Research on Integrated Energy System of Power Grid Based on Artificial Intelligence Algorithm of Machine Learning

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Abstract. To advance the revolution in energy production and consumption, and to build a clean, low-carbon, safe and efficient energy system, it is necessary to develop a new generation of smarter power systems and integrated energy systems. Artificial Intelligence (AI) is currently one of the most disruptive science and technology, with strong processing capabilities in computational intelligence, perceptual intelligence and cognitive intelligence. Aiming at practical engineering problems such as the lack of accurate monitoring of the state of terminal equipment in the current comprehensive energy operation and maintenance management and control, the fault diagnosis mechanism is not perfect and the accuracy is low, a comprehensive energy operation and maintenance management and control scheme based on machine learning is proposed. Focusing on comprehensive energy service operation and maintenance management and control, in-depth mining of operation and maintenance and fault diagnosis data, integrating service system related expert information, establishing a comprehensive energy service terminal health evaluation model, and achieving a comprehensive evaluation of the health status of comprehensive energy services.

1. Introduction
With the access of renewable energy, the flexible use of active loads (such as electric vehicles, etc.), and large-scale regional interconnection, the power grid has evolved into a typical dynamic system with huge dimensions. The power system, gas system, and thermal system are increasingly coupled, and an integrated energy system (IES) with electricity as the core will surely be formed. The primary problem facing his research is that in most cases it is difficult to establish an accurate mathematical model, or it is difficult to describe it solely with mathematical models. In recent years, various artificial intelligence (AI) technologies, such as machine learning, swarm intelligence evolutionary algorithms, fuzzy logic, expert systems, etc., have made great breakthroughs in data resolution, learning power and computing power, and have been applied to intelligent manufacturing and intelligence. Medical and other fields have shown gratifying application effects. The State Council's "New Generation Artificial Intelligence Development Plan" has established artificial intelligence research as a national strategy. The application of artificial intelligence technology in electric power and integrated energy systems will realize the combination of intelligent sensing and physical state, data-driven and simulation models, and auxiliary decision-making and operation control, thereby effectively improving the ability to control complex systems and improving operations Changes in the security and business service model of the country, change the traditional energy utilization model, and promote the energy revolution [1].
With the rise of artificial intelligence technology, the application research of big data and machine learning provides a new way of thinking and approach for comprehensive energy operation and maintenance management and control. In view of this, a comprehensive energy operation and maintenance management and control platform based on machine learning is built around the comprehensive energy service system, combined with the comprehensive energy management and control system and end-user data, to achieve real-time monitoring and comprehensive evaluation of comprehensive energy management and control, and to provide decision support for management, control, operation and maintenance. Improve the comprehensive energy service level.

2. Integrated energy service and operation and maintenance control

2.1. Integrated energy services
On the supply side, comprehensive energy services are extended to provide society with energy such as electricity, oil and gas, gas, and heat. Enterprises are on the supply side of the energy ecological chain. In the past, they were only responsible for production and did not participate in circulation and consumption. New energy system reforms and regional energy Internet and other new technological changes have provided policies, systems and technical support for the implementation of industrial chain extension on the supply side [2].

2.2. Traditional operation and maintenance control
With the development of integrated energy services, the traditional operation and maintenance management and control mode is inefficient, and it is difficult to meet the needs of integrated energy management and control operation and maintenance. The following problems need to be solved urgently:

(1) There are many types of terminal equipment for comprehensive energy management and control, and the installation is not centralized and easy to malfunction. However, the integrated energy management and control system lacks the ability to monitor the operation status of the terminal equipment, and it is difficult to quickly and comprehensively reflect the operation status of the integrated energy terminal. It is very necessary to improve the ability of monitoring and analysing the operation status of integrated energy service terminal equipment and the ability of fault identification.

(2) Terminal equipment is overly dependent on passive maintenance, and lacks equipment health assessment and risk warning. When the terminal equipment fails, it can only go to the site for fault detection and maintenance, which reduces the reliability of the integrated energy management control system. Therefore, it is imperative to achieve an objective and accurate evaluation of the health status of the control terminal equipment, as well as risk early warning, and to take corresponding preventive measures. Change the arrangement of the inspection plan, according to the health status of the equipment, from regular scheduled maintenance to targeted operation and maintenance to improve the efficiency of operation and maintenance.

