Proceedings of Business and Economic Studies, 2024, Volume 7, Issue 6
http://ojs.bbwpublisher.com/index.php/PBES
Online ISSN: 2209-265X
Print ISSN: 2209-2641

Exploring the Pathways of Power Grid Marketing Management Based on Big Data

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Abstract: The electric power industry is undergoing profound transformations driven by big data, posing challenges to the traditional power grid marketing management model. These challenges include neglecting market demands, insufficient data support, and inadequate customer service. The application of big data technology offers innovative solutions for power grid marketing management, encompassing critical aspects such as data collection and integration, storage management, analysis, and mining. By leveraging these technologies, power grid enterprises can precisely understand customer needs, optimize marketing strategies, and enhance operational efficiency. This paper explores strategies for power grid marketing management based on big data, addressing areas such as customer segmentation and personalized services, as well as market demand forecasting and response. Furthermore, it proposes implementation pathways, including essential elements such as organizational structure and team building, data quality and governance systems, training, and cultural development. These efforts aim to ensure the effective application of big data technology and maximize its value.

Keywords: Big data technology; Power grid marketing management; Implementation pathways

Online publication: December 23, 2024

1. Introduction

Amid the transformation of the electric power industry, big data technology has emerged as a core driver of innovation in power grid marketing management. Traditional models have struggled to adapt to evolving market and customer demands, creating an urgent need for the adoption of new technologies and methods to improve management effectiveness and operational efficiency [1]. This paper examines the application pathways of big data in power grid marketing management, conducting an in-depth analysis of key technological applications and strategic optimizations. Additionally, it proposes an implementation framework designed to offer rigorous and professional references and guidance for power grid enterprises seeking to enhance their big data practices.

2. Key technologies of big data in power grid marketing management

2.1. Data collection and integration technology

In power grid marketing management, data collection and integration represent fundamental processes in the application of big data technology. Smart grid big data is characterized by dispersion, diversity, and complexity, making the integration of data from multiple sources essential. By utilizing the ETL (Extract, Transform, Load) process—comprising data extraction, transformation, and loading—data can be retrieved from source systems, transformed to meet business requirements, and ultimately loaded into target data systems.

In this process, data extraction involves retrieving required data from various source systems; data transformation entails adjusting data formats and types while cleaning and processing erroneous or inconsistent data; and data loading refers to transferring the processed data into the target system [2]. To perform these functions effectively, technologies such as workflow systems, scheduling engines, and rule engines are often employed to enhance functionality.

Furthermore, the diverse types and complex characteristics of smart grid big data, which involve numerous application systems, necessitate the use of advanced integration technologies. These include data federation, middleware-based models, and data warehousing, enabling the integrated processing of multi-source heterogeneous data.

2.2. Data storage and management technology

Data storage and management are critical components of the application of big data in power grid marketing management. In smart grid big data, structured data constitutes a significant proportion, though unstructured and semi-structured data are also present. Different storage technologies are required for these varying data types.

For unstructured data, distributed file systems such as Hadoop's Hadoop Distributed File System (HDFS) are suitable, offering high scalability, fault tolerance, and throughput. For semi-structured data, distributed storage systems like HBase are effective, particularly for data with complex and varied structures. For structured data, traditional relational database systems such as Oracle remain relevant.

In addition, data security and privacy protection are vital aspects of data storage and management. Comprehensive strategies must be developed to ensure the confidentiality, integrity, and security of the data [3].

2.3. Data analysis and mining technology

Data analysis and mining represent the core value of big data applications in power grid marketing management. The massive volume, complex diversity, and rapid changes characteristic of big data render traditional data analysis algorithms insufficient. Consequently, the development of new analytical methods or the enhancement of existing methods is necessary.

Data mining techniques include classification, association analysis, clustering, anomaly detection, and regression analysis, each encompassing various algorithms. In smart grid applications, these algorithms often require optimization and parallelization for distributed processing. Machine learning technology is particularly impactful in data analysis and mining, as it identifies patterns based on empirical observations and is especially useful in areas where theoretical models are unavailable.

