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CONSTRUCTION, INSTALLATION AND PROTECTION OF TELECOMMUNICATION CABLES IN PUBLIC NETWORKS

Rationale for minimum data set for evaluating energy efficiency and for controlling data centre equipment in view of power saving

Summary

This Technical Paper describes rationale for minimum data set for evaluating energy efficiency and for controlling data centre equipment in view of power saving based on Recommendation ITU-T L.1300. More precisely, this Technical Paper reports data set necessary for: evaluation of energy efficiency and coordinated control to save power in data centres. Finally, it provides a summary of minimum data set and gap analysis with other standardization works.

Keywords

Best practice, data centre, energy efficient, information and communication technology and climate change (ICT & CC).

Change Log

This document contains Version 1 of the ITU-T Technical Paper on "*Rationale for minimum data set for evaluating energy efficiency and for controlling data centre equipment in view of power saving*" approved at the ITU-T Study Group 5 meeting held in Lima, 2-13 December 2013.

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Summary

This Technical Paper describes rationale for minimum data set for evaluating energy efficiency and for controlling data centre equipment in view of power saving based on Recommendation ITU-T L.1300.

1 Scope

This Technical Paper describes rationale for minimum data set for evaluating energy efficiency and for controlling data centre equipment in view of power saving based on Recommendation ITU-T L.1300. The scope of this Technical Paper includes:

– an introduction of rationale for minimum data set for evaluating energy efficiency and for controlling data centre equipment;
– data set necessary for evaluation of energy efficiency in data centres;
– data set necessary for coordinated control to save power in data centres; and
– summary of minimum data set and gap analysis with other standardization works.

2 Definitions

This Technical Paper uses the following terms:

2.1 Dynamic data: Data that should be obtained from data centre equipment periodically.

2.2 Static data: Data that should be treated statically.

3 Abbreviations

COP Coefficient of Performance

CRAC Computer Room Air Conditioner

CRAH Computer Room Air Handler

DCiE Data Centre infrastructure Efficiency

DPPE Data centre Performance Per Energy

GEC Green Energy Coefficient

HVAC Heating Ventilation and Air Conditioning

ITEE IT equipment Energy Efficiency

ITEU IT Equipment Utilization

KVM Keyboard, Video monitor, and Mouse

MIB Management Information Base

PDU Power Distribution Unit

PUE Power Usage Effectiveness

RDU Rack Distribution Unit

UPS Uninterruptible Power Supply

VAV Variable Air Volume

4 Introduction

Energy consumption in data centres is increasing year by year with the growth in the data centre market. In order to mitigate global warming, it is an urgent task to reduce power consumption in data centres. Generally, ICT equipment (e.g., servers, routers, switches, storage units) and facility equipment (e.g., power delivery components, heating ventilation and air conditioning (HVAC) system components) account for a large percentage of energy consumption in data centres. Thus, power-saving measures for these components are necessary to reduce overall power consumption.

Evaluation of energy efficiency in data centres is necessary to know how green the data centre is and to investigate the effect of power-saving measures. To evaluate whether the data centre is power efficient, it is necessary to continuously trace metrics which represent the energy efficiency of the data centre. An example of such a metric is power usage effectiveness (PUE) or its reciprocal, data centre infrastructure efficiency (DCiE), both of which express the energy efficiency of facility equipment.

In addition to power-saving measures for each component, energy consumption in data centres can be further reduced by implementing "coordinated control" of ICT equipment and facility equipment. In general, ICT equipment and facility equipment are separately controlled. If facility equipment is controlled in a coordinated way according to the arrangement of the workload of ICT equipment, further power reduction can be achieved.

To evaluate energy efficiency in data centres and to control data centre equipment to achieve power saving, necessary data needs to be collected from the data centre equipment. Nowadays, sensors can be installed to collect necessary data, but the installation cost can be very high. It is also possible to obtain monitoring information directly from data centre equipment by using, for example, a management information base (MIB) for ICT equipment. However, it is difficult to collect necessary data in an integrated fashion because a data centre is generally a multivendor environment, and each vendor defines its own measurement point and allocation address.

Based on this situation, this document describes the minimum data set necessary for evaluating energy efficiency and for controlling data centre equipment to save power in data centres. The data set includes two types of data:

- data that should be obtained from data centre equipment periodically (dynamic data);
- data that should be treated statically (static data).

