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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 infrastructure management system based on big data and artificial intelligence technology

Recommendation ITU-T L.1305

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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Recommendation ITU-T L.1305

Data centre infrastructure management system based on big data and artificial intelligence technology

Summary

Recommendation ITU-T L.1305 contains technical specifications of a data centre infrastructure management (DCIM) system, with the following aspects being covered: principles, management objects, management system schemes, data collection function requirements, operational function requirements, energy saving management, capacity management for information and communication technology (ICT) and facilities, other operational function requirements and intelligent controlling on systems to maximize green energy use.

Other aspects such as maintenance function requirements, early alarm and protection based on big data analysis and intelligent controlling on systems to decrease the cost for maintenance are also considered.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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Keywords

Artificial intelligence (AI) technology, big data, DCIM, functional requirements.

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Introduction

Full-stack cloud technology is becoming increasingly popular among industry users in this the second decade of cloud computing technology. Full stack cloud platforms bring converged solutions for enterprise digital transformation across numerous areas, including microprocessors, hardware and software to help customers achieve a more comprehensive, flexible and long-term evolution cloud platform to help them achieve their business goals. Full-stack cloud platforms, in the era of the large-scale application of high-density servers, all-flash storage and fabric networks with sharply increased power density, imposes higher requirements on infrastructure reliability as described in [b-ITU-T Y.3500]. For example, infrastructure faults must be quickly identified, isolated and self-healed to prevent impacts on Internet technology (IT) service. In addition, with the migration and adjustment of IT loads on the cloud platform, power fluctuations will become the norm and precise and dynamic cooling technology will become the direction of development. Therefore, in the era of full-stack cloud platforms, data centre infrastructure and IT systems need to be converged and collaborate to break the boundaries of existing data centres. Building a full-stack cloud data centre must include resource convergence, data intelligence and service innovation to ensure high availability and energy saving of IT services.

An intelligent management system performs deep machine learning based on data centres of different types and the working conditions of different devices. It identifies optimal policies and helps data centres run more efficiently. For example, using massive data analysis techniques, conducting in-depth analyses of each component (and of key components) of the power supply and distribution system of the data centre, proactive detection and early warning of traditional passive faults can be handled by proactive risk prevention where faulty components are isolated and the fault impact scope is automatically reported to the IT system. In addition, out-of-warranty component reminders can be sent to procurement personnel in advance in order to reduce the risks of alarms and major accidents and prevent to IT services from being affected. As another example, an artificial intelligence (AI) algorithm, such as a deep neural network, can be used to implement automatic control and optimization of a data centre temperature control system in combination with real-time analysis and prediction of power consumption requirements of an IT service so as to implement optimal working conditions of the heat load of the IT equipment, the cooling output of the temperature control indoor unit and all links of the outdoor cooling station, greatly reducing the power consumption of the data centre.

In reviewing the development history of the past few years, it was found that data centre infrastructure management (DCIM) systems often encountered delivery difficulties. Rollout times were pushed forward and application delivery was difficult to achieve. Primarily this was because the integration and deployment of DCIMs are complex, typically involving the interconnection and commissioning of a large number of devices and systems. System deployment periods usually span several months or even a year, and system deployment risks are difficult to control. In addition, while the intention of DCIMs is to reduce risks, improve efficiency, improve capacity prediction and enhance service agility, they are often limited by the data integrity and availability at the bottom layer. Thus it is difficult to build a complete business flow in actual projects that can help users achieve their business goals.

Recommendation ITU-T L.1305

Data centre infrastructure management system based on big data and artificial intelligence technology

1 Scope

This Recommendation describes specifications of a data centre infrastructure management (DCIM) system based on big data and artificial intelligence (AI) technology. The system will manage all infrastructure in the data centre at the same time through a comprehensive platform.

The scope of this Recommendation includes:

– network infrastructure of management systems;
– standardization of data collection of the installed module;
– interconnection among various kinds of monitoring sub-systems;
– requirements for different functions in a DCIM.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

None.

3 Definitions

3.1 Terms defined elsewhere

None.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 data centre infrastructure management (DCIM): A data centre infrastructure management (DCIM) system that provides real-time monitoring of all data centre infrastructure that support correctly operating information and communication technology (ICT) devices. The purpose of a DCIM is to manage all types of infrastructure, including uninterruptible power supply (UPS), air conditioning, power distribution unit (PDU), etc., simultaneously, within a unified platform. The operation efficiency of the data centre would be maximized and the stability would be promoted through analysing and classifying the relevant data.

3.2.2 full-stack cloud: A solution that implements all possible cloud levels.

NOTE – Based on Annex A of [b-ITU-T Y.3500].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI Artificial Intelligence

app Application

BMS Building Management System

B/S Browser/Server

COP Coefficient of Performance

DCIM Data Centre Infrastructure Management

DDC Data Device Controller

DNN Deep Neural Network

ICT Information Communication Technology

IDC Integrated Data Centre

IoT Internet of Things

IMEI International Mobile Equipment Identity

IT Internet Technology

KPI Key Performance Indicator

NFC Near Field Communication

NMS Network Management System

O&M Operation and Maintenance

OPC Open Protocol Communication

PAD Packet Assembler/Disassembler

PaaS Platform as a Service

PDU Power Distribution Unit

PLC Programmable Logic Controller

PMS Power Management System

PUE Power Usage Effectiveness

QR Quick Response

RoI Return on Investment

SPCN System Power Control Network

SaaS Software as a Service

UPS Uninterruptible Power Supply

5 Conventions

None.

6 Structure of DCIM system

The data centre infrastructure management (DCIM) system collects relevant data such that basic collection and transmission devices can be comprehensively used to access the uniform monitoring DCIM platform to interconnect different types of monitored items. A possible structure for a DCIM system is shown in the Figure 1. This figure illustrates an example of structure, however, not all subsystems need to be present but may be merged into larger subsystems.

