frontiers | Frontiers in Energy Research

OPINION
published: 10 May 2022
doi: 10.3389/fenrg.2022.900890

# Key Concepts and Framework of Power Distribution and Utilization of Transparent Power Grids

*Bin Liu*[1]*, *Zhukui Tan*[1] *and Chaofan Lan*[2]

[1]Electric Power Research Institute of Guizhou Power Grid Co., Ltd., Guiyang, China, [2]College of Electric Power, South China University of Technology, Guangzhou, China

**Keywords: transparency, power distribution and utilization, micro smart sensors, digital twin, internet of things—IoT**

## INTRODUCTION

Smart power distribution and utilization is the most concerned field in the development of smart grids from the construction of conventional distribution automation systems to the control related to the access of high-proportion distributed generation (solar, wind, and energy storage); from the demand side management related to electricity consumption to the charging and discharging of electric vehicles, microgrids, and DC distribution; and from the Internet of Things and cloud computing to big data and energy Internet and so forth, involving a wide range of new technologies emerging endlessly (Wu et al., 2017; Liang et al., 2018; Tian, 2019). The development of smart power distribution and utilization to the extreme is transparent power distribution and utilization. The concept of transparent distribution and utilization comes from the concept of transparent power grids (Mo, 2021). At present, no scholars have carried out research on the application architecture of transparent power distribution and utilization, and there are only a few studies referring to the transparent power grid. Zhang et al. briefly introduced the meaning, characteristics, and implementation process of a low-voltage transparent distribution network (Zhang et al., 2019). Li et al. believed that the transparent power grid was an advanced form of the ubiquitous power Internet of Things (Li et al., 2020). Zhou et al. analyzed and discussed the architecture and key technologies of transparent substations (Zhou et al., 2022). In this article, the architecture of the transparent distribution and utilization application system is clarified, and some views on relevant technical factors are put forward.

OPEN ACCESS

**Edited by:**
*Bo Yang, Kunming University of Science and Technology, China*

**Reviewed by:**
*Si Chen, University of Glasgow, United Kingdom*
*Jian Chen, Yancheng Institute of Technology, China*

***Correspondence:**
*Bin Liu*
*2322157814@qq.com*

**Specialty section:**
*This article was submitted to Smart Grids, a section of the journal Frontiers in Energy Research*

**Received:** *21 March 2022*
**Accepted:** *30 March 2022*
**Published:** *10 May 2022*

**Citation:**
*Liu B, Tan Z and Lan C (2022) Key Concepts and Framework of Power Distribution and Utilization of Transparent Power Grids. Front. Energy Res. 10:900890. doi: 10.3389/fenrg.2022.900890*

## OVERALL ARCHITECTURE

According to the concept of transparent grids, in order to achieve transparent distribution and utilization of electricity, it is necessary to collect, upload, identify, and monitor the operation data of grid-connected equipment and key nodes in real time based on modern information and communication technology and centrally reflect them on the distribution network visualization platform so as to achieve a transparent distribution and utilization mode of full data acquisition, full state visibility, and full situation prediction (Mo, 2021).

Zhang et al. (2019) pointed out that according to the characteristics of transparent distribution and utilization, the realization process can be divided into three stages, namely, the data transparency stage, state transparency stage, and situation transparency stage. These three stages contain different connotations of transparent distribution and utilization of electricity, showing a progressive relationship, and the former stage is the foundation of the next stage. Li et al. (2020) proposed that the advanced form of the ubiquitous power Internet of Things is a transparent grid. Using micro smart sensors, advanced communication technology, and big data analysis technology (Wu and Zeng, 2020) of the Internet of Things, power grid practitioners can understand the significance, laws, and values of power grid