The definition of such a minimum data set is intended to facilitate the evaluation and control of equipment under a multivendor environment. The means of collecting the data from data centre equipment is outside the scope of this Technical Paper and should be addressed as a future task.

In this part we consider:

Dynamic data: Data that should be obtained from data centre equipment periodically.

Static data: Data that should be treated statically.

5 Data set necessary for evaluation of energy efficiency in data centres

This clause describes the minimum data set necessary for evaluating energy efficiency in data centres. The necessary data set is described, based on the analysis of the following metrics for evaluating energy efficiency of data centres.

Table 1 lists examples of metrics which represent the energy efficiency of a data centre. Table 2 shows the relation between the metrics and the parameters.

Table 1 – Examples of metrics representing energy efficiency of data centres

Metrics	Definitional identity	Notes
PUE: power usage effectiveness	Total energy consumption of data centre/Energy consumption of ICT equipment.	PUE is proposed by the Green Grid, and determines the energy efficiency of a data centre infrastructure. The reciprocal of PUE is DCiE.
ITEU: IT equipment utilization	Energy consumption of ICT equipment/total rated power of ICT equipment.	ITEU is proposed by the Green IT Promotion Council, and represents the degree of energy saving by virtual and operational techniques using the potential ICT equipment capacity without waste. A reduction in equipment to be installed is promoted by using only the number of devices needed to meet the required ICT capacity without waste.
ITEE: IT equipment energy efficiency	(Total server capacity + Total storage capacity + Total NW equipment capacity)/Total rated power of ICT equipment	ITEE is proposed by the Green IT Promotion Council, and aims to promote energy saving by encouraging the installation of equipment with high processing capacity per unit of electric power.
GEC: Green energy coefficient	Green (natural energy) energy/total energy consumption of data centre.	GEC is proposed by the Green IT Promotion Council, and is a value obtained by dividing green energy produced and used in a data centre by the total power consumption. It is introduced to promote the use of green energy.
DPPE: Datacentre performance per energy	Function of the four metrics PUE, ITEU, ITEE, GEC.	DPPE is proposed by the Green IT Promotion Council, and indicates the energy efficiency of data centres as a whole. It may be expressed as the product of the other four metrics.

Table 2 – Relation between metrics and parameters

Parameters used in the metrics	Type of information	PUE	ITEU	ITEE	GEC	DPPE
Total energy consumption of data centre	Dynamic	✓			✓	✓
Energy consumption of ICT equipment	Dynamic	✓	✓			✓
Green energy produced and used in data centre	Dynamic				✓	✓
Rated power of ICT equipment	Static		✓	✓		✓
Server capacity	Static			✓		✓
NW equipment capacity	Static			✓		✓
Storage capacity	Static			✓		✓

Here, energy consumption of ICT equipment includes all of the ICT equipment, i.e., computing, storage, and network equipment, along with supplemental equipment, i.e., KVM switches, monitors, and workstations/laptops used to monitor or otherwise control the data centre. On the other hand, total data centre energy consumption includes all of the ICT equipment power plus everything that supports the ICT equipment, such as power delivery components, HVAC system components, and other miscellaneous component loads, such as physical security and building management systems. Table 3 gives examples of components quoted from [b-TGG WP14].

Table 3 – Examples of components of facility and ICT equipment

Facility	
	Power
	Transfer switch
	UPS
	DC batteries/rectifiers (non-UPS – telco nodes)
	Generator
	Transformer (step down)
	Power distribution unit (PDU)
	Rack distribution unit (RDU)
	Breaker panels
	Distribution wiring
	Lighting
	Heating, ventilation and air conditioning (HVAC)
	Cooling tower
	Condenser water pumps
	Chillers
	Chilled water pumps
	Computer room air conditioners (CRACs)
	Computer room air handlers (CRAHs)
	Dry cooler
	Supply fans
	Return fans
	Air economizer
	Water-side economizer
	Humidifier
	In-row, in-rack and in-chassis cooling solutions
	Physical security
	Fire suppression
	Water detection
	Physical security servers/devices
	Building management system
	Servers/devices used to control management of data centre
	Probes/sensors
IT equipment	
	Computer devices
	Servers
	Network devices

