Research on Inventory Control Method Based on Demand Response in Power System

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Abstract.

The supply chain is a network system composed of interconnected members such as suppliers, manufacturers, wholesalers, retailers and end customers. Inventory plays a major role in supply chain management and directly affects the cost and service quality of the entire supply chain system. Inventory control in the supply chain environment is not only closely related to a single enterprise itself, but also closely related to all enterprises in the supply chain. It is necessary to coordinate management with a holistic concept to achieve the overall optimal goal of the system. Aiming at the problems of low standardization in the field of power material management, material procurement plans and material demand plans are out of touch, and material inventory is too high, this article analyzes the problems of power material inventory management, researches and applies inventory control strategies, and combines its own corporate characteristics , Based on historical consumption data, extract and analyze the demand characteristics of electric power materials, and based on this to classify them scientifically and comprehensively, design the overall inventory control strategy of electric power materials, and build its dynamic inventory control model for different types of power materials , Realize the optimization and adjustment of inventory management, which can effectively improve the efficiency of inventory management and reduce the logistics management cost of the enterprise.

Keywords. Power system, demand side response, inventory control, intelligent system, thermoelectric materials.

1. INTRODUCTION

The State Grid Co., Ltd. covers 88% of the country's land area and has a population of more than 1.1 billion. It has built a number of UHV transmission projects and has become the world's largest power grid with the strongest transmission capacity and the largest scale of new energy integration, which is related to national energy security. It is a super large state-owned key enterprise that is the lifeline of the national economy. With the rapid growth of the grid scale and the increasing number of engineering projects, the task of transforming and upgrading the traditional distribution network to the smart distribution network is becoming more and more urgent. The business data of the power grid is showing an explosive growth trend, and the "volume, type, and time" characteristics of big data are increasing. It highlights that the traditional static electricity material supply chain will gradually be replaced by a highly flexible and data-driven material supply chain, which puts forward higher requirements for the accuracy of inventory control.

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The inventory of power supplies directly affects the cost and quality of the entire grid system. Inventory is an effective means to buffer the contradiction between supply and demand. The purpose is to maintain a reasonable level of inventory under the premise of ensuring the normal production and operation of the enterprise. There are three commonly used reserve modes in power companies, which are divided into physical reserve, agreement reserve and dynamic turnover. Physical storage is the most effective and quickest way of inventory management, but a large amount of physical storage for a long time not only takes up a large amount of capital, but also is not conducive to the flow of materials and is likely to cause scrap. The main goal of traditional inventory management is to classify and focus on the required inventory of the enterprise, and to determine the order time and order quantity at the same time. The ultimate goal is to minimize the cost of enterprise inventory. However, with the diversification of demand and the increase of uncertainty, traditional inventory management methods are difficult to achieve desired results. Therefore, it has important theoretical significance and practical value to explore the multi-granularity inventory control method oriented to the demand side response of the power system.

2. RELATED WORK

The inventory control problem is a classic topic in optimization theory. Literature [1] believes that both the deterministic demand model and the random demand model for a given demand distribution are relatively mature. In terms of related demand, the theory of material demand planning (MRP) and the enterprise resource planning (ERP) developed on this basis The theory has solved such problems well. However, with the development of the times, market demand has undergone great changes, and the demand for many products exhibits non-stationary distribution characteristics. In terms of inventory control in the two-level supply chain, literature [2] compared with the model of retailers holding inventory and central inventory separately, and found that by establishing multiple retailers, inventory managers can reduce the total cost of inventory control and increase the company. income. In the aspect of cooperation and competition in the supply chain, literature [3] conducted a detailed analysis of the two, and used the game theory method to obtain the optimal strategy; literature [4] established a system that includes multiple retailers, multiple suppliers and A warehouse model; literature [5] studies the pros and cons of information sharing under the multi-retailer model; and literature [6] summarizes the current supplier inventory management model.

In the aspect of multi-level supply chain inventory control, the literature [7] studied the optimal purchase quantity problem under the supplier-managed inventory mode in the multi-level supply chain; the literature [8] studied the issue of consumable inventory economical batch order earlier; The literature [9] improved the dynamic inventory model proposed by Arrow-Harris-Marshak that the customer demand distribution changes over time, and also studied the inventory control problem when the demand information is unknown. Among them, the demand distribution is stable and has unknown parameters, but with Certain prior distribution knowledge; Literature [10] studied under the assumption that the prediction error obeys the normal distribution, from the perspective of satisfying the service level constraint, proposed a non-stationary demand inventory control strategy based on heuristic algorithm.

