

Huawei Data Center Facility Certification Training

HCIA-Data Center Facility

Trainee Guide for Data Center Facility Engineers

ISSUE:2.0



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About This Document

Overview

This document is applicable to the candidates who are preparing for the HCIA- Data Center Facility exam and the readers who want to understand EHS safety knowledge, Development History and Trend of Data Center, Working principles and main product categories of the 8 Subsystems of the Data Center Facility. The 8 subsystems of the data center facility are as follows: power distribution system, cooling system, integrated cabling system, monitoring system, fire extinguishing system, lightning protection and grounding system, cabinet system, and interior decoration system.

Description

This guide Contains 11 chapters, covering EHS safety knowledge, Development History and Trend of Data Center, Working principles and main product categories of the 8 Subsystems of the Data Center Facility. The 8 subsystems of the data center facility are as follows: power distribution system, cooling system, integrated cabling system, monitoring system, fire extinguishing system, lightning protection and grounding system, cabinet system, and interior decoration system.

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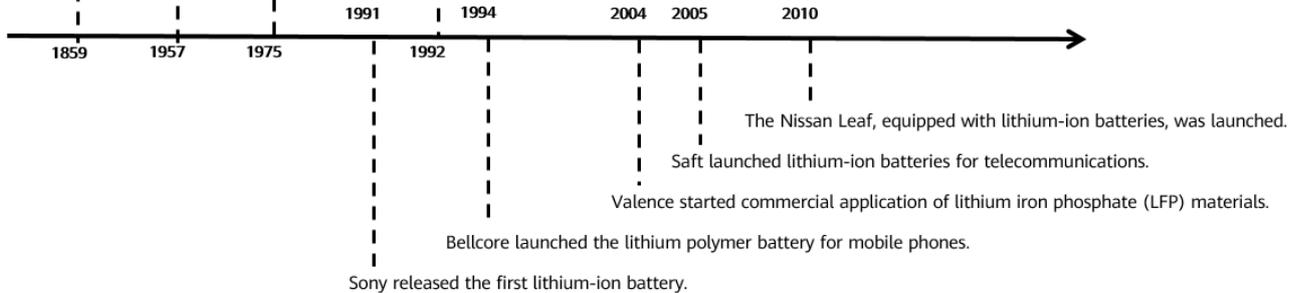
6.2.1 History

French physicist Gaston Planté invented the (open-type) lead-acid battery.

Sonnenschein invented the gel battery.

Gates Corporation applied for the invention patent of the valve regulated lead acid (VRLA) battery.

The use of VRLA batteries increased significantly in Europe and the Americas.
In Asian countries, the telecommunications sector advocated the use of VRLA batteries.



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1 EHS Introduction

1.1 Introduction

1.1.1 Foreword

The document describes the various safety accidents caused by misoperation and lack of relevant safety knowledge in practice and introduces corresponding ways to avoid them, with a view to ensuring a safe environment.

1.1.2 Objectives

Upon completion of this task, you will be able to:

- Understand the importance of safety training,
- Understand causes of accidents in work,
- Understand ways to avoid accidents,
- Understand how to implement protection.

1.2 Introduction to EHS

1.2.1 Concept

EHS is short for environment, health, and safety.

The EHS management system establishes a systematic prevention and management mechanism to minimize various accidents, environmental hazards, and occupational diseases. It improves the safety, environment, and health performance of enterprises.



Figure 1-1 EHS

1.2.2 Functions

Helps enterprises meet the laws and regulations on environment, health, and safety.

Helps protect the environment and meet the requirements of the strategy for sustainable development.

Helps maintain the reputation of enterprises and enhance their competitiveness.

Helps reduce enterprise costs and save energy and resources.

Helps reduce the occurrence of various accidents and ensure the health and safety of employees.

Helps meet public expectations and maintain favorable public and social relationships.

Helps enterprises effectively combine economic benefits, social benefits, and environmental benefits.

1.3 Accident Probability and Personnel Qualification

1.3.1 Heinrich's Law

A famous U.S. safety engineer Heinrich induced Heinrich's Law in 1931. He counted 550,000 mechanical accidents, including non-injury accidents, 1666 fatalities and serious injuries, and 48,334 minor injuries. Later, he came to an important conclusion: the proportion of casualties (serious injuries and deaths), minor injuries, and unsafe behaviors in mechanical accidents was 1:29:300. This law of accidents is internationally recognized.

For different production processes and different types of accidents, the preceding proportion relationship may not be the same. However, this statistical rule indicates that in the same activity, numerous accidents inevitably lead to major casualty accidents. To prevent the occurrence of major accidents, we must reduce and eliminate non-injury accidents, and pay attention to the risks of accidents and near misses. Otherwise, serious accidents will occur.

No accident does not mean no accident will occur.

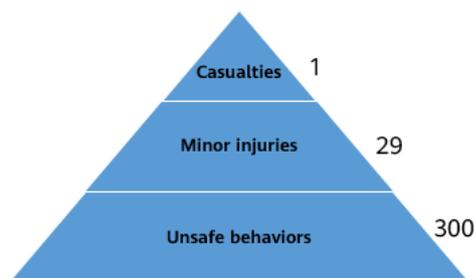


Figure 1-2 Heinrich's Law

1.3.2 Staff's Mental Status Affects the Probability of Accidents

Four states

- Rush
- Complacent
- Fatigued
- Frustrated

Four possible results

- Eyes away
- Absent-minded
- Dangerous areas
- Imbalanced/dragged/clipped

These errors increase the injury risk

1.3.3 Sufficient Preparations to Reduce Fatal Errors

Electricians must have good health and be free of diseases or physiological defects that affect their work, such as mental disease, heart attack, faint, and color blindness.

Operators must be well rested before performing an important operation. Working under fatigue is not allowed.

Huawei equipment can be installed, operated, and maintained only by personnel who have received a thorough training, understand all necessary safety precautions, and are able to correctly perform all operations.

Only trained and qualified personnel are allowed to install, operate, and maintain the equipment.

Only personnel certified or authorized by Huawei are allowed to replace or change the equipment or components (including software).

When operating the equipment, comply with local laws and regulations. The safety instructions in the document are only supplements to the local laws and regulations.

1.4 PPE Protection Overview

1.4.1 PPE Protection

Definition

- The production process is filled with dangerous and harmful factors, which harm workers' bodies and health and even endanger their lives. Personal protective equipment (PPE) refers to articles workers wear during production to avoid or reduce accidents and occupational hazards.

Functions

- Protects our bodies against harms incurred by equipment or facilities during production, namely, to prevent work-related injuries.
- Effectively ensures our health and prevents us from occupational diseases.
- Though all production processes are filled with dangerous and harmful factors, correctly using and wearing PPE is an effective measure to ensure work safety.

Table 1-1 Common operation scenarios and PPE

No	Operation		Mandatory PPE	Recommended PPE
1	Operations involving objects falling and colliding		1. Safety helmet; 2. Protective shoes	Safety net
2	Operations with flying scraps		Shock-proof goggles	
3	Operations involving sharp instruments		Anti-mechanical harm gloves (cut resistant gloves)	
4	Low-voltage (below 1 kV) electric operations		1. Insulation gloves; 2. Insulation shoes	Insulation protective clothing
5	High-voltage electric operations	1-10 kV	1. Insulation gloves; 2. Insulation shoes; 3. Insulation protective clothing	
6		10-500 kV	Electricity shielding clothing	
7	Operations involving high temperature substances		High-temperature resistant gloves	
8	Operations involving low temperature substances		Low-temperature resistant gloves	Low-temperature resistant clothing
9	Operations at heights		1. Safety helmet; 2. Safety belt	Safety net
11	Operations involving toxic substances		1. Chemical resistant gloves; 2. Gas mask	
12	Operations with corrosive substances		1. Anti-corrosion goggles; 2. Acid and alkali resistant gloves; 3. Acid (alkali) resistant clothing	Chemical resistant shoes
13	Operations with pollution risks		1. Acid and alkali resistant gloves; 2. Chemical resistant clothing	Safety net

1.4.2 PPE - Head Protection

Head Protection

- Safety helmet: special protective equipment
 - Three certificates: production license, product qualification certificate, safety sign/safety authentication certificate).
- Common head protection equipment: safety helmet and ESD cap.



Figure 1-3 Safety helmet



Figure 1-4 ESD cap

1.4.3 PPE - Facial Protection

Facial Protection

- Facial protection refers to wearing protective articles to protect your eyes and face from smoke, dust, metal sparks, flying scraps, heat, electromagnetic radiation, laser, and chemical splashes.
- Common facial protection equipment: laser safety glasses, goggles, and protective masks.



Figure 1-5 Welding mask



Figure 1-6 Protective masks

1.4.4 PPE - Hand Protection

Hand Protection

- Gloves worn by workers during production to protect their hands and arms are called “hand protection equipment” .
- Common hand protection equipment: rubber protective gloves (to prevent corrosion against acid, alkali, and other dangerous and chemical substances), finger cots, heat- and cold-resistant gloves, cut resistant gloves, and cotton gloves.



Finger cots



Cut resistant gloves



Cold-resistant gloves



Rubber protective gloves

Figure 1-7 Hand protective equipment

1.4.5 PPE - Foot Protection

Foot Protection

- Protective wears used to protect the workers' feet against hazardous substances and energy.
- Common foot protection equipment: ESD shoes, puncture-proof shoes, high-temperature resistant shoes, insulation protective shoes, and acid and alkali resistant shoes.



ESD shoes



Insulation protective shoes



Puncture-proof shoes

Figure 1-8 Foot protective equipment

1.4.6 PPE - Falling Protection

Falling Protection

- Working at heights refers to operating at a height of 2 m or more with the possibility of falling down, such as installing high towers or cleaning walls of high buildings.
- Securing workers operating at heights to a fixed object using a rope or belt to avoid falling from heights or making a net under the working region to protect those workers who accidentally fall from the heights.



Figure 1-9 Falling protective equipment

1.5 Engineering Construction Safety

1.5.1 General Safety

Personal safety

- Do not operate the equipment or cables during thunderstorms.
- Wear electrostatic discharge (ESD) clothing, ESD gloves, and an ESD wrist strap before operating equipment such as an uninterruptible power system (UPS) and air conditioner. Remove conductive objects such as jewelry and watches to avoid electric shocks or burns.
- In the outbreak of fire, evacuate the building or equipment area and press the fire alarm bell or make a fire call. Do not enter the burning building again in any case.

Grounding requirements (for the equipment that need to be grounded)

- Ground the equipment before installing it. When removing the equipment, remove the ground cable at last.
- Do not damage the ground conductor.
- Do not operate the equipment when the ground conductor is not installed. Before operating the equipment, check its electrical connection to ensure it is reliably grounded.

Regulatory requirements

- Comply with local laws and regulations when operating the equipment. The safety considerations in the product manual are only supplements to the local safety regulations.
- Only qualified and trained personnel are allowed to install, operate, and maintain the equipment.

1.5.2 Handling (Loading) Safety

Manual handling safety

- A quarter of accidents are related to handling.
- Handling accidents account for 6% of serious accidents.
- Most handling accidents cause a loss of more than three workdays.
- Most handling accidents cause back muscle strains or sprains.
- Muscle sprains or strains are mostly caused by improper force and (or) prolonged force. Incorrect posture and excessive repetitive movements are the main causes of muscle sprains or strains.
- Muscle strains and sprains are hard to fully recover.

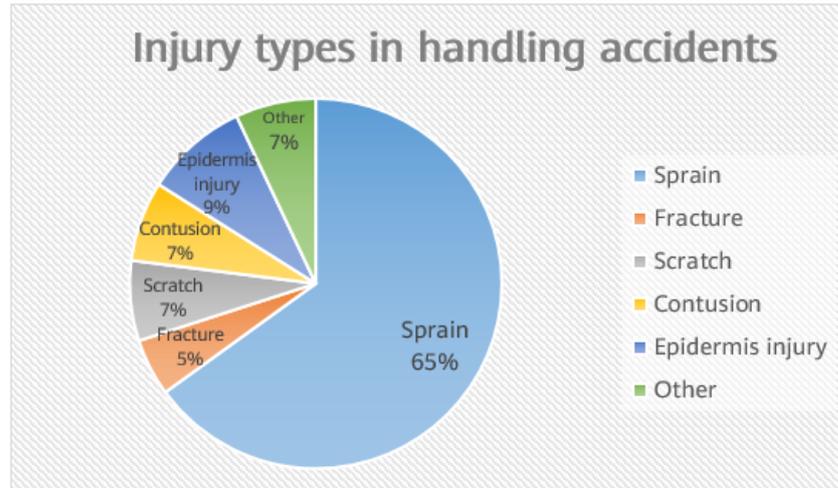


Figure 1-10 Injury types in handling accidents

Preventive measures

- Improve the layout and logistics and storage location of loads.
- Improve the carrying efficiency.
- Try to keep the load you push in the direction consistent with that your eyes see and pull the load instead of carrying it.
- Control the carrying frequency to reduce fatigue.
- Have flexible rest time.
- Ensure adequate space when carrying loads in partnership. Hold the load firm and carry it in a coordinated manner.
- Wear PPE accessories that do not bring safety risks.
- The auxiliary transporting equipment should be in good condition.
- Reduce workload.
- Reduce load volume.
- Facilitate the control of load.
- Keep the surface of the package clean and free from dirt, oil stains, and corrosive products.
- Ensure that the package is free from sharp edges, unfilled corners, and rough surface.
- Avoid scalding or frostbite by using auxiliary equipment and PPE.
- Reduce space obstacles.
- Ensure that the ground or work surface is in good condition.
- Do not carry load on a steep slope.
- When carrying objects on the ground of great height difference, use stairs or slopes as transition to facilitate the load carrying.
- Avoid strong wind interference.
- Lighting.

1.5.3 Mechanical Safety

Drilling holes

- Remove cables inside a cabinet before drilling holes on the cabinet.
- Wear a pair of goggles when drilling holes to protect your eyes from metal scraps.
- Wear protective gloves when drilling holes.
- Prevent metal scraps from falling into the cabinet. Clean up metal scraps in time after drilling.

Fans

- Place the component, screws and tools in a safe place when replacing a component. If any of them fall into an operating fan, the fan and relevant equipment will be damaged.
- Do not insert your fingers and boards into the operating fan until the fan is switched off and stops running when replacing a component near a fan; otherwise, you may get hurt or damage the equipment.



Figure 1-11 Fan

1.5.4 Electrical Safety

Personal safety refers to the safety of personnel in electrical operations. The following lists the two main causes.

Lack of electrical safety knowledge.

Non-compliant acts.

Equipment safety refers to the safety of electrical equipment and auxiliary devices.

Electric Current Effects to the Human Body

- Ventricular fibrillation: When the heart quivers instead of pumps due to disorganized electrical activity in the ventricles. It results in cardiac arrest with loss of consciousness and no pulse.
- Suffocation: When the current flows through the respiratory center in brain, it inhibits the breathing; when excessive current flows through the chest in a certain time, it leads to abnormal contraction of chest muscles, resulting in respiratory arrest.

- Electric shocks also bring intense spasm, causing secondary accidents, such as tumble and falling.

Current intensity: The higher the current, the greater the harms to human bodies.

Energized duration: The longer the energized duration, the lower the body impedance, and the greater the harms of electric shock.

International Electrotechnical Commission (IEC) stipulated that the contact voltage threshold (equivalent to the safe voltage) is 50 V, and that no preventive measures against electric shocks are needed for 25 V or lower voltages.

Sensing current: minimum value of electric current sensed by human bodies. Average sensing current ranges from 0.7 - 1.1 mA. In general, sensing current brings no harm to human bodies.

Let-go current: maximum value of electric current through the body of a person at which that person can release himself or herself. Average let-go current ranges from 10 - 16 mA. In general, let-go current can be tolerated and cause no harms.

Deadly current: minimum value of electric current that endangers life within a short time. 100 mA and higher current causes death. When the current is below DC 50 mA and industrial frequency 30 mA, it does not pose life risks. (So, DC 50 mA and industrial frequency 30 mA are regarded as the upper thresholds of safe current.)

Protective grounding means that a certain point of electrical devices or energized circuits is directly connected to the ground, or a certain point of the de-energized part is manually connected to the ground.

- Working grounding refers the connection to the ground with a view to ensuring the normal operation of the power system, for instance, the neutral point grounding in the three-phase and four-wire low-voltage power distribution system.
- Safe grounding refers to the connection to the ground with a view to ensuring personal and equipment safety, including protective grounding (against electric shocks), surge protection grounding, ESD grounding, and shield grounding.

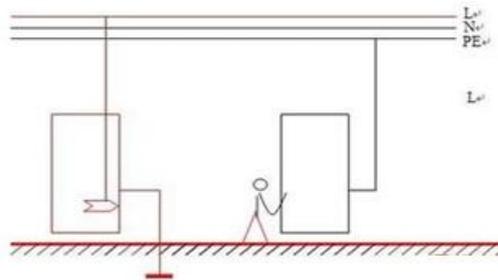


Figure 1-12 Protective grounding

- Note: Metal parts that pose dangerous voltage risks due to insulation damage or other causes must be grounded. Metal shells of electrical devices, such as motors, transformers, switches, and lighting devices, should all be grounded. In common low-voltage systems, ground resistance should be less than 4 ohms.

Protective connecting to neutral

- Refers to connecting the non-energized part of electrical devices in normal circumstances to the neutral wire of the power grid. It is worth noting that in the three-phase and four-wire power system, metal shells of the electrical devices are both

grounded and connected to the neutral wire. This measure is called "repetitive grounding protection."

- Note: Installing fuses and switches in the ground cable loop is not allowed.

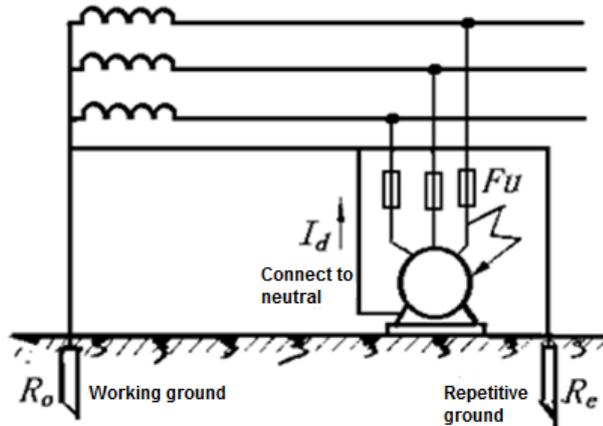


Figure 1-13 Protective connecting to neutral

Surge Protection Measures

- SPD types: Lightning rod, lightning wire, lightning net, lightning belt, and surge protector.

Tips for individual lightning protection

- Do not stay in open areas, mountain tops, ridges, or rooftops.
- Do not stay near iron gates, metal clotheslines, and railway tracks.
- Do not stay in the swimming pool, lakes, or seaside or under isolated trees.
- Close doors and windows to avoid flank-striking lightning or lightning balls.

In general, the lightning rod is used to protect the outdoor power transformation and distribution devices, buildings, and structures. The lightning wire is used to protect the power cables.

The lightning net and belt are used to protect the buildings. The surge protector is used to protect the devices.

Measures against body ESD accidents

- Use ESD floor/shoes/socks (static electricity conducted to the ground from feet). Put on ESD footgear and stand on the ESD floor, mats, and carpets to form a combined grounding.
- Wear an ESD wrist strap and ground it (static electricity conducted to the ground from hands). Discharge the static electricity on the body from hands. The ESD wrist strap is composed of an ESD elastic, snap, spring, resistor, and plug/clip. The inner layer of the elastic is braided with ESD yarns and the outer layer is braided with common yarns.



Figure 1-14 ESD wrist strap

Establish comprehensive safety regulations and rules, and enhance the related education and trainings.

Electrical operations must be performed by qualified personnel. Personnel without related certificates must not maintain or repair electrical devices or perform unauthorized operations.

Electrical device safety

- The electrical devices should be protected from corrosion and moisture.
- The metal shells of electrical devices must be grounded (or connected to the neutral wire).
- Do not use electrical devices over their rated values.

Check the following items of instruments before working.

- Insulation condition.
- Validity period.
- Voltage level.

Implement the work ticket system when checking, maintaining, or cleaning the power-off electrical devices.

To check, maintain, or clean the power-off electrical devices, the following safety measures must be taken.

- Power off.
- Check the power.
- Install the ground cable.
- Hang a sign and set a shelter.

Precautions Against Ground Cable Installation

- All ground cables and the energized parts should be kept a proper distance required by regulations.
- After checking that the device under maintenance is non-energized, promptly ground the device and perform a three-phase short circuit.

- The ground resistance must meet requirements.

Precautions Against Power Check

- Put "Do not switch on." signs on handles that can power on the device.
- Do not move or remove the shelter, ground, or other signs without permission during the construction.

Operations performed after power-off must be carried out under supervision.

Disconnect the power supply before you carry or move electrical devices.