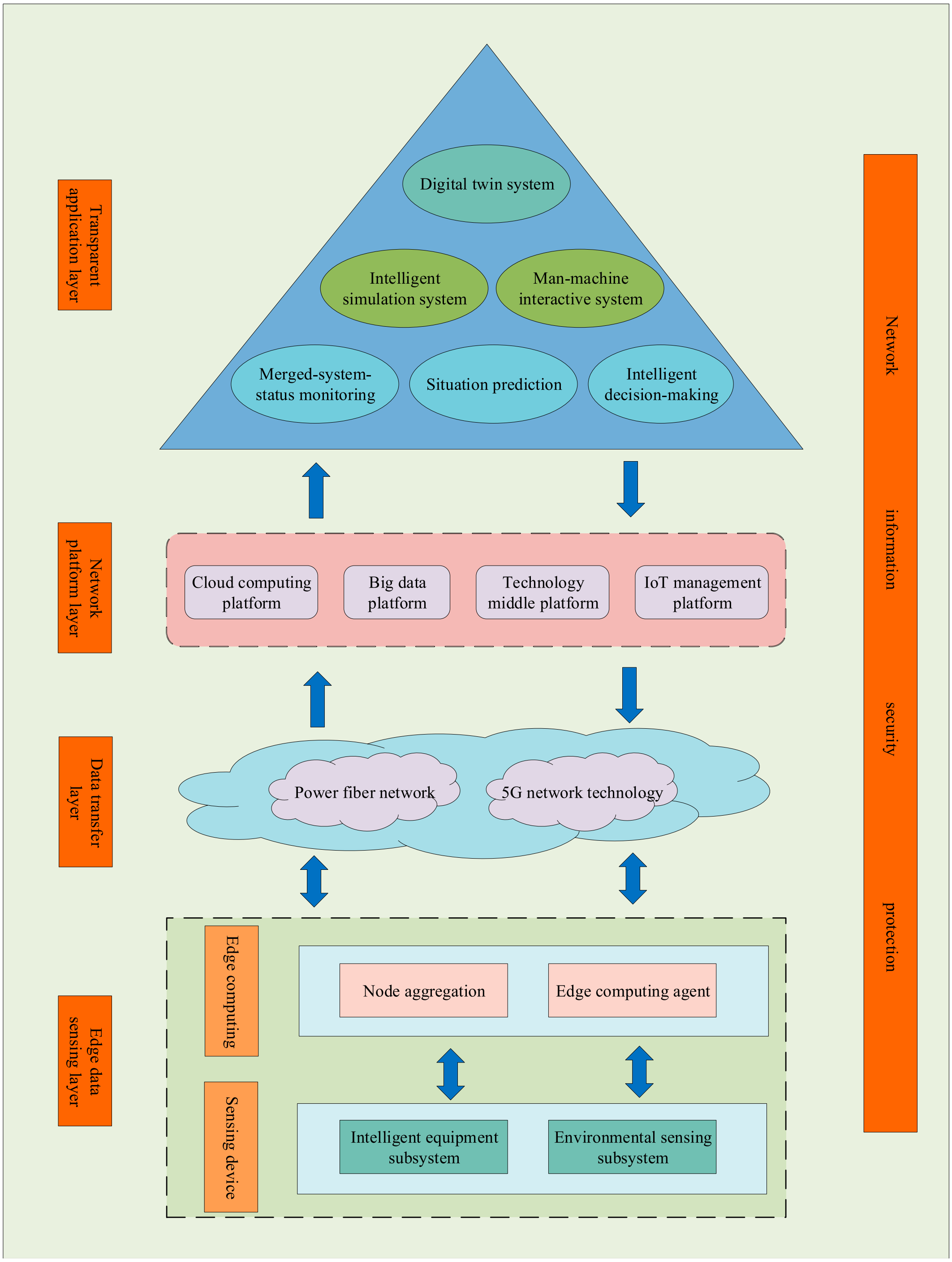


**FIGURE 1 |** Overall framework of transparent power distribution applications.

measurement data, regulation behavior, market information, and other types of data and master the characteristics and strategies of operation from microgrids to complex large power grids. In addition, Zhou Ke et al. proposed a transparent substation architecture, including an edge perception layer, network transmission layer, and platform application layer to form a transparent substation system from bottom to top. Information security protection runs through the whole architecture level and ensures the information security of transparent substations in all directions and dimensions (Zhou et al., 2022).

Since there is no research on the application architecture of transparent distribution and utilization, the application architecture of transparent distribution and utilization can refer to the overall architecture of a transparent power grid and transparent substation.

The application architecture of transparent distribution and utilization is divided into four levels, namely, the edge data sensing layer, data transmission layer, network platform layer, and transparent application layer, as shown in **Figure 1**.

