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Article

Failure Prediction and Life Cycle Management of Power Equipment Based on Big Data Analysis

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Abstract: With the continuous development of China's industrial process, the social demand for electricity is increasing. Under the influence of new energy grid connection to build smart grid, the stability and security of the power grid system are particularly affected by the unstable characteristics of new energy. In view of the protection of the safe and stable operation of power, it is very necessary to monitor the information of power equipment, especially for the unpredictable power failure analysis is the key to ensure the safety of electricity use. However, due to the wide variety and huge quantity of power equipment and the frequent fluctuation of monitoring data affected by the natural environment, the amount of data of equipment information will grow rapidly in a short time, which has exceeded the ability of ordinary computers to handle. With the increasing size and complexity of power equipment, its fault prediction and life cycle management become very important. The emergence of big data analysis technology provides a new way to solve this problem. This paper first expounds the importance and status quo of power equipment fault prediction and life cycle management, then introduces the application principle and related technologies of big data analysis in this field, and then discusses the power equipment fault prediction method and life cycle management strategy based on big data analysis in detail. Finally, the effectiveness of this method is verified through practical cases. The future development is also prospected.

Keywords: failure prediction; life cycle management; power equipment; big data analysis

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1. Introduction

Power equipment is an important part of power system, its safe and reliable operation is directly related to the stability and quality of power supply. Traditional power equipment fault prediction and maintenance mainly rely on regular inspection and experience judgment, which has problems such as low efficiency, high cost, and difficult to accurately predict faults. With the rapid development of information technology, a large amount of data is generated in power system, such as equipment operating parameters, monitoring data, maintenance records and so on. Big data analysis technology can mine and analyze these massive data, extract valuable information, and provide scientific basis for failure prediction and life cycle management of power equipment.

In 2010, the State Grid proposed the overall plan of introducing new energy power generation into the traditional power grid to build a smart grid [1]. In recent years, with the continuous development of electronic information technology, the degree of intelligent power grid is getting higher and higher, and the power supply from new energy is also increasing. However, new energy power generation is greatly affected by the natural environment, which makes the peak load pressure of the power grid increasing. It is easy to cause the failure of power equipment. In addition, the power equipment that fails also has a process of equipment deterioration, that is, the equipment that fails does not suddenly happen at some point. The failure is caused by the continuous decline in the performance and reliability of the equipment during operation, the loss of conductivity of conductive materials, the structural damage of equipment components, and the destruction of material insulation. Therefore, it is necessary to adopt effective measures to monitor the operating status information of power equipment and evaluate the possibility of power equipment failure, so as to maintain and repair the equipment in time before the power failure and avoid the occurrence of a large area of power failure.

With the popularity of big data and cloud computing applications, the application of big data in power service is more feasible, because the amount of data generated in the process of power service is not only large, but also the structure is complex, which is suitable for big data analysis to make scientific predictions. Due to the large number and complex types of power system equipment, it is very difficult to monitor and manage the performance of the equipment, and the data information generated by the power system is very large. In theory, the stability of power equipment performance can be effectively monitored through big data analysis, and the linear and nonlinear relationship between the data generated by the power system can be used to divide the performance indicators, so as to determine the possible causes of power failures [2]. Therefore, the use of big data technology to study the stability of power system equipment performance and automatic analysis of power failure has a certain theoretical significance for promoting power safety.

2. The Importance and Status of Power Equipment Fault Prediction and Life Cycle Management

2.1. The Importance

Power equipment failure is one of the main causes of power failure. Through effective fault prediction, it can discover potential faults in advance, and take timely maintenance or replacement measures to prevent equipment faults and ensure a continuous and stable power supply. For example, in the power grid, transformers are important power equipment, and if the transformer fails, it may lead to a large area of power outage. Through real-time monitoring and analysis of transformer oil temperature, winding temperature, dissolved gas in oil and other parameters, the use of advanced fault prediction technology, can judge in advance whether the transformer has trouble, and timely treatment, so as to avoid the occurrence of power failure accidents [1]. The traditional equipment maintenance methods are mainly regular maintenance and post-maintenance. Regular maintenance often does not consider the actual operating state of the equipment, which is easy to cause excessive maintenance and increase maintenance costs; Post-maintenance is carried out after the equipment fails, at which time the equipment has been damaged, the maintenance cost is higher, and the reliability of the power supply will be affected. The fault prediction can accurately determine whether the equipment needs maintenance and when to carry out maintenance according to the actual operating state of the equipment, so as to achieve state maintenance, so as to avoid excessive maintenance and post-maintenance, and reduce maintenance costs. During the operation of power equipment, its performance will gradually decline over time. By fault prediction, it can detect the trend of device performance deterioration in time and take appropriate measures to adjust and maintain the device, delaying the deterioration of device performance and prolonging the service life of the device. For example, the vibration, temperature and other parameters of the generator are monitored and analyzed, the abnormal operating state of the generator is found in time, and measures such as load adjustment and replacement of parts can effectively extend the service life of the generator [3].