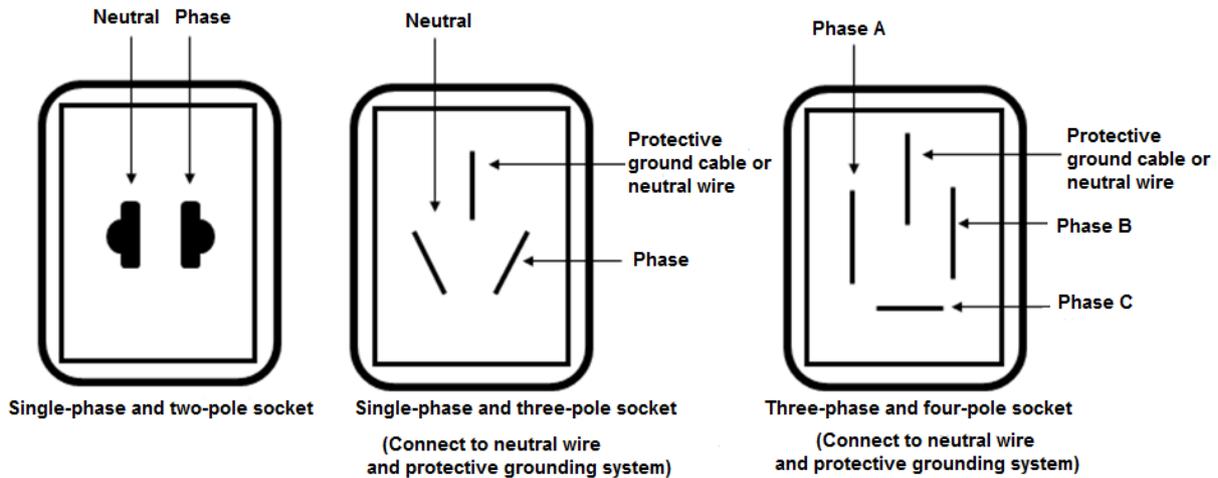


Figure 1-15 Socket

1.5.5 Welding Safety

Welder shells must be grounded or connected to the neutral wire. Only electricians are allowed to install or uninstall the welder power system. The insulation resistance between the winding and iron core as well as between the winding, lead, and shell should not be less than 0.5 mΩ in the primary and secondary winding self-check of the welder.

The welder should be put in a rainproof place with good ventilation. Do not put combustible or explosive articles at the welding site. Wear protective equipment as required before welding.

Welding tongs and cables must be well insulated and securely connected. Wear gloves before changing welding rods. When working in a damp environment, stand on the insulation rubber or wooden floors.

Do not weld pressurized containers or pipes. Power off the electrical devices before welding them.

Disconnect the power supply first before moving the welding cables as the working sites change. Do not climb a ladder holding welding cables.

Clear the welding slag using the electric arc and wear protective glasses in the process to protect yourself.

Outdoor welding operations are not allowed in thunderstorm days.

Obtain a permit from relevant departments before welding in combustible and explosive gas and liquid diffusion areas.

After the welding, disconnect the power supply from the welder, and check the site. Ensure that there is no fire hazard at the site before leaving.

If combustible or explosive articles are stacked near the welding site, do not weld until they are completely removed or effective safety measures are taken.

If a welding machine is on fire, disconnect the power supply from it first.

Extinguish the fire using CO₂ or 1211 fire extinguishers. Do not use the foam fire extinguisher.

Apply for the fire operation approval and surveillance measures in accordance with the site firefighting system before welding.

1.5.6 Battery Safety

- Basic protective measures (before battery installation and maintenance)
- Use dedicated insulated tools.
- Wear protective goggles and take other necessary protective measures.
- Wear rubber gloves and a protective coat to guard against electrolyte overflow.
- Protect a lithium battery from mechanical vibration, collision, punctures, and strong impact. Otherwise, the battery may catch fire.

Battery short circuit

- To avoid battery short circuit, do not maintain batteries with power on.
- Battery short-circuits may cause personal injury. The high transient current generated by a short-circuit may release a surge of energy and cause fire.

Hazardous gas

- Lead-acid batteries in use emit flammable gas. Take ventilation and fireproofing measures at the sites where lead-acid batteries are used.
- The lithium battery is an enclosed battery system and will not release any gases under normal operations. If the lithium battery is severely misused, for example, being burned or thunderstruck, the battery may be damaged, resulting in electrolyte leakage. Because the electrolyte is of organic carbonate nature, it may produce CO₂, CO, and N₂ after being burned.

Electrolyte leakage

- Protect your skin and eyes from electrolyte leakage. If your body meets electrolyte leakage, wash with clean water immediately and visit a doctor.



Figure 1-16 A battery accident in an equipment room

1.5.7 Air Conditioner Safety

High temperature and high pressure

- Misoperation may cause high system pressure, which leads to the refrigerant system to crack or explode.
- Pay attention to high-temperature components, such as the compressor, refrigerant pipe and electric heater.
- Pay attention to high-pressure components, such as the compressor and refrigerant pipe.

Refrigerant frostbite

- Refrigerant leakage may cause frostbite. Take protective measures (such as wearing goggles and antifreeze gloves) when handling refrigerant.
- Pay attention to low-temperature components, such as the evaporator.

High-speed operation

- Pay attention to high-speed rotational components, such as fans.



Figure 1-17 Precision air conditioner

Temperature of the R410a refrigerant can be as low as -52°C the second it ejects from the cylinder, which can instantly frostbite human skins and underlying muscles, and the frostbitten skins become necrotic. In addition, if humans inhale too much refrigerant in a short time, they are likely to be suffocated to death. Therefore, having a general knowledge of refrigerant leak types in operating air conditioners and familiarizing with the related countermeasures are crucial in ensuring the safety of operators.



Figure 1-18 Refrigerant frostbite

Minor leaks: If minor leaks occur in the pipe connection points or welding positions during the system running, tighten the connection ports, or re-weld the faulty positions after the system refrigerant is released. Minor leaks bring no personal injuries.



Figure 1-19 Refrigerant leakage

Before welding the connection point of the indoor and outdoor units, completely exhaust nitrogen from the units, and ensure that related parts are in good condition.

Wear protective goggles and antifreeze gloves when refrigerant is involved in the operation.



Figure 1-20 Goggles



Figure 1-21 Antifreeze gloves

A nitrogen reducing valve must be equipped when operating the nitrogen cylinder.



Figure 1-22 Nitrogen reducing valve

Pipe break or needle valve plug damage: When the air conditioning pipes break or the needle valve plug is damaged, there will be major refrigerant leaks. The following lists the correct way to solve this problem.

Promptly open the doors of the air conditioner cabinets in a safe place.

Evacuate all persons in the air conditioner room.

Open all doors and windows that can be opened.

After refrigerant in the air conditioning system leaks out completely and the air inside the air conditioner room is safe to breathe (no obvious smell), you are allowed to continue the next operation.

- Note: In the event of major refrigerant leaks, do not try to stop the leak.

Refrigerant cylinder damage: When the upper body of the refrigerant cylinder breaks or the safety port bursts, there will be major refrigerant leaks. The following lists the correct way to solve this problem.

Promptly open the doors of the air conditioner cabinets in a safe place.

Evacuate all persons in the air conditioner room.

Open all doors and windows that can be opened.

After refrigerant in the cylinder leaks out completely and the air inside the air conditioner room is safe to breathe (no obvious smell), you are allowed to continue the next operation.

- Note: In the event of major refrigerant leaks, do not try to stop the leak.

Connection pipe damage during refrigerant charging: If leaks occur due to breaks or damage of the connection pipe during the refrigerant charging, promptly close the valves on both sides, and replace the connection pipe. If there is only one valve, (for example, the pipe is connected to the needle valve), promptly close the valve, disconnect the pipe from the other end, and then replace the connection pipe.

- Note: If one end of the connection pipe is disconnected due to leaks at that end, promptly place a heavy object on the pipe so that the high-pressure gas ejection will do no personal harms. Then, proceed following preceding instructions.

Internal and external fans are high-speed rotational components, pay attention to the following instructions when maintaining them.

- When maintaining the fans, motors, or adjacent components (such as fan guards), disconnect their power supply, and lock the power supply hangtag.
- When operating such as maintaining adjacent the fans, prevent dropping tools or other articles in the rotating fans, because broken fans or other pieces flying out might hurt someone.
- Do not wear hangers, such as necklace, employee ID card, and bracelet, when operating rotational components.

1.6 Quiz

1. (Multiple) Which of the following measures can reduce risks during transportation?

- A Control transportation frequency and reduce fatigue
- B Proper use of personal protective equipment
- C Avoid strong wind interference.
- D Good lighting conditions

1.7 Summary

- Introduction to EHS
- Accident Probability and Personnel Qualification
- PPE Protection Overview
- Engineering Construction Safety

2 Data Center Facility Knowledge

2.1 Introduction

2.1.1 Foreword

This slides describe the development, key components, common standards, and common energy consumption indicators of the data center infrastructure.

2.1.2 Objectives

Upon completion of this course, you will:

- Know the history of data center development;
- Know the common standards of data centers;
- Know the composition and energy consumption indicators of data centers;
- Know the Huawei data center products.

2.2 Introduction to Data Center Development

2.2.1 Development History of Global Data Centers

In 1942, the first electronic digital universal computer was born.

Before 1990, data centers were mainly used for government and scientific research applications, but seldom for commercial applications. Data centers were large yet few.

From 1991 to 2000, Internet companies emerged, so did commercial data centers. These data centers were small, but they increased gradually.

From 2001 to 2011, the data volume from governments, the Internet, and financial transactions soared. Governmental and commercial data centers began to develop rapidly.

Since 2012, cloud data centers have become a new trend around the globe thanks to the increase of data center technologies and applications, Internet data centers (IDCs) have been integrated and upgraded. Large scale, professionalization, and environmental protection have become the leading features.

2.2.2 Data Center Infrastructure Development Trend

Modular Data Center

- Small and medium data centers are constructed to be simple, easy to use, reliable, and controllable in operation and maintenance (O&M). Compared with traditional data centers, modular data centers have unparalleled advantages in the four aspects.
 - Integrated modular data centers are constructed quickly and have low requirements on the deployment environment.
 - Modular products can be pre-integrated and pre-commissioned in the factory in advance. They also provide the intelligent management function.
- For large data centers, the power density of information IT equipment is increasing. Modular data centers adopt in-row closely coupled cooling, which greatly improves the cooling efficiency. This adapts to the development trend of high power density.



Figure 2-1 Huawei Modular Data Center

Cloud Data Center

- The application and deepening of cloud computing promote the transformation of data center construction, operations management, and service modes.
 - Data traffic explosion, shared infrastructure, and improved resource utilization drive large-scale data centers.
 - Cloud computing enables flexible expansion, dynamic allocation, and centralized management and control of data centers.
 - The construction of cloud data centers creates new growth points and promote industry adjustment, transformation, and upgrade.
 - As the power consumption of data centers increases, a more efficient and energy-saving cooling system is required.

Environmental Protection

- With the rapid development in informatization, the construction of global data centers is accelerated. Their power consumption accounts for 1.1% to 1.5% of the global total.
- Clean energy, such as wind and solar energy, is increasingly used in data centers.
- There is a call for saving energy and reducing consumption to reduce power usage effectiveness (PUE) of data centers.
 - Energy conservation and consumption reduction are common. However, the future trend is to make them more comprehensive, efficient, and properly regulated.

Intelligent Management

- Inefficient data centers lead to high costs, and data center infrastructure management (DCIM) is of vital importance.
 - Manage and monitor IT equipment, facility equipment, and IT processes in a unified manner.
 - Support resource management and asset management.
 - Support technologies such as real-time information, simulation, and remote monitoring.
 - Intelligent terminals, virtual reality (VR), artificial intelligence, wearable equipment, and Internet of Things (IoT) also promote intelligent management of data centers.

2.2.3 Introduction to Data Center Lifecycle

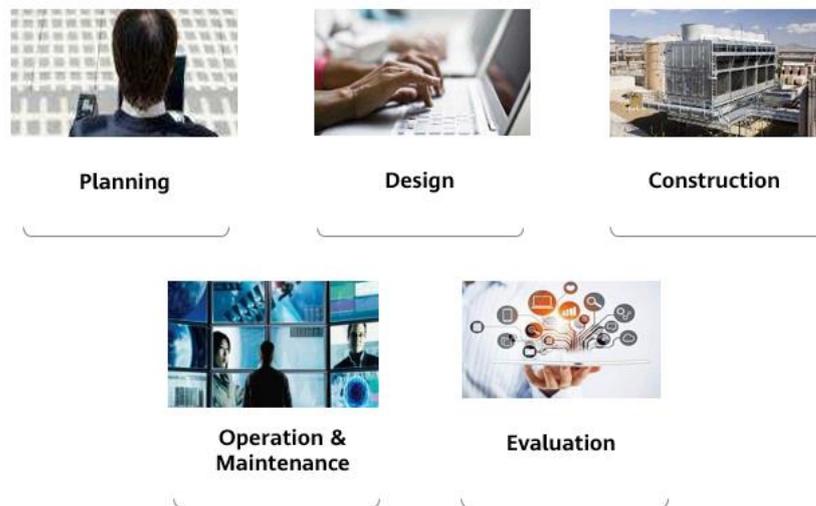


Figure 2-2 Data Center Lifecycle

Plan: This phase is the key to the success of the entire data center project. In this phase, the data center owner and manager need to build the prototype of the system architecture and project budget, and select the model design for the system. They also need to identify and determine the factors that may affect the system design. Once the system concept is defined, it is possible to prepare the site selection assessment.

Design: The core content of the design phase is to convert the planning result into diagrams and construction documents. In this phase, it is equally important to ensure that the right people join the project at the right time. The design team should include IT and design engineers, possibly even architects and mechanical, electrical, and water supply and drainage engineers. The construction team consists of electrical, network, mechanical, low-voltage contractors and subcontractors. The data center owner or manager is responsible for selecting these teams and reviewing all design achievements.

Build: In this phase, the documents of the construction team and the professional skills of the equipment supplier are combined. The phase is an excellent opportunity for the management team and employees to learn and improve. Commissioning can bring valuable documents to help improve equipment operating status. Although commissioning is not completely necessary, it helps the entire team better understand the complexity of

the data center by detecting the response of the entire system to external inputs and external changes.

Operate: This is the longest and costliest phase in the data center lifecycle. It may last for up to 20 years. Successful O&M projects require effective management of environmental health and safety, personnel management, emergency preparedness and response, training, performance monitoring, maintenance, archiving, infrastructure, quality, energy, and finance.

Assess: This phase is often overlooked. However, it actually provides a lot of valuable information and feasibility advice for understanding how the operator and infrastructure system operate. Analyze the power supply, cooling, space capability, and usage trend continuously and periodically to better determine whether the infrastructure meets the design intention. The assessment phase also includes the appraisal of employee efficiency and O&M project performance. In the five phases, O&M mainly involves operation and assessment. To better understand the data center, the O&M team can participate in the planning phase.

2.3 Composition of Data Center Infrastructure

2.3.1 Composition of the Data Center Facility

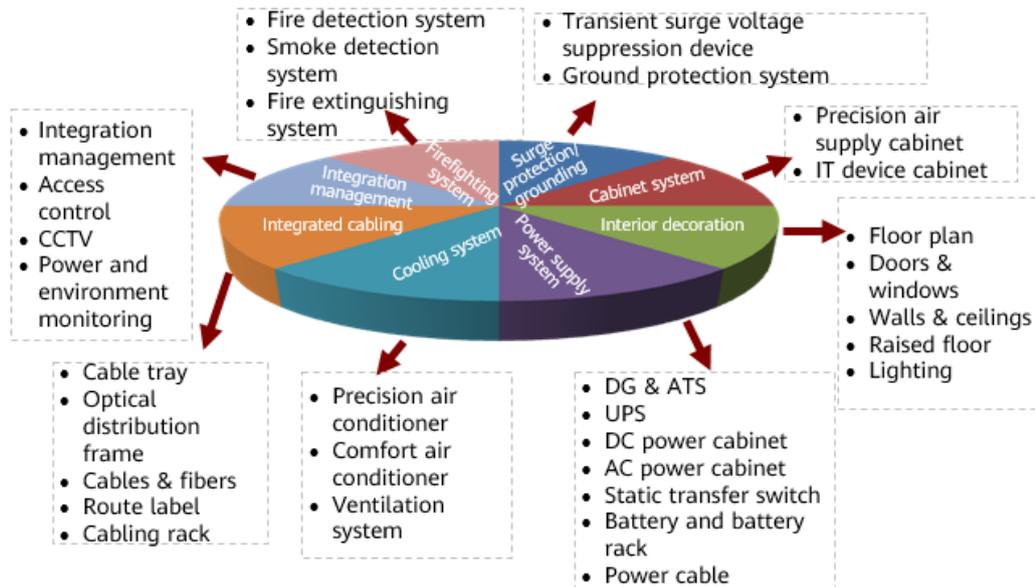


Figure 2-3 Eight subsystems of data center facility

2.3.2 Power Supply System

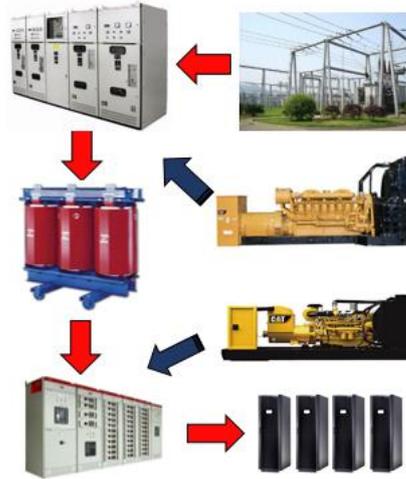


Figure 2-4 Power Supply System

High-voltage power transformation and distribution system: Converts the 6 kV/10 kV/35 kV three-phase mains to 380 V/400 V three-phase mains and distributes power for downstream low-voltage devices.

DG system: As the backup power source, the DG system instantly supplies power to downstream devices once the mains power fails. There are low-voltage and medium-voltage DGs.

Automatic transfer switch (ATS) system: Automatically switches between one mains and the other and between the mains and the DG.

Low-voltage distribution system: distributes the upstream electric energy to various electrical equipment, such as the uninterruptible power system (UPS), air conditioner, and lighting equipment, based on requirements, standards, and specifications.

UPS system: purifies and backs up electric energy, and provides pure and reliable power protection for IT loads.

UPS output power distribution system: distributes the UPS output electric energy to various IT equipment based on requirements and standards.

Rack power distribution system: distributes the electric energy inside the racks.

- 48 V DC power supply: provides safe and reliable power supply for communication equipment.

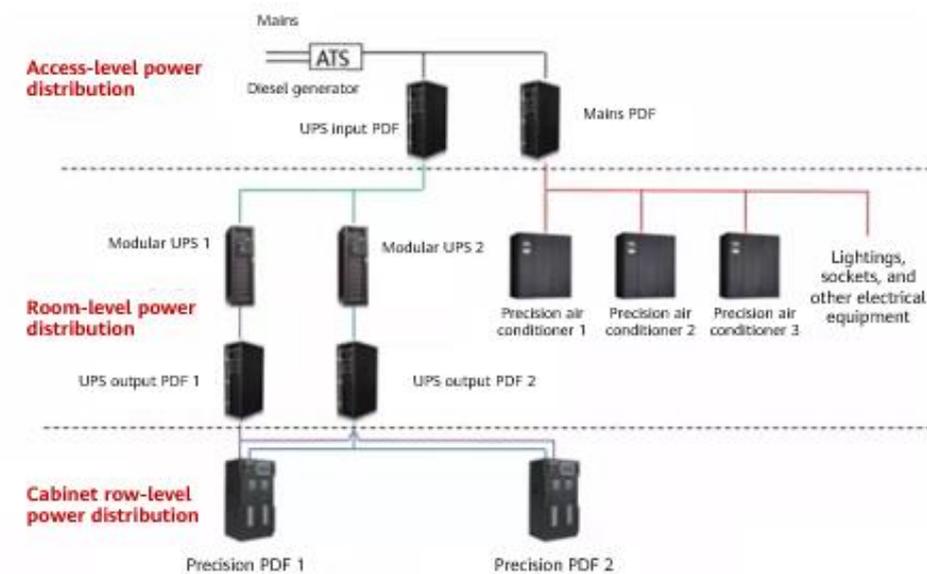


Figure 2-5 Common power distribution architecture of data centers

In addition, the power supply and distribution system in a data center supplies and distributes power for the air conditioning, lighting, and other systems. It ensures the normal operation of the data center.

2.3.3 Cooling System

With the development of the society and the application of new technologies, the power consumption and power density of the data center increase significantly. The cooling system ensures that the equipment in a data center work in a proper environment.