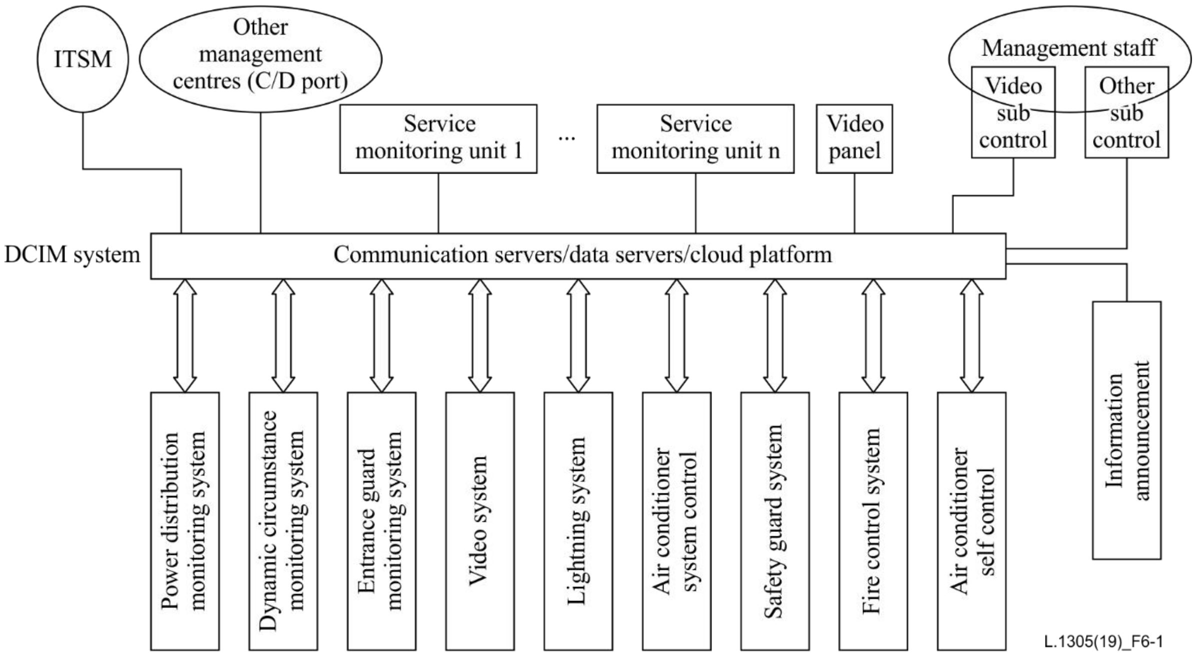

Figure 1 – Example structure of a DCIM system

When some subsystems are required to be designed, it is better to use a system-access mode where various port protocols are allowed in order to connect different subsystems to the whole DCIM. Examples of different types of port protocols include open protocol communication (OPC), building automation and control network (BACnet), etc. It is common to construct subsystems in most integrated data centre (IDC) rooms. An alternative management system structure is shown in Figure 2; this figure illustrates an example in which some subsystems are not connected directly to servers but rather, a site data collecting system is present. This configuration has the functionality to convert different protocols used by the server, perform some operations and control some infrastructure equipment.

Some of the subsystems included in both figures are:

– Information announcement: corresponding to all systems dedicated to distribute information inside the data centre, such as display, acoustic announcement, etc.;

– Air conditioner self-control: the part of DCIM dedicated to automatically control the cooling infrastructure inside the data centre, automatically regulating the functionality status to obtain the temperature and humidity necessary for the correct operation of the data centre;

– Fire control system: controls the fire detection inside the data centre and manages the fire extinguishing solutions;

– Safety guard system: controls all parts linked to data centre security;

– Air conditioner system control: controls the setting of temperature inside all data centre buildings;

– Lightning system: controls the lighting inside the data centre;

– Video system: manages all video surveillance systems inside and outside the data centre;

– Entrance guard monitoring system: dedicated to access control all or part of the data centre;

– Power distribution monitoring system: controls all infrastructure used to provide electrical energy at the data centre.

