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Recommendation

ITU-T Q.4069 (09/2022)

SERIES Q: Switching and signalling, and associated measurements and tests

Testing specifications – Testing specifications for IMT-2020 and IoT

Testing requirements and procedures for Internet of things-based green data centres

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Recommendation ITU-T Q.4069

Testing requirements and procedures for Internet of things-based green data centres

Summary

Recommendation ITU-T Q.4069 specifies testing requirements and procedures for green data centres (GDCs) based on the Internet of things (IoT).

The testing requirements include those for: interoperability between platform, systems and IoT devices; functions (e.g., analysis of IoT device status); and self-optimization (e.g., data quality audit). The testing procedures include those for: interoperability; functions; and self-optimization.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T Q.4069	2022-09-29	11	11.1002/1000/15046

Keywords

Artificial intelligence, data centre, energy management, Internet of Things, testing.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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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.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure, e.g., interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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Testing requirements and procedures for Internet of things-based green data centres

1 Scope

This Recommendation describes green data centres (GDCs) based on the Internet of things (IoT), which includes multiple IoT devices, monitoring systems and the energy management platform, to save energy. This Recommendation specifies testing requirements for: interoperability; functions; and self-optimization, as well as the related testing procedures for IoT-based GDCs.

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.

[ITU-T L.1300] Recommendation ITU-T L.1300 (2011), *Best practices for green data centres.*

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 data centre [b-ITU-T Y.4051]: Structure, or group of structures, dedicated to the centralized accommodation, interconnection and operation of information technology and network telecommunications equipment providing data storage, processing and transport services together with all the facilities and infrastructures for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability.

NOTE 1 – A structure can consist of multiple buildings and/or spaces with specific functions to support the primary function.

NOTE 2 – The boundaries of the structure or space considered the data centre, which includes the information and communication technology equipment and supporting environmental controls, can be defined within a larger structure or building.

3.1.2 green data centre [ITU-T L.1300]: A repository for the storage, management, and dissemination of data in which the mechanical, lighting, electrical and computer systems are designed for maximum energy efficiency and minimum environmental impact. The construction and operation of a green data centre includes advanced technologies and strategies.

3.1.3 Internet of things (IoT) [b-ITU-T Y.2060]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

3.1.4 power usage effectiveness (PUE) [b-ISO/IEC 30134-2]: Ratio of the data centre total energy consumption to information technology equipment energy consumption, calculated, measured or assessed across the same period.

3.2 Terms defined in this Recommendation

None.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AI Artificial Intelligence

CPU Central Processing Unit

DC Data Centre

DCM Dynamic Circumstance Monitoring

GDC Green Data Centre

IoT Internet of Things

IT Information Technology

PUE Power Usage Effectiveness

SPM Server Performance Monitoring

5 Conventions

In this Recommendation:

The phrase "is required" indicates a requirement that must be strictly followed and from which no deviation is permitted, if conformity to this Recommendation is to be claimed.

The phrase "is recommended" indicates a requirement that is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformity.

The phrase "can optionally" indicates an optional requirement that is permissible, without implying any sense of being recommended. This term is not intended to imply that the vendor's implementation must provide the option, and the feature can be optionally enabled by the network operator or service provider. Rather, it means the vendor may optionally provide the feature and still claim conformity with this Recommendation.

6 Overview of green data centre energy management platform

A data centre (DC) is defined in clause 3.1.1. A GDC is operated and managed to maximize energy efficiency and minimize environmental impact [ITU-T L.1300].

A DC is centred on equipment with high energy consumption, and usually relies on manual operation and maintenance, while a GDC mainly focuses on reduction of energy consumption by effective supervision, management, operation and control.

The rapid development of technology and its application to various fields and industries combines the requirements of consumption reduction between the IoT and GDCs, thus saving energy in and reducing emissions from the latter.

The structure of an IoT-based GDC as shown in Figure 6-1 integrates systems for dynamic circumstance monitoring (DCM), cooling and server performance monitoring (SPM), as well as an energy management platform by using IoT technologies to achieve comprehensive monitoring and management of a DC. A DCM system provides monitoring of temperature and humidity, leakage, smoke, uninterruptible power supply, etc. through a variety of IoT devices and equipment, while a cooling system monitors cooling equipment and controls adjustment remotely. An SPM system

monitors information technology (IT) equipment and controls adjustment remotely, while GDC energy management analyses energy saving based on artificial intelligence (AI) of a DC.

