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Research Article

A Data-Driven Approach for Electric Energy Equipment Using Wireless Sensing Technology in the Context of Carbon Neutrality

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In this paper, we use wireless sensing technology to conduct an in-depth study and analysis of data-driven power energy equipment in the context of carbon neutrality. For the high-order uncertainty of renewable energy power generation and the nonlinearity of the tidal equation, a set of orthogonal bases under arbitrary probability space can be constructed by itself using the high-order information of renewable energy power generation statistics, and then, polynomials fit the state variables such as voltage in the tidal equation using the orthogonal bases and calculate the fitting parameters using the stochastic Gallatin integration method. Based on the analysis of the online monitoring project of the main power equipment in the substation, a substation power equipment condition monitoring system is designed to realize the real-time monitoring of the temperature status of power equipment, substation smoke and temperature, and humidity environment, and the feasibility and advanced of the system are verified by elaborating the analysis. Using wireless transmission to send real-time temperature information to the monitoring background, the infrared thermal imaging online monitoring system is designed around the front-end data acquisition system, transmission network, background data processing, and display module. Saving-investment equilibrium means that total investment equals total savings; government budget balance can be achieved through government savings or deficits. When both supply chain approaches enter into the same environmental competition, the added value that consumers value the product because of the carbon-neutral approach becomes smaller in the coefficient constraint of green effort investment cost due to the competition between the two supply chains, which in turn increases the green investment cost of the supply chain with the green effort carbon-neutral approach, indicating that in the case of competition, consumers, when faced with two products produced by two supply chains, are interested in the product with the carbon-neutral approach has less value-added, and some of the demand is shifted to the product not produced with the carbon-neutral approach.

1. Introduction

In the new round of global scientific and technological revolution and industrial upgrading, energy Internet has become the focus of competing development in the world, and accelerating the construction of energy Internet based on the smart grid is the necessary way to promote the common construction, cofinancing, and sharing of electric energy and the intelligent upgrading of the electric power industry, which is of great significance to enhance the competitiveness of equipment manufacturing industry [1]. The construction of intelligent substations has attracted wide attention from researchers. However, with the rapid growth of the scale of distribution automatic control, precise load control, and power consumption information collection of power grids; the gradual expansion of power grid control to the end; the increasing number of new businesses and applications such as distributed power supplies, clean energy, electric vehicles, and smart households, prompting a significant increase in the information collection points and collection volume of power communication systems; and the explosive growth of information collection demand for the security, reliability, real-time, ubiquity, and broadband have put forward higher requirements [2]. However, manual inspection requires a lot of workforce and time due to the large workload, and the quality of inspection is affected by subjective factors such

as the work experience of operation and maintenance personnel, making the monitoring results unreliable. It caused a huge threat to the personal safety of operation and maintenance personnel. And substation intelligent inspection robot instead of manual inspection to make up for the above defects and shortcomings greatly guarantees the objectivity and reliability of inspection, but inspection robot also has some shortcomings, such as expensive, monitoring accuracy and precision by the environment, and some equipment inspection by site restrictions. Based on the above factors, in the large-scale intelligent substation construction and transformation, real-time online monitoring of substation power equipment status comes into being, using practical sensing elements to continuously monitor power equipment in operation in real-time and obtain relevant data, and combined with certain expert system software to judge the operating status of the equipment and predict the remaining life of the equipment, to timely find the failure of power equipment precursors and provide data support for equipment maintenance [3]. The total operating time is about 2498.5 days or about 6.8 years. If the collection period is extended to 30 min/time, and the report is reported every 6 hours, the collection terminal can work continuously for more than 10 years. Condition monitoring of power equipment can greatly reduce equipment failure during the maintenance period; provide the technical basis for equipment maintenance, timely discovery of equipment defects, and abnormal symptoms; ensure safe operation of equipment; and improve power supply reliability.

In the process of achieving the 2050 carbon neutrality target, global carbon emissions will gradually rise to the highest value and then gradually achieve carbon-neutral growth and eventually achieve carbon neutrality completely [4]. From the perspective of the fashion supply chain, for a secondary supply chain consisting of a manufacturer and a retailer, the game theory approach is applied in the model to establish a noncooperative influence on the supply chain to construct different models of manufacturer-retailer profit demand inputs, and after a preliminary exploration of the supply chain performance after the application of carbon neutrality, the impact of the carbon neutrality approach on market demand, retailer pricing, manufacturer pricing, retailer, and manufacturer profits. We also consider the competition between two supply chain strategies without and with the carbon-neutral approach to explore the impact of the carbon-neutral approach on market demand when consumers have a choice of two products [5]. Finally, we examine the cost of green inputs and offsetting carbon neutrality concerning the intensity of environmental gains and losses, the environmental gains and losses due to carbon emissions under both approaches, and the change in the intensity of environmental gains and losses as a percentage of manufacturer revenue.

The achievement of energy conservation, emission reduction, and energy and environmental constraint targets cannot simply be rigidly achieved at the cost of slowing down economic growth but requires attention to internal adjustments. Energy consumption intensity, expressed by the amount of energy consumed per unit of output, reflects the degree of dependence of economic development on energy, as well as the efficiency of energy utilization. Reducing energy consumption intensity has long been one of the important ways to achieve energy conservation and emission reduction, and China's energy consumption intensity is still at a high level, with great reduction potential. Against the above background, this paper takes energy consumption intensity as the research object and studies the characteristics of changes in China's energy consumption intensity in terms of historical trends, volatility shocks, and industry elasticity, respectively. Secondly, the influencing factors of energy consumption intensity changes and their regional differences are further studied. Finally, the reduction rate of energy consumption intensity in the industry in the future is predicted, and the carbon emissions and carbon intensity reduction potential are predicted based on this. The study of the above issues can provide a basis for the formulation of energy conservation and emission reduction and energy efficiency improvement policies. The analysis of energy fee intensity at the regional level helps to understand spatial differences and to develop targeted policies for different regional development to gain competitive advantages. Overall, by studying the characteristics and connotations of energy consumption intensity and carbon emissions in China, this study can provide policymakers with feasible methods to solve practical problems from a scientific perspective and has significant practical significance and reference value for formulating energy economic policies, promoting low-carbon development, and implementing sustainable development strategies. It also helps to achieve the energy-saving and emission reduction targets set by the Chinese Government in an efficient and high-quality manner.