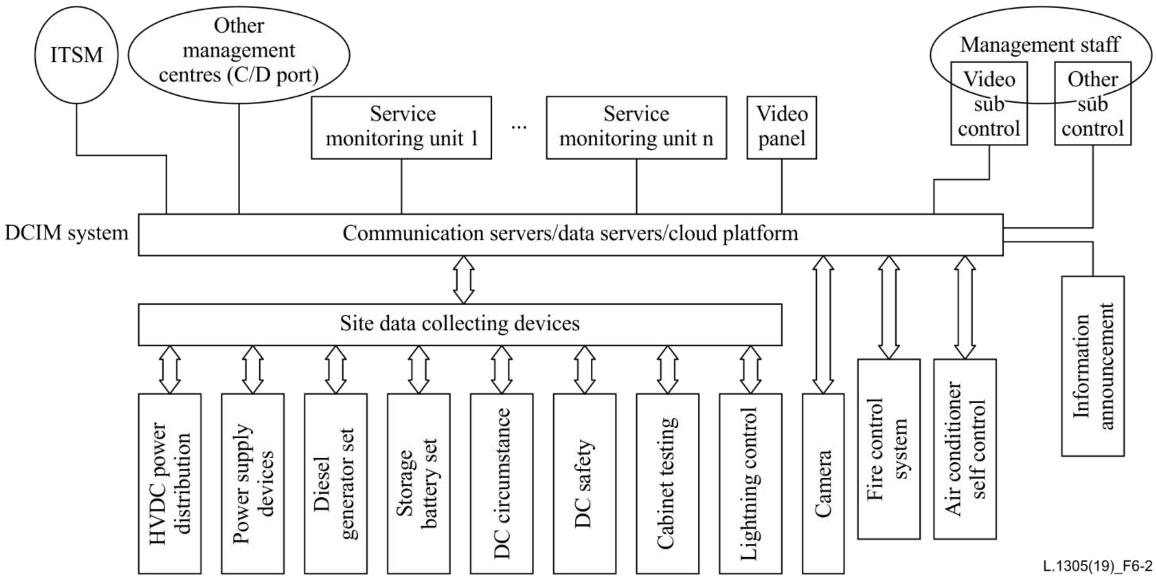

Figure 2 – Example structure of a DCIM system with subsystems

7 Monitoring parts of a DCIM system

The establishment of a DCIM system has the following effects on the operating subsystems of the data centre:

– provides sustainable optimization of the power supply, cooling part and physical area usage;

– achieves higher power efficiency and better management processes;

– establishes and optimizes the modules of the data centre to provide good strategies for obtaining higher energy efficiency;

– strengthens the ability for resource and asset management through revealing the connecting relationship between resources and assets.

Therefore, based on the management interface of the DCIM system, the five aspects to be monitored of a DCIM system are as follows:

1) Power supply devices: includes high-voltage power distribution parts, low-voltage power distribution parts, voltage transformers, stand-by power supply systems, power transformers and other kinds of electric devices for an IT cabinet. The DCIM system is used to monitor operating conditions and power consumption;

2) Air conditioning devices: includes various unit-type air conditioners, such as cooling towers of central air conditioners, cool-water machine sets and terminal machine sets of indoor air conditioners;

3) Data centre environment: parameters such as the temperature, relative humidity, air flow, and hot spots (if present) are monitored by the DCIM system as environmental aspects. Moreover, the monitoring area not only covers the room, but also equipment cabinets and the module data centre area. It also includes monitoring video and surveillance systems;

4) Lightning system: there are different types of lightning protections based on the management requirements of the data centre. As a prerequisite of lightning for

management, the working mode should be adjusted automatically to reduce the power consumption and working load;

5) Fire control system: information on the fire control system and status of the fire control system should be transferred to the DCIM system so that there will be in-time protection through the system.

8 Cloud pre-integration and standardization

Pre-integration and standardization is the preferred solution for DCIM to simplify the system deployment process and reduce delivery risks.

8.1 Cloud pre-integration

DCIM preconfigures device information of mainstream vendors in the industry and implements plug-and-play for devices through pre-integration and pre-verification, greatly shortening the project delivery period and reducing system deployment risks. In addition, pre-integration and pre-testing are implemented with IT application systems to greatly reduce onsite integration and commissioning, provide customers with a set of overall solutions, support quick service rollout and deployment and achieve business benefits as soon as possible.

8.2 Constructing an all-digital data centre model based on actual service requirements

Based on the summary of data centre operation and maintenance (O&M) practices, a complete and effective data centre digital model is developed from the O&M service layer to clearly define the content, precision and collection frequency of each device indicator to provide comprehensive data support for upper-layer service applications. In addition, Internet of things (IoT) and AI technologies help customers eliminate digital blind spots of data centres by identifying u-bits and wireless networking of devices and sensors.

In addition, IoT and AI technologies are used together with IT intelligent shelving algorithms, accurate system power control network (SPCN) resource matching, and three dimensional (3D) visualized display, that improves data centre resource utilization and maximizes return on investment (ROI).

Based on the full-stack cloud platform architecture, the intelligent management system introduces big data, AI and IoT technologies. Using real-time and historical data analysis and mining of data centres, the intelligent management system helps customers better predict device faults or solve capacity insufficiency problems, continuously improve the energy efficiency of data centres and help customers reduce expenditure on open source application.

9 Full-stack digital maintenance

For data centre maintenance, the DCIM system should provide maintenance support modules, which include the following functions:

– availability management, effectively managing data centre maintenance activities such as inspection and maintenance, ensuring reliable operation of the data centre;
– maintenance process, providing maintenance processes and work orders related to data centres;
– shift management, managing maintenance personnel and on-duty information, and supporting maintenance activities;
– maintenance knowledge library, providing knowledge management, ensuring the normalization and inheritance of maintenance experience;
– mobile access, improving data centre maintenance efficiency through mobility.

Figure 3 shows the architecture of the maintenance process.

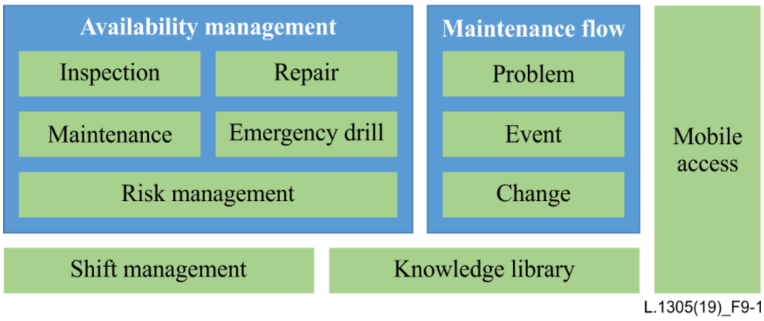

Figure 3 – DCIM maintenance support modules

9.1 Availability management

The DCIM system must support the data centre inspection function to help users perform routine inspections on the data centre with the assistance of mobile applications (apps). This improves the inspection efficiency and quality. The requirements are as follows:

– maintenance personnel can create inspection plans and define device, content, period, and persons responsible for data centre inspection based on enterprise maintenance standards;

– automatically generates and dispatches inspection tasks to specified persons responsible for maintenance based on inspection plans and pushes these tasks to mobile phones. The person responsible for inspection can view and process inspection tasks on mobile terminals such as mobile phones. If a preventive maintenance inspection task is not processed within the specified time, the person responsible for preventive maintenance inspection must be notified in a timely manner;

– to ensure that the inspection personnel arrive at the inspection site on time, the system supports signing through near field communication (NFC) tags and quick response (QR) code scanning. In addition, the digital signature function can be used to prevent illegal shifts;

– the system should provide inspection templates and inspection items with detailed inspection contents for routine inspection. The system should provide at least 10 types of common templates, including uninterruptible power supply (UPS), air conditioner, transformer, power distribution cabinet, floor and data centre and provide at least 500 inspection items.

