Research on Power Marketing Decision-Making Algorithm Based on Bayesian Network

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Abstract. With the rapid development of the economy, fully leveraging the priority role of electricity is of great significance for accelerating the modernization of electricity, continuously meeting the growing demand for electricity and social production and consumption, and promoting socio-economic development. Among them, the role of electricity marketing is becoming increasingly prominent. How to fully mine and utilize the large amount of power marketing data accumulated by electric power enterprises over the years, so as to provide reliable support for the analysis and research of power marketing decisions. Bayesian network is a graphical pattern used to represent the continuous probability distribution of a set of variables, which provides causal information to discover potential relationships between data, and because of these characteristics, it is widely used in data mining. Therefore, this paper applies Bayesian network to the analysis and research of power marketing decision, and establishes a Bayesian network suitable for power marketing decision-making for customer value evaluation and provides reliable support for marketing decision-making.

Keywords: Bayesian network · Power marketing decisions · Data mining

1 Introduction

With the rapid development of the economy and the gradual expansion of the electricity market, electricity marketing has become the main means of competition for power enterprises. The number of electricity customers is increasing, and a large amount of data is piled up in the database. At the same time, power marketing has the characteristics of multiple data sources, mixed data types, and uneven data quality. The above characteristics of power marketing make it urgent need a technical support that can quickly process massive data, so as to provide reliable support for power marketing decision analysis and research. Bayesian networks have the dual advantages of probability theory and graph theory, which provide us with a more effective way to solve uncertainty problems, which can help us solve two problems often encountered in mathematics and engineering: uncertainty and complexity. Bayesian networks can be applied to data mining of large-scale databases, which provides a very effective method for decision analysis, and has gradually become the most effective method for database knowledge

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discovery and decision analysis systems. This paper introduces Bayesian network technology into power marketing, proposes to use Bayesian network to establish an analysis model, improves the practicability and intelligence of the entire decision analysis software, makes enterprise decision-making management more scientific and reasonable, and has practical significance for better serving national economic development and improving the satisfaction of electricity customers.

2 Bayesian Network Modeling and Optimization

2.1 Bayesian Network Concept

Bayesian networks, also known as probability networks, Causal networks, and belief networks et al., first developed by R. Howard and J Proposed by Matbeson. Bayesian networks originated in Bayesian statistics and are graphical models based on probability theory, as shown in Fig. 1. Bayesian networks provide a natural and intuitive method for the expression of uncertain knowledge, which can effectively comprehensively process a lot of uncertain information and make comprehensive theoretical inferences of probability and graphical network models, and have the ability to use intuitive graphs to reason about the importance of the system on network elements.

Formally, a Bayesian network is a directed acyclic graph (DAG). Each node in the network represents an attribute, and each edge represents a dependency between nodes.The edge from node A to node B represents causality, that is, the value of node B depends on the value of node A. The variables of Bayesian networks are discrete. Each node is associated with a series of parameters. Use Ni for a node, and $\prod$ Ni for the Ni parent node set. The parameters of Ni are conditional probability distributions expressed in the form P (Ni|$\prod$Ni), which is the probability distribution of each $\prod$ Ni.

2.2 Bayesian Network Modeling and Optimization

Applying Bayesian networks to model begins with understanding the variables in the network and their states and interrelationships, and then building the right model for the problem to be solved. Bayesian network modeling is divided into three phases: problem analysis, model design, and model testing. The modeling should follow the principle of wholeness, the principle of decomposition one by one, the principle of model simplification, and the principle of feedback, and the built model completes specific functions and tasks at each stage, and finally can build an ideal model to meet the problem analysis. At present, the modeling methods proposed by researchers are

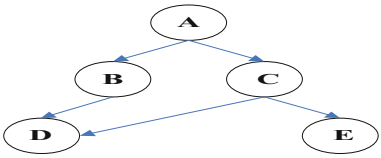

Fig. 1. Schematic diagram of Bayesian network

roughly divided into the following three types: relying on domain experts to model, modeling after learning from data, and creating models from the knowledge base.