2. Related Works

Carbon neutrality, also known as offsetting carbon emissions, is a system that aims at carbon neutrality by planning and sorting out the processes that may generate carbon emissions, understanding the carbon emission levels of different parts of the system from multiple aspects, and then making the overall net carbon emissions of the system zero or keeping them within the scope of the system's target through carbon collection/capture [6]. The data-driven polynomial chaotic expansion method can be applied to the situation with limited statistical data. It is necessary to point out that the main difference between the generalized polynomial chaotic expansion method and the data-driven polynomial chaotic expansion method is that the calculation methods of the polynomial basis of the two are different. The former is selected from the Wiener-Askey mechanism, and the latter directly uses several moments of statistical data. Construct a polynomial basis. Only if these factors can have a reasonable range of values under the premise of the existence of optimal solutions can the goal of a green supply chain be achieved [7]. Therefore, the current problem of green supply chain channel selection and pricing is less related to the luxury industry but more a comprehensive study of channel selection plus energy efficiency, supply chain coordination, and uncertain environment [8].

The basic idea of wireless sensor networks first originated in the United States military to meet its own operational needs, the traditional sensors using point-to-point signal transmission, connected to sensing controllers, constituted the prototype of sensor networks in human history [9], that is, the distributed sensor network with comprehensive information processing ability, which uses modern micro sensor nodes to monitor the activities of the enemy. Subsequently, several studies on wireless sensor networks have been carried out, and corresponding results have been achieved [10]. Condition monitoring technology for substation power equipment is developing very rapidly, and most of the power equipment has developed various condition monitoring schemes to varying degrees [11]. Compared with preventive testing, condition monitoring systems use more sensitive sensors to collect insulation deterioration information in power equipment operation and rely on computer networks and rich software support to process and identify the information [12]. The online condition monitoring system uses some online preventive test programs to reflect the operating status of power equipment more accurately, to achieve a comprehensive diagnosis of the operating status of power equipment, and to promote the transition from periodic maintenance to condition maintenance of power equipment [13].

The stability of the renewable energy power generation system itself is not as stable as that of the traditional synchronous machine, and the system stability margin also fluctuates greatly when the system operating state changes randomly in a wide range, which makes it difficult to apply the system stability analysis results based on the determined operating state with small disturbances in practice. Considering that uncertainty is an inherent characteristic of renewable energy power generation systems and the common probability distribution model is difficult to accurately describe the uncertainties in the actual system, it is necessary to research the uncertainty analysis method of high proportional renewable energy power systems for higher-order uncertainties. The significance and necessity of condition monitoring of power equipment, the principle of infrared temperature measurement of power equipment, the development and application of wireless communication technology, and the progress of domestic and international research on wireless sensing network and substation power equipment condition monitoring technology are described, and the research on existing online condition monitoring technology of power equipment is elaborated.

3. Wireless Sensing Technology for Carbon-Neutral Data-Driven Analysis of Electric Energy Equipment

3.1. Design of Data-Driven Wireless Sensing Technology Based on. Various equipment in power systems often has abnormal temperature states due to the occurrence of equipment faults, and temperature monitoring using infrared thermography can diagnose the fault conditions of the equipment to a certain extent. However, in terms of the current development level, the application of infrared thermal imaging camera in power equipment condition monitoring has its one-sidedness, mainly for the power equipment internal diagnosis of certain faults; there are still some difficulties that need to cooperate with other conventional methods to make a comprehensive diagnosis of the fault [14], such as reading, writing, adding, and deleting. Permission means permission to perform these operations in a protected system and data source, such as publishing and subscribing. The distribution relationship between permissions and executive roles is a many-to-many relationship. LoRa technology is based on chirp pulse coded modulation, which has the low power consumption characteristic of FSK modulation used in traditional wireless communication technology and at the same time greatly improves the communication distance, minimizes power consumption, and saves transmission cost; LoRa adopts frequency hopping spread spectrum technology, and the link budget is as high as 157 dB, which makes its communication distance greatly increased.

The basic principle of the frequency hopping spread spectrum scheme is that part of each LoRa packet is sent through a hopping channel selected in a frequency lookup table managed by the microcontroller, and at the end of the scheduled hopping cycle, the transmitter and receiver switch to the next channel in the hopping predefined list to continue sending and receiving the next part of the packet. The frequency hopping transmitting and receiving process starts at channel 0 [15]. The preamble and header are first transmitted in channel 0. After the transmission is completed, the first interrupt signal is generated, and the microcontroller responds to the interrupt by jumping to channel 1 according to the preagreed frequency, and the first hop is completed. While jumping, the channel counter reading located in the register increases and generates an interrupt signal, and the microcontroller responds to the interrupt by jumping to channel 2 and repeating the above frequency hopping process. The frequency hopping reception process starts from channel 0. After the detection of the valid preamble code is completed, the receiver starts the above frequency hopping process as well.

$$w \approx \sum_{k} C_k^2 P_2^k(X), \tag{1}$$

where C_k^2 is a constant corresponding to the polynomial basis P_2^k.