Jun[11] constructed a mathematical model of the emergency material supply network, de-dimensionalized the cost function and the time function, and then weighted the composite, comprehensively analyzed the time and cost of emergency material supply, and dealt with emergency materials according to the best material supply chain plan. The reserve model for emergency supplies is recommended, and the feasibility of the mathematical model is verified through specific cases.

From the above research on adaptive inventory control at home and abroad, it can be found that adaptive inventory control can well cope with non-stationary demand and improve system efficiency. Using adaptive inventory control can adaptively track inventory control targets so that the model is optimal. However, most of the above documents are based on continuous demand, and do not consider the adaptive inventory control strategy for discrete random demand. Aiming at the inventory control problem of non-stationary random demand supply chain, this paper proposes an improved control strategy that can make the inventory model meet the given service level and reduce the bullwhip effect.

3. DEMAND-SIDE RESPONSE POWER MATERIAL INVENTORY CONTROL

3.1. Demand-side classification method of electric power materials

To study the inventory control methods of different types of power materials in response to the demand side, we first need to understand the properties of power materials and the basic work of inventory management, that is, the classification of power supplies. However, the difficulty in the classification of power materials is that there are many types, varieties, and uses of power materials. Therefore, the classification principles are not the same. From different perspectives, power materials can be classified as follows:

(1) According to the nature of the project

It can be divided into overhaul materials, daily maintenance materials, and emergency repair materials. Among them, the overhaul materials mainly refer to the planned overhaul and replacement of power supplies and equipment, the daily maintenance materials mainly refer to the planned maintenance of non-overcurrent power materials, and the emergency repair materials mainly refer to the emergency repairs caused by the increase in power load (such as weather emergency repairs, external forces). Destruction emergency repairs and general emergency repairs, etc.).

(2) By material category

It can be divided into raw materials (including metal, building materials, etc.), overhead line equipment, substation equipment (including one, two, and three times), cables and accessories, tools, office supplies (including non-productive equipment), and so on.

(3) According to the use of the team

According to the classification of the teams (departments) in which the power materials are used, they can be divided into materials for the electric test shift, materials for the relay protection shift, and materials for the installation and succession shift.

(4) According to the supply method

Classified according to the way of supplying customers of electric power materials, it can be divided into supply materials (provided by the warehouse), direct transfer materials (directly sent to the site by the supplier), adjustment materials (materials transferred from warehouse), etc.

(5) According to purchasing frequency

According to the classification of power material procurement frequency, it can be divided into weekly procurement of materials, monthly procurement of materials, and quarterly procurement of materials.

(6) According to grid standards

According to the classification of power materials specified by the State Grid, they can be divided into large categories of materials (including primary and secondary equipment, installation materials, metal materials, tools, etc.), and medium-level materials (such as transformers, fuse boxes, and cables). , Cement products, commonly used fittings, etc.), small materials (such as line angle iron cross arm, ordinary bolts, etc.).

3.2. Extraction and analysis of demand-side features of power materials

The extraction and analysis of the demand characteristics of power materials is the basis of the classification of power materials, and it is also the basis of the design of power materials inventory control strategy. It has important theoretical value and practical significance for the management of power materials inventory. Electric power supplies generally have the following characteristics: a wide range of types, diverse specifications, uneven standardization, different levels of planned demand for materials, different rules, different volatility, and fast or slow update speeds, and so on. Therefore, combined with the actual situation of the warehouse power materials, the demand characteristic model Q for the design of the power materials inventory strategy is established as follows:

$$Q=\{M,U,P,V,R,S,L,G\}$$

where M represents importance, U represents urgency, P represents periodicity, V represents universality, R represents regionality, S represents substitution, L represents liquidity, and G represents regularity.

(1) Importance characteristics are used to describe the value characteristics of power materials and the key characteristics of measuring service levels. The power materials are mainly classified according to the ABC analysis principle. The value range of the importance M is {3,2,1}, corresponding to three levels of very important, generally important, and unimportant respectively. According to the actual situation, the rules are formulated as follows: the value of the material is high or the demand is large (about 80%), and the importance of the material with a small number of items (about 20%) is 3, that is, very important material; the value or demand is moderate (About 15%), the importance of materials with a moderate number of items (between 20% and 50%) is 2, that is, generally important materials; the value is lower (about 5%), and the number of items is more (50%) The importance of the materials above) is 1, that is, unimportant materials;

(2) The urgency characteristic is to describe the strength of the customer's requirements for the response speed of the required materials. Here, this characteristic can be measured by the proportion of emergency repairs. From a business perspective, each demand outbound record of electric materials will have an order number corresponding to one of them, and the first digit of the order number indicates the specific purpose of the outbound material, such as overhaul, emergency repair, Infrastructure, etc., so the urgency U can be expressed as:

$$U = q/X \times 100\%$$

Among them, q is the amount of emergency repairs out of the warehouse, X is the total amount of materials out of the warehouse, when U>48%, the urgency is relatively high, when U<15%, the urgency is relatively low.

