# A Survey of Power-Grid Artificial Intelligence

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**Abstract:** This paper describes in detail the existing and the potential application scenarios of artificial intelligence in various related fields of power grid based on the national policy orientation and the layout plan of State Grid Corporation of China. Some core technology research directions of power-grid artificial intelligence like intelligent sensing, artificial intelligence platform, big data, machine learning, computer vision, etc. to be launched in the future are highlighted in the paper.

## 1. Introduction

Artificial intelligence began in the "Artificial Intelligence (AI) Summer Symposium" held at Dartmouth College in 1956. The development of 60 years has experienced three waves. With the development of a new generation of information technology, data is rapidly accumulated, computing power is greatly improved, algorithm models continue to evolve, industry applications are rapidly emerging. Cross-media intelligence, group intelligence, autonomous intelligence systems, and hybrid intelligence have become new development directions.

Artificial intelligence is a new technical science that studies and develops theories, methods, techniques, and application systems for simulating, extending, and extending human intelligence. One of the main goals of artificial intelligence research is to enable machines to perform complex tasks that typically require human intelligence.

As an energy carrier, the power grid is a comprehensive system with complex networks, numerous equipment and complicated technologies. Traditional operation and maintenance overhaul cannot guarantee the reliable and effective management of grid equipment. The combination of artificial intelligence and grid application technology will gradually realize the combination of intelligent sensing and physical state, data driving and simulation model, auxiliary decision and operation control, thus effectively improving the ability to control complex power environment, the security of power operations and the transformation of business models. State Grid Corporation has many years of research accumulation and technical achievements in the field of artificial intelligence, but with the advancement of smart grid construction, the power field has put forward more technical requirements for artificial intelligence applications.

## 2. AI Application in Power Grid

With the improvement of computer technology and the breakthrough development of deep learning technology in recent years, artificial intelligence technology has been popular all over the world and has been valued by more and more countries in the world. In August 2016, the State Council issued the “13th Five-Year National Science and Technology Innovation Plan”, which clarified artificial intelligence as the main direction for developing a new generation of information technology. The national science and technology plan. The plan specifically proposes to vigorously develop disruptive technologies that lead the industry transformation, and re-emphasizes the importance of artificial intelligence.

Responding to the national science and technology innovation plan, “State Grid Corporation's Medium and Long-term Science and Technology Development Plan for 2030” also included artificial intelligence technology as one of the key tasks in the basic and common technology fields. Combined with the actual business needs of the power grid, research on basic common technologies including big data basic theory, pattern recognition, image recognition, speech recognition, expert system, natural language processing, operational planning, and deep learning has been carried out. These basic common technologies provide basic technical support for power grid security and control, power transmission and transformation, power distribution and consumption, new energy, and business management.

### 2.1 Power Grid Security and Control

In recent years, research on artificial intelligence that has been carried out in the direction of large-scale power grid analysis and control involves data textization, stable feature extraction, operational situation assessment, and intelligent control. Artificial intelligence technology has also played an active role in load forecasting and telemetry data quality monitoring. The assisted decision-making analysis technology based on artificial intelligence is put into demonstration application, and the sub-station centralized monitoring data intelligent analysis and auxiliary decision-making, regulation cloud platform and big data technology are put into practical application.

In the future, intelligent identification and control of power grid faults, intelligent station domain protection and fault early warning analysis will be the two main research directions of artificial intelligence technology in the field of grid security and control. Some potential application requirements include: intelligent learning and online mining of power grid control strategies and control rules, intelligent identification of power system faults and weak points, intelligent fault location, relay protection accident analysis, and device implicit fault warning. The implementation of these technologies relies on wide-area multi-source information, deep learning, pattern recognition and other artificial intelligence methods.

### 2.2 Power Transmission and Transformation

The application needs in the field of power transmission and transformation mainly come from the condition monitoring of power transmission and transformation equipment, transmission channel monitoring and the safety of unattended substations. At present, based on massive video images collected by helicopters, UAV (Unmanned Aerial Vehicle), patrol robots and remote sensing satellites, traditional artificial intelligence technologies such as support vector machines (SVM) and shallow neural networks (SNN) have been used to realize automatic label classification of typical dangers hidden in the equipment, the characteristic recognition of transmission line galloping disasters and non-galloping disasters. The intelligent detection of substation equipment status such as "knife gate and switch state detection", "automatic meter reading", "foreign object suspension and equipment appearance abnormality detection", "transformer sound abnormality detection", and "temperature abnormality detection" have also been gradually carried out.

