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Series L

Supplement 48

(07/2022)

SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Data centre energy saving: Application of AI technology in improving energy efficiency of telecommunication room and data centre infrastructure

ITU-T L-series Recommendations – Supplement 48

ITU-T

ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

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Supplement 48 to ITU-T L-series Recommendations

Data centre energy saving: Application of AI technology in improving energy efficiency of telecommunication room and data centre infrastructure

Summary

Telecommunication room and data centre (DC) infrastructure includes a large number of items of information and communication equipment. In order to keep equipment running continuously and reliably, the rooms where it is located will necessarily be equipped with air conditioners to create a suitable environment for equipment operation. This will cause a large amount of energy consumption and carbon emissions. This Supplement focuses on the application of AI technology and other emerging technologies such as digital twins to improve the energy efficiency and reduce the carbon emissions of telecommunication room and DC infrastructures.

Most of the existing telecommunication room and DC infrastructures do not have the full ability to identify the distribution of indoor temperatures. Therefore, it is difficult to analyse the heat flow and its related power consumption in real time and make appropriate adjustments in a timely manner. Consequently, this leads to unnecessary consumption of energy. Supplement 48 to the ITU-T L-series Recommendations will address how AI-based power management can provide the following capabilities:

- Data collections in telecommunication room and DC infrastructure;
- Real-time analysis of the historical power consumption and parameters of the target equipment room;
- The ability to train an intelligent model;
- Making reasonable adjustments dynamically to the air conditioning and temperature, so as to achieve energy saving in the telecommunication room and DC infrastructure.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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AI, DC infrastructure, digital twin, energy saving, telecommunication room.

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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1 Scope

This Supplement identifies the new application of AI technology in improving energy efficiency of telecommunication room and data centre (DC) infrastructures. It will address how AI-based power management can provide the following capabilities:

- Data collection in telecommunication room and DC infrastructure;
- Real-time analysis of the historical power consumption data and parameters of the target telecommunication room;
- The ability to train an intelligent model;
- Making reasonable adjustments dynamically to the air conditioning and temperature, so as to achieve energy saving in the telecommunication room and DC infrastructure.

2 References

[ITU-T F.749.4] Recommendation ITU-T F.749.4 (2021), *Use cases and requirements for multimedia communication enabled vehicle systems using artificial intelligence.*

[ITU-T F.749.13] Recommendation ITU-T F.749.13 (2021), *Framework and requirements for civilian unmanned aerial vehicle flight control using artificial intelligence*.

[ITU-T L.1305] Recommendation ITU-T L.1305 (2019), *Data centre infrastructure management system based on big data and artificial intelligence technology*.

[ISO TR 24464] ISO TR 24464:2020, *Automation systems and integration – Industrial data – Visualization elements of digital twins.*

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following terms defined elsewhere:

3.1.1 artificial intelligence (AI) [ITU-T F.749.4]: An interdisciplinary field, usually regarded as a branch of computer science, dealing with models and systems for the performance of functions generally associated with human intelligence, such as reasoning and learning.

3.1.2 digital twin [ISO/TR 24464]: Compound model composed of a physical asset, an avatar and an interface.

3.2 Terms defined in this Supplement

None.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

ACU Air Conditioning Unit

AI Artificial Intelligence

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BA	Building Automation
BMS	Building Management System
CFD	Computational Fluid Dynamics
DC	Data Centre
DCIM	Data Centre Infrastructure Management
DNN	Depth Neural Network
IT	Information Technology
KPI	Key Performance Indicator
PUE	Power Usage Effectiveness
SLA	Service Level Agreement

5 Conventions

None.

6 AI technology

6.1 AI concepts

Artificial intelligence (AI) is a new technical science that studies and develops theories, methods, technologies and application systems for simulating, extending and expanding human intelligence. At the Dartmouth conference in 1956, John McCarthy suggested that "artificial intelligence is to make machines behave like people behave intelligently", marking the birth of AI. Different from the natural intelligence embodied by human beings and other animals, AI is the general name of the intelligence embodied by machines. The goal of AI is to achieve a system of understanding, thinking, learning and behaving like humans.

