requirements of chips, international standard conversion, and other directions, and there are no specific requirements for power specific chips [11]. Traditional power chips are mainly used in power grid sensing, measurement, control, and communication. According to different application scenarios, they can be divided into main control chip, sensor chip, security chip, communication chip, and RFID chip. The typical architecture modules of these chips are shown in Table 1.

The processor module in Table 1 includes the main processor and the coprocessor. The function module refers to the circuits required for the chip to complete specific functions, such as memory and flash memory control circuit of the main control chip, A/D conversion circuit of the sensor chip, safety logic circuit of the security chip, radio frequency circuit, and the radio frequency identification chip. It can be found from Table 1 that these traditional chips have communication module, power management module, function module, and external interface.

In order to make the chip industry be able to serve the power grid construction safely and reliably, it is necessary to clarify the requirements of the power industry on the chip function, performance, reliability, security, and real-time performance and design the power dedicated chip functional architecture of the largest convention under a variety of power intelligent application scenarios, combined with the architecture module of traditional chip, considering that the power special chip also has the ability of intelligent calculation and analysis and needs high-performance processor and high-speed and large-capacity memory. This paper summarizes the general architecture module of power dedicated chip into specific scene processor module, memory module, communication module, power management module, function module, and external interface [28].

3.2. Design Principles and Technical Requirements of Power Chip. When designing the power chip, we should analyze the requirements of different application scenarios of the power system and choose the general architecture module of the chip. At the same time, we should study the intelligent processing and identification algorithm suitable for the power chip with limited resources, build the algorithm library of power dedicated chip, and deploy it in the specific

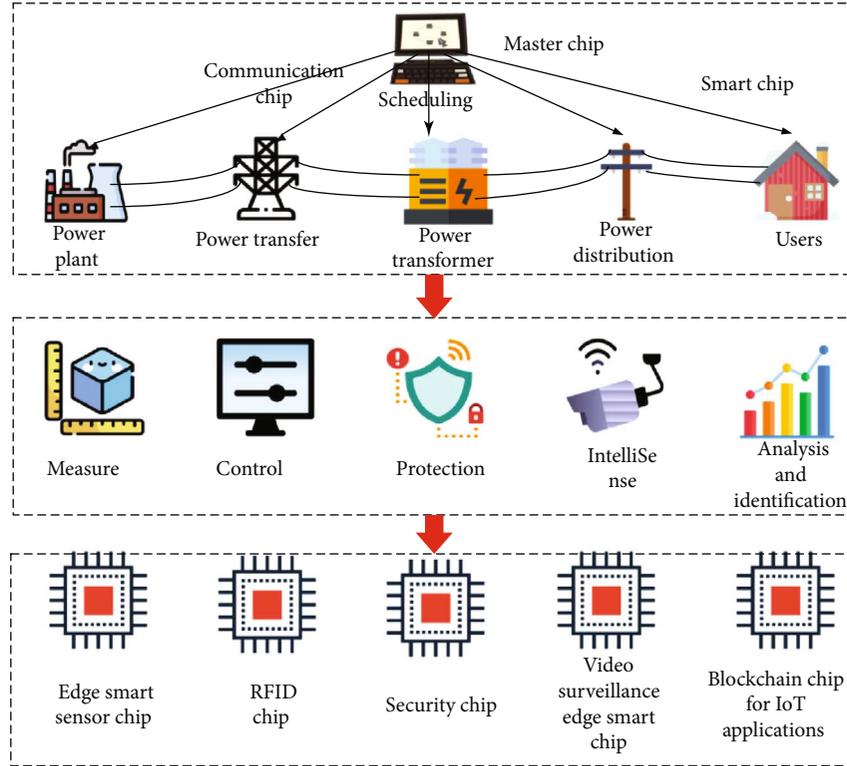


FIGURE 1: Application and classification of power chips.

TABLE 1: Traditional power chip architecture modules.

Chip type	Master chip	Sensor chip	Security chip	Communication chip	RFID chip
Processor module	√		√	√	
Memory module	√		√		√
Communication module	√	√	√	√	√
Power management module	√	√	√	√	√
Functional module	√	√	√	√	√
External interface	√	√	√	√	√

scene processor module. The common intelligent algorithms of power chip are shown in Table 2.

The design of power dedicated chip not only needs to meet the scene requirements but also designs the structure and details of the power chip in combination with the technical requirements of power equipment environment, information security, and business real time. At the same time, select a specific scenario processor with appropriate performance and power consumption. The technical principles that should be followed in the power special chip mainly include the following aspects:

(1) *Reliability*. Most of the power equipment in smart grid is arranged outdoors, facing various severe weather conditions, geomagnetism, radiation, electric field, and other interference, so the power chip must be stable and charged in the environment of wide temperature, high humidity, salt fog, ice and snow, electromagnetic radiation, and so on. In partic-

ular, in the EMC (electromagnetic compatibility) design of power special chip, functional test should be done first to check whether the EMC index of the chip can meet the requirements, and then, protective design is needed, which involves filtering and shielding circuit and adjusting the wire layout in the chip [29, 30].