In addition to the data centre inspection, the DCIM system also supports maintenance activities, such as repair, maintenance, and emergency drills. The DCIM system manages maintenance activities in all aspects. The main functions are as follows:

– support the repair and maintenance of infrastructure equipment in the data centre, including the UPS, generator set, power distribution cabinet, air conditioner, chillers, etc.;

– create and trace device maintenance work orders and maintenance tasks and manage tasks in a closed-loop manner by dispatching, approving, and confirming work orders. In addition, maintenance personnel can view and process tasks on mobile terminals such as mobile phones;

– automatically save the repair and maintenance records of the equipment. Data cannot be modified and can be used as a reference for evaluating the equipment status;

– allow maintenance personnel to create emergency drill plans, develop and upload emergency drill plans, and submit them for approval. In addition, support the tracing and handling of emergency drills, and collect statistics on the completion of emergency drills;

– at least four types of emergency drill solution templates are required, such as fire emergency drills in data centres, water leakage drills in data centres, emergency drills for air conditioning system faults, and emergency drills for power supply and distribution system faults.

To ensure the reliability of the data centre and manage potential risks during maintenance, the risks must be tracked and handled by the risk management process. The requirements for risk management are as follows:

– support quick creation of risk work-orders based on maintenance activities, such as inspection, repair, and maintenance and perform closed-loop management based on the approval, dispatch, and confirmation of work orders to ensure a timely resolution. In addition, provide for sending emails or short messages to notify related responsible persons to handle risks;
– collect statistics on and analyse risk work-orders, learn the number of total and closed risks, so that O&M personnel can evaluate the current risks of the data centre;
– after a risk work order is created it cannot be deleted randomly. If closing the application is necessary, approval must be obtained from upper-level management personnel before closing the archive.

9.2 Maintenance process management

The DCIM system must provide maintenance process management, including problem management, events management and change management processes covering the data centre infrastructure maintenance process.

– problem management: This is the main exit of fault management and comprises events that cannot be solved in fault management, repeated events, or typical or large events. Generally, the person responsible for fault management initiates a task in the problem management project and submits the problem to the problem management process for handling;
– change management: Implement the implementation of requirement orders and system change orders, including the formulation of change solutions and progress plans, approval of changes, preparation of change implementation, formulation and approval of implementation solutions, and verification tests. Engineering and maintenance changes can be deployed in the actual production environment through release management;
– event management: An event that causes or may cause infrastructure service interruption or service quality deterioration, which does not comply with standard operation activities, and quickly recovers the service capability management process.

The maintenance process must meet the following requirements:

– support the creation, approval, execution and closure of work orders for problems, changes and events, and allow users to add or delete process nodes. For example, add or reduce work order approvals to accurately match the maintenance process of the data centre of the project;
– collects statistics on and analyses the execution of problems, changes, and event work orders, and collects statistics on the number of closed work orders and the number of abnormal work orders to improve work order processing efficiency;
– users can view and handle problem work orders on mobile terminals, such as mobile phones;
– remote notification of problems, changes and event work orders must be supported. Persons responsible for work order handling can be notified by email.

In addition, the DCIM system should allow users to customize processes. Users should be able to create new service processes or modify existing processes to meet business development requirements.

9.3 Shift management

To manage the on-duty process of O&M personnel, ensure that all O&M activities are performed by personnel, standardize the handover shift, reduce equipment room O&M risks, and improve equipment room availability, the DCIM system should support shift management. This function must meet the following requirements:

– manage information about maintenance personnel, including personal information, position information and group and contact information, and support common operations such as adding, modifying and deleting records;
– when an employee exits, their information can be saved in the historical information database for easy query;
– maintenance personnel, responsibilities and shifts can be defined, and operations such as maintenance personnel, shift, overtime and leave management can be performed;
– records of shifts between maintenance groups are supported for future audits and backtracking. The handover process can be closed only after the recipient confirms it;
– all maintenance work orders dispatched by the system can be automatically matched to maintenance groups and personnel based on duty information.

9.4 Maintenance knowledge library

The DCIM system must provide a maintenance knowledge library for maintenance personnel to summarize and effectively transfer daily maintenance knowledge. The requirements for the maintenance knowledge library are as follows:

– data centre infrastructure, such as power supplies and distribution systems, cooling systems, and fire extinguishing systems must be covered. Knowledge documents, such as construction solutions, technical solutions, events, problems, faults and complaint solutions may be included;
– users can create maintenance knowledge and upload device operation guides and typical trouble-shooting cases to the knowledge library;
– supervisors can approve the maintenance knowledge created by users and release the knowledge to the knowledge library to control the pace and quality of knowledge release;
– users can view, share, comment on and revise maintenance knowledge, quickly search for key words, and select high-value and common maintenance knowledge based on the ranking mechanism.

