Research and Practice of Big Data Technology in Energy System

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Abstract. The characteristics of the massive data is inspected which is accumulated by the energy management system of industrial enterprises during the production process. They are real-time, massive, non-linear, and even unstructured, meanwhile some implicit correlation are hidden between them. These correlations have not yet been fully learned and unearthed. Here big data technology is proposed to improve the availability of energy data for the energy saving and consumption reduction. The general pattern of big data application is proposed in energy management systems. On this basis, some algorithms are applied to the actual management process, including parameter prediction, status monitoring, operation optimization and performance evaluation. Finally, two practical examples of the constructed model are presented including compressed air prediction and Operation prediction of air-conditioning system. The results show that big data technology can improve the efficiency of data acquisition, expand data applications, and exert greater data value.

1. Introduction to Energy Big Data of Industrial Enterprise

With the development of information technology and the growth of data volume, big data technology has become an energyful tool to promote enterprise development and competition. With exponential growth in data volume, massive unstructured data is introduced into big data, so the data become increasingly complex with complicated hierarchical relationships. Compared with traditional data, big data technology shows obvious advantages in terms of data volume, production speed, data structure diversity, and data value. Data assets can be retrieved from big data, thereby improving the efficiency of data acquisition, expanding data applications, and exerting greater data value[1,2].

The data of energy system in industrial enterprises conforms to the characteristics of big data. It is an urgent task to apply deep, multi-scale and all-dimensional data mining method and knowledge extraction out of energy big data[3,4]. It is of great significance to find the method based on big data and improve the availability of energy data for the energy saving and consumption reduction in the modern production, which is reflected as follows:

(1) Large amount of historical and real-time data are accumulated in the energy system, which are mostly idle and less utilized. It’s urgent to take advantage of these data, to optimize the energy operation, and to instruct production process. Thus we can improve enterprise efficiency and energy utilization rate, reduce the cost of equipment maintenance and technical innovation, and improve the safety and reliability of the production process[5].

(2) To improve the quality of process production control, to promote advanced control, and to optimize operation strategies. Online operational control and optimization requires accurate modeling of the object. But it will cost a large amount of resources to establish the mechanism model of the
complex process. If data-driven models are established based on big data technology, the data analysis and prediction can be greatly improved over the modeling efficiency.

(3) Through methods based on big data, many hidden information can be discovered which may interest enterprise decision makers. After information and knowledge is effectively extracted of big data, anomaly detection is more accurate and is easy to be revised.

2. The Pattern of Big Data in Practical Application

The general pattern of big data application in practice is shown in Figure 1, including construction of big data platform, modeling theme determination, data preparation and pretreatment, algorithm selection, model generation, model validation, encapsulation of deployment model.

(1) Construction of big data platform
In big data platform, structured and unstructured data in power/energy system are retrieved and stored in a big data platform over distributed system. The data must be in accordance with a unique standard to provide a basis for the effective utilization of data.

(2) Modeling theme determination
The initiative and key step of the modeling process is to determine the modeling theme. The theme may be determined by the actual problems encountered in energy operation and the modeling requirements. The available data stored in the big data platform plays a significant role. A clear modeling theme is the positioning of the entire modeling process, to ensure the model is available and practical. Different modeling themes will direct the selection of model algorithms whose accuracy and response vary.

(3) Data preparation
Nowadays data is easy to be acquired within sensor system which are build along with the wide application of information technology in industrial enterprise. According to the modeling theme, the parameters are determined from theory and mechanism analysis, statistical analysis, data analysis, field experience, etc. The initial parameters can be reasonably determined. The sample set is chose to prepare more comprehensive data for the model theme.

(4) Data preprocessing
The data is complex. So the data preprocessing is the key to modeling. To ensure the accuracy of modeling data, the abnormal data in the real-time data stream must be eliminated. The number of modeling parameters must be further reduced by feature parameter selection, which ensure the modeling accuracy and modeling time.

(5) Algorithm selection
Big data model relies on the relationship between data to reflect the relationship between feature parameters, modeling objectives and modeling themes. Modeling themes can reflect the modeling purpose to a certain extent and provide materials to choose reasonable and appropriate algorithms. According to the purpose of modelling prediction, classification, optimization or condition evaluation, algorithms can be selected in advance.

(6) Model generation
After the modeling data and algorithm are both determined, the program can be executed to generate the model, that is, to determine the key architecture parameters and constraints of the model.
(7) Model validation
Before the model is applied, the model needs to be verified to ensure that the model has certain generalization ability and adaptability. The model should be portable and applicable to the actual operating conditions of the modeling object. There are two kinds of validation methods: one is to test the model with historical data for short-term validation; the other is to apply the model to the actual operation and verify the model with future data for long-term validation.

(8) Deployment model
According to the application requirements of the model, the model is encapsulated and deployed to the system. The model is updated according to the real-time modeling requirements and data update to adapt to the changes of the assembling unit. It is a process of repeated modeling and constant updating.

3. Application Scope of Big Data in Energy System
With the investment of industrial enterprise automation, the enterprise has rich data resources. Big data technology may be applied in energy management as the following.