6.2 Machine learning

By the 1980s, a way to achieve AI machine learning had been developed. The types of machine learning include supervised learning (training data marks correct answers, divided into regression and classification) and unsupervised learning (training data is not marked, specific structures are extracted from data by clustering). Machine learning means that you give an algorithm as much sample data as possible, that is, training data it can use to make predictions or decisions about events in the real world without the need to perform tasks through explicit programming. An often-cited example is that of identifying cats: the machine learns thousands of pictures of cats, and it can recognize the appearance of a cat without having to define "cat" in the system.

The training process of machine learning is as follows: firstly, the hypothetical model is defined, such as linear classification, linear regression, logical regression, deep neural network and so on; secondly, the loss function is defined to measure the quality of the trained model. In the end, an algorithm, such as the least square method or the gradient descent method, is selected to optimize the hypothesis model and finally obtain the optimal solution. Different hypothetical models use different algorithms, such that linear regression is usually solved by the least square method, logical regression is solved by the gradient descent method, and neural network is solved by reverse derivation. In today's big data area, machine learning is essential. The purpose of collecting, transmitting and storing big data is to "utilize" big data (data pre-processing, data mining, etc.), and without machine learning technology to analyse big data, utilization will not be possible.

6.3 Deep learning

By the 2000s, a method to realize deep machine learning (learning based on deep neural networks) had been developed, which was inspired by the physiological structure of the human brain, using a multilayer neural network to establish an algorithm. The cognitive behaviour of simulating the interaction between neurons can also be seen in the example of identifying cats. If a shallow machine learning system is used, it takes time to define the edge of a cat, while deep learning uses a multilayer learning algorithm to understand the data. The first few layers can calculate the edge of a cat image, and the latter layers can focus on the cat's whiskers and eyes. Compared with shallow machine learning, deep learning usually requires more data and higher computational power, but less manual intervention.

6.4 Digital twin technology

6.4.1 Digital twin concept

The digital twin concept refers to the creation of a completely corresponding and consistent virtual model for physical entities in the real world in a digital way, which can simulate their behaviour and performance in the real environment in real time.

6.4.2 Digital twin in data centres

Because of characteristics including a high security requirement, high trial and error cost and high energy consumption, it is very important to predict data centre security and energy consumption management. The whole life cycle of the data centre is divided into layout planning, process planning, rapid delivery, energy consumption optimization, intelligent operation and maintenance. Numerical simulation technology can be used in the planning, design and construction stage, and digital twin technology can be used in the operation and maintenance stage of the data centre.

In the planning and design stage, the performance of data centre equipment and systems can be verified in advance by numerical simulation technology, and the possible quality and function defects of the equipment and systems can be captured as soon as possible to ensure that the design requirements are met.

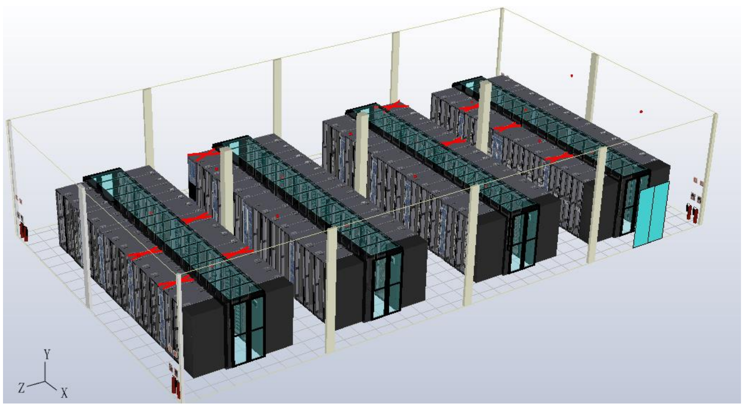

Figure 1 – DC digital model

Figure 1 illustrates an example of a DC digital model. The digital model formed in the planning, design and construction stage can be reused in the operation and maintenance stage; through a digital twin model the real-time information of the system, air conditioning equipment, power equipment and so on in the actual operation process can be obtained, other scenarios such as equipment change and scheme management in the future can be predicted and troubleshot, and the management of the real data centre in the digital model can be realized.