- Large sensible heat: The IT equipment and power devices in a data center dissipate heat through transferring, convection, and radiation, resulting in temperature rise in the equipment room. This type of heat is sensible heat. The heat dissipation capacity of a server cabinet ranges from thousands of watts to dozens of thousands of watts per hour, and the sensible heat ratio in the equipment room can reach 95%.
- Low latent heat: Latent heat is energy that changes the humidity ratio in air but not change the temperature in the equipment room. There is no moisture dissipation equipment in the equipment room. The latent heat mainly comes from staff and outdoor air.
- Large air volume and small enthalpy difference: Because of small latent heat in the equipment room, there is little humidity to be dehumidified. The temperature of air does not need to drop to below the dew point temperature before the air flows through the air conditioner evaporator. Therefore, the effective temperature difference and the enthalpy difference are small.
- Non-stop operation and perennial cooling.
- Multiple air flow modes: In data centers, the air flow mode is determined by heat source and its distribution characteristics, story height, equipment layout, and cables. Downflow, upflow, and regional air flow are the main air flow modes

- Plenum chamber air supply: The air supply of air conditioners in the equipment room generally uses the space under the raised floor or above the ceiling for the plenum chamber air supply. The pressure stabilizing layer formed in the chamber ensures even air flow. The height of the plenum chamber should be lifted as high as possible.
- Strict requirements for temperature and humidity: Over temperature will lead to a higher equipment failure rate and lower reliability of servers and even equipment breakdowns. A high relative humidity may cause short circuits, corrosion, and condensation on equipment in the data center. Low relative humidity may generate electrostatic discharge (ESD) that affects equipment running.
- Strict requirements for air cleanliness: There are strict requirements for air cleanliness in a data center. In a high-humidity environment, dust accelerates equipment corrosion and shortens its service life. In addition, accumulated dust on the heat sink increases the thermal resistance and reduces the heat exchange efficiency. Corrosive gases can quickly destroy metal films and conductors on printed circuit boards, resulting in increased resistance at terminations. Therefore, the air conditioning system for a data center must be equipped with efficient and proper filtering devices to filter out dust from the circulating air according to related standards.

Based on the scale and total capacity of data centers, there are now two prevalent solutions: air cooled cooling system and chilled water cooling system. In general, the chilled water solution is primarily used in extra large and large-sized data centers, and the air cooled solution is usually used in small- and medium-sized data centers.

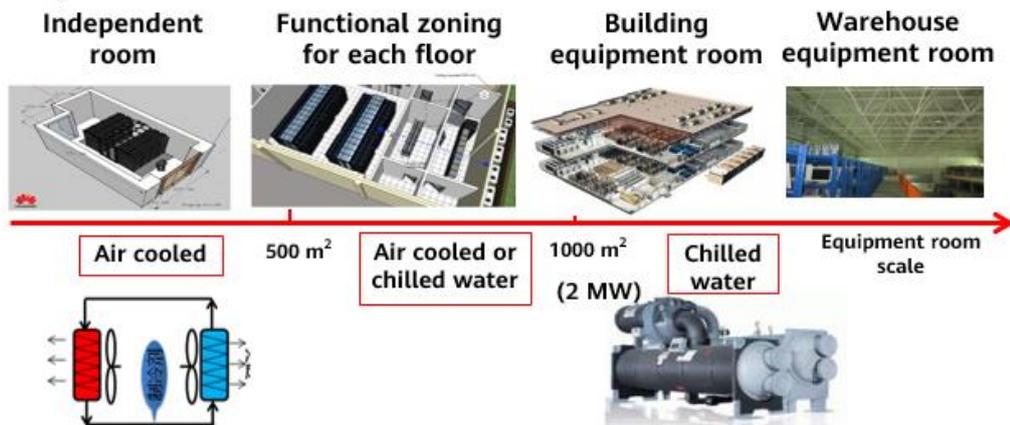


Figure 2-6 Data center cooling solution

Three cooling configurations: equipment room cooling, in-row cooling, and cabinet cooling.

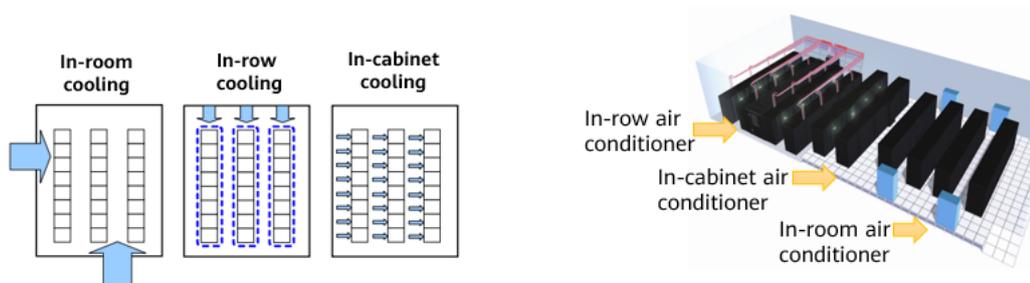


Figure 2-7 Three cooling configurations

- Cabinet-level cooling is the most flexible mode, can be deployed in shortest time, and supports the highest power density. However, extra expenditure is required.
- In-row cooling has many advantages similar to those of the cabinet-level cooling, for example, flexibility, deployment speed, and power density, and has a relatively low cost.
- In-room cooling can fast change the cooling distribution mode by configuring new perforated floors. In low-density data centers, all cabinets can share the cooling redundancy. This cooling mode has cost advantages and is also the simplest mode.

2.3.4 Data Center Integrated Management

Concept: The monitoring system in the equipment room implements central monitoring and maintenance management over the power and environment in the equipment room to improve the reliability of the data center and security of data devices, facilitate O&M, and increase management efficiency.

Objects: The power system, environment system, firefighting system, and security system are the primary objects to be monitored.

Functions: Based on the integrated network cabling system, the monitoring system in the equipment room adopts distributed monitoring, with the host placed in the monitoring room to run the software, to monitor all subsystems in a centralized manner using a uniform LCD. The monitoring system can monitor the operating status and parameters of all devices in real time, promptly generate alarms in forms of multimedia, voice, calls, and SMS when some components or parameters are abnormal, record historical data and alarms, and intelligently provide expert diagnosis, remote monitoring management, and web browsing.

- **Smart devices:** Smart devices are monitored through communication ports (including RS232/422/485 bus serial and TCP/IP network communication ports). Smart devices include the UPS, master air conditioner, power meter, T/H sensor, ATS, chiller, and generator.
- **Non-smart devices:** Non-smart devices are monitored through external smart meters or dry contacts. Non-smart devices include the security switch, power distribution switch, water leakage detection switch, and SPD.

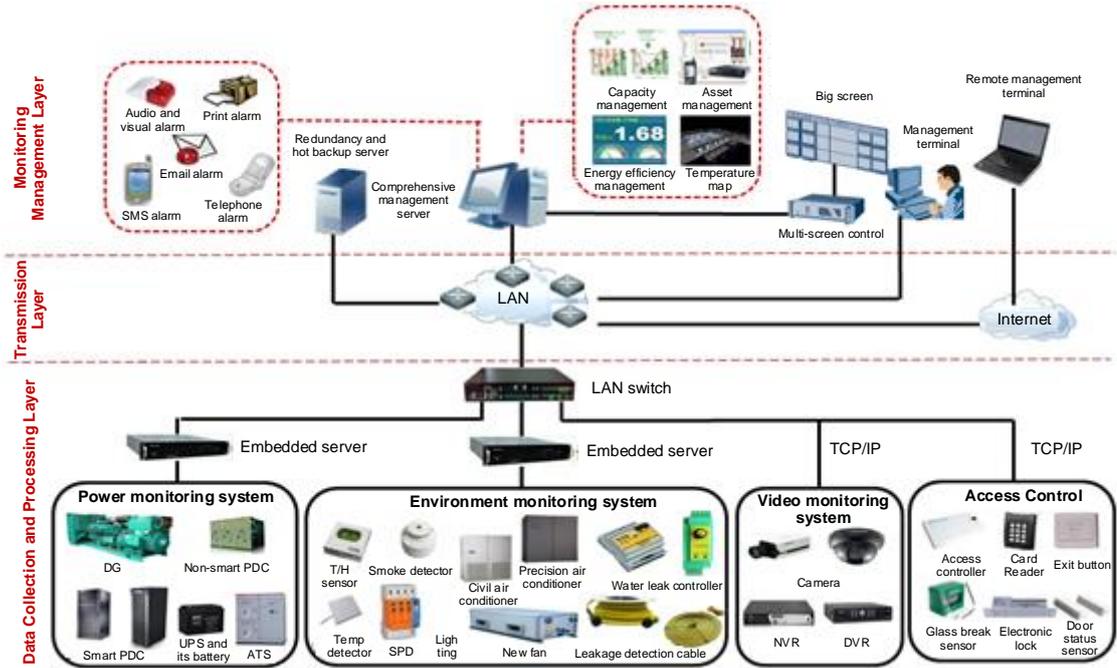


Figure 2-8 Common monitoring system architecture

2.4 Introduction to Data Center Standards

2.4.1 Overview of Data Center Standards

Standards are a way to unify the language and reduce communication costs. They are designed to make things simpler.

General standards

- Code for Design of Data Centers (GB 50174-2017)
- Data Center Site Infrastructure Tier Standard - Operational Sustainability
- Data Center Site Infrastructure Tier Standard - Topology
- TIA-942-B-2017, Telecommunication Infrastructure Standard for Data Centers, USA

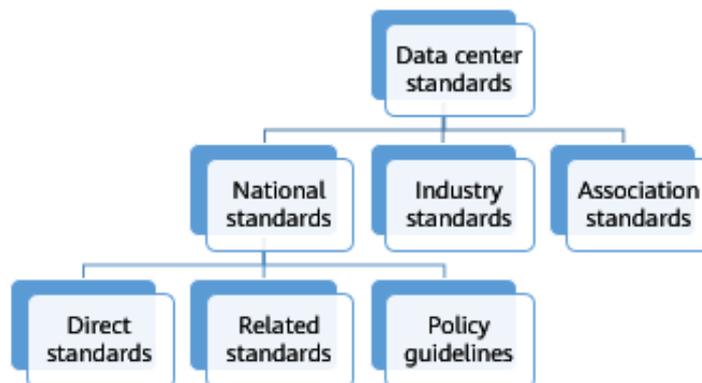


Figure 2-9 Data Center Standards

- GB 50174-2017 is the main reference standard for data center design and construction in China.
- Tier standards are released by the Uptime Institute and are mainly used for Uptime Institute certification services. To obtain Uptime Institute certification, design, construction, and O&M must comply with Tier standards.

2.4.2 Introduction to Uptime Tier Standards

The Uptime Institute is a well-known data center standards organization and an independent certifier. Uptime Tier certification consists of three parts: Tier Certification of Design Documents, Tier Certification of Constructed Facility, and Tier Certification of Operational Sustainability.

According to the Uptime Tier standards, data center infrastructure is classified into four levels:

- Tier I: Basic Data Center Site Infrastructure
- Tier II: Redundant Site Infrastructure Capacity Components
- Tier III: Concurrently Maintainable Site Infrastructure
- Tier IV: Fault Tolerant Site Infrastructure

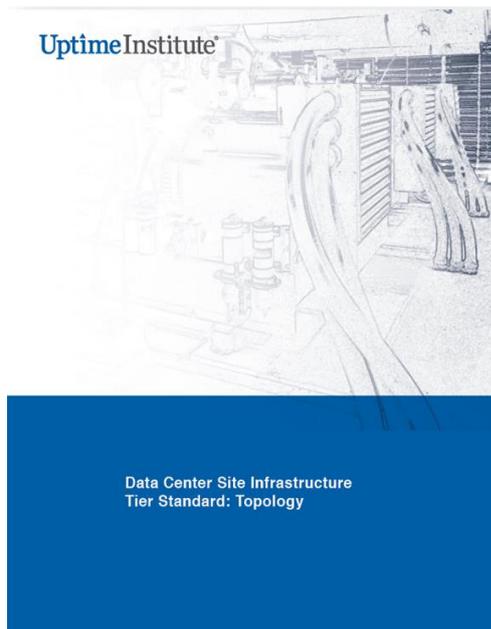


Figure 2-10 Uptime Tier Standard

2.4.3 Introduction to TIA-942 Standard

TIA-942-B-2017 is Telecommunications Infrastructure Standard for Data Centers released by the USA. It classifies data centers into four classes based on the usefulness and security of infrastructure. Its appendix describes the technical requirements of the four classes for telecommunications, architectural infrastructure, electrical, and mechanical infrastructure.

- I Data Center: Basic

- II Data Center: Redundant Component
- III Data Center: Concurrently Maintainable
- IV Data Center: Fault Tolerant

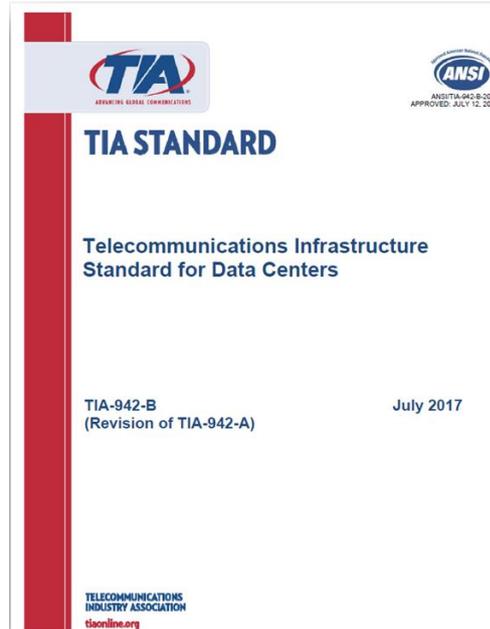


Figure 2-11 TIA-942 Standard

- TIA: Telecommunications Industry Association is an important industry association in the global communications and information technology industry.
- At the beginning of 2000, the Uptime Institute authorized the TIA committee to use the Tier concept. In the first version of TIA-942-2005, data centers were classified into four tiers: Tier 1, Tier 2, Tier 3 and Tier 4. In 2013, the Uptime Institute canceled the Tier authorization. Later, data centers are classified into four classes: I, II, III, and IV according to TIA standards.

2.4.4 Introduction to Other Standards

ISO/IEC 30134 series standards

Including five volumes

- Overview and general requirements - 2016
- Power usage effectiveness (PUE) - 2016
- Renewable energy factor (REF) - 2016
- IT equipment energy efficiency for servers (ITEE) - 2017
- IT equipment utilization for servers (ITEU_SV) - 2017

EU EN 50600 series standards

- By 2017, the European Committee for Electrotechnical Standardization (CENELEC) of the European Union (EU) has released the EN 50600 series standards, which include four parts in 10 standard texts. The EN 50600 series standards specify three levels of systems for availability, physical security, and energy efficiency implementation. It also

provides requirements and suggestions on data center operation, processes and management.

Japan JDCC FS-001 standard

- Based on the TIA-942 standard, the JDCC FS-001 standard classifies data centers into four levels. It is also supplemented and modified based on the actual situation of Japan. The JDCC FS-001 standard incorporates the unique elements of Japan, including earthquake risk and assessment, reliability of commercial electric power, and products of high efficiency, and reliability.

2.5 Common Energy Consumption Indicators

2.5.1 Data Center Power Consumption

Power consumption of data centers includes the IT device loads, cooling device loads, lighting loads, and device power losses.

Because the power consumption of IT devices is difficult to reduce and that of the cooling system is the lion's share, lowering the power consumption of the cooling system is the key to improve the energy efficiency of the data center.

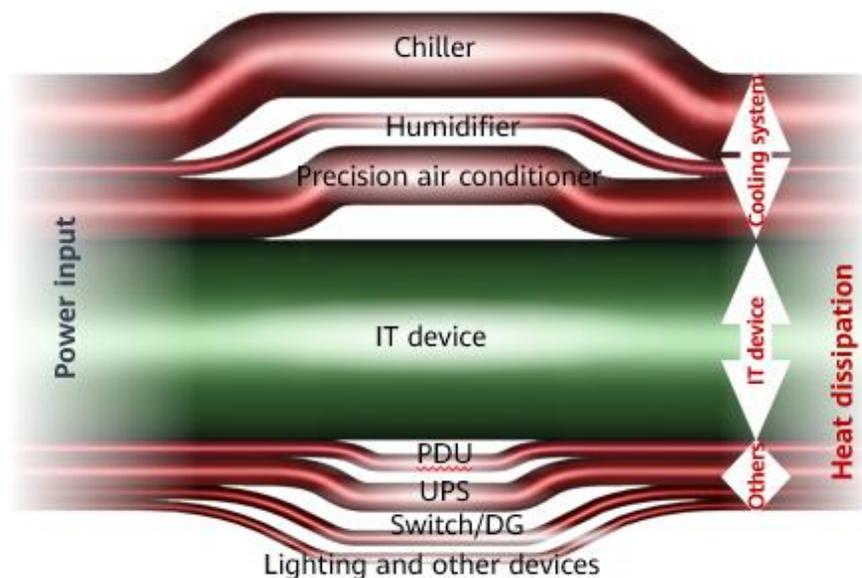


Figure 2-12 Data Center Power Consumption

Main sources of the data center energy consumption include the IT devices, lighting system, air conditioner, and power and distribution system. A lot of enterprises and scholars across the world made significant research in the data center energy consumption. Though the results differ in the exact proportion of each factor, the factors that constitute the energy consumption and the order of these factors by importance are largely the same.

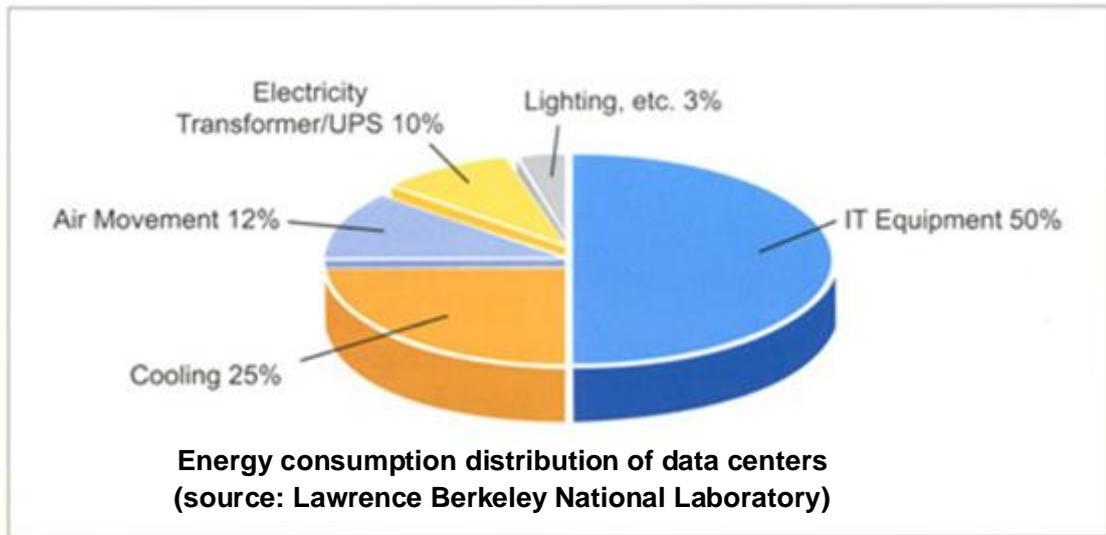


Figure 2-13 Energy consumption distribution of data centers

2.5.2 Power Consumption Index - PUE

Power usage effectiveness (PUE) is a widely-used comprehensive indicator inside and outside China that measures the data center infrastructure efficiency (DCiE). The formula is: $PUE = P_{Total}/P_{IT}$, where P_{Total} indicates the total power consumption of the data center and P_{IT} indicates the power consumption of the IT devices.

Table 2-1 Energy Efficiency Level

PUE	DCiE	Energy Efficiency Level
3.0	33%	Extremely poor
2.5	40%	Poor
2.0	50%	Average
1.5	67%	Good
1.2	83%	Excellent
3.0	33%	Extremely poor

- In essence, the PUE is used to calculate how much power of the total power supplied to the data center is actually applied to the IT devices. The PUE ranges from 1.0 to infinity. The greater the PUE value of the DC equipment room, the more the power consumed by the DC infrastructure, such as the cooling and power supply. The PUE is easy to be defined and calculated. Measure the total power consumption of the data center and that of the IT devices respectively, you can immediately calculate the PUE of the entire data center.
- The total power consumption of the data center indicates all power consumption required to maintain the normal operation of the data center, including the power consumption of the IT devices, cooling devices, power supply and distribution system,

and other facilities. If the building where lies the data center is also for office running and other purposes, the power consumption incurred by office running and others must not be included in the total power consumption of the data center. In data centers, only power consumed by the IT devices is regarded as meaningful power.

2.5.3 Power Consumption Index - pPUE

Partial PUE (pPUE) is an extension to the PUE concept and used to evaluate and analyze the energy efficiency of part of the data center or devices.

Before the pPUE is performed, the data center should be divided into different zones. The zone can be an equipment room in a multi-story data center building or a container module in a container data center.

pPUE is used to represent the energy efficiency of some zones or devices, and can be greater or less than the PUE. Generally, to improve the overall efficiency, we must first ameliorate the efficiency of devices or zones with greater pPUE values in the data center. pPUE is applicable to the partial energy efficiency evaluation of modular data centers built based on containers or other modular units, or large-sized data centers composed of many buildings and equipment rooms.



Figure 2-14 Huawei container data center

2.5.4 Power Consumption Index - CLF/PLF

CLF is short for cooling load factor and PLF power load factor. CLF is used to represent the ratio between the power consumption of the cooling devices and that of the IT devices. PLF is used to represent the ratio between the power consumption of the power and distribution system and that of the IT devices.

CLF and PLF are supplements and extensions to PUE. Calculating CLF and PLF can help you analyze in a detailed manner the respective energy efficiency of the cooling system and power and distribution system.