(2) *Security*. The data carried in the power dedicated chip is related to the national economy and people's living and privacy. In the past, major equipment failures at home and abroad have problems such as data leakage and sending and receiving errors. Therefore, independent information encryption function module should be considered in the design of power dedicated chip, so as to realize encrypted and secure communication between power equipment and cloud [31, 32].

(3) *Real Time*. The data acquisition, accurate measurement, data transmission, real-time control, and business scheduling

TABLE 2: Electric power chip algorithm library.

Chip category	Algorithm
Network communication	Message encoding and decoding, repeated message filtering, broadcast storm suppression, information security encryption
Electrical parameter data processing and calculation	Message processing, digital filtering, phase sequence calculation, harmonic calculation
Intelligent perception and analysis recognition	Target detection, target tracking, semantic segmentation, behavior and gesture recognition

of smart grid require very high real-time performance, which not only refers to the real-time data acquisition but also includes the real-time data processing, analysis, and decision-making. If the real-time performance cannot be guaranteed, the state data of power grid may be delayed and the stability of power grid can be misjudged. It is of great significance to design excellent high-performance and low-power power dedicated chips for the construction of real-time power IoT.

4. Key Technology

With the chip and terminal of intelligent processing capacity, more and more power chips will undertake the task of intelligent processing. Moreover, the current intelligent processing algorithm is mainly carried out in the resource-rich cloud platform. How to deploy the existing intelligent processing methods to the power chip is facing a huge challenge. Therefore, this paper focuses on the key technologies involved in the development of power chip intelligence, including lightweight intelligent processing model, cloud-edge-terminal collaboration technology, and security protection technology.

4.1. Lightweight Intelligent Processing Model for Power Chip

4.1.1. Lightweight Model Design. The research on lightweight model design mainly focuses on the construction of lightweight deep learning framework and the design of lightweight intelligent analysis model. (1) The lightweight deep learning framework is designed to provide intelligent analysis environment on power chip. In 2017, Google first proposed a lightweight deep learning algorithm framework for mobile and embedded devices named TensorFlow Lite, which can run deep learning models on low-latency mobile devices, and it takes up less memory space [33]. Jia et al. proposed a lightweight Caffe framework. In April 2017, Facebook added the functions such as recursive neural networks on the basis of Caffe and proposed the Caffe2 framework to make the framework better on mobile terminals. In March 2018, the Caffe2 was incorporated into the PyTorch framework, and the mainstream PyTorch and MXNet frameworks also began to support edge-terminal deep learning models [34]. Each framework including TensorFlow Lite, Caffe2, MXNet, and PyTorch has its own advantages and disadvantages, none of which can perform well in terms of delay, memory occupied, and reasoning effect [35]. (2) Lightweight model design is to consider the limited computing resources of power chips and

directly design an intelligent analysis algorithm suitable for resource limited chips, such as SqueezeNet, MobileNet, ShuffleNet, and XceptionNet with faster and smaller network architecture. In addition, some scholars build lightweight intelligent analysis model through neural architecture search (NAS), which commonly uses the neural architecture search (NAS) method to search for lightweight deep learning models suitable for artificial intelligence (AI) chip. In 2016, Google [36] first proposed an architecture search method that uses the reinforcement learning to produce convolutional neural network architectures. Its basic idea is to automatically search out an optimal network architecture for different tasks by defining search space, search strategy, and evaluation prediction. In recent years, the researches on network architecture search (NAS) have mainly focused on the definition of NAS search space, NAS search algorithms, and evaluation of model performance [37]. The definition of search space is to determine the candidate network structures to be searched. At present, there are mainly two types of search space: global search space and local search space [38]. There are three main types of NAS search algorithms including search algorithms based on reinforcement learning, search method based on evolutionary algorithms, and search method based on gradients. The evaluation of model performance is to evaluate the network architecture performance obtained in the process of neural network architecture search. The most direct method is to train the obtained network architecture on the target dataset, get weights to the model, and then the inference effect of the model determined by using the test samples. However, the main problem of this method is that the search efficiency is low, which requires huge computing resources, the selection of network super parameters is difficult, and the network search is easy to fall into local optimum. So this method needs further research and optimization [39].

4.1.2. Compression and Acceleration of Model. The main methods of model compression include model pruning, parameter sharing, and simplified convolution kernel, currently [40]. Parameter pruning is to evaluate importance of structure and parameters of a deep learning model. Under the premise of ensuring accuracy of the models, redundant or less important network structures and parameters are to be cut to achieve the purpose of lightweight the deep network. Wang et al. [41] proposed a channel pruning model compression method based on discriminant force and applied it to the ice thickness monitoring of transmission lines. The ice thickness model after channel pruning was

deployed in the front-end ice monitoring device, so as to realize the front-end identification of ice thickness. Parameter sharing is to share a same quantized value among similar model parameters of the deep learning models to achieve deep learning model compression. Wu et al. [42] studied the influence of two parameter quantization methods of 8-bit computing and floating-point computing on the performance of deep learning models, and the research results show that the two quantization methods perform well for deep learning models. The method of simplifying the convolution kernel is to simplify the convolution kernel of the convolutional neural network, reducing or simplifying the high-dimensional convolution kernel to achieve model compression. MobileNet proposed by Howard et al. [43] is a typical model compression method that simplifies the convolution kernel. MobileNet uses depth wise separable convolution (DSC) to replace the classic 3D convolution in convolution neural network for feature extraction. This model can reduce the redundant information of convolution kernel, greatly reduces the calculation of deep learning network, and is adapted to the terminal with limited resources [44]. But in general, the research of lightweight model is not mature enough, and whether it is successfully applied in power chip for intelligent analysis and processing needs further verification.

