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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

Smart energy solutions for data centres

Recommendation ITU-T L.1381

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.1381

Smart energy solutions for data centres

Summary

Recommendation ITU-T L.1381 considers a smart control strategy for the entire energy system, including power-feeding and cooling solutions, of data centres to achieve higher energy efficiency and to decrease overall energy consumption.

Firstly, for a multiple energy input system, including photovoltaic (PV) solar panels, wind, fuel cells, the electrical grid, power generators and batteries, can be connected to a system. Recommendation ITU-T L.1381 considers how to control these different energy inputs in a smart way to increase energy efficiency and to decrease carbon emissions. In addition, for smart cooling systems, Recommendation ITU-T L.1381 considers how to use outside cool air and maximize utilization of information and communication technology (ICT) side cooling, e.g., ICT rack cooling, row cooling methods and liquid cooling.

Recommendation ITU-T L.1381 focuses on smart energy solutions for data centres to achieve green and sustainable goals, including those which are environmentally friendly, decrease carbon emissions, increase energy efficiency and extend product life.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
1.0	ITU-T L.1381	2020-06-29	5	11.1002/1000/14305

Keywords

CCHP, data centre, direct AC mains supply, evaporative cooling, green energy, liquid cooling, Smart energy, smart environmental parameters controlling solution.

* 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/11.1002/1000/114305-en>.

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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.

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Recommendation ITU-T L.1381

Smart energy solutions for data centres

1 Scope

This Recommendation establishes requirements for data centre smart energy solutions, including those for smart power feeding, cooling and safety. This Recommendation considers energy efficiency and environmental impacts for all solutions, including combined cooling heat and power (CCHP) systems, direct grid supply, green energy system, liquid cooling, evaporative cooling and smart control of environmental parameters.

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

This Recommendation uses the following terms defined elsewhere:

3.1.1 photovoltaic (PV) system [b-ITU-T L.1380]: A system composed of solar cell array, solar array energy converter, AC/DC power supply and related power distribution elements (e.g., circuit breakers), that can be coupled to batteries.

3.1.2 smart energy [b-ITU-T L.1380]: A power system that uses a smart control technique system to autonomously combine various energy supplies according to the working conditions of power supply and load.

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 liquid cooling technique: Direct removal of the heat from electronic elements in devices using liquid for heat exchange.

3.2.2 evaporative cooling technique: Direct removal of the heat from electronic elements in devices situated in dry and hot areas using liquid evaporation.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AC	Alternating Current
CCHP	Combined Cooling Heat and Power
CFC	Chlorofluorocarbon
COP	Coefficient Of Performance

DC	Direct Current
DEC	Direct Evaporative Cooling
ICT	Information and Communication Technology
IEC	Indirect Evaporative Cooling
PUE	Power Usage Effectiveness
PV	Photovoltaic
UPS	Uninterruptible Power System

5 Conventions

None.

6 Combined cooling heat and power solution

A CCHP solution, which is usually arranged near the user, uses natural gas as a primary energy source to generate power, and meanwhile uses waste heat of the gas generator to produce cooling or heating power. Both grid power and a diesel generator are also required to ensure reliability of the energy supply. A typical structure of a natural gas distributed energy system for data centres is shown in Figure 1.

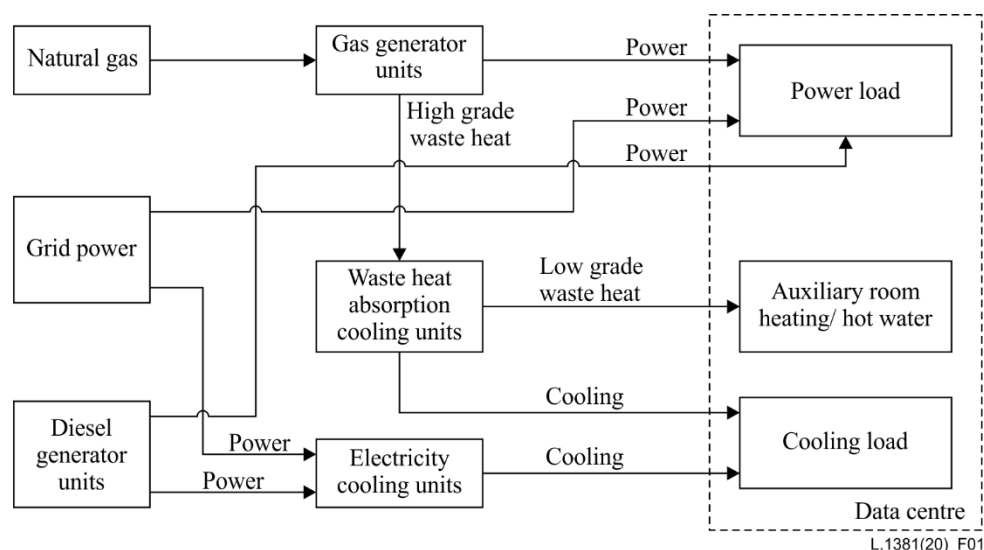


Figure 1 – Combined cooling heat and power system structure for data centres

6.1 Main units requirement

Natural gas generator units are mainly divided into two types according to their technology: one is the gas turbine and the other is the gas internal combustion engine.