2.5.5 Power Consumption Index - RER

Renewable energy ratio (RER) is used to measure the utilization of renewable sources to renew the solar energy, wind energy, and hydro energy, and promote the use of carbon-free or low-carbon sources. In general, renewable energy indicates recyclable energy

sources in nature, such as the solar energy, wind energy, hydro energy, biomass energy, geothermal energy, and ocean energy. Renewable energy sources are environment-friendly in use, widely distributed, and can be exploited locally. Fossil fuels, such as coal, oil, and gas, and nuclear energy constitute the counterpart of renewable energy.

In particular, RER is a new indicator proposed at the China Cloud Computing Promotion and Policy Forum in light of the fast growth of renewable energy sources in China. Now, RER is submitted to The Green Grid (TGG), an internationally-renowned organization that commits itself to improving the IT efficiency, for discussion.

2.6 Panorama of Huawei Data Center Solutions

Huawei provides a full series (small to large data centers) of FusionModule data center facility solutions for industries, enterprise digital transformation, and data center service providers. In addition, Huawei also provides solutions of UPS and cooling for key equipment in industries (such as manufacturing and rail transportation).



Figure 2-15 Panorama of Huawei Data Center Solutions

2.7 Quiz

- 1、 (Single) Which of the following belong to the power supply system?
 - A UPS
 - B CCTV
 - C Access control system
 - D Cable tray
- 2、 (Single) Which of the following is not an energy consumption indicator of a data center?
 - A PUE
 - B pPUE

C RER

D PFC

2.8 Summary

- Introduction to Data Center Development
- Composition of Data Center Infrastructure
- Introduction to Data Center Standards
- Common Energy Consumption Indicators
- Panorama of Huawei Data Center Solutions

3 Basic Knowledge of Power Distribution

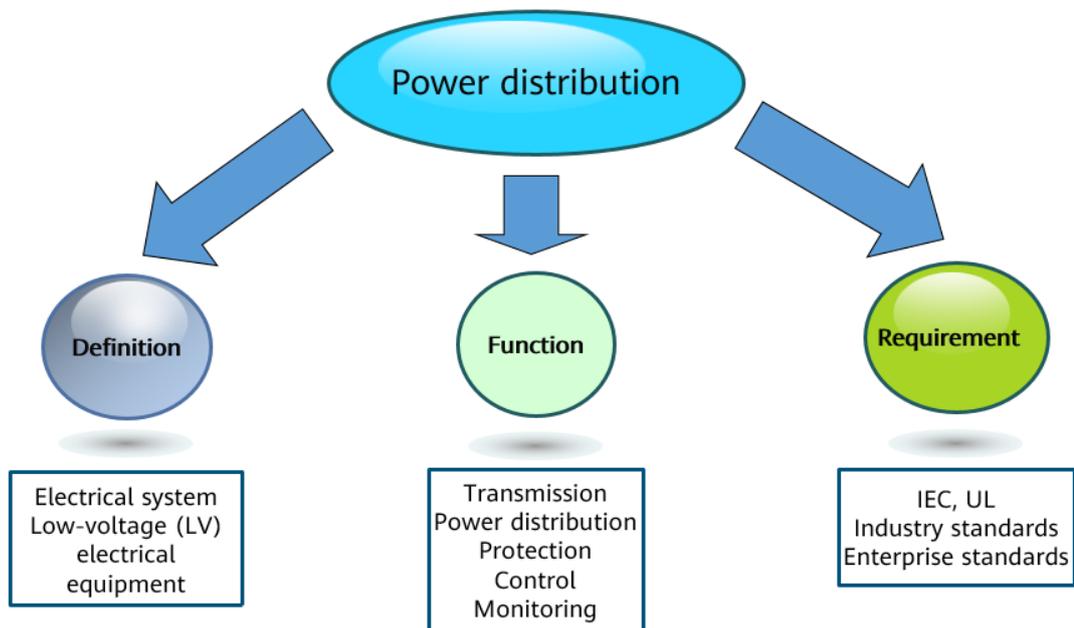
3.1 Objectives

After learning this course, you will be able to:

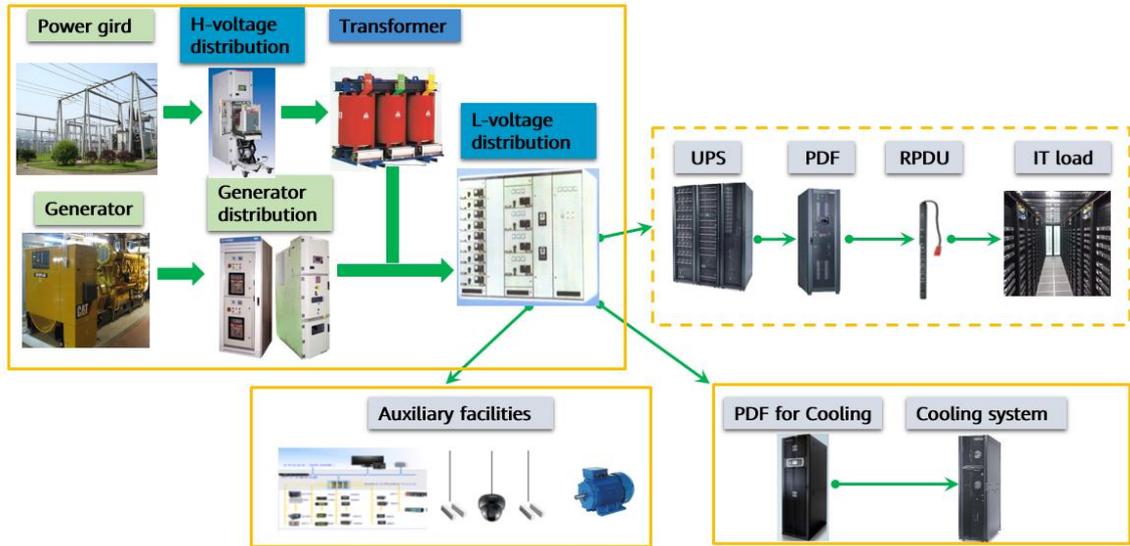
- Understand the basic concepts of power distribution
- Know the grounding system
- Know the common power distribution products

3.2 Power Distribution System Overview

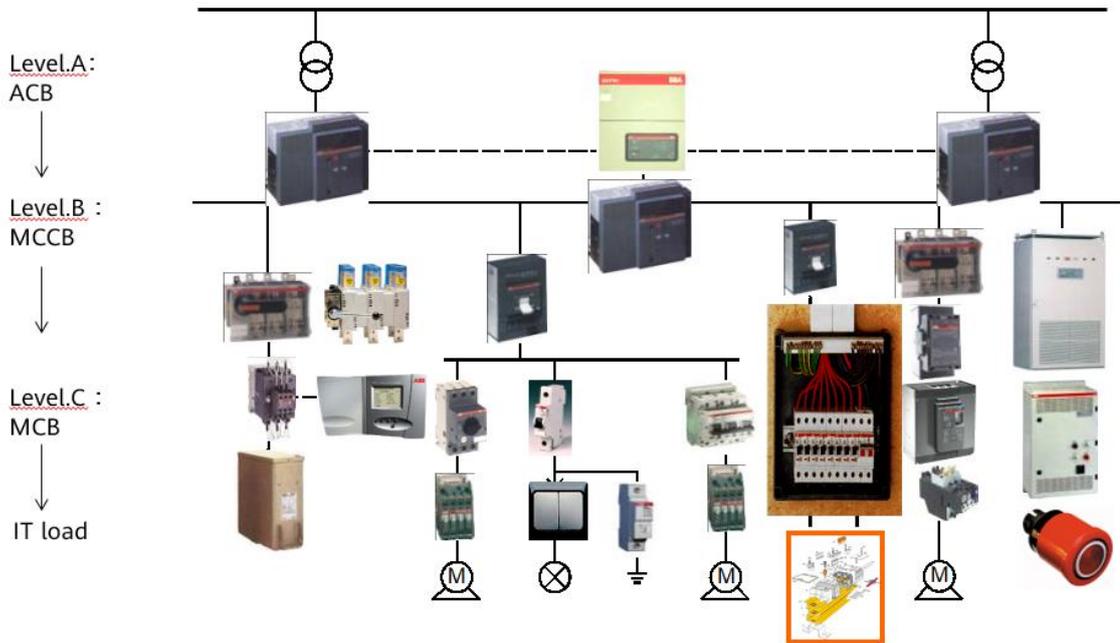
3.2.1 What Is Power Distribution?



3.2.2 Data Center Distribution System



3.2.3 Low-Voltage Electrical Devices



3.3 Basic Concepts of the Power Distribution System

3.3.1 Power Supply

Dual power supplies: A load has two power supplies, which are considered independent of each other for safety.

Emergency power supply system: To ensure personal safety, the emergency power supply system protects the environment and other equipment from being damaged.

Emergency power supply (power supply for safety facilities): It serves as a part of the emergency power supply system.

- In data centers, it means power supply for emergency lights, fire pumps, and other safety equipment.

Standby power supply: When the normal power supply is powered off, the standby power supply is used to maintain the power supply required by the equipment for non-safety reasons.

- The standby power supply can be a generator set or a dedicated feed loop independent of the normal power supply.

3.3.2 Power Supply Requirements

Uptime Institute Uptime specifies the power supply reliability requirements of data centers of different levels.

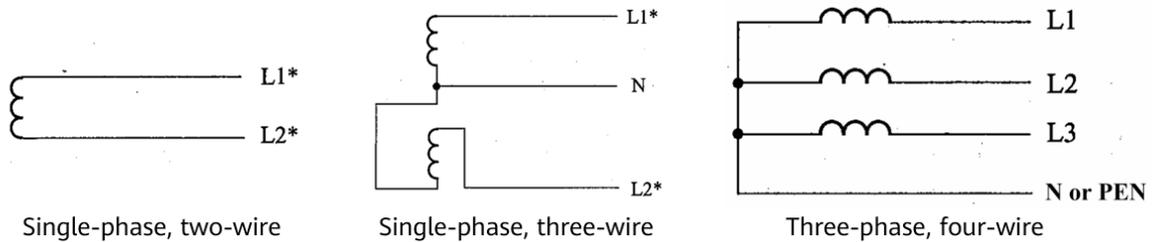
Data Center Tier	Tier IV	Tier III	Tier II	Tier I
Overall function requirement	Fault tolerance (one fault), active-active power supply and distribution routes	Planned online maintenance, active-standby power supply and distribution routes	One power supply and distribution route	One power supply and distribution route
Mains input requirement	/	/	/	/
DG requirement	2N is recommended, but N+1 can also be used.	N+1	N+1	N
UPS requirement	2N	N+1	N+1	N
Backup time requirement	Meeting DG startup requirements	Meeting DG startup requirements	Meeting DG startup requirements	Meeting DG startup requirements
DG fuel storage requirement	12 hours	12 hours	12 hours	No specific requirements

3.3.3 Voltage

The power grid transmits 110 kV, 35 kV, 20 kV, and 10 kV power to enterprises. Then the transformer decreases the voltage to 380 V, and the LV power distribution system transmits the power to the power-consuming equipment in data centers.

When 220 V/380 V single-phase power-consuming equipment is connected to a three-phase system, it is recommended that the three phases be balanced.

For the 220 V load supplied by the LV power grid, if the line current is less than or equal to 60 A, the 220 V single-phase power supply can be used. When the line current is greater than 60 A, the 380 V three-phase four-wire power supply is recommended.



3.3.4 Load Characteristics: Resistor, Capacitor, and Inductor

Resistors have the function of blocking current and can be used as electric heating parts to convert electric energy into internal energy. It is marked as R or r, and the unit is ohm.

Capacitors are two unconnected plates used to store and discharge electric charges, converting electrical energy into electric field energy. It is marked as C, and the unit is F.

Inductors are spiral coils, in which a changing magnetic field is generated by changing a current, and the magnetic field is prevented from converting electric energy into magnetic energy by changing a magnetic flux. It is marked as L, and the unit is H.

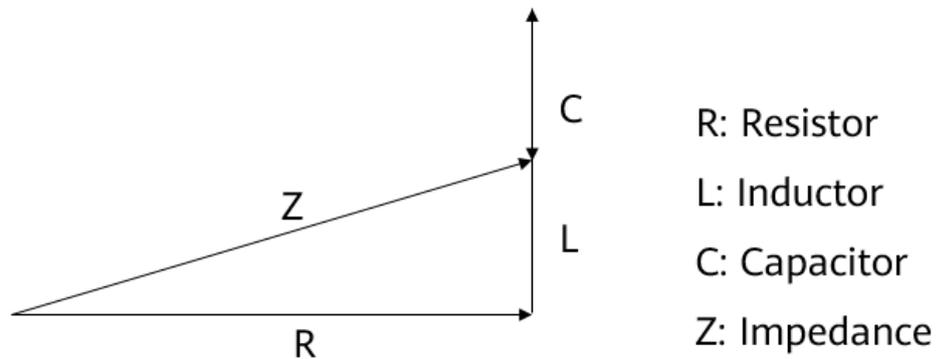


Figure 3-1 Impedance vector diagram

3.3.5 Power

There are three kinds of power supplied to the load by the power supply: active power, reactive power, and apparent power.

Active power (P): the power that can convert electric energy into other forms of energy and can be directly consumed

The formula for calculating the power of a three-phase circuit is as follows: $P = \sqrt{3}UI\cos\phi$

Reactive power (Q): When the load contains inductors or capacitors, the equipment generates reactive power. Equipment such as transformers and motors require the magnetic field generated by reactive power to work. Therefore, reactive power is not useless.

The formula for calculating the power of a three-phase circuit is as follows: $Q = \sqrt{3}UI\sin\phi$

Apparent power (S): the sum of active power P and reactive power Q

The formula for calculating the power of a three-phase circuit is as follows: $S^2 = Q^2 + P^2 = \sqrt{3}UI$

3.3.6 Power Quality and Harmonic

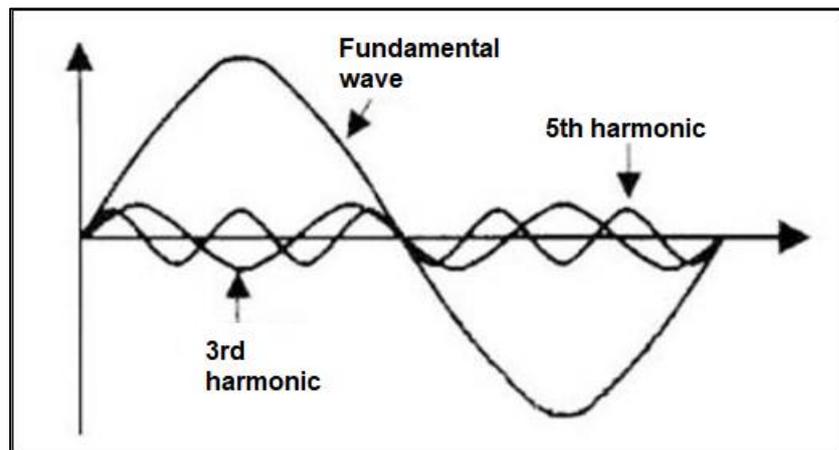
Power quality: refers to the voltage quality, that is, the quality of the voltage amplitude, frequency, and waveform. The main technical specifications include harmonic, voltage deviation, power supply interruption, three-phase voltage imbalance, and voltage fluctuation and flicker. The ideal power quality means the sinusoidal voltage with constant power and constant amplitude, as well as continuous power supply.

Power quality issues may cause great loss to data centers. Common power quality issues of data centers include harmonic, voltage deviation, and power supply interruption.

We will focus on these three issues this time.

3.3.7 Power Quality and Harmonic

Harmonic: In the AC power grid, the voltage and current waveforms of much non-linear electrical equipment are not complete sine waveforms. The part that is the same as the industrial frequency (50 Hz) is the fundamental wave. The wave whose frequency is a multiple of the fundamental wave frequency (greater than 1) is the harmonic wave.



3.3.8 Voltage Deviation

The voltage deviation is the relative deviation of the operating voltage to the nominal voltage of the power supply and distribution system under normal operating conditions. The value is expressed in percentage:

$$\Delta u = \frac{U - U_n}{U_n} \times 100\%.$$

Δu : voltage deviation percentage, 100%

U : operating voltage (V)

U_n : nominal voltage of the system (V)

3.3.9 Power Supply Reliability

Power supply reliability: refers to the continuous power supply capability of a power supply system.

The electric energy of a data center is mainly from the power grid. The power supply reliability of the power grid directly affects the power supply system architecture (power supply configuration and battery configuration) of the data center. The mains power supply reliability is classified into the following types.

3.4 Common LV Electrical Equipment

3.4.1 Abstract

3.4.1.1 LV Power Distribution Equipment

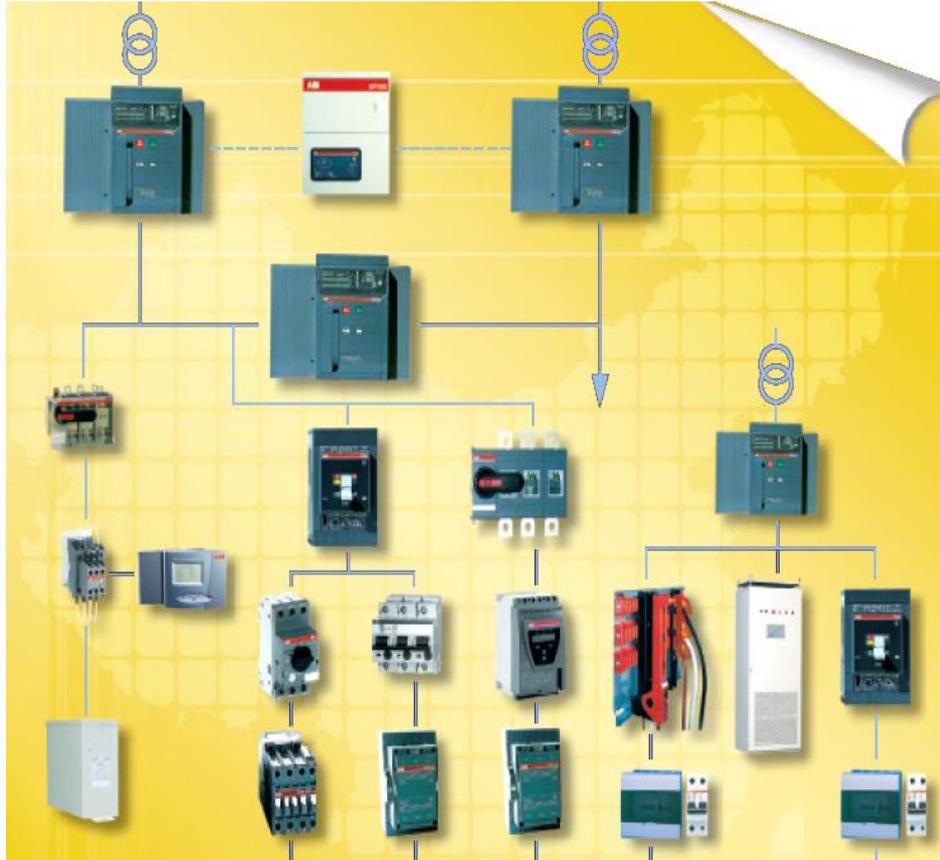
Type	Power Outage Times (Times/Year)	Power Outage Duration (Hours/Times)
Class 1 power supply	≤ 12	≤ 0.5
Class 2 power supply	≤ 42	≤ 6
Class 3 power supply	≤ 54	≤ 8
Class 4 power supply	Seasonal long-time power outage occurs or no mains is available.	

Definition

- Based on the usage requirements and control signals, the LV power distribution equipment can connect and disconnect the circuits with the rated voltage of 1000 V AC or 1500 V DC or below using one or more components manually or automatically to control, adjust, convert, detect, and protect the controlled objects in the circuit.

Common equipment

- Conversion equipment: transformer and diesel generator (DG)
- Control equipment: power distribution frame (PDF), circuit breaker, and fuse
- Auxiliary materials: cables



3.4.2 Conversion Equipment

3.4.2.1 Transformer

A transformer consists of an iron core and two or more coils (windings) with different numbers of turns wound around the iron core.

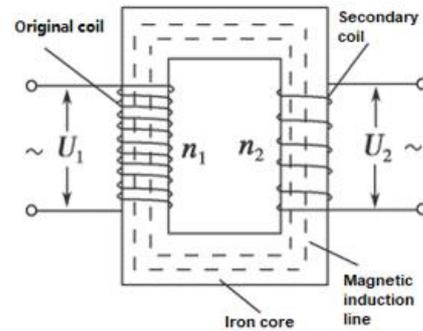
In a data center, the transformer converts the 10 kV/20 kV voltage on the power grid side into 400 V voltage for equipment.

Common transformer types:

- Common oil-immersed transformer: applies to substations in normal environments.
- Dry-type transformer: applies to places with high fireproof requirements or substations in damp and dusty environments.