A digital twin in data centre is often inseparable from computational fluid dynamics (CFD) simulation technology. A 3D data centre model built by CFD software can not only reproduce the situation of the data centre, but also connect with the physical data centre dynamically and in real time through the interface, so it is called a twin model. Corrected digital twin models have been highly unified with physics (usually more than 90% CFD satisfies the accuracy requirements of model simulation and measured comparison), and their digital attributes are of great significance to predict the future operation state, energy utilization rate, space utilization rate and operational risk of the data centre.

Therefore, both static numerical simulation technology and dynamic digital twin technology provide an important basis for the safe and energy-saving operation of a data centre and the decision making of personnel, which plays an important role in the operation of the data centre.

6.5 Digital twin and AI

Digital twin and AI are a pair of companion technologies. In an actual running data centre, tens of thousands of pieces of data will be generated in each system and item of equipment, and a data centre cannot transmit all data in real time because of the limitation of sensor position, quantity and other factors. The monitoring system's function is local and one-sided. Digital twin technology can not only monitor the parameters of each system and equipment, but also predict the running state of data centre in the future. After "filtering and cleaning", data mining and data analysis of the AI algorithm, the data generated by a digital twin can be trained to save energy.

Digital twinning has been widely used in the energy saving control of air conditioning terminal and chilled water systems. It is believed that with the continuous evolution of digital twin technology, a digital twin will become closer to the real world.

7 AI energy-saving application scenarios

7.1 AI energy saving implement process

The refrigeration system is the supplier of cooling capacity, and the DC is the demander of cooling capacity. Take the water-cooling system as an example, the cooling demand model of the computer room can be built by using the water temperature difference and water flow rate. As the provider of cooling capacity, the capacity of the refrigeration system to provide cooling capacity is related to environmental parameters (external temperature and humidity), and also related to adjustable parameters (freezing pump frequency). When the adjustable parameters are fixed, the higher the temperature and humidity of the external environment, the weaker the capability to provide cooling capacity. When the external environment is fixed, improving the operating power of the refrigeration system will also increase cooling capacity, but will increase power consumption. AI energy saving needs an algorithm model to learn the relationship between refrigeration capacity and environmental parameters and to adjust those parameters [b-Zhang].

Meanwhile, the energy utilization ratio of a refrigeration system has a relationship with environmental parameters and adjustable parameters, which can be fitted by an algorithm model. In addition, different refrigeration systems have different refrigeration capacities and different energy utilization curves.

Figure 2 provides an implementation process of data processing and parameters control.

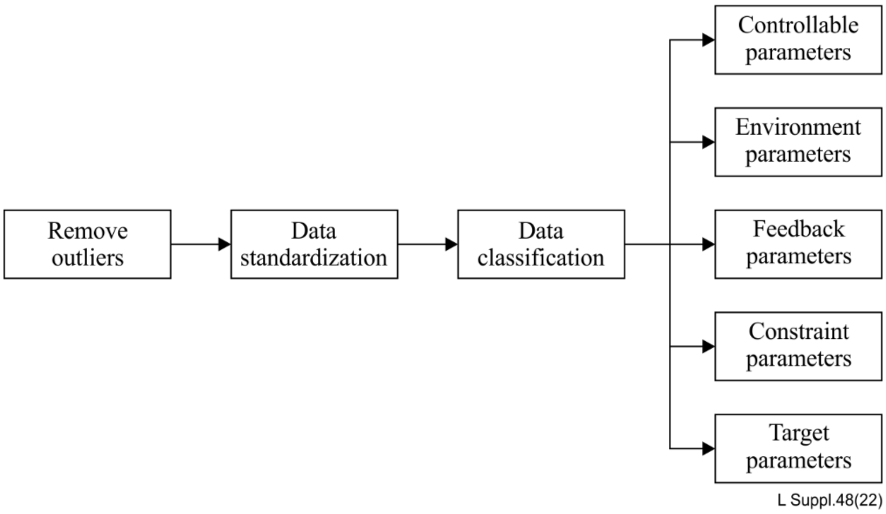

Figure 2 – Process of data processing and parameters control

Controllable parameters: frequency of cooling pumps, freezing pumps and the pumps used in cooling water towers.