Table 3 – Examples of components of facility and ICT equipment

	Switches
	Routers
	IT support systems
	Printers
	PCs/workstations
	Remote management (KVM/console/etc.)
	Miscellaneous devices
	Security encryption, storage encryption, appliances, etc.
	Storage
	Storage devices – switches, storage array
	Backup devices – media libraries, virtual media libraries
	Telecommunications
	All telco devices

source [b-TGG WP14]

Table 2 indicates that the dynamic data necessary for calculating these metrics are the total energy consumption of the data centre and the energy consumption of ICT equipment, both of which are used in the calculation of PUE. Green energy produced and used in the data centre is also dynamic data, but does not need to be included in the data set because the scope of this Technical Paper is a data set for evaluating power efficiency, not energy efficiency. Thus, consideration of the source of power is beyond the scope of this paper. Other parameters in Table 2 are static data which can be obtained from equipment specifications.

To determine the total energy consumption of the data centre and the energy consumption of ICT equipment, some approaches to measuring PUE are described in [b-TGG WP14], as shown in Table 4. PUE calculation is more precise at higher levels, and locations to measure annual energy consumption of the data centre and of ICT equipment, as well as the minimum measurement interval, are defined for each level. Figure 1 shows an example of a power feeding system in a data centre with the measurement locations indicated. The higher the level, the shorter measurement interval is recommended, and thus, it would be easier to obtain energy consumption of ICT equipment if the input power of ICT equipment and the output power of power equipment (i.e., UPS, rectifier, PDU) could be collected as dynamic data from the equipment. On the other hand, for total power consumption, it is recommended that input power be measured in the utility meter when calculating PUE.

In addition, cooling equipment accounts for a large percentage of energy consumption in data centres, thus input power of cooling equipment should be collected as well.

Therefore, inclusion of the input power of ICT equipment and cooling equipment and the output power of the UPS, rectifier, and PDU to the data set, is necessary to evaluate the power efficiency.

Table 4 – Measurement approaches of PUE

	Level 1 (basic)	Level 2 (intermediate)	Level 3 (advanced)
IT equipment power Total facility power where:	UPS Data centre input power	PDU Data centre input power less shared HVAC	Server… Data centre input power less shared HVAC plus building lighting, security
Minimum measurement interval	1 month/1 week	Daily	Continuous (XX min)

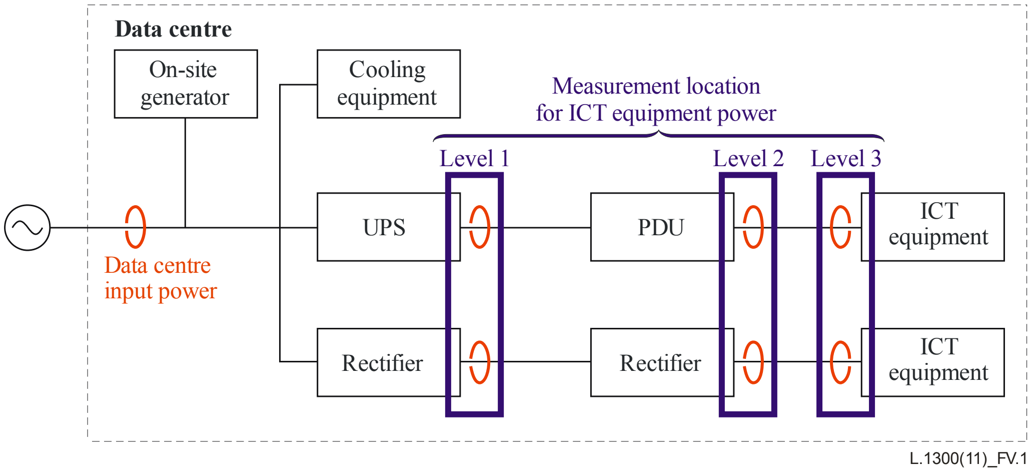


Figure 1 – Example of a power feeding system of a data centre

6 Data set necessary for coordinated control to save power in data centres

This clause describes the minimum data set necessary for coordinated control to reduce the total energy consumption of data centres. First, the effect of coordinated control is explained in clause 6.1. The description of the control architecture and the scope of the data set follow in clause 6.2. Then, clause 6.3 describes the details of the data set on ICT equipment, cooling equipment, power equipment, and the equipment configuration.