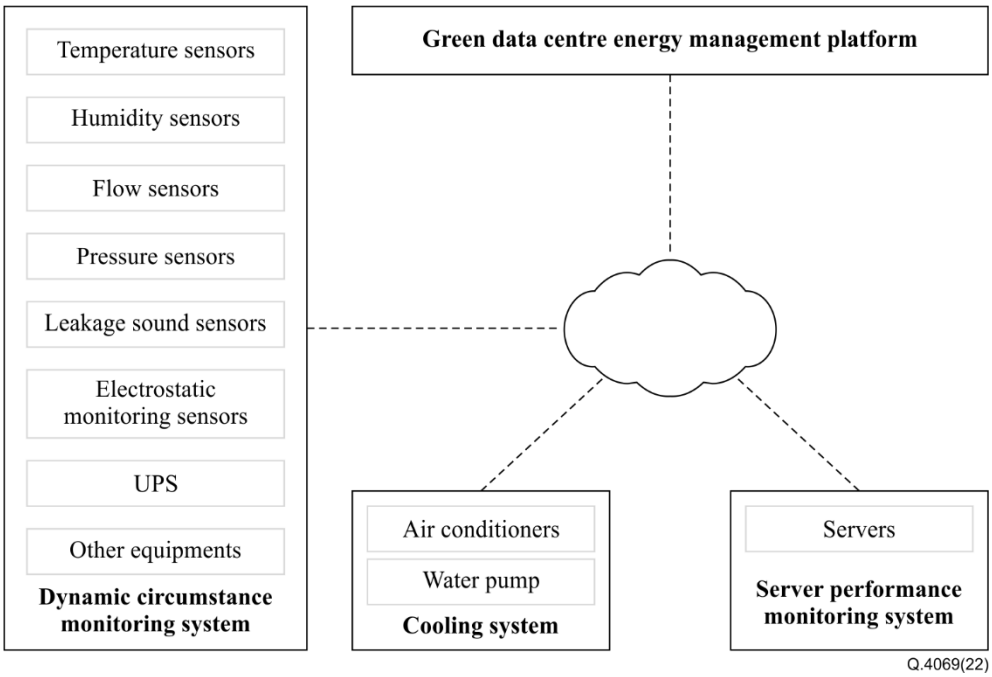


Figure 6-1 – Structure of Internet of things-based green data centre

A GDC energy management platform includes functions such as collection, storage, processing and analysis of data, AI model management, control policy determination, policy management and data visualization.

Data collection means that a GDC energy management platform can collect measurements relating to energy consumed and environmental conditions (e.g., temperature or humidity data) from other systems in real time or periodically.

The collected data can be stored in the platform in certain rules, such as all data in a DC should be stored together.

The data processing and analysis function adds, deletes, modifies and checks,, cleans, tags, and statistically mines data.

AI models management includes their training and tuning. AI models can provide long- and short-term statistics based on real-time and historical data, trend analysis and prediction of the load, and key performance indicators such as PUE.

Control policy determination means fixing instructions and suggested behaviour for controlling and adjusting systems for cooling and SPM, as a result of reductions in energy consumption for cooling and by servers.

Policy management includes querying, modification, issue and execution of feedback on energy-saving policies for DCs.

Figure 6-2 shows the energy-saving control flow of an IoT-based GDC, whose energy management platform can collect data from systems for DCM, cooling and SPM, as well as issue energy-saving control policies to the systems for cooling and SPM to achieve intelligent energy management for DCs.

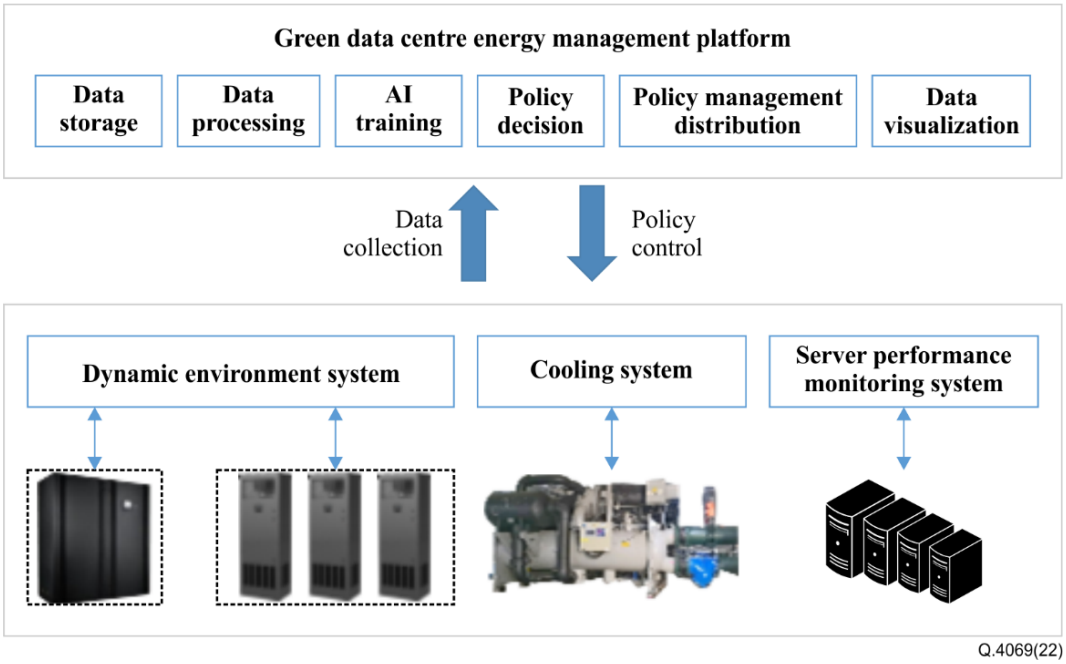


Figure 6-2 – The energy-saving control flow of an IoT-based green data centre

A GDC energy management platform provides a data visualization interface that is shown in Figure 6-3. The data visualization interface provides a comprehensive view of all DCs and a detailed view of a DC. Data visualization displays energy-saving indicators including: energy saving and cost saving statistics per day, week, month, quarter or year; energy saving rate; PUE change trend; and temperature change trend.