Bayesian network modeling is mainly divided into three steps: first, understand the component nodes of the model; Second, grasp the network structure of the model through the causal relationship between nodes; Third, the posterior probability is calculated based on the network structure and the prior probability of the constituent nodes.

1. Identify the relevant variables and their state space

Clearly defining variable bands and variable domains is a top priority in the model building process. Typically, appropriate variable groups and variable domains are determined based on expert experience or sampling.

2. Determine the structure of the Bayesian network

Network structures are used to represent relationships between Bayesian network nodes. Taking the Bayesian network model construction process as an example, there are two main bases for network structure construction: one is that the network structure is determined based on a large number of sample data, and the other is directly specified based on expert knowledge.

3. Determine the conditional probability distribution of the node

The influence relationship between nodes can be represented by a conditional probability table. There are three ways to define conditional probability tables: one is to obtain a large number of sample data of research objects and obtain probability tables according to Bayes' related theory; The second is to use expert knowledge to determine probability tables; The third is to define the conditional probability table according to the formula. You can choose different methods according to different scenarios, or you can combine these three methods according to the actual situation.

When we build a Bayesian network model, in order to verify whether the model meets the requirements, we need to test the correctness of the model network structure, the correctness of the probability distribution values, and the correctness of the test using the known cases in the case library. If the test results are not satisfactory, we modify the model several times until we get a satisfactory result.

3 Power Marketing Theory and Focus Issues

3.1 Electricity Marketing Theory

Electricity marketing refers to the power enterprises in the changing electricity market environment, in order to meet the needs of consumers for electricity, through a series of market activities of power enterprises, to provide users with high-quality, reliable and abundant electricity. The core of power marketing is: electric power enterprises must face the market and consumers, must adapt to the changing market and make correct adjustments to marketing strategies in a timely manner; Electric power enterprises should provide consumers with qualified electric energy and satisfactory services; Utilities need to get electricity into the hands of consumers with minimal investment and as quickly as

possible: Utilities should and can only achieve their goals in consumer satisfaction. The concept of electric power marketing requires that all behaviors of electric power enterprises take the demand of the electricity market as the starting point and meet the main needs of the electricity market as the center. The concept of electricity marketing got rid of the long-term heavy power generation and neglected electricity consumption; Heavy power distribution, ignoring power quality; Heavy electricity fee recycling, ignoring the backward concept of service quality. The concept of electricity marketing is a kind of marketing idea that we advocate to guide power production and operation activities.

3.2 Current Problems in Electricity Marketing

In recent years, China has put forward the "dual carbon" goal and further proposed relevant measures to achieve the "dual carbon" goal. The "dual carbon" goal will promote the comprehensive green transformation of economic and social development, accelerate the green and low-carbon development of energy and electricity, further improve the level of electrification in various fields, and have a profound impact on China's "14th Five-Year Plan" power supply and demand situation. Moreover, the main characteristics of power supply and demand in the "14th Five-Year Plan" are as follows: electricity demand maintains rapid growth, the "double peak" characteristics of electricity load in summer and winter are more significant, the contribution of new energy to the power balance during peak load hours is limited, and the "double peak" in summer and winter is facing power supply pressure, and hydropower accounts for comparison In high areas, there is a certain power gap during the dry winter period. In the face of the severe power supply and demand situation, analyze the main characteristics and main problems of the power supply and demand situation in the 14th Five-Year Plan, study the change trend of China's total electricity demand and structure, total power supply and structure during the "14th Five-Year Plan" period under the "dual carbon" goal, carry out power and electricity balance measurement in different provinces and subregions, adhere to the "demand response priority, orderly power consumption guarantee, and power saving assistance", further increase efforts, do detailed and solid demand-side management, and give full play to the role of supply and demand regulation. In order to ensure that when the load of the power grid peaks and the power generation capacity is insufficient, the people's livelihood, public services and important users use electricity. Cooperate with the government to strictly follow the load of 20% to improve the orderly electricity consumption plan and carry out orderly use. In-depth investigation of user load characteristics and production and operation methods, customer value assessment, and then scientifically and reasonably determine the scale, time period and execution mode of user participation in orderly electricity consumption; Cooperate with the government to formulate a plan for continuous electricity users to take turns off and stop, classify policies according to the energy intensity of different industries and enterprises, reduce the impact on the production and operation of enterprises as much as possible, and help the smooth operation of the economy and society.

