Calculation of Rational Inventory of Spare Parts in Power Enterprise Based on Chronological-Order Prediction

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Abstract Material, the basis for the normal operation of enterprises, is greatly demanded in power grid enterprises, shows strong effectiveness, and directly affects the operation costs of enterprises. The whole logistics process of enterprises, including purchasing, handling, transportation and distribution of materials, is inseparable from inventory. In short, inventory has penetrated into every link of the whole logistics system. At present, the role of inventory has been attached great importance to large enterprise management process. Inventory management requires huge investment, thus it becomes the center and ultimate goal of inventory management and logistics management to reduce inventory and inventory costs or even realize no inventory.

This study proposes methods to reasonably calculate the spare parts inventory, and puts forward solutions to optimized management of spare parts inventory in power enterprises, with the final purpose to improve management mode of traditional spare parts and achieve intensive, lean, standard management of spare parts in power grid enterprises.

Keywords Inventory • Power enterprise • Prediction • Spare part

1 Introduction

Spare part (Shuichi Kobayashi 2010), a common term, refers to all the parts related to equipments. Literally, it refers to spare items and spare components. It can be

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generally inclusive or narrowly meaningful, and covers all spare goods, namely different spare items in different industries.

In fact, in both repair industry and manufacturing industry, in equipment repair or production process, in order to shorten the interval time of repair, the enterprises will, according to the laws of part abrasion and service life of equipments, process, purchase and reserve the parts that are easily wearable and need timely replacement in advance (Goldman 2003).

Power grid enterprises have to deal with heavy operation and maintenance tasks as well as complex equipments and technology, thus how to reduce inventory funds, eliminate blind procurement and improve efficiency of fund use with the premise to guarantee the supply has become one of the urgent problems to be solved. Therefore, efficient orderly and lean inventory management can reduce the cost of enterprise operations, and has become the source of enterprises' third profit (Jin Hanxin et al. 2008).

2 Classification of Spare Part Inventory Types

This section, with S Power Supply Bureau as an example, analyzes the total number of types of repaired material and the use frequency of each type of material, respectively summaries the total amount of material from 2006 February to 2010 February, and concludes that the spare parts can be divided into three categories (Wang Daoping and Hou Meiling 2011): 1st category: those with large inventory and frequent delivery, accounting for 13.84 %; 2nd category – those with large inventory and infrequent delivery accounting for 29.96 %; third category – those with small inventory and infrequent delivery, accounting for 56.20 %.

3 Prediction-Based Model of Rational Inventory of Spare Parts (Table 1)

3.1 Model of Rational Inventory of 1st Spare Parts

3.1.1 Analysis of Rational Inventory of 1st Category Spare Parts

According to the classification criteria of spare parts, some data about materials issued from 2006 February to 2010 February are selected, as is shown in Table 2.

Based on analysis of the above data, the characteristics and methods to identify inventory of 1st category materials are drawn:

Characteristic: they are most widely, frequently regularly or irregularly used in repair and maintenance process, and their procurement cycle is short in general;

Table 1 Methods to calculate S power supply enterprise's rational inventory of three categories of spare parts

Inventory type	Name	Proportion (%)	Method to calculate rational inventory
1st category	Commonly-used spare parts	13.84	Multivariate statistical forecast method
2nd category	Easily wearable spare parts	29.96	Real-time inventory average method
3rd category	Emergency spare parts	56.20	Maximum real-time inventory value method

Data sources: data about the use of S power supply enterprise's spare parts (02/2006–02/2010)

Table 2 Data about S power supply enterprises' materials issued (02/2006–02/2010)

Material name	Issue times	Amount of materials issued	Material name	Issue times	Amount of materials issued
Dis-connector	833	1,698	Plastic cable	911	44,955
10 kV overhead insulated conductor	373	135,665.5	Copper wire	278	3,290
10 kV XLPE cable	713	34,597.5	XLPE cable	542	28,130.54
Jacket insulation wire	555	99,762.89	Low-voltage indoor cable terminal	503	1,159
Low-voltage circuit breaker	308	370	10 kV ring main unit	130	155