Environmental parameters: air temperature, humidity.

Feedback parameters: water temperature, temperature difference and so on in each item of equipment.

Constraint parameters: threshold value or parameter range of equipment operation.

Target parameters: power usage effectiveness (PUE) value, defined as a visual expression of energy efficiency.

Figure 3 shows the optimization method of the PUE parameter. PUE curve fitting parameter optimization method: through the illustrated four parameters, using machine learning and deep learning algorithm, considering the influence of time series and related parameters, accurately fitting the optimization target PUE value. Adjustable parameters are optimized to make the PUE value the lowest.

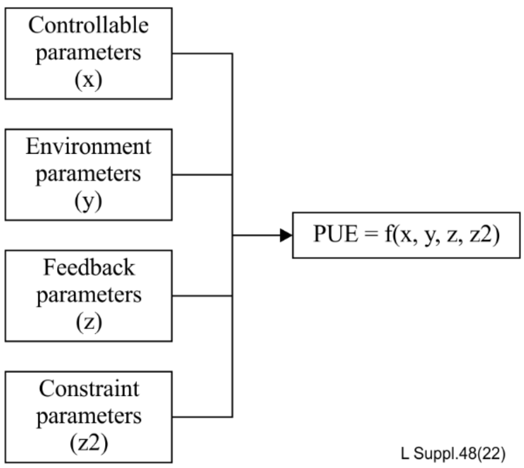

Figure 3 – Optimization method of PUE parameter

Data centre AI energy-saving process, including data acquisition access and storage, artificial intelligence algorithm platform, visual interactive interface, device command value control output, feedback and monitoring system and other functions, auxiliary data centre to achieve efficient operation and maintenance:

Key index prediction: using machine learning and depth learning algorithm to accurately predict PUE and other parameters to provide accurate PUE perception for operators.

Advice of operation strategy: through machine learning and decision optimization algorithm, the best equipment operation combination and parameters that can reduce the PUE can be directly linked to the equipment and automatically controlled.

Intelligent operation and maintenance monitoring: 24 hours for daily monitoring and system maintenance services, real-time monitoring of equipment operation status, key performance indicator (KPI) changes and failures and other information.

Closed-loop tracking control: the algorithm outputs the operation parameter strategy of the equipment; the system can track the parameter change and the energy saving output effect in real time, promote the feedback of the model learning effect, carry on the self-learning upgrade and realize the closed-loop control.

Promote BA (building automation) upgrade: update and repair existing BA systems through problem and fault analysis, add or upgrade the existing sensors and communication equipment to provide sufficient data support for the algorithm.

7.2 Process of energy saving tuning with AI

The application of dynamic tuning by AI is shown in Figure 4; the necessary sensor data can be accessed with data access layer and can offer comprehensive data mining ability and intelligent analysis algorithm of data which contains common foundation framework and the machine learning algorithm, deep learning algorithm and neural network algorithm. The internal relationships and values of sensor data can be identified by automatic selection and process of feature, automatic adjustment and training. The complete solution of data mining applications for data centre can be obtained by data analysis, integration, shown, test and evaluation. Systematic ability of operation and maintenance can be offered, as can the collection of data through the integration of the AI platform and BA system. The data interaction can be accomplished by protocol. The data conversion module can also carry out the data cleaning and data formatting. The whole process of data mining, such as data storage, analysis and process inside the system can be released. The forecast of data, operation of the machine, checking, monitoring and the export of authority management can be implemented by data visualization platform.