The life cycle of power equipment includes procurement, installation, operation, maintenance, decommissioning and other stages. By managing the life cycle of power devices, it can reasonably plan and configure the resource requirements of power devices at each stage, and improve the utilization efficiency of resources. For example, in the equipment procurement stage, it can choose cost-effective equipment according to the actual needs and performance requirements of the equipment; When the device is running, it can optimize maintenance plans and arrange maintenance personnel and resources to reduce maintenance costs [4]. Lifecycle management emphasizes the management of equipment from design to decommissioning. By taking effective measures at each stage, the performance and reliability of equipment can be improved. In the equipment design stage, advanced design concepts and technologies can be adopted to improve the performance and quality of equipment; During the running of the device, it can monitor and analyze the running status of the device in real time to discover the abnormal situation of the device and take appropriate measures to ensure the normal running of the device. With the attention of society to environmental protection and sustainable development, the life cycle management of power equipment has been paid more and more attention. Through the life cycle management of power equipment, the impact on the environment during the production, operation and decommissioning of the equipment can be reduced, the recycling of resources can be realized, and the sustainable development of the power industry can be promoted. For example, in the decommissioning stage, equipment can be recycled and reused to reduce waste emissions and reduce environmental pollution [5].

Power equipment fault prediction and life cycle management are mutually complementary. Fault prediction provides an important decision basis for life cycle management. Accurate fault prediction helps it rationally arrange maintenance and replacement plans for devices and optimize life cycle management for devices [4]. Lifecycle management provides a comprehensive data support and management framework for fault prediction. By collecting and analyzing the lifecycle data of devices, the accuracy and reliability of fault prediction can be improved. For example, during device procurement, it can select devices with high reliability and low maintenance cost by analyzing historical fault data and performance data of the devices [6]. During the running of the device, it can predict faults by monitoring the running status of the device in real time, discover hidden faults of the device in time, and take maintenance or replacement measures according to the life cycle management policies of the device. In the decommissioning stage, the fault history and performance data of the equipment can be summarized and analyzed, which can provide reference for the purchase and design of new equipment.

2.2. The Status

2.2.1. Current Situation of Power Equipment Failure Prediction

At present, the current technical methods of power equipment fault prediction include: sensor-based monitoring method, data analysis method and expert system method.

Sensor-based monitoring method: At present, various kinds of sensors are widely used to monitor the operating parameters of power equipment in real time, such as temperature, humidity, vibration, current, voltage, etc. For example, the oil temperature sensor and winding temperature sensor are installed on the transformer, and the change of these parameters is monitored to determine whether the equipment is abnormal. When the oil temperature or winding temperature exceeds the normal range, it may indicate that the equipment has a hidden trouble [6].

Data analysis method: Use big data analysis, machine learning and other technologies to dig deeply into the monitoring data. Big data analysis can process massive equipment operation data and find potential rules and abnormal patterns in the data. Machine learning algorithms, such as neural networks and support vector machines, can build fault prediction models based on historical data to predict the future failure probability of equipment. For example, by learning a large amount of transformer fault data, the neural network model can identify the characteristic patterns associated with the fault, so as to give a fault warning in advance [2].

Expert systems Approach: Expert systems are intelligent systems built on the knowledge and experience of domain experts. It stores the knowledge of experts in the system in the form of rules or models, and gives fault diagnosis and prediction results through the analysis and reasoning of equipment operation data. For example, in the circuit breaker fault prediction, the expert system can judge the fault possibility according to the operating times of the circuit breaker, contact wear, insulation performance and other factors, combined with expert experience [5].

