A Survey of Development and Application of Artificial Intelligence in Smart Grid

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Abstract. In recent years, with the development of the deep learning as the core technology, artificial intelligence has made a series of major breakthroughs, which have caused the industrialization of artificial intelligence. Facing the current situation, this paper summarizes the development history of artificial intelligence, introduces the current artificial intelligence research in the smart-grid area and its trends in the future, at last presents a technology architecture for artificial intelligence development in the smart grid.

1. Introduction
In the computer vision and the chess between man and machine, the artificial intelligence technology with deep learning as the core has achieved a major breakthrough, setting off an upsurge in the industrialization of artificial intelligence around the world. As a traditional industry, how smart grids follow the development trend of artificial intelligence, introducing mature technologies and development frontier theory of artificial intelligence, and further perfecting the smart grid technology architecture system has become an urgent issue in current research.

2. The concept and development history of artificial intelligence

2.1. Concept
Professor Nelson of the Artificial Intelligence Research Center at Stanford University in the United States has defined artificial intelligence as a discipline: knowledge about how to express knowledge, acquire knowledge, and use knowledge. The definition of the functions implemented by artificial intelligence is that intelligent machines perform functions related to human intelligence, such as judgment, reasoning, proof, recognition learning and problem solving. These reflect the basic ideas and basic content of artificial intelligence, that is, artificial intelligence is the study of human intelligence activities. From a practical point of view, artificial intelligence is a knowledge engineering: knowledge as the object, research knowledge acquisition, knowledge representation and knowledge use[1].

2.2. Development history
Recalling the development of artificial intelligence, it can be roughly divided into four stages of gestation period, formation period, application period and high-speed development period[2]:

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Incubation period: In 1943, "MP neuron model" was first proposed in the paper of American neurophysiologist Warren McCulloch and the mathematician Walter Pitts, which implemented a simple circuit to simulate the brain nerves for the first time. In 1951, two Princeton mathematics graduate students constructed the first artificial neural network. Before this, many early philosophers and mathematicians' ideology and theory inspired the development of artificial intelligence, such as Aristotle's syllogism deduction method and Bayesian inference event probability theory [3].

Formation period: Artificial intelligence terminology was first born at the Dartmouth Conference in 1956. This meeting was considered to be a historical event that opened up the field of artificial intelligence. In 1969, International Conference on Artificial Intelligence marked that artificial intelligence has gained international recognition.

Application period: In the early 1970s, Perception promoted the development of practical applications of artificial intelligence in solving algebra application problems and proving geometric theorems. The Hopfield neural network in the 1980s promoted the wide application of knowledge expert systems and produced huge economic benefits.

High-speed development period: At the beginning of the 21st century, with the continuous breakthrough of deep learning neural network technology, artificial intelligence has achieved great success in image recognition and the application of the man-machine warfare of chess, driving the industrialization of artificial intelligence.

3. Research Status of Artificial Intelligence in Power Grid
After the State Grid Corporation proposed the goal of building a strong smart grid, combining artificial intelligence technologies such as artificial neural networks, intelligent fuzzy logic, big data analysis technologies, and genetic algorithms, it has conducted forward-looking research in power network security control, power transmission and transformation, power distribution, new energy and other fields, based on independent innovation. At present, it has accumulated a wealth of research results in the power system fault diagnosis, intelligent control, relay protection and temporary steady state calculations, short-term load forecasting and other related work.

3.1. Grid Control
In power systems, recursive neural networks are used to build simulation knowledge models for power simulation information. Combined with data mining technology, through the extraction of the stability characteristics of the power grid and the identification of the system transient stability, solutions of the system operation situation assessment, optimization control, and coordinated control have been proposed. The results were actually applied in standby dispatching systems and load forecasting software, which provided strong support for intelligent aided decision-making in power grid monitoring, network analysis, and index management and control.