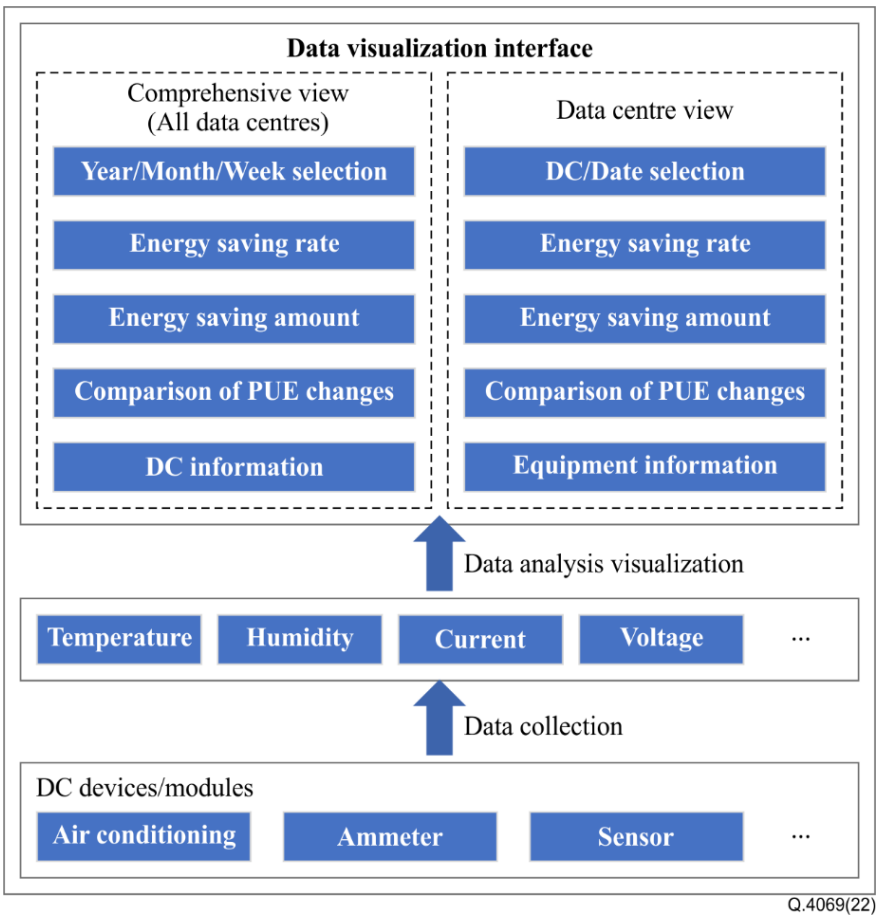


Figure 6-3 – The interaction between devices or modules and data visualization interface

7 Testing requirements of green data centre energy management platform

7.1 Interoperability testing requirements

Interoperability testing is applied to interfaces between a GDC energy management platform and systems for DCM, cooling, and SPMfor data querying and remote adjustment, by Modbus, simple network management protocol, WebService and other protocol interfaces.

According to different service monitoring and analysis tasks, interoperability testing between a GDC energy management platform and a DCM system includes but is not limited to the following aspects.

It is recommended that the GDC energy management platform support pulling the environment and energy consumption-related data of DCs from the DCM system once or periodically.

It is recommended that the GDC energy management platform support querying real-time data (e.g., cabinet real-time temperature, air conditioner data, cabinet load, outdoor real-time temperature) through appropriate data query interfaces with the DCM system.

It is recommended that the DCM system support pushing the environment and energy consumption-related data of DCs to the GDC energy management platform once or periodically.

It is recommended that the DCM system support sending requests for sensor equipment status statistics and prediction to the GDC energy management platform.

According to different service monitoring and analysis tasks, interoperability testing between a GDC energy management platform and a cooling system includes but not is not limited to the following aspects.

It is recommended that the GDC energy management platform support pulling the data of a chilled water station from the cooling system once or periodically.

NOTE – A chilled water station includes (one or several) chillers, chilled pumps, cooling pumps and cooling towers.

It is recommended that the GDC energy management platform support querying real-time data of a chilled water station through appropriate data query interfaces between cooling systems.

It is recommended that the GDC energy management platform support distributing cooling equipment control policies to the cooling system.

It is recommended that the cooling system support pushing the data of a chilled water station to the GDC energy management platform once or periodically.

It is recommended that the cooling system support sending requests for cooling equipment energy consumption statistics and prediction to the GDC energy management platform.

According to different service monitoring and analysis tasks, interoperability testing between a GDC energy management platform and an SPM system includes but is not limited to the following aspects.

It is recommended that the GDC energy management platform support pulling the resource usage and configuration-related data of IT equipment from the SPM system once or periodically.

It is recommended that the GDC energy management platform support querying real-time data of physical or virtual machines through appropriate data query interfaces between SPM systems.

It is recommended that the GDC energy management platform support distributing server equipment control policies to the SPM system.

It is recommended that the SPM system support pushing the resource usage and configuration-related data of IT equipment to the GDC energy management platform once or periodically.

It is recommended that the SPM system support sending the requests for server equipment energy consumption statistics and prediction to the GDC energy management platform.

It is recommended that the granularity of the time stamp for data pulling or pushing testing be at the second level.

It is recommended that the accuracy of the remote adjustment testing for energy saving reach 100%.

7.2 Functional testing requirements

These functional testing requirements should support collection, processing and analysis of data, AI model management, control policy determination and data visualization.

It is recommended that the GDC energy management platform collect minute-level measure data from systems for dynamic environmental monitoring, cooling and service performance monitoring, such as air-conditioning operation data, current and voltage of IT load and air-conditioning, temperature and humidity of cabinet or computer room.

It is recommended that the GDC energy management platform store real-time measurement data categorized by DC identification and data type.

It is recommended that the GDC energy management platform should periodically perform data cleaning, classification and use of AI models for data trend fitting and prediction on stored measure data.

It is recommended that the platform support massive data processing and analysis, AI model training, data reasoning and AI service encapsulation.

It is recommended that the GDC energy management platform provide online management of AI models. After training, files for models such as those for temperature prediction, energy consumption

prediction and thermal balance, can be saved to the AI model library, and establish the corresponding relationship between the AI models and the DCs.

It is recommended that data visualization support meeting the needs of monitoring and commissioning, with low human-machine interaction latency.

It is recommended that data visualization display graphical representations of the data breakdown and analysis results for each monitoring system.

It is recommended that data visualization include functions such as historical data query, environmental parameter adjustment and abnormal alarms.

It is recommended that the GDC energy management platform provide a policy reference of a refrigeration equipment parameter at the policy control module based on the AI analysis.

It is recommended that the GDC energy management platform support providing scale up or down policies of virtual machines, thereby automatically reducing the energy of IT equipment.