In the actual power system, fault prediction technology has been applied to some extent. Many power enterprises have established equipment condition monitoring system to monitor and warn the key power equipment in real time. For example, some large substations have adopted advanced online monitoring technology to carry out all-round monitoring of transformers, circuit breakers and other equipment, which greatly improves the detection rate and processing timeliness of equipment failures [6]. However, the current application of fault prediction technology still has some limitations, some enterprises monitoring system data utilization is not high, the accuracy and reliability of fault prediction needs to be further improved.

The operating data of power equipment comes from a wide range of sources, the quality of the data is uneven, and there are some problems such as noise and missing value. These problems can affect the accuracy of data analysis and fault prediction models. For example, sensor failure or communication interference can lead to inaccurate data acquisition, skewering failure prediction results. There are various failure modes of power equipment, and different types of faults may be caused by multiple factors together, and the fault manifestations are complex. This makes it difficult to build an accurate fault prediction model, and more factors and characteristics need to be considered. For example, generator failure may be related to mechanical, electrical, thermal and other factors, so it is difficult to accurately identify the cause of failure and predict the occurrence of failure [7]. With the continuous upgrading of power equipment and the change of operating environment, the existing fault prediction model may not be able to adapt to the new equipment and working conditions. The model needs to be constantly updated and optimized to improve its adaptability and accuracy.

2.2.2. Current Situation of Power Equipment Life Cycle Management

At present, the life cycle management mode of power equipment includes traditional management mode and condition maintenance management mode.

Traditional management model: Traditional power equipment life cycle management is mainly based on experience and regular maintenance schedule. The device is repaired and maintained at fixed intervals regardless of the actual running status of the device. This management mode easily leads to over-maintenance or under-maintenance, which increases the maintenance cost of the equipment and reduces the service life of the equipment.

Status maintenance management mode: The status maintenance management mode makes maintenance decisions based on the actual running status of the equipment. Through real-time monitoring of equipment status parameters, combined with fault prediction technology, determine whether equipment needs to be maintained and when. This management mode can improve the reliability of equipment and reduce maintenance costs, but it needs the support of advanced monitoring technology and data analysis capabilities.

At present, some advanced power enterprises have begun to adopt the condition maintenance management mode, gradually replacing the traditional regular maintenance mode. Through the establishment of the equipment life cycle management system, the procurement, installation, operation, maintenance, decommissioning and other stages of equipment are comprehensively managed. For example, in the stage of equipment procurement, comprehensive consideration of equipment performance, reliability, price and other factors to choose the best equipment; In the operation phase of the equipment, real-time monitoring of equipment status, according to the status assessment results to develop a reasonable maintenance plan [8]. However, the status maintenance management mode still faces some difficulties in the process of promotion and application, such as the low acceptance of new technologies by some enterprises and the lack of relevant professionals.

The life cycle management of power equipment involves many departments and links, and the information systems among all departments are often independent of each other, so it is difficult to share and integrate information. As a result, the information of the whole life cycle of the equipment is incomplete and untimely, which affects the accuracy and scientific nature of management decisions. For example, the information of the device procurement department cannot be effectively shared with that of the operation and maintenance department. As a result, the maintenance plan may not match the actual device situation [7]. The implementation of the condition maintenance management mode requires a large amount of funds to be invested in the installation of monitoring equipment and the construction of data analysis system. Although condition maintenance can reduce maintenance costs in the long run, the cost investment is larger in the short run. How to achieve the balance of cost and benefit under the premise of ensuring equipment reliability is an important challenge faced by power enterprises.

3. Big Data Analysis in Power Equipment Failure Prediction Related Technologies

At present, the relevant standards and norms of power equipment life cycle management are not perfect enough, and there are differences in management methods and evaluation indicators among different enterprises. This is not conducive to the standardized development of the industry and the exchange of experience, but also affects the effect of the whole life cycle management of equipment.

