Deloitte.

国家电网
STATE GRID
全球能源互联网研究院有限公司
GLOBAL ENERGY INTERCONNECTION RESEARCH INSTITUTE co.,Ltd.

5G Empowers
The Future of Electricity

Preface

5G is changing society, and electricity is lighting up the future. Nevertheless, how does 5G empower the smart grid? What application scenarios are covered? Where are the major challenges? How to move from technology innovation to commercial practice? These questions are what inspired this report.

From the requirements, technology development, test and verification of 5G scenarios in 2014, to the full-scale 5G trails in 2018, to 5G pilot commercialization in 2019, and full commercialization in 2020, 5G's value extends from the laboratory to vertical applications, enabling more improvement in the development of existing products, service enhancement, and business expansion throughout various industries.

It is estimated that 5G-enabled global digitalization revenues for ten major industries will be USD1.3 trillion in 2026, with energy and utilities (water, electricity, gas, etc.) accounting for the highest share of 19%, or about USD250 billion. Electricity is undoubtedly a key track and explosive industry for 5G vertical applications. 5G communication features are highly compatible with the requirements of electric power communication. 5G can fully empower the application scenarios of smart grid, which will have far-reaching social impact on and great economic value to the electricity industry.

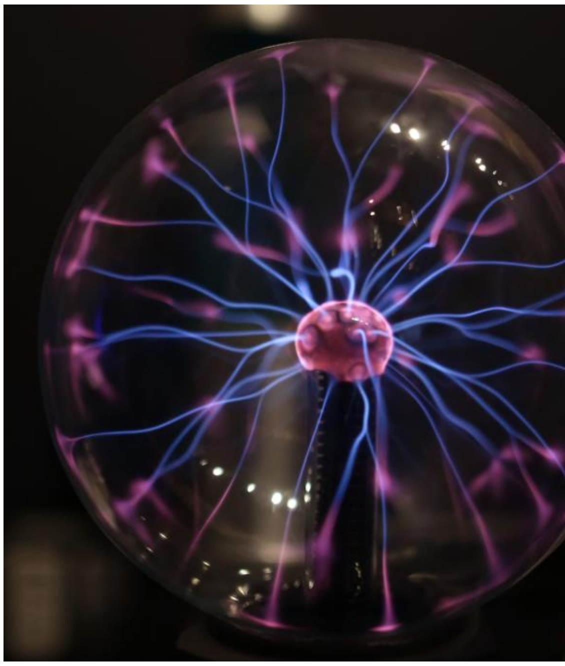
In this context, the Global Energy Interconnection Research Institute (GEIRI) and Deloitte China co-authored the report. Backed by the State Grid's Electric Power Communication Network (EPCN) Laboratory, Mr. Zhou Fei, Mr. Li Binglin, Mr. Wu Peng, and Mr. Guo Yunfei of GEIRI, who have insight into the electricity industry, reviewed four application scenarios of 5G in the industry, and analyzed the specific applications, architecture and communication requirements in each scenario. With years of consulting experience and insights into the industry, Ms. Jiang Vivian, Mr. Guo Kevin Xiaobo, Ms. Zhang Jennifer, and Ms. Qu Jill Qianru of Deloitte China pinpointed the major challenges of 5G applications and made constructive comments on key measures for 5G commercial use in the electricity industry. These useful studies, analyses, and discussions target the main questions that companies within the ecosystem have about "5G empowers electricity", and contain insights and constructive suggestions from the writing team, which can help relevant companies actively address the challenges and move from technology innovation to commercial application.

The past isn't even past, but the future has arrived. Enjoy your reading!

Tony Hu
Dean of Deloitte 5G Next Generation Application Academy

Contents

1. 5G drives the future of electricity



Most of the electric power scenarios will be built on the Energy Internet, where energy is generated and shared anytime and anywhere just like information, presenting new trends and characteristics: clean and friendly power generation, combination of multiple distributed clean power sources, integration of energy storage and electric vehicles, as well as balance of decentralization, reliability and load, with clean and low-carbon, grid-power source coordination, flexible and efficient features; safe and efficient power transmission/transformation, characterized by situation awareness, flexibility, reliability, and coordinated optimization; flexible and reliable power distribution, featuring controllable, compatible and economical nature; diverse and interactive power consumption, with the characteristics of diversity, two-way interaction, flexibility, energy saving and efficiency.

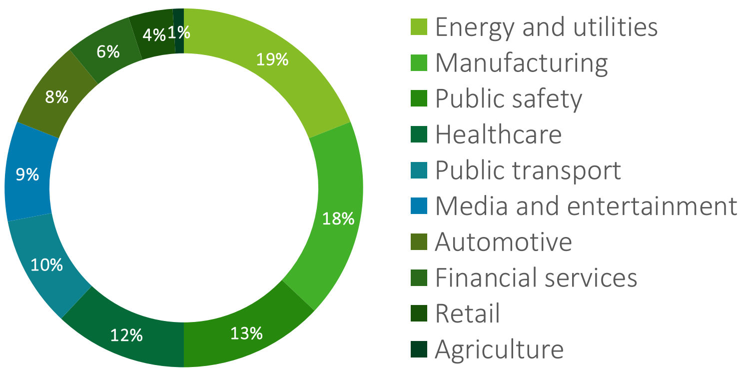
Communication technology lays the foundation for digital applications in the electricity industry, and supports the development of the Energy Internet. Power grids are currently interconnected through different types of communication networks. However, as the electricity needs grow increasingly diverse, a more sophisticated, inclusive and innovative system is required to interconnect mass equipment and transfer data.

1.1 5G in the electricity industry

The 5G-enabled three scenarios – enhanced mobile bandwidth (eMBB), ultra-reliable low latency communication (uRLLC) and massive machine type communication (mMTC) - have the technical characteristics of ultra-high bandwidth, ultra-low latency and large scale connectivity, and play an important role in the power generation, transmission, transformation, distribution, consumption, dispatching and emergency communication process in the power system. They can transform the EPCN and comprehensively promote the informatization of the power system. It is estimated that 5G-enabled global digitalization revenues for ten major industries will be USD1.3 trillion in 2026, with energy and utilities (water, electricity, gas, etc.) accounting for the highest share of 19%[1], or about USD250 billion.

Figure 1: 5G-enabled digitalization revenues by industry in 2026

5G-enabled industry digitalization revenues will be USD1.3 trillion in 2026



Source: Ericsson, *The Industry Impact of 5G*, Deloitte Research.

5G communication features highly compatible with EPCN requirements

5G networks have much higher peak, regional and edge rates than 4G. With a peak rate of up to 20Gbps, 5G can satisfy the demand for massive data transmission, such as high-definition (HD) video and virtual reality. 5G communication latency is an order of magnitude less than 4G, particularly the air interface latency of about 1ms, thus laying the root for power differential protection, precise load shedding and other ultra-low latency applications. A 5G network has higher capacity, enabling the connection of 1 million terminals per square kilometer, e.g. smart home appliances, and using the power of Internet of Things (IoT) technology can access massive smart terminals. 5G technology reduces energy consumption of sensors or nodes by optimizing communication principles, thus eliminating the need to replace communication device batteries or the need to recharge, which provides a good technical basis for the Internet of Everything.

Figure 2: 5G communication features highly compatible with EPCN requirements

EPCN requirements	5G communication features	Description
Reliable operation	High reliability	Safe and reliable operation is a basic requirement for power systems, and highly reliable 5G can raise grid reliability.
Flexible response and precise control	Low latency	Power systems require flexible response, and zero disruption in some services. 5G millisecond latency can match the grid's real-time communication needs.
Massive data transmission	High rate	The continuous increase in the scale of power IoT applications generates massive real-time measurement data and video surveillance data. High-speed 5G will strongly support massive data transmission.
Internet of Everything	Massive connection	Widely connected 5G helps the grid to connect smart terminals at scale.
Long battery life	Low energy consumption	5G optimizes communication hardware protocols and improves the battery life of grid devices.

Source: *Power System Technology*, Deloitte Research.

5G features highly compatible with smart grid performance

The 5G-based smart grid will greatly facilitate the penetration of distributed new energy, distributed energy storage, electric vehicles, high-power electric smart machines and other new appliances into homes, commercial buildings, factories and designed zones, while providing connectivity for personalized, diverse and market-oriented energy supply services. 5G offers an ubiquitous, flexible, cost-efficient, quality new technology option for power terminal access networks, and serves as a powerful foundation for building a more secure, reliable, green, and efficient smart grid. 5G+Smart Grid will significantly reduce the average power outage time for customers and effectively improve power supply reliability and management efficiency. It will also greatly enrich and expand grid application scenarios, reduce costs and increase benefits, and help transform the grid into an integrated energy service provider to deliver better integrated power services to customers. 5G will greatly affect the power quality, response speed and service scope of power supply services. The launch of full-scale smart grid services due to 5G will significantly improve the quality of grid services. 5G-based power quality monitoring and management can reduce power supply faults or failures. The new technology also enables rapid customer service response, as well as fast and convenient new energy installation, electric charging pile installation, electricity bill settlement, billing inquiries, and minute-by-minute electricity consumption inquiries.

1.2 Global and Chinese 5G+electricity development

A total of 42 countries and regions have deployed 5G for commercial use, 386 operators have announced investments in 5G, and 81 operators have launched one or more 5G services that support 3GPP standards.

Standard developing

Standardization ensures interoperability and network security of devices and solutions connected to the 5G network. Third Generation Partnership Project (3GPP) is the foremost international organization for 5G standards development, with members from transportation, energy and other key vertical industries for communication applications. 3GPP enrolled 500 members from more than 40 countries, including the three major telecom operators, i.e. China Mobile, China Telecom and China Unicom, as well as major communications equipment manufacturers, such as Huawei and ZTE. China Electric Power Research Institute (or Energy Interconnection Technology Research Institute of State Grid) joined the international standardization organization 3GPP in April 2020, marking an important step for Chinese electric power companies to participate in the development of 5G international standards.