Explicit header mode is the default mode of LoRa operation, in which the header contains payload information such as payload length in bytes and forward error correction code rate and whether optional 16-bit cyclic redundancy check is turned on. The header sends the payload information according to the maximum error correction code, including the payload length in bytes, the forward error correction code rate, and whether to turn on the optional 16-bit cyclic redundancy check. The header is sent following the maximum error correction code and additionally contains its cyclic redundancy check to cause the receiver to discard invalid header packets. In specific cases where the payload

length, coding rate, and cyclic redundancy checks are fixed or known, the implicit header mode is typically invoked to shorten the transmission time by manually setting the payload length, coding rate, and cyclic redundancy checks at both ends of the wireless link, as shown in Figure 1. In the profit of retailers, because the best results of carbon neutralization methods that do not use green inputs are numerical and lack the impact of the corresponding cost coefficient, only when the cost coefficient of green inputs is less than the added value of consumers to carbon neutral products the mathematical result of the coefficient.

The wireless sensing system mainly monitors the status of power equipment in real-time, and the sensor device and LoRa wireless communication module cooperate to realize the real-time collection of power equipment status data, and each sensor node in the system has a wireless communication function. The system is mainly composed of terminal nodes, gateway nodes, and a back-end equipment monitoring centre [16]. The overall structure of the LoRa wireless communication technology-based power equipment status monitoring system is shown in Figure 1. The LoRa gateway node is equivalent to a router, which can collect and process the information and transmit the processed information to the backend equipment monitoring centre to realize the management of each LoRa node; in the backend equipment monitoring centre, the operation and maintenance personnel can base on the real-time collected equipment status information and decide on the status of the power equipment. In the background equipment monitoring centre, operation and maintenance personnel can make timely judgments on the operation status of power equipment based on the real-time collected equipment status information to effectively avoid power equipment accidents and bigger disasters.

Since in traditional methods such as the generalized polynomial chaos expansion method, only orthogonal bases are considered for the probability space of independent univariate variables (e.g., Gaussian distribution); the original correlated multidimensional probability space needs to be removed from correlation by the Nataf transform before the generalized polynomial chaos expansion method can be used. In the framework of the generalized polynomial chaos expansion method, the orthogonal basis in the multidimensional probability space is the tensor product of the orthogonal bases of the independent univariate probability space.

$$P_2^k(X) = \prod_{i=1}^{n} K_i^2 P^{(k_1,k_2,\cdots,k_n)}(X), \tag{2}$$

where $P_2^k(X)$ represents the kth order polynomial basis associated with a one-dimensional random variable x; the main components of the terminal node are the sensor acquisition module, wireless communication module, microprocessor module, and power supply module [17]. The functions of the sensor acquisition module are mainly to use the ultrasonic signal sensor to receive the ultrasonic signal generated by radiation in the process of partial discharge to realize the online monitoring of partial discharge, to use the smoke sensor to monitor the smoke situation of the substation in real-time, and to use the temperature and humidity sensor to monitor the temperature and humidity situation of the substation in real-time; the wireless communication module refers to the use of LoRa wireless communication module to transfer the sensor module collected. The LoRa wireless communication module is used to transmit the data information collected by the sensor module to the LoRa gateway node; the power module provides energy supply to the whole terminal node module.

This part is the data guarantee of the big data platform. The data integration part is the foundation of the entire big data platform. It analyses the sources, characteristics, storage, and usage requirements of various types of big data in power and designs and adopts corresponding collection strategies, methods, tools, and interfaces according to its data characteristics. Since the Schmidt orthogonalization method constructs a set of orthogonal bases in a given inner product space from a set of bases in an arbitrary inner product space, a set of bases needs to be chosen as initial conditions. Without loss of generality, the initial polynomial basis is first chosen to be composed of linearly independent monomials concerning a d-dimensional random variable X and represented by a set, the elements of which are defined as follows.

$$e_j(X) = \prod_{i=1}^{n} X_i^2, j_i \in N, \tag{3}$$

where e is the maximum order of the polynomial basis; the goal of the energy Internet is to personnel social welfare services process, with the assistance of big data, can be based on the needs of consumers, the formation of their internal processes for in-depth reanalysis and redesign of interactive real-time feedback. Therefore, the process reengineering brought by the energy Internet is not ordinary resource allocation, but a deep management change, from the original one-way transmission of energy services, consumers passively accept to a two-way interactive intelligent network, including not only the consumer orientation of the energy provider but also the adaptation of consumers to the emerging energy network, until reaching a dynamic balance between the two sides of the common demand, as shown in Figure 2.

Power station big data sources are mainly defined as data from various business systems or offline measurements in the current power production process, and professional data from cross fields and qua industries such as meteorological data, demographic data, and urban planning data may be accessed in the future. Grid control is gradually expanding to the end. The increasing number of new services and applications such as distributed power, clean energy, electric vehicles, and smart homes has greatly increased the information collection points and collection volume of the power communication system, and the demand for information collection has exploded. The security, reliability, real-time, ubiquity, and broadbandization of smart grids put forward