3.1. Key Technology

3.1.1. Hadoop Technology

Hadoop technology is a popular Distributed computer storage System, HDFS (Hadoop Distributed File System), which uses the parallel computing framework Mapreduce, has high reliability, strong scalability, fast processing speed, and high fault tolerance. It adopts mature Jave language to implement on Linux system and has good security. The reliability of Hadoop technology is reflected in the maintenance of stored data to generate multiple copies, which can be re-distributed in the case of breakpoints in data processing to ensure data integrity and availability. Scalability is reflected in Hadoop technology, which enables flexible data distribution among computer clusters, expands the cluster to each node, and adjusts the number of nodes according to the amount of data. The processing speed is also reflected in Hadoop technology, which enables dynamic data movement on nodes, and enables each node to maintain dynamic balance. When a node is crowded, it can quickly find other nodes, so that the system access speed is very fast. Fault tolerance is reflected in Hadoop technology, which stores multiple copies of data and can redistribute failed tasks to achieve breakpoint transmission. Use of Hadoop technology cluster Hundreds of common computers become a node in the cluster network, through the TCP/IP network to build a resource pool, users call data resources from different nodes to the client according to demand, to achieve data processing and utilization. Hadoop technology adopts Mapreduce data processing model, which can process and analyze large-scale data. MapReduce includes multiple Map tasks, which can automatically carry out parallel computation, which has the characteristics of fast processing efficiency and reliability of the data distribution node. The implementation method is to Map the -group key value through a map mapping function, Master/Slave architecture, components include Client component, JobTracker component, TaskTracker component and Task component. The structure of Mapreduce model is shown in Figure 1:

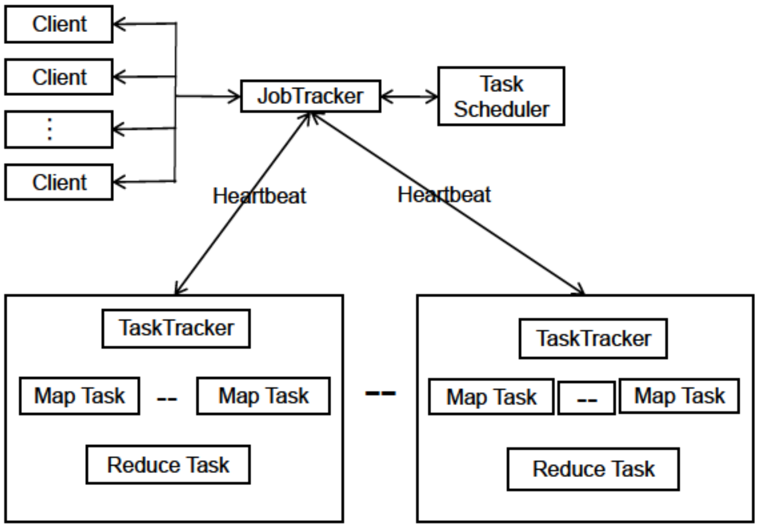

Figure 1. MapReduce Model Structure.

The Client component submits a program written by a user to the JobTracker component, the JobTracker component schedules user operations and resource addresses, the TaskTracker component receives and executes JobTracker commands and reports them, and the Task component processes tasks. During resource processing, the TaskTracker divides node resources into equal quantities by Slot, and the Task processes tasks according to the Split meta information.

3.1.2. Recursive Random Search Algorithm

Recursive random search algorithm can find the optimal sample of the target by recursive random sampling. The algorithm has strong automatic optimization ability, and has good application value for network parameter configuration optimization, black box optimization, combination optimization and so on. Recursive random search algorithm for the optimization of complex systems, it has the advantages of adaptive probabilistic search, automatic adjustment of sample space random sampling and shrinking sample space without affecting the search for the optimal solution, and has a good performance in search accuracy and search efficiency. In the Hadohado-based power equipment monitoring system, the type of monitoring equipment is complex, the type of equipment is multiple, and the generated number structure and frequency are inconsistent, which increase the difficulty of power fault judgment. The recursive random search algorithm can quickly locate the parameter samples of power equipment when power faults occur by moving the sample space and constantly shrinking the space. The accuracy of fault judgment is improved by recursive search until the critical value of power equipment fault is accurately judged. Therefore, in the design of automatic power failure analysis system based on big data, recursive random search algorithm is used to automatically optimize the critical value of power failure, and the accurate early-warning parameter value of power equipment is obtained.