In August 2020, the 5G smart grid research project was established in the 3GPP Release 18 (R18) standard, which was jointly initiated by 28 participants led by China Telecom, including State Grid, China Southern Power Grid, Huawei, China Mobile and China Unicom as members of 5G Deterministic Networking Alliance, as well as other operators and equipment manufacturers at home and abroad. The project covers traditional energy system services, remote control and protection, metering and advanced metering infrastructure, distributed power generation, distributed automation, demand response, energy management systems, power distribution management systems, as well as other smart grid services. It is the first end-to-end standards system to define the 5G+smart grid, and creates a standards framework and platform for the rapidly evolving 5G+smart grid.

Commercial deployment

Many countries place a high priority on 5G deployment. The EU has identified 5G as a key initiative to build a "digital single market" and plans to deploy 5G in all member states by the end of 2020, focusing on 5G applications in vertical sectors, such as automotive, healthcare and electricity. The US 5G development plan focuses on its three major operators. In particular, AT&T and T-Mobile have announced low-band coverage of 5G networks across the country. The plan works towards a common 5G software standard applicable to all 5G hardware devices in order to free from its dependence on 5G equipment manufacturers; Dell, Microsoft and AT&T are currently considered as the lead players in developing the US 5G infrastructure. Three major telecom operators in Japan launched 5G services successively in March 2020, marking its beginning of the 5G era. South Korea had a 5G NSA pre-commercial trial during the 2018 PyeongChang Winter Olympics and began commercial deployment in March 2019. China started to make requirements, develop technology, and run testing and verification for 5G scenarios in 2014, with full-scale 5G trails in 2018, 5G pilot commercialization in 2019 and full commercialization in 2020.

2020 is critical for China 5G construction. The three major operators plan to build 550,000 5G base stations by the end of the year, including 300,000 by China Mobile and 250,000 jointly by China Unicom and China Telecom. The operators' financial reports for the first three quarters show that they have over fulfilled their 5G network construction targets, with SA core networks covering all cities above the prefecture level in 31 provinces, autonomous regions and municipalities. According to the Ministry of Industry and Information Technology (MIIT), by the end of September, a total of 690,000 5G base stations were opened nationwide, accounting for more than 75% of the global total, with over 160 million users and over 32,000 base stations for industry applications, and many typical application scenarios have emerged, such as data collection and perception, HD video, machine vision, precise remote control, field assistance, and digital twin.

Figure 3: China leads the world in 5G commercialization

5G commercialization progress in major countries

<table>
<tr><th></th><th>2017</th><th>2018</th><th>2019H1</th><th>2019H2</th><th>2020</th><th>After 2021</th></tr>
<tr><td rowspan="3">First tier
China, the US, Japan, Korea and some European countries</td><td colspan="3">5G R&D and trials</td><td colspan="3"></td></tr>
<tr><td colspan="2"></td><td colspan="2">Commercial use</td><td colspan="2"></td></tr>
<tr><td colspan="4"></td><td colspan="2">Large-scale commercial use</td></tr>
<tr><td rowspan="3">Second tier
Most European countries</td><td></td><td colspan="3">5G R&D and trials</td><td colspan="2"></td></tr>
<tr><td colspan="4"></td><td colspan="2">Commercial use</td></tr>
<tr><td colspan="5"></td><td>Large-scale commercial use</td></tr>
<tr><td rowspan="2">Third tier
Emerging countries in Asia Pacific and the Americas</td><td colspan="2"></td><td colspan="3">5G R&D and trials</td><td></td></tr>
<tr><td colspan="5"></td><td>Commercial use</td></tr>
</table>

China takes the lead in 5G	The U.S. leads in 5G strength overall
• China has become a leader in 5G technology with commercial 5G contracts covering 30 countries, including 20 in Europe • China leads the world in the number of cities where 5G is commercially available • In 2030, the direct economic value added by 5G will exceed RMB3 trillion, contributing 5.8% to GDP growth • China's 5G mobile phone shipments are expected to be 140 million units in 2020, accounting for nearly 80% of the global share • China started to develop 6G technology • China now has over 60% of the world's 5G base stations	• AT&T has achieved nationwide coverage of its 5G network, with access for both business and personal users • T-Mobile has expanded its mid-band 5G coverage to 81 new cities and plans to employ Sprint's 2.5 GHz spectrum assets in thousands of locations by the end of 2020 • With the 2020 launch of Apple's 5G iPhone, 5G phones are expected to contribute approximately 20% of total mobile phone sales in the country, as the brand dominates nearly 40% of the U.S. smartphone market • The four largest mobile operators in the U.S. have acquired 4.082 million 5G subscribers

Source: Deloitte Research.

Industry applications

In March 2020, the MIIT and the National Development and Reform Commission issued the *Circular on Organizing Implementation of the New Infrastructure Construction Project in 2020 (Broadband Network and 5G Field)*, which focuses on supporting innovative applications of 5G in seven industries, including smart grids. The circular indicates that regarding the scale application of 5G technology in smart grid, the state will develop 5G end-to-end network slicing and resource scheduling system, as well as key network equipment and prototype system based on the 5G network architecture and smart grid scenarios to provide integrated smart grid solutions incorporating 5G technology.

Under the guidance of national policies, 5G smart grid construction plans have been made across the country, particularly in Xiong'an, Inner Mongolia, Yunnan and Hainan, where 5G smart grid construction have been initiated. In Xiong'an, for example, 5G is deeply integrated with power grid engineering construction, and the adaptability of 5G-based power services has been verified on a pilot basis, with distribution automation and electricity information collection services selected for bearing capacity testing. Moreover, the first domestic "5G+MEC (Mobile Edge Computing)" power protection IoT demonstration project based on SA (Stand-Alone) architecture was officially put into operation in October 2020 in Xiong’an with world-class core technology.

The power grid companies are pioneers and leaders in research and engineering 5G smart grid technology. State Grid has extensive 5G service research and application practice, concentrating on 5G smart grid erection, control services (e.g., differential protection for distribution network) and mobile inspection services (e.g., video interaction). The first phase of the Qingdao 5G Smart Grid Project, jointly developed by the State Grid Qingdao Electric Supply Company, China Telecom Qingdao Branch and Huawei Technologies Co., Ltd., was officially delivered and put into operation in July 2020. As reported, this project can not only automatically remove faults in distribution lines within tens of milliseconds, but also reduce the power consumption of each 5G base station by 20% through a peak-clipping and valley-filling strategy. This greatly alleviates the problem of high energy consumption by 5G technology. China Southern Power Grid also actively works on pilot and joint application, specializing in 5G smart grid control services like differential protection for distribution network. China Southern Power Grid and China Mobile established the largest 5G Smart Grid Application Demonstration Zone in Mingzhuwan area of Nansha District, Guangzhou, with 54 application scenarios and 14 services launched.

In addition, operators have accelerated their 5G cooperation with the electricity industry and put the "5G empowers electricity" into practice, including control (precise load control, and differential protection for distribution network), collection (electricity consumption information collection) and mobile inspection services. Some power equipment companies also work closely with communication equipment companies and are ready to enter the market.

S

2. Major 5G application scenarios in the electricity industry

There are four major application scenarios for 5G in the electricity industry: control services, collection services, mobile application services, and new services of the power grid typified by multi-station integration. In control services, 5G technology optimizes energy distribution to avoid the impact of mass power outages on business and residential electricity consumption, and is also used for online monitoring of real-time dynamic data in the distribution network. In collection services, 5G drives the collection and provision of raw power consumption across the system. In mobile application services, 5G prevents safety accidents and environmental pollution, reduces manual inspection workload, and allows for simple hot-line operations in the future. In multi-station integration services, 5G technology promotes the construction of platform-based and sharing companies.

Figure 4: The four major application scenarios of 5G in the electricity industry

Scenario	Sub-scenario	5G enabling	Communication requirements				
			Bandwidth	Latency	Reliability	Connection density	Security
Control services	1 Precise load control	• According to DC power loss, the interruptible load of massive distributed power users is precisely controlled to **enable the interaction between the grid and power sources/loads**, as well as instantaneous balance of power supply and demand.	<256kbps	Master station to terminal ≤50ms	>99.999%	<1,000 devices /100km²	High security requirements, particularly exclusive resources and physical isolation
	2 Differential protection for distribution network	• Terminal sampling and operating data are collected, and **a fast response to the fault is made with differential protection algorithms. If a fault is identified, the terminal disconnects appropriate switch, and thus the fault is precisely located and isolated in the distribution network.** The service is fast, dynamically adaptable, and reliable in fault identification.	<10 Mbps	End to end in the service system ⩽15ms, end to end in the communication system ⩽10ms	>99.999%	<1,000 devices /100km	High security requirements, particularly exclusive resources and physical isolation
Collection services	3 Electricity consumption information collection	• The service provides **automatic electricity consumption information collection**, metering anomaly monitoring, power quality monitoring, electricity consumption analysis and management. The electricity consumption information collection system consists of master stations, remote and local channels, concentrators and collectors/meters.	Upstream<2Mbps, downstream<1Mbps	Public/private transformer check, low-voltage set copy <3s, accurate fee control <200ms	>99.99%	<10,000 devices/km²	High security requirements, such as authenticated encryption, access area authentication, IoT slicing, and logical isolation
Mobile application services	4 Mobile inspection	• The service involves three major scenarios: transformer station inspection robot, mobile field operation control, and emergency ad hoc network integrated application. **Mobile inspection targets low-rate mobile scenarios and monitors the overall environment of the server room, which helps to prevent safety accidents and environmental pollution, reduce manual inspection workload, and improve operation and maintenance efficiency.**	Constant and stable bandwidth of 4-100Mbps by scenario	Multimedia data <200ms, control data <100ms	99.9% for multimedia data, 99.999% for control data	2 to 10 devices, concentrated in local areas	
New services of the power grid	5 Multi-station integration	•The service provides local storage and edge computing for data from transformer stations. As an extension of cloud computing, network edge computing supports and strengthens smart grid business internally, and expands energy service channels externally. As a result, **it accelerates the development of power IoT and provides resource sharing services to the community.**	100Mbps-1G	5ms-20ms		10 to 1000 devices, concentrated in local areas	

Source: GEIRI, Deloitte Research.