4.2. Cloud-Edge-Terminal Collaboration Technology. With the development of edge computing and chip technology, more and more data processing tasks will be completed in terminals with AI chips, but it does not mean that cloud computing will be replaced. Because the memory and computing power of the edge computing devices and chips are relatively small and the computing resources are limited, only some lightweight deep learning networks can be deployed, so the tasks and data that can be processed are limited. Generally, the trained lightweight deep learning model is embedded in the edge computing device or power AI chip. Cloud computing is far away from the data source, there will be a certain delay in obtaining data, so it cannot achieve real-time data analysis and processing. But the cloud computing center is rich in computing resources, which can deploy complex deep learning models with higher accuracy and complete the training work of the model. Therefore, it is the key to promote and apply the power chip and edge intelligent technology to study the cloud-edge-terminal collaboration technology [45].

Cloud-edge-terminal collaboration technology involves storage, communication, task allocation, and model training and so on. According to the different dominant players, there are three modes of cloud-edge-terminal collaboration technology [46]. (1) Cloud-oriented collaboration technology: that is, cloud is responsible for model training and task assignment, and only the specific tasks are distributed to the edge and terminal for execution. (2) Terminal-oriented collaboration technology: the terminal allocates the main tasks according to its own computing power and memory and interacts with the intelligent processing results with the cloud and edge devices. (3) Cloud-edge-terminal collaborative optimization technology: that is to say, the task comput-

ing power and communication at the cloud edge are optimized in advance, and then, each link is configured and set according to the optimization results.

In the research of cloud-edge-terminal collaboration technology, Niu et al. [47] constructed a service response framework of power system based on cloud edge collaboration and proposed a load allocation mechanism of power IoT oriented to edge computing to minimize service delay. To solve the problem of task unloading in edge computing, Yao et al. [48] mainly studied the cost optimization of task scheduling in smart grid environment and proposed a task optimization algorithm based on green greedy algorithm, which provides a solution for the real-time power data analysis collected by smart devices in smart grid environment. Edge computing is an important supplement of cloud computing. Huang et al. [49] proposed a cloud edge collaboration framework for smart grid real-time video monitoring and proposed an efficient heuristic algorithm based on simulated annealing strategy for collaborative optimization. Zahoor et al. [50] proposed a smart grid resource management model based on cloud-fog computing. The core idea of the model is to establish the hierarchical structure of cloud-fog computing and provide different types of computing services for smart grid resource management. Aiming at the resource allocation problem of fog computing in ubiquitous smart grid, a dynamic resource allocation framework is proposed by Li et al. [51]. A dynamic differential game model is established, which can help service providers to make the optimal dynamic strategy when users change the strategy, to meet the needs of power grid users while maximizing resource utilization and efficiency. But the current power chip-related collaborative technology is still in its infancy, and cloud-edge-terminal collaborative technology as an important topic in the application of edge computing needs more discussion and research.

4.3. Security Protection Technology of Power Chip. In recent years, there have been many cybersecurity incidents in the power system. As one of the key national facilities, the power system has always been one of the important targets subject to cyberattacks. Security protection of the power system is of great significance to ensure safe and stable operation of the power grid [52–55]. However, with the rise and development of edge intelligence and power chip technology, a large number of user data are processed in the edge intelligent terminal. Although the edge and distributed intelligent processing mode has higher processing efficiency, the security protection ability at the edge end is relatively poor, it is easier to be invaded by attackers, and there are higher potential security risks. Therefore, the research on the security technology of power chip is the key to the application and promotion of power chip.

At present, some scholars have explored the chip security technology. Songlin et al. [56] proposed an edge computing system for smart grid based on the IoT. The system can achieve the connection and management of entity terminals, providing real-time analysis and processing of massive data by edge computing under edge computing. With the help of edge computing paradigm, he realized and proposed a

privacy protection strategy based on edge computing to ensure the security of the smart grid system under edge computing. Aiming at the security requirements in data transmission of smart grid under edge computing, a secure data aggregation (SDA) scheme based on Domino Ferrer additive privacy is proposed by Okay and Ozdemir [57]. The protocol not only ensures low communication and storage overhead but also achieves end-to-end confidentiality. Gai et al. [58] combined the block chain and edge computing technology and proposed a model permissioned blockchain edge model for smart grid network (PBEM-SGN) aiming at two important issues of privacy protection and energy security in smart grid. This model uses group signature and secret channel authorization technology to ensure the legitimacy of users to improve the security of smart grid. Yuan and Li [59] proposed a trust mechanism for IoT edge devices based on multisource feedback information fusion. Since the proposed multisource feedback mechanism is used for global trust computing, it is highly reliable to malicious attacks caused by malicious feedback providers. However, currently, such technologies related to edge computing and power AI chip are not mature enough. The security protection for edge computing and AI chip is an emerging research field, and it still has a long way to go in the future.