The comprehensive and fine perception ability is the foundation to realize the transparency of distribution and utilization, and the realization of the everywhere visibility of distribution and utilization and the pursuit of a higher degree of perception fine grain are the basic requirements for the perception layer of transparent edge data of distribution and utilization. The edge data sensing layer takes micro smart sensors as the core, which is composed of a sensing device module and an edge computing module (Zhao et al., 2021). It is the basis of transparent power distribution. The intelligent sensing module is composed of an intelligent sensing subsystem and environmental sensing subsystem. In the intelligent sensing subsystem, it is mainly realized through advanced sensing technology and intelligent chip technology (Sun et al., 2020) to monitor the data of electrical quantities such as voltage, current, frequency, and phase and the data of non-electrical quantities such as temperature, humidity, and sound. The core of the environmental perception subsystem is the micro smart sensors of environmental perception, which can realize the functions of non-contact perception, intelligent judgment, and independent early warning of equipment and the environmental state in the distribution and utilization system. The edge computing module is a distributed intelligent agent at the edge of the network. The data of each subsystem of the sensing device layer are connected to the edge computing module. The sensing data are processed and analyzed locally, and a small closed loop is formed with the sensing device module. The key data are extracted and then uploaded to the cloud platform, which reduces the cloud computing pressure and improves the efficiency of system operation decisions (Xiang et al., 2017; Chen et al., 2022). The data transmission layer is mainly responsible for the reliable and efficient transmission of data in transparent distribution and power systems and solves the communication problem between devices at all levels so as to realize more extensive interconnection functions. It should have high reliability, low delay, and differentiation characteristics (Yao et al., 2021). It can be supported by a 5G network with a high speed and low delay (Xiang et al., 2017; Wang et al., 2019). The network platform layer is mainly composed of a cloud computing platform, a big data platform, a technology middle platform, and an Internet of Things management platform. The cloud platform mainly provides ultra-strong computing power and large-scale hardware resource integration capability (Li and Xu, 2018). Big data platforms provide data and data analysis capabilities for business platforms. The technology middle platform is the business service sharing center of transparent distribution and power systems, which provides data, technology, and business sharing service components. The IoT management platform mainly standardizes the management of massive networking equipment in the transparent distribution and utilization system and improves the fine management level of IoT equipment. The transparent application layer is based on the perception layer of all-round sensing data according to the data relationship and combined with virtual reality technology to develop a digital twin system. The digital twinning system of power distribution and utilization is the key to the construction of transparent power distribution and utilization (Han, 2021), the last link of power distribution and utilization transparency, the key to the transparent presentation of power distribution and utilization systems to operation and maintenance personnel, and the structural basis for the realization of other business functions. Through the digital twin system, the operation and maintenance personnel can obtain and analyze all kinds of operation data, perceive the subtle changes of the system, and realize the advanced system simulation of three-dimensional dynamic reality and entity behavior interactions. However, at present, the research and development of micro smart sensors are not mature (Zhou et al., 2022), the digital twin technology is still in the initial exploration stage (Tang et al., 2020), and the standards related to the digital twin are still in the preliminary formulation stage (Han, 2021). Therefore, there are still many technical problems to be solved in the construction of transparent power distribution and utilization application systems, which is a brand new and challenging task.

## KEY TECHNOLOGY

Massive micro smart sensors are the basis for building a transparent power distribution application system and the key components for realizing a comprehensive state perception of the power distribution system. The construction of the edge data sensing layer requires a large number of sensors, which first requires that the size of the sensor is small enough to be installed on various devices and transmission lines. Second, the sensor should be equipped with a microprocessor, capable of two-way communication and intelligent functions, and can take energy from itself without a battery (Li et al., 2019). Li et al. proposed a microcurrent measurement technology based on tunnel magnetoresistance (Li et al., 2019). The micro smart sensors have high sensitivity and a large measurement range, low power consumption, and low cost, but the measurement accuracy needs to be improved. Guo et al. (2021) believed that non-intrusive load monitoring technology was the basic technical means for the construction of a transparent power grid. Compared with the invasive load monitoring technology, the invasive load monitoring used various sensors to monitor the equipment alone, while the non-intrusive load monitoring used the bus data to obtain the operation state of each load through the algorithm analysis through the software algorithm. Before the application of low-cost small and micro intelligent sensors, non-invasive load monitoring technology has obvious cost advantages, but the accuracy of the algorithm is difficult to guarantee. In addition, some researchers began to study the semi-intrusive load monitoring technology based on a small number of measurement points. The original single-point load monitoring task is assigned to each measurement point, which reduces the difficulty of load identification at a single measurement point and has better performance (Nipun et al., 2014). A digital twin is another key technology to realize transparent power distribution. Li believed that the key link in building a transparent power grid software platform was to build a digital twin power grid (Li, 2022). Tang et al. (2020) studied the digital twin architecture of the AC/DC distribution network. The authors believed that the digital twin system of future mature distribution networks would realize the full data acquisition, full state visibility, and full situation prediction of the distribution network. However, due to the fact that the domestic digital twin technology research started late, the practical application is not mature enough; therefore, to build a mature transparent distribution system, the relevant mature hardware and software technology is an urgent problem to be solved.

## DISCUSSION AND CONCLUSION

The application system of transparent power distribution and utilization needs to be constructed from four aspects, namely, the edge data sensing layer, data transmission layer, network platform layer, and transparent application layer. At present, the main technical problems are the data sensing method of the edge data sensing layer and the development and application of digital twinning technology in the transparent application layer, as follows:

1) The development and research of micro smart sensors are not yet mature. Although the current research institute of China Southern Power Grid has developed a micro current sensor based on tunnel magnetoresistance, it has not been widely applied, and more types of micro smart sensors need to be developed.
2) In addition to hardware, in terms of data perception, non-intrusive schemes can also be used to obtain the data information of each measurement point by using software algorithms, which is also a scheme for future research.
3) In the transparent application layer, the development of a digital twin system is the most important, and it is also a key link in the construction of transparent power distribution. Research on related technologies, personnel training, and further development of digital twin technology standards are urgent problems to be solved.