4 Application of Bayesian Networks in Power Marketing Decisions

4.1 Customer Value Evaluation Reasoning Model Design

(1) Establishment of attribute model

Analysis of user characteristics in the electricity market - In the electricity market, users and other members of the electricity market are equal and mutually beneficial. For the open electricity market, users can choose the supply side and trade mode that suits their own needs. So from the power supply side, it is itself a supplier, and the user is a consumer. In marketing, merchants in order to save marketing costs in order to obtain more profits, so should collect, process and process the massive information of consumers to determine specific consumer groups and consumer needs, so that the next consumption behavior of these consumer groups can be judged. Then, based on these, targeted marketing of specific content is carried out to the already identified consumer groups. Similarly, in the power market, the power supplier, as a supplier, must also fully understand the characteristics of the user's load, so that the user's behavior can be classified, so as to develop a competitive power supply strategy under the premise of ensuring the safe and stable operation of the system. All of this can be done using Bayesian networks.

The power system is a system that balances both supply and demand in real time. As a platform connecting power supply and demand and a front-end that directly serves users, the power grid shoulders a heavy responsibility for ensuring power supply. Comprehensively considering the influencing factors of China's macroeconomy, key industries, energy conservation and power saving, and electric energy substitution during the "14th Five-Year Plan" period, the departmental analysis method is used to predict the growth trend of electricity consumption in key industries such as ferrous metals, non-ferrous metals, building materials, chemicals, as well as tertiary industries and residents, and then predict the growth trend of electricity consumption in the whole society, and the maximum load utilization hour method is used to predict the maximum load (Fig. 2).

The power system operation simulation model based on mixed integer programming is based on the principle of minimizing the total cost during the operation period, and the total cost includes fuel cost, start-stop cost, fixed/variable operation cost, line loss and emission cost during the operation period. It can simulate the operating status and new energy consumption of various units of the 8760H full-time system, and can give the power balance, power balance and peak regulation balance (Fig. 3).

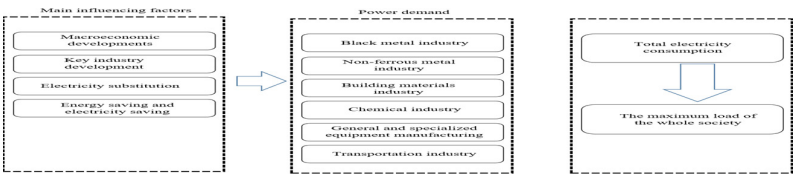

Fig. 2. Power demand forecasting model

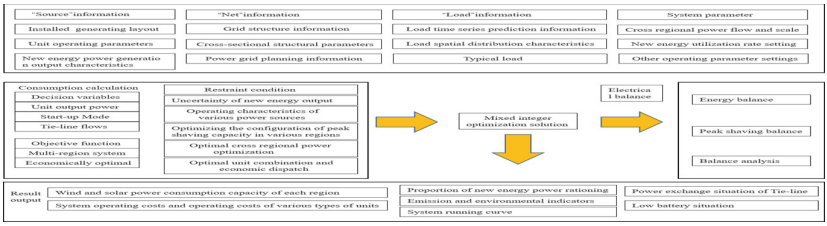

Fig. 3. Power system production simulation model

(2) Construction theory of network models

Use Bayesian networks for data mining, apply Bayesian formula 1, and analyze the causal relationship of variables. Based on prior knowledge, construct Bayesian network structures. The constructed network can fully reflect the causal relationship between variables in the training data.

$$P(S^h \Big| D, \xi) = \frac{P(D, S^h|\xi)}{P(D|\xi)} \tag{1}$$

where $P(D|\xi)$ are structure-independent quantities. Determine the prior probability of the candidate network structure $P(S^h|\xi)$, and then complete the selection of the network structure. A simple approach is to follow the Bayesian hypothesis and consider the prior probabilities of all candidate networks to be equal.