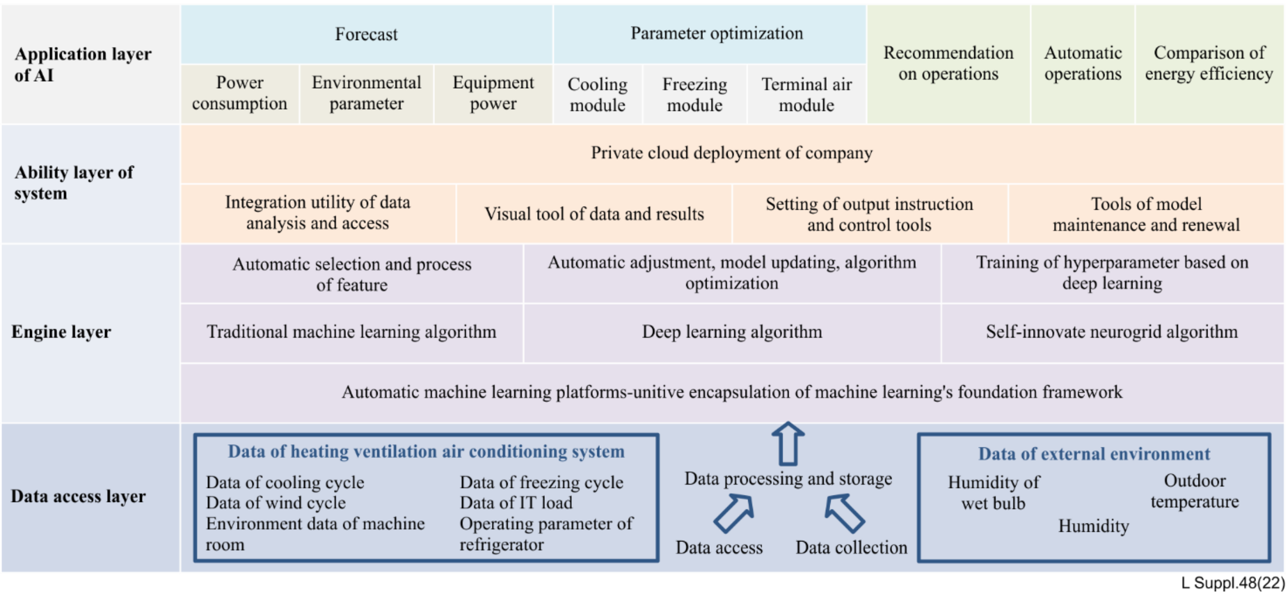

Figure 4 – Overall architecture diagram of AI energy-saving tuning

The modules used in this system are shown as follows:

The data acquisition module: it can obtain data from the building management system (BMS), building automation (BA) system and data centre infrastructure management (DCIM) (system, parse the data protocol, transfer to the data format that the system needs and send the data-to-data processing module. The main functions include importing the BMS/BA/DCIM historical base and basic information of equipment, receiving the real-time performance data of the machine sent from the BMS/BA/DCIM and sending the data-to-data process module by service interface.

Data process module: its function is receiving the data from the data acquisition module, storing the data locally and satisfying the forecasting movement of the algorithm module.

The data storage module: it is responsible for the permanent storing of data and dividing the data into hot and cold data for storing. The cold data can be used for shown of history analysis, while the hot data can be used for real-time inquiry and analysis.

Intelligent analysis of arithmetic module: its function mainly includes three parts: model training, model self-learning and closed-loop tracking. The optimized operation composition and parameters for reducing PUE can be supplied by machine learning, deep learning and forecast module, forecast of PUE, environmental parameter and equipment power.

Device module: it has the function of controlling the equipment based on the controlling instructions derived from arithmetic. This module can receive the output results and control instrument then adjust and control the parameters of the equipment.

Self-monitoring module: it can implement the inside monitoring, recognition the emergency warnings and common warnings such as failures of data acquisition, equipment controlling, arithmetic training and so on. The function of this module also includes warning alert cooperation with the visualization platform, giving pre-warning to the head monitoring station such as to the controlling system of machine rooms. If there is no problem, the system can self-recover by running the self-triggered procedure.

Data visualization module: it can provide the data analysis and showing by visual component. The main functions include the management of pages, views and elements, management of user rights, operation log management and the alert and curvilinear figure display.

The different modules and their functions are illustrated in Figure 5.