In the future, power transmission and transformation equipment inspection and transmission channel risk assessment, and UAV intelligent inspection on transmission lines will be the two main research directions of artificial intelligence technology in the field of power transmission and transformation. Component fault identification, intelligent identification of hidden dangers on lines, risk assessment of channel environment changes, active obstacle avoidance and autonomous cruise by unmanned aircraft in complex operating environments are all urgent requirements.

### 2.3 Power Distribution and Consumption

In terms of power distribution and metering, the application scenarios include distribution network assessment and active coordination, disaster situation awareness, illegal electricity usage behavior analysis, energy meter operation error analysis, metering equipment status assessment, load forecasting, peak resource scheduling, customer intent identification, etc. Intelligent monitoring of

equipment health status, anti-stealing technology, on-line analysis and fault prediction of distribution network operation, efficient operation on site and intelligent warning of safety risks will be the four main areas of artificial intelligence technology in the field of power distribution and consumption. Other potential applications include intelligent diagnosis and remote calibration of measuring equipment, intelligent decision-making of anti-stealing, intelligent grading warning, automatic analysis and pushing of fault causes, risk management and control of power field operations, and intelligent identification of work orders.

### 2.4 New Energy

The artificial intelligence technology that has been put into use now involves electric power weather forecasting, new energy power forecasting, new energy optimization scheduling, and performance evaluation of new energy power stations, but there is still room for improvement in the level of intelligence of related applications. In the future, the assessment of new energy consumption capacity and adaptive evaluation of power generation performance will be the two main research directions of artificial intelligence in the field of new energy.

### 2.5 Business Management

In the field of business management, knowledge bases, expert systems and decision support systems related to grid business have been established. However, the research foundations in enterprise security certification, smart office, business decision-making, risk management and control are still weak.

In the future, identity security certification and intelligent control of electric power warehouse robots will be the two main research directions of artificial intelligence technology in the field of enterprise management. The recognition technology of real digital identity such as voiceprint, face, fingerprint, etc. can realize multi-level authentication mechanism of different identity recognition modes, cracking the problem of identity information fraud and misappropriation. The beat control and grid-visual cruise technology of warehouse robot and can realize automatic warehousing, picking and shipping of electric power equipment, and greatly improve the efficiency of power warehouse management.

## 3. Key Technologies of Power-Grid AI

Power-grid artificial intelligence is a specialized artificial intelligence that creatively combines the related theories, techniques and methods of artificial intelligence and the physical laws, technology and knowledge of power systems. Referring to the basic hierarchical structure of artificial intelligence, the core technical directions of power-grid artificial intelligence can be summarized as Fig. 1.

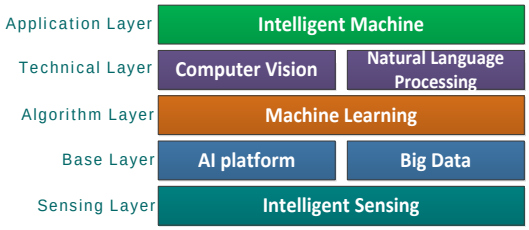


Figure 1. Core technology direction of power-grid artificial intelligence.

### 3.1 Intelligent Sensing

The massive meta-data of artificial intelligence comes from the comprehensive sensing and collection of information. Intelligent sensing is the core technology of artificial intelligence. It is the infrastructure component of electric power dispatching, protection measurement and control, security operation and maintenance, and online monitoring. It is regarded as the tertiary electric power

equipment and plays a fundamental and extensive role in the safe and stable operation of the power grid. It is the basis for the grid cyber-physical systems (GCPS).

As shown in Fig. 2, the research in the field of intelligent sensing needs to focus on breakthrough core technologies such as advanced sensing, edge intelligence, network connection, and micro-source energy extraction to establish R&D and verification environments for intelligent sensor used in grid applications.

a. Advanced sensing technology includes front-end sensing mechanism research, sensitive material analysis, signal processing, circuit debugging, etc., and needs to focus on optical/magnetic sensing technology.

b. The edge intelligence technology sinks the lightweight artificial intelligence algorithm to the sensing terminal to realize cloud-to-end interaction and collaboration through local acceleration and real-time computing.

c. The network connection technology specifically involves large-scale connection of sensor networks, small data, low power consumption, self-organization and other technologies, as well as IPv6 end-to-end addressing and secure interconnection technologies.

d. To realize the self-supply of the sensor power supply, it is necessary to overcome the energy-acquisition technology in the complex environment like electromagnetic field, electric field, vibration, temperature difference, the photo-electricity, etc., and the wireless charging and the nano energy system are also desirable means.