4.4. Power Chip Performance Testing Technology. The power chip industry is divided into four parts: design, manufacturing, packaging, and testing. The testing technology of power chip is one of the important supporting technologies for the development of power chip industry and also the key link to ensure the performance and quality of power chip. However, the current research mainly focuses on the performance testing of general-purpose chips. It includes the architecture design of chip test platform, high-speed signal test, and chip test optimization [60, 61]. The current test research on power chip is relatively scarce, and the test technology of power chip is lagging behind; there is no authoritative test system of power chip, which is extremely unfavorable to the development of power chip technology. In particular, the power system is a strong electricity environment; electromagnetic interference has a great impact on the power chip, how to find the special problems of power chip under high voltage and strong electromagnetic environment and form the standard system of EMC research and performance function detection of power chip under strong electromagnetic environment. Therefore, it is urgent to study the performance test technology of power chip and form a comprehensive and complete chip test system.

5. Application Scenarios of Power Chip

5.1. Intelligent Terminal of Power Distribution and Utilization. The distribution and utilization information acquisition system is a system for collecting, monitoring, and processing power distribution and utilization information of power users. The system is logically divided into three levels: master station layer, communication channel layer, and acquisition equipment layer [62, 63]. The main station layer includes marketing acquisition business application,

front-end acquisition platform, and database management system; the communication channel layer mainly adopts optical fiber private network, 230 MHz wireless private network, APN wireless private network, micro power wireless, and other networks; the acquisition equipment layer includes concentrator, collector, and watt hour meter. In the operation of the whole system, the acquisition layer equipment obtains the user's measurement information through the distribution network acquisition terminal and transmits the information to the master station through the communication channel layer. The master station records, counts, and analyzes all the data and realizes the automatic collection of power consumption information, abnormal measurement monitoring, power quality monitoring, power consumption analysis and management, relevant information release, distributed energy monitoring, and so on, information interaction and other functions of intelligent electrical equipment [64, 65].

The intelligent chip carried in the distribution and consumption collection terminal realizes the front-end intelligent analysis and processing of the collected data and then builds a cloud edge end collaborative intelligent processing framework for power distribution and utilization data, which avoids the data congestion and response delay caused by the massive distribution and consumption data uploaded to the monitoring center. The architecture of the distribution and utilization collection system based on the intelligent chip is shown in Figure 2. The existing distribution and utilization terminal chip is mainly used for information communication. In comparison, the intelligent chip integrates powerful data processing module, which can intelligently analyze and process the data collected by the power distribution terminal. Moreover, the data processing ability is stronger and the response time is faster. It can better meet the real-time requirements of data processing in distribution network and greatly meet the power distribution chip facing the bottleneck demand.

5.2. Intelligent Inspection of Substation. In recent years, with the rapid development of artificial intelligence technology, robots begin to simulate human thinking and complete complex tasks. The intelligent inspection robot is used in the substation for equipment inspection, taking photos and archiving for key parts and meters, detecting meter scale, and real-time infrared monitoring of equipment temperature. The collected pictures and data are transmitted to the background inspection system in real time through wireless communication (power 4G), so as to complete equipment inspection in high-risk environment instead of staff [66, 67].

Nowadays, most substations are equipped with rail or trackless inspection robots, but the intelligent identification method of inspection images cannot meet the practical requirements, so most of the inspection robots are idle, which means the equipment images collected by the inspection robots and the defect detection are carried out through manual inspection. The test results have a great relationship with the quality of personnel, and the efficiency is low [68, 69]. Substation intelligent inspection chip technology can effectively solve the current dilemma. The topology of substation