3.2. Power Transmission and Distribution
In the forecasting and warning platform for transmission line galloping, artificial neural network prediction methods were used to establish the characteristics of galloping feature recognition and early-warning forecasting models. From 2015 onwards, many accurate predictions were provided in practice. In terms of smart inspections, computer vision technology in drones and smart inspection robots is used to identify equipment defects, automatic label classification, and defect intelligence diagnosis for typical equipment, such as transformers, switches, towers, insulators, poles of towers, metal rust, line tree barriers, etc. Preliminary application has been made in the intelligent analysis management and control system.

3.3. Distribution Network
With the popularization of smart meters and the application of power consumption information acquisition systems, machine learning and pattern recognition are widely used in metering device management, such as: online monitoring and intelligent diagnosis, error analysis of power meter
operation, status assessment, life cycle quality assessment, etc. The anti-theft monitoring technology for metering devices, the performance evaluation and detection technology for online metering devices, and the measurement and on-line calibration technology for transformer gates were proposed. Anti-DC transformers, wide-band voltage/current transformers, AC/DC transformers, loop status inspection instruments, transformer substation transformer online calibration systems were developed. Electronic transformers extremely cold, high altitude long-term live monitoring test base was established.

3.4. New Energy Field

The research and application of artificial intelligence in the new energy field is mainly reflected in the prediction of electricity weather and new-energy power generation, model parameter testing, and evaluation of plant performance. In the power weather and new energy generation power forecasting, the new energy power prediction method based on the artificial neural network is adopted to improve the prediction accuracy of the new energy power, and then accurately recognize the new energy absorption capacity under different operating conditions. In view of the instability and intermittent nature of photovoltaic power generation, an electromechanical transient model for photovoltaic power plants was proposed. In the model, model parameters are corrected through sample data. The model is also applied to grid-connected photovoltaic power generation product testing platforms, photovoltaic power generation performance evaluation platforms, and photovoltaic power generation simulation test platforms.

4. The development trend of artificial intelligence in the power grid field

With the development of smart grid business, the accuracy of the analysis and prediction of invisible faults is required to be higher. The level of intelligence in self-determination, self-judgment, and self-healing of operational status is required to be higher. Optimal regulation of energy supply and demand on both sides is required to be better. Therefore, there is an urgent need to update computer technologies to solve the core problems of intelligent security defence, intelligent decision-making, intelligent solution, intelligent scheduling, autonomous learning, and self-adaptation in large power grids.

4.1. Trend 1: Accumulated autonomous machine learning will drive smart grid autonomous management

Smart grid autonomous management can use machine learning to realize intelligent planning, intelligent decision-making, and intelligent understanding of the system, and promote the intelligent level of smart grid self-management. At present, the application of smart grid stealth fault identification, grid parameter assessment and intelligent control, grid equipment defect assessment, and relay protection adaptability are typical problems faced by researchers. The accumulative autonomous machine learning will further strengthen the self-learning function of the smart grid and enhance the self-learning level of the smart grid in perception, thinking, and action.

4.2. Trend 2: Expert System Changes to Knowledge-Driven Knowledge Information System

The earliest and most active application of artificial intelligence was the expert system, which was closely linked with knowledge engineering. At present, the solution to many problems in smart grids also depends on the experience and knowledge of experts. Through a knowledge-driven knowledge information system, experts can build knowledge and experience in a certain field, and use the inference engine mechanism in the knowledge information system to simulate the work decisions of human experts. The establishment of power grid knowledge encyclopaedia of fault diagnosis, intelligent control, fault location and analysis, and energy router self-determination and so on will be an important practice direction for smart grid knowledge engineering. Through the knowledge information system, the relationship between things can be clearly expressed, and intelligent reasoning can be realized, which has broad application prospects in intelligent decision-making and information recommendation applications.
4.3. Trend 3: Solving and Solving Complex Problems