2.1 Control services

Grid control services require low latency, highly reliable and secure communications, which are fit for uRRLC application scenarios for the 5G technology system. Typical control services include precise load shedding control services, and differential protection services for distribution networks.

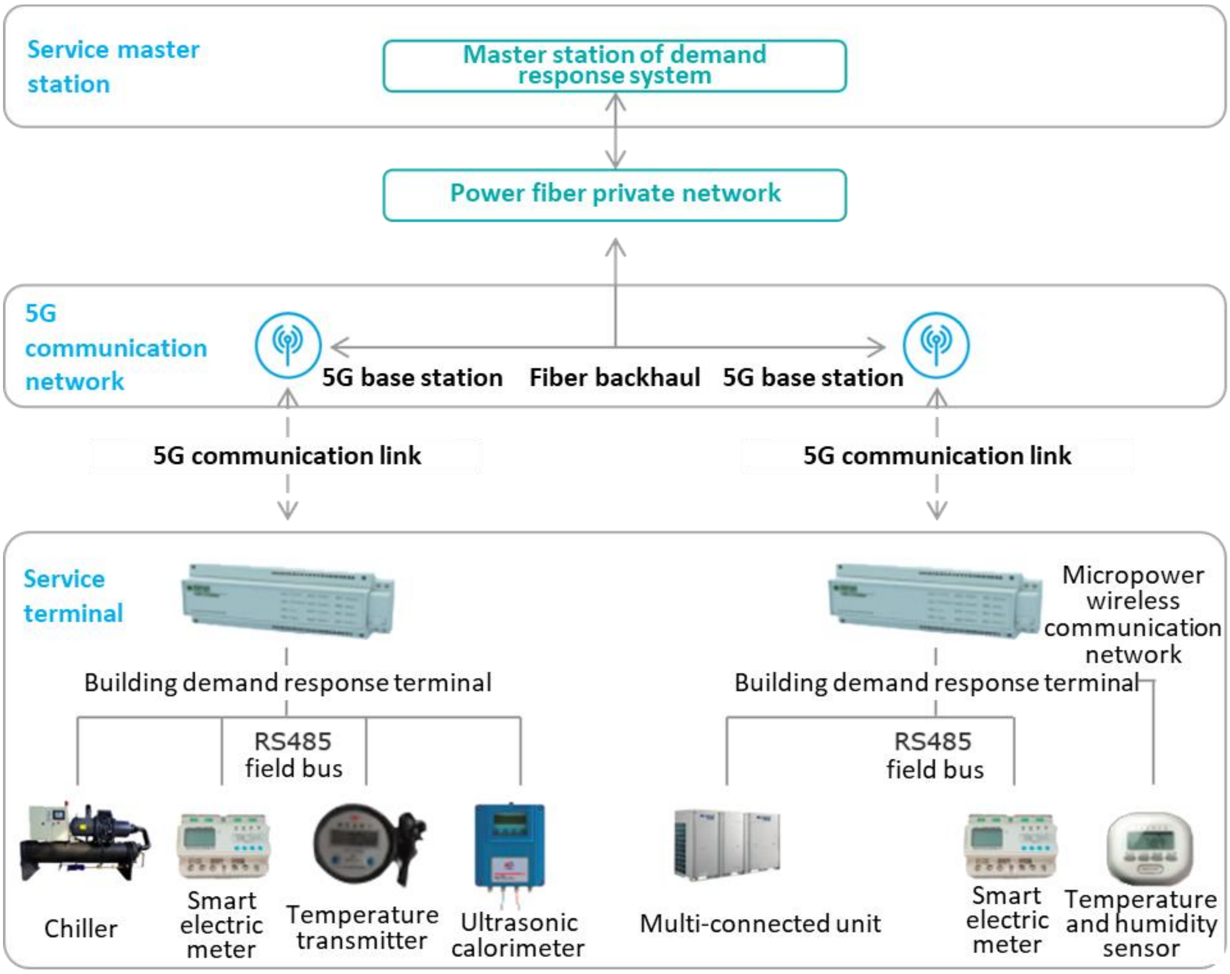
2.1.1 Precise load control

1) Application scenarios

Precise load control technology refers to the precise control of massive distributed power users' interruptible load according to DC power loss in the context of DC blocking, large active power shortages and sharp frequency drops in the receiving-end grid due to successive phase change failures and faults in multi-infeed DC power grid. This enables good interaction between the grid and power sources/loads as well as instantaneous balance of power supply and demand, supports optimal energy distribution on a large scale, avoids mass power outages, and minimizes grid losses and the impact on business and residential electricity consumption.

The precise load control system consists of service terminals, demand response terminals, a communication network and a master station system. In this case, the service terminal is connected to the building's demand response terminal via a local network, and then to the master station of the demand response system via a 5G communication network. The specific application scenarios are shown in the figure below.

Figure 5: Application scenarios for 5G-based precision load control services



Source: GEIRI.

2) Communication requirements

The precise load control system requires fast restoration of the supply and demand balance within the large grid. The grid frequency must be restored to its normal value (50Hz) within about 650ms after a DC blocking fault, so the latency of the communication channel from the master station to the terminal for transmitting load shedding commands does not exceed 50ms. The less the whole-set action time of the precision load control system, the faster the grid fault recovery. Therefore, the communication latency shall be minimized. The requirements for communication emphasize latency, availability, security and reliability. The details are as follows.

- Bandwidth: <256kbps
- Latency: Master/sub-station to terminal ≤50ms
- Reliability: ＞99.999%
- Connection density: <1,000 devices/100km²
- Network slicing: End-to-end hard network slicing with exclusive access to slicing resources
- Security: High security requirements, particularly exclusive resources and physical isolation
- Timing accuracy: <10us
- Communication mode: Master-slave mode, always-on and uninterrupted high frequency communication

2.1.2 Differential protection for distribution network

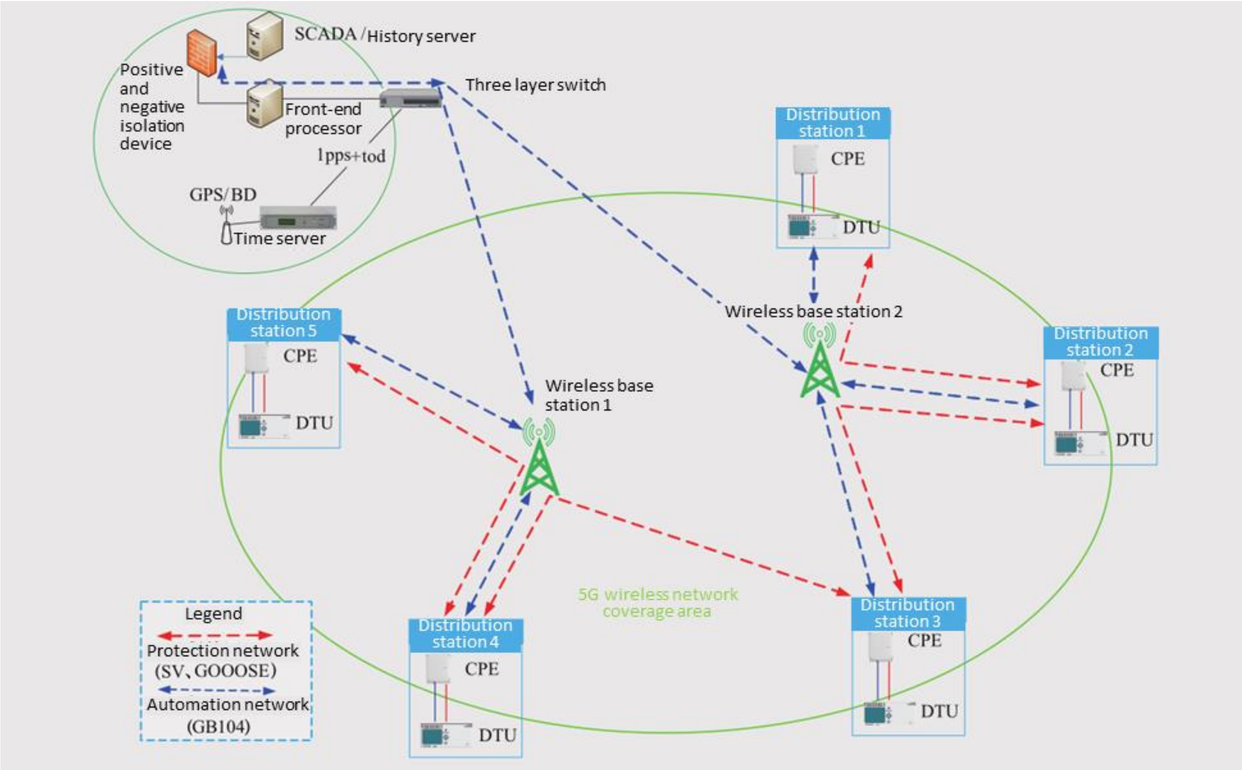
1) Application scenarios

As a mature technology applied to high-voltage transmission networks, differential protection provides an ideal solution to problems caused by the connection of distributed power sources to the distribution network. It works by comparing the current values (vectors) of two or more differential protection terminals at the identical moment. If their difference exceeds the setting value, the terminal identifies a fault and disconnects appropriate circuit breakers or switches for differential protection, which enables the precise location and isolation of faults in the distribution network.