9.5 Mobile access

The DCIM system should provide mobile maintenance auxiliary software, which can be installed on mobile terminals such as mobile phones and packet assembler/disassemblers (PADs) to improve routine maintenance efficiency. The maintenance auxiliary software must support the following functions:

– view and operate current maintenance tasks, including data centre inspection and equipment maintenance;
– view and handle data centre maintenance processes, including problem and risk management work orders;

– enable maintenance personnel to sign in onsite by means of NFC communication and QR code scanning, ensuring that maintenance personnel can arrive at the data centre to perform maintenance;

– key performance indicator (KPI) information about the data centre, such as power usage effectiveness (PUE), power consumption and number of current alarms can be viewed to quickly learn about the running status of the data centre.

In addition, to ensure system security, mobile app access control must be provided. The international mobile station equipment identity (IMEI) codes of mobile apps can be bound to prevent unauthorized users from accessing the system.

10 Intelligence strategy based on big data and AI technology

Using smart analyses, the DCIM system can make a data centre more stable and energy efficient for long-term operations. All resources can be adequately used to enhance the usage efficiency.

The detailed strategies are as follows:

– **provide passive responses to be active predictions**. Aiming to address parallel and massive warning information, the DCIM system AI technology should provide mechanisms for key warning information recognition. For example, numerous warning messages may occur in the condition when the grid is off, including grid disconnecting alarms, UPS input low-voltage alarms, PDU low-voltage alarms, etc. If the DCIM system AI technology can determine where the original alarm was produced, it could assist maintenance staff in solving the key problem in a timely manner and reduce the probability of safety problems;

– **automate management of infrastructure resources**. A DCIM system with AI technology can help maintenance staff automatically record the location and manage information and changes of all devices. Whatever the condition that has changed, the relevant information should be updated in real-time in the system to avoid any human-induced mistakes;

– **use AI technology to decrease the system cost and increase efficiency**. The DCIM system can adjust the cooling volume and power capacity according to the ICT devices. The cooling system and power system is dynamically controlled to increase the efficiency of the entire data centre.

11 AI working principles for data centre energy efficiency optimization

11.1 Principles of the AI service in the cooling system

The PUE of a data centre is a comprehensive evaluation indicator. Due to the complex association between cooling and device heat dissipation, device configuration, equipment room environment and atmospheric conditions, after the O&M system reaches a certain maturity level, manpower or expertise alone cannot meet the requirements for further reducing energy consumption. For example, a small increase in the temperature of the cold aisle may cause many changes in the cooling system, and the power consumption of the cooling system, cooling tower, heat exchanger and water pump will increase or decrease, and the power consumption will not be linear. The result may be that the temperature of the cold aisle increases and the total power consumption increases. The interaction between refrigeration and electrical systems and various complex feedback loops makes it difficult to accurately derive the efficiency of data centres by using traditional engineering formulas.

To further optimize the working status and reduce energy consumption of the equipment, the system formed by the equipment is optimized. At the service layer, the following three problems need to be considered:

1) ensure that each component of the cooling system runs in an efficient range according to the natural curve of the equipment;

2) according to the principle of equal marginal efficiency, the optimum combination of components in the refrigeration system is worked out. For example, what is the working condition of the cooling tower and cooling pump when a 1000 KW cooling capacity is also output? Which combination is most energy-efficient? In a certain state, can a power reduction 1kw be applied to other devices, while increasing the total cooling capacity of the system?

3) the IT load is associated with the cooling system to balance the heating and cooling capacity.

11.2 Principle of the AI algorithm of the cooling system

11.2.1 AI principles

A new control algorithm is established for overall optimal cooling working conditions. It is necessary to use historical data to train the neural network, output the predicted PUE and the relationship between the PUE and various feature data, and guide the DCIM to perform corresponding optimization control according to the current weather and load conditions, so as to achieve the energy saving target.

Big data-based analysis has the following steps:

– data collection: Collect operating parameters of the cooling station, end air conditioner and IT load system;

– data governance: The automatic management tool is used to reduce and clean parameters;

– feature engineering: Use mathematical tools to analyse the correlation between the completed tables and find the key parameters related to the PUE, including control factors, environment factors and process factors;

– model training: Use the deep neural network (DNN) algorithm to train the PUE model (the prediction precision must be greater than or equal to 99.5% and the error does not exceed 0.005);

– reasoning and decision-making: The forecast and decision model are released to the centralized control system to provide a decision model that can be optimized online.

11.2.2 Deep neural network

A machine learning algorithm should be used to find the relationship between different devices and parameters of different systems. A mathematical model should be established by using a large sensor dataset to understand the relationship between operation parameters to find the optimal parameters.

A neural network has an input layer, an output layer and multiple hidden layers. An input characteristic vector is transformed to an output layer by means of implicit layer transformation, and a classification result is obtained at an output layer. Multilayer perceptron can remove the constraints of early discrete transmission functions. Use continuous functions such as sigmoid or tanh to simulate the response of neurons to excitation. Use a reverse propagation or backpropagation (BP) algorithm for training.

Considering the complexity of the data centre cooling system, the DCIM system data should be obtained for the electrical system, cooling system and environment parameters to find the system feature values and use the feature values to organize the DNN network.

11.2.3 AI algorithm framework

The AI algorithm framework includes data acquisition, model and basic algorithms, algorithm frameworks, management components, intelligent services and application integration:

– data acquisition includes data collection, data processing, and data storage;

– model and basic algorithms: This mainly resolves the sampling and cleaning of big data, obtains the optimal operator, and supports the quick solution of the model;

– the algorithm framework selects the machine learning algorithm based on the logical association, performs pattern matching and finds the applicability of the algorithm;

– the management component manages the life cycle of a model based on the model evolution, such as releasing a new model and rolling back the model and supports the evolution of models after learning;

– the intelligent service is used to preset the reasoning model, recommend and predict the model and make decisions on adjustable parameters. In the actual running process, the parameter group that can be adjusted and can be obtained through the decision system;

– the application integration service is used to visualize AI services, adapt scenarios of different cooling systems and visualize data process analysis and control effects.