It is recommended that the GDC energy management platform support conducting unified management of implemented energy-saving policies, including policy generation, issue, execution, feedback and energy-saving effectiveness evaluation.

It is recommended that the GDC energy management platform support minute-level policies issuing to other systems.

It is recommended that the GDC energy management platform support: manual data maintenance;, addition, deletion, modification and checking of dynamic data; chilled water station data; environmental data; static information of the DC; and batch export of query data.

It is recommended that the GDC energy management platform support monitoring, trend prediction and pre-alarm reminders of the ambient temperature, cabinet temperature and cabinet current.

7.3 Self-optimization testing requirements

A GDC energy management platform is required to continuously improve the energy efficiency of DCs and help customers reduce operating expenditure.

It is recommended that the platform support data quality audit to give data analysis reports that indicate the numerical nulls and abnormal values of collected data on air conditioner parameters, environmental temperature and humidity, total energy consumption, IT equipment load, etc.

It is recommended that the platform support self-check of policy execution, generating an alarm if a failure occurs.

It is recommended that the platform support automatic updating and distribution of policies when the environment inside and outside the DC changes.

8 Testing procedure

8.1 General description

Testing of IoT-based GDCs requires a specific model network that enables wireless or wired communications between devices and systems, as well as systems and the GDC energy management platform.

NOTE – According to [b-ITU-T Q.3952]:

– wireless technologies: WiFi, ZigBee, Z-Wave, 6LoWPAN, RPL, Bluetooth, Thread, GSM/GPRS/EDGE (2G), UMTS/HSPA (3G), LTE (4G, including LTE-M), NFC, Sigfox, LoRa, LoRaWAN, NB-IoT etc.

– wired technology: Ethernet.

In addition, before implementing testing, specialized client software (e.g., systems for DCM, cooling, SPM; GDC energy management platform) is installed in the software modules, and test tools such as thermometers and power meters are installed ready for use.

8.2 Interoperability testing procedure

Interoperability testing procedures include interface testing between the GDC energy management platform and systems for DCM, cooling, SPM, which are shown in Figures 8-1, 8-2, and 8-3, respectively, in order to test real-time data query and remote control.

Figure 8-1 – Interface testing between the GDC energy management platform and the DCM system

Figure 8-2 – Interface testing between the GDC energy management platform and the cooling system

Figure 8-3 – Interface testing between the GDC energy management platform and the SPM system

8.2.1 Testing of interface by air conditioner real-time data query

This procedure tests the interface between the GDC energy management platform and the DCM system by querying air conditioner real-time data as listed in in Table 8-1.

Table 8-1 – The testing of interface by air conditioner real-time data query

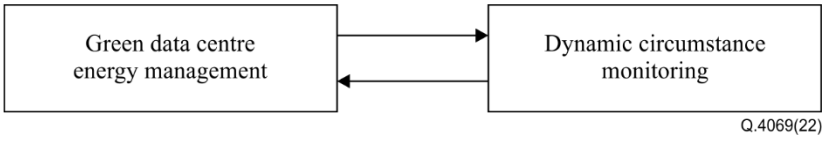
Test number	No. 01
Test name	The testing of interface by air conditioner real-time data query
Type of test	Interoperability
Test goal	The testing on available query of air conditioner real-time data
Configuration	
Test procedure	1) Test sends the air conditioner data query request with key parameters such as air conditioner IDs from the GDC energy management platform to the DCM system. 2) Test receives air conditioner data query response on the GDC energy management platform.

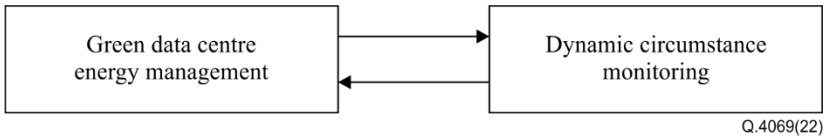
Table 8-1 – The testing of interface by air conditioner real-time data query

Test number	No. 01
Expected results	1) Result indicates the success of the air conditioner data query (e.g., 200 OK). 2) Data indicates air conditioner data query results, including air conditioner ID, time, return temperature, setting temperature, setting humidity, setting status (on/off), fan speed, and air conditioner mode.

8.2.2 Testing of interface by cabinet real-time temperature and humidity query

This procedure tests the interface between the GDC energy management platform and the DCM system by querying cabinet real-time temperature and humidity as listed in Table 8-2.

Table 8-2 – The testing of interface by cabinet real-time temperature and humidity query

Test number	No. 02
Test name	The testing of interface by cabinet real-time temperature and humidity query
Type of test	Interoperability
Test goal	The testing on available query of cabinet real-time temperature and humidity
Configuration	
Test procedure	1) Test sends a cabinet real-time temperature data query request with key parameters such as cabinet IDs from the GDC energy management platform to the DCM system. 2) Test receives cabinet temperature data query response on the GDC energy management platform.
Expected results	1) Result indicates the success of the cabinet temperature data query (e.g., 200 OK). 2) Data indicates the cabinet temperature data query results, including cabinet ID, time, cabinet location, test height, temperature and humidity.

8.2.3 Testing of interface by real-time load query

This procedure tests the interface between the GDC energy management platform and the DCM system by querying real-time load of cabinet and air conditioner as listed in Table 8-3.