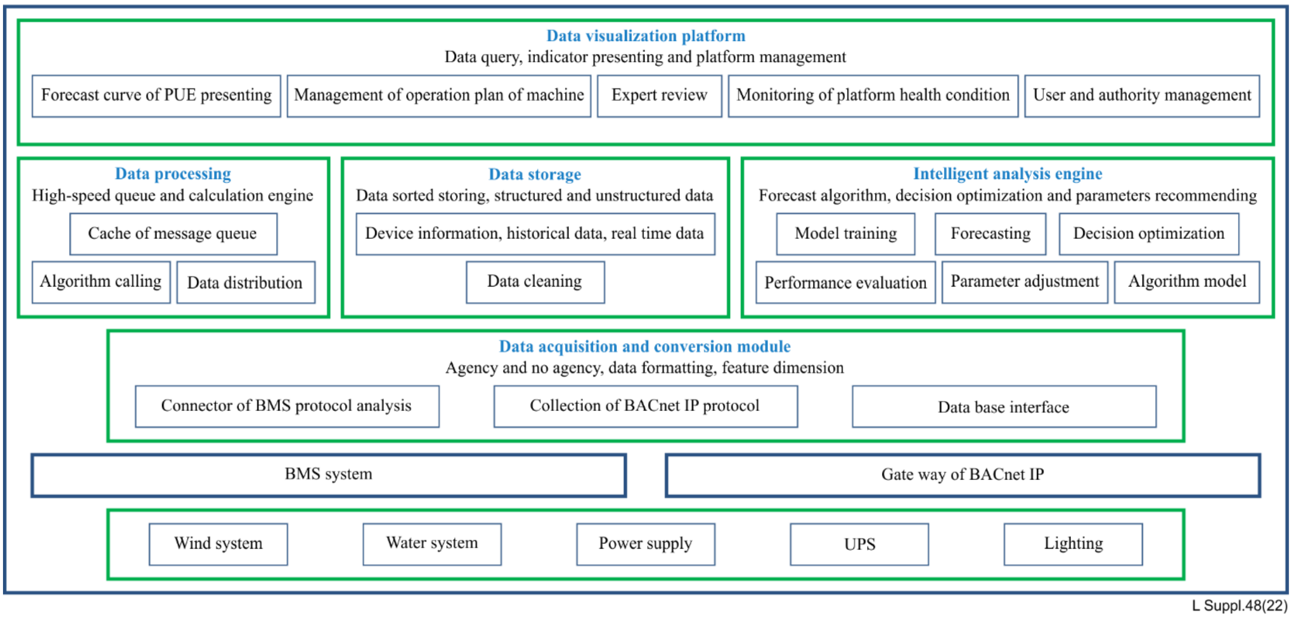

Figure 5 – Functions of the data acquisition module

7.3 Air conditioning system energy saving controlled by AI

For a chilled water or direct expansion air conditioning system, the energy consuming component in the air conditioner in DC infrastructure is the air conditioning unit (ACU) fans, so the energy saving is mainly reflected in the energy consumption of the fan.

The reduction of the fan speed can effectively reduce the energy consumption of the fan. Fan laws have proved this statement in theory.

According to the fan laws, when the rotating speed of the same fan (with the same fan diameter and the same air density) changes, the ratio of the fan shaft power before and after the speed change is directly proportional to the third power of the fan speed. For example, if the fan speed is reduced to 90%, the input power will be reduced to 72.9%.

The minimum air conditioning fan speed can be realized by an AI algorithm, that is, using on-site and real-time monitoring data, with AI technology such as supervised learning or reinforcement learning, etc., the accurate evaluation of the minimum terminal fan speed that meets the inlet temperature requirements of IT equipment will be achieved.

Reducing the fan speed is mainly applicable to the following two scenarios:

1) Reducing the fan speed without adjusting the control temperature.

In this scenario, the air conditioner output air volume exceeds the required air volume of the IT equipment, therefore, reducing the speed can reduce the excess air volume output and obtain the optimal fan output when the air supply volume is close to the required air volume of the IT equipment.

2) Adjust the control temperature to reduce the fan speed.

Under the condition of achieving a balance between air supply and air demand, the fan speed can be further reduced by increasing the control temperature. To increase the air conditioner control temperature, the DC room needs to meet the following two conditions.