11.2.4 AI deployment and running framework

AI provides training and reasoning platforms. The cloud deployment mode can be used. The inference platform (bearer model) can be deployed independently from the management system to the physical machine, cloud, or the management system. The training platform is deployed independently.

11.2.5 AI service node requirements

The recommended service deployment scheme is as follows:

– deploy AI services based on platform as a service (PaaS) and software as a service (SaaS);

– PaaS: stores, cleans, and calculates big data;

– SaaS: the training platform is mainly used to fit the prediction model and the service model;

– SaaS: the reasoning platform completes the optimization of control parameters.

11.2.6 AI parameter requirements

In a data centre, there are many systems related to energy efficiency. When focusing on the cooling system, the big data generated by the building management system (BMS), power management system (PMS) and control system needs to be summarized and used for big data mining. By acquiring data and studying data by machine learning, a model is established to predict and improve the energy efficiency of the data centre.

Table 1 gives an example of the feature parameters to be collected by the AI cooling control. The recommended collection period is five minutes.

Table 1 – Parameter necessary for AI cooling functionality

Data collection requirements	Unit	Value	Parameter range	Precision
Start		1	0∽1	
Suspension		0		
Common teamwork mode		0	0∽1	

Table 1 – Parameter necessary for AI cooling functionality

Data collection requirements	Unit	Value	Parameter range	Precision
Energy-saving teamwork mode		1		
Compressed cooling mode		0	0∽2	
Online charging / cooling mode		0	0∽2	
Cold storage bypass mode		1	0∽2	
Reverse charging mode		2	0∽2	
Outdoor dry bulb temperature 1~N	°C		~50∽70	0.1
Outdoor relative humidity 1~N	%		0∽100	0.1
Outdoor wet bulb temperature 1~N	°C		~50∽70	0.1
Real-time cooling capacity of the cooling station	kW		0∽20000	1
Real-time power of the cooling station	kW		0∽3500	0.1
Real-time energy efficiency coefficient of performance (COP)			0∽100	0.1
Real-time system load rate of the cooling station	%		0∽100	0.1
Chilled water supply temperature setting for the chilled water station	°C		0∽70	0.1
Chilled water real-time water supply temperature of the chilled water station	°C		0∽70	0.1
Chilled water real-time return water temperature of the chilled water station	°C		0∽70	0.1
Chilled water temperature in real time	°C		0∽70	0.1
Real-time chilled water return temperature of the chilled water station	°C		0∽70	0.1
Minimum pressure difference between chilled water supply and return	kPa		0∽1000	1
Maximum pressure difference between chilled water supply and return	kPa		0∽1000	1
Chilled water real-time supply and return pressure difference 1-2	kPa		0∽1000	1
Chilled water real-time return water flow of the chilled water station 1-2	m/h		0∽1000	1
Chilled water real-time bypass water flow 1-2	m/h		0∽10000	1
Outdoor wet ball temperature setting point in compressed cooling mode	°C		0∽70	0.1
Real-time water supply temperature on the chilled side of the chiller 1~N	°C		0∽70	0.1
Real-time return water temperature on the chilled side of the chiller 1~N	°C		0∽70	0.1

Table 1 – Parameter necessary for AI cooling functionality

Data collection requirements	Unit	Value	Parameter range	Precision
Real-time water supply flow on the chilled side of the chiller 1~N	m/h		0∽15000	1
Number of running refrigerators	Platform		0∽4	1
Number of remaining available refrigerators	Platform		0∽4	1
Maximum number of cold air conditioners	Platform		0∽4	1
Minimum number of cold air conditioners	Platform		0∽4	0.1
Total current operating power of the chiller	kW		0∽2500	0.1
Current operating power of the chiller 1~N	kW		0∽800	0.1
Current load of the cooling machine 1~N	%		0∽100	0.1
Cooling capacity load of the cooling system 1~N	%		0∽100	0.1
Cooling capacity load point of the chiller	%		0∽100	0.1
Cooling capacity load point of the cooling machine	%		0∽100	0.1
Minimum cooling capacity load of the cooling machine	%		0∽100	0.1
Maximum cooling capacity of the cooling unit	%		0∽100	0.1
Cooling system operating frequency 1~N	Hz		0∽100	0.1
Condenser pressure of the chiller 1~N	kPa		0∽10000	1
Refrigerant evaporator pressure 1~N	kPa		0∽10000	1
Cooling system running status 1~N				
Maximum operating current load of the chiller	%		0∽100	0.1
Number of cooling pumps that have been running	Platform		0∽4	1
Number of remaining cooling pumps for available refrigerators	Platform		0∽4	1
Maximum number of cooling pumps for cooling	Platform		0∽4	1
Minimum running quantity of cooling pump	Platform		0∽4	1
Total current operating power of the cooling pump	kW		0∽500	0.1
Current operating power of the cooling pump 1~N	kW		0∽150	0.1
Current operating frequency of the cooling pump 1~N	Hz		0∽50	0.1
Chiller cooling pump frequency point	Hz		0∽100	0.1