The gas turbine generator unit is an internal combustion-type power machine that uses continuously flowing gas to drive the impeller to rotate at high speed and convert the energy of the fuel into mechanical energy to drive the generator.

The internal combustion engine generator unit uses a heat engine. By burning the fuel inside the machine, the heat energy released is directly converted into mechanical energy to drive the generator.

The waste heat absorption cooling unit uses waste heat discharged from the gas turbine or internal combustion engine as a heat source and the water as a refrigerant; a lithium bromide aqueous solution

is used as the absorbent. The water absorbs heat in a low-pressure vacuum environment, while the lithium bromide solution absorbs water vapour easily, making the equipment capable of cooling.

Considering reliability requirements, the energy supply system used in data centres can employ grid power and an electric cooling unit as the backup power source and cooling source, respectively. A diesel generator unit is also an option when the grid cannot be used.

6.2 Control strategies

A CCHP system is characterized by multiple input energy sources and multiple types of output. It must predict and track changes in user load demand and automatically adjust its own complex system to improve energy efficiency in meeting user needs. The level and advantages of system integration require implementation of automatic control and operational adjustment techniques.

If energy sources are in normal work mode, the system operates in two ways to economize on the time-dependent cost of electricity.

- (1) When the cost of electricity is high, usually during the daytime, the system uses natural gas alone as energy source to provide power, cooling and heating through gas generator units and waste heat absorption cooling units for the whole data centre, while the grid and diesel generator are in standby mode.
- (2) When the cost of electricity is low, usually at nighttime, the system uses the grid alone to power information and communication technology (ICT) equipment and electric cooling units for the whole data centre, while the diesel generator and natural gas are in standby mode.

When faults occur, the system should operate as follows.

- (1) If the grid fails, the gas generator provides power to the ICT equipment while the waste heat absorption cooling units cool the whole data centre.
- (2) If the gas supply fails, the grid provides power to the ICT equipment and electric cooling units cool the whole data centre.
- (3) If both the grid and gas supply fail, the diesel generator units start to provide power to the ICT equipment and electric cooling units cooling the whole data centre.

7 Direct alternating current mains supply solution

With the requirement for sustainable development of ICT, power supply has become a significant issue. Power efficiency enhancement is one of the most important methods of deriving maximum power from an electrical field.

Because alternating current (AC) mains are increasingly reliable, ICT power supply sourcing is gradually progressing from the "1 + 1" AC uninterruptible power system (UPS) dual-way mode to direct from AC mains, further increasing power efficiency.

See Figure 2.

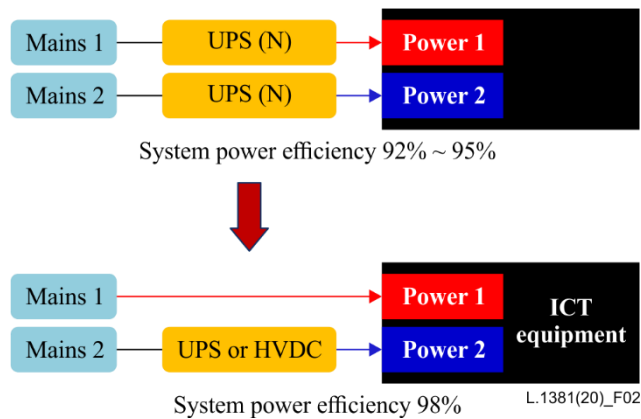


Figure 2 – System promotion from 2N uninterruptible power system to direct alternating current mains supply solution

This direct AC mains supply solution is a kind of hybrid power supply, in one way, it can be supplied from the AC mains and the other with AC UPS or UP to 400 V direct current (DC) system. The specific framework is shown in Figure 3.

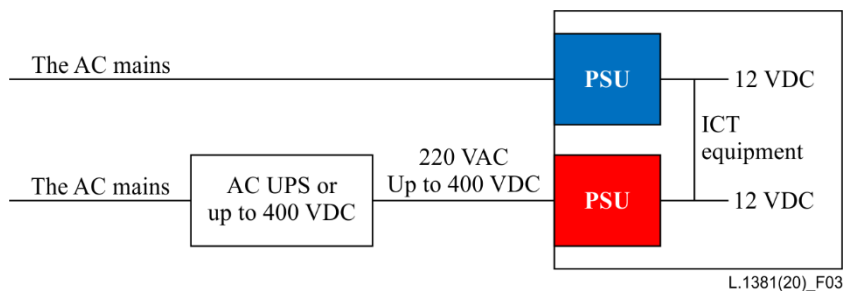


Figure 3 – Direct alternating current mains solution framework

If one of these fails, such as in abnormal power supply of AC mains (amplitude or frequency of voltage), the circuit switches to the other way to get the uninterruptible power supply.

A direct AC mains supply is more stable than a UPS because it is less subject to power switching. Furthermore, a direct AC mains supply can decrease power loss on the circuit, to give a power efficiency value of about 98%.