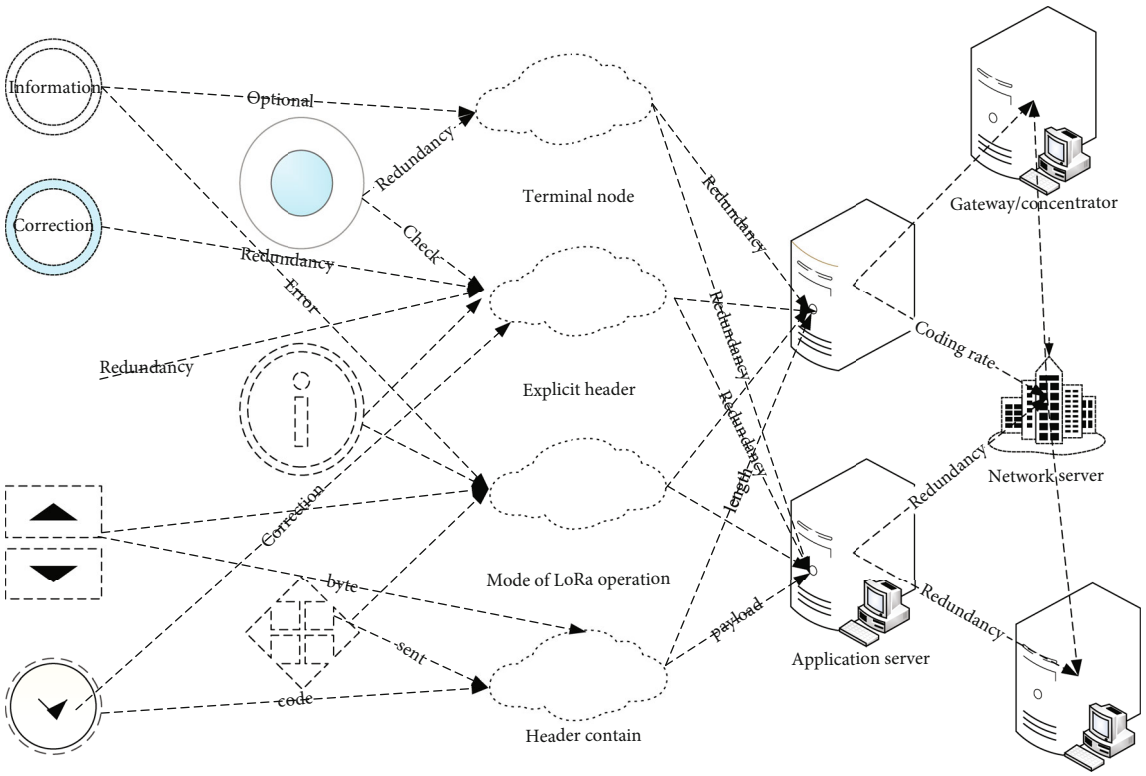

Figure 1: LoRa WAN network architecture.

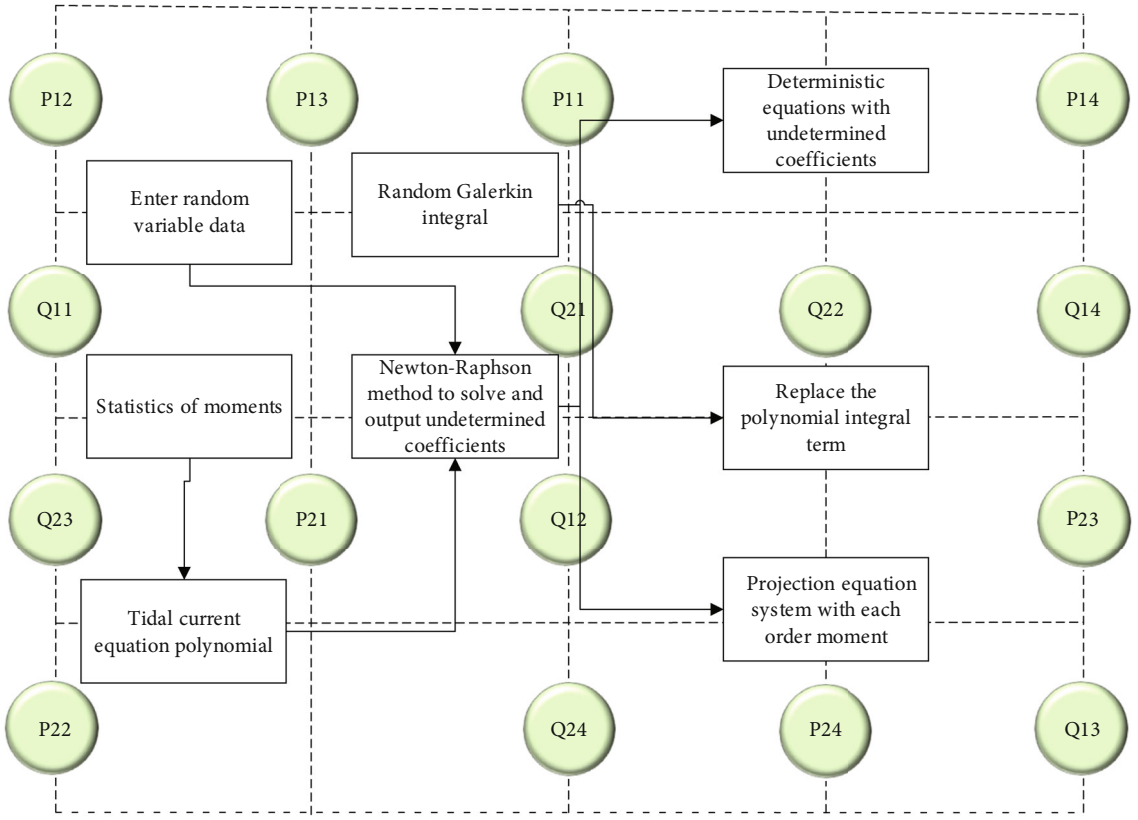

Figure 2: Data-driven design.

higher requirements. These data types not only contain a large amount of structured data but also more unstructured data such as documents and images, which is the data guarantee of the big data platform. The data integration part is the foundation of the whole big data platform, which deeply analyses the sources, characteristics, storage, and usage requirements of various types of power big data and designs and adopts corresponding collection strategies, methods, tools, and interfaces according to their data characteristics, to ensure the integrity and efficiency of the big data collection process. Data integration technology mainly uses message queues, data import tools, data extraction tools, data replication tools, and other methods to realize structured/unstructured, massive historical/real-time/quasi-real-time, and internal/external data access.

Considering that there is a weak local discharge signal when partial discharge monitoring is carried out, at this time, to improve the reliability of partial discharge monitoring, it is necessary to use a high-gain amplifier to amplify the original output ultrasonic signal; this design uses a multistage amplification circuit to amplify the useful information in the sensor acquisition signal and suppress noise interference, improve the signal-to-noise ratio of the system, and ensure the whole analogy channel bandwidth, at the same time by the influence of the substation monitoring environment interference, the need to apply band-pass filtering of the acquisition signal in the environmental noise and other filtering processing, and the effective filtering of the monitoring site interference signal.