Data sources: data about the use of S power supply enterprise's spare parts (02/2006–02/2010)

Defined interval value: times of issue: $n \geq 50$; amount of materials issued: $Q \geq 100$;

Methods to calculate rational inventory: multivariate statistical prediction method (Zhang Yuan 2010) $Q = \alpha_i q_i' + \beta_i q_i'' + \chi_i q_i'''$ is adopted, wherein q_i' means predicted value with method of moving average; q_i'' means predicted value with method of index smoothing forecasting, q_i''' means predicted value with method of periodic fluctuation; α, β, χ means the adjustment coefficient of predicted values, and the sum of them is 1. It is advantageous to eliminate the shortcomings of single prediction method by means of changing the proportion between the adjustment coefficients (Yang Lihua 2010).

Table 3 S power supply enterprise's monthly issue capacity of 10 kV RMU (02/2006–02/2010) (Unit: Set)

Time	Amount of issued RMU	Time	Amount of issued RMU	Time	Amount of issued RMU
2006/10	4	2007/12	8	2009/04	6
2006/12	2	2008/01	4	2009/05	1
2007/01	3	2008/04	10	2009/06	4
2007/03	1	2008/06	11	2009/07	15
2007/04	2	2008/07	5	2009/08	2
2007/06	3	2008/09	3	2009/09	2
2007/07	6	2008/10	9	2009/10	2
2007/08	1	2008/11	7	2009/11	8
2007/09	5	2008/12	24	2009/12	2
2007/10	6	2009/02	1	2010/01	5
2007/11	4	2009/03	4	2010/02	3

Data sources: data about the use of S power supply enterprise's spare parts (02/2006–02/2010)

3.1.2 Calculation of Rational Inventory of 1st Category Materials with 10 kV RUM as an Example

10 kV RMU is taken as an example to illustrate the methods to determine reasonable materials inventory of 1st category material. Monthly issue capacity of 10 kV RMU (02/2006–02/2010) is shown in Table 3.

1. Prediction and analysis with the moving average method

Figure 1 shows data comparison of predicted value and actual value of 10 kV RMU with moving average method (Sun Yiwei 2007).

The data of issue in 2009 predicted with moving average method is consistent with trend curve of real data; The predicted value slightly delays from the actual value; Compared with the peak of actual value in Decembers, predicted value decreases.

2. Prediction and analysis with single exponential smoothing method

According to single exponential smoothing method (Jim Owens 2006), all the past historical data are weighted for average, and weighted coefficient gradually decays with time passing by.

Figure 2 shows predicted value and actual value of 10 kV RMU based on single exponential smoothing method.

The data of issue in 2009 predicted with single exponential smoothing method is consistent with trend curve of real data; The predicted value slightly delays from the actual value; Compared with the peak of actual value in Decembers, predicted value decreases, however, the degree of reduction with single exponential smoothing method is slightly smaller than that with moving average method.

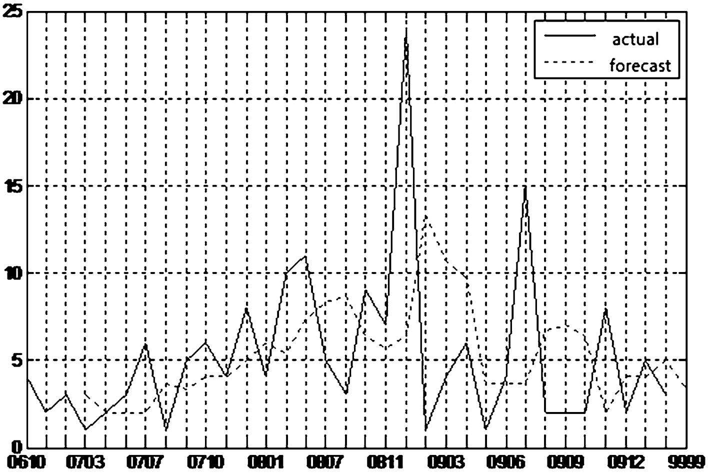

Fig. 1 10 kV RUM moving contrast average method the measurement and actual volume trend (Data sources: the predicted value and actual value obtained with moving average method will be compared and drawn in Matlab)