(3) Periodicity refers to the size of the interval between the relevant time nodes in the process of power supplies from the previous purchase to this purchase, mainly including purchase lead time, purchase cycle, etc.

(4) The universal characteristic means the degree of matching between the actual situation of the power materials in the warehouse and the technical standards prescribed by the State Grid Corporation, that is, the degree of standardization.

(5) Regional characteristics means determining whether it is a special material for a certain area or a general material for the entire Fujian Province or Fuzhou area according to the attribute characteristics and technical characteristics of the power material itself.

(6) Substitution characteristics indicate whether electric power materials can be substituted for each other between different uses, and the degree of substitution under different order requirements, which can be measured by the overlap ratio of the number of items.

(7) Liquidity characteristics are the characteristics of the circulation speed and circulation speed of power materials within a period of time, that is, the monthly number of out of the warehouse, the average number of out of the warehouse each month, and the average amount of out of the warehouse each time. Liquidity L can be expressed as:

$$\mathrm{L} = \varepsilon_1 N + \varepsilon_2 T + \varepsilon_3 E$$

where N represents the number of monthly shipments, T represents the average monthly shipments, and E represents the average shipment volume per time. ε_1, ε_2, and ε_3 respectively represent the weight coefficients, which will be optimized in the experiment.

(8) The characteristic of regularity indicates whether the historical demand for power materials has a certain regularity, which can be measured by statistics such as the standard deviation coefficient of the consumption data. The regularity G can be calculated as:

$$\mathrm{G} = \sigma/\mathrm{x} \times 100\%$$

where σ is the standard deviation and x is the average.

From the point of view of the use of materials, the regularity of repairing materials is poor. G⩾80% means strong regularity, 50%<G<80% means moderate regularity, and G⩽50% means weak regularity.

3.3. Inventory control strategy for demand side response

The entire supply chain system of power materials includes suppliers, multi-level warehouses, and project sites. Because different types of power materials have different demand characteristics, their distribution modes and inventory control strategies are also different, and there are special regulations for urgency or safety. The materials are usually provided by the supplier to the professional warehouse, and then distributed to the project site. For the general planned materials, a two-level inventory control strategy is used, and the supplier provides the regional distribution center for the centralized inventory. The center sorts the materials that are in the warehouse, and uses the circular distribution mode or the cross-docking mode to distribute the front-end warehouses, which is the second distribution of the terminal inventory. For the framework agreement materials and temporary emergency procurement materials, they are directly sent by the supplier. Go to the project site to prevent delays in the construction period.

Before designing the overall inventory control strategy for electric power materials, first divide the electric power material inventory according to the item overlap degree of the materials. The item overlap degree refers to the degree to which the various specifications of each material used for different purposes overlap each other. It is divided into planned inventory and order inventory. Materials with a high overlap ratio of items used across the year are classified as planned inventory, which requires a certain amount of inventory to be stored in the warehouse, and vice versa, is classified as order inventory. Such materials are stored in a certain amount. The amount of funds to purchase in accordance with the order.

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According to the regular demand characteristics of electric power materials, the planned inventory and the order inventory can be further divided. For the planned inventory materials with low regularity, especially the emergency repair materials, a dynamic inventory control strategy can be adopted, that is, according to the demand characteristics of different types of power materials The inventory is dynamically controlled at a specific point in time, and the control strategy is realized by adjusting and modifying the upper limit and lower limit of the inventory of materials. For planned inventory materials with high regularity, such as overhaul materials, the inventory control of the MRP system can be used. In the replenishment strategy, the more important materials should be inspected on a weekly basis, while the less important materials can be inspected a little longer, for example, on a monthly basis. Similarly, order inventory can be further divided according to the characteristics of regular demand. For order inventory materials with low regularity, the VMI inventory replenishment mode can be adopted, that is, to establish a cooperative relationship with suppliers, and the electric power material company will formulate the master plan, and Suppliers are allowed to set up inventory and implement management. Suppliers can continuously and timely obtain accurate demand information, thereby achieving precise control of inventory. For order inventory materials with high regularity, the JIT distribution model can be adopted, which is based on the coordination center. Inventory control strategies can establish alliances with suppliers or agents close to the warehouse and sign contracts (such as framework agreements) to realize the on-time distribution of power supplies and improve the stability of the supply chain.