3.2. Carbon Neutral Electric Energy Equipment Data-Driven Analysis. The status information data of the power equipment collected by each monitoring node is received by the wireless transceiver module of the gateway node and sent to the microprocessor module through its serial port, and the microprocessor module receives this data information for corresponding processing, and the processed data transmits the data information to the upper computer through the USB to the serial port [18]. The data acquisition module is completed by two modules: the sensor module and the microprocessor. The sensor mainly collects analogy current signals and needs to be able to collect multiple data at the same time; the main controller module is mainly responsible for controlling the status of the sensor and processing the collected data. The interconnection between the energy Internet has a more complex energy transfer relationship. The energy supply of the energy internet can be produced either within the region or from other regions. Similarly, on the energy consumption side, the energy produced in the region can be consumed as well as energy supplied by other regions. When the energy supply within the region is greater than the energy demand, energy can be exported through the energy transmission pipeline to supply energy to other regions to achieve interregional energy interconnection optimization and coordinated operation. Therefore, the energy Internet has the characteristics of the bilateral flow of energy between electrical and other forms of energy and the coordinated and optimal allocation of energy across regions. Practical sensor elements are used to continuously monitor the power equipment under operating conditions in real time and obtain relevant data, combined with certain expert system software to judge the operating status of the equipment and predict the remaining life of the equipment.

$$Y_t = \alpha - \sum_{i=1}^{p} \beta_i^2 Y_{t-1} + \varepsilon_t^2, \tag{4}$$

where Y is the k-dimensional endogenous variable and is the k-dimensional error vector and $\beta_i^2 Y_{t-1}$ is the matrix of coefficients to be estimated. In practical applications, the VAR model is more theoretical than empirical. At the same time, the VAR model can estimate the lagged terms of all endogenous variables, describing the dynamic correlation between them. Using this model, it is possible to analyse the impact of a shock on the system dynamics when the model encounters shock. The impulse response function can test for this "contagious" diffusion effect [19]. The impulse response function reflects the behaviour of the variables themselves, as well as other variables in the system, when the errors in the system subjected to a shock, and the impact on their future performance, etc. Using variance decomposition, the degree of influence of each structure on the endogenous variables can be analysed to further evaluate the importance of different structural shocks. This approach can verify the evolution of the dynamic behaviour of the variables over time. However, the VAR model also has drawbacks, as the model construction is not based on actual economic theory and lacks structural constraints imposed on the variables of interest, resulting in variable estimation and correlation tests that are often not accurate enough. Also, when major shocks occur, the VAR model is not stable, resulting in an impulse response function that is not unique, as shown in Figure 3.

Fuel transfer personnel should pay attention to the dynamic information of the production and transportation links in the mine in real-time, do a good job of docking with the information of receiving and unloading and storage in the plant, and communicate and coordinate well to ensure the normal and smooth operation of all links of shipping, transportation, and coal unloading. With the goal of not incurring demurrage as much as possible, we should grasp the berth and leaning dynamics of loading port in real-time, reasonably transfer vessels, and the efficiency of unloading port should be improved year by year. Employees with strong execution should be selected as shunting staff, which should be adequately equipped and zoned to ensure that the plan is executed. Game theory is used in the model to establish supply chain structure under noncooperative influence. Different manufacturers and retailers profit demand input models, after preliminary exploration of the supply chain performance after carbon neutrality and application.

$$\beta \geq \frac{(1-\theta)(1+\varepsilon)}{6\theta}. \tag{5}$$

Using the optimal results for the supply chain without the green effort carbon-neutral approach in a noncompetitive environment, we can see that only a quarter of the

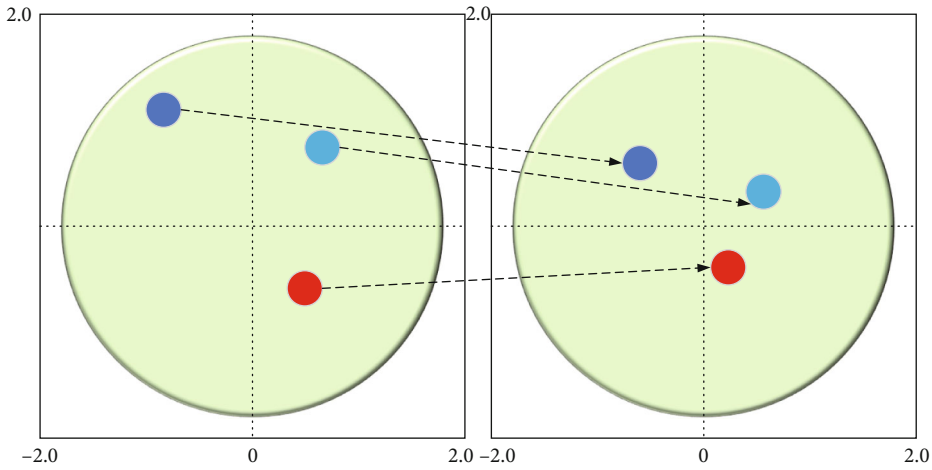

Figure 3: AR root test plot.

market demand is met, the green effort is zero relative to the supply chain with the carbon-neutral approach, carbon emissions are not reduced by any measures at the production stage, the cost of offsetting carbon emissions depends on consumer demand, and the intensity of environmental gains and losses is the greatest, suggesting that manufacturers' profit maximization and sustainability are opposites. In the comparison of individual items, except for the retail price and wholesale price where we can visually compare the size, in market demand, manufacturer's profit, and retailer's profit, because the optimal results of the carbon-neutral approach without green inputs are numerical and lack the influence of the corresponding cost coefficients, the cost coefficients of green inputs can only be reduced if they are smaller than the mathematical results containing the added value coefficients of consumers to carbon-neutral goods. The cost coefficients of carbon emissions are in the constraint of the cost coefficients of green inputs, so that the performance of one of the outcomes of market demand, manufacturer, and retailer can be optimized. But in a comparison of two supply chains collectively, only the smallest needs to be chosen as the benchmark for comparison to obtain consistent results for market demand, manufacturer, and retailer sizes.