(3) The failure detection and elimination of integrated energy management and control terminal equipment is not standardized, and a closed-loop process is not formed, and there is a lack of standardized management of equipment operation information, fault information, and maintenance and operation records.

(4) At present, the comprehensive energy management and control lacks equipment maintenance information and historical failure analysis, it is difficult to grasp the internal laws of terminal equipment failures, and there is a lack of effective data support for maintenance strategies, equipment selection and spare parts management.

3. Application of machine learning algorithms in integrated energy management
The concept of deep learning originated from the research and expansion of artificial neural networks. The multilayer perceptron with multiple hidden layers is a typical deep learning structure. Among them, the first several hidden layers can automatically construct new features from the data in an unsupervised manner, and then extract more abstract high-level category attributes layer by layer, and discover the...
deep feature representation of the data. Similar to traditional machine learning methods, deep learning can also be divided into supervised learning and unsupervised learning [3]. Convolutional neural network (CNN) is a machine learning model under deep supervised learning, while deep belief network (DBN), stacked autoencoder (SAE) and restricted Boltzmann machine are under unsupervised learning Machine learning model. Figure 1 shows a typical deep learning regression prediction model.

![Figure 1. Deep learning regression prediction model](image)

The first step of chaotic time series prediction is to reconstruct the phase space. \( x_1, x_2, ..., x_N \) chaotic time series A is set to reconstruct the phase space using the delayed coordinate method. The state vector at a certain point in the reconstructed state space can be described as:

\[
X_i = (x_i, x_{i+\tau}, ..., x_{i+(m-1)\tau})^T
\]  

(1)

In formula (1), \( m \) is the embedding dimension, \( \tau \) is the delay time, \( i=1, 2, ..., M \), \( M = n-(m-1)\tau \) is the number of phase points. Suppose \( n \) learning samples \( (x_i, y_i), i=1,2,...,N \), where \( x_i \) represents the sample input, the \( y_i \) model outputs the expected value, and the SVM estimation function is:

\[
f(x) = w^T \varphi(x) + b
\]  

(2)

In formula (2), \( w \) represents the weight vector, and \( b \) represents the bias vector. Use the optimization function to optimize the target value, namely:

\[
\min J = \frac{1}{2} \|w\|^2 + C \sum_{i=1}^{N} (\xi_i^+ + \xi_i^-)
\]  

(3)
Modelling based on machine learning is a combination of process and control requirements, using a data-driven method to find the control law of the system to achieve the optimal control goal of the system, and the accuracy of the mechanism model of the complex system is not high. In addition, the integrated energy management and control system is a complex model with a high degree of coupling. Traditional mathematical methods cannot establish its precise mechanism model [4]. Therefore, the integrated energy modelling method based on machine learning can improve the level of management, control, operation and maintenance, and accurately identify System failure is of great significance. The integrated energy modelling process based on machine learning can be divided into:

1. Obtain data. The choice of sample data is mainly to select relatively high correlation data from the massive data as the source input of the machine learning algorithm, and select the smallest amount of data samples to achieve the optimal model dynamic effect is the most ideal situation for obtaining sample data. Here is mainly to obtain user energy consumption data, terminal equipment status data, and real-time operation data of the integrated energy service system.

2. Feature engineering selection. Feature engineering is an important part of machine learning projects. The selection of feature engineering plays a time-consuming and complicated role in a series of machine learning tasks, but it is also an indispensable part. Feature engineering includes feature construction, feature extraction and original data feature selection. Feature engineering extraction can give full play to the maximum effectiveness of the original data, so that the effectiveness of the algorithm can be significantly improved.

3. Model training, parameter tuning and evaluation. After completing the preliminary preparations for machine learning, the training data needs to be used to complete the training, optimization and evaluation steps of the comprehensive energy management and control model. The trained dynamic model needs further parameter adjustment and optimization, and the new model needs to be diagnosed again. This is an iterative and continuous approximation process that requires constant attempts to achieve the best state [5].