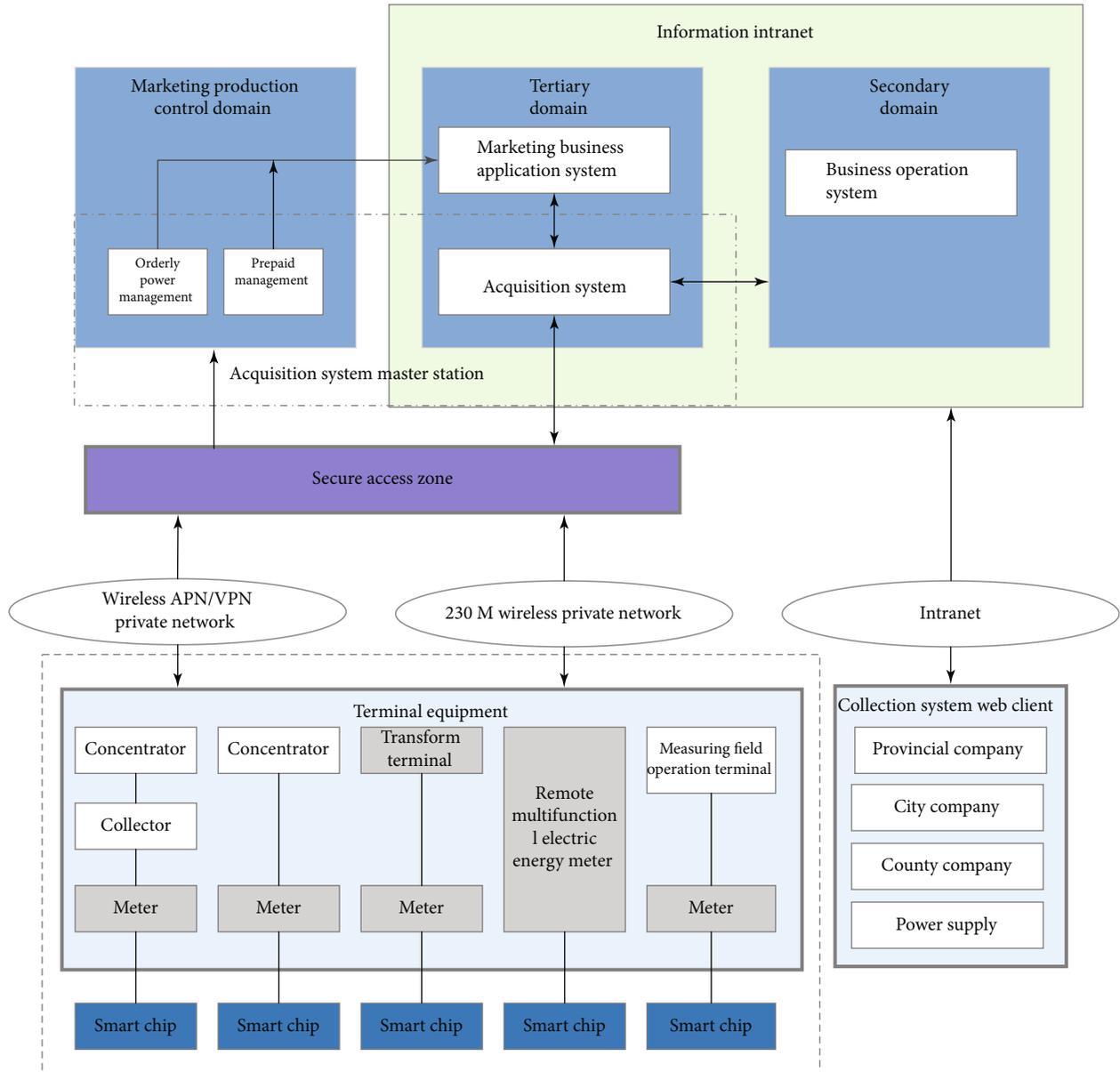


FIGURE 2: Network topology diagram of electricity collection system based on smart chip.

intelligent inspection system based on intelligent chip is shown in Figure 3.

As shown in Figure 4, through the intelligent chip on the inspection robot, real-time recognition and intelligent analysis of the collected equipment images are carried out, by using big data analysis and artificial intelligence technology, centralized management and control of terminals, automatic discrimination of push abnormal results, traceability of inspection process, acquisition of historical inspection situation, etc., thus forming an intelligent inspection framework of cloud end cooperation, providing technical support for the realization of unmanned inspection of substation.

5.3. Edge Intelligent Video Surveillance. With the continuous development of strong smart grid construction, higher requirements are put forward for video monitoring system,

through the installation of network cameras in substations, transmission lines, business halls, and other places to collect onsite analog or digital video signals, access to the power grid through the video transmission network, and display the unified video monitoring platform to complete the daily inspection of substation and video monitoring of business hall. However, due to the large number of monitoring devices in the power grid, if all the video data of power grid security monitoring are uploaded to the cloud server, the amount of video monitoring data is relatively large. The computing capacity of cloud server is limited, and the delay is high, so the real-time performance of video monitoring cannot be guaranteed [70, 71]. The former power system also has power chips for video monitoring, but the image processing capacity of the existing chip technology is limited. So it cannot be applied to the processing requirements of massive video