Roles represent a set of access rights, and the node-to-role assignment relationship is a many-to-one relationship [20]. A node can be granted only one execution role; however, a role can be assigned to multiple nodes. A node that is a publisher will be granted an execution role based on the topic, and if it is a subscriber, it will be granted its corresponding execution role based on the agent. Publishers of different topics will need different permissions to handle data and resources. Operations mean different commands to be executed on the data source, such as read, write, add, and delete. Permissions denote permission to perform these operations in a protected system and data source, such as publish and subscribe. The relationship between permissions and the assignment of executive roles is a many-to-many relationship. Thus, the system can assign multiple access rights to a role. The publisher role is granted publish-related permissions, and the subscriber is granted subscription-related permissions.

$$S_k^a(u,v) = \frac{1}{n}\sum_{i=1}^{m} P_2^k(u,v). \tag{6}$$

In different cases, we can adjust the structure and attribute similarity weights. If the attribute information is more helpful than the structure information for interest prediction, S_k^aset to greater than 0.5 nodes in the same community are more likely to have similar interests. The more common communities, the higher the likelihood that nodes have similar interests, i.e., the higher the similarity, as shown in Figure 4.

The method of carbon neutral will have an impact on market demand. Finally, it studies the green investment and the cost of offsetting carbon neutrality according to the intensity of environmental gains and losses and discusses the environmental gains and losses caused by carbon emissions under the two methods and the changes in the proportion of environmental gains and losses in the manufacturer's income. It is necessary to point out that the main difference between the generalized polynomial chaos expansion method and the data-driven polynomial chaos expansion method is that the polynomial bases of the two are computed differently that the former is chosen from the Wiener-Askey mechanism and the latter constructs the polynomial bases directly using the information of several order moments of the statistical data.

Although the generalized short-circuit ratio of a power electronic multifeeder system can analyse the system's small disturbance stability margin analytically, however, the system is subject to random fluctuations of renewable energy power and uncertainty in the stability margin during operation. The generalized short-circuit ratio determined under deterministic operating conditions cannot quantify the small disturbance stability margin under stochastic conditions. Therefore, calculating the small disturbance probabilistic

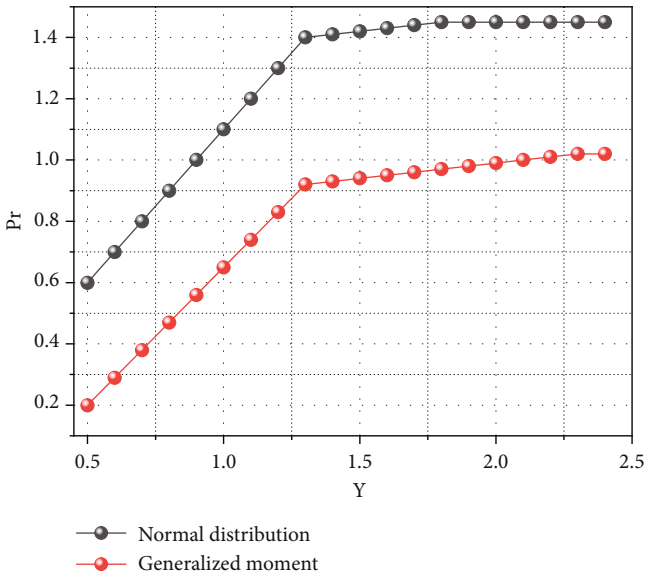

Figure 4: Comparison of generalized moments and normal distribution results.

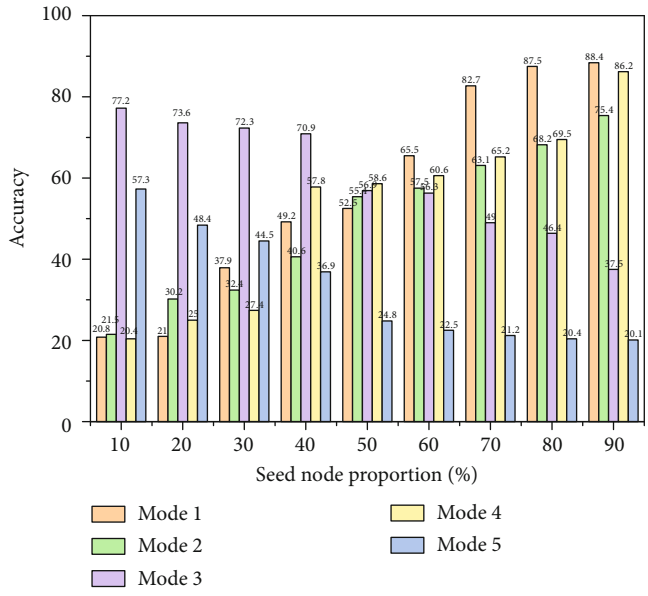

Figure 5: Effect of seed node ratio on accuracy.

stability margin for multifeeder systems is important for the dynamic stability assessment of multifeeder systems.

4. Results and Analysis

4.1. Data-Driven Wireless Sensing Performance Results. Figure 5 demonstrates the effect of the proportion of seed nodes on prediction accuracy. The initial probability distribution of interest is predicted based on the interest of the seed nodes within the community, and after updating the algorithm iteratively, a significant improvement in prediction accuracy is achieved. Due to the randomness of seed node selection, the initial accuracy showed a decrease in the 40% to 50% interval. However, the final performance was improved after the update iterations, proving the robustness of the model. As the percentage of seed nodes increases, the prediction accuracy also becomes higher.