6.1 Power saving due to coordinated control

The effects of controlling multiple pieces of cooling equipment in a coordinated way are described here.

The efficiency of a computer room air conditioner (CRAC) varies with the load factor and operation mode. When each CRAC is controlled to satisfy its own temperature setting, the overall efficiency of all CRACs is not necessarily high. As shown in Figure 2, when one of the CRACs in variable air volume (VAV) mode has a disproportionate load and the thermostats of adjacent CRACs remain switched off, the overall efficiency may be low.

An experiment was conducted to see if the total energy consumption could be reduced by adjusting the load balance among the CRACs. The temperature setting of each CRAC was adjusted so they would operate at higher efficiency.

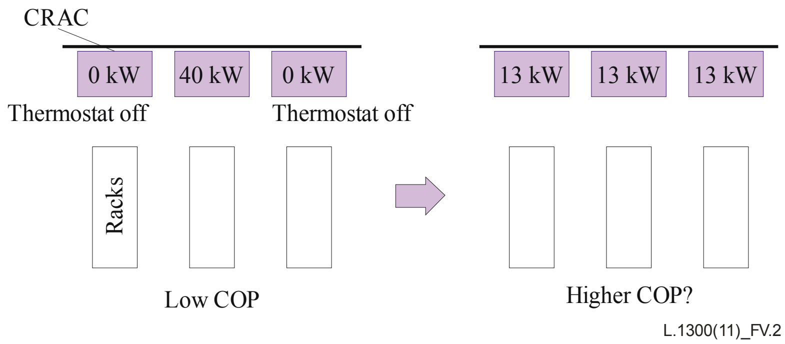


Figure 2 – Illustration of a server room (COP: coefficient of performance)

The correlation between the outside temperature and the energy consumption of CRACs is shown in Figure 3. This shows that the energy consumption of CRACs can be reduced by adjusting the load balance. For example, when the outside temperature is 15°C, the reduction in energy consumption of CRACs is estimated to be 17.5%. Note that this estimated value is only valid for the experimental environment, but the result indicates that coordinated control among CRACs makes it possible to save a large amount of power. For power saving, it is important to control multiple CRACs by optimally responding to the heat generation due to the operation of ICT equipment.

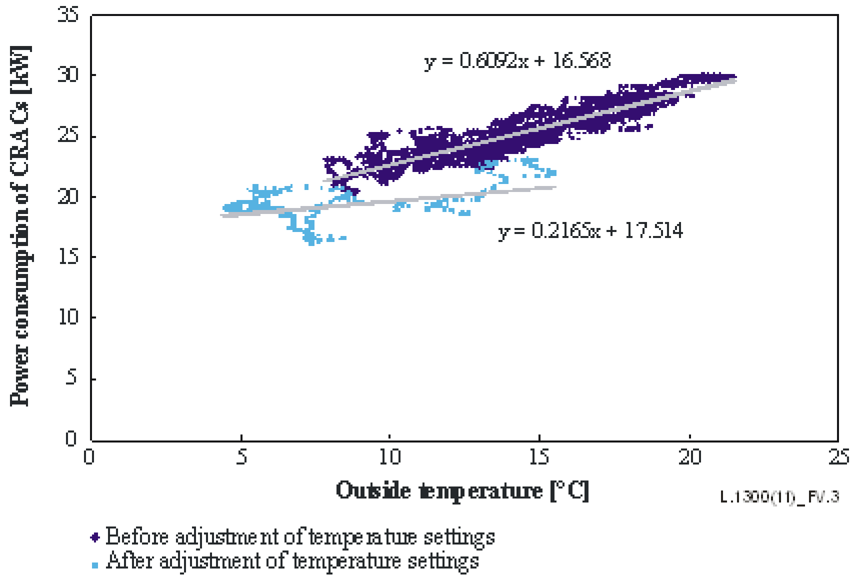


Figure 3 – Correlation of outside temperature and energy consumption of CRACs

6.2 Control architecture

Figure 4 illustrates an example of control architecture for power saving in data centres. A facility controller collects the dynamic data and sets the control parameters of ICT equipment and facility equipment. The facility controller also manages static data of ICT and facility equipment, such as equipment ID, equipment characteristics, server room configuration, and rack configuration. An ICT task controller manages and controls the work load of ICT equipment.