3.2. Demand Analysis

With the continuous development of sensor technology, it has become an important means for electric power enterprises to monitor the state information of equipment when sensors are applied to electric power equipment. At present, the commonly used power failure analysis method is to monitor by obtaining the current information and voltage information of the power equipment, and determine whether it exceeds the limited value of the power grid operation, and because of the different types of power equipment, the collection method and the type of data collection are also different, such as: Partial discharge, vibration analysis and other methods are used for transformer faults, wavelet analysis and neural network analysis for motor faults, vibration analysis and tripping profile analysis for circuit breaker faults. The fault information data generated by different types of power equipment not only has different structural characteristics, but also has a huge amount of data. Although the Hadoop-based power equipment status information system can store a large amount of power equipment status information, it is still limited in power fault analysis, especially in algorithm. The traditional KMeans clustering algorithm not only converges slowly during operation, but also fails to achieve ideal results.

In the past power failure analysis, fixed parameter values are usually used to analyze the time and cause of the possible failure of power equipment. However, due to some differences in the performance of power equipment under different conditions, such as different operating time and operating environment of power equipment, there will be large errors in fault assessment using fixed parameter values. Therefore, the automatic power fault analysis system based on big data needs to be able to automatically analyze power faults on the basis of the existing system, and can automatically adjust the fault limit of power equipment according to the tracking of the running state of power equipment, with the goal of improving the accuracy of power fault analysis and the efficiency of analysis. At present, there is no Hadoop-based power equipment status information system, which focuses on constantly processing the increasing mass data, but is still lacking in power failure self-analysis. In order to realize automatic analysis of power failure, By deep learning and mining the operating mechanism of power equipment and the critical value of power equipment operating state in the Hadoop-based power equipment status information system, it is necessary to effectively capture the feature samples of equipment status information, and adopt an efficient algorithm to complete the accurate judgment of the possibility of power equipment failure.

4. Power Equipment Life Cycle Management Strategy Based on Big Data Analysis

The whole life cycle database of equipment is established to record the whole process data of equipment from procurement, installation, operation, maintenance to decommissioning. By analyzing the data, it can understand the running status and performance changes of the device, and provide a basis for the maintenance and management of the device. Make a proper maintenance plan based on the fault prediction results and running status of the device. Maintenance is performed based on the actual device status to avoid overmaintenance or undermaintenance. At the same time, big data analysis technology is used to analyze maintenance historical data, optimize maintenance strategies, and improve maintenance efficiency and quality. Through the performance evaluation and the remaining life prediction of the equipment, it provides support for the equipment renewal decision. When the performance of the device deteriorates to a certain extent or the remaining service life is short, update the device in time to ensure the safe and reliable operation of the device.

The characteristic of the whole life cycle management of equipment is to manage and monitor the whole process of the service life cycle of equipment, that is, from equipment purchase, equipment operation, equipment change, equipment maintenance until equipment scrap, so as to comprehensively monitor the operating status of equipment. The whole life cycle management of equipment can be divided into three stages according to the time perspective, which are the early management of equipment, the management of equipment in use and the management of equipment in the later stage. Its goal is to reduce the failure rate of equipment and improve the reliability of equipment operation through physical management and asset management in the early stage, use and late stage of equipment.

Equipment early stage: Equipment early stage management Equipment early stage management includes equipment demand analysis, equipment procurement, installation and commissioning, acceptance and put into use related management processes. The process includes equipment demand planning and feasibility study analysis, procurement review, installation, commissioning and equipment transfer.

The management in the use of the equipment usually refers to the management process that begins after the equipment has reached the acceptance standard and can be put into use after a period of trial operation. From the perspective of the equipment life cycle, the process occupies most of the equipment life cycle and is the most important link in the equipment life cycle management, including equipment maintenance and repair.

Post-equipment: Post-equipment management Post-equipment management refers to the process of mothballed management after equipment is decommissioned or scrapped after equipment is decommissioned. Under normal circumstances, the equipment is in the running state for a long time. In some special cases, there is a shutdown state. In this case, the equipment will be shut down and sealed. Equipment obsolescence is when the equipment reaches the age of use or can no longer be in service due to accidents and failures.