Transformer



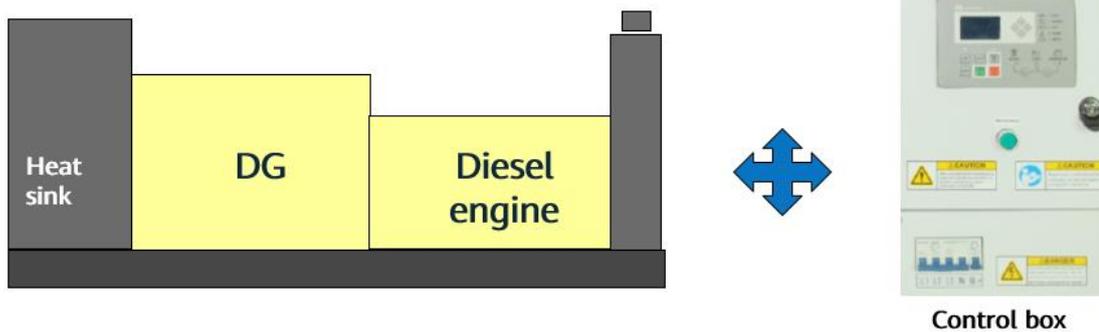
Transformer structure

3.4.2.2 DG

A DG is a combination of a diesel engine and a generator (usually an AC generator) to generate power in cases of a mains outage

The DG starts and burns diesel fuel to convert chemical energy into power, ensuring normal operation of the data center.

The whole set is generally composed of a diesel engine, generator, control box, fuel tank, battery for starting and controlling, protection equipment, emergency cabinet, and so on.



3.4.3 Control equipment

3.4.3.1 LV PDF

The rated current of the LV PDF is 50 Hz AC. The power distribution system with a rated voltage of 380 V is used as the driving force for power conversion and control for lighting and power distribution.

The LV PDF should adapt to the rated circuit value and installation conditions. The basic features are as follows:

- Rated operating voltage
- Rated frequency
- Rated operating current
- Indoor and outdoor types, Ingress protection (IP) rating
- Fixed type or drawer type



Figure 3-2 LV PDF

3.4.3.2 IP Rating

IP rating refers to the protection level of protecting electrical equipment against intrusion of foreign objects. IP rating consists of two digits. The first digit indicates the level of protection against dust and foreign object intrusion. The second digit indicates the level of protection against moisture and water intrusion. The larger the value, the higher the protection level.

Table 3-1 The meaning of first digit

Digit	Dustproof Range	Description
0	No protection	There is no special protection against people or objects outside.
1	Prevents intrusion of solid objects with a diameter of greater than 50 mm.	Prevents human bodies (such as palms) from contacting internal electrical parts due to accidents and prevents large foreign objects (with a diameter greater than 50 mm) from intrusion.
2	Prevents intrusion of solid objects with a diameter of greater than 12.5 mm.	Prevents fingers from contacting internal electrical parts and prevents medium-sized foreign objects (with a diameter greater than 12.5 mm) from intrusion.
3	Prevents intrusion of solid objects with a diameter of greater than 2.5 mm.	Prevents tools, wires, and similar small objects whose diameter or thickness is greater than 2.5 mm from contacting internal electrical parts.
4	Prevents intrusion of solid objects with a diameter of greater than 1.0 mm.	Prevents tools, wires, and similar small objects whose diameter or thickness is greater than 1.0 mm from contacting internal electrical parts.

5	Prevents foreign objects and dust.	Prevents foreign objects from intrusion. Although dust cannot be completely prevented, the dust does not affect the normal operation of electrical equipment.
6	Prevents foreign objects and dust.	Prevents foreign objects and dust from intrusion.

Table 3-2 The meaning of second digit

Digit	Waterproof Range	Description
0	No protection	There is no special protection against water or moisture.
1	Prevents droplets from intrusion.	Vertical droplets (such as condensed water) do not cause damage to electrical equipment.
2	When the equipment is tilted by 15 degrees, droplets can still be prevented.	When the electrical equipment is tilted by 15 degrees, droplets do not damage the equipment.
3	Prevents sprayed water from intrusion.	Prevents rain or damage caused by water sprayed in the direction less than 60 degrees from the vertical angle.
4	Prevents splashing water from intrusion.	Prevents splashing water in all directions from intruding into electrical equipment and causing damage.
5	Prevents water jets.	Prevents water jets from all directions from the nozzle from intruding into the electrical equipment and causing damage.
6	Prevents large waves from intrusion.	Prevents damage caused by the invasion of large waves for electrical equipment installed on the deck.
7	Prevents water intrusion during immersion.	Ensures that the electrical equipment is not damaged due to water immersion when electrical equipment is immersed in water for a certain period of time or the water pressure is below a certain standard.
8	Prevents water intrusion during sinking.	Ensure that no damage is caused by water immersion when the electrical equipment sinks indefinitely under specified water pressure.

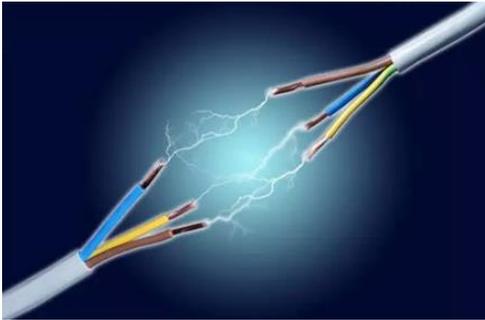
3.4.3.3 Low-Voltage Circuit Breakers

Function:

- Switch
- Overload protection
- Short circuit protection (instant /short delay)

Classification:

- ACB (Air Circuit Breaker)
- MCCB (Mould Case Circuit Breaker)
- MCB (Miniature Circuit Breaker)
- HY-MAG (Hydraulic-pressure Magnetic Circuit Breaker)
- RCD (Residual Current Device)



3.4.3.4 Low-Voltage Circuit Breakers - ACB

Definition:

- The type of circuit breaker, which operates in air (where air-blast as an arc quenching medium) at atmospheric pressure, is known to be an Air Circuit Breaker.

Application and Uses:

- Used for main power distribution in large industrial plant.
- Used for protection of transformers, capacitors and generators.
- Carry heavy current (thousands of amperes).
- Intelligent monitoring functions: remote control, alarms and data transmission.



3.4.3.5 Low-Voltage Circuit Breakers - MCCB

Definition:

- MCCB is a type of electrical protection device that is commonly used when load currents exceed the capabilities of miniature circuit breakers.

Features:

- Used in industrial areas widely.
- carry medium current (hundreds of amperes).
- High breaking capability (Icu Ics).
- operated rapidly.
- The tripping devices are interchangeable and adjustable.
- Intelligent monitoring functions: catenation, remote control,
- alarms and data transmission.



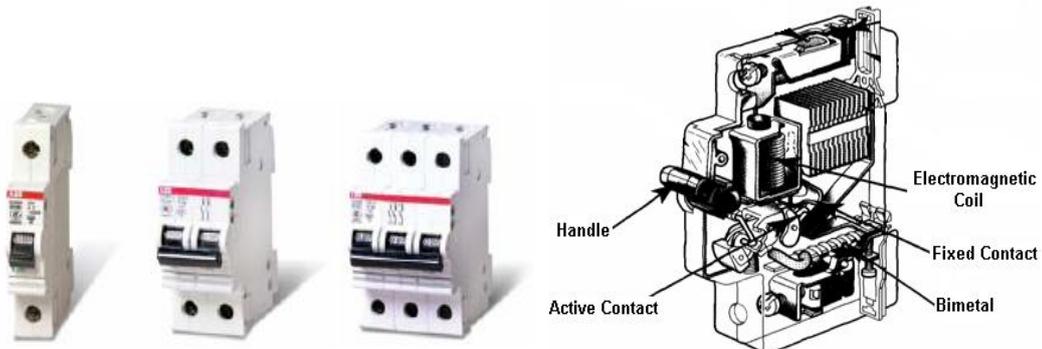
3.4.3.6 Low-Voltage Circuit Breakers - MCB (1)

Definition:

- An MCB or miniature circuit breaker is an electromagnetic device that embodies complete enclosure in a molded insulating material.

Main parameters:

- Carry miniature current (from 1 A to 100 A usually)
- Nearest to the loads
- Rated voltage U_n : 230 V/400 Vac, 60Vdc
- Rated breaking current I_{cu} : 4.5 kA, 6 kA, 10 kA...
- Characteristic: B, C or D
- Tripping principle: Thermal-Magnetic tripping (TM)

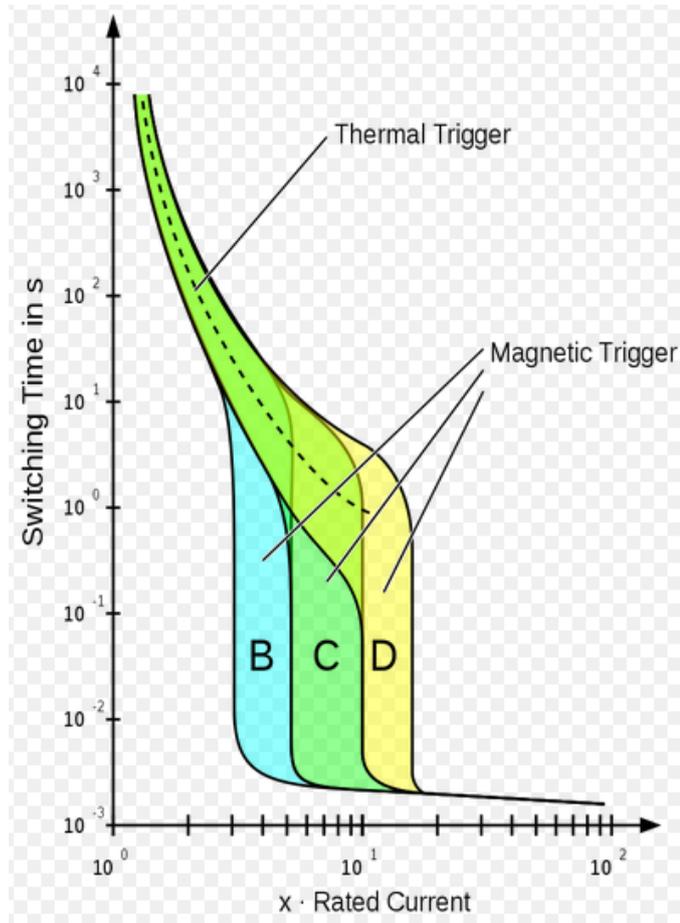


3.4.3.7 Low-Voltage Circuit Breakers - MCB (2)

Tripping Characteristics

- Definition:
 - B, C, D according to IEC 60898
 - Z, K according to IEC 60947-2
- Application:
 - Characteristics Z (2-3) In
 - Characteristics B (3-5)In
 - Characteristics C (5-10) In
 - Characteristics D (10-20)In
 - Characteristics K (8 -15)In

Characteristic C is suggested for the MCB in the ICT loads scenario.



3.4.3.8 Low-Voltage Circuit Breakers - RCD

Principle:

- Kirchoffs Law: $\sum I=0$

- Earth leakage current protector

Classification:

- By Principle:
 - Electromagnetic type
 - Electronic type
- By over current protection:
 - Residual Current Circuit Breaker (RCCB)
 - Residual current Circuit Breaker with Over-current protection (RCBO)
- By relay time: instant type, selected type

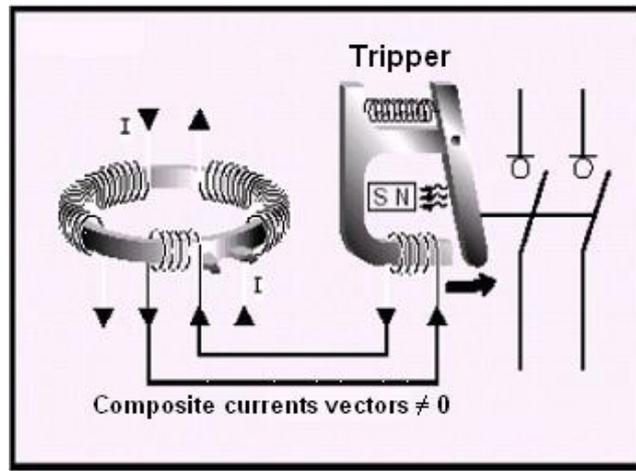


Figure 3-3 Magnetic type RCD

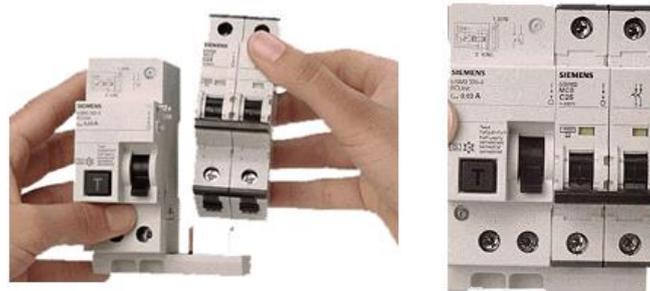


Figure 3-4 RCCB

3.4.3.9 Transfer Switch

Definition:

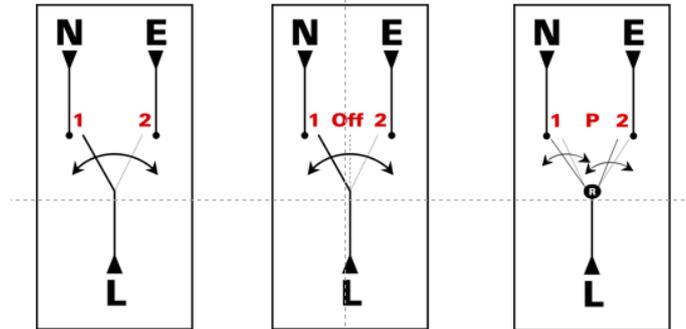
- A transfer switch is an electrical switch that switches a load between two sources.

Classification:

- ATS: Automatic Transfer Switch (Mechanical action)
- STS: Static Transfer Switch (SCR)

Types

- Open transition
- Closed transition
- Soft loading



3.4.3.10 Fuse

Definition:

- Widely applied in low voltage distribution and control systems
- One key short-circuit protection device for a single electrical equipment.

Classification:

- Based on the breaking range: g (for full range breaking) and a (for partial breaking)
- Based on the classification: G (common fuse) and M (for motor circuits)

Feature parameters:

- Rated voltage
- Rated current
- Rated breaking capability
- Time-Current feature



Fuses



Holder



Puller

3.4.3.11 Disconnecter

Definition

- It is mainly used to isolate the power supply, transfer switching, and connect and cut off the small-current circuit. It has no arc extinguishing function.

Feature

- During electrical equipment maintenance, the disconnecter can provide an electrical interval, which is a visible disconnection point.
- The disconnecter cannot be operated with load. It can be operated only when the circuit breaker is disconnected.

Classification by structure

- Knife switch
- Fuse-type knife switch
- Classification by operation mode
- Manual disconnecter
- Automatic disconnecter



Knife switch



Fuse-type knife switch



Automatic disconnecter

3.4.3.12 SPD

Definition

- SPD is installed at the front end of equipment to protect the equipment from being damaged by overvoltage or overcurrent caused by external cables.

Feature

- Protection level: level I, II, and III, or class B, C, and D
- Maximum discharge current I_{max} : maximum single shot current the SPD can handle without getting damaged
- Nominal discharge current I_n : through-current capability that enables the SPD to endure surge
- Rated impulse voltage value U_w : resistance capability that enables the SPD to prevent overvoltage
- Residual voltage: peak voltage between SPD terminals when the discharge current passes through

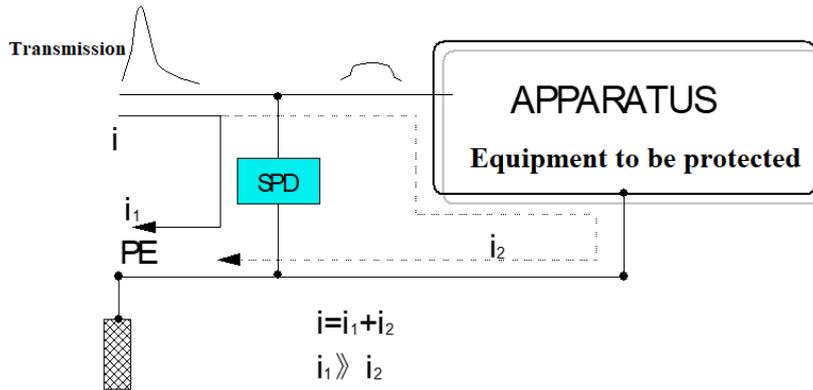


Table 3-3 Impulse current and nominal current of the SPD

Lightning Protection Level	General Power Distribution Box (PDB)		Branch PDB	Equipment Room PDB
	Class 1 test	Class 2 test	Class 2 test	Class 2 test
	I_{imp} (kA)	I_n (kA)	I_n (kA)	I_n (kA)
B	≥ 15	≥ 60	≥ 30	≥ 5
C	≥ 12.5	≥ 50	≥ 20	≥ 3
D	≥ 12.5	≥ 50	≥ 10	≥ 3

3.4.4 Auxiliary materials

3.4.4.1 Introduction to Power Cables

The basic structure of a power cable consists of the core (conductor), insulation layer, shield layer, and protection layer.

Copper, aluminum, and aluminum alloy are usually used as cable conductors. Copper conductors are recommended for data center cables.

Cables can be classified into DC cables and AC cables based on the power system.

Basic cable features:

- Cable type

- Rated operating voltage
- Insulating material
- Conductor type
- Cross-sectional area



3.4.4.2 Naming Rules for Power Cables

ZRC L - YJV 22 - 3 × 120mm² + 1 × 70mm²
 | | | | | | | | | | |
 1 2 3 4 5 6 7 6 7

No.	Meaning	Value
1	Type code	ZRC: class C flame retardant
2	Conductor	L: aluminum; T: copper
3	Insulation layer code	YJ: <u>crosslinked polyethylene</u> ; V: PVC sheath
4	Protection layer code	V: PVC sheath
5	Armored layer code	0: none; 2: double steel belt; 3: thin steel wire
6	Number of cable cores	3: three-core cable
7	Cross-sectional area	120: 120 mm ²

3.5 Common Grounding Systems

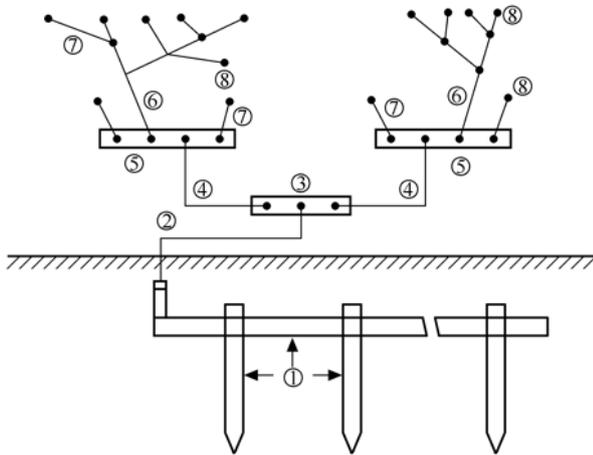
3.5.1 Grounding System Overview

Concept

- Grounding is to connect the grounding terminals of electrical equipment or communication equipment to the ground through grounding devices and inject the electric charges of the grounding terminals into the ground for the purpose of working or protection. In this way, the dangerous voltage is reduced and electromagnetic interference is prevented.

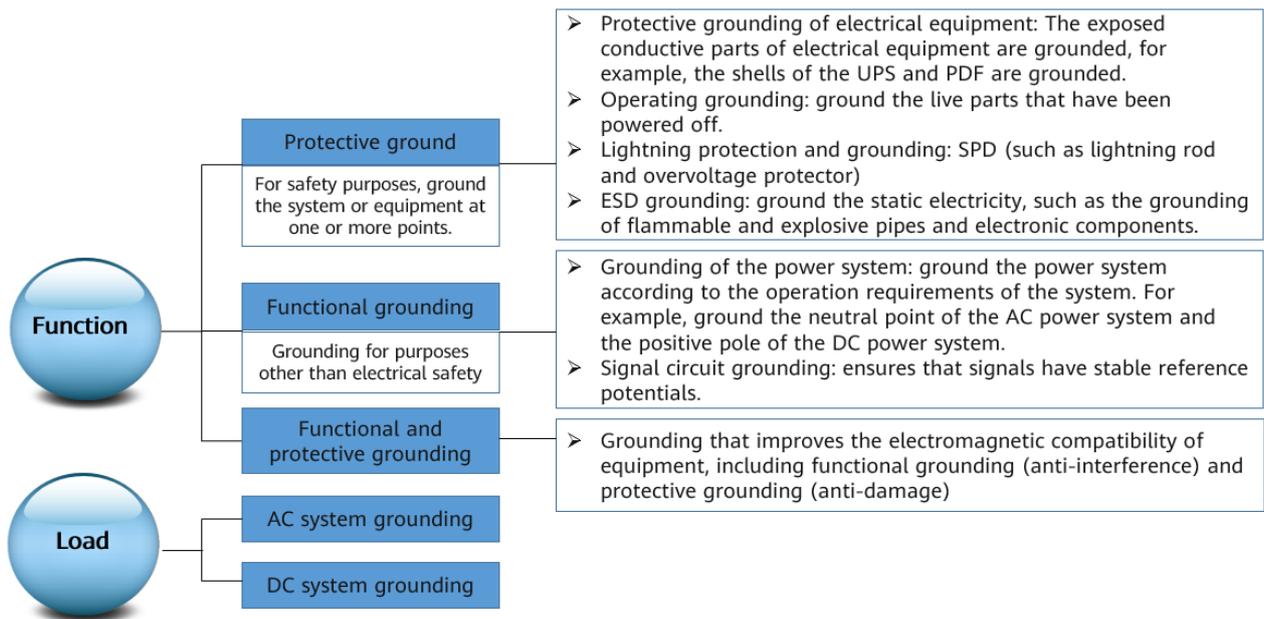
3.5.2 Components of the Grounding System

The grounding device consists of all grounding bodies and grounding leads. The grounding system is formed by connecting the grounding devices to the grounding terminals of the electrical equipment through the ground cable.