When the AC UPS/up to 400 VDC is on stand-by, there is inevitable no-load loss. In other words, it is not 100% sure that the highest power efficiency can be obtained when the load rate is 100% from the direct AC mains power supply.

So it is proposed that a smart power supply be used, which can calculate in real time the power efficiencies of the AC mains and AC UPS/up to 400 VDC circuit, respectively, and regulate smartly the ratio of output powers of these two power circuits to achieve higher system energy efficiency. This kind of electrical power supply is smart, because it is based on relevant data collection and high-speed computing techniques to determine how to automatically fix the output power ratio between the two different power supplies, namely the direct AC mains circuit and AC UPS/up to 400 VDC circuit.

A 12 VDC ICT device is chosen and installed together with an embedded DC power supply in an ICT device pack. The switching mode of the power supply is $N + N'$, where N is the number of modules of AC/12 VDC with the AC mains power supply and N' is the number of modules that are up to 400 VDC/12 VDC with an up to 400 VDC power supply.

The smart regulation module in an embedded power supply can regulate the output power ratio between two different modules to increase system power efficiency.

8 Green energy solutions

Because the energy consumption of ICT equipment is increasing rapidly, green energy is one option to decrease the environmental impacts of data centres. The power supply structure is shown in Figure 4.

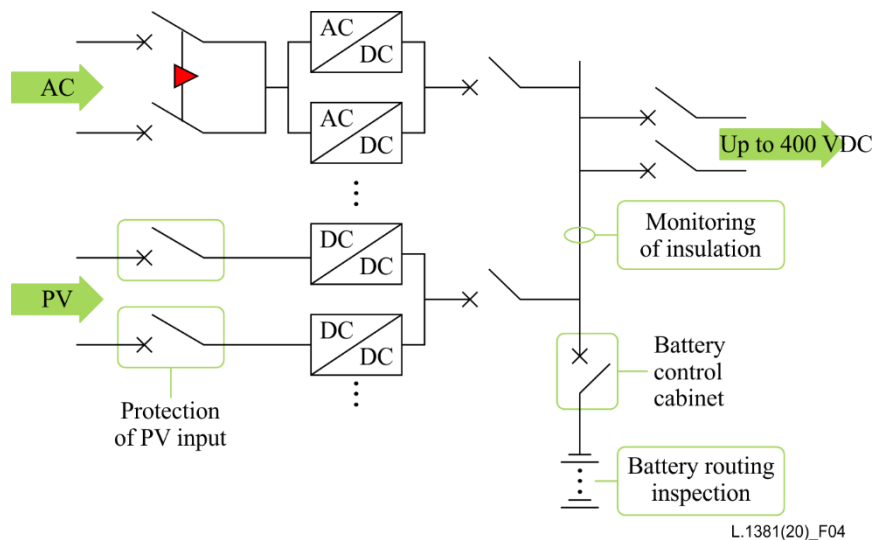


Figure 4 – PV and the mains hybrid solution

The system can maintain maximum output power by adjusting the output voltage in a smart way, by which the output voltage of the rectifiers that are connected to the solar photovoltaic system is higher than that of the rectifiers connected to the AC mains. When the output current of the PV system is lower than the load current, i.e., if the PV system output power is not sufficient for the load power, the PV output voltage decreases automatically to a value equal to the voltage of the rectifier connected to the AC mains, so that the whole ICT equipment is powered by PV and the mains together. The most important is the output voltage of the rectifiers that are connected to the PV system and the AC mains should be dynamically adjusted according to the load power, so that the whole system is controlled by a smart power solution.

Figure 5 depicts a typical PV energy system configuration, including a PV energy system consisting of one or more PV panels, DC/AC inverters and battery systems. PV panels convert the solar rays into electricity and generate DC, which is converted into AC by a DC/AC inverter. A battery system may be used to store the electricity generated for later discharge to the electrical grid or to absorb the fluctuation of output power from PV panels. The AC power converted by the DC/AC inverter feeds back into power loads or cooling loads in data centres.

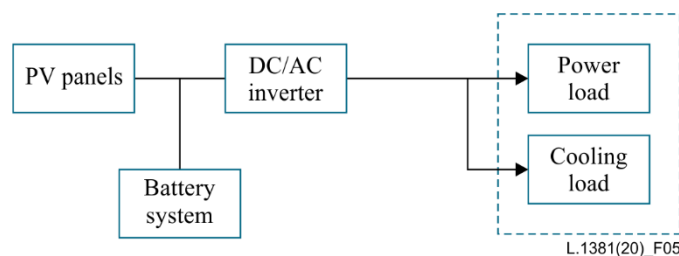


Figure 5 – Photovoltaic energy system solution

9 Liquid cooling system

Based on the way in which heat-emitting electronic elements and refrigerant are in contact, the mode of liquid cooling can be normally divided into three types: freezing plate; spray; and immersion. See clauses 9.1 to 9.3.