First, that the airflow distribution and cooling configuration in the DC room are reasonable, and the maximum airflow inlet temperature of the current IT equipment is within the allowable range required by ASHRAE, so as to provide safety guarantee for improving the control temperature.

Second, that numerical simulation technology has been used to calculate the digital twin model, predict and improve the reasonable value of control temperature in advance and reduce the potential safety hazards of IT equipment.

There are two benefits of increasing the control temperature:

1) After increasing the control temperature of the ACU, the energy efficiency of the unit can be effectively improved, and energy saving can be realized.
2) Improving the air distribution system in the room will improve the ACU supply efficiency, and can then further reduce the fan speed and achieve the purpose of energy saving.

Finally, the fan speed value should be sent down to the on-site environmental control system. The trained model will automatically adjust the fan control value according to the load change of IT equipment and keep the fan running with minimum energy consumption.

7.4 Chilled water system energy saving controlled by AI

AI energy efficiency adjustment, that is, using AI technology to connect the data between the IT load to the refrigeration system and the whole external environment, to collect, manage, train and reason based on a large amount of historical operation and maintenance data, and to obtain the PUE prediction model.

Realizing the energy saving in a chilled water system with AI requires the cooperation of software and hardware. For example, the chiller, water pump, valve, terminal and other components have AI accessible interfaces, and AI and equipment data are exchanged and shared. The specific implementation can be divided into four steps as shown in Figure 6.

1) **The data acquisition**: through the moving ring management system, collects the freezing station (including outdoor working conditions, freezing station operating state, etc.), terminal air conditioning (including cold and hot aisle temperature, terminal operating state, etc.), IT load (including IT load change, historical PUE, etc.) and other system operating parameters.

2) **Data governance**: the original data collected into the data lake on the cloud, desensitization, merging, noise reduction, cleaning, correlation analysis feature engineering and other governance, to provide high-quality data for subsequent model training.

3) **Model training**: using managed high-quality data, a training depth neural network (DNN), an output high-precision PUE prediction model and a business prediction model (for SLA business operation guarantee). The PUE model will be updated in real time according to the optimization situation in the early stage of operation, and continuously optimized during stable operation.

4) **Reasoning execution**: the trained PUE prediction model is distributed to the reasoning platform. The online reasoning is completed by using relevant algorithms with the current outdoor environment and business forecast model under the IT load as constraints. The lowest adjustable parameter combination of PUE is obtained. Finally, the group of parameters is issued to the group control system for execution. When the outdoor wet bulb temperature and its load change, the next round of reasoning and optimization will be triggered automatically, and the adjustment cycle can also be set manually according to the business requirements.

In the initial operation of AI tuning, the inference parameters are confirmed by experts and then issued to ensure business security. After a month of manual judgement, the instruction parameters can be automatically issued. Finally, through standardized practice guidance, continuous optimization and regular measurement, the best PUE can be obtained.