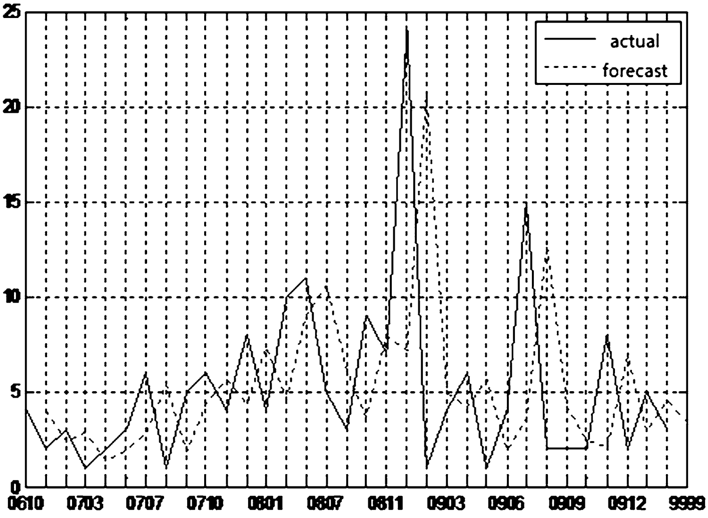

Fig. 2 Comparison of predicted value and actual value of 10 kV RMU obtained with single exponential smoothing method (Data sources: the predicted value and actual value obtained with single exponential smoothing method will be compared and drawn in Matlab)

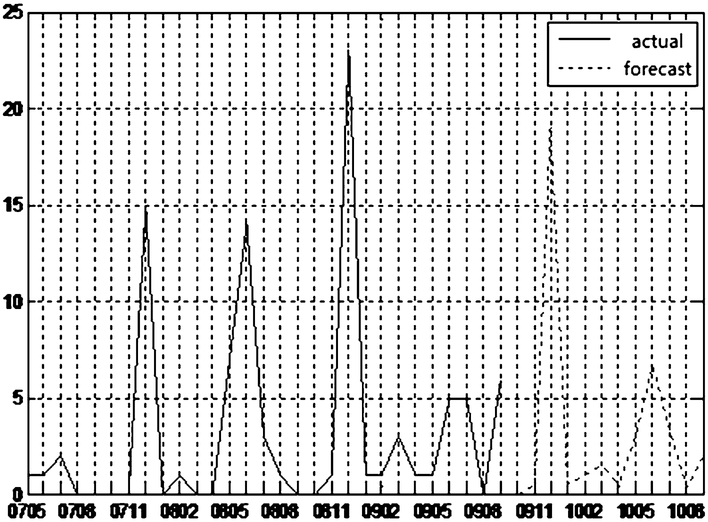

Fig. 3 Comparison of predicted value and actual value of 10 kV RMU obtained with periodic fluctuation prediction method (Data sources: the predicted value and actual value obtained with periodic fluctuation prediction method will be compared and drawn in Matlab)

3. Prediction and analysis with the periodic fluctuation method

According to historical data (of generally at least two complete cycles), average demand d0 is determined, then the cycle coefficient of each period of a cycle is determined, and then the demand of next cycle is predicted (Narahari 2000).

Figure 3 shows predicted value and actual value of 10 kV RMU based on periodic fluctuation prediction method (Olson 2012).

The data of issue in 2009 predicted with periodic fluctuation prediction method is consistent with trend curve of real data; The predicted value slightly delays from the actual value; The peak of predicted value of actual value in Decembers is better.

4. Determination of rational inventory of 10 kV RUM
According to multivariate statistical prediction calculation formula $Q = \alpha_i q_i^{'} + \beta_i q_i^{''} + \chi_i q_i^{'''}$, rational inventory of 10 kV RMU in 2009 is shown in Fig. 4.