9.1 The freezing plate type of cooling

In practice, the freezing plate is usually installed with the heat-emitting electronic elements, and the heat is removed by the refrigerant passing through the freezing plate. This setup is mainly aimed at large-scale heat emission in servers, while other electronic elements with small-scale heat emission must rely on air-cooling. Therefore, the liquid cooling of servers with a freezing plate is also called dual air and liquid cooling. During operation, there is no need for the refrigerant in the freezing plate to contact the cooled electronic elements directly, so this setup has high safety. The system structure is shown in Figure 6.

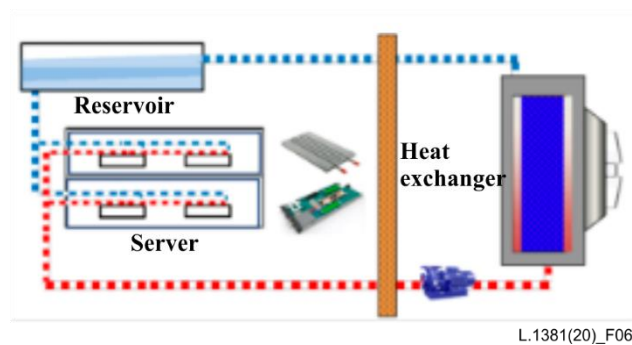


Figure 6 – Freezing plate type of cooling solution

9.2 Spray type of cooling

This cooling method requires holes to be drilled at the top of servers to allow entry of liquid. The refrigerant is then sprayed on to heat-emitting parts based on their specific position and volume as shown in Figure 7 to achieve server cooling. It is important that the cooling efficiency be high, because the sprayed liquid comes directly into contact with the electronic elements cooled. The disadvantage is that the liquid evaporates when in contact with materials at high temperature, meaning refrigerant vapour and droplets can spread outside the server cabinet, which impairs ambient cleanliness in the data centre and maybe adversely affects other devices.

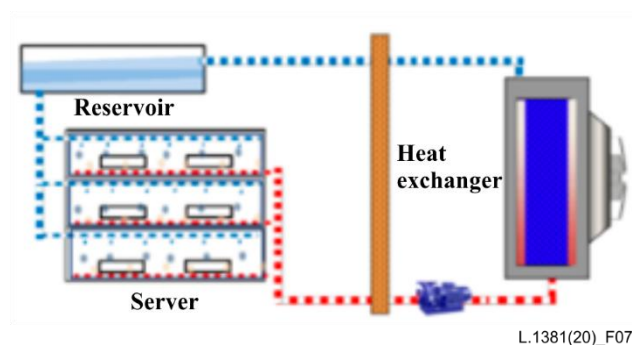


Figure 7 – Spray type of cooling solution

9.3 Immersion type of cooling

Heat-emitting electronic elements are immersed in refrigerant and heat removed by its recycle flow is a typical direct-contact liquid cooling method. The efficiency of heat dissipation is much higher and the noise much less than those of the freezing plate type of cooling. So, when the density of heat

is high, the immersion type is a better cooling choice. In practice, the technique can be achieved by both phase-change and single-phase cooling and the heat can be dissipated through the use of a dry coil and cooling tower.

9.3.1 Phase change type of cooling

In this type of cooling, the refrigerant changes phase in the process of heat dissipation. The phase change means that the efficiency of heat exchange is high, but control is complicated. The pressure changes during the phase change process, so container requirements are strict to avoid refrigerant contamination. An example is shown in Figure 8.

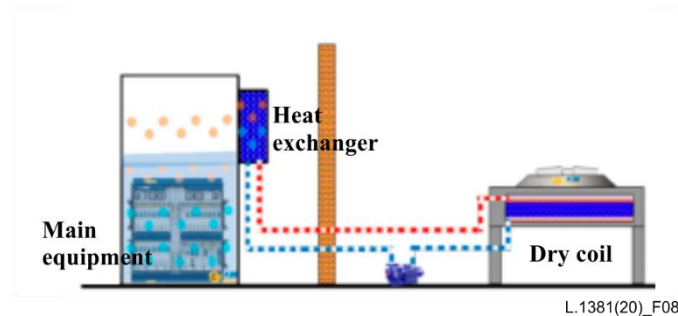


Figure 8 – Phase change liquid cooling solution

9.3.2 Single phase type of cooling

In this type of cooling, the refrigerant remains in the liquid phase throughout the whole process of heat dissipation. The boiling point should thus be high to facilitate control of refrigerant volatilization and compatibility with electronic elements of servers. Compared with phase-change liquid cooling, efficiency is lower. Based on the regulation of application scenario, a dry coil solution, shown in Figure 9, or a cooling tower solution, shown in Figure 10, can be used to dissipate heat.