This document focuses on the control parameters of ICT equipment and facility equipment that directly contribute to power saving, and on the dynamic data which should be collected from ICT and facility equipment in order to set the control parameters. It also describes examples of the static data the facility controller should manage. However, data managed in the ICT task controller are outside the scope of this Technical Paper because the arrangement of work load does not directly contribute to power saving.

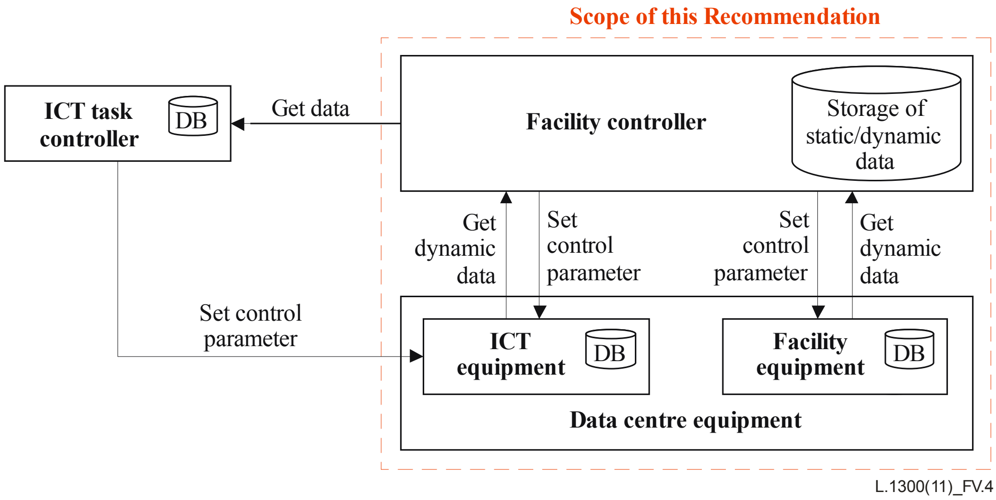


Figure 4 – Example of control architecture

6.3 Details on data set

6.3.1 ICT equipment

✓ Power state setting of ICT equipment (shutdown, activation) (dynamic data)

Energy consumption varies depending on the power state of ICT equipment (i.e., shutdown, sleep state, active state). Examples of energy consumption patterns due to the power state of ICT equipment are shown in Figure 5. Some types of equipment can reduce their energy consumption by changing their power state to the sleep state (as shown in (1) in Figure 5), and other types can only achieve a large reduction in energy consumption by changing the power state to shutdown (as shown in (2)). Some other types cannot achieve a significant reduction in energy consumption just by changing their power state (as shown in (3)).

Based on these characteristics, energy consumption can be reduced by setting the appropriate power state of ICT equipment based on the workload. Therefore, the power state of ICT equipment should be included in the data set as a control parameter.

✓ Present power state of ICT equipment (shutdown, sleep, active) (dynamic data)

Prior to changing the power state of ICT equipment, it is necessary to determine whether the present power state is shutdown, in sleep mode, or active. For example, when ICT equipment is required to be shut down, the power state needs to be checked to make sure it is in sleep mode.

Therefore, the power state of ICT equipment should be collected as dynamic data.

✓ Input power of ICT equipment (dynamic data)

Input power of ICT equipment should be collected as dynamic data in order to check whether the power is reduced by changing the power state.

✓ Energy consumption data of ICT equipment under shutdown and sleep modes (static data)

If these data are available, it will be effective for power saving to preferentially shut down ICT equipment. Large power reduction is achieved when its power state is changed from stand-by to a shutdown state.

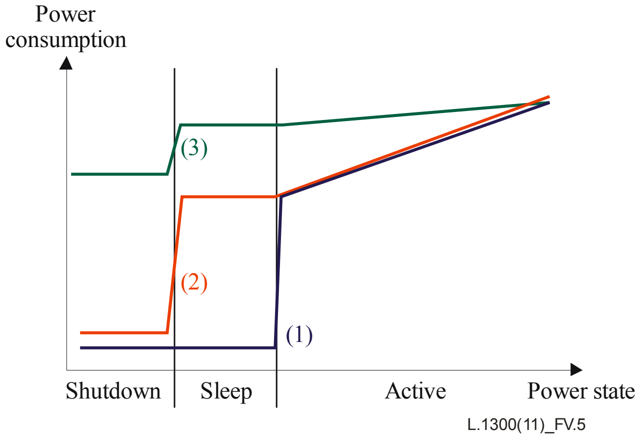


Figure 5 – Power patterns due to the power state of ICT equipment

✓ Equipment ID and description (static data)

These are necessary for identifying each piece of equipment.