Furthermore, deep learning, a specialized field within machine learning, has been successfully applied to smart grid big data mining [4]. For structured and unstructured data within smart grid big data, selecting appropriate analytical methods is essential for uncovering hidden patterns and correlations. These insights provide a scientific basis for optimizing power grid marketing management.

3. Optimization of power grid marketing strategies based on big data

3.1. Customer segmentation and personalized services

Customer segmentation serves as the foundation for developing personalized service strategies. By employing big data technology to analyze and mine electricity consumption behaviors, customers can be categorized into distinct groups, enabling a more precise understanding of their needs. The specific segmentation details are outlined in **Table 1**:

Table 1. Customer segmentation dimensions based on electricity consumption behavior

Customer segmentation dimension	Specific description	Segmentation criteria
Electricity usage patterns	Reflects users' electricity consumption characteristics and volume at different times of the day.	Peak-valley usage: Significant fluctuations in daily electricity consumption with clear peak and off-peak periods. Stable usage: Relatively stable electricity consumption throughout the day with minimal fluctuations. High-load usage: Consistently high electricity consumption with significant load.
Electricity usage habit	Reflects users' preferences and habits in daily electricity usage.	Preference for energy-saving devices: Tendency to use energy-efficient appliances, such as LED lights and energy-saving air conditioners. Frequent device adjustments: Regularly adjusting appliance usage, such as changing air conditioner temperatures or turning lights on/off. Fixed habits: Stable electricity usage patterns with minimal habit changes.
Electricity demand	Reflects users' specific electricity needs at different times or under varying circumstances.	Seasonal demand changes: Significant variations in electricity use during specific seasons, such as increased air conditioning in summer or heating devices in winter. Holiday demand changes: Noticeable shifts in electricity consumption during holidays, such as potential increases or decreases during long vacations.

3.2. Market demand forecasting and response

3.2.1. Short-term and long-term electricity demand forecasting

Electricity demand forecasting, a core component of grid marketing strategies, encompasses both short-term and long-term projections.

(1) Short-term forecasting: Focuses on fluctuations in electricity demand over a period ranging from hours to weeks. By integrating historical consumption data, weather forecasts, and holiday information and applying time series analysis and machine learning techniques, short-term demand trends can be accurately predicted. These insights help optimize power generation plans and maintain grid supply-demand balance [5].

(2) Long-term forecasting: Projects electricity demand trends over several years or decades. Factors such as economic growth, population dynamics, industrial structural changes, and new energy developments are comprehensively analyzed. Complex forecasting models integrate macroeconomic data, energy policies, and technological advancements, providing a scientific basis for strategic planning, grid infrastructure development, and power source allocation for electric power enterprises.

3.2.2. Formulation of demand-side response strategies

Demand-side response mechanisms aim to incentivize users to reduce electricity consumption during peak periods and increase usage during off-peak times. These strategies balance grid supply and demand while enhancing system stability and cost efficiency.

Formulating demand-side strategies requires analyzing user consumption behaviors, demand, and price sensitivity. Big data facilitates identifying response potential among user groups, enabling the design of tailored strategies. For instance, peak-off-peak electricity price discounts encourage industrial users to shift their electricity consumption to off-peak hours, while smart meters and home automation technology allow residential users to monitor and adjust their electricity usage in real time [6].

3.3. Design of dynamic pricing mechanisms

Dynamic pricing mechanisms, a crucial aspect of demand response, encourage users to optimize their electricity usage based on market supply and demand through real-time price adjustments.

When designing such mechanisms, considerations include market conditions, user behavior, price sensitivity, and operational costs. Big data analysis enables monitoring of real-time market changes to adjust electricity prices flexibly. For example, electricity prices may be increased during peak demand periods to discourage excessive use, while reduced prices during surplus supply encourage consumption. This strategy enhances grid stability, promotes energy conservation, guides users in restructuring their consumption habits, and supports the sustainable development of the electricity market.

