Design and realization of metering production plan management system

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Abstract. The metrology verification center is currently developing towards intelligent, unmanned and highly reliable. For the problem of inaccurate demand reporting of electric power company, metrology verification center heavy manual planning and low efficiency, the metrology production plan management system is developed. Firstly, metrology equipment demand forecast model is constructed by integrating all kinds of metrology equipment installation history data and policy factors. It realizes the accurate prediction of the demand for metrology equipment of electric power company and supported the metrology verification center to arrange verification production and purchase new meters. Secondly, during the production planning process, intelligent auxiliary method is used. Applying demand forecast results, through analysis and quantification of many factors that affect the preparation of plans, generates arrival plans, verification plans and distribution plans that cover the metrology verification center all production business processes. It improves planning efficiency, shortens the planning cycle and achieves overall control of production rhythm.

1. Introduction

At present, the production process of electricity metrology industry mainly includes arrival reception, acceptance of storage, verification test and distribution [1], which conducts unified planning and centralized coordination through production planning [2]. How to manage the production plan reasonably and accurately is the key issue to ensure the orderly, efficient and stable metrology production. The preparation, adjustment and management of the current production plan are mainly done manually by production management personnel. The main measures include manually making production planning based on meter demand and adjusting production plans based on offline data such as the supply progress of meter supplier, verification progress and distribution progress. There are shortcomings such as long preparation cycle, great difficulty, low resource utilization and low risk control ability.

With the increase in the amount of meters used by electric power company and the continuous transformation of production conditions, the manual orchestration plan has also highlighted other serious shortcomings. Firstly, the meter usage demand involves many units, which is difficult to evaluate and it is impossible to confirm the feasibility of the demand and the execution risks. Secondly, the meter usage demand is frequently adjusted. But the manual adjustment cycle is long and the work is tedious and error-prone. Besides it cannot meet the timeliness demand in actual work. Finally, the
resource allocation is difficult. Due to the long production cycle and numerous resources, it is difficult to estimate the production schedule and staffing in a longer period.

In addition, monthly and annual demand involve a large number of meter categories and complex data. If the demand is estimated too much, it will easily cause inventory backlog. If the demand estimate is small, it will affect the meter installation and power connection. Based on experience, power supply companies estimate the demand for energy meters, with different calculation methods and different considerations, and accuracy is difficult to guarantee.

From the above problems, it can be seen that the current metrology production planning management method is single, the information is low and the demand is inaccurate. At the same time, the lack of a complete plan management technology solution causes the production process of the enterprise to be sluggish, which severely limits the work efficiency of the enterprise. Restricted the development of enterprises. Reference [3] carried out research on the planning of the verification plan and its problems, but did not carry out research on the arrival and distribution plans associated with the verification. Reference [4] carried out a study on the production plan management system of the metrology verification center, but did not involve precise demand forecasting. This article not only conducts accurate forecasting research on meter demand, but also conducts comprehensive research on arrival plan, inspection plan and delivery plan.

Based on the forecasting model developed to achieve accurate forecasting of the meter usage demand of electric power company, this paper takes the demand as the guide and takes reasonable control of production as the goal. It builds a production plan orchestration model, which compiles the optimal arrival plan, verification plan and distribution automatically. The metrology production plan management system is designed, which optimizes the configuration of each production process and provides efficiency production, resource utilization, risk management and control capabilities. And it accelerates the development of the metrology verification center.

By analyzing the business and functional requirements of the metrology production plan management system, the design scheme of the metrology production plan management system based on micro-service are proposed. It achieves the purpose of decentralization, has the characteristics of strong scalability, flexible deployment, easy maintenance, etc. And it improves the concurrent processing capability of the system.

2. Design of metrology production plan management system

The metrology production planning management system firstly builds a prediction model for the metrology equipment demand and uses technologies such as big data [5-7] and machine learning [8-9] to achieve accurate predictions for the metrology equipment demand. Secondly, using the results of demand forecasting, combined with production factors such as inventory and production cycle, a planning scheduling model is constructed to realize the automatic production of metrology production plans. Finally, through statistics and analysis of the plan execution progress, execution quality and other indicators, real-time monitoring of the plan execution process is realized.

The system adopts a layered architecture and establishes a multi-level, loosely coupled metrology production planning management system. The system adopts modular development to flexibly and quickly respond to business expansion requirements for system expansion. Based on the operation and maintenance system, standard specification system and safety guarantee system, the system technical architecture is constructed. The technical architecture is specifically divided into data layer, support layer, application layer and presentation layer. See Figure 1 for details.