In 2009, predicted value of 10 kV RUM $Q = \alpha_i q_i^{'} + \beta_i q_i^{''} + \chi_i q_i^{'''} = 56$ is higher than the actual demand, and less than the amount defined in manual of spare part inventory; this prediction method can reasonably reflect the actual demand of spare parts.

Therefore, the above calculation method can help to determine rational inventory of 1st category materials.

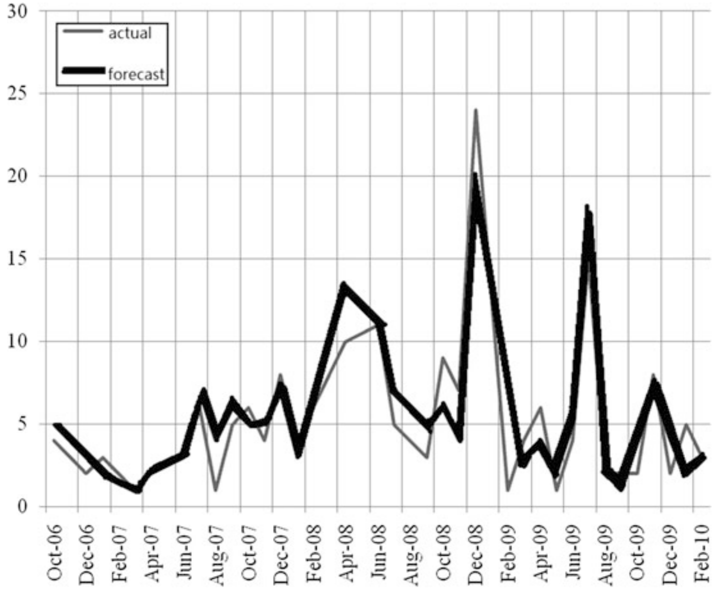

Fig. 4 Comparison of predicted value and actual value of 10 kV RMU obtained with periodic fluctuation prediction method (Data sources: according to the comparison of actual value and predicted value obtained via multivariate statistical prediction formula)

Table 4 Data about S power supply enterprises' materials issued (02/2006–02/2010)

Material name	Issue times	Amount of materials issued	Material name	Issue times	Amount of materials issued
Cable	1	1200	Anti-theft bolt	3	1,800
Glass insulator	10	1196	Low-voltage cable	1	1,642
Link plate	4	42	10 kV single high angle steel tower	33	1,798
Aluminum alloy wire	5	240	Composite glass steel protection tube	10	49

Data sources: data about the use of S power supply enterprise's spare parts (02/2006–02/2010)

3.2 Model of Rational Inventory of 2nd Category Materials

3.2.1 Analysis of Rational Inventory of 2nd Category Materials

According to classification criteria of spare parts, some data about materials issued from 2006 February to 2010 February are selected, as is shown in Table 4.

Analysis of the above data leads to characteristics of 2nd category materials and methods to determine its rational inventory:

Table 5 Data about S power supply enterprises' materials issued (02/2006–02/2010)

Material name	Issue times	Amount of materials issued	Material name	Issue times	Amount of materials issued
Fixed four-unit RUM	1	1	10 kV D11 oil-immersed transformer	4	4
Fault indicator	1	2	Low-voltage power box	1	1
RMU with shared box	1	1	High voltage switch cabinet	1	1
Indoor double-circuit double-transformer unit RUM	1	1	10 kV porcelain drop-style switch	2	2
Intelligent air circuit breaker	1	1	Extensible SF6 RUM with shared box	1	1

Data sources: data about the use of S power supply enterprise's spare parts (02/2006–02/2010)

Characteristic: they are less important, with relatively short procurement cycle;

Defined interval value: times of issue: $n \leq 50n$; amount of materials issued: $Q \geq 2$;

3.2.2 Calculation of Rational Inventory of 2nd Category Materials with Glass Insulator as an Example

According to mean of real-time inventory $Q = \frac{q}{n}$, wherein q means the total amount of issue (01/2006–02/2010), n means the times of issue (01/2006–02/2010). For example, the real-time rational inventory of glass insulator is $1{,}196/10 \approx 120$.