As distributed new energy sources are connected to the distribution network on a large scale, the charging load of electric vehicles will grow rapidly. As a result, the source, network and load of the distribution network are subject to constant random fluctuations and intermittency due to the greater spatial and temporal uncertainty, and bi-directional currents, multiple source faults and many other issues come to the fore. In respond to the multiple harmonics and strong noise characteristics of the distribution network, high-precision and miniature synchronized phasor measurement units (PMU) are applied for the online monitoring of its real-time dynamic data.

The distribution network automation system generally consists of a distribution master station, distribution substations (optional and usually located in transformer stations), distribution remote terminals (FTU, DTU, TTU, etc.) and a communication network. The distribution master station models, monitors in real time and synchronizes the clock for the entire power distribution system. The distribution management system makes dynamic analysis on the topology of the entire distribution network and transmits data on topology changes to each DTU or FTU terminal. The system also makes dynamic analysis on the differential protection function of the terminal and decides whether to enable/disable its protection function. As for differential protection, a subsystem of the distribution network automation system, its DTU and FTU transmit respective sampling and tripping data to neighboring terminals, and collect sampling and operating data from neighboring terminals for quick response to faults using differential protection algorithms. The service is fast, dynamically adaptable, and reliable in fault identification. The specific application scenario is shown in the figure below.

Figure 6: 5G-based differential protection system



Source: GEIRI.

2) Communication requirements

The differential protection service is determined by the current difference between its terminals at the identical moment, and requires two or more interconnected terminals to be time synchronized, with timing accuracy <10µs and information interaction latency ≤12ms (peer to peer maximum latency). Its requirements for communication focus on latency, availability and reliability. The details are as follows.

- Bandwidth: <10Mbps
- Latency: End to end in the service system ≤15ms, end to end in the communication system ≤10ms
- Reliability: ＞99.999%
- Connection density: <1,000 devices/100km²
- Network slicing: End-to-end hard network slicing with exclusive access to slicing resources
- Security: High security requirements, particularly exclusive resources and physical isolation
- Timing accuracy: <10us
- Communication mode: Multi-party, master-slave (for automation service) and device-to-device mode; always-on and uninterrupted high frequency communication

2.2 Collection services

Despite the difficulty of wired communication coverage, grid collection services require communication with massive sites and connection, but have no strict requirements for latency and are therefore suitable for mMTC application scenarios under the 5G technology system. A typical service is the collection of electricity consumption information.

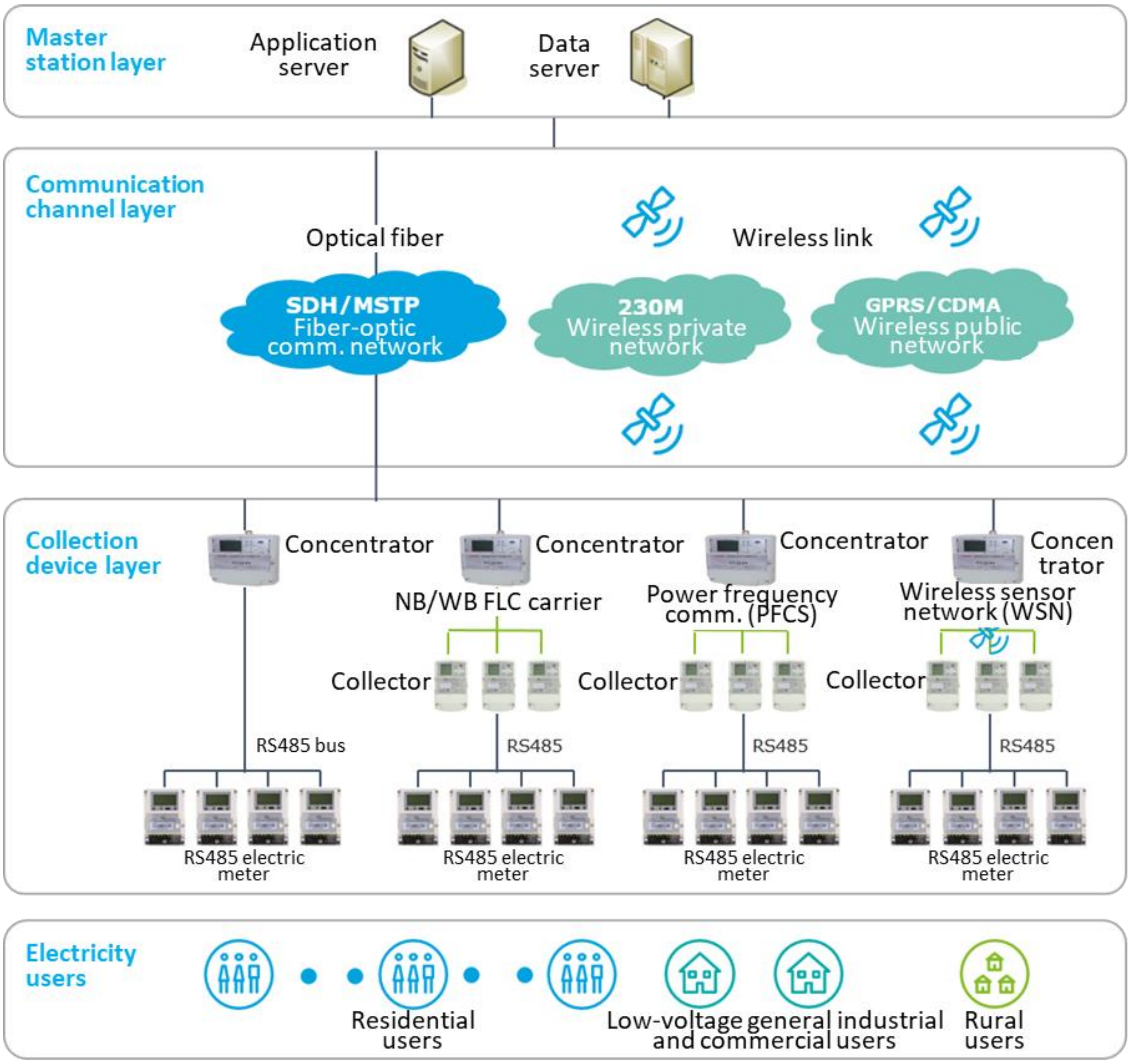
2.2.1 Electricity consumption information collection

1) Application scenarios

The service provides automatic electricity consumption information collection, metering anomaly monitoring, power quality monitoring, electricity consumption analysis and management. The electricity consumption information collection system consists of master stations, remote and local channels, concentrators and collectors/meters. The system involves both upstream and downstream transmissions. The upstream transmission refers to the electric meter data of low-voltage commercial and industrial, residential as well as public (distribution) transformer users are uploaded to the concentrator via the collector (optional), and then transmitted to the system's master station through the upstream communication channel; the electric meter data of private transformer users are uploaded to the appropriate terminal and then transmitted to the system's master station through the upstream channel. Most of the terminals are deployed in corridors, eaves as well as distribution rooms of the community, and some in basements.

The electricity consumption information collection system is logically divided into the master station layer, communication channel layer and collection device layer. The master station layer consists of marketing and collection service applications, front-end collection platform, as well as database. Service applications implement various service logics of the system; data collection includes terminal power consumption information collection and protocol analysis; control operations are executed by service terminals; and the front-end processor is used for communication management and scheduling of terminals. The communication channel layer provides the link basis for information interaction between the master station and the terminal/collection device, and is classified into wired and wireless communication channels, such as fiber-optic private network, wireless public network, wireless private network, and medium voltage power line carrier. Collection devices, as the base layer of the electricity information collection system, collect and supply raw electricity consumption information for the entire system. The specific application scenario is shown in the figure below.

Figure 7: Electricity consumption information collection system



Source: GEIRI.

2) Communication requirements

The service requires a communication rate of no less than 1.05 kbps with customers, and a transmission rate of at least 2.5 kbps for load control commands. The detailed communication requirements are as follows.

- Bandwidth: upstream <2Mbps, downstream <1Mbps
- Latency: public/private transformer check, low-voltage set copy <3s, accurate fee control <200ms
- Reliability: ＞99.99%
- Connection density: <10,000 devices/km²
- Security: high security requirements, such as authenticated encryption, access area authentication, IoT slicing, and logical isolation
- Communication mode: always online, frequency ≤5mins/time

2.3 Mobile application services

The mobile application services' communication requirements are characterized by high bandwidth and security, so they are suitable for eMBB application scenarios under the 5G technology system. A typical service is mobile inspection.