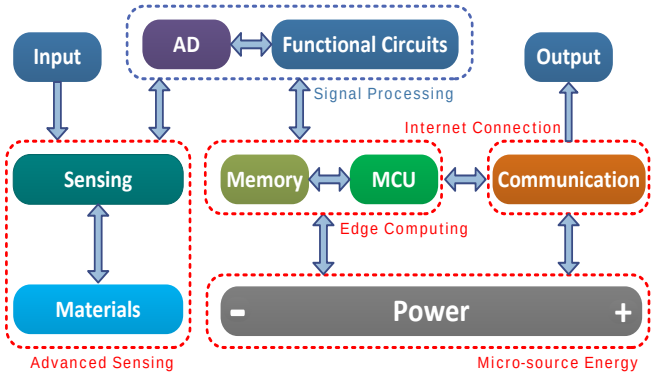


Figure 2. The structure decomposition of intelligent sensor.

### 3.2 Artificial Intelligence Platform

The artificial intelligence platform for power-grid applications needs to integrate a variety of mainstream artificial intelligence computing frameworks, provide rich machine learning algorithms and model libraries, and use container technology to achieve unified scheduling management of basic resources and rapid deployment of the environment. The power-grid artificial intelligence platform aims to realize the one-stop management of the whole process from data acquisition, data processing, model training, algorithm development to service release. Fig. 3 shows the platform layout based on the stratification theory of artificial intelligence technology.

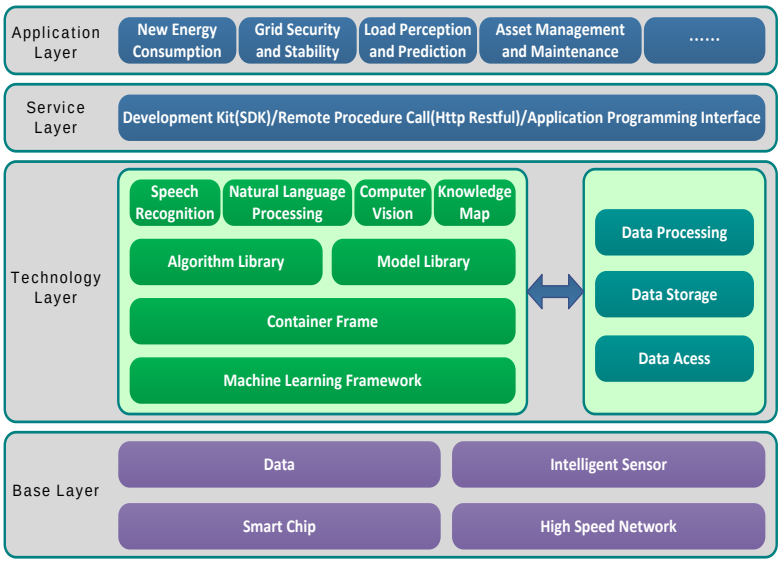


Figure 3. The layout of artificial intelligence platform for power grid.

### 3.3 Big Data

Big data research method based on data drive can provide customized solutions for infrastructure construction, equipment status maintenance, distribution network planning and other requirements in the power grid. Big data processing, data analysis and mining, unified data model, data security and other technologies are the more urgent technical entry point for power grid. The big data unified platform composed of massive data storage and access, intelligent operation and maintenance, cross-engine data exchange and correlation, intelligent resource scheduling and other technologies is a powerful guarantee for the demonstration of the application models like the security and stability analysis of large-scale power grids, overload warning, urban power maps, data assets labeling, equipment status monitoring, etc.

### 3.4 Machine Learning

Frontier technology theories and algorithm models such as deep learning and reinforcement learning are the current focus of research. By studying the open source training framework of machine learning, a machine learning algorithm library for power systems can be constructed. According to the applicability and limitations of machine learning algorithms, adaptability improvement and optimization can be carried out to form a machine learning application model for a specific power-grid scenario. Among them, complex grid fault feature identification, power generation and load forecasting, power equipment status evaluation, etc. are machine learning application models that need to be focused on.

### 3.5 Computer Vision

The application of computer vision in the field of power grid mainly focuses on target recognition and defect detection of power inspection and surveillance images, but the current technology has not yet met the accuracy and efficiency requirements required for production. At this stage, we will focus on the construction of power image resource library, multi-target detection and defect recognition for power-grid image, design of power-grid vision chip, virtual/augmented reality interaction, and 3D reconstruction. It is also necessary to develop intelligent auxiliary annotation technology, equipment detection and defect recognition algorithm based on domain knowledge and deep learning, and form equipment-level power-grid vision module to realize real-time electric power equipment identification and defect detection.