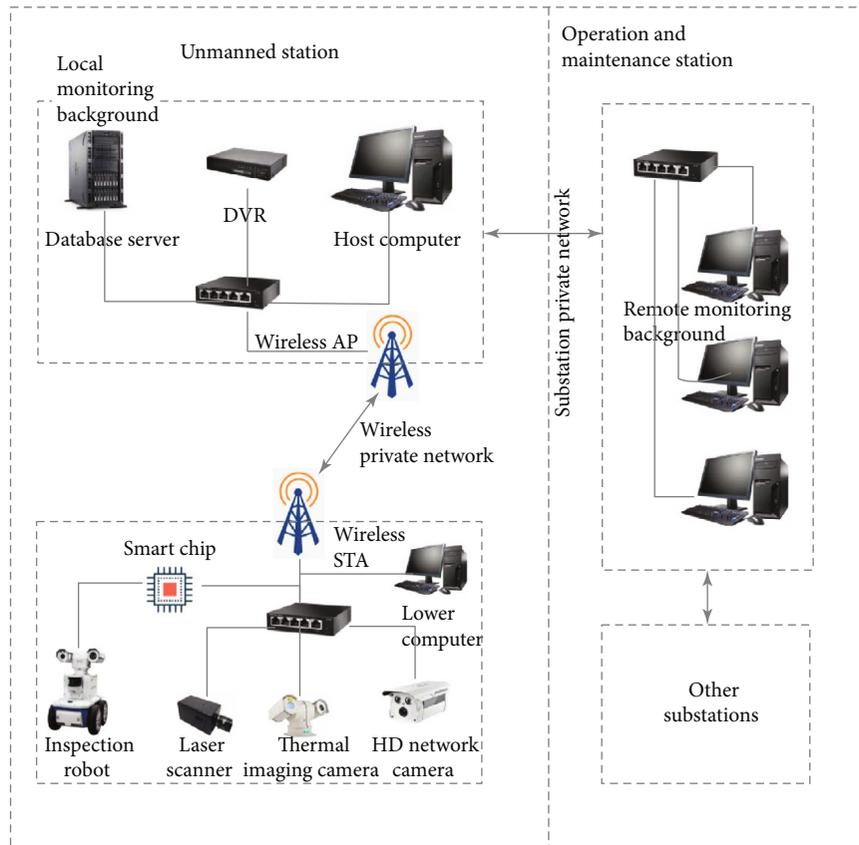


FIGURE 3: Topology diagram of intelligent inspection robot system for substation based on smart chip.

monitoring images generated under the background of power IoT and energy Internet. Vision intelligent processing chip and edge computing technology provide a solution for massive image visual processing. The topology of video monitoring system based on edge intelligent chip is shown in Figure 4.

As shown in Figure 4, the edge intelligent analysis and processing of power grid video monitoring can be realized by carrying the edge intelligent chip into the video monitoring terminal, which greatly improves the analysis and storage capacity of massive video and meets the demand of power system video monitoring massive power image intelligent analysis.

5.4. Edge Intelligent Sensor. With the continuous development and expansion of power grid scale, the state monitoring of electrical equipment has gradually become an important part of the company's operation and management. Power grid equipment has the characteristics of large number, wide variety, high value, long service cycle, wide distribution, and complex operation environment. The state evaluation and diagnosis ability of relevant equipment and channels is insufficient, which cannot support the rapid growth of the demand for operation and maintenance management of distribution equipment. Therefore, through the IoT technology, using the camera, position sensor, temperature sensor, humidity sensor, smoke sensor, pressure sensor, and other equipment installed on the column, box type and station transformer area, the operation status of the external environment, transformer, and low-voltage distribution box can

be monitored. Through public network and private network, the data is transmitted to the back-end monitoring platform. The back-end monitoring platform analyzes the collected data, pushes the early-warning information synchronously, and monitors the onsite operating environment and status of power system equipment in real time [72–75].

However, with the proposal and promotion of the strategic planning of the power IoT, the demand of the power system for sensors with intelligent analysis ability is increasing rapidly. However, the data processing capacity of the existing sensor chips is limited, which cannot meet the processing requirements of the massive power data generated under the background of the power IoT. Therefore, it is urgent to develop “micro” intelligent sensors with strong data processing ability. By carrying the edge intelligent chip in the existing sensors, the intelligent upgrading of the existing commonly used sensors can be realized, so as to realize the edge terminal processing of the collected data, which greatly improves the power grid information collection ability and data analysis ability. The architecture of the environmental monitoring system for electrical equipment based on the edge intelligent sensor is shown in Figure 5.

6. Scientific Problems and Technical Bottlenecks

6.1. Scientific Problems. The research and development of power specific chip is still in its infancy, and the key scientific