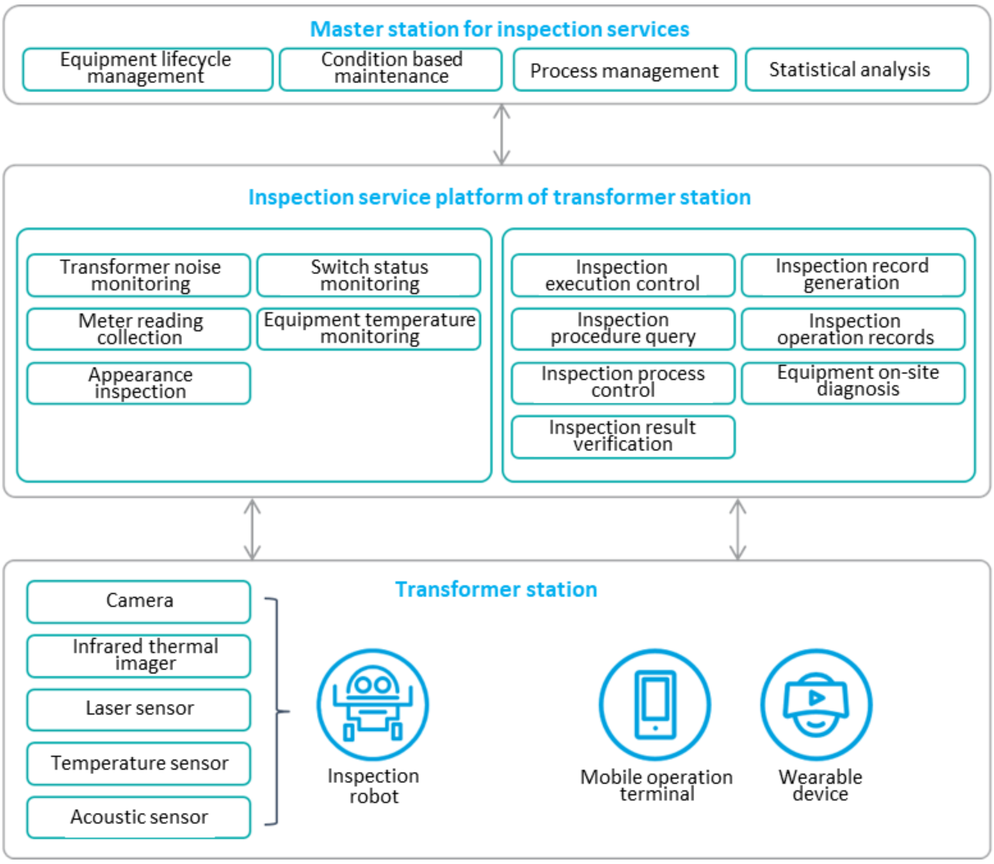
2.3.1 Mobile inspection

1) Application scenarios

Mobile inspection involves three major scenarios: transformer station inspection robot, mobile field operation control, and emergency ad hoc network integrated application. The service mainly targets low and medium rate mobile scenarios in power production management and monitors the overall environment of the server room by collecting and identifying pictures and videos of power distribution cabinets and switchgears to extract information on their operating and switch status. This prevents safety incidents and environmental pollution, reduces the manual inspection workload to avoid the uncertainty of manual field work, and greatly improves operation and maintenance (O&M) efficiency by reducing labor costs. The service even allows inspection robot to perform simple hot-line operations in the future.

The inspection robot service focuses on comprehensive monitoring of the electrical primary equipment status and security inspections within the scope of 110kV and above transformer stations. At present, the inspection robot is mainly connected to Wifi, and most of its inspection videos are kept locally in the station and cannot be transmitted back to the remote monitoring center in real time. The application scenarios are shown below.

Figure 8: Application scenarios for mobile inspection services



Source: GEIRI.

2) Communication requirements

In the future, inspection robots for transformer stations will mainly be equipped with multi-channel HD video cameras or environmental monitoring sensors, and will be capable of transmitting relevant inspection data back to the remote monitoring center in real time. In some cases, inspection robots even perform simple hot-line operations, for example opening and closing barrier gates. The service requires multi-channel HD video returns at Mbps, and remote control of the inspection robot with millisecond latency. Communication requirements of the mobile inspection include:

- Bandwidth: constant and stable bandwidth of 4-100Mbps by scenario
- Latency: multimedia data <200ms, control data <100ms
- Reliability: 99.9% for multimedia data, 99.999% for control data
- Isolation: the service basically falls into power grid's Safety Zone III, which has lower security requirements than Zone I/II. However, a few control functions, e.g., the control information required to remotely operate the inspection robot, are in Zone I/II.
- Connection density: 2 to 10 devices, concentrated in local areas
- Mobility: relatively low mobility at 10-120km/h

2.4 New services of the power grid

The new services of the power grid emerge with the construction of smart grid and power IoT, which present more individual communication needs but lack the same accumulation of communications as traditional services. 5G technology can be well integrated with traditional communication methods to satisfy individual communication needs of various such new services. A typical new service of the power grid is multi-station integration.

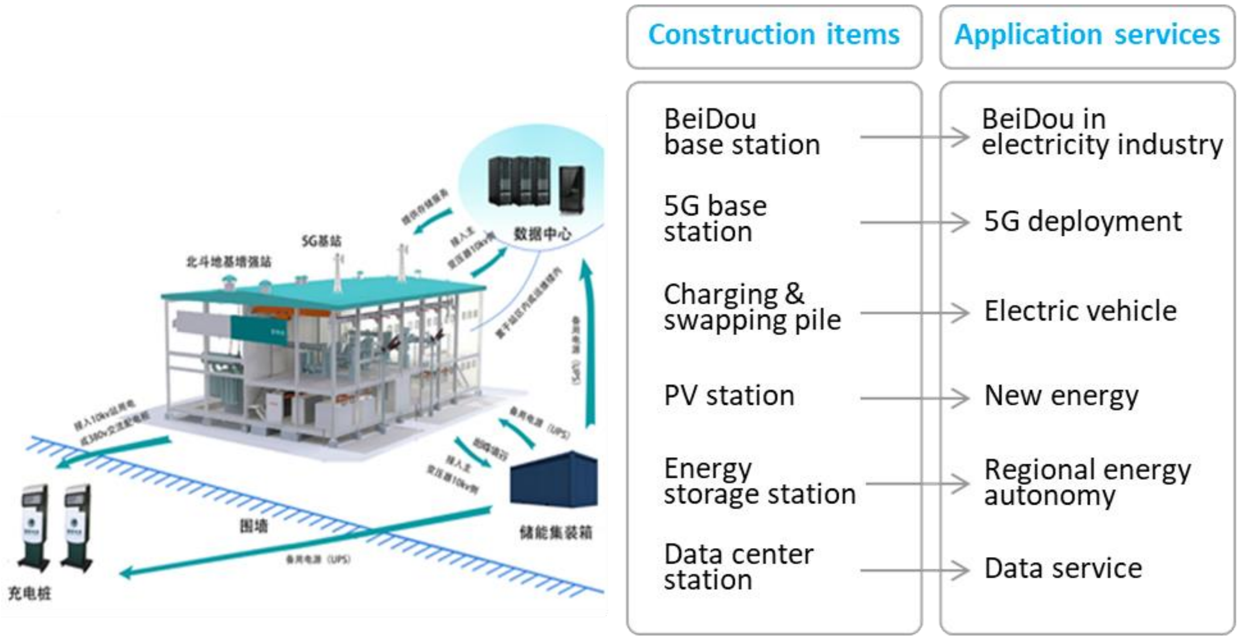
2.4.1 Multi-station integration

1) Application scenarios

Multi-station integration services make full use of transformer stations, new energy stations, energy storage stations, electric vehicle charging stations, power supply business halls, pumped storage power stations and other sites to build data center stations of different levels and application scenarios. The data center station provides local storage and edge computing for data from transformer stations. As an extension of cloud computing, network edge computing migrates the cloud computing platform and its capabilities to the edge networks, such as transformer stations and new energy stations, to better support high bandwidth, low latency and localized services and provide resource sharing services to the community.

Multi-station integration explores utilizing transformer station resources to build and operate data center stations, 5G base stations, BeiDou ground-based augmentation stations, charging piles, energy storage stations, etc. The service supports and strengthens smart grid business internally, and expands energy service channels externally. As a result, it accelerates the development of power IoT and helps electric power companies build a sharing platform to create value for society. Typical application scenarios are shown below.