Table 8-3 – The testing of interface by real-time load query

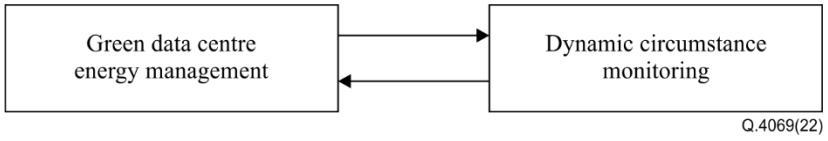
Test number	No. 03
Test name	The testing of interface by real-time load query
Type of test	Interoperability
Test goal	The testing on available query of real-time load
Configuration	

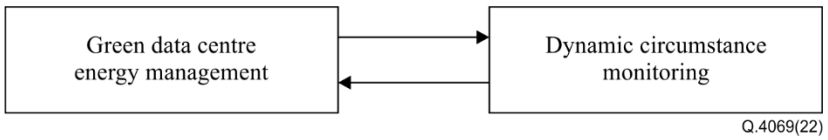
Table 8-3 – The testing of interface by real-time load query

Test number	No. 03
Test procedure	1) Test sends load data query request with key parameters such as cabinet IDs (or air conditioner IDs) from the GDC energy management platform to the DCM system. 2) Test receives cabinet load data query response on the GDC energy management platform.
Expected results	1) Result indicates the success of the cabinet load data query (e.g., 200 OK). 2) Data indicates the cabinet load data query results, including cabinet IDs (or air conditioner IDs), current, voltage and active power.

8.2.4 Testing of interface by outdoor real-time temperature and humidity query

This procedure tests the interface between the GDC energy management platform and the DCM system by querying outdoor real-time temperature and humidity as listed in in Table 8-4.

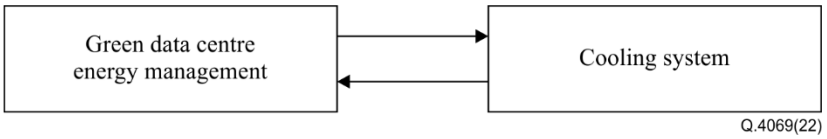
Table 8-4 – The testing of interface by outdoor real-time temperature and humidity query

Test number	No. 04
Test name	The testing of interface by outdoor real-time temperature and humidity
Type of test	Interoperability
Test goal	The testing on available query of outdoor real-time temperature and humidity
Configuration	
Test procedure	1) Test sends outdoor real-time temperature data query request with key parameters such as DC ID from the GDC energy management platform to the DCM system. 2) Test receives the outdoor real-time temperature data query response on the GDC energy management platform.
Expected results	1) Result indicates the success of the outdoor data query (e.g., 200 OK). 2) Data indicates the outdoor real-time data query results, including DC ID, outdoor temperature and outdoor humidity.

8.2.5 Testing of interface by air conditioner remote adjustment

This procedure tests the interface between the GDC energy management platform and the cooling system by remotely adjusting air conditioner parameters as listed in Table 8-5.

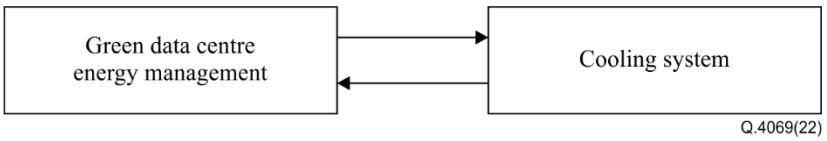
Table 8-5 – The testing of interface by air conditioner remote adjustment

Test number	No. 05
Test name	The testing of interface by air conditioner remote adjustment
Type of test	Interoperability
Test goal	The testing on available remote adjustment of air conditioner
Configuration	
Test procedure	1) Test sends the remote adjustment request with key parameters such as air conditioner ID, setting status, fan rated power, fan minimum power and setting temperature from the GDC energy management platform to the DCM system. 2) Test receives the remote adjustment response on the GDC energy management platform.
Expected results	1) Result indicates the success of air conditioner remote adjustment. (e.g., 200 OK).

8.2.6 Testing of interface by chiller real-time data query

This procedure tests the interface between the GDC energy management platform and the cooling system by querying chiller real-time data as listed in Table 8-6.

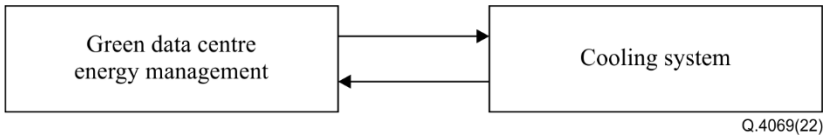
Table 8-6 – The testing of interface by chiller real-time data query

Test number	No. 06
Test name	The testing of interface by chiller real-time data query
Type of test	Interoperability
Test goal	The testing on available query of chiller real-time data
Configuration	
Test procedure	1) Test sends the chiller real-time data query request with key parameters such as chiller IDs from the GDC energy management platform to the DCM system. 2) Test receives the chiller real-time data query response on the GDC energy management platform.
Expected results	1) Result indicates the success of the chiller data query (e.g., 200 OK). 2) Data indicates the chiller data query results, including chiller ID, evaporation temperature, condensation temperature, chilled water supply temperature, chilled water return temperature, cooling capacity, real-time power, real-time system load rate and chilled water supply temperature setting.

8.2.7 Testing of interface by chilled pump real-time data query

This procedure tests the interface between the GDC energy management platform and the cooling system by querying chilled pump data as listed in Table 8-7.

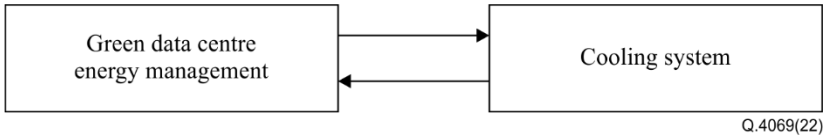
Table 8-7 – The testing of interface by chilled pump data query

Test number	No. 07
Test name	The testing of interface by chilled pump data query
Type of test	Interoperability
Test goal	The testing on available query of chilled pump data
Configuration	
Test procedure	1) Test sends the chilled pump data query request with key parameters such as chilled pump IDs from the GDC energy management platform to the DCM system. 2) Test receives the chilled pump data query response on the GDC energy management platform.
Expected results	1) Result indicates the success of the chilled pump data query (e.g., 200 OK). 2) Data indicates the chilled pump data query results, including chilled pump ID, frequency, voltage, current and active power.