- Presentation layer, visualize the application layer functions by monitoring large screens and mobile terminals.
- Application layer, implements functions such as demand forecast management, production plan management and production plan tracking.
- Support layer, supports the application layer, providing demand forecasting model planning analysis services, production planning orchestration model calculation analysis services and data analysis processing services.
3. System functions
The metrology production plan management system mainly includes demand forecast management, production plan management and production plan tracking.

3.1. Demand forecast management
Demand forecast management includes basic data management, forecast model management and metrology equipment demand forecast.

- Basic data management, provides internal structured data, internal non-resultant data and external data management, including functions such as raw data import, intelligent identification of engineering plan reports, external feature import and data cleaning.
- Predictive model management, provides management of model raw data maintenance, model parameter configuration, model feature configuration and model construction process.
- Forecast of metrology equipment demand, call the demand prediction model to generate metrology equipment demand, including natural and non-natural demand. Natural demand includes monthly and annual expansion, new installations, scattered installations and failure replacement demand. Non-natural demand includes monthly and annual functional transformation, batch replacement and supporting engineering demand.

3.2. Production planning management
Production plan management includes production factor management, production plan preparation, production plan optimization and production plan deviation handling.

(1) The production factors are the basic data conditions automatically generated by the production plan, including working hours, production capacity and control parameters. Specifically includes daily
inspection capacity, normal arrival batch value, storage capacity, sealing capacity, necessary inventory cycle on arrival, required inventory cycle on inspection, necessary inventory cycle on seal, storage capacity, maximum storage capacity utilization, inventory overtime cycle, supplier maximum monthly supply and distribution capacity.

2) Production Plan making is the process of applying the production plan orchestration model to automatically generate the production plan. The model uses demand forecast results and production factor information as inputs. The plans include monthly arrival plan, weekly arrival plan, monthly inspection plan, and weekly inspection plan, monthly delivery plan, and weekly delivery plan.

3) Production plan tuning is to solve the problems of manually adjusting the production plan, the business relationship to the deployment plan, the adjustment process being complicated and difficult, and the adjustment of the production plan of one business link needs to adjust other related business links. The tuning methods include manually adjusting production factors such as working hours and verification capabilities, and then automatically regenerating the production plan based on the production plan's automatic generation algorithm; manual adjustment to advance the planning time, delay the planning time, increase the number of plans, reduce the planned content such as the planned quantity, and according to the user's adjustment content and adjustment method, the production plan adjustment algorithm automatically adjusts the associated plan.

4) Production plan execution deviation is used to deal with the execution deviation, when the plan execution result does not completely match the production plan. Deviation process is divided into deviation statistics, deviation evaluation and deviation processing.

Due to the many factors affecting measurement production, any temporary changes (such as unscheduled supply by the manufacturer, failure of the automated verification line, etc.) will lead to deviations in the execution of the plan. There are unpredictable and inevitable characteristics of the execution deviation. The purpose is to ensure that deviations that occur in the measurement production process are recorded, analyzed, evaluated and handled, to maintain the consistency of plan execution, to correct existing production risks and to reduce or avoid unreasonable deviations from recurring.

- Deviation statistics. According to the production plan preparation cycle, the execution results of the production plan are regularly counted, and the difference between the execution results and the production plan of the same period is compared to determine whether there is a deviation in execution. Plan execution deviation mainly includes lag execution deviation and early execution deviation. Lag execution deviation refers to the delivery, inspection and delivery plans that are not executed according to the planned time. Early execution deviation refers to the plan that is executed earlier than the planned time.

- Deviation evaluation. Evaluate the risks caused by measurement execution deviation and classify deviations based on the degree of impact of execution deviation on measurement production, including minor deviations and general deviations. Minor deviation refers to the deviation of a small part of the plan, which will not have a special impact on subsequent production measurement, and requires no further correction and preventive measures. General deviation refers to deviations that occur in multiple batches within a certain planning period, or the deviation between the execution quantity and the planned quantity is too large and has already had an actual or potential impact on the measurement production. Such deviations need to be addressed in a timely manner and correction and Remedial measures to eliminate the negative effects that have been caused.

- Deviation processing. Deviation treatment is divided into deviation prevention measures and automatic treatment methods. Preventive measures are to control the measurement production from the enterprise's standards and systems in strict accordance with the production plan to reduce the occurrence of excessive deviations in production execution. The automatic processing algorithm mainly includes two parts. When the lag execution deviation occurs, the lag part is adjusted to the next cycle production plan and assess execution risk. When there is an early execution deviation, the early part is removed from the subsequent plan and readjust the follow-up plan based on monthly distribution needs.
3.3. Production plan tracking

Production plan tracking mainly includes production plan viewing, key indicators statistics and production plan analysis.