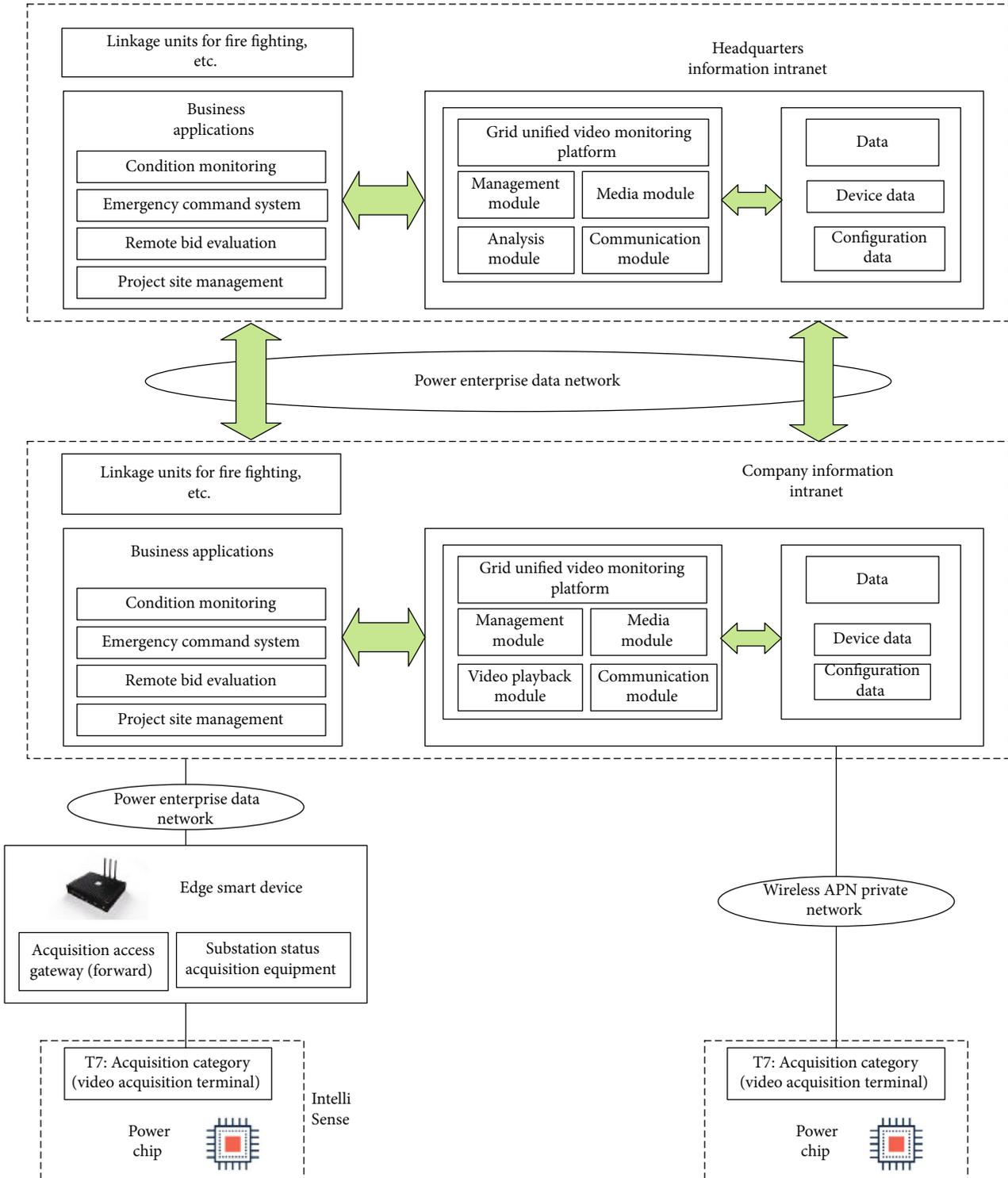


FIGURE 4: Topology diagram of unified video monitoring platform for power grid based on AI chip.

problem to be solved is how to realize the chip-based intelligent perception and analysis of the power IoT facing the fragmentation of scene and the complex data information. The IoT of power system has caused massive demand for intelligent scenarios and business data to be analyzed, and the computing resources of power chips are limited. Therefore, the research on the chip intelligent perception and efficient anal-

ysis architecture model of the power IoT is the focus of the power special chip research and also an important scientific problem to be solved.

In addition, in the practical application of the chip, it is usually faced with the influence of many factors, such as electricity, magnetism, and force, which lead to the degradation or failure of chip performance. Due to the complexity of