## AUTHOR CONTRIBUTIONS

BL: writing the original draft and editing. ZT: visualization and contribution to the discussion of the topic. CL: supervising.

## FUNDING

This work was supported by the research and demonstration on key technologies of safe smart distribution and utilization in tourism areas based on the industrial internet (GZKJXM20210347).

## REFERENCES

Chen, Y. J., Cai, Z. X., and Sun, Y. Y. (2022). An Optimization Method of Edge Computing Terminal Deployment and Service Allocation in Power Internet of Things. *South. Power Syst. Tech.*, 1–8.

Guo, H. X., Lu, J. W., and Yang, P. (2021). Review on Key Techniques of Non-intrusive Load Monitoring. *Electric Power Automation Equipment* 41 (01), 135–146.

Han, Y. F. (2021). *Let the Grid Display ' Road Condition ' Information in Real Time like a Traffic Network*. Beijing: China Energy News.

Li, J., and Xu, S. C. (2018). Smart Power System Big Data Processing Platform in Cloud Environments. *Comp. Eng. Des.* 39 (10), 3073–3079.

Li, L. C. (2022). Construction of New Power System with Transparent Power Grid. *Power Enterprise Manag.* 01, 14–17.

Li, P., Yuan, Z. Y., and Tian, B. (2019). Micro Current Measurement Technology Based on Tunnel Magnetoresistance. *South. Power Syst. Tech.* 13 (04), 2–10.

Li, Q. H., Zhang, Y. J., and Chen, J. Q. (2020). Development Patterns and Challenges of Ubiquitous Power Internet of Things. *Automation Electric Power Syst.* 44 (01), 13–22.

Liang, Y., Huang, L., and Hu, Z. W. (2018). Cyber Physical Systems in Future Smart Power Distribution and Utilization: Technologies, Prospects and Challenges. *Distribution & Utilization* 35 (03), 2–9.

Mo, F. (2021). *Building Transparent Power Grid to Serve New Power System*. Beijing: China Electric Power Daily.

Nipun, B., Jack, K., and Oliver, P. (2014). NILMTK: An Open Source Toolkit for Non-intrusive Load Monitoring. *STATISTICS*

Sun, Z. B., Feng, Z., and Feng, W. J. (2020). Research on Intelligent Sensing Technology of New Energy Vehicle Control System. *Auto Time* 21, 105–106.

Tang, Q. Q., Chen, B., and Deng, W. Y. (2020). Application Research of Digital Twin Technology in AC-DC Distribution Network. *Guangdong Electric Power* 33 (12), 118–124.

Tian, S. M. (2019). *Key Technology and Application of Big Data in Intelligent Distribution and Utilization*. Beijing: State Grid Shanghai Electric Power Company.

Wang, Y., Chen, Q. X., and Zhang, N. (2019). Fusion of the 5G Communication and the Ubiquitous Electric Internet of Things: Application Analysis and Research Prospects. *Power Syst. Tech.* 43 (05), 1575–1585.

Wu, K. L., and Zeng, B. (2020). Overview of Power Big Data Analysis Technology and Application Research. *Inf. Commun.* 9, 158–159.

Wu, L., Guan, R. M., and Zhuang, J. (2017). The Whole Design and Key Technology for Smart Distribution and Utilization Park. *Distribution & Utilization* 34 (07), 2–8.

Xiang, H. Y., Xiao, Y. W., and Zhang, X. (2017). Edge Computing and Network Slicing Technology in 5G. *Telecommunications Sci.* 33 (06), 54–63.

Yao, W. J., Shi, J. L., and Chen, X. X. (2021). Reliable Routing and Reliability Evaluation of Power Optical Communication Ring Networks. *J. Nanjing Univ. Posts Telecommunications: Nat. Sci. Edition* 41 (03), 23–29.

Zhang, Y. J., Liu, S. L., and Jiang, J. Q. (2019). Research Review on Low-Voltage Intelligent Distribution Network Technology. *Guangdong Electric Power* 32 (01), 1–12.

Zhao, H., Miao, K., and Chen, L. (2021). Research on Networking Scheme of Power Internet of Things Based on Edge Computing. *Microcontrollers Embedded Syst.* 21 (10), 7–11.

Zhou, K., Wang, X. M., and Qiu, X. Y. (2022). Analysis of Transparent Substation Architecture and Key Technologies Empowered by Digital Technology. *Electr. Meas. Instrument*, 1–10.

**Conflict of Interest:** BL and ZT were employed by the company Electric Power Research Institute of Guizhou Power Grid Co., Ltd.

The remaining author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.