(3) Design of the network model

Taking the main influencing factors of electricity consumption risk as the nodes of Bayesian networks, the Bayesian network is constructed by eliminating a large number of unreasonable combinations through the construction method of Bayesian networks. In order to accurately discover the abnormal situation of user power consumption, the user risk assessment model adopts a layer-by-layer filtering structural model, as shown in Fig. 4. Real-time dynamic monitoring of user power consumption.

In the figure, each filter node is given two attributes, "pass and fail", the user information that fails means that the user does not have the risk of electricity consumption and will be automatically screened and eliminated, while the passed information indicates that the user has the risk of electricity consumption and needs to be further screened until all screening and filtering links are completed.Practice of Bayesian Network Application in Power Marketing Decision System.

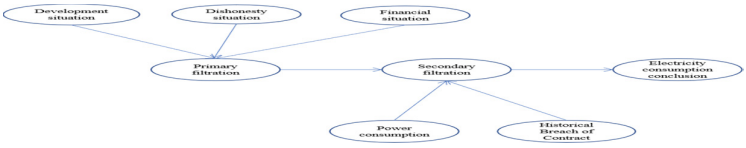

Fig. 4. Schematic dragram of Bayesian network model for dynamic monitoring of user power consumption risk

4.2 Practice of Bayesian Network Application in Power Marketing Decision System

In practice, we often encounter more complex Bayesian networks, so the simulation operation process will be relatively cumbersome. This paper will use GeNIe software to implement simulation calculations. GeNIe version 2.0 is used, which very quickly creates, edits, saves and loads intuitive and standard graphical interfaces to analyze correlation diagrams and make decisions based on probabilistic inference (Fig. 5).

To illustrate the simplification of our thinking and calculations, each node now has only two properties. Convert the model into a nodal diagram represented by letters. GeNIe2.0 simulation software replaces the complex process of our manual calculations and transforms the results into intuitive model diagrams, as shown in Fig. 6.

This conclusion is in forward reasoning, taking the total amount of electricity of the elements and the amount of investment as evidence conditions to obtain the result, combined with the probability table, it is obvious that the positive rate of return decreases. In addition, we can also use Bayesian networks for reverse inference. Taking the yield as evidence, assuming that the positive rate of return is 1, reverse reasoning is carried out to obtain the factors that have a greater impact on the rate of return, and Fig. 7 can be obtained by GeNIe2.0 simulation software.

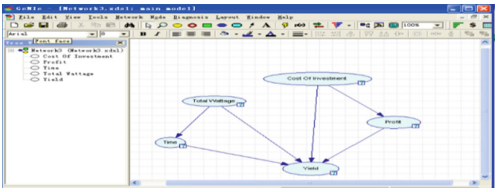

Fig. 5. Simulation interface

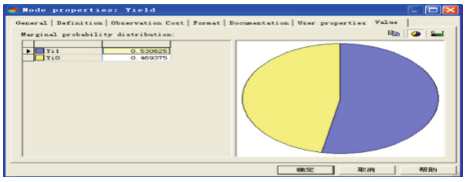

Fig. 6. Yield posterior probability of nodes

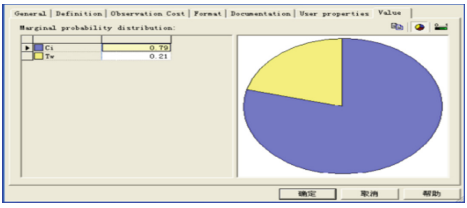

Fig. 7. Probability of element node influence Yield

It can be seen that the rate of return is more affected by the total amount of investment. In order to reduce the size of the probability table, the demand interval division in this simulation is coarse, but in practical applications, in order to make decisions more conveniently, we can refine it as needed, while also considering other factors affecting the model. Through the comparison and analysis of historical empirical data and the relevant data obtained based on the decision-making analysis of power marketing Bayesian network in this paper, it can be seen that in the past power marketing process, the customer risk classification of power marketing staff is relatively vague, and the power marketing decision often only considers the electricity demand and arrears amount for marketing decisions, and the prediction results often cannot accurately reflect the comprehensive situation, which is easy to produce sudden power consumption risks, so that the losses are expanded and the interests of power supply enterprises are damaged. These conclusions prove that the customer electricity risk prediction model based on Bayesian network is applicable and reliable, which plays a good warning and control role for power supply enterprises to carry out power consumption inspection and risk prevention for users in the future, and provides a scientific basis for power marketing decision-making.