8.2.8 Testing of interface by cooling pump real-time data query

This procedure tests the interface between the GDC energy management platform and the cooling system by querying cooling pump data as listed in Table 8-8.

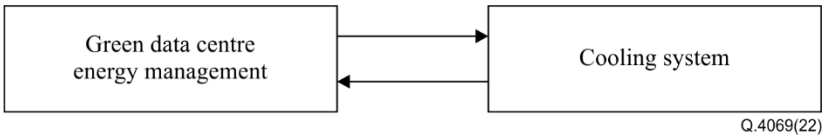
Table 8-8 – The testing of interface by cooling pump real-time data query

Test number	No. 08
Test name	The testing of interface by cooling pump real-time data query
Type of test	Interoperability
Test goal	The testing on available query of cooling pump real-time data
Configuration	
Test procedure	1) Test sends the cooling pump data query request with key parameters such as cooling pump IDs from the GDC energy management platform to the DCM system. 2) Test receives the cooling pump data query response on GDC energy management platform.
Expected results	1) Result indicates the success of the cooling pump data query (e.g., 200 OK). 2) Data indicates the cooling pump data query results, including cooling pump ID, frequency, voltage, current, active power and etc.

8.2.9 Testing of interface by cooling tower real-time data query

This procedure tests the interface between the GDC energy management platform and the cooling system by querying cooling tower data as listed in Table 8-9.

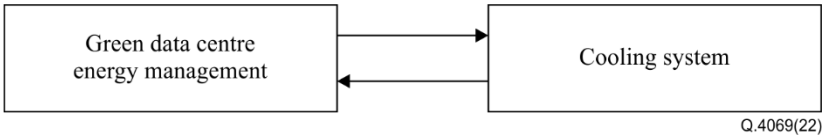
Table 8-9 – The testing of interface by cooling tower real-time data query

Test number	No. 09
Test name	The testing of interface by cooling tower real-time data query
Type of test	Interoperability
Test goal	The testing on available query of cooling tower real-time data
Configuration	
Test procedure	1) Test sends the cooling tower data query request with key parameters such as cooling tower IDs and tower fan IDs from the GDC energy management platform to the DCM system. 2) Test receives cooling tower data query response on the GDC energy management platform.
Expected results	1) Result indicates the success of the cooling tower data query (e.g., 200 OK). 2) Data indicates the cooling tower data query results, including cooling tower ID, fan status, fan speed, voltage, current and active power.

8.2.10 Testing of interface by chilled water station remote adjustment

This procedure tests the interface between GDC energy management platform and cooling system in Table 8-10 to adjust chilled water station parameters.

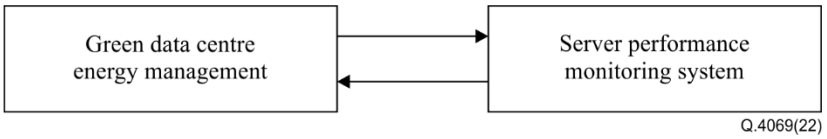
Table 8-10 – The testing of interface by chilled water station remote adjustment

Test number	No. 10
Test name	The testing of interface by chilled water station remote adjustment
Type of test	Interoperability
Test goal	The testing on available remote adjustment of chilled water station
Configuration	
Test procedure	1) Test sends remote adjustment request with key parameters such as chiller ID, chilled water supply temperature setting, chilled/cooling pump ID and frequency, and tower fan status from the GDC energy management platform to the DCM system. 2) Test receives the remote adjustment response on the GDC energy management platform.
Expected results	1) Result indicates the success of chilled water station remote adjustment (e.g., 200 OK).

8.2.11 Testing of interface by machine real-time data query

This procedure tests the interface between the GDC energy management platform and the SPM system by querying machine real-time data as listed in Table 8-11.

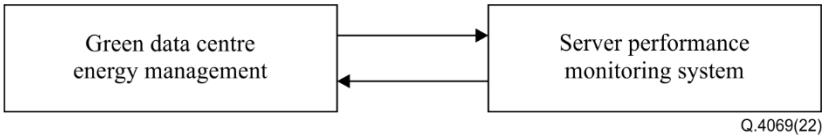
Table 8-11 – The testing of interface by machine real-time data query

Test number	No. 11
Test name	The testing of interface by machine real-time data query
Type of test	Interoperability
Test goal	The testing on available query of machine real-time data
Configuration	
Test procedure	1) Test sends machine real-time data query request with key parameters such as DC ID, device IDs and Resource IDs from the GDC energy management platform to the DCM system. 2) Test receives the machine data query response on the GDC energy management platform.
Expected results	1) Result indicates the success of machine data query (e.g., 200 OK). 2) Data indicates the machine data query results, including device ID, resource ID, maximum central processing unit (CPU) usage, minimum CPU usage, average CPU usage, maximum memory usage, minimum memory usage, average memory usage, maximum network traffic, minimum network traffic and average network traffic.

8.2.12 Testing of interface by machine remote adjustment

This procedure tests the interface between GDC energy management platform and SPM system in Table 8-12 to adjust machine parameters.

Table 8-12 – The testing of interface by machine remote adjustment

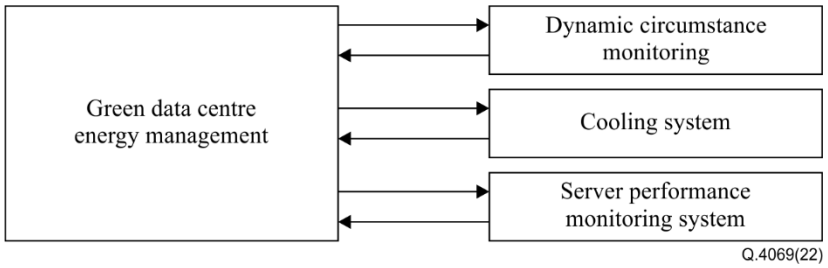
Test number	No. 12
Test name	The testing of interface by machine remote adjustment
Type of test	Interoperability
Test goal	The testing on available remote adjustment of machines
Configuration	
Test procedure	1) Test sends the machine remote adjustment request with key parameters such as DC ID, device ID, device on/off setting, fan speed setting, CPU frequency, and etc. from the GDC energy management platform to the DCM system. 2) Test receives the machine remote adjustment response on the GDC energy management platform.
Expected results	1) Result indicates the success of machine remote adjustment (e.g., 200 OK).