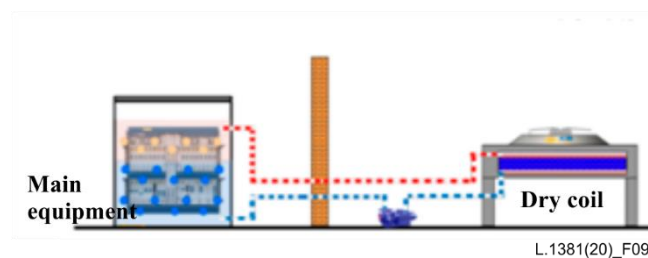


Figure 9 – Immersion + single phase + dry cooling solution

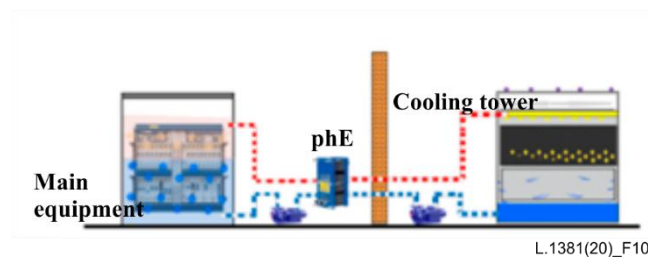


Figure 10 – Immersion + single phase + cooling tower solution

10 Evaporative cooling solution

Evaporative cooling is a recently developed technique that uses liquid evaporation to cool dry and hot areas. The energy of dry air is increased by saturating air with moisture. Unsaturated dry air makes contact with recycled water and is cooled by absorbing the latent heat of water evaporation.

Compared with a mechanical air conditioner, one with evaporative cooling does not use a compressor and consumes power from just a wind turbine and water pump. Also, this new technique exploits a natural cooling source (dry air power) without chlorofluorocarbon (CFC) refrigerants, so the power consumption of operation is low less and the technique is environmental friendly.

Evaporative cooling solution involves wind evaporative cooling (producing cool air) and water evaporative cooling (producing cool water) according to different production method. The corresponding devices are described accordingly as "for wind evaporative cooling" and "for water evaporative cooling". In addition, based on the way of water comes into contact with air, the evaporative cooling solution can be divided into direct and indirect evaporative cooling (IEC) types.

10.1 The principle of direct evaporative cooling

Direct evaporative cooling (DEC) means there is direct contact between water and the air over a large area. Due to water evaporation, the temperature of both water and air decreases while relative humidity increases. Therefore, detectable heat becomes latent heat in the ambient air, this process is called heat isolation, cooling and relative humidification. The whole process of evaporative cooling finishes in a cooling tower, water spray room or other device with heat isolation and humidification. This kind of evaporative cooling technique can be used with direct natural cooling to increase the time period for natural cooling to take effect and reduce power consumption. The working principle of DEC is illustrated in Figure 11.

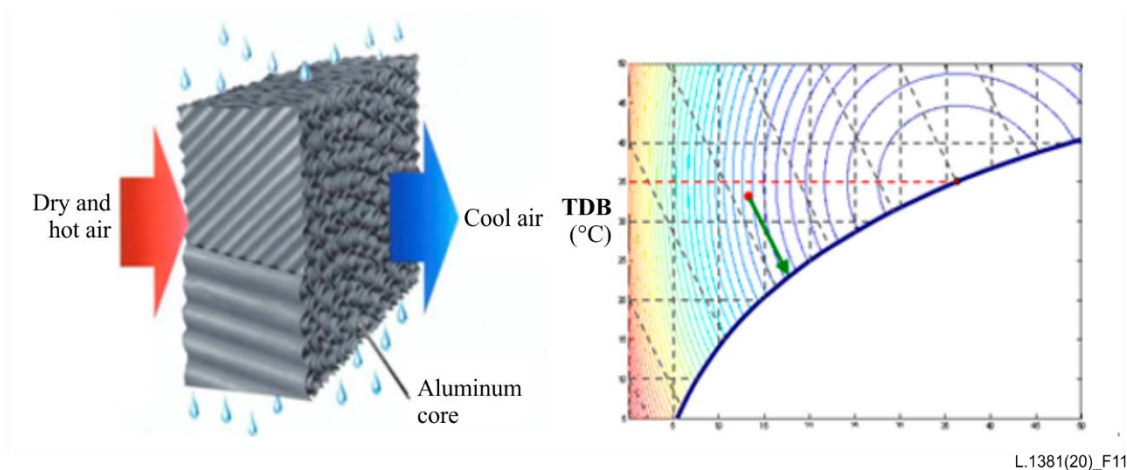


Figure 11 – Principle of direct evaporative cooling

10.2 The principle of indirect evaporative cooling

In this type of cooling, the primary and secondary air are in inverse-parallel flow. In the secondary air, the dry-bulb temperature is reduced by water evaporation from a wet surface. Primary air, separated by a dividing wall, is cooled by heat conduction and only there may have detectable heat exchange. During this process, the dry-bulb and wet-bulb temperature of primary air decreases, while the humidity is constant, consequently, the air flow receives less enthalpy. The limitation of cooling by air flow is the temperature of dew bulb from intake air. The working principle of IEC is illustrated in Figure 12.