5 Conclusion

Bayesian networks have rich probabilistic expression capabilities and uncertain knowledge expression forms, and their graphical representation is intuitive and clear, which can be used for various information causal reasoning and knowledge discovery. Based on Bayesian network decision analysis system, power marketing analysis can be carried out with the help of a good graphical interface, which can make full use of the historical experience data of power grid enterprises for reasoning, obtain the data of decision-making requirements, and reveal the operation law or existing risk points in marketing management, so as to provide decision-making basis for decision-makers of power grid enterprises, which proves the rationality of Bayesian network model in power marketing decision analysis. On the basis of analyzing the power marketing and decision-making system, the framework structure of the power marketing decision analysis system based on Bayesian network is constructed, which lays a foundation for further research on the marketing decision analysis system. Combined with specific data, Bayesian network is applied to the power supply company's customer power risk prediction, and the users are divided into different risk levels, which provides a basis for the power supply company to take corresponding prevention and control measures in advance, and effectively reduces the loss caused by user problems.

References

1. Xu Jiazhen Research on project family risk evaluation based on Bayesian network[D]. Changsha: Hunan University, 2014
2. Xiao Min Design and implementation of power marketing decision-making and auxiliary decision-making system[D]. Chengdu: University of Electronic Science and Technology of China, 2015
3. Feng Zhe Analysis and research of supply and demand law and strategy of electric power marketing[D]. Tianjin: Tianjin University, 2017

4. TANG Keqiang, WANG Shuquan, SUN Qiang Research on new marketing electricity cost recovery control and its application[J]. Electric Power, 2016, 49(11): 70–74
5. Li Zhiyong, Chen Zhigang, Xu Zheng, et al Identification of the leading factors in the growth of electricity consumption in China [J]. Automation of Electric Power Systems, 2010, 34(23): 30–35
6. Wang Hui, Shen Yidi, Xu Haocheng, et al Optimal sales pricing strategy of electricity sales companies based on electricity user segment[J]. Smart Power, 2021, 49(7): 44–51
7. Yu Yixin Smart grid for the 21st century [J]. Journal of Tianjin University (Natural Science and Engineering Technology Edition), 2020, 53(6): 551–556
8. Wang Yue, Liu Yingjia, Ji Ling, et al Structural analysis of global electricity trading network[J]. Electric Power Construction, 2016, 37(3): 129–136.
9. Bayes T R. Transactions. An Essay Towards Solving a Problem in the Doctrine of Chances[J]. Philosophical 1763,53:370~418.
10. FAN Jiancong Data mining and applied research using Bayesian methods.[D]. Shandong: Shandong University of Science and Technology, 2003
11. Wu Xin Research on power system fault diagnosis based on improved Bayesian network method. [D], Zhejiang: Zhejiang University, 2005
12. Zhang Shaozhong Research on Knowledge Discovery and Decision Making Based on Bayesian Network.[D], Dalian: Doctoral Dissertation, Dalian University of Technology, 2003
13. SONG Xiaolin, HUANG Luhan, HE Yunlong, et al. Data collected based on smart energy metersTaihu relationsIdentify new approaches[J]. electrical measurement and instrumentation,2020, 57(23) : 140–145.
14. LIU Sijie, BAI Yang, CHEN Zhongfei, et al. Research framework of early warning of energy and power industry chain under the background of carbon neutrality[J]. Guangdong Electric Power, 2021, 34(10): 1–9
15. ZHANG Haisheng, CAO Zhe, YANG Changhai, et al Research on Collusion Behavior Identification in Electricity Market Based on AdaBoost-DT Algorithm[J]. Electric Power Engineering Technology, 2020, 39(2): 152–158