8.3 Functional testing procedure

8.3.1 Testing of function by energy-saving policy management and issue

This procedure tests the normality of the energy-saving policy management and issue function; details are listed in Table 8-13.

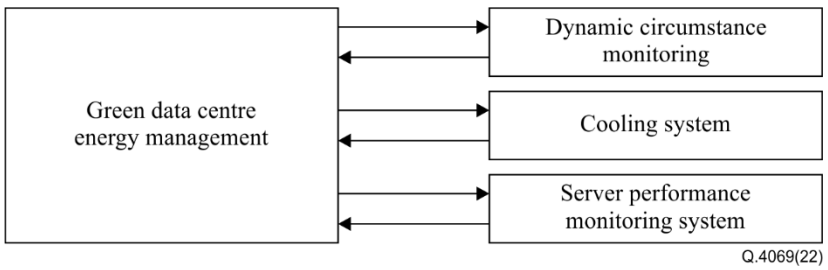
Table 8-13 – The testing of function by energy-saving policy management and issue

Test number	No. 13
Test name	The testing of function by energy-saving policy management and issue
Type of test	Functionality
Test goal	The testing on available function of energy-saving policy management and issue
Configuration	
Test procedure	1) Test the addition, issue, modification, query, and deletion operations of the policy lists on the GDC energy management platform. 2) Test receives the return results on the GDC energy management platform.
Expected results	1) Result indicates the success of addition, modification, query, and deletion operations of the policy. 2) Policy issued by the platform is consistent with the operation result in the DCs.

8.3.2 Test on function of energy saving policy triggering

This procedure tests the automatic triggering of the energy-saving policy with a change in environment; details are listed in Table 8-14.

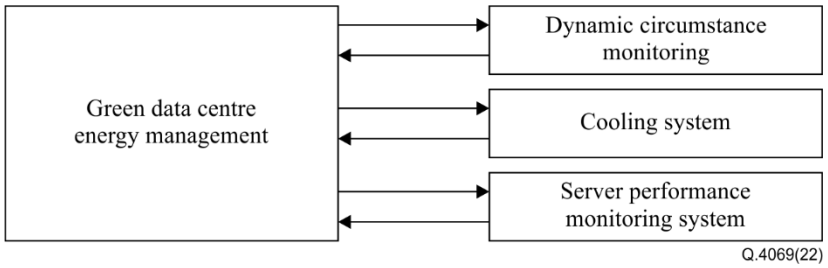
Table 8-14 – The testing of the function of energy saving policy triggering

Test number	No. 14
Test name	The testing of the function of energy saving policy triggering
Type of test	Functionality
Test goal	The testing on available function of automatic energy saving policy triggering
Configuration	
Test procedure	1) Selects a certain DC, records its current cooling policy. 2) Manually configures timed tasks and policy trigger conditions (e.g., a 2°C increase in the external environment). 3) Detects the comparison of the cooling policy when the temperature threshold is reached with the recorded policy.
Expected results	1) Cooling policy could be triggered automatically when the temperature threshold is reached.

8.3.3 Testing of the online management function of AI models

This procedure tests the online management function of AI models; details are listed in Table 8-15.

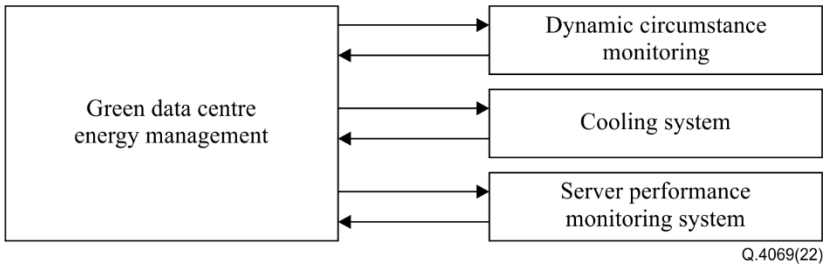
Table 8-15 – The testing of the online management function of AI models

Test number	No. 15
Test name	The testing of the online management function of AI models
Type of test	Functionality
Test goal	The testing on available on online management function of AI models
Configuration	
Test procedure	1) Selects a trained model, checks whether it can be uploaded to the AI model library. 2) Tests the modification, queries and deletes AI models in the library.
Expected results	1) The models in the library can be uploaded, modified, queried and deleted normally.

8.3.4 Test the visualization function

This procedure tests the data visualization function; details are listed in Table 8-16.

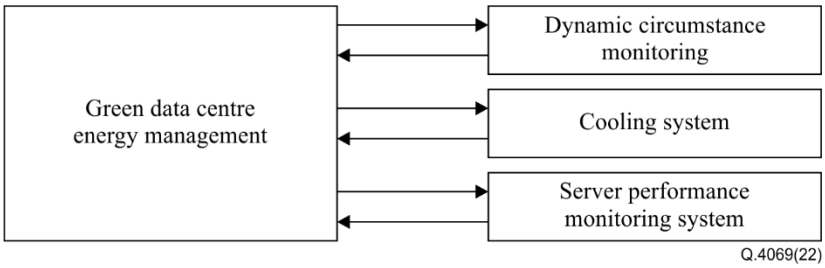
Table 8-16 – The testing of the visualization function

Test number	No. 16
Test name	The testing of the visualization function
Type of test	Functionality
Test goal	The testing on available visualization function
Configuration	
Test procedure	1) Tests whether the data graphic of all data centres can be displayed. 2) Tests whether the data graphic of a specific data centre can be displayed.
Expected results	1) The visualization function of all data centres supports data graphic of total energy saving, total cost saving statistics, expected energy saving rate. 2) The visualization function of a specific data centre supports data graphic of energy saving statistics, detailed energy saving policies, PUE change trend and temperature change trend before and after energy saving policies.