Figure 9: 5G-based multi-station integration application scenarios

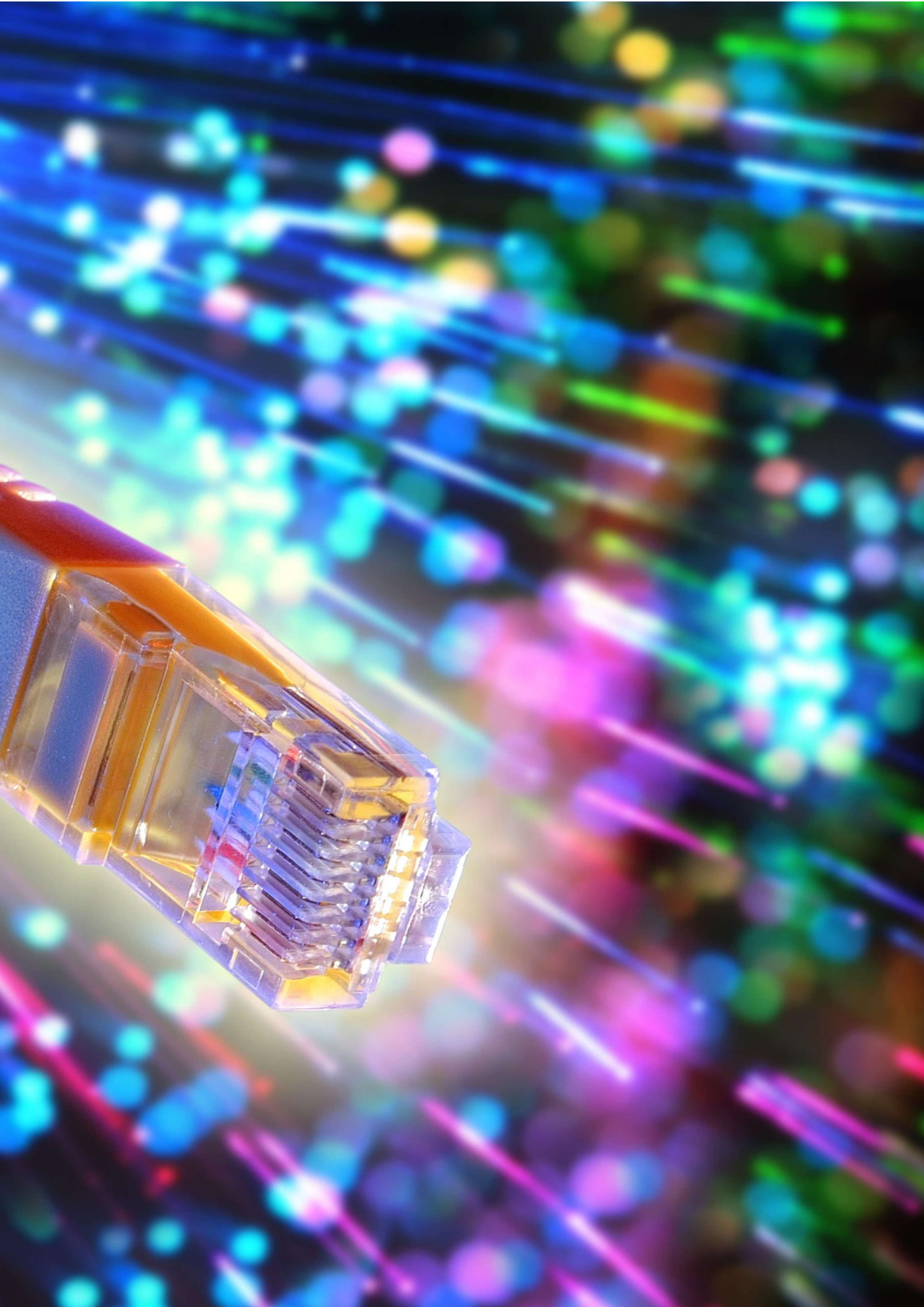


Source: GEIRI.

2) Communication requirements

Multi-station integration and edge computing technologies are available for Internet of Vehicles (IoV), HD video, AR/VR, smart security and other related services, with communication requirements including:

- IoV and HD video: bandwidth >100Mbps, latency <10ms
- AR/VR: bandwidth in 100Mbps-1G, latency <5ms
- Smart security: bandwidth >20Mbps, latency <20ms
- Connection density: 10 to 1000 devices, concentrated in local areas



3. 5G application challenges in the electricity industry

3.1 Security and power service adaptability pending verification

At present, the 5G application in vertical industries generally suffer from inadequate 5G network coverage, limited technical maturity, and supporting industries under cultivation, and so does the electricity industry. Compared with 4G networks, 5G networks can tailor security protection mechanisms for slices based on service requirements, provide slices with hierarchical security services required by users and security isolation between slices, as well as enable security deployment and management of users' virtual networks due to enhanced security in the network design. However, the power system has special requirements for the reliability and security of the communication network, and new requirements for the existing power security defense architecture and network management have emerged with network features, such as 5G network slicing, core network penetration, ultra-low latency service bearing and massive connections. In the current immature 5G technology and 5G commercial environment, it remains to be verified how 5G technology can meet the security needs of power services under the Energy Internet.

Different entities shall work together to clarify the boundaries of security responsibilities and promote 5G development and security defense in parallel. Power enterprises, network operators and equipment suppliers need to further quantify network specifications and architecture, including 5G network slicing security, service isolation, end-to-end service latency, and negotiate network capacity exposure, network management interface and other requirements. As a result, they will be able to provide solutions that meet the multi-scenario and differentiated needs in the electricity industry, and to implement technology validation and demonstration. In addition, government departments, standardization organizations, enterprises and research institutes are expected to play an active role in creating a multi-party 5G security governance system.

Figure 10: Security risks for 5G applications in the electricity industry

Security risks	Challenges
Terminal security	• Security authentication for massive terminals • Risks of massive devices connected to the network • Even with strict certification standards, device manufacturers may only seek to meet minimum terminal security requirements to reduce costs
Network security	• Differentiated security needs: authenticated encryption and isolation on the air interface side • 5G network slice security needs: without proper isolation mechanisms, a hacked low-protection network slice may be used as a springboard to attack other slices, resulting in disruption to the normal operation of the power system • Network boundary security defense needs: core network penetration blurs network boundaries, making it difficult to implement fine-grained, high-intensity prevention and control of boundaries, which poses security risks • New business model security needs
Application security	• At this stage, 5G network slicing is not designed for power services, so it is difficult to meet the differentiated security protection demands of power services due to the poor matching of resources in the application process. • 5G edge computing platform can deploy multiple applications sharing related resources. Once the protection of an application is breached, the safe operation of other applications on the platform will be affected, which, coupled with some additional functions of edge computing that are not required by the electricity industry, will lead to resource waste and efficiency decrease of the grid. • The application industry chain is not mature, especially in terminals and modules, with few manufacturers, high price, single form and poor business adaptability, so it's unable to meet the demands of power service applications. • The test scenarios for the adaptability of 5G and power services are relatively limited and their adaptability needs to be tested and verified on a larger scale.
Data security	• Data security • User privacy needs

Source: Deloitte Research.

3.2 Commercial value and cost balance

The construction and operating costs of 5G remains a challenge for the industry. Operators have publicly stated that the high costs of 5G comes from: the number of 5G base stations is three times more than 4G[2]; the power consumption of a single 5G base station is three times that of a 4G; and the price of a single 5G base station may be three times that of a 4G base station. The larger power and higher energy consumption of 5G base stations increase construction and maintenance costs significantly. The construction costs of a macro base station (including the costs of main equipment, power supporting facilities, civil construction, software, etc.) is estimated to be about RMB400,000, and the annual comprehensive electricity cost for a single base station tenant is about RMB20,000 to 30,000[3]. The demand for rapid expansion of 5G base stations on the one hand, and the uncertainty of investment returns and business models on the other, put enterprises under pressure of 5G construction and O&M costs.

For operators, 2C market is saturated and slowing down, so 2B will become the potential revenue growth point and major track. For electricity enterprises, the high speed, high capacity, high reliability, low latency and low energy consumption characteristics of 5G communication match the basic needs of the smart grid system for reliability, flexible response and collaborative control, massive data transmission, and long battery life . 5G can help create smart grid system and new business value.

In the context of 5G speeding up beyond expectations promoted by the state, it is particularly important for enterprises to find a balance between commercial values and costs. Enterprises need to select the most promising application scenarios and explore co-construction the sharing model to reduce costs and increase efficiency, so as to gradually move from a single-point to a multi-point breakthroughs and then to an industry-wide promotion.

3.3 Unclear business models

The business model of "5G+Electricity" has not yet formed, and enterprises are still seeking positioning and core business models.

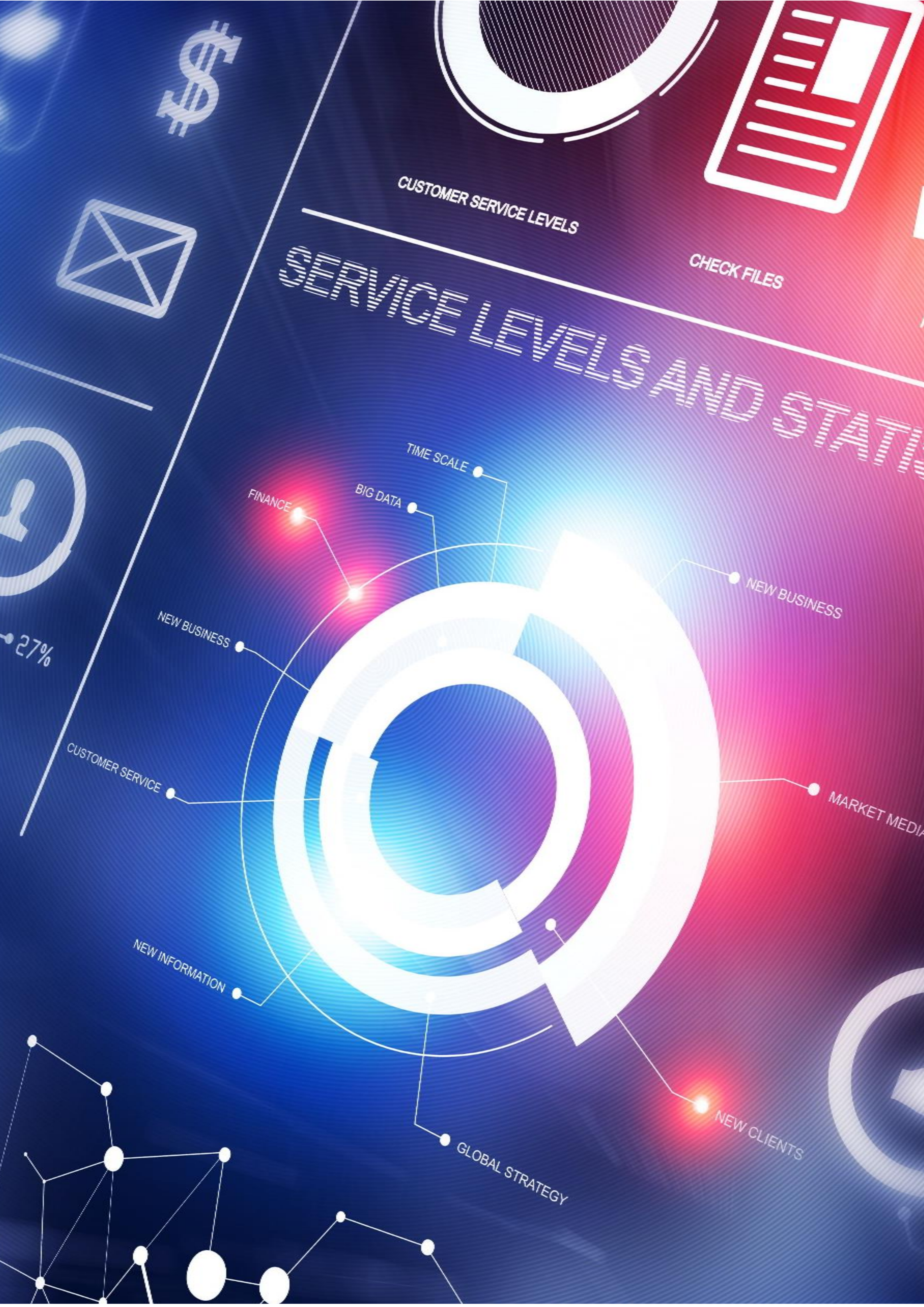
Taking the 5G network slicing service as an example, the grid business is mainly divided into four categories: safety production, customer services, operation and governance, as well as quality and efficiency improvement. Each category has many different specific services. For example, safety production contains a variety of application scenarios, such as transmission line online monitoring, drone inspection, smart power transformation, distribution IoT, distribution network protection, as well as short-circuit current calculation and analysis. Different services have different metrics in latency, bandwidth, connection density, synchronization, reliability and security isolation. 5G network slicing can meet security partition and isolation needs of different grid services: power control slicing can achieve millisecond-level latency to ensure reliable transmission of distribution control data and commands; power monitoring slicing can collect massive electricity meter data and upload inspection data of intelligent devices like drones; power communication slicing can meet the secure call needs of private networks in the electricity industry.[4]