✓ Inlet temperature of ICT equipment (dynamic data)

✓ Operating temperature range of ICT equipment (static data)

ICT equipment has an operating temperature range, and cooling equipment must be controlled to meet this temperature range for each piece of ICT equipment. Therefore, the inlet temperature of ICT equipment should be collected, and control parameters of cooling equipment should be determined to keep the inlet temperature of ICT equipment within the allowable range.

6.3.2 Cooling equipment

✓ On-off state of cooling equipment (dynamic data)

For areas where there is a small heat load, power consumption can be reduced by switching off the cooling equipment. Therefore, the on-off state of cooling equipment should be included in the data set as a control parameter.

✓ Temperature of refrigerant supplied from the indoor unit to the ICT equipment (dynamic data)

✓ Amount of refrigerant supplied from the indoor unit to the ICT equipment (dynamic data)

Generally, as shown in Figure 6, cooling equipment is composed of indoor and outdoor units. This equipment controls the temperature and the amount of refrigerant supplied from the indoor unit to the ICT equipment, in response to the heat generation due to the operation of ICT equipment. A large amount of power is used in devices that cool the refrigerant and in those that transport the refrigerant. For example, the former device is a compressor and the latter device a fan when the refrigerant is air, while the former device is a chiller and cooling tower, and the latter a pump when the refrigerant is water. Power saving depends on the control of these devices, and the temperature setting and amount of refrigerant supplied from the indoor unit to the ICT equipment affects their operation. Thus, these parameters should be included in the data set as control parameters.

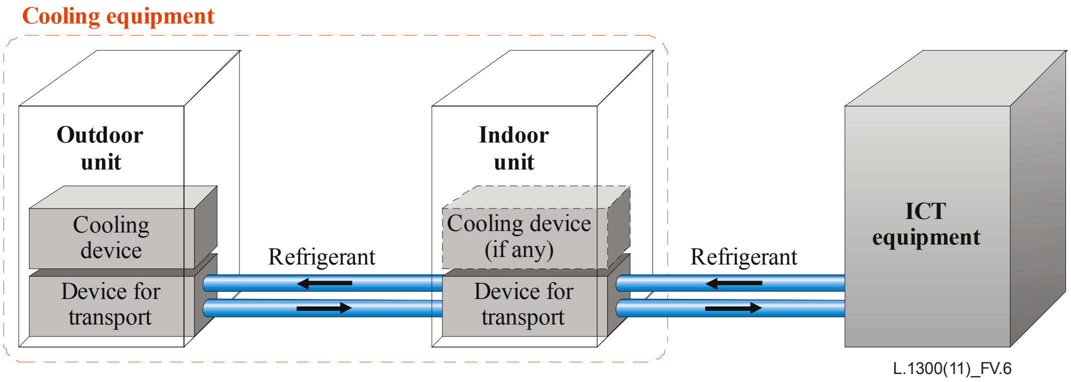


Figure 6 – General configuration of cooling equipment

NOTE – If the temperature and amount of refrigerant cannot be obtained from the cooling equipment, it can be estimated by using alternative data that can be obtained from the cooling equipment and from static data of the cooling equipment.

Take the amount of refrigerant supplied from the indoor unit of cooling equipment as an example. This corresponds to the supply air volume for cooling equipment using air as the refrigerant. With certain types of cooling equipment, the supply air volume cannot be obtained as dynamic data. In this case, the fan speed, if available, can be used to estimate the supply air volume. Static data such as the number of fans and the sectional area of each fan can be used for estimation.

Since available data from cooling equipment depends on the control method, the estimation method using dynamic and static data can be discussed further for each control method at a later date.

- ✓ Equipment ID and description (static data)

  These are necessary for identifying each piece of equipment.