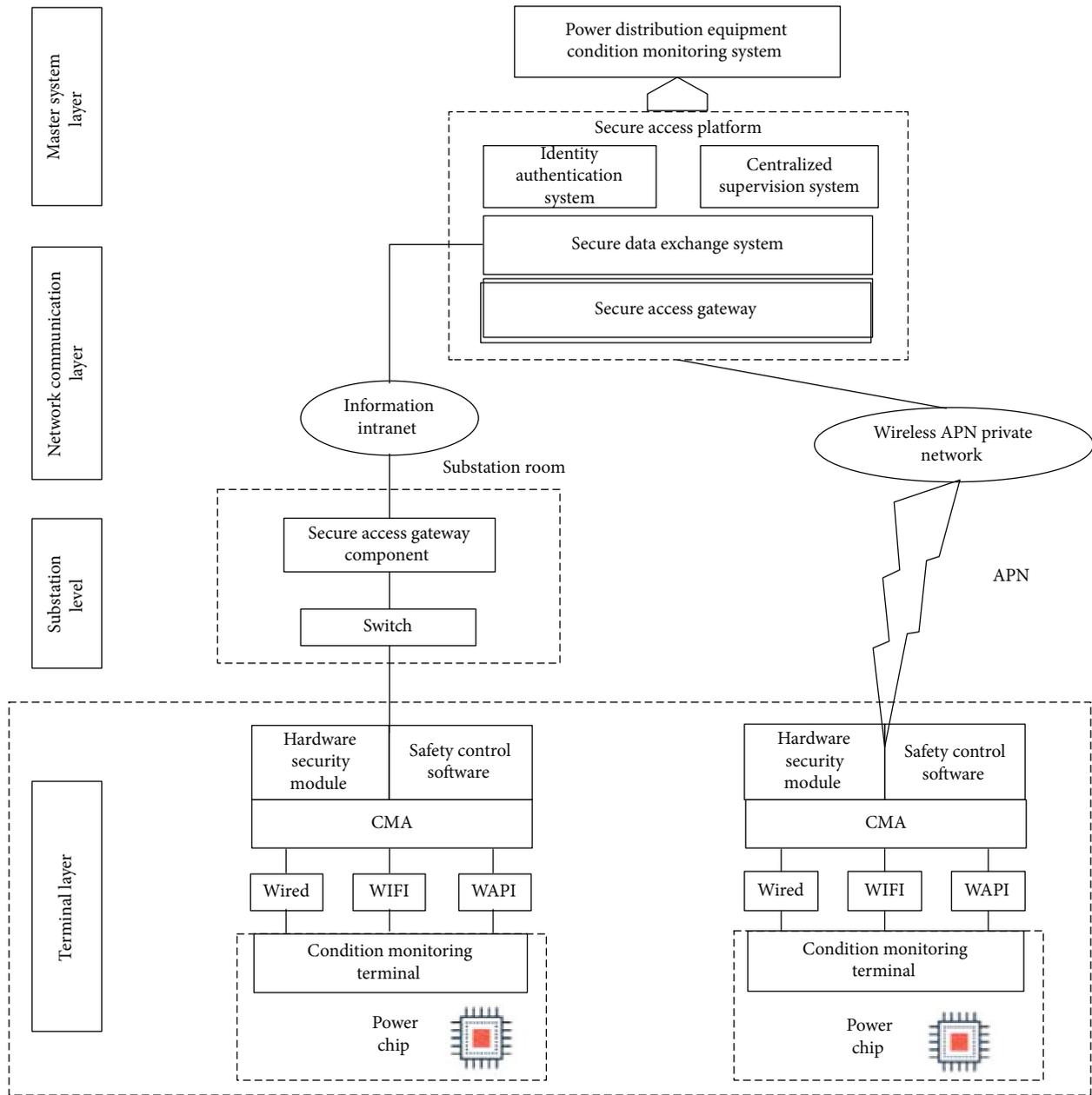


FIGURE 5: Architecture diagram of the environmental monitoring system for electrical equipment based on power chips.

electromagnetic environment, the diversity of equipment structure, and the small and micro nature of power chips, it is often difficult to find out the physical mechanism of power chip failure, and it is difficult to determine and reproduce the failure causes and processes of power chips. Therefore, it is another scientific problem to study the influence of complex electromagnetic environment on chip performance and qualitative analysis.

6.2. *Key Technical Bottlenecks.* The key technical bottlenecks in the field of power chips mainly include the following four aspects:

(1) To meet the needs of energy and power industry, the architecture design of power dedicated chip is discussed. Due

to the specific industry requirements of the energy and power industry, it is necessary to design and optimize the chip architecture and configuration, rather than simply use the general chip architecture. How to optimize the architecture and redundancy according to the specific needs of the energy and power industry and how to research and optimize the configuration of customized architecture are the key bottlenecks to realize the independent control of power chips

(2) The problem of chip level power intelligent algorithm for protection, measurement, and control and intelligent sensor services is presented. Power protection, measurement and control, environmental monitoring, and other business need high precision, high reliability, small and micro, integration, so the corresponding edge intelligent analysis

algorithm of power chip also needs to be optimized. On how to consider the requirements of protection, measurement, control, and sensing in the field of energy and power, research and verifying various new applicability algorithms in the environment of miniaturization, distribution, and integration is the key to realize the intelligent upgrade of power chip

(3) Performance compatibility and detection of power chip in strong electromagnetic environment: power system is a strong power operation environment; electromagnetic interference has a great impact on power chips. How to find the special problems of power chips in high voltage and strong electromagnetic environment and to form the EMC research and performance function testing standard system of power chips under strong electromagnetic environment is of great significance to the application and promotion of power chips

(4) Intelligent customization of power chip under the demand of power fragmentation scenario: with the development of the power IoT, all scenarios of power system need chips with intelligent analysis function. It is of great significance to study the integrated application problems of power chips, such as easy-to-use requirements, edge intelligent algorithm requirements, large-scale tasks, and information flow collaboration, when applied to different engineering scenarios and specific systems

7. Conclusion

This paper discusses the specificity of power chip, puts forward the definition and research object of power chip, analyzes its typical application scenarios, and looks forward to the scientific problems and main technical bottlenecks of power chip. The main conclusions are as follows:

(1) Power chip is the inevitable product of the development of power IoT, artificial intelligence, and chip and measurement technology. And it is also the priority development field of the power industry in the future. The key to data perception and analysis in the construction of the power IoT is also the basis for the grid to realize full customer state perception and business full penetration

(2) At present, the focus of power chip research is on architecture design, chip level intelligent algorithm, performance test system and method, scene fragmentation application, autonomous chip algorithm and structure framework, etc.; breaking through the bottleneck of chip is the key to solve the problem of independent and controllable power chip

Data Availability

The data presented in this study are available on request from the corresponding author: dr.mohamed.abdelaziz@mu.edu.eg.

Conflicts of Interest

The authors declare no conflict of interest.

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