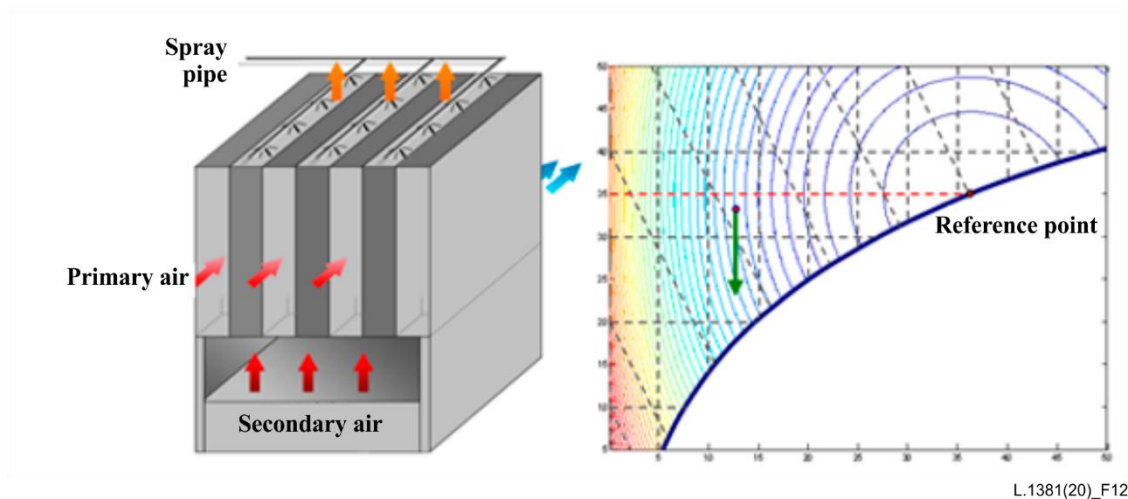


Figure 12 – Principle of indirect evaporative cooling

10.3 The principle of evaporative air cooling system

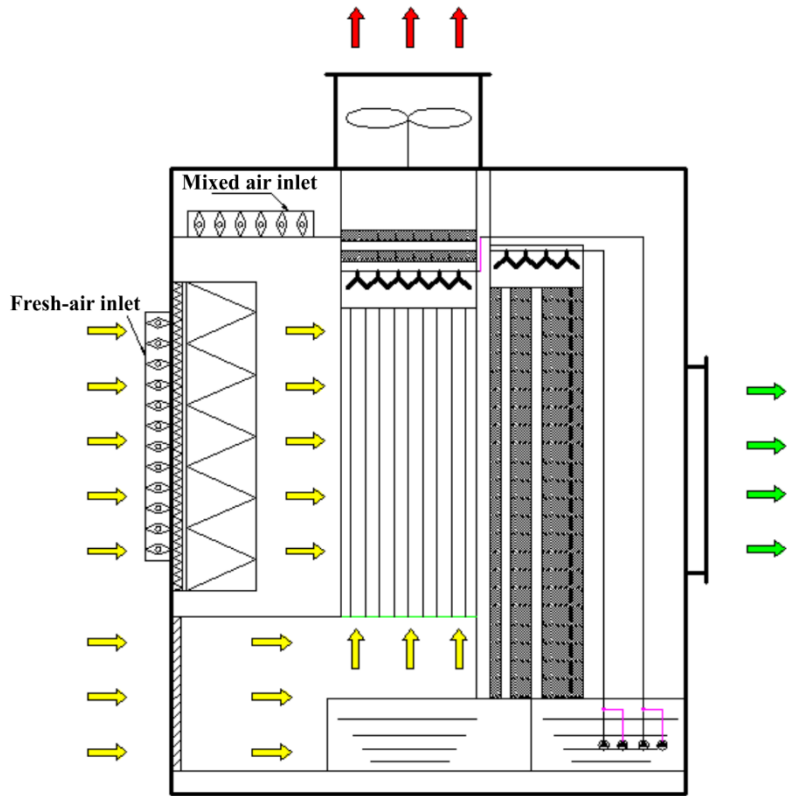
The evaporative air cooling system makes use of both IEC and DEC techniques, which means that the wet-bulb temperature of air can first be reduced by an IEC heat exchanger and then using DEC to get cooling at constant enthalpy.

There are three different application scenarios from this air cooling system, examples are listed in Table 1.

Table 1 – Example of indirect evaporative cooling-direct evaporative cooling air cooling system operation logic with multi-season

No.	Name of scenario	Operation mode	Suggestive value range of outdoor temperature	IEC	DEC	Note
1	Summer No. 1	IEC + DEC	$\geq 25^{\circ}\text{C}$	ON	ON	Filter with wet mode level 3+dry mode level 1
2	Summer No. 2	DEC	5-25 $^{\circ}\text{C}$	OFF	ON	
3	Winter No. 3	DEC + primary air mode (part of it in data centre)	0-5 $^{\circ}\text{C}$	OFF	ON	No spray in primary air