The greatest advantage of artificial intelligence technology lies in constructing coping mechanisms for unexpected factors, improving the quality of countermeasures against unanticipated factors, and enabling problems that may cause losses to achieve a more effective response under the influence of a complete preplan. In the large-scale power grid, there are three major problems that urgently need to be addressed: the intelligent monitoring, intelligent dispatching in the operating state of the power system, and providing solutions quickly in the face of unexpected situations. Applications such as power system autonomy and coordination control, load characteristics analysis and prediction, fault location, and new energy consumption need to be developed. And it will drive artificial intelligence to solve the complex problems of the smart grid more efficiently and more accurately, and better enhance the quality of R&D of cutting-edge smart grid technologies.

5. Blueprints for Artificial Intelligence in the Grid Field

At present, there is no clear artificial intelligence system architecture system at home and abroad. In order to facilitate the effective development of artificial intelligence in the field of power grids, this paper designs a blueprint for the development of artificial intelligence in the field of smart grids. In order to further support the technological development path of artificial intelligence in the smart grid field, according to figure 1, the development blueprint of artificial intelligence in the smart grid is divided into three layers: base layer, technology layer, and business application layer.

![Figure 1 Artificial intelligence development blueprint in smart grid](Image)

The basic layer mainly includes cloud computing, big data, internet of things, and sensors, providing the basic guarantee for the development of artificial intelligence in the field of smart grids.

The technology layer mainly includes artificial intelligence frontier theory and algorithm, knowledge engineering, big data analysis technology, deep learning technology, computer natural language understanding, computer vision understanding, brain-like intelligence science. Artificial intelligence frontier theory and algorithms are the cornerstone and core of the entire development blueprint, and support the development of application technologies such as big data analysis, deep

| Typical Applications | Technology | Knowledge Engineering |
|----------------------|------------|-----------------------|
| Power Grid Monitoring | Computer Natural Language Understanding | Artificial Intelligence Frontier Theory and Algorithm |
| Power Grid Operation | Brain-like Intelligent Calculation | Recurrent Neural Networks (RNN) |
| Power Grid Planning | Computer Vision Understanding | Long and Short Memory Neural Networks (LSTM) |
| Power Grid Control | Big Data Analytic | Convolutional Neural Networks (CNN) |
| Power Grid Decision Making | Deep Learning | Recurrent Brain Function Neural Networks (RBF) |
| Power Grid Planning | Knowledge Engineering | Bayesian Algorithm |
| Power Grid Control | Base Layer | Clustering Algorithm |
| Power Grid Decision Making | Cloud Computing | Reinforcement Algorithm |
| Other | Sensor | Regularization Algorithm |
| Other | Big Data | Proximity Algorithm |
| Other | Internet of Things | Others |
learning (machine learning), knowledge engineering, computer natural language understanding, computer vision understanding, and brain intelligence computing.

The business application layer mainly focuses on the business application scenarios of the smart grid transmission, distribution, distribution, and power consumption. Through the comprehensive application of artificial intelligence application technologies, the company will improve the level of intelligence in the power grid and promote the development of a new generation of smart grid systems.

The blueprint for artificial intelligence in the grid field has been proposed. It will promote the formation of a smart grid technology research system featuring artificial intelligence, continue to enrich smart grid technologies and drive the development of artificial smart grids featuring "intelligence, intelligent thinking, and smart actions."

6. Conclusion
The future of artificial intelligence technology has broad application prospects, and it covers almost all areas of labor. Although the theoretical basis of artificial intelligence needs to be perfected, its internal development law remains uncertain, and artificial intelligence even faces the challenge of security risks and moral hazard. However, the trend of intelligent technology development is inevitable. The traditional electric power industry should actively face the upsurge of artificial intelligence, seize the opportunity, strengthen forward-looking prevention and policy guidance, actively introduce research and mature technologies, explore immature technologies, improve the smart grid technology architecture system, and accelerate the continuous improvement of the level of smart grid.

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