(1) Production plan viewing. Filter and query the production plan information according to the conditions of the unit of use, plan year and month, plan week, bidding lot, supplier, carrier chip manufacturer, business link, equipment category, equipment specification, range of arrival batch and other conditions.

(2) Key indicators statistics. Form a statistical production plan statistical report for core indicators, including the monthly distribution demand compliance of each unit on a monthly basis, the plan execution progress, the plan execution quality and supplier arrival schedule.

(3) Production plan analysis. The production plan uses charts to analyze the execution risks of the plan, including inventory analysis, workload analysis, execution risk analysis, and demand compliance analysis. Inventory analysis is to analyze the inventory trend of the planned cycle according to the natural week and natural month. The inventory amount is composed of the counts of the to-be-checked meter and the count of the to-be-delivered meter. The workload analysis is to show the arrival of each week by the natural week and natural month. Cargo workload and maximum storage capacity, inspection workload and maximum inspection capacity for each week, distribution workload and maximum warehouse delivery capability for each week, and production surplus capacity for each week, perform risk analysis. It refers to the parallel degree of the arrival and verification work, verification and distribution work in each week of the analysis of natural week and natural month; the analysis of demand compliance refers to the analysis of the completion of demand.

4. Key technologies

4.1. Demand forecasting model

The demand forecasting model is to classify the measurement equipment demand according to the installation type [10], and select the long-term and short-term memory network algorithm [11-12] or time series algorithm [13-14] to implement the demand forecasting for the commonly used meters with a large amount based on the unit root test method. The gray model [15-16] is used to realize the demand forecast of small and uncommon meters. For unnatural needs, the template forecasting method is used to combine and form the final forecast results of the measurement equipment, including annual demand forecast and monthly demand forecast. See Figure 2 for details.

![Figure 2. Demand forecasting general idea.](image-url)
(1) Data pre-processing, integrating and integrating the measurement asset files, assembly and disassembly records, measurement point files, customers and other information of the provincial metrology production scheduling platform, marketing business application system and metrology automation system for data pre-processing. Identify external factors that affect demand by business type, and regularly import external data through web crawlers and files.

(2) Refine the type of demand, and use the correlation analysis method to classify the natural demand into three types industrial expansion and new installation, scattered installation, and fault replacement. The unnatural demand is divided into functional transformation, batch replacement, and supporting engineering class.

(3) Differentiate the characteristics of demand, and determine the forecast period through mobile smoothing check. The forecast period for the meter with a large amount is commonly used for months, and the forecast period for the meter with a small amount is not commonly used.

(4) Select a forecasting model. For monthly demand forecasting for large-volume common meters, firstly use the unit root test method to perform stability calculations on the time series of the three types of demand for industrial expansion and installation, scattered installation, and fault replacement. Second, for stable demand Types build autoregressive moving average models for demand forecasting, and build non-stationary demand types for long-term and short-term memory network models for demand forecasting. For the small and uncommon meters, the usage is small and the demand is not stable. The annual forecast is applicable, and the gray forecast model is used for demand forecasting.

(5) Obtain unnatural demand, demand of offline document import and auxiliary input, and finally integrate with natural demand to form a central monthly and annual demand.

4.2. Planning model
Production planning is driven by demand and inventory in turn, as shown in Figure 3.

![Figure 3. Production planning method.](image)

(1) The demand is the source of driving the production plan. The most fundamental purpose of producing a production plan is to meet the needs of the metrology equipment reported by the meter unit. The measurement equipment demand includes annual meter demand and monthly meter demand. Here, the demand forecasting model is used as input.

(2) The process of inventory change (inventory volume change, inventory ratio change, and equipment status change) is a process that meets the demand of the meter [17]. The meter usage demand is divided into steady monthly delivery demand and sudden temporary delivery demand. When considering inventory, the steady monthly delivery demand and temporary delivery demand are met by integrating the necessary inventory and safety inventory.

- Necessary inventory is the necessary inventory to meet the demand for stable meters. It is a dynamic quantity that changes continuously as the process of meeting the demand of meters is driven. The necessary inventory cycle is used to analyze and quantify the necessary inventory. The total amount of necessary inventory turnover is estimated by measuring the necessary inventory cycle, which includes the amount of inventory necessary to meet the monthly table and the amount of inventory produced within the necessary inventory cycle of the next month.