(1) Dynamic inventory control strategy

The dynamic control control strategy usually has a short inventory inspection cycle. Generally, continuous inspection is adopted. The lower and upper limit of the inventory are set according to relevant parameters. If the current inventory reaches the lower limit of the inventory, the replenishment signal will be sent immediately to replenish the upper limit of the inventory. It is generally applicable to materials with high value, liquidity and urgency. It can be expressed as:

$$E = e \times MAD$$

$$s = p \times n + E$$

$$S = q \times n + s$$

$$Q = S - s$$

where e is the safety stock factor, which is determined by urgency, that is, the basic safety stock of materials, E is the safety stock, s is the lower limit of inventory, p is the purchase lead time coefficient, n is the demand forecast, S is the upper limit of inventory, q Is the purchase cycle coefficient, Q is the order quantity, and MAD is the relative error percentage.

(2) MRP system inventory control

The inventory control strategy of the MRP system has a long check cycle, usually monthly. Under the condition of not breaking through the safety stock, when the check point is reached, the replenishment is implemented and the inventory is added to the upper limit. It is generally suitable for general value and relatively liquidity. High and low urgency supplies. It can be expressed as:

$$E = e \times MAD$$

$$S = q \times n + E$$

$$Q = S - x$$

where x is the current inventory.

(3) VMI inventory replenishment control

The check cycle of the inventory control strategy of the MRP system is generally based on a month. When the inventory reaches the lower limit, the replenishment signal is sent immediately. The replenishment amount can be calculated according to the model. It is generally suitable for high value, low liquidity, and emergency High-quality materials. It can be expressed as:

$$E = e \times MAD$$

$$s = p \times n + E$$

$$Q = q \times n$$

(4) JIT control

The JIT control strategy usually takes the point of demand occurrence as the inspection cycle, and implements a monthly inspection strategy. Without breaking the safety stock, when the check point is reached, the replenishment is implemented. The replenishment volume can be calculated according to the model, which is generally applicable to the value Generally, materials with relatively low mobility and urgency. It can be expressed as:

$$E = e \times MAD$$

$$Q = q \times n$$

In summary, on the basis of demand characteristics analysis and cluster analysis, the dynamic inventory control strategy of each type of power materials is determined. However, the demand characteristics and clustering results of power materials are not constant. The company makes some changes to the actual situation each year to adjust its inventory control strategy based on the new analysis results, which shows that the inventory control strategy based on demand characteristics analysis has great flexibility and can be more in line with the actual situation.

4. EXPERIMENTAL ANALYSIS

In the simulation example, a two-level supply chain consisting of a warehouse and multiple suppliers is considered. The MATLAB simulation test is mainly performed when the demand distribution of power projects is unknown, and then the experimental model when the demand distribution is known is compared with the former. A certain type of commonly used materials is used as the object to experiment to evaluate the pros and cons of the model established in this chapter.

4.1. Inventory simulation when demand distribution is known

When the demand is known, the demand information is predicted by exponential smoothing once. Assuming that the demand per unit time is D~N(50,102), the actual initial demand is the random number generated in the interval [45,55], the predicted initial demand is 50. The model runs for 24 cycles (months). And the simulation runs 20 times to get the average data. The model time is taken as the unit time.