3.3 Model of Rational Inventory of 3rd Category of Materials

3.3.1 Analysis of Rational Inventory of 3rd Category of Materials

According to the classification criteria of spare parts, some data about materials issued from 2006 February to 2010 February are selected, as is shown in Table 5.

Based on analysis of the above data, the characteristics and methods to identify inventory of 3rd category materials are drawn:

Characteristic: they are important, with relatively long procurement cycle in general;

Table 6 S power supply enterprise's rational inventory of spare parts

1st category materials		2nd category materials		3rd category materials	
Materials name	Annual rational inventory	Materials name	Real-time rational inventory	Materials name	Real-time rational inventory
Low-voltage circuit breaker	93	Anti-theft bolt	600	Motor protection tripping button	1
Low-voltage indoor cable accessories	400	Waterproof tape	30	Meter box	2
Low-voltage insulated wire	322,407	Low voltage cable	19	Heat-shrinkable busbar protection casing	1

Data sources: S power supply enterprise's rational inventory of spare parts is calculated according to rational inventory model

Defined interval value: times of issue: $n \leq 5$; amount of materials issued: $q \leq 2$;

3.3.2 Calculation of Rational Inventory of 3rd Category Materials with Fixed Four-Unit RUM as an Example

According to maximum of real-time inventory $Q = Maxq$, wherein q denotes the amount of issue. For example, the real-time rational inventory of fixed four-unit RUM is 1.

3.3.3 Calculation of Rational Inventory of Spare Parts

According to the data of issue of spare parts and corresponding methods to calculate rational inventory (02/2006–02/2010), the rational inventory of recorded spare parts is calculated, and some are shown in Table 6.

4 Conclusion

Research on S power supply enterprise's rational inventory (Garg 2004) of spare parts complies with the current status of Chinese large-scale power grid enterprises, thus it is of great significance in practice and potential application, provides scientific decision support for business reconstruction of enterprise inventories and lean management, and helps to improve enterprises' innovation ability.

References

Garg D (2004) Design of Six Sigma Supply Chains. IEEE Trans Autom Sci Eng 1(1):38–57
Goldman LI (2003) Crystal ball for Six Sigma tutorial. In: Proceedings of the winter simulation conference, Denver, USA
Jim Owens (2006) Availability optimization using spares modeling and the Six Sigma process. In: Reliability and maintainability symposium, 2006. RAMS' 06. Annual, Newport Beach, 23–26 Jan 2006, pp 636–640
Jin Hanxin, Wang Liang, Huo Yan (2008) Warehousing & inventory management. Chongqing University Press, Chongqing, pp 10–16
Narahari Y (2000) Design of synchronized supply chains: a Six Sigma tolerancing approach. In: Proceedings of the 2000 IEEE, international conference on robotics & automation, San Francisco, Apr 2000
Olson RJ (2012) Micro and nano R&D fab safety, inert gas reduction, a lean Six-Sigma approach. University/Government/Industry, Micro/Nano symposium (UGIM), 2012 19th Biennial, IEEE 2012, Berkeley, 9–10 July 2012, p 1
Shuichi Kobayashi (2010) Lean manufacturing 009: inventory management (Zhang Shupeng). Eastern Publishing Co., Ltd., Beijing, pp 151–162
Sun Yiwei (2007) Optimization of inventory management with improved process based on Six Sigma. Logistics Sci-Tech 31(7):92–97
Wang Daoping, Hou Meiling (2011) Supply chain inventory management and control. Peking University Press, Beijing, pp 203–2215
Yang Lihua (2010) Optimization of material inventory based on Six Sigma management. Logistics Sci-Tech 34(7):104–107
Zhang Yuan (2010) Research on the application of Six-Sigma's method to supply chain management. In: Proceedings of the 2010 IEEE, international conference on automation and logistics, Hong Kong/Macau, 16–20 Aug 2010