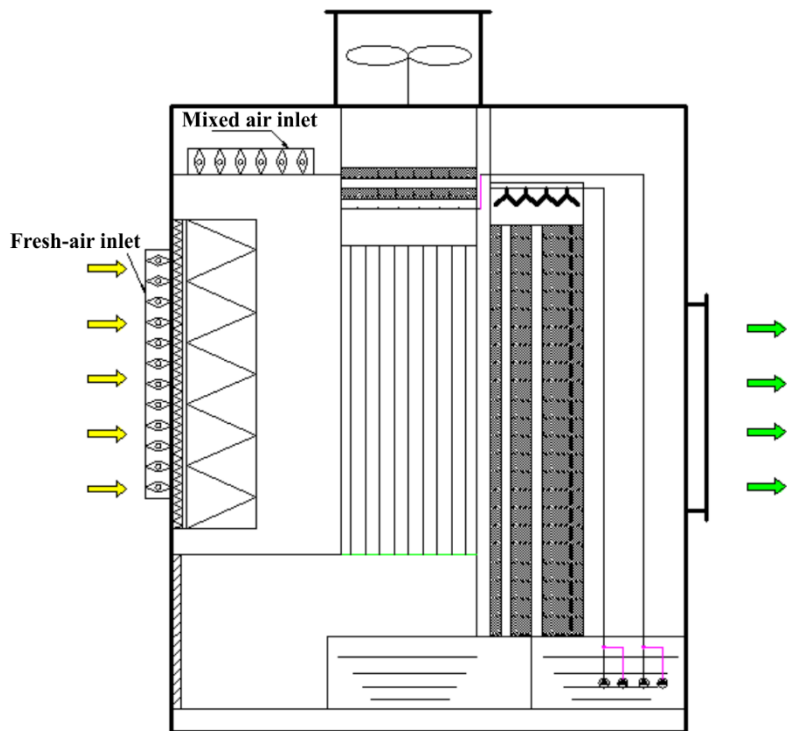
- 1) Summer No. 1: The principle of IEC + DEC operation is illustrated in Figure 13.



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Figure 13 – Mode of summer No. 1

- 2) Summer No. 2: The principle of DEC operation is illustrated in Figure 14.



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Figure 14 – Mode of summer No. 2

- 3) Winter No. 3: The principle of DEC + hybrid air operation (no spray, part of primary air in data centre) is illustrated in Figure 15.

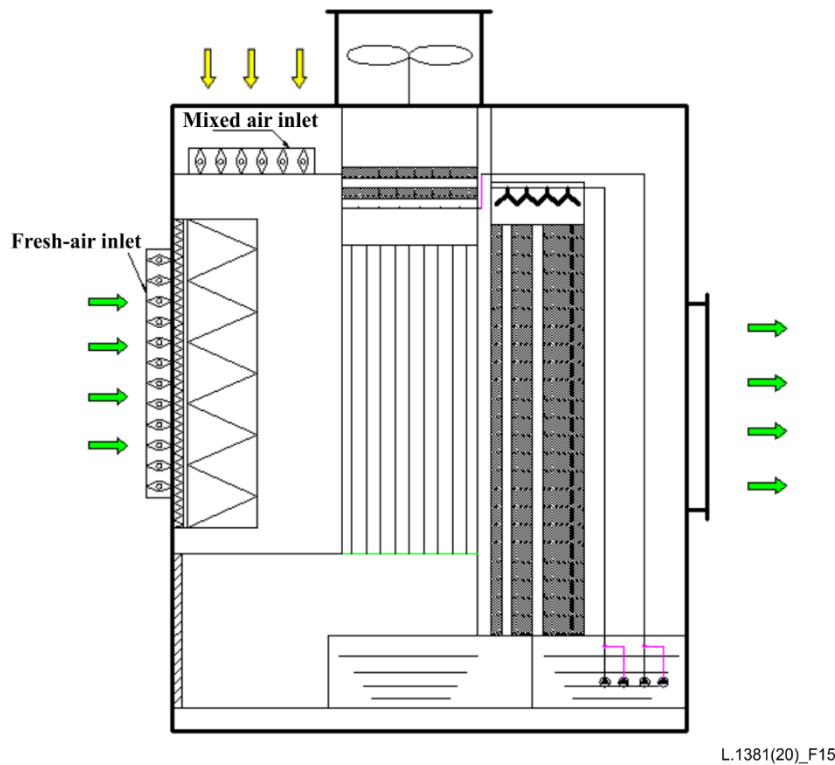


Figure 15 – Mode of winter No. 3

10.4 The characteristics and advantages of an evaporative air cooling system

- 1) There is no need to use a compressor, so the coefficient of performance (COP) of a machine setup is more than 10 and the power usage effectiveness (PUE) can reach 1.1. An evaporative air-cooling system can operate at 30% of the power consumption of a conventional air-cooling system.
- 2) Pure and recycled dry air power are used as the motivating power and eliminate the usage of CFCs and lithium bromide solution as refrigerants. Greenhouse gases are reduced through this type of cooling.
- 3) The system is simple, with constant temperature and air pressure, so that it is easy to maintain and manage. Due to the use of clean dry air power for cooling, there is no harm to people or the environment.
- 4) The maximum input power of an evaporative air cooling system is just 30% of that of a system with a compressor, so electrical power consumption is reduced. In other words, the number of equipment cabinets can be increased for the same electrical power consumption. If there is no need for more equipment cabinets, the cost of low-voltage power system can be directly reduced.