4. Implementation path of big data in power grid marketing management

4.1. Organizational structure and team building

The effective implementation of big data in power grid marketing management requires the establishment of a dedicated big data management department. This department should oversee the planning of big data strategies, integration of data resources, construction of data platforms, and promotion of data applications. It should be staffed with professionals such as data engineers, analysts, and scientists skilled in data processing, analysis, and mining, as well as proficient in utilizing big data technologies and tools.

Given the cross-disciplinary nature of big data applications, which span power marketing, information technology, and data analysis, cross-functional teams are necessary. Team members must collaborate closely to address technical and business challenges [7]. Emphasis should be placed on talent cultivation and recruitment, supported by incentive mechanisms designed to encourage active participation in big data projects.

4.2. Data quality and governance system

Constructing a data quality and governance system is fundamental to ensuring data accuracy, consistency, and security in the application of big data to power grid marketing management. A comprehensive set of data quality management standards should be formulated to address data completeness, accuracy, consistency, and timeliness. These standards will guide data collection, storage, processing, and analysis to ensure reliability and effectiveness (as outlined in **Table 2**).

A robust data governance process must be implemented, encompassing all stages of data handling with clear operational guidelines and norms. The establishment of a governance organizational structure, defining roles and responsibilities, is essential for unified and efficient data management.

Data security and compliance are critical aspects, necessitating protective measures such as encryption and access control, along with regular security audits and compliance reviews to mitigate risks and ensure lawful data usage [8]. These steps will collectively create a reliable data quality and governance framework, offering robust support for power grid marketing management.

Table 2. Specific contents and requirements of data quality management standards

Dimension	Requirements
Data accuracy	Data must truthfully reflect actual conditions, avoiding errors or deviations. Regular verification and cleaning processes to address outliers, duplicates, and errors. Proper data collection and entry methods to minimize human error.
Data consistency	Consistent representation of identical data across systems or databases. Correct relational associations between data (e.g., primary-foreign key relationships). Unified data formats and standards to enable seamless data exchange and sharing.
Data timeliness	Timely updates to reflect current business status and information. Defined update frequencies (e.g., real-time or daily updates). Clear strategies for handling outdated data, such as archiving or deletion.

4.3. Training and cultural development

Training and cultural development are essential for realizing the value of big data and promoting continuous organizational progress. A systematic training program should be established to enhance employees' data literacy, covering areas such as technical foundations, analytical methods, and data visualization. Diverse formats, including internal lectures, external seminars, and online courses, ensure that employees acquire the necessary skills to support decision-making and business optimization [9].

Practical exposure to data science practices should be encouraged to deepen employees' understanding of big data technologies. At the cultural level, fostering a data-driven mindset is vital. Activities such as data-sharing platforms and analysis competitions can stimulate enthusiasm for data innovation, creating a work environment centered around data-driven decision-making.

Leadership plays a pivotal role in integrating data into strategic planning and operations. To sustain progress, innovation incentive mechanisms such as funding, resources, and dedicated time should be introduced to encourage the exploration of new applications and models. Additionally, a continuous feedback system should be established to evaluate the effectiveness of big data applications regularly, collect stakeholder feedback, and optimize solutions. These measures ensure that big data continues to generate value for the enterprise [10].

5. Conclusion

In conclusion, big data technology holds substantial potential and critical significance in power grid marketing management. By strengthening data quality and governance, optimizing marketing strategies, and improving risk and fault warning capabilities, power grid enterprises can more precisely understand customer needs, enhance operational efficiency, and mitigate risks effectively. Furthermore, prioritizing organizational structure and team building, alongside training and cultural development, is essential for ensuring the successful implementation of big data technology and fully leveraging the value of data.

Looking ahead, with the ongoing advancement of big data technology, power grid marketing management is poised to enter a new era characterized by intelligence, precision, and efficiency.

Disclosure statement

The author declares no conflict of interest.

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