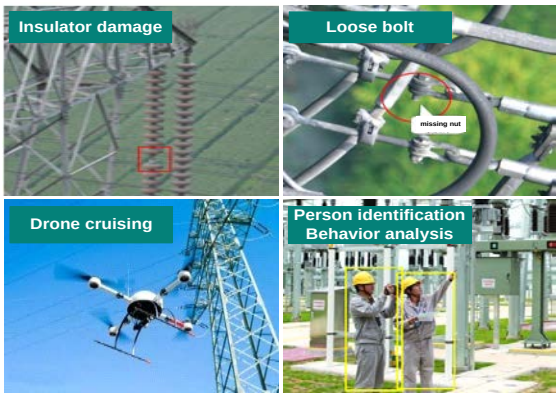


Figure 4. Application scenario of computer vision.

### 3.6 Natural Language Processing

The operational rules, scheduling instructions and reports, marketing archives, etc., which exist in text form in the power system, are all power texts. Combined with new word discovery technology and word meaning network mining technology, a power-topic vocabulary library based on power texts can be constructed. Secondly, by studying the techniques of power text feature extraction, grid ontology modeling, knowledge processing and reasoning, the power knowledge map in different fields can be gradually constructed. Knowledge maps in the areas of regulation, maintenance and marketing can support applications such as power dispatching robots, grid equipment intelligent operation and maintenance, and intelligent customer service to form a new generation of intelligent search and question-and-answer solutions for power gird.

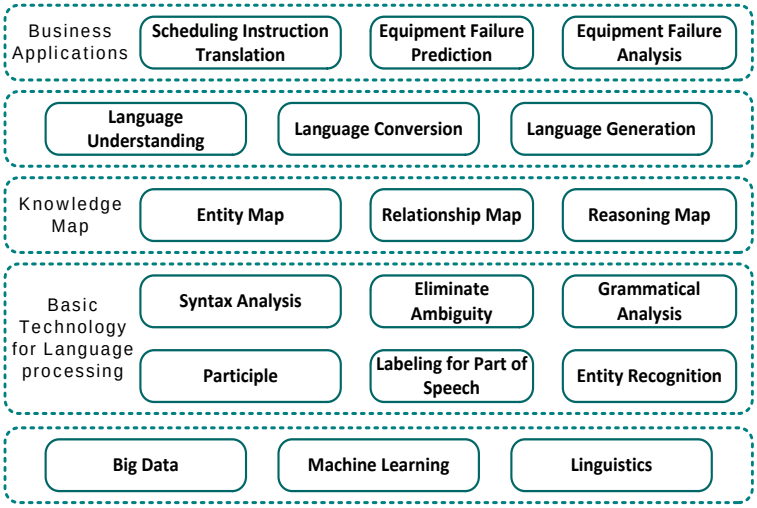


Figure 5. Application and technical support of natural language processing in power-grid systems.

### 3.7 Intelligent Robot

Robots for application scenarios such as power inspection, service, operation, and regulation are named as power-gird robots. At present, the power-grid robot is still in the stage of “automatic repetitive action in a single mode”, which cannot meet the demand of the grid for autonomous intelligent behavior. In the direction of intelligent robots, it is necessary to focus on breaking through the core technologies of AI algorithm packaging, self-identification, autonomous behavior, independent learning, human-machine cooperation, etc., to realize the autonomy and intelligence of power-grid robots. The framework of power-grid intelligent robot is shown in Fig. 6.

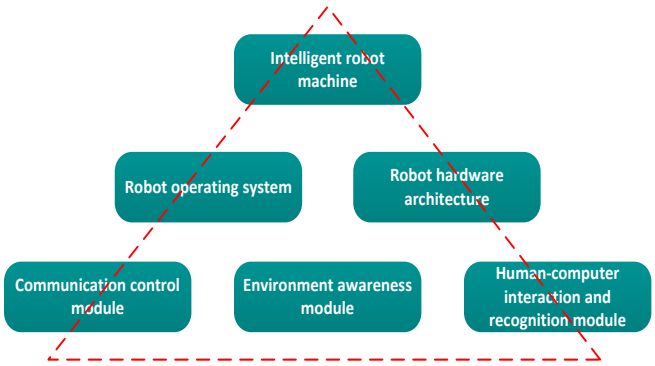


Figure 6. The ontology framework of intelligent robot.

## 4. Conclusion

This paper closely combines the development requirements of power grid applications, outlines the research and application of artificial intelligence technology in various power fields, and actively explores the combination of traditional power grid technology and artificial intelligence, big data and intelligent sensing technology. At the same time, the paper focuses on common key technologies such as intelligent sensing, big data, machine learning, computer vision, natural language processing and intelligent robots, and points out the development direction of core technology of power-grid artificial intelligence.

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