- ✓ Input power of cooling equipment (dynamic data)

  The input power of cooling equipment should be collected as dynamic data in order to check whether the power is reduced by changing the settings of the control parameters.

- ✓ Inlet temperature of indoor unit (dynamic data)
- ✓ Outside temperature (dynamic data)
- ✓ Energy consumption characteristics of device used for cooling the refrigerant (static data)
- ✓ Temperature setting range of refrigerant supplied from the indoor unit to the ICT equipment (static data).
- ✓ Temperature setting step size of refrigerant supplied from the indoor unit to the ICT equipment (static data).

Operation of devices that cool the refrigerant (e.g., compressor, chiller) depends on the difference between the inlet temperature of the indoor unit and the temperature setting of the refrigerant supplied from the indoor unit to the ICT equipment. The outside temperature (e.g., inlet temperature of outside unit as a measurement point) also affects the operation, thus, it should also be collected. Thus, energy consumption characteristics of devices used to cool the refrigerant (i.e., the relation between power consumption, outside temperature, supply temperature of refrigerant, and amount of refrigerant supplied) is necessary to determine the optimal supply temperature setting. Additionally, the temperature setting range and step size of the refrigerant supplied from the indoor unit should be collected, and the optimal supply temperature setting should meet these conditions.

- ✓ Amount of refrigerant supplied from the indoor unit of cooling equipment (dynamic data).
- ✓ Presence or absence of mode controlling the amount of refrigerant supplied (static data).

✓ Rated amount of refrigerant supplied from the indoor unit to the ICT equipment (static data).

✓ Energy consumption characteristics of devices used to transport the refrigerant (static data).

Operation of devices used to transport the refrigerant (e.g., fans, pumps) depends on the setting of the amount of refrigerant. Thus, energy consumption characteristics of the device used to transport the refrigerant are necessary to determine the optimal setting of the amount of transported refrigerant. Additionally, the rated amount of refrigerant is necessary to understand the transport limit.

6.3.3 Power equipment

✓ Equipment ID and description (static data)

These are necessary to identify each piece of equipment.

✓ Efficiency characteristics (i.e., load percentage versus efficiency) (static data)

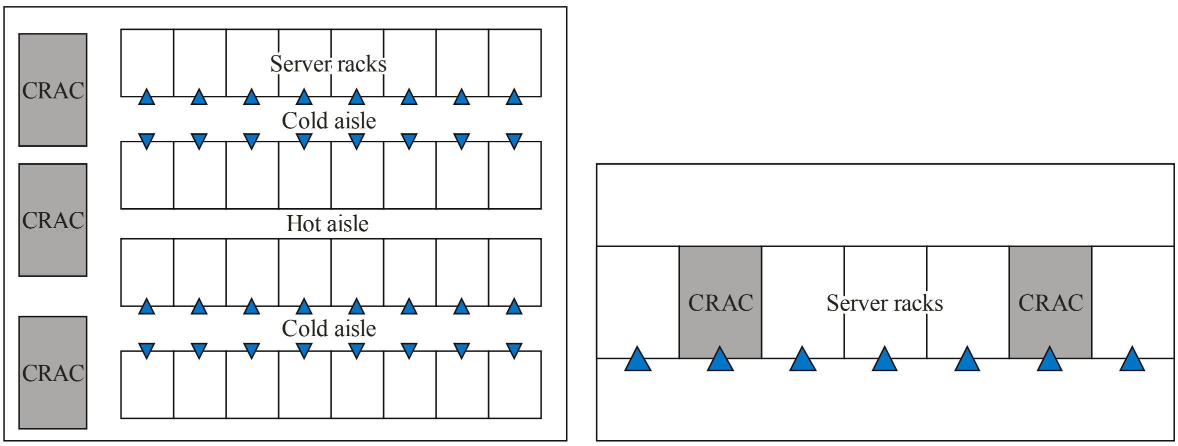
Power equipment has individual efficiency characteristics, and such equipment should be operated at high efficiency in order to save power. Efficiency characteristics are necessary as static data to determine the optimal operating point of power equipment.

6.3.4 Equipment configuration

✓ Configuration of server room (static data)

Figure 6 illustrates a common configuration of a server room, which depends on the cooling method. As shown in Figure 7(a), a common cooling method in data centres is to cool the whole server room by supplying cold air from cooling equipment to cold aisles via a free access floor. In addition, installing modular cooling equipment in rack rows, as shown in Figure 7(b), is an efficient method for cooling racks with high heat density.