- ① Ground conductor
- ② Ground lead
- ③ Ground bar
- ④ Ground cable
- ⑤ Ground bar of the power distribution panel
- ⑥ Busbar to the communications equipment room
- ⑦ Ground branch cable
- ⑧ Ground terminal of the equipment

3.5.3 Grounding Types



3.5.4 Earthing system Introduction

Definition:

- To connect the metallic (conductive) Parts of an Electric appliance or installations to the earth (ground) is called Earthing. IEC 60364 distinguishes three families of earthing arrangements, using the two-letter codes TN, TT, and IT.

The first letter indicates the connection between earth and the power-supply equipment (generator or transformer):

- "T" — Direct connection of a point with earth (Latin: terra)

- "I" — No point is connected with earth (isolation), except perhaps via a high impedance.

The second letter indicates the connection between earth and the electrical device being supplied:

- "T" — Earth connection is by a local direct connection to earth (Latin: terra), usually via a ground rod.
- "N" — Earth connection is supplied by the electricity supply Network, either as a separate protective earth (PE) conductor or combined with the neutral conductor.

Classification: TN(TN-C, TN-S,TN-C-S,) 、 IT、 TT.

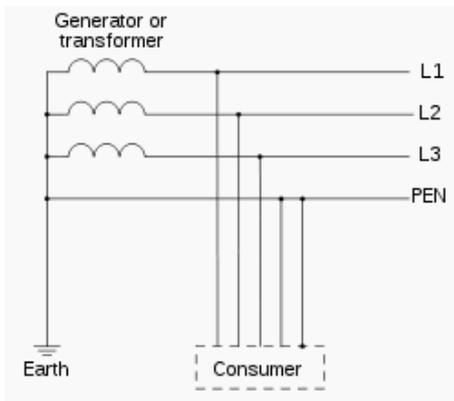
3.5.5 Earthing system Introduction - TN

Definition:

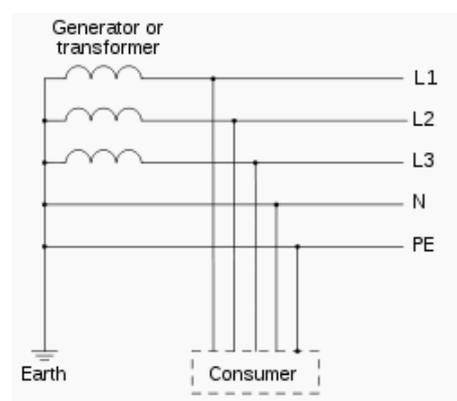
- In a TN earthing system, one of the points in the generator or transformer is connected with earth, usually the star point in a three-phase system. The body of the electrical device is connected with earth via this earth connection at the transformer.

Classification:

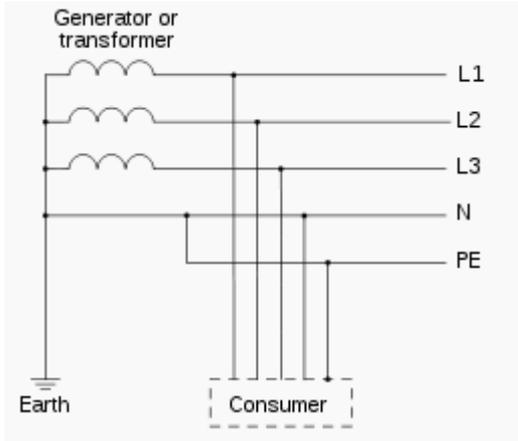
- TN-S: PE and N are separate conductors that are connected together only near the power source. This arrangement is a current standard for most residential and industrial electric systems particularly in Europe.
- TN-C: combined PEN conductor fulfills the functions of both a PE and an N conductor.
- TN-C-S: combined PEN conductor from transformer to building distribution point, but separate PE and N conductors in fixed indoor wiring and flexible power cords.



TN-C



TN-S

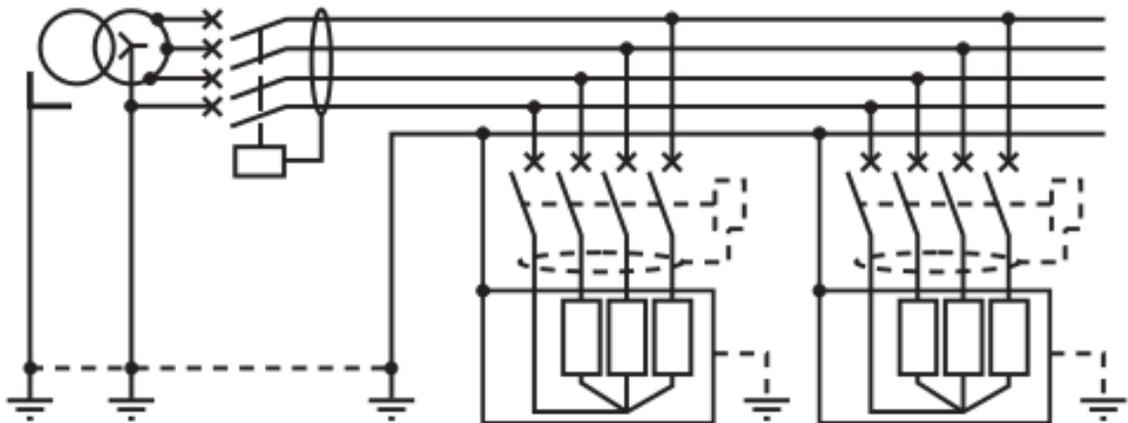


TN-C-S

3.5.6 Earthing system Introduction - TT

Definition:

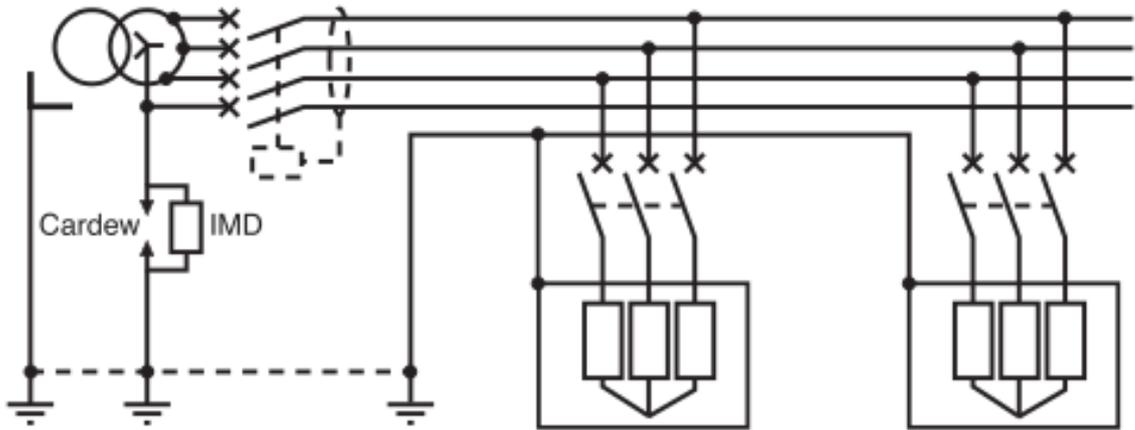
- The TT system : Technique for the protection of persons: the exposed conductive parts are earthed and residual current devices (RCDs) are used.
- Operating technique: interruption for the first insulation fault.



3.5.7 Earthing system Introduction - IT

Definition:

- In an IT network, the electrical distribution system has no connection to earth at all, or it has only a high impedance connection.



3.6 Quiz

1. (Single) Which of the following is the most common grounding system in a data center?
 - A TN-S
 - B TN-C
 - C TN-C-S
 - D TT
 - E IT

3.7 Summary

- Data Center Power Distribution Overview
- Basic Concepts of the Power Distribution System
- Common LV Electrical Equipment
- Common Grounding Systems
- Introduction to Data Center Digital Power Products

4 Basic Knowledge of UPS

4.1 Introduction

4.1.1 Foreword

The chapter describes UPS basic knowledge, including the function and work principle of UPS and the common configuration solution.

4.1.2 Objectives

On completion of this course, you will be able to:

- Know the basic function of UPS;
- Know the basic working mode of UPS;
- Know the common configuration solution of UPS.

4.2 What Is a UPS

4.2.1 UPS Development History

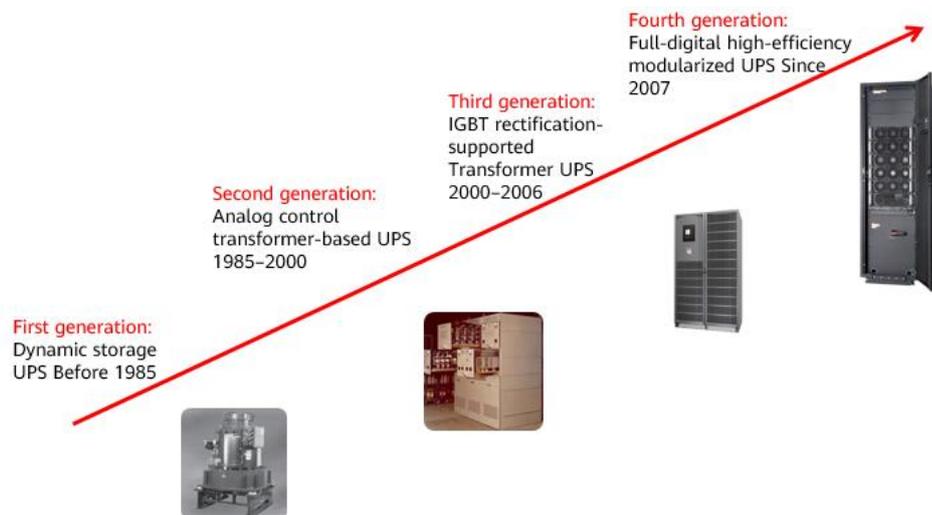


Figure 4-1 UPS Development History

First generation: Efficiency: 50% – 60%, Key components: flywheel or generator; Control mode: analog control.

Second generation:1985 – 2000, Efficiency: < 88%, Key components: silicon controlled rectifier (SCR), Control mode: analog control.

Third generation: 2000 – 2006;Efficiency: 92% – 94%, Key components: insulated gate bipolar transistor (IGBT) and metal-oxide semiconductor (MOS), Control mode: semi-digital UPS.

Fourth generation: Since 2007, Efficiency: > 96%, Key components: MOS (IGBT)+digital signal processing (DSP), Control mode: full-digital, redundant, and dual-bus.

An uninterruptible power supply (UPS) is an energy conversion device that uses the battery chemical energy for backup to supply uninterruptible power when power failures, such as mains disconnection or exceptions, occur.

4.2.2 Why Is the UPS Required?

Power grid pollution affects network and device security.

- Power interruption, voltage fluctuation, transient peak currents, voltage surges, and high-voltage pulses which damage servers, routers, and disk arrays.
- Harmonic distortion, high-frequency interruption, and frequency drifts which substantially increase the bit error rate (BER) and decrease the data transmission rate.

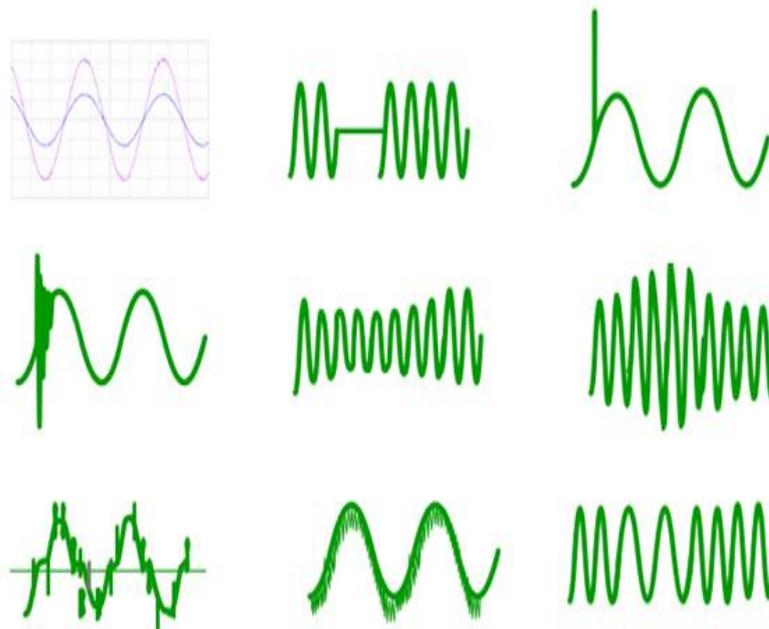


Figure 4-2 Power grid faults

4.2.3 UPS Functions

Uninterruptible power supply

- Solving the problem of mains outage.
 - When the mains fails, batteries in the UPS supply power to loads.

Power purification

- Solving the problem of power grid pollution.
 - Increases the input power factor, decreases harmonic pollution to the power grid, and supplies pure power to loads.

Stable AC outputs

- Solving the problem of mains voltage fluctuation.
 - The UPS supports a wide input voltage range, which ensures stable outputs for loads when the mains voltage fluctuates.

Power management

- Solving the problem during AC power maintenance.
 - As an important power supply device, the UPS can be monitored by the network management system (NMS), ensuring easy maintenance.

4.2.4 UPS System Classification

By structure:

- Offline UPS;
- Line-interactive UPS;
- Online UPS.

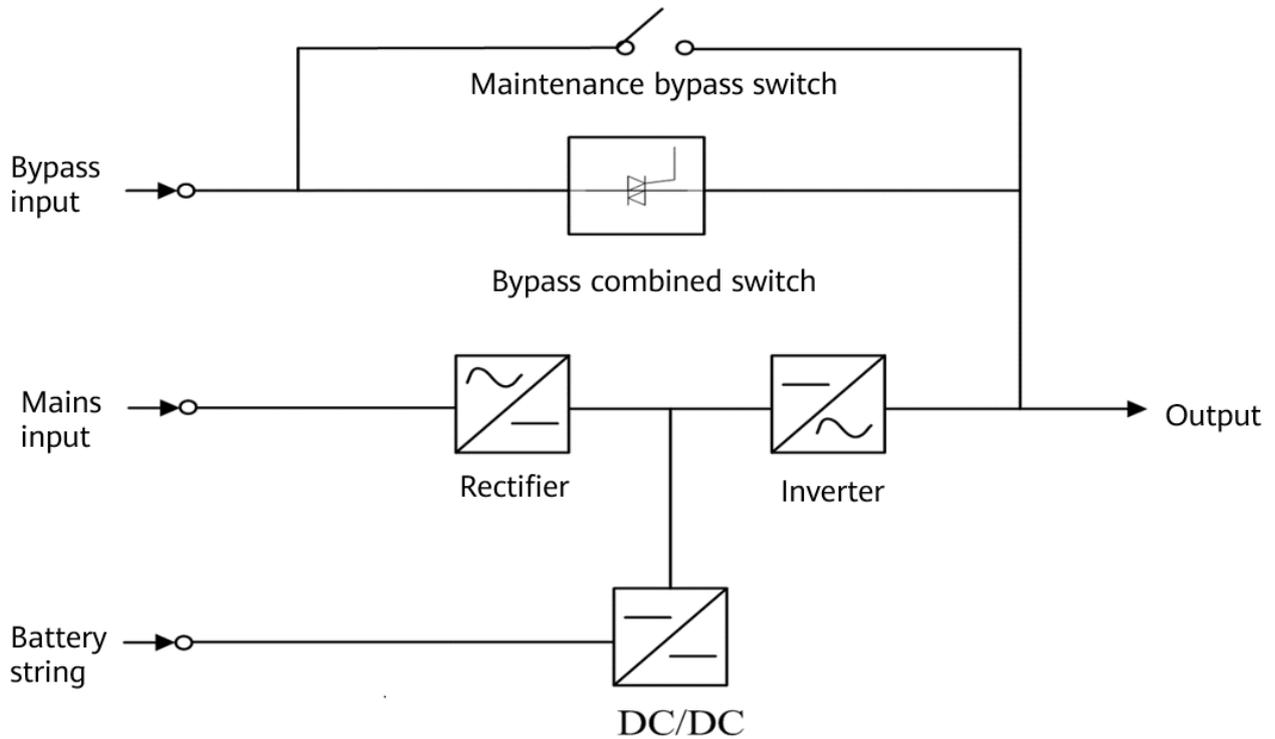
By capacity:

- Small-sized UPS (< 20 kVA);
- Medium-sized UPS (20 kVA to 200 kVA);
- Large-sized UPS (> 200 kVA).

By installation method:

- Tower-mounted UPS;
- Rack-mounted UPS.

4.2.5 Composition of an UPS



UA08000002

Figure 4-3 Composition of an UPS

- UPSs are classified into off-line UPSs, line-interactive UPSs, and double-conversion UPSs. Currently, double-conversion UPSs are mainly used.

Rectifier

- Functions of the rectifier
 - Converts AC power into DC power.
 - Implements power factor correction (PFC) and voltage boosting.
 - Reduces the pollution to the power grid.

Inverter

- During a mains outage, the inverter converts the DC power supplied by batteries into AC power for loads. It also converts DC power from the boost circuit of the upstream rectifier into pure AC power for loads by high-speed operation of switching diodes.
- Functions of the inverter module
 - Converts DC power into AC power.
 - Converts DC power from batteries into AC power.
 - Provides pure AC power by high-speed operation of switching diodes.

Bypass Module

- Functions of the bypass module

- Internal bypass: When the main converter becomes faulty or fails to work properly, for example, due to overtemperature or overload, the UPS can switch to internal bypass mode automatically and manually.
- Maintenance bypass: It is used to separate one or more power circuits of the UPS to ensure security and/or power continuity of loads during maintenance. When the maintenance bypass is enabled, the main power supply or backup power supply can supply power to loads. In this case, loads are not protected.

Charger

- Charges batteries when the AC input is normal.

Batteries

- Batteries supply DC power to the inverter to ensure continuous power supply when a mains outage occurs.
- Typically, the battery voltage is 2 V, 6 V, or 12 V. UPSs often use 12 V batteries. Batteries are connected in serial or parallel to provide required DC current and backup capacity.

4.2.6 UPS Working Modes

Normal Mode

- In normal cases, the UPS works in inverter mode (normal mode);
- In this mode, the mains supplies power to customers' loads using rectifiers and inverters;
- UPS supplies power to the batteries using chargers.

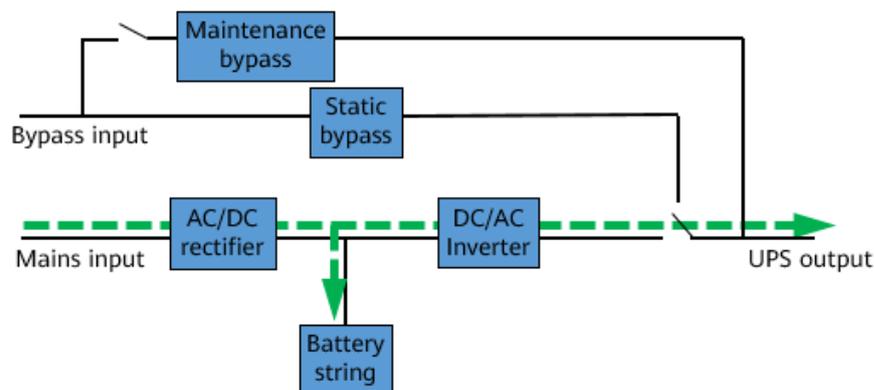


Figure 4-4 Normal Mode

Battery Mode

- If the mains supply fails or exceptions occur, the UPS immediately switches to the battery mode.
- In this case, batteries supply power to customers' loads using inverters.
- After the mains recovers, the UPS immediately switches back to the normal mode.

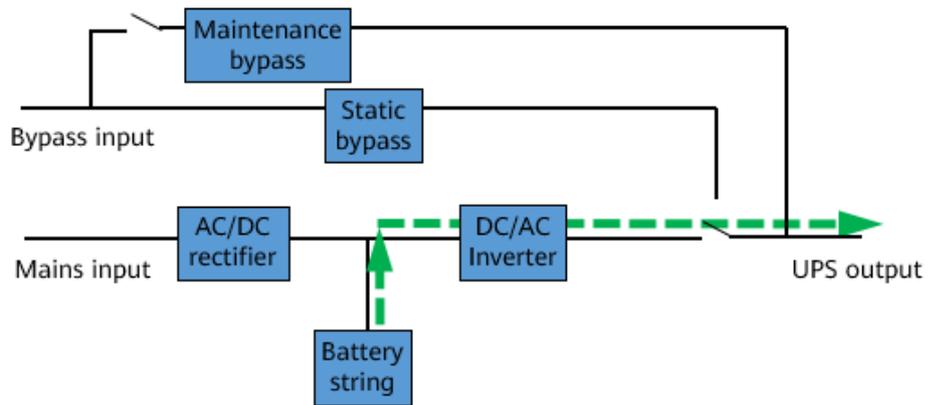


Figure 4-5 Battery Mode

Bypass Mode

- If a UPS is faulty, it immediately switches to the bypass mode (static bypass mode) for power supply;
- In this case, the bypass power source supply power to customers' loads through the static bypass.