8.3.5 Testing of alarm temperature threshold configuration function

This procedure tests the alarm temperature threshold configuration function; details are listed in Table 8-17.

Table 8-17 – The testing of the alarm temperature threshold configuration function

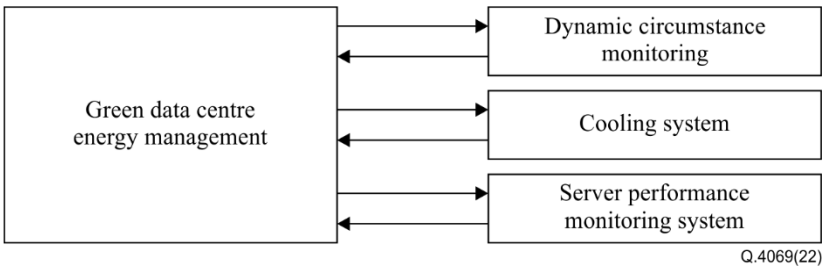
Test number	No. 17
Test name	The testing of the alarm temperature threshold configuration function
Type of test	Functionality
Test goal	The testing on available configuration function of alarm temperature threshold
Configuration	
Test procedure	1) Tests configuring alarm temperature threshold according to operation requirements of the DC, e.g., adjust the temperature threshold from 28°C to 26°C. 2) Tests whether alarm reminders occur after setting alarm temperature thresholds.
Expected results	1) Alarm temperature threshold is configurable.

8.4 Self-optimization testing procedure

8.4.1 Testing of automatic data quality audit

This procedure tests the automatic data quality audit; details are listed in Table 8-18.

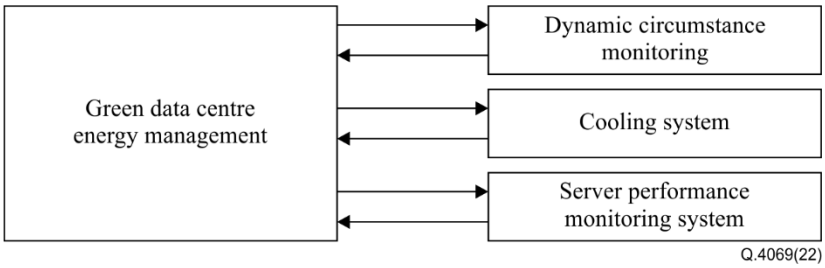
Table 8-18 – The testing of the automatic data quality audit

Test number	No. 18
Test name	The testing of the automatic data quality audit
Type of test	Extension capabilities
Test goal	The testing on available automatic data quality audit
Configuration	
Test procedure	1) Tests the automatic generation of daily data analysis report for a selected DC.
Expected results	1) Daily data analysis report can be generated automatically.

8.4.2 Testing of self-check of policy execution

This procedure tests the policy execution result monitoring; details are listed in Table 8-19.

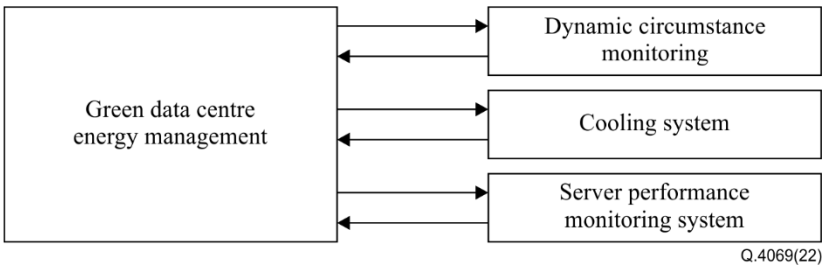
Table 8-19 – The testing of self-check of policy execution

Test number	No. 19
Test name	The testing of self-check of policy execution
Type of test	Extension capabilities
Test goal	The testing on available self-check of policy execution
Configuration	
Test procedure	1) Creates and issues remote adjustment policies for air conditioners. 2) Tests the self-check report of policy execution and response of actual status of air conditioners.
Expected results	1) Self-check report indicates that policies are consistent with the actual status of air conditioners.

8.4.3 Test automatic updating and optimization of policies

This procedure tests policy automation according to environment and load changes; details are listed in Table 8-20.

Table 8-20 – The testing of the automatic updating and optimization of policies

Test number	No. 20
Test name	The testing of the automatic updating and optimization of policies
Type of test	Extension capabilities
Test goal	The testing on available automatic updating and optimization of policies
Configuration	
Test procedure	1) Selects a DC by load query and outdoor temperature query to determine a DC with big changes in load and temperature. 2) Compares the air conditioner parameter differences in the policies before and after the load and temperature changes.
Expected results	1) Air conditioner parameter configuration is optimized with the changes in load and temperature.

Bibliography

[b-ITU-T Q.3952] Recommendation ITU-T Q.3952 (2018), *The architecture and facilities of a model network for Internet of things testing.*

[b-ITU-T Y.4000] Recommendation ITU-T Y.4000 (2012), *Overview of the Internet of things.*

[b-ITU-T Y.4051] Recommendation ITU-T Y.4051 (2019), *Vocabulary for smart cities and communities.*

[b-ISO/IEC 30134-2] ISO/IEC 30134-2:2016, *Information technology – Data centres – Key performance indicators – Part 2: Power usage effectiveness (PUE).*

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