4. Model evaluation and error analysis. Through the processed test data, the dynamic model established in the previous step is evaluated and verified, and the dynamic error and correlation coefficient are observed. If the parameters are not suitable, steps (2) and (3) need to be repeated.

5. Model fusion. Model fusion refers to training multiple models and then integrating them into a single model according to a certain method, making the dynamic model simple and easy to implement, while improving the accuracy of the algorithm. The main methods are the front-end data fusion of the model and the back-end model fusion.

4. Integrated energy system design

4.1. Energy supply relationship of multi-energy complementary distributed energy system in the region

The diversification of multi-energy complementary distributed energy, the difference of power supply capacity and the diversification of load structure lead to the difference of the internal elements of each level and the difference of the connection relationship between the levels. In the regional multi-energy complementary distributed energy station, the main energy flows from the input of primary energy to the energy end users are electric energy flow, thermal energy flow and natural gas flow. The specific energy supply relationship of the multi-energy complementary distributed energy system in the region is shown in Figure 2. The primary energy input in the region is mainly supplied by wind, light, natural gas fuel, domestic waste, biomass and external power grids. In addition to producing high-quality electric power, gas turbines can also use thermal steam to meet the thermal load demand and industrial steam demand in the new area, and can provide part of the thermal steam for the refrigeration of the steam-type absorption refrigerator and the gas absorption refrigerator for use. To meet part of the cold energy demand, the other part of the cold energy demand is met by electric energy conversion. The surplus electric energy can also charge the energy storage device [6].
Figure 2. Energy supply relationship of multi-energy complementary distributed energy system in the region

4.2. Framework of Integrated Energy Management System

Based on the concept of a regional multi-energy complementary distributed energy circular economy system, a regional multi-energy complementary integrated energy management system is built, as shown in Figure 3. The system consists of two parts: the energy integrated management and control center system and the monitoring system of each distributed energy source and the load monitoring system (including: building energy integrated management and control system, charging station monitoring system, user energy consumption monitoring system). The information exchange between the power system dispatch center and the distributed energy system in the region is managed by the energy integrated management and control center system.

Figure 3. Regional multi-energy complementary integrated energy management system architecture
4.3. **Function Module**
According to the problem of poor customizability of each module of China's "Internet +" energy management platform at this stage, different functions and method engines can be formulated according to different application places. In this way, it is possible to facilitate users' requirements for various functions and reduce corresponding costs.

4.3.1. **Energy monitoring module.** The application panoramic data platform can not only realize the storage and application of large amounts of data, but also provide corresponding data analysis and prevention and early warning functions. Collecting and analysing statistical data from data sources can realize the informatization, automation and intelligence of data source collection and analysis; and establishing a strict assessment system through corresponding analysis can improve overall management efficiency, save overall costs, and achieve "Economic benefits of "Internet +" energy management platform.

4.3.2. **Situational awareness module.** It is very important for data collection and prediction. At this stage, China's science and technology continue to develop. A variety of advanced artificial intelligence algorithms can be used to achieve goals, and manual calculations can be guided, and basic assessments can be made for some more complex data and unpredictable situations, thereby minimizing risks. The risk assessment engine is mainly derived from the prior inspection of the distribution network. It is necessary to comprehensively consider the safety of the overall production and operation plan, and clarify the serious impact of some fluctuations and uncertainties in the previous operation on the overall production safety. The risk assessment engine can perform a comprehensive analysis of failures, laying a foundation for the overall development of the system. Figure 4 shows the functional module diagram.

![Figure 4. Function module diagram](image)

5. **Conclusion**
The multi-energy complementary distributed energy system can concentrate multiple complementary distributed energy sources in the same network, thereby improving the energy efficiency, economy and stability of the entire regional energy system. Based on the actual situation of the project, this paper
proposes to consider the distributed energy, each energy load and the energy service in the region as a whole, and carry out integrated energy management and control according to a unique operation mode. Based on the proposed regional multi-energy complementary distributed energy circular economy system, an integrated energy management and control center will be established, and an integrated energy management system platform will be established. Under the premise of ensuring the stability, safety and reliability of the regional power system, the energy system performs multi-energy complementation and optimal dispatching in order to maximize the energy efficiency of the entire system and maximize the economic benefits.

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