Table 1 – Parameter necessary for AI cooling functionality

Data collection requirements	Unit	Value	Parameter range	Precision
Cooling pump reduction frequency point of cooling pump	Hz		0∽100	0.1
Minimum operating frequency of cooling pump	Hz		0∽100	0.1
Maximum operating frequency of cooling pump	Hz		0∽100	0.1
Cooling pump running status 1-4				
Pressure difference between the inlet and outlet of the cooling pump 1-4	kPa		0∽1000	1
Number of chilled water pumps that have been run for once	Platform		0∽4	1
Number of remaining chilled water pumps	Platform		0∽4	1
Maximum running quantity of the first chilled water pump	Platform		0∽4	1
Minimum running quantity limit for the first chilled water pump	Platform		0∽4	1
Total current operating power of the first chilled water pump	kW		0∽500	0.1
Current operating power of the first chilled pump 1~N	kW		0∽150	0.1
Current operating frequency of the first chilled pump 1~N	Hz		0∽50	0.1
Frequency point at which the primary refrigerant pump is added	Hz		0∽100	0.1
Frequency point of primary refrigerant pump reduction	Hz		0∽100	0.1
Minimum operating frequency of the primary refrigerant pump	Hz		0∽100	0.1
Maximum operating frequency of the primary refrigerant pump	Hz		0∽100	0.1
Running status of the first chilled pump 1-4				
Inlet and outlet pressure difference of the first chilled pump 1-4	kPa		0∽1000	1
Number of running cooling towers	Platform		0∽4	1
Number of remaining cooling towers	Platform		0∽4	1
Maximum number of cooling towers	Platform		0∽4	1
Minimum number of cooling towers	Platform		0∽4	1
Total operating power of the cooling tower	kW		0∽400	0.1
Current operating power of the cooling tower 1-8	kW		0∽100	0.1

Table 1 – Parameter necessary for AI cooling functionality

Data collection requirements	Unit	Value	Parameter range	Precision
Current operating frequency of the cooling tower 1-8	Hz		0∽50	0.1
Cooling tower adding frequency point	Hz		0∽100	0.1
Cooling tower reduction frequency	Hz		0∽100	0.1
Minimum operating frequency of the cooling tower	Hz		0∽100	0.1
Maximum operating frequency of the cooling tower	Hz		0∽100	0.1
Cooling tower running status 1-4				
Cooling tower fan running status				
Temperature sequence at the same temperature layer of the chilled water tank 1~N	°C		0∽70	1
Outlet temperature of the chilled water tank	°C		0∽70	1
Water inlet and outlet pressure difference of the chilled water tank 1~N	kPa		0∽1000	1
Cooling capacity 1~N	kW			1
Cooling mode				
Number of running cold air conditioners				
Running quantity of the first chilled water pump				
Cooling tower running quantity				
The primary cooling pump operates at the same frequency				
Cooling pump running on the same frequency				
Operating power of the first chilled pump				
Cooling tower operating power				
Cooling pump operating power				
Chilled water supply temperature of the cooling station				

Annex A

Interconnection between the AI cooling and a third-party teamwork control system and AI function process

(This annex forms an integral part of this Recommendation.)

The third-party teamwork control system uses the BACnet or ModBUS-TCP protocol.

Interface requirements:

– interface integration requirements: The third-party teamwork control system supports the browser/server (B/S) architecture. You can access the web interface of the third-party teamwork control system through links on the upper-layer network management system (NMS) DCIM;

– data integration requirements: The third-party teamwork control system uploads the data of the site based on the interface protocol requirements. The data are carried on the energy saving algorithm of the DCIM and can be optimized based on the data. In addition, the energy saving algorithm can analyse and store these data;

– control integration requirements: The energy saving algorithm carried on the NMS DCIM delivers the optimization command to the third-party teamwork control system. The teamwork control system runs related commands and reports the execution status when ensuring that the working condition implemented is safe and stable. If the command threatens the stability of the site, skip this step. In addition, the teamwork control system must be able to switch between the energy saving mode and the normal mode without abnormal shutdown or restart due to switching.

Figure A.1 shows the networking architecture of the data centre.

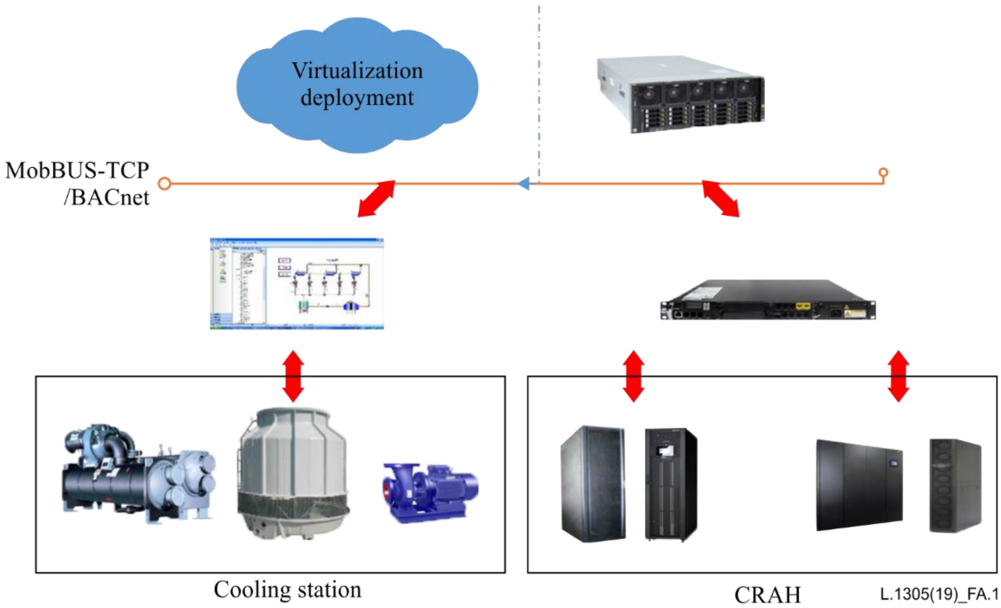

Figure A.1 – Networking architecture of the data centre

The teamwork control system of the data centre is controlled by the programmable logic controller (PLC) controller or data device controller (DDC). The two servers work in active/standby mode. DCIM uses a data centre DCIM system, which uses the BACnet protocol. On the DCIM interface, you can navigate through the address link.