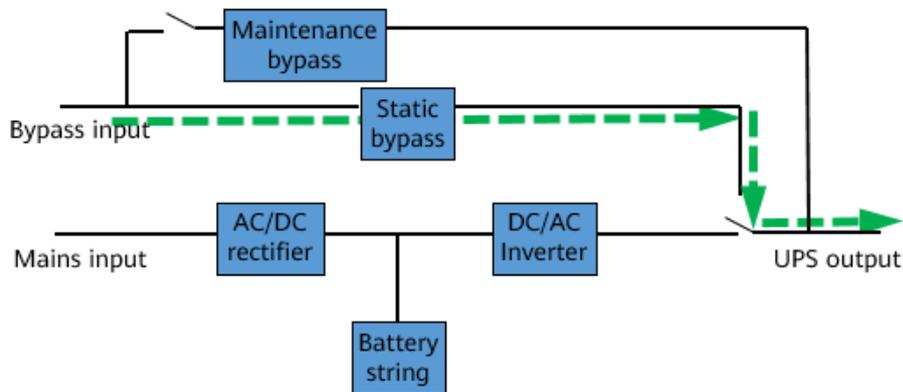


Figure 4-6 Bypass Mode

Maint. Mode

- When a faulty UPS is maintained, the UPS must be manually switched to the maintenance bypass mode.

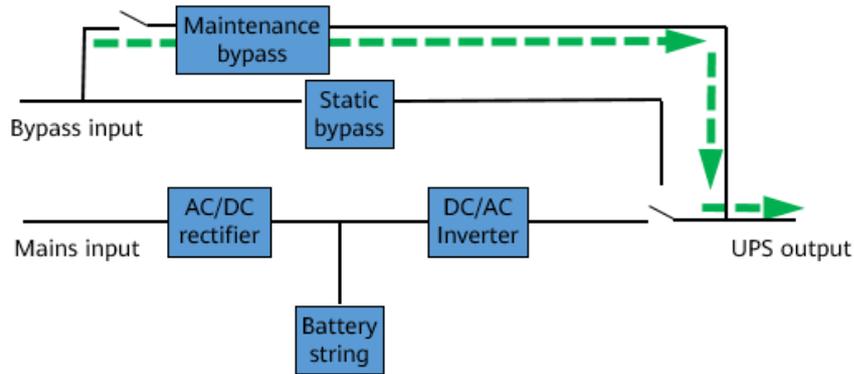


Figure 4-7 Maint. Mode

ECO Mode

- In this mode, if the bypass voltage and frequency are in the specified range, the UPS supplies power to loads over the bypass. If the bypass voltage and frequency are outside the range, the UPS transfers to normal or battery mode.

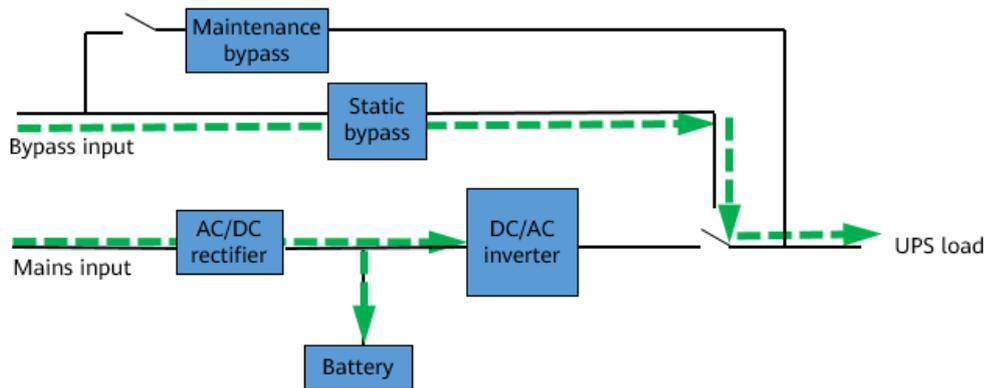


Figure 4-8 ECO Mode

4.2.7 UPS Key Parameters

Capacity

- The UPS loading capability can be indicated by the apparent power (kVA) or active power (kW), for example, 200 kVA or 180 kW. Since output capacitors of inverter units generate reactive power, the active power value cannot exceed the apparent power value.

Output power factor

- The output power factor indicates the UPS capability for carrying loads with active power. Generally, the output power factor is 0.7, 0.8, 0.9, or 1.

Efficiency

- Under the same customers' loads, higher UPS efficiency leads to less UPS loss and operating expense (OPEX). In normal cases, efficiency of medium- and large-sized UPSs is higher than 0.9.

Input voltage and frequency range

- If the input voltage and frequency range is wide, the UPS is adaptable to poor power grids. When the input voltage and frequency exceed the threshold, the UPS switches to the battery mode. A wide voltage range reduces the number of battery discharge times and therefore prolongs the battery lifespan.

Overload capability

- The high overload capability ensures power supply quality. If the UPS overloads, it works in normal mode for a short period and then switches to the static bypass mode. If overload persists, the UPS shuts down.

Input current harmonic

- The low total distortion of the input current waveform (THDi) reduces pollution to the power grid.

4.2.8 Rack&Tower - mounted UPS

Rack-mounted UPS

- Can be placed in a standard 19-inch cabinet;
- Provides a 20 kVA power capacity or lower;
- Enables customers to use rack-mounted batteries.



Figure 4-9 Rack-mounted UPS

Tower-mounted UPS

- Can be placed on the ground or desk;
- Provides a power capacity of 0.5 kVA to 1500 kVA, capacity higher than 3 kVA is placed on the ground.



Figure 4-10 Tower-mounted UPS

4.2.9 Modularized UPS

The modularized design facilitates capacity expansion and prevents excessive investment in initial construction.

The redundancy design increases reliability and availability.

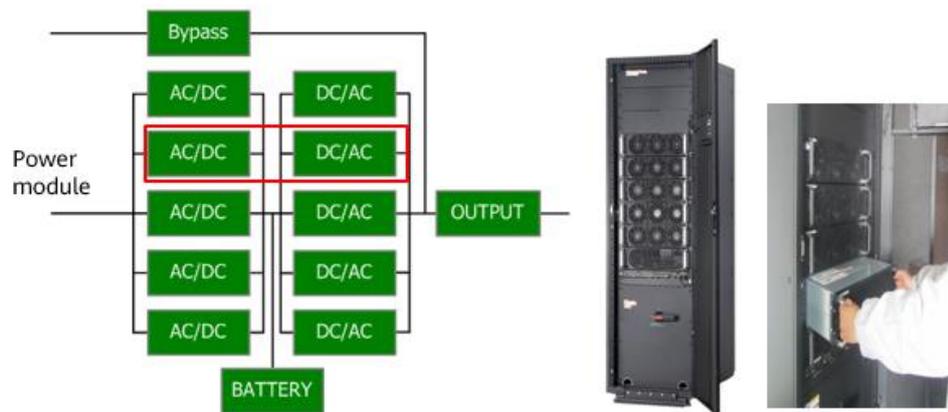


Figure 4-11 Modularized UPS

4.3 Huawei UPS Solutions

4.3.1 Huawei UPSs



Figure 4-12 Huawei UPSs

4.3.2 UPS2000-G Small-sized UPS Solution

Introduction

- N+X redundancy and single UPS configuration based on different reliability requirements;
- Power backup time from 10 minutes to 2 hours and an intelligent management solution;
- Network-wide monitoring platform.

Advantages

- High reliability and efficiency, ensuring power supply continuity and reducing the OPEX;
- Intelligent battery management, prolonging the battery lifespan;
- Network-wide monitoring platform, improving system maintainability and reducing the OPEX.

Application scenarios

- Customer service centers;
- Offices NMS servers;
- Access devices.



Figure 4-13 UPS2000-G: 1 kVA to 20 kVA

4.3.3 L and M-sized UPS5000-A Solution

Introduction

- N+X redundancy and dual-bus configuration based on different reliability requirements;
- Power backup time from 10 minutes to 2 hours;
- Compatible with the NetEco.

Advantages

- High reliability and efficiency, protecting investment and reducing the OPEX;
- Flexible configuration, meeting different requirements;
- Intelligent battery management and network-wide monitoring platform, improving system maintainability.

Application scenarios

- Equipment rooms of data centers, such as the IDC;
- Central equipment rooms.



Figure 4-14 UPS5000-A

4.3.4 L and M-sized UPS5000-E/S Solution

Introduction

- Modularized design, enabling smooth capacity expansion with load increasing;
- N+X redundancy and dual-bus configuration based on different reliability requirements;

- Network-wide monitoring platform, covering all power supply facilities.

Advantages

- High efficiency and modularization, preventing low-efficiency power system running as services increase in initial construction;
- Network-wide monitoring platform, improving system maintainability and reducing the OPEX;
- Flexible configuration and strong expansion capability, meeting different requirements.

Application scenarios

- Key equipment, such as routers, charging servers, and value-added servers in core equipment rooms;
- IT equipment in key convergence equipment rooms and switching rooms.



Figure 4-15 UPS5000-E

4.3.5 FusionPower

Introduction

- Integrates the UPS input and output cabinets and UPS, and achieves a system efficiency of 97%.
- Uses the iPower intelligent technology to improve system reliability and reduce O&M costs for customers.
- Adopts the all-in-one design to effectively reduce the power distribution workload, as well as save footprint and installation time.

Feature

- The redundancy design for all modules improves reliability. Visualized monitoring of all links improves O&M efficiency.
- The iBattery monitors the battery status to eliminate fire risks.
- High efficiency at low load: The efficiency is higher than 96% when the load rate ranges from 20% to 50%, saving electricity fees.



Figure 4-16 FusionPower

4.4 Common Configuration Solutions

4.4.1 Single UPS System

A single UPS system meets the power supply requirements to key loads. N indicates the number of UPSs required for minimum power supply.

Single UPS system advantages:

- Simple configuration and low cost;
- High running efficiency.

Single UPS system disadvantages:

- The usability is limited. If the UPS is faulty, loads are powered in bypass mode, and the power supply quality cannot be guaranteed;
- During UPS, battery, or power distribution device maintenance, the load power supply quality cannot be guaranteed;
- No redundant system exists. When the UPS is faulty, loads are lack of protection;
- Multiple single point failures exist.

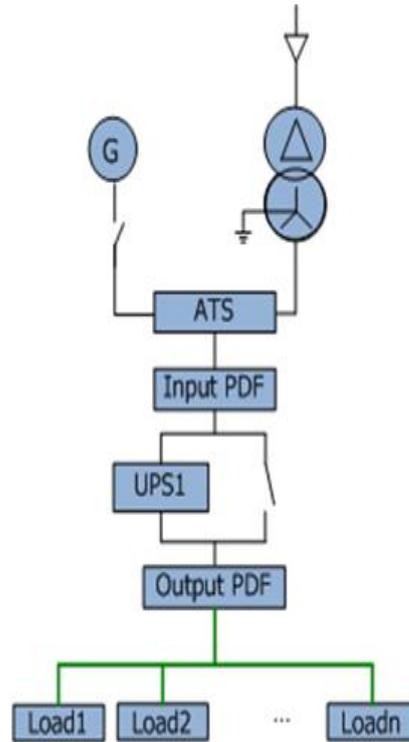


Figure 4-17 Single UPS System

- ATS: automatic transfer switch
- PDF: power distribution frame

4.4.2 Redundant Parallel or N+1 System

Redundant parallel system configuration solution

- When a UPS is faulty, key loads do not need to be powered in bypass mode.
- Outputs of multiple UPSs with the same capacity in a parallel system can be converged.
- Communications cables are required to connecting UPSs in a parallel system to ensure output phase and amplitude synchronization between UPSs.

N+1 system advantages:

- The N+1 system can properly run if a UPS is faulty, which has higher reliability than the N system;
- The system design is simple with low costs.

N+1 system disadvantages:

- UPSs used in an N+1 system must be of the same design, manufacturer, rated specifications, technique, and configurations;
- Single point failures exist in inputs and outputs of the N+1 system;
- If a single UPS and its downstream devices (except for batteries) are maintained, loads cannot be protected;
- The UPS load ratio and the operation efficiency is low.

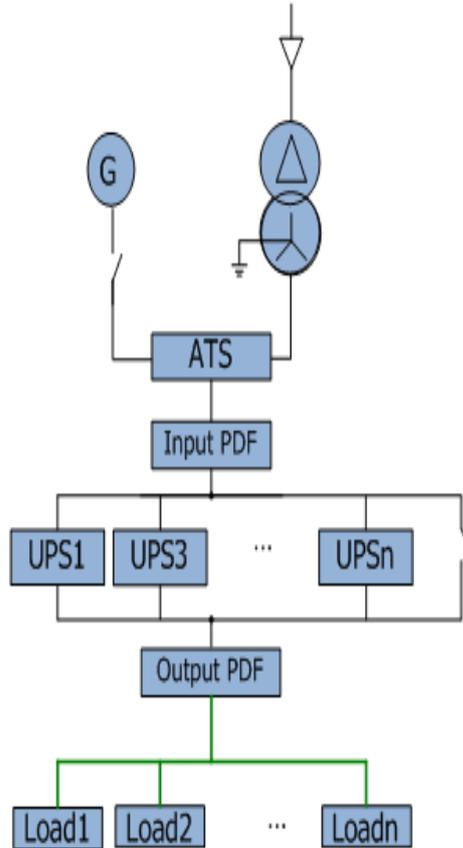


Figure 4-18 N+1 System

4.4.3 Dual-Bus Redundancy System

Dual-bus system advantages:

- Two independent power supplies are available, preventing single point failures and providing powerful fault tolerance;
- The system provides comprehensive input and output redundant configuration;
- UPSs, batteries, and other power distribution devices can be maintained without transferring loads to the bypass mode.

Dual-bus system disadvantages:

- Redundancy design, leading to high costs;
- Low load ratio and low efficiency.

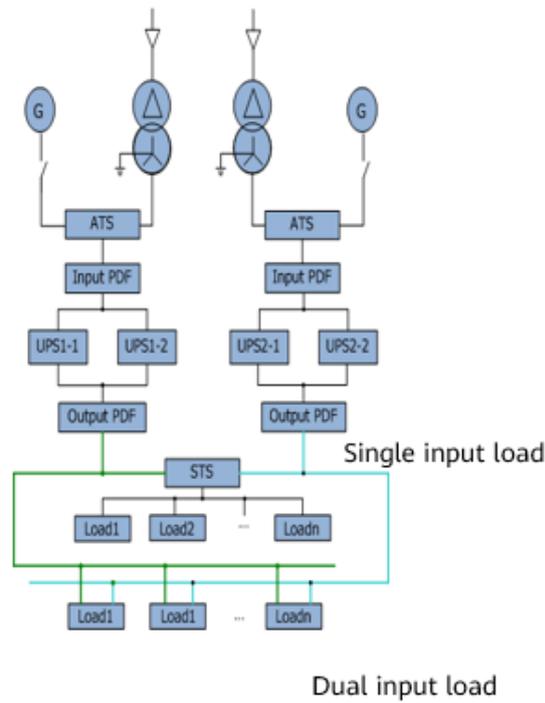


Figure 4-19 Dual-Bus Redundancy System

4.5 Typical Application Scenarios

4.5.1 UPS Application

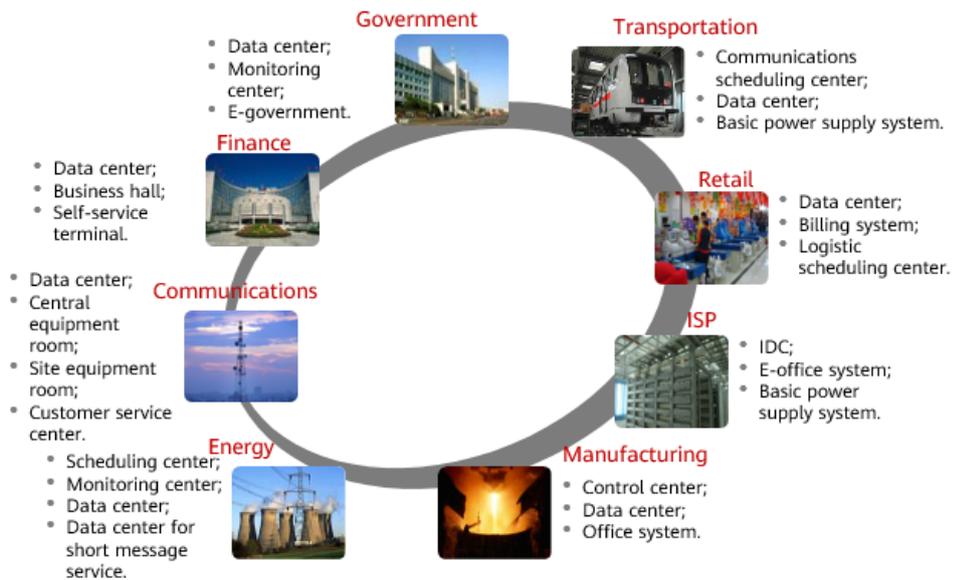


Figure 4-20 UPS Application

4.5.2 UPS Load Types

IT equipment

- Server and storage device
- Switch and router
- Terminal
- ATM



Figure 4-21 Enterprise network equipment room



Figure 4-22 Data center

Industrial facilities

- Industrial control system
- Automated production line
- Precision instrument



Figure 4-23 Automated production line



Figure 4-24 System control center

Personal use

- PC
- Household appliance such as acoustics



Figure 4-25 Office



Figure 4-26 Household acoustics

4.5.3 Scenario

Large-sized IDC

- Important loads, such as servers and storage devices, require reliable power supply systems.
- Large- and medium-sized equipment rooms require the UPS capacity of 300 kVA or higher and power backup time from 10 minutes to 2 hours.
- The system must be smoothly upgraded in the future.
- An intelligent remote monitoring solution must be provided to ensure uninterruptible power supply in an integrated manner.



Figure 4-27 Large-sized IDC

NMS

- High load importance requires a reliable power supply system.
- NMSs require that UPSs be fast deployed, easily installed and maintained, and transferred between tower-mounted and rack-mounted.
- NMSs require the UPS capacity of 1 kW to 10 kW and power backup time of 1 hour.
- NMSs feature abundant ports, easy maintenance, and simple cable routing.



Figure 4-28 NMS

Centralized Equipment Room

- High service importance requires a reliable power supply system.
- Provincial centralized equipment rooms require the UPS capacity of 60 kVA to 200 kVA and more than 1 hour power backup time.
- The UPSs must be applicable to multiple types of loads and servers and meet efficiency and energy conservation requirements.

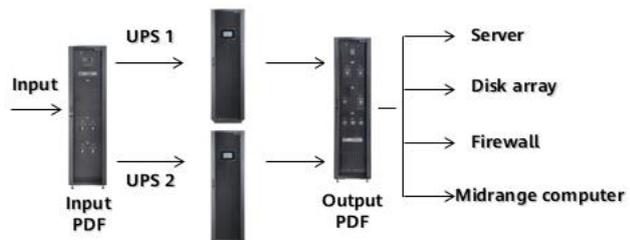


Figure 4-29 Centralized Equipment Room

4.6 Quiz

- 1、(Short Answer Question) Why do we need UPS ?
- 2、(Short Answer Question) What is the benefit of module UPS?
- 3、(Short Answer Question) Which configuration solution is used at your site?

4.7 Summary

- The chapter describes UPS basic knowledge, including the function and work principle of UPS and the common configuration solution.

5 Basic Knowledge of Huawei DC Power Systems

5.1 Introduction

5.1.1 Foreword

DC power systems are widely used in communication base stations and some data center CT scenarios. The slides describe the basic knowledge of Huawei - 48 V DC power systems.

5.1.2 Objectives

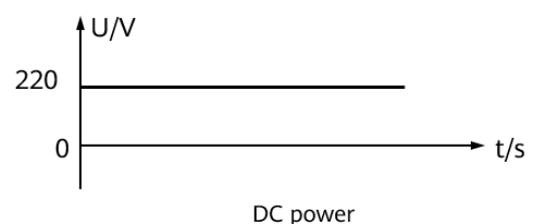
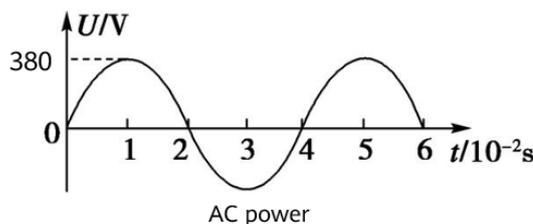
Upon completion of this course, you will be able to understand the main functions of Huawei DC power systems, understand the architecture and basic composition of DC power systems, and master the basic knowledge of DC power system battery management.

5.2 Abstract

5.2.1 DC Power System Application Scenarios

AC power (mains) and its direction change periodically as time changes.

DC power and its direction do not change with time. It is steady current.



DC power is used for powering electronic devices, and AC power is used for upstream electric energy transmission.

DC arcs are more difficult to be extinguished than AC arcs. Unless otherwise specified, do not mix AC and DC devices.