The related research and deployment of network slicing is still in the development stage, and there are three potential business models for its application in the electricity industry. Electricity enterprises play different roles and require different resources and capabilities under different models. Relevant enterprises need to work together to explore which model is more feasible or find a new one (see Figure 11).

Figure 11: Potential business models for 5G network slicing application in the electricity industry

	Communications operator	Electricity enterprises
Standard model	• Build infrastructure • Provide value-added services	• Rent one or more of these slices depending on business needs
Hybrid leasing model	• Build end-to-end 5G networks • Provide value-added services	• Lease the most complex, expensive and difficult to maintain infrastructure networks from operators, including base stations and core networks • Build an independent management plane to meet the demand for visual and transparent management of network slicing resources • Use existing private transmission networks as much as possible
Hosting model	• Provide O&M management services	• Get 5G spectrum resources • Build an independent private 5G network with exclusive resources • Host the O&M management of 5G private network slices to operators to leverage their experience and advantages in network operation

Source: Public information.


CUSTOMER SERVICE LEVELS
CHECK FILES
SERVICE LEVELS AND STATIS
TIME SCALE
BIG DATA
FINANCE
NEW BUSINESS
NEW BUSINESS
27%
CUSTOMER SERVICE
MARKET MEDIA
NEW INFORMATION
NEW CLIENTS
GLOBAL STRATEGY

4. From technology to business

4.1 Deeply involved standards of development

5G industry standardization is the basis to scale. The 5G smart grid research project led by Chinese enterprises was successfully established in 3GPP R18, laying the foundation for the 5G+smart grid end-to-end standard system. China Electric Power Research Institute (Energy Interconnection Technology Research Institute of State Grid) has joined the international standardization organization 3GPP to participate in standards development, which will enable 5G technology to better serve vertical industries.

In the future, electricity enterprises can think about how to deeply participate in developing 5G technology standards and promote the standardization of 5G applications in the electricity industry from the perspective of standards sources, stakeholders, key considerations and follow-up.

Sources of standards: Enterprises can develop new standards in a variety of ways, most commonly by revising prior standards, codifying existing practice, and addressing emerging needs. Developing standards to address emerging needs requires the participants reach a consensus on which needs to prioritize and then develop solutions around those needs.

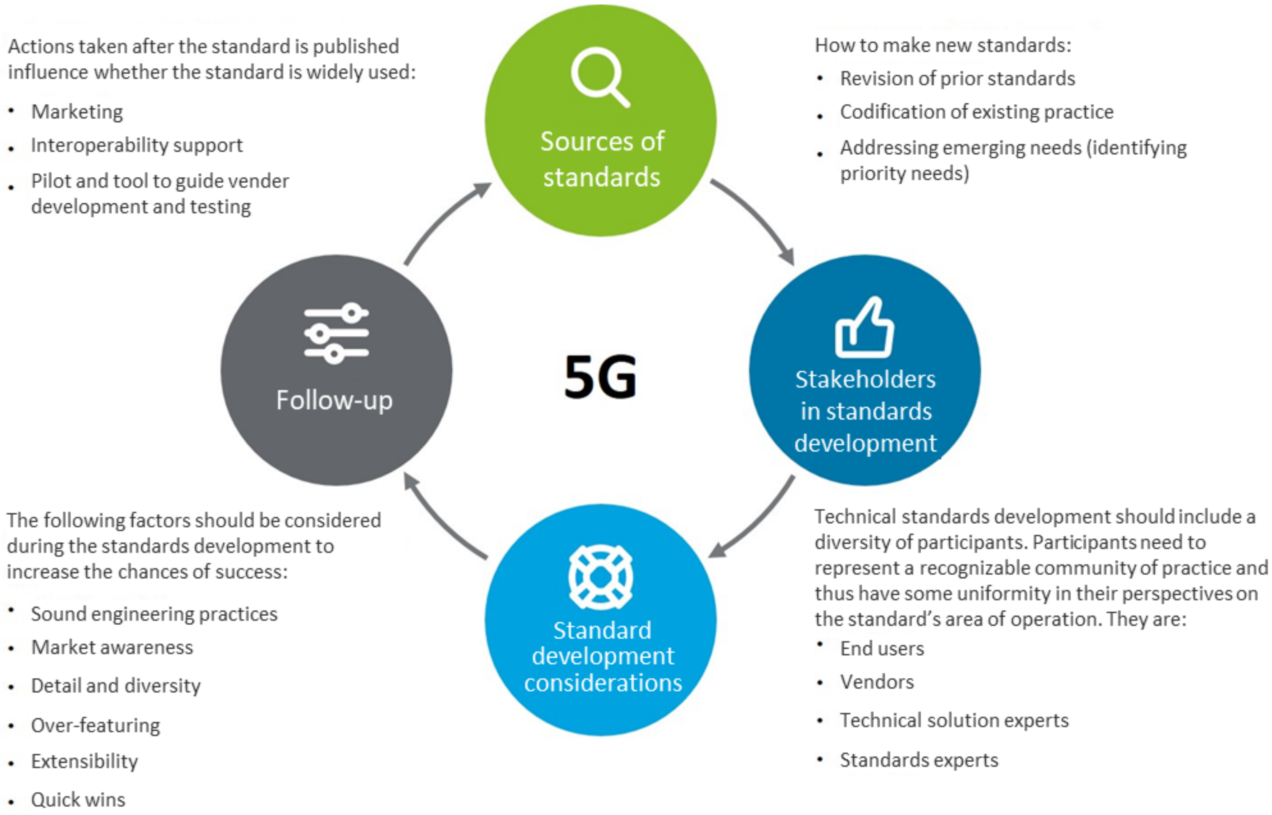
Stakeholders of technical standards: They attempt to include participants such as end users, vendors, technical solution experts and standards experts in the standards development effort.

Standard development considerations: The standards development process begins when they become a standards body participant. This process includes collecting requirements from participants, identifying a mutually acceptable set of practices around which to unify, and engineering a technical solution that will become the basis of a technical standard, during which the following factors should also be considered to increase the chances of success[5].

- Engineering practices: Agree upon and ensure that sound engineering practices are observed in the development of technical standards.
- Market awareness: Understand the values of the standard's target market and align design decisions and tradeoffs with those values.
- Detail and diversity: Avoid attempting to codify a high degree of detail in support of a highly diverse community. Detail in a standard should be balanced against the diversity in practice of the communities it serves.
- Over-featuring: Be conservative in the number of use cases and features (optional or required) a standard supports.
- Extensibility: Understand how a standard supports customized use by vendors and users. If appropriate, support customization via well-defined extension points and procedures.
- Quick wins: Smaller, more narrowly scoped standards have a greater chance of successful completion and adoption than large, multi-part standards.

Follow-up: Many companies incorrectly believe that once the standard is written and published, that adoption of and conformance with that standard will handle itself. In fact, the actions taken after publication can mean the difference between a standard receiving widespread adoption or fading into insignificance. Enterprises should actively market the standard, support interoperability, and develop tools to help suppliers with tests and development.

Figure 12: Key factors to drive industry standardization



Source: Deloitte Research.

4.2 Selection of the most promising application scenarios

5G has diverse application scenarios in the electricity industry, and we need to view the application of 5G in different scenarios with a development perspective. The 5G standards are not yet completed. Network optimization takes time, and 5G networks in different periods will drive application scenarios that require different network maturity. At this stage, the accurate selection of the most promising application scenarios forms the basis for the implementation of 5G. Deloitte introduces the following five dimensions from the strategic significance and market perspective to assess the potential of 5G application scenarios in the electricity industry.

Strategic significance

- Value creation potential: The application helps fill the technology or innovation gaps in the electricity industry during the evolution of the Energy Internet, which enables enterprises to become future value creators.
- Fit with policy: Its development is supported by relevant policies, and the industry benefits from government support for faster development.

Market potential

- Electricity demand scale: The market scale and growth rate of the application are assed to promote the commercialization of 5G in the industry.
- Commercial viability: The application has the digital basis and the urgent demand for 5G solutions. Its requirements for 5G network maturity are in line with the status quo of technology development, which adapts to the development logic of "construction for use and use for construction".
- Disruptive impact: It has a disruptive impact, such as fulfilling some currently unmet needs or changing user consumption habits.