As the centralized management system of the entire data centre, the DCIM manages all links in the cooling system in a centralized manner. To prevent the DCIM from customizing the development page for each project and to shorten the system delivery time, the address link on the DCIM can be used to access the web page of the teamwork control system in B/S mode. Users can use the browser on the DCIM client and can manage the cooling station like a browser on the teamwork server client.

Requirements for the teamwork control system are as follows:

– the group-control-system supports the B/S architecture;
– direct access to the web page of the teamwork control system through the browser of the remote DCIM client to view and operate data;
– the teamwork control system of the chilled water station communicates with the DCIM through the heartbeat signal. The teamwork control system of the chilled site uploads 0-1000 characters to the DCIM every 10 seconds. The DCIM delivers 0-1000 characters to the teamwork control system every 10 seconds. When the teamwork control system receives no change for 10 consecutive times, it automatically exits the energy saving mode, the system runs in common control mode and reports a communication fault. If the received characters are different for 10 consecutive times, the communication fault is automatically rectified and the system works in energy-saving mode again.

The teamwork control system has two working modes:

1) common control mode: The teamwork control system automatically executes all control logic, including device addition and suppression, speed adjustment, cooling mode switching, bypass, and charging and cooling. The DCIM only monitors status information;
2) energy-saving control mode: The teamwork control system receives instructions from the DCIM to complete specified actions, including the number of devices in the command package, rotational speed, power, temperature, and differential pressure. The teamwork control system performs actions based on the instructions delivered by the DCIM, if no control instruction is delivered, teamwork control is still available.

After the teamwork control system is connected, it periodically receives heartbeat signals from the DCIM. Once the DCIM startup instruction is transferred to the energy-saving control mode, the teamwork control system performs actions according to the energy-saving control mode.

In the energy-saving control mode, the original fault detection logic and protection logic of the teamwork control system still exist and are not restricted by the DCIM. In energy-saving mode, the teamwork control system receives the command table from the DCIM.

Requirements for the teamwork control system are as follows:

– The teamwork control system is controlled to work in normal mode. When the switching instruction is transferred to the energy-saving mode, the device addition, deletion, and adjustment under the energy-saving mode are controlled by the DCIM;
– The teamwork control items that do not meet the energy saving control mode are summarized and uploaded to the DCIM system according to the DCIM requirements;
– The teamwork control system switches between two control modes to ensure smooth transition;
– Fault protection logic in energy-saving mode. The teamwork control system still performs the fault protection logic, such as sensor faults and device faults. After detecting faults, the teamwork control system provides alarm signals or updates the number of available devices;

– In energy-saving mode, when the number of devices is optimized, the teamwork control system performs only the quantity change, and other control points control the teamwork control system;
– In energy saving mode, when water temperature optimization is performed, the teamwork control system adjusts the water temperature based on the target water temperature target. When exiting the optimization, the chilled water outlet temperature is automatically restored to the water temperature before optimization;
– In energy saving mode, when power optimization is performed, the teamwork control system ensures that the number of devices remains unchanged, and the devices in the teamwork control system control the power based on the same frequency;

Table A.1 reports the teamwork control working status for different cooling modes.

Table A.1 – **Teamwork control system working status per cooling mode**

Cooling mode	Teamwork control working status
Cooling mode	The teamwork control system is not controlled by the energy saving algorithm control point.
Compressed cooling mode	Control of inlet and outlet water bypass adjustment valve of cooling side main pipe and control of inlet and outlet water bypass regulating valve of chilled side main pipe
Partial natural cold mode	Control of inlet and outlet water bypass adjustment valve of cooling side main pipe and control of inlet and outlet water bypass regulating valve of chilled side main pipe
Fully natural cold mode	Control of inlet and outlet by-pass regulating valve of cooling side and control of inlet and outlet water bypass regulating valve of chilled side main pipe

– In energy saving mode, when the system exits the energy-saving mode abnormally, the teamwork control system of the chilled water station can take over the control of the cooling station in time and control the cooling station according to its own requirements. In addition, the chilled water supply temperature can be automatically switched to the preset value of the chilled water supply temperature before entering the energy saving mode, in addition, the cold storage mode automatically restores to the control mode before entering the energy-saving mode;
– In energy saving mode, when the DCIM delivers the intra-frequency control instruction to the teamwork control system, the same equipment in the teamwork control system of the refrigerating station automatically performs at the same frequency and adjusts the control according to the control target;
– When the intra-frequency control takes effect, the devices of the same type are delivered at the maximum frequency, and then are added and subtracted at the same time based on the control target. Table A.2 contains the control target of some cooling system parts when intra-frequency control takes effect.

Table A.2 – **Controlling condition for some unit intra-frequency control to take effect**

Device name	Cooling tower	Cooling pump	Chilled pump
Intra-frequency backward control target	Cooling water outlet temperature	Cooling side temperature difference	Minimum differential pressure on the chilled side

When the chilled water pump is of the same frequency, the minimum pressure difference between the chilled water supply and return water is used as the target to ensure the minimum flow.

In energy saving mode, the teamwork control system performs the corresponding charging and discharging mode according to the energy-saving algorithm. After the energy-saving mode is exited, the teamwork control system automatically restores the charging and cooling control mode before entering the energy-saving mode.

Appendix I

ETSI control and monitoring standard

(This appendix does not form an integral part of this Recommendation.)

Information on item to be monitored and the information that the monitoring system needs is provided and available in [b-ETSI 202 336x].

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