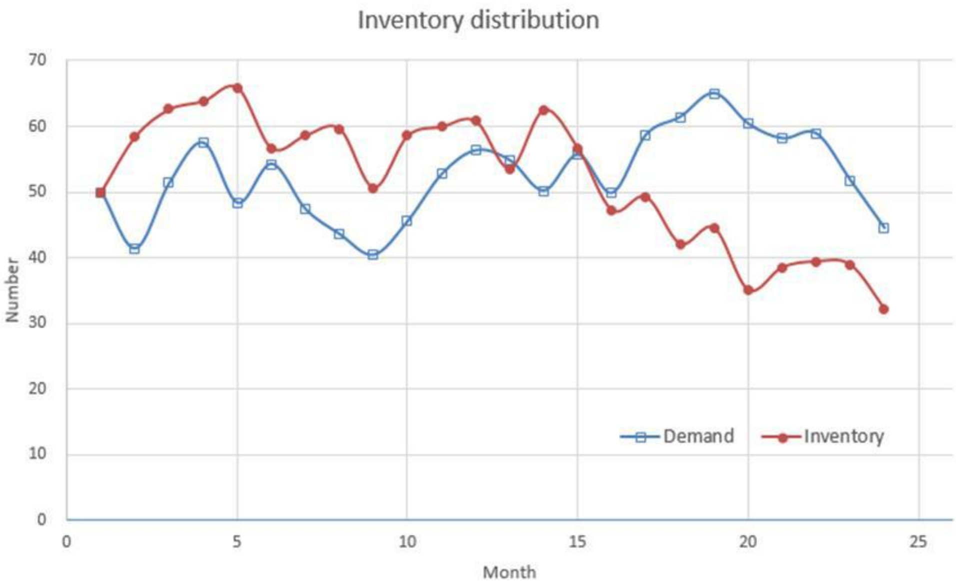

Figure 1. Inventory and demand curve

Figure 1 shows the actual data of demand and inventory when the demand distribution obeys the normal distribution, where the box represents the demand number, and the dot represents the inventory number. We can see that there are 13 cases where the inventory is greater than the demand, and the average demand overflow is 21%; there are 10 times when the inventory is less than the demand, and the average under-demand rate is 24%. Excessive inventory will lead to occupation of inventory space, thereby resulting in waste; insufficient inventory will lead to unsatisfied demand. Therefore, it is not good if the inventory is too large or too small.

4.2. Inventory control simulation

Through the dynamic inventory control strategy, MRP system inventory control strategy, VMI inventory replenishment control strategy, and JIT control strategy proposed in this paper, multi-granular inventory control is carried out. The results are shown in Figure 2 as follow.

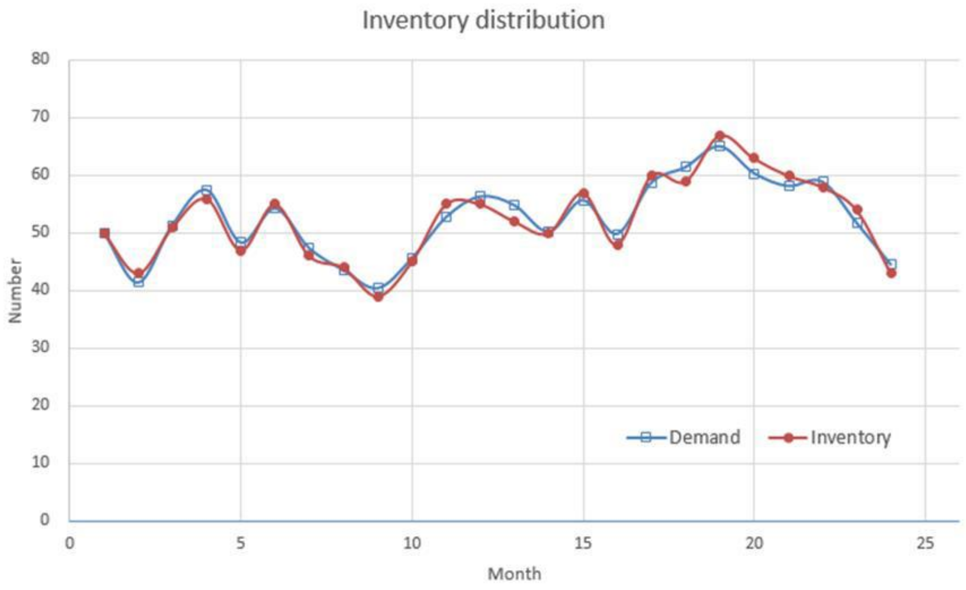

Figure 2. Curve of multi-granularity inventory control results

Figure 2 reflects that the controlled inventory can better meet the changes in demand, thereby improving the efficiency of inventory management.

5. Conclusion

As power projects show growth and complexity, inventory control has become more and more complex. Multi-granularity inventory control based on the demand side has attracted more and more attention due to its characteristics of evaluation and update at any time. The multi-granularity inventory control method proposed in this paper combines inventory and multi-objective optimization theory, proves the applicability and feasibility of the proposed method, and provides practical guidance and decision-making reference for improving the level of intensive management of power production and maintenance materials. The next step of the research will be extended to the construction of a dynamic inventory management model for power materials, that is, to further set the dynamic safety inventory of various materials based on the supply cycle, supply lead time, historical safety inventory, and historical procurement batches of various materials. Dynamic lead time inventory, dynamic cycle inventory. At the same time, it dynamically updates the parameters of the demand management model, and builds a dynamic multi-level inventory management model on this basis to realize timely adjustment of inventory quotas according to changes in demand, and reduce inventory backlogs while ensuring the safe and stable operation of the power grid. Occupation of inventory funds.

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