Figure 13: Application potential assessment – Typical control and collection services as an example

	Precise load control The traditional way is to remove the whole line. In the future, interruptible non-critical loads shall be removed with priority , and business impact reduced through fine-grained control to improve user experience	**Electricity consumption information collection** Automatic collection of electricity consumption information, metering anomaly monitoring, power quality monitoring, electricity consumption analysis and management, information release, intelligent interaction of electricity consumption information, etc.
Value creation potential	• Support for the optimization of energy distribution on a large scale, and network improvement to enhance the reliability of power transmission and supply	• High value creation potential, contributing to filling the technology and innovation shortcomings of intelligent power consumption
Fit with policy	• New infrastructures and "Internet+" smart energy promoted from the national level	• New infrastructures and "Internet+" smart energy promoted from the national level
Electricity demand scale	• Distribution network automation system coverage of 90% and distribution communication network coverage of 95% • Increased requirements for distribution network automation system due to household PV and electric vehicles	• Limited scale in the short term as the market depends on the number of connected terminals • In the long term, a large number of new businesses will emerge once terminals reaches a certain scale
Commercial viability	• With digital basis and urgent demands • Requirements for great isolation, low latency and high reliability of the network, with testing and application demonstrations underway	• Low potential for rapid implementation in the short term, with high requirements for the number of connected terminals, network bandwidth and reliability
Disruptive impact	• Optimization of traditional power services to avoid mass power outages and minimize the impact on customers' electricity consumption	• Information is used for value-added services (such as, energy conservation and energy trading) and changes in customer energy consumption habits

Source: Deloitte Research.

4.3 Business model innovation

The most important change in the transformation from 4G to 5G is not the technology, but the business model. The business model in the 5G era will shift from the B2X model (B2B/B2C/B2G) to the B2B2X model – the communication operators will, in the 5G environment they have built, offer a certain value-added service to power enterprises, which enable the power enterprises to play a central role and provide new services to end users that were not available before.

5G application will provide three value creation channels for the electricity industry, including traditional power services optimization, data-driven value creation, and energy consumption upgrades centered on customer demand.

Figure 14: 5G-enabled three value creation channels for the electricity industry

	Traditional power services optimization	Data-driven services	Energy consumption upgrades
Value source	• New energy and energy storage combined to the grid • Increased reliability and security of power supply • Increased efficiency of asset operations	• Big data for electricity	• Satisfaction of diversified energy demand • Guidance of user consumption pattern change
5G enabling	• Clean energy resource assessment, assessment on adjusting distributed energy storage, as well as power generation forecasting and coordination in uRRLC and mMTC scenarios • Drone inspection in eMBB scenario	• Continuous data supply to power operators or equipment suppliers in mMTC scenario	• Energy saving and emissions reduction for users in mMTC scenario • Smart city, smart home, and smart transportation
Business model	• Mainly traditional business models	• Sale of energy consumption data, equipment operation status and other data • Establishment of the data management platform • Data-driven innovative services	• SaaS energy efficiency management platform • Energy trading platform • Integrated energy supply • Multi-station integration

Source: Deloitte Research.

Traditional power services optimization

5G enables the optimization of traditional power services, mainly including new energy and energy storage combined to the grid, power supply reliability, and asset operation efficiency.

The large-scale grid connection of renewable energy power generation will bring new challenges to the operation and management of the power grid. The intermittent and random characteristics of renewable energy bring difficulties to the power balance and operation control. Their distributed penetration makes the distribution network change from a passive network with one-way power flow to an active network with two-way power flow.[6] As the communication needs of grid devices, power terminals and electricity customers explode, 5G technology will support the intelligence of the energy infrastructure and two-way energy distribution, and help develop new business models to improve the efficiency of producing, delivering, using and coordinating limited energy resources.

As for reliability, the unique customizable 5G network slicing technology can offer end-to-end protection for grid applications with high isolation requirements, to better meet the power network's demand for "industry-specific network", and provide differentiated network services for different smart grid services. For example, the three types of applications mentioned above can be parallelized in a 5G network to meet the multiple needs of users for security, reliability and flexibility.

For asset operation efficiency improvement, in transformer station robot inspection and other low and medium rate mobile scenarios in power production management, the 5G network with large bandwidth can not only carry out mobile/flight control of inspection robots to significantly improve inspection efficiency while reducing labor costs and safety risks, but also send HD videos and images back to the command center for analysis and processing in a timely manner to improve O&M efficiency.

Data-driven value creation

In collection service scenarios, grid enterprises or electricity meter manufacturers can continuously obtain various energy data (e.g. power) and data related to the operating status of the energy system (e.g. power grid voltage) from customers. These primary data contain important information, such as users' consumption habits and lifestyles, which can provide macroeconomic forecasting bellwether for government agencies or generate great business value in other multi-industry fields.

Under the premise of giving full consideration to personal privacy security, if the above-mentioned primary energy consumption data and equipment operating status data are further processed and analyzed, and a large data center or cloud platform is established, it is possible to achieve efficient management of massive data and provide a basis for in-depth user insights.

Data-driven innovative services are highly anticipated. 5G collection services realize value materially by providing innovative services to energy users, electricity retailers and new energy development enterprises, which can be fully applied in the exploration of energy consumption characteristics and potential, energy consumption prediction and analysis, energy market trading and other innovative services[7].

For example, the State Grid Big Data Center uses electricity big data to create an electricity economic index. The electricity economic index utilizes the objective and high-frequency electricity big data to reflect the macroeconomic development situation at regional and industry levels from the perspective of electricity consumption. Electricity big data analysis enables the sharing of cross-provincial and multi-industry electricity data, enhances the insight of regional industry development trend, delivers data services for government agencies' decision making, supports industry development, and provides data basis for investment[8].

Another example is Google's Deepmind team, which accurately predicts wind power generation 36 hours in advance, offering smarter assessments and analysis of wind farm operations[9]. With less variability in wind power, renewables will become "predictable and valuable enough", which provides wind farm operators with more data-driven assessments to meet future power needs, helping to balance power supply and demand on the grid.

Energy consumption upgrades centered on user demands

User-centered consumption upgrading can not only meet the diversified energy needs of users, with user convenience as the core of the business models, but also change user consumption habits and provide innovative goods and services, thus creating new values for the entire energy system.[10]

For example, the SaaS-based energy efficiency management platform can make a comprehensive assessment of the energy consumption status of users, such as enterprises, designed zones and campuses, to design personalized energy-saving solutions, which reduces energy consumption costs and makes users' energy consumption behavior friendlier to the energy system. Another example is that the production equipment and pipe network resources of energy networks, such as power grids, heat networks and gas networks, are integrated to build a multi-energy coupled integrated energy supply system, which provides users with an comprehensive "energy package", saving them the hassle of purchasing products from multiple suppliers.

The integration of 5G with the electricity industry cannot be accomplished by one or two enterprises. Companies have their own resource and capability advantages and shall cooperate to explore viable business models on the core value path.

Figure 15: 5G+electricity multi-industry cooperation basis

	5G commercial license	5G standards or patents	Wireless communication spectrum resources	Base station site resources	Infrastructure planning and construction	Network operations	Understanding of electricity customer demands
Electricity enterprises							
Telecom operators							
China Broadcasting Network							
China Tower							
Equipment suppliers							

Source: Deloitte Research.

Endnotes

[1] Ericsson, *The Industry Impact of 5G*, https://www.ericsson.com/en/networks/trending/insights-and-reports/industry-business-impact-of-5g

[2] August 7, 2020, http://www.xinhuanet.com/2020-08/07/c_1126335750.htm

[3] August 11, 2020, https://tech.sina.cn/t/2020-08-11/detail-iivhvpwy0436862.d.html

[4] October 30, 2020, https://m.c114.com.cn/w5218-1142586.html

[5] *Best practice for technical standard creation*, MITRE Corporate, April 2017 , https://www.mitre.org/publications/technical-papers/best-practices-for-technical-standard-creation

[6] November 13, 2020, https://www.china5e.com/news/news-1103883-1.html

[7] June 11, 2019, https://www.sohu.com/a/319915748_269757

[8] September 10, 2019, https://m.sohu.com/a/340136702_777609

[9] February 27, 2019, https://www.sohu.com/a/297915632_485557

[10] Chen Qixin and Wang Yi, *Energy Internet Development Study,* Tsinghua University

5. Contacts

Jiang, Vivian
Deputy CEO, Deloitte China
Tel: +86 21 6141 1098
Email: vivjiang@deloitte.com.cn

Guo, Kevin Xiao Bo
Leading Partner of Energy, Resource & Industrials Industry, Deloitte China
Tel: +86 10 8520 7379
Email: kguo@deloitte.com.cn

Zhang, Jennifer
Lead Client Service Partner, Strategic Clients, Deloitte China
Tel: +86 20 2885 8608
Email: jenzhang@deloitte.com.cn

Qu, Jill Qianru
Director, Deloitte Research
Tel: +86 10 8520 7047
Email: jiqu@deloitte.com.cn

Zhou Fei
President
Academy of Information and Communications Technology, GEIRI
Tel: +86 10 6660 1800
Email: zhoufei@geiri.sgcc.com.cn

Li, Binglin
Director of Communication Technology
Academy of Information and Communications Technology, GEIRI
Tel: +86 25 8309 5585
Email: libinglin@geiri.sgcc.com.cn

Wu Peng
Head of Wireless Communication Technology
Academy of Information and Communications Technology, GEIRI
Tel: +86 25 8309 5591
Email: wupeng@geiri.sgcc.com.cn

Guo Yunfei
Senior Engineer
Academy of Information and Communications Technology, GEIRI
Tel: +86 25 8309 5586
Email: guoyunfei@geiri.sgcc.com.cn