5. Power Equipment Failure Prediction and Life Cycle Management Design Based on Data Analysis

According to the demand analysis of the automatic power fault analysis system based on big data, the system is required to have the functions of data capture, analysis and prediction and limit parameter optimization. After the power failure analysis system based on big data runs, it first invokes the performance indicator capture function module and injects the BTrace tool into the Slave node of the power device status information system based on Hadoop to capture the power device status information and write the data captured to XML. File. Keating Hadoop's Power Equipment status information system monitors the power equipment status information for an inch, resulting in XML. The file is uploaded to the HDFS of an automatic power fault analysis system based on big data. it need to optimize the minimum value of the power device fault parameter, and visualize the maximum value of the device fault, and run the Visualize script to select the Visualize device fault information to obtain the analysis result. Its design process is shown in Figure 2.

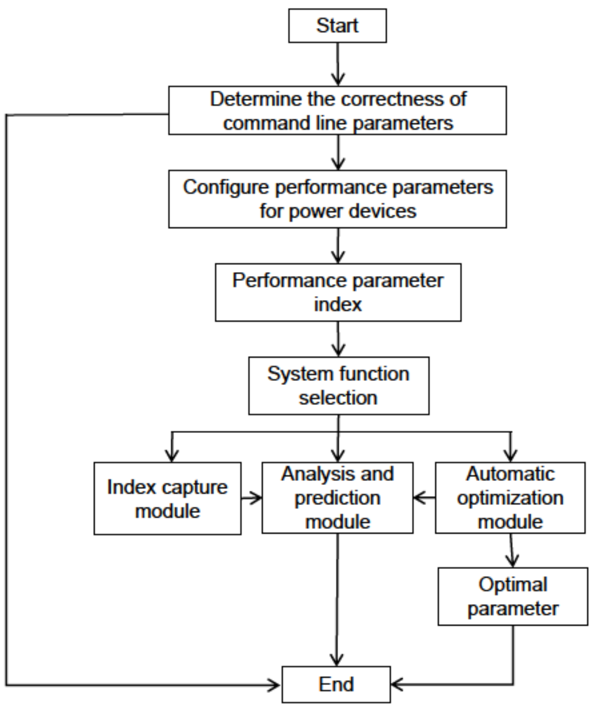

Figure 2. Design Flow of Power Fault Automatic Analysis System Based on Big Data.

To perform automatic power fault analysis, it must first set the operating parameter limits of the analysis power equipment, which can be initially set according to the performance indicators in the power equipment operation reference manual (the performance indicators in the power equipment operation reference manual are used as the analysis standards for newly installed power equipment). Users select the power equipment objects to be analyzed, and the system will make a selection according to the user's selection. Carry out automatic analysis of power failure, execute the function module of power equipment operation status capture, analysis and prediction module and system optimization module, use big data analysis to obtain the maximum limit parameter during the operation of power equipment, replace the initial performance index set value of the equipment, and perform automatic analysis of power failure.

6. Conclusion and Prospect

With the continuous extension of the application of big data technology in power grid, more and more attention has been paid to the applicability of power failure analysis. As a representative system of power equipment condition monitoring, the functional extension of Hadoop platform is a key research object for power security. The Hadoop-based power equipment status information system can only monitor the running status of power equipment and manually judge the possibility of power equipment failure, which not only puts forward high requirements on the technical level of monitoring personnel, but also lacks the accuracy and flexibility of judgment. Therefore, to improve the ability of automatic identification and analysis of power faults is the key to improve the condition monitoring system of power equipment. In this paper, big data performance analysis tools are introduced into power condition monitoring, the accuracy and efficiency of fault analysis are improved by setting data space range, and the limit value of power equipment operating state is optimized by recursive random search algorithm, so as to improve the accuracy of power fault analysis.

With the continuous development of big data analysis technology and the intelligent upgrade of power system, power equipment fault prediction and life cycle management based on big data analysis will usher in a broader development prospect. In this paper, the application of equipment lifecycle management is not deep enough. Because the time dimension of data analysis is not wide enough, the analysis does not consider equipment family history, equipment maintenance history and other information. From the perspective of the whole life cycle management of the equipment, the data such as the family history and maintenance history of the equipment have a great impact on the future health state of the equipment. Therefore, in the future, when the data conditions are met, the health status of the equipment can be comprehensively analyzed and evaluated by combining the family history, historical maintenance, defects and other data of the equipment.

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