The results of comparing this paper's work with other models shown to verify the importance of overlapping communities on prediction accuracy. The most significant difference between the models is the calculation of similarity in the overlapping communities. In this paper, the combined similarity of nodes under overlapping communities is higher than the similarity computed in individual communities. Through the analysis of the intensity of energy charges at the regional level, it is helpful to understand spatial differences, formulate targeted policies for the development of different regions, and gain competitive advantages. In Models 1 and 2, the combined similarity is the maximum and minimum similarity under common communities, respectively. Model 3 does not consider community division, and all nodes are in one large community. The testing of the communication function of the terminal shows that the communication module works properly. Then, the power consumption of the terminal system needs to be tested in combination with hardware and software. From the power consumption analysis, it is known that the test includes the current in the sleep state of the acquisition terminal, the current in the acquisition state, and the current during data upload, and the current consumption in these states directly determines the power consumption performance of the remote acquisition terminal. The terminal needs a certain discharge time to enter the sleep state from the working state, and it takes about 2 minutes for the terminal to be completely discharged after the discharge voltage test by the voltmeter; therefore, after entering the sleep state, the terminal needs to ensure at least 2 minutes of sleep time, and the power consumption test is shown in Table 1.

The acquisition terminal designed in this paper accesses the hibernation state immediately after processing data and is in the sleep state when there is no work, and the set terminal has no standby power consumption, and the standby power consumption of the terminal is negligible. Therefore, the power consumption of the remote acquisition terminal is composed of three parts: the sleep state, the data acquisition state, and the data upload state. In actual application, assuming that the acquisition cycle of the remote acquisition terminal is 15 minutes/time and the upload cycle is 6 hours/time, the remote data acquisition terminal consumes about 13717.772 mA∗s of electric energy in the acquisition state, 372.211 mA∗s of electric energy in the sleep state, and 591.907 mA∗s of electric energy in the transmission state every day, so the total daily electric energy consumption of the acquisition terminal is about 14678.772 mA∗s. Therefore, the total daily power consumption of the collection terminal is about 14678.89 mA∗s. Minimize power consumption and save transmission costs; LoRa adopts frequency hopping spread spectrum technology, and the link budget is as high as 157 dB, which greatly increases its communication distance.

The collection terminal adopts the lithium battery of the EAST'FIR brand, the specification of which is 3.7 V∗

Table 1: Measurement data sheet.

Group	Sleep state (μA)	Sleep state (μA)	Sending status (mA)
1	34.5	78	86.9
2	53.1	42.5	39.4
3	86.2	60.5	71
4	83.9	31.7	41.4
5	74.6	34.5	59.7
6	57.8	58.6	55.5
7	56.8	42.7	64.6
8	54.6	46.9	80.5
9	25	81.7	89.1
10	45.2	21.3	69.6

9800 mAh. Taking this power supply as an example, it can be calculated that the total time that the low-power collection terminal can operate is about 2498.5 days, i.e., about 6.8 years. If the acquisition cycle extended to 30 min/time and reported every 6 hours, the acquisition terminal can work continuously for more than 10 years. The calculation results show that the designed NB-IoT-based low-power remote acquisition terminal can meet the operating index requirement of more than 5 years of operation. For the low-power acquisition terminal device, the device is in the dormant state for a long time, so the power consumption level of the sleep state is of vital significance and is an important indicator of the low-power performance of the remote acquisition terminal.

5. Carbon Neutral Electric Energy Equipment Data-Driven Results

The development of the energy Internet is not an easy task in terms of the specific technologies needed for its discovery and must require a high level of technical support. Without the perfection of these technologies, the maturation and large-scale application of the energy Internet is unlikely to be successful. Therefore, to achieve significant development of the energy Internet, it is necessary to carry out large-scale technological innovation and breakthrough the core technical limitations of these applications, to successfully carry out large-scale commercial applications and promotion. The development of the energy Internet requires a high degree of technical difficulty and spans a wide range of industries that cannot be accomplished by a few companies. Therefore, technological innovation in the energy Internet industry is a huge and complex system project, which requires cross-border cooperation among different industries and enterprises, as well as the formation of closer technological innovation alliances among enterprises and industries, to jointly carry out technological innovation activities around the core technology of the energy Internet, promote the innovation and change of energy science and technology, and drive the great development of energy Internet-related industries.

To clarify whether carbon trading has a significant impact on corporate renewable energy development, it is necessary to compare the difference in the degree of corporate renewable energy development before and after the implementation of the carbon trading market. However, many factors can have some impact on corporate renewable energy development, such as firm size, the number of patents, the share of technicians, environmental regulations, and market share. The development of corporate renewable energy may be based on government subsidies to companies, which reduce investment costs and thus promote their development, or companies may sell their excess carbon allowances in the carbon trading market to gain additional revenue, thus reducing costs and promoting their development. The header sends the relevant information of the payload according to the maximum error correction code, which mainly includes the payload length expressed in bytes and the forward error correction code rate and whether the optional 16-bit cyclic redundancy check is turned on. Therefore, it is necessary to use the double-difference method to test whether it is because the establishment of the carbon trading market has had an impact on the development of renewable energy by firms, as shown in Figure 6.

This module mainly covers product market equilibrium, saving-investment equilibrium, government budget balance, and balance of payment equilibrium and follows neoclassical macro closure conditions. According to neoclassical theory, investment and all prices are endogenously determined by the model, and labour and capital fully utilized, which is also referred to as factor market equilibrium. Specifically, product market equilibrium requires that aggregate supply and demand for goods are balanced; factor market equilibrium includes equilibrium in labour and capital markets; saving-investment equilibrium means that aggregate investment equals aggregate savings, and government budget equilibrium can be achieved by government savings or deficits. In addition, the balance of payments is defined as imports equalling exports plus net inflows of foreign capital.