- Safety stock is a necessary stock to meet temporary demand [18-20]. The safety stock can be quantitatively calculated according to the demand proportion according to the monthly distribution demand of the next month, and the safety stock amount needs to be considered when scheduling the production plan for this month.

(3) The production plan generation process is a process of decomposing the order list on the time dimension and business process according to the inventory demand.

Consider the following when generating a production plan:
• The total production plan cannot exceed the production unit's capacity, including storage capacity, inspection capacity, inventory capacity, and vehicle distribution capacity.
• The order list involved in the preparation of the production plan must not exceed the scope of the tender and contract.
• The production plan is moderate in intensity, the production process is balanced, and the risks are controllable.

Fully consider the enforceability of the production plan, the minimum planning cycle of the production plan is the natural week, and it covers the arrival, inspection and distribution links. In order to meet this demand, the plan generation method is explained from two aspects of the planning cycle and business links.

Figure 4. Planning flow chart.

1) The production plan is continuously refined according to the planning cycle of the year, month and week. The annual production plan schedules the total amount of work for each month with a monthly planning cycle. The methods include controlling the total amount of work in each month to not exceed the capacity of the measurement center; controlling the inventory of each month not to exceed the maximum utilization of the storage capacity; Effective working hours are relatively balanced; the monthly production plan uses the month as the planning cycle, and the bidding measurement equipment is decomposed according to the total amount of work scheduled in the annual plan. The methods specifically include controlling the planned amount of each month to not exceed the total work amount of the annual production plan and winning the bid. To meet the personalized needs such as the configurable batch value; weekly production plan takes week as the planning cycle, and the work scheduled by the monthly production plan is divided into weeks, the purpose is to control the workload of each week, so that each weekly average daily workload is balanced; the adjustment cycle is implemented with the natural week and natural month as the plan to implement the feedback, and the production plan is adjusted in a timely manner.

2) The production plan is based on monthly distribution demand and is reversed according to the business processes of arrival, inspection and distribution. The distribution plan is prepared based on...
fully meeting monthly distribution demand, and the demand compliance is 100%; the verification plan comprehensively considers the monthly required quantity, the next cycle to verify the necessary inventory cycle, and the safety stock amount; the arrival plan comprehensively considers this month must Arrivals, arrivals required for the next inventory cycle necessary inventory cycle, and safety stock.

In addition, the control of risk factors is fully considered in the planning process, and it is carried out in two dimensions, horizontal and vertical. Horizontally, the planning cycle sequence from year to month and week is adopted horizontally, and planning from distribution to inspection and arrival is adopted vertically. The derivation sequence is compiled step by step through 9 steps to finally form a monthly and weekly arrival and dispatch plan. See Figure 4 for details.

4.3. **Plan execution risk control**

Plan execution risk control is based on the annual distribution plan, annual inspection plan, and annual arrival plan to control the risk factors in the plan execution process. According to the order of priority, the risk of production capacity, inventory risk, and work stability Risks are processed in order from highest to lowest during execution.

   (1) Capacity risk control refers to risk control such as maximum inspection capacity and maximum outbound storage capacity for the annual arrival and distribution plan. According to the year, month, equipment category, and equipment specifications, the capacity risk of the arrival, verification and distribution links is handled to ensure that the monthly arrival volume and monthly delivery volume do not exceed the maximum monthly outbound capacity and the monthly inspection quantity does not exceed the maximum monthly inspection capacity.

   (2) Inventory risk control is the maximum storage capacity and utilization risk control of the annual arrival and allocation plan. Calculate changes in total inventory by year, month, equipment category and equipment specifications to avoid inventory in the planning execution exceeding total storage capacity utilization.

   (3) Work smoothness risk control refers to the risk control of annual working hours and arrival working hours, etc. Calculate the effective working hours (in days) of each month by month, equipment category and equipment specification. Balance the effective working hours of each month to make the working hours comparable and avoid situations where the work intensity difference at different times is too large.

5. **Conclusions**

In order to meet the business management and control demand of the production rhythm for the metrology center, this paper designs a metrology production plan management system for the problems existing in the production plan management of the metrology center and implements the system functions. The system is designed based on micro-service architecture, which has the advantages of strong scalability, flexible deployment and easy maintenance. At present, the system has been used in many provincial-level metrology center of the State Grid Corporation of China, and has three major functions demand forecast management, production plan management and production plan tracking. The demand forecast accuracy rate reaches 93.55%. The entire system optimizes the configuration of each production process, providing efficiency production, resource utilization and risk management and control capabilities.

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