![Figure 1. General pattern of big data application](image)
(1) Parameter prediction
There are a large amount of data stored in the energy database of an industrial enterprise, including online operation data, offline sensor data and secondary data processed by human. For some parameters that are difficult to be retrieved online, the correlation models can be created between these parameters and the online parameters by mining the accumulated historical data. The parameters that are difficult to measure online are reflected by the parameters that can be measured online, so as to realize the on-line prediction. In addition, based on big data technology, the prediction model of some online sensor parameters is established, which can realize the calibration and inspection of online measurement data.

(2) Status monitoring and fault diagnosis
It is the premise of safe operation to monitor the operation status of the equipment, find out the problems in time and carry out fault diagnosis and maintenance. Big data technology provides tools to effective analyzing, extracting and reusing of these data. The application of online monitoring technology provides real-time continuous operation data for the unit state monitoring. The use of big data technology to establish a model for data analysis will not affect the operation of the equipment, and it can temporarily replace the detection device to make judgment, which provides the basis for timely troubleshooting.

(3) Operation optimization and control
Operation optimization is based on performance evaluation and energy consumption analysis. By analyzing the performance parameters and indicators of energy system operation status, the influence of performance parameters or operation status on energy supply and quality is determined. Big data technology can make comprehensive use of energy equipment operation status, operation parameters, operation records and other data to discover knowledge, mine the optimal operating conditions, determine the optimization target value, conduct energy consumption analysis and diagnosis of consumption difference, and guide the operation adjustment of energy system, so as to provide guidance for the economic operation, energy saving and consumption reduction of plant kinetic energy management and control.

(4) Performance evaluation and decision support
Through regular statistical analysis of key operating parameters and important indicators of energy system, big data technology is used to dig deep energy performance information. Comprehensive and multi-level assessment of energy is conducted, which provides operational evaluation and equipment state adjustment support for managers, and reference basis for decision makers. The data of the energy system are analyzed comprehensively, and the overall performance is evaluated to facilitate the decision maker to make reasonable prediction.

4. The Application Case of Big Data in Energy System

(1) Prediction Compressed air consumption
According to the production plan, combined with historical air pressure data, the historical air pressure data can be regarded as a time series and the production planning worksheet as an impact factor. Through data training, a machine learning model is established to predict the next day air pressure and air pressure flow peak and consumption curve. The results are presented by visualization technology. Compressed air prediction is to simulate and predict the future compressed air consumption of each air-using unit through production arrangements and compressed air prediction models. By comparing and analyzing the historical actual consumption with the predicted consumption, the prediction model can be gradually optimized on the accuracy and effectiveness. The prediction of compressed air includes instantaneous flow prediction and cumulative consumption prediction. The air compressor opening strategy is formulated through the prediction of instantaneous flow and air compressor power. Examples of compressed air prediction simulation are shown in Figure 2.
Figure 2. Instantaneous flow prediction simulation of the compressed air

(2) Operation prediction of air-conditioning system

To achieve the temperature and humidity required by the production process, it is necessary to activate the air-conditioning unit for pre-cooling in advance, to ensure that the air-conditioning area is within the temperature range during the planned execution. The time from when the air conditioner is turned on in advance to when the air conditioner starts to be used is called the air conditioner start time. Too long an air conditioner startup time will cause unnecessary waste of energy consumption, while an air conditioner startup time that is too short will make the temperature and humidity of the control area not satisfied to the process requirements at the beginning of production.

Air-conditioning start-up time prediction refers to the establishment of a suitable model based on historical data of air-conditioning operation and indoor and outdoor environment within a certain period of time. The model can evaluate the need for a certain air-conditioning area on the second day from the start-up to the process temperature and humidity requirements based on the weather prediction data time.

The air-conditioning system is a multi-variable, nonlinear and complex system with large delay. During operation, it is affected by many factors such as outdoor temperature and humidity, solar radiation, indoor load, and heat dissipation of maintenance structures. Big data prediction model can be established with input—the indoor temperature of the day, the outdoor temperature of the day, the indoor humidity of the day, the outdoor humidity of the day, the area of the air-conditioning area, the weather prediction temperature of the next day, and the weather prediction humidity of the next day as the model input parameters, and output—the air conditioner on time.

In the process of air-conditioning start-up time prediction, the historical data of air-conditioning start-up is processed and analyzed first, and classified according to different working conditions, as shown in Figure 3.
According to different working conditions, combined with other factors, support vector machine modeling is used to predict the start-up time. The air-conditioning start-up prediction operation tracking is shown in Figure 4.

The prediction model will automatically revise the prediction results at regular intervals. In the rolling predicting process, when the predicted time point + the predicted time = the planned time of reaching the target, the system automatically prompts the air conditioner to start to form the air conditioner starting strategy. The system also tracks and records the operation of the air conditioner and whether the indoor temperature and humidity are within the required range of the production area. Moreover, in the optimization stage of predicting the start-up time, in addition to accurate screening of the modeling data, it is also necessary to add appropriate redundancy, which not only guarantees the requirements of the production process, but also achieves the purpose of energy saving and emission reduction.

5. Summarize
The analysis and application of enterprise energy big data, can realize the dynamic perception of energy supply and strengthen the strategic guidance on energy supply, equipment operation and maintenance, provide a more scientific decision-making mechanism. Further use of big data analysis,
can realize the identification of energy-saving points, dynamically monitor energy-saving target, tap the potential of energy efficiency, to achieve the energy-saving development goal of industrial enterprises.

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