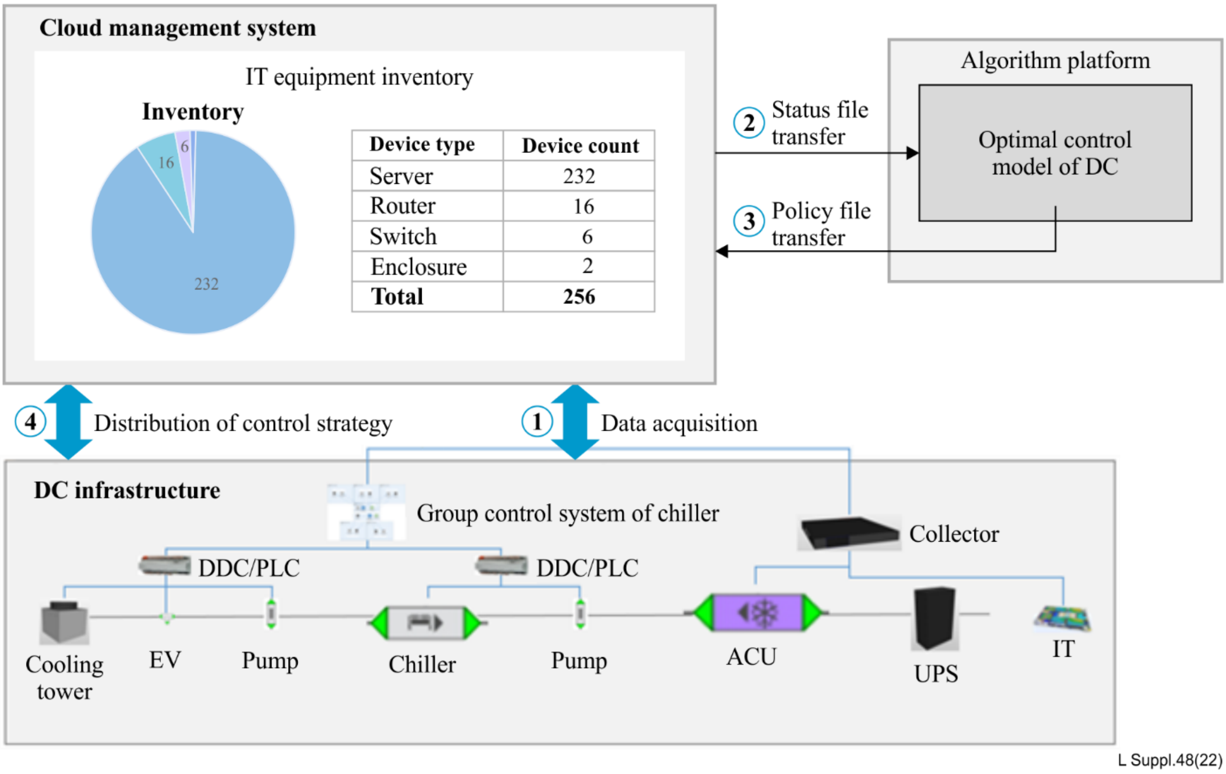

Figure 6 – Implementation steps of AI energy efficiency tuning

AI energy efficiency tuning has the following value characteristics:

1) Energy saving and high efficiency, overall regulation of refrigeration system, and system level energy efficiency optimization.

2) The operation is safe. The data reading and command parameter distribution are executed through the group control system without directly controlling the refrigeration equipment. When the AI optimization function is disabled, the BMS system will automatically return to the state before optimization; The AI reasoning process follows the operation and maintenance specifications, meets the parameter range constraints of the refrigeration system, and the reasoning results meet the SLA requirements. It can be confirmed by experts before issuance and implementation, so as to enhance the system security.

8 Future prospects

8.1 Risks for AI application

Data security risks: The general AI model and data which are stored in public cloud may be at risk of being stolen and the operation of the data centre may face unknown security risks. Moreover, the ability of technical personnel will be not enough to handle the increasing data in the future. The AI model will have the ability to control and optimize the operation parameters of the cooling system automatically with the continuous improvement of the AI decision-making level. As a result, the engineers will have fewer opportunities to participate in the operation and that also means fewer human errors will exist. Moreover, an intelligent firewall controlled by AI will increase the safety level of the public cloud and control system significantly.

Coupling conflict: The operation system of the data centre contains multiple control subsystems, and every subsystem has an independent control model. This operation system will become more and more complex in the future. If these subsystems work independently, there may be conflicts between them. The AI system will give an excellent coordinate controlling for this huge and integrated system.

8.2 Prospects for AI application

At present, although the energy consumption of the optimized data centre has been reduced by 10% via the AI cooling system manufactured by some vendors, obtaining the optimized energy consumption model requires a lot of data and training time, and the feedback speed has not been fast enough until now. The improvement of the AI model algorithm is expected in the future and is not limited to data-driven machine learning, but also integrated with a physical model algorithm, optimization calculation and experience accumulation.

AI energy saving can greatly reduce the energy consumption of a data centre that contains IT equipment and cooling systems. The energy consumption models of IT equipment and data centre infrastructures will be used to form a more complex AI model. The AI model can make multiple optimization and control objectives for the data centre, such as data capacity, energy efficiency, safety and other indicators. The AI model will balance these objectives and provide a best solution control plan.

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