To control multiple pieces of cooling equipment in a coordinated way, it is necessary to determine which cooling equipment should be preferentially controlled in response to the operation status of ICT equipment. Configuration information of the server room helps to understand the cooling zone of each piece of cooling equipment and the preferential order of control.



(a) Server room cooling system (b) Rack cooling system

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Figure 7 – Common configuration of a server room

✓ Connection between ICT equipment and power equipment (static data)

To control the power supply of ICT equipment, knowing which ICT equipment is connected to which power equipment is necessary as static data.

7 Summary of minimum data set and gap analysis with other standardization works

The minimum data set necessary for evaluating energy efficiency and for controlling data centre equipment for power saving in data centres is summarized in Table 5. Dynamic information necessary from each type of equipment is shown in Table 5(a), while an example of static information that the facility manager manages, such as equipment specifications, is shown in Table 5(b). Note that a comparison with data sets discussed in other standardization works (ECMA and ETSI) has been added to Table 5 (a). A "✓" in the table indicates that the data is included in the data set.

ECMA is working on "Smart Data Centre Resource Monitoring and Control" [b-ECMA], which defines the data set necessary for resource monitoring and control in data centres, while ETSI ES 202 336 [b-ETSI ES 202 336] is working on a monitoring/management interface of infrastructure equipment. In [b-ECMA], servers and air conditioners are included in the scope. Most of the minimum data set in Table 5(a) is covered in [b-ECMA], but the amount of refrigerant supplied is not covered. On the other hand, [b-ETSI ES 202 336] focuses on air conditioning equipment and power equipment. The minimum data set in Table 5(a) is covered in [b-ETSI ES 202 336].

Table 5 – Minimum data set for evaluating energy efficiency and for controlling data centre equipment for power saving in data centres

(a) Dynamic information necessary from each type of equipment

Type of equipment		Purpose	Data set		Data flow direction	Other data sets	
						ECMA	ETSI ES 202 336
ICT equipment		Evaluation and control	Input power		G	✓	(Note 1)
		Control	Inlet temperature		G	✓	
			Power state (shutdown, sleep, active)		G	✓	
			Power state (shut down, activate)		S	✓	
Facility equipment	Cooling equipment	Evaluation and control	Input power		G	✓	✓
		Control	Inlet temperature of indoor unit		G	✓	✓
			Outside temperature		G	✓	✓
			Amount of transport of refrigerant from indoor unit to ICT equipment	Supply airflow volume (if refrigerant is air)	G/S		✓ (Note 2)
				Supply water volume (if refrigerant is water)	G/S	(Note 3)	
			On-off state		G/S	✓	✓

			Temperature of refrigerant from indoor unit to ICT equipment	Supply air temperature (if refrigerant is air)	G/S	✓	✓
				Supply water temperature (if refrigerant is water)	G/S	(Note 3)	
	Power equipment (UPS, rectifier, PDU)	Evaluation	Output power		G	(Note 4)	✓
NOTE 1 – [b-ETSI ES 202 336] limits its scope to facility equipment. NOTE 2 – "Fan speed" is included in [b-ETSI ES 202 336-6] draft. Supply air volume can be calculated by using static data such as number of fans and sectional area of each fan. NOTE 3 – Cooling equipment using water as a refrigerant is not included in the scope. NOTE 4 – Scope of ECMA's data set is monitoring and control, not evaluation.							

(b) Example of static information that the facility controller manages

Type of equipment	Data set
Configuration	Configuration of the server room
	Connection between ICT equipment and power equipment
ICT equipment	Equipment ID and description
	Operating temperature range
Cooling equipment	Equipment ID and description
	Energy consumption characteristics of devices used to cool the refrigerant
	Energy consumption characteristics of devices used to transport the refrigerant
	Presence or absence of the mode controlling the amount of refrigerant transported
	Temperature setting range of refrigerant supplied from the indoor unit
	Temperature setting step size of refrigerant supplied from the indoor unit
	Rated amount of refrigerant supplied from the indoor unit
Power equipment	Equipment ID and description
	Efficiency characteristics

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