10.5 Applicable fields and conditions

This Recommendation applies especially for series of data centres with different scales in places with good air quality. For places with poor air quality, the IEC + compressor cooling mode can be chosen to greatly increase the time period of natural cooling. When using evaporative cooling solutions in data centres, the following aspects should be considered.

- 1) It is important to ensure that the mode switch basis is in accordance with the climate situation in specific places by analysing annual meteorological parameters.

- 2) It is important to install devices for water conditioning and primary air filtering with different levels according to natural situation of specific places, e.g., quality of water and air. In this way, the system can be maintained within a reasonable range of attenuation.
- 3) It should take into account the principle of adaptation to local conditions that is constructed for a data centre, including such items as natural resources, the climate situation and investor needs. In fact, the use of standby compressor cooling is preferred to make this contribution more convenient for social support.
- 4) Note that optimization of the ratio of volume and cooling quantity of an evaporative cooling system means that the volume of the machine setup can be reduced while maintaining adequate cooling power.

11 Smart control of environmental conditions

11.1 Smart tracking of temperature

The air cooling system can track condition parameters in the immediate surroundings (whether they are cool or warm for each air cooling device). The air cooling system should also track changes over day and night and the seasons.

If the system can adjust the indoor temperature smoothly and stably, the working safety of interchanger can be promoted. When indoor temperature increases, the system can automatically decrease the setting value and ensure adequate cooling volume to save power consumption. When the temperature is too low, the system should automatically start a warming output mode to minimize redundant warming and energy waste within the preset ambient temperature range in data centres.

11.2 Smart tracking of relative humidity

The air cooling system has six working modes: cooling, warming, dehumidification, humidification, air flow, standby.

The smart system can maintain indoor relative humidity within the range 40% to 70% and avoid redundant dehumidification to decrease energy loss. When outside the preset relative humidity value range, dehumidification or humidification should start automatically. This kind of dynamic control can make the air cooling system work ideally.

11.3 Smart ON/OFF $N + 1$ redundant function

This function should smartly control the power consumption of an $N + 1$ redundant air cooling system to reduce energy loss. In other words, the system should constantly control the temperature accurately and smartly control the ON/OFF mode of a redundant system according to changes in outdoor temperature.

11.4 Self-adaptation control technique

According to real working conditions from different data centres, a computerized modulation technique can automatically order the number of ON/OFF air-cooling settings to obtain maximum cooling power efficiency under the same system number. Considering the probability of changes in working conditions, the technique can establish the period ordering modulation function for temperature. The order, number of ON/OFF redundant systems and other auto control techniques are based on series of working condition monitoring data, working temperature, number of air cooling systems and position coordinates. The smart system can then establish a mathematical model for simulation of the optimal arrangement of the temperature field and then determine automatic and effective ordering and control. On this basis, with the same cooling power, optimum efficiency is reached.

See Figure 16.

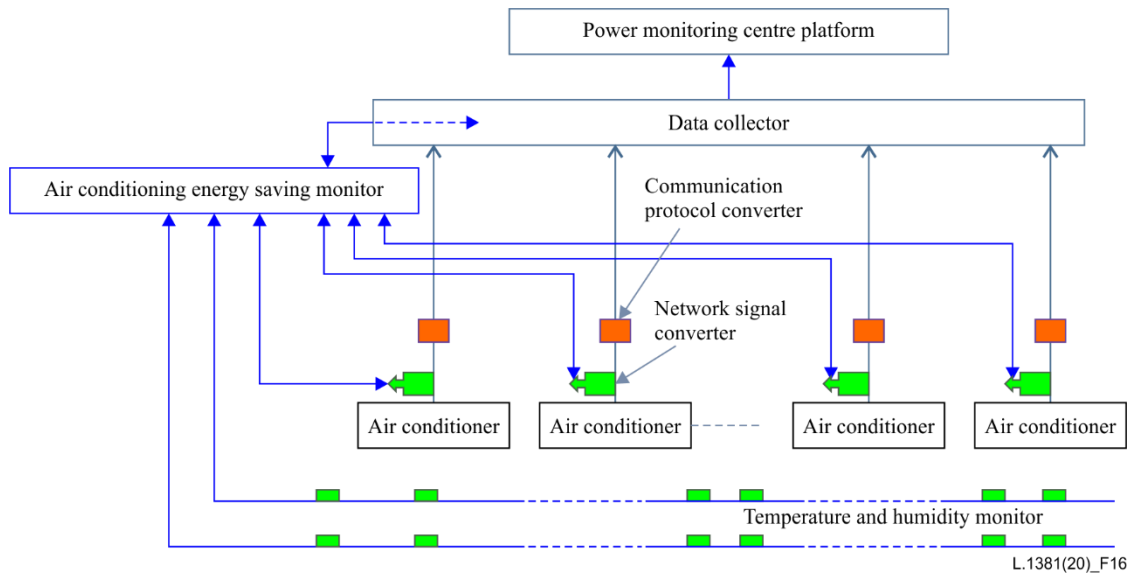


Figure 16 – Smart control of cooling system

Bibliography

[b-ITU-T L.1380]

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Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities
Series Z	Languages and general software aspects for telecommunication systems