The humidity of the substation environment can effectively reduce the floating sink existing in the air of the substation and reduce the harm to the operation of the equipment, while the substation power equipment needs to be in a suitable temperature environment to achieve normal and stable work, so a suitable temperature and a humidity environment are important to ensure the long-term stable work of the entire substation power equipment, and it is necessary to monitor the temperature and humidity environment of the substation. The results of satisfaction assessment based on confidence uncertainty are shown in Figure 7 and the trends of the predicted happy probability distribution, uncertainty, and unhappy probability distribution in satisfaction. The experimental results show that the uncertainty decreases with the increase of trip records.

Given the high-order uncertainty of the renewable energy power and the nonlinearity of the tidal equation, a set of orthogonal bases in any probability space can be constructed by using the high-order moment information of the renewable energy power statistics, and then, the orthogonal bases can be used to polynomials fit the voltage and other state variables in the tidal equation, and the fitted parameters are calculated by the stochastic integration method.

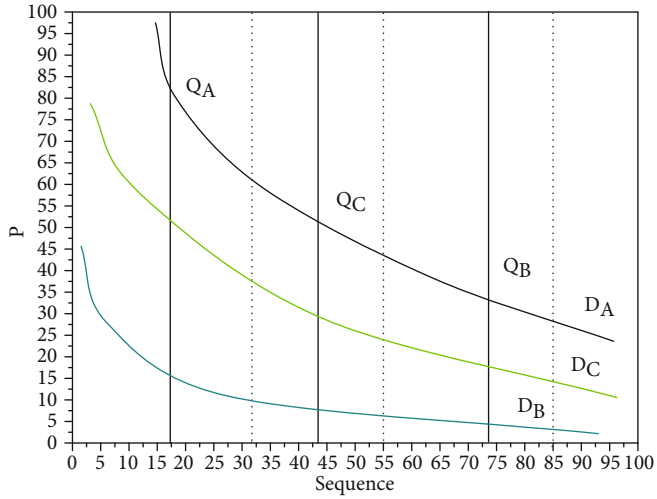

Figure 6: Carbon emission results.

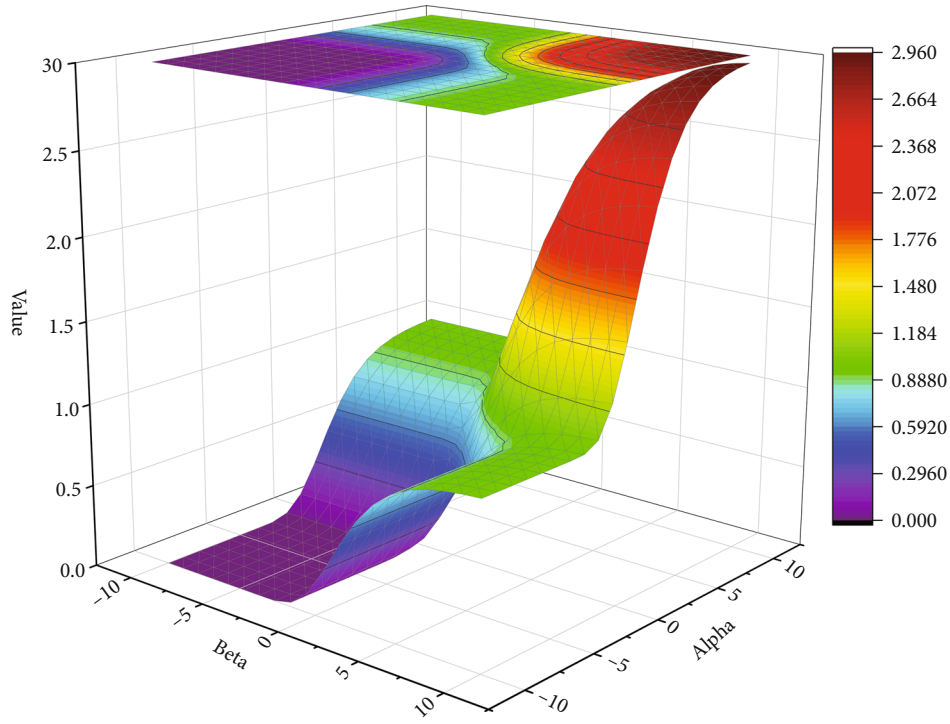

Figure 7: Data-driven results for electric energy equipment.

The analysis of the algorithm shows that the proposed method can effectively handle the stochastic tidal analysis with correlation and is more accurate than the traditional transformation method.

6. Conclusion

A time series-based structural vector autoregressive model, combined with impulse effect function and variance decomposition methods, is used to study the fluctuation characteristics of energy consumption intensity and the dynamic impact of energy structure on energy consumption intensity changes and the degree of shocks. Realize the online monitoring of partial discharge, use the smoke sensor to monitor the smoke condition of the substation in real time, and use the temperature and humidity sensor to monitor the temperature and humidity condition of the substation in real time; the wireless communication module refers to the use of the LoRa wireless communication module to transmit the data information collected by the sensor module to LoRa gateway node. The information advantage and trading platform of the energy Internet, the sharing economy derived from it, also optimize the allocation of resources. As the energy Internet perfectly bridges the gap between energy demanders and energy producers, it allows

some energy consumers to share part of their temporarily inexhaustible energy with energy demanders through the energy Internet. On the one hand, incentive policies are used to increase the motivation of enterprises to take the initiative in technological innovation, energy-saving, and emission reduction and to guide them to invest more money and energy in low-carbon production through the establishment of preferential policies. On the other hand, it regulates industry behaviour through binding policies, promotes the establishment of environmental management standards for enterprises, and strengthens the access threshold for key industries such as high energy consumption and high pollution.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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