5.2.2 Basic Functions of Huawei DC Power Systems

Two basic functions

- Rectification

- Converts 220 V AC or 380 V AC power into -48 V DC power.
- Provides redundancy for rectifiers.
- Battery management
 - Manages the charge and discharge of batteries connected in parallel on the output side. That is, batteries can be charged and discharged with appropriate voltages, currents, and modes to ensure that the DC load operates uninterruptedly when the AC power failure occurs.

5.2.3 Output Voltage

Why is the polarity negative?

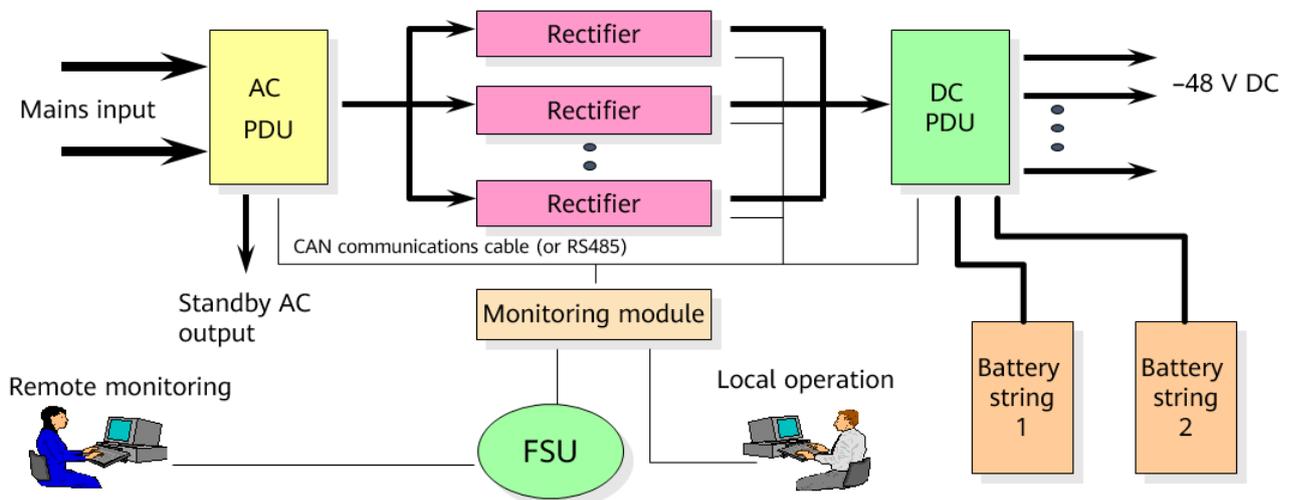
- Due to historical reasons, the positive pole of the telecom power supply was grounded at the early stage, forming a loop through the ground and saving cables.
- The positive grounding can reduce the corrosion of negative devices.

Why is the voltage -48 V?

- The early-stage power systems use the original lead-acid batteries, and the voltage is a multiple of the basic (single battery) voltage 1.2 V.
- According to the device component and line capabilities, 48 V voltage is selected to ensure the communication distance of local calls and security.

5.2.4 Logical Composition

The telecom power system consists of the AC power distribution unit (PDU), DC PDU, rectifier, and monitoring unit.

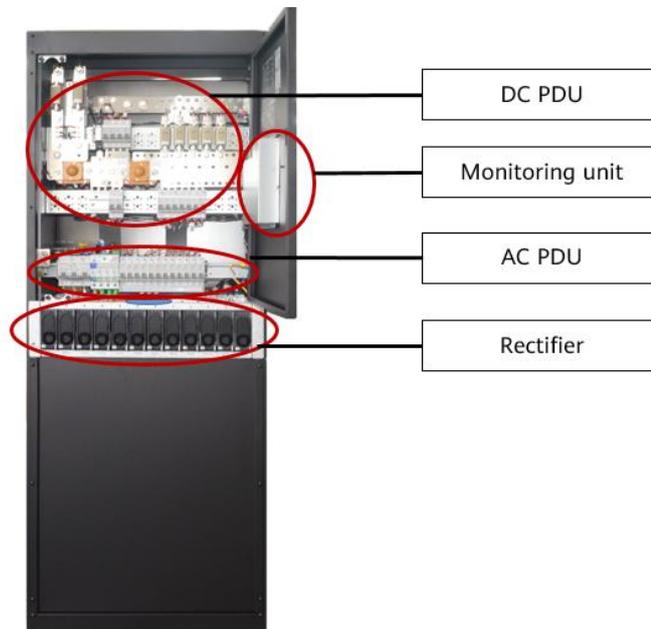


5.3 Architecture and Components

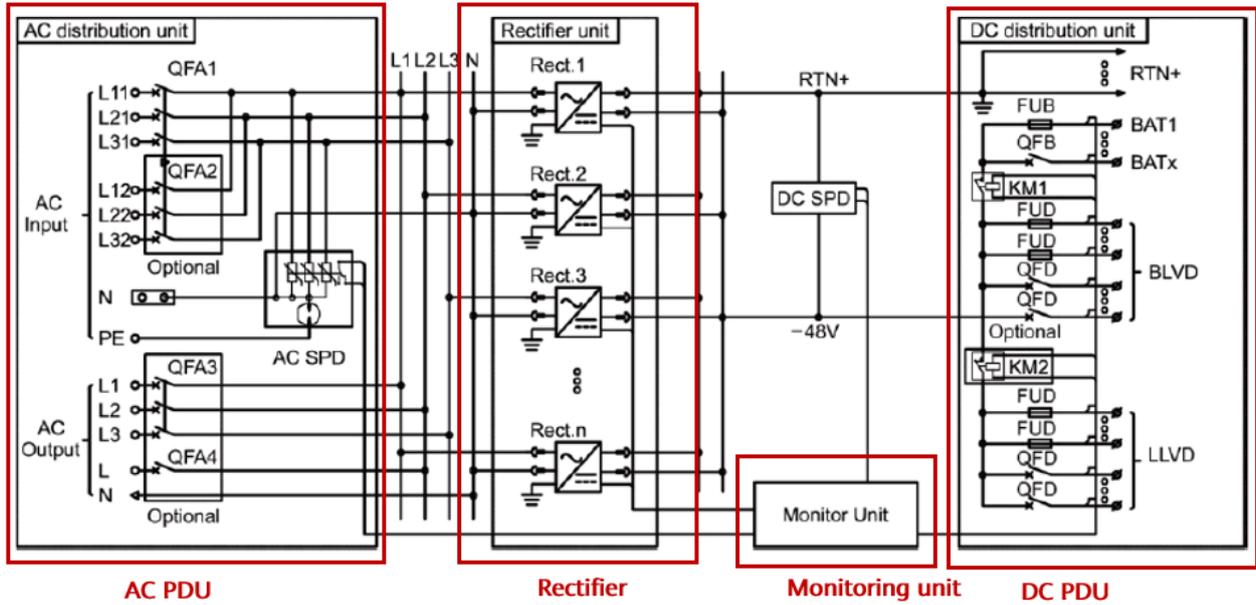
5.3.1 Physical Architecture

Basic components

- AC PDU
 - AC input, AC output, AC surge protective device (SPD), and line protection
- Rectifier
 - Converts AC power into DC power (high-frequency switch rectification).
- DC PDU
 - DC junction, output, SPD, load power-off, and battery protection
- Monitoring unit
 - Measures AC and DC power distribution signals; manages, controls, and monitors rectifiers; analyzes and outputs alarms; manages loads and batteries.



5.3.2 Electrical Conceptual Diagram



5.3.3 Rectifier Parameters

Input

- Input voltage range
- Input frequency range
- Power factor

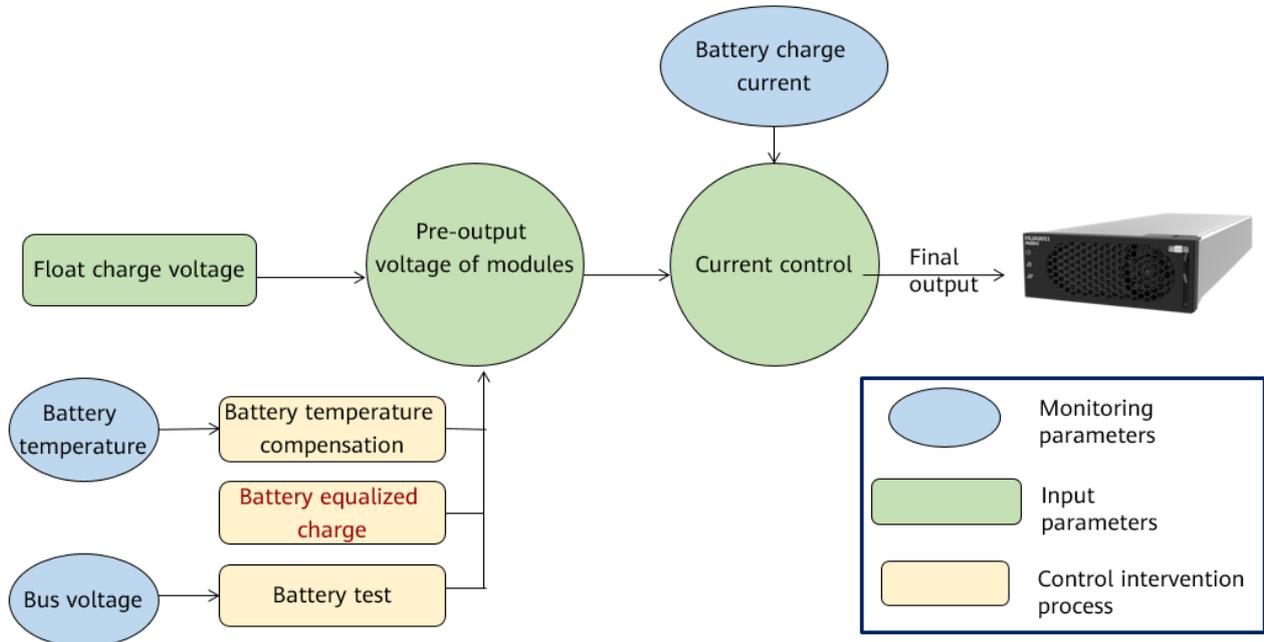
Output

- Output voltage adjustment range
- Output current adjustment range
- Regulated voltage precision



5.4 Battery Management

5.4.1 Working Principle



5.4.2 Main Functions

Equalized charge and floating charge management:

- When the real-time battery capacity, charge current, and charge time meet certain conditions, the equalized charge and float charge modes switch with each other.

Battery disconnection protection:

- After an AC outage occurs or rectifiers become faulty, batteries start discharging and the battery voltage decreases. If the AC power does not recover when the battery voltage decreases to a certain extent, batteries need to be disconnected to prevent battery damage.

Temperature compensation:

- When the batteries are being charged, the temperature increases slowly. To ensure that the batteries work at a proper temperature, the battery charge voltage is decreased when the battery temperature is too high and the battery charge voltage is increased when the battery temperature is too low.

5.5 Application Scenarios

5.5.1 Application Scenarios

DC power systems are widely used in communication base stations and some data center CT scenarios.



Figure 5-1 Communication base station scenario

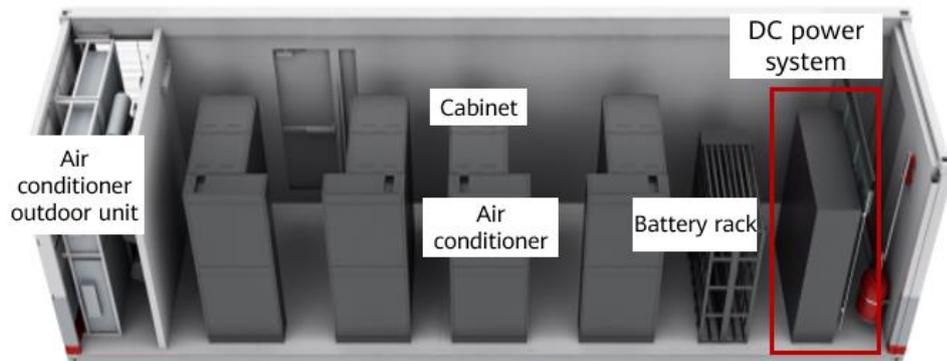
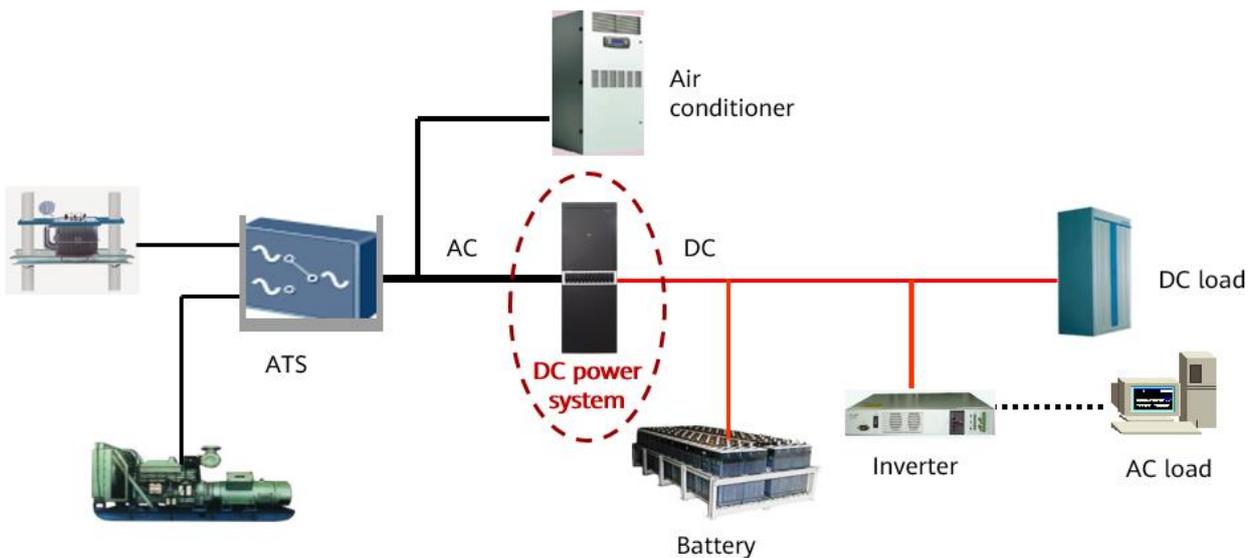


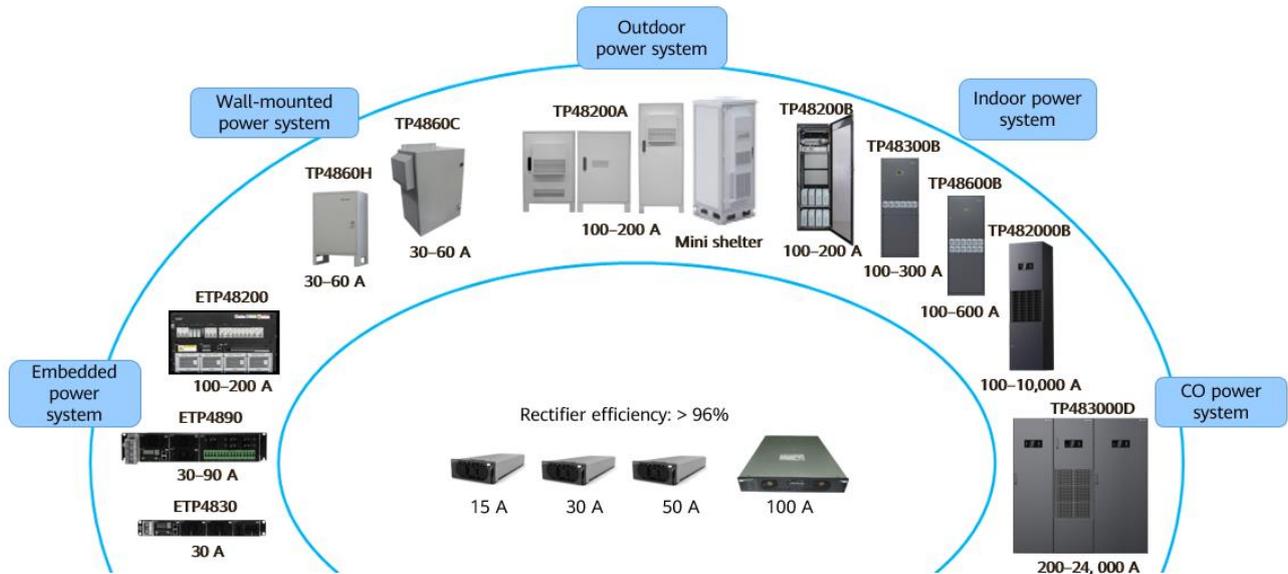
Figure 5-2 Data center CT scenario

5.5.2 Position in the Power Distribution System

The mains enters the rectifiers through the AC PDU. The rectifiers convert AC power into – 48 V DC power, and then the DC PDU distributes the power to DC devices.



5.6 Huawei DC Power Systems



5.7 Quiz

1. (Short Answer Question) What are the basic functions of DC power systems?
2. (Short Answer Question) What are the basic components of a DC power system?

5.8 Summary

After learning this chapter, we are able to:

- Understand the telecom power.
- Understand the architecture and composition of DC power systems.
- Master the principles and features of DC power systems.

6 Basic Knowledge of Batteries

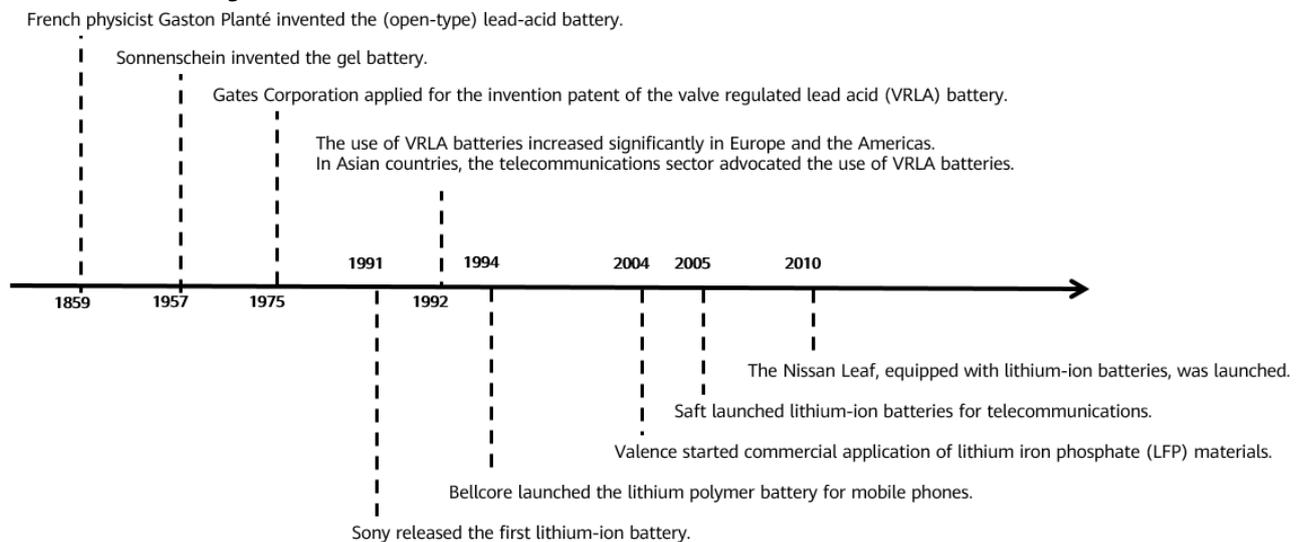
6.1 Objectives

On completion of this course, you will be able to:

- Understand the battery development and application in the ICT field.
- Get familiar with the classification and naming of batteries.
- Get familiar with the basic principles and structure of batteries.
- Understand the performance differences between lead-acid and lithium-ion batteries.

6.2 Battery Overview

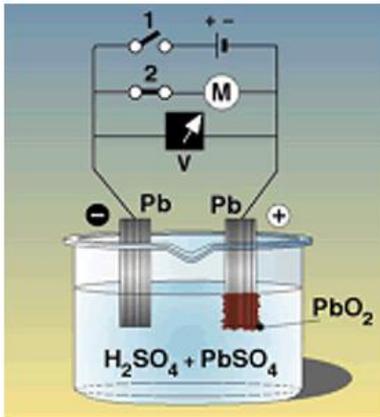
6.2.1 History



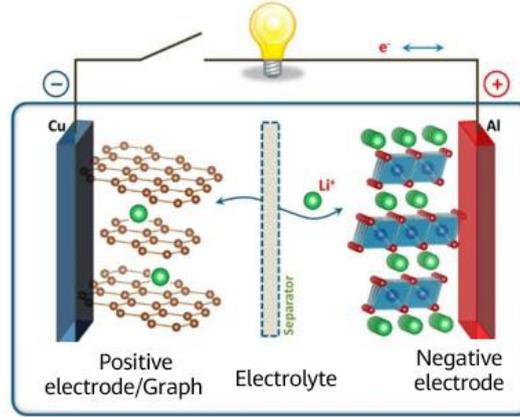
6.2.2 Definition

A chemical battery, generally referred to as battery, is a device that converts chemical energy into electrical energy. After a battery is discharged, it can be recharged to regenerate the internal active substances, that is, to convert the electrical energy into chemical energy. It converts chemical energy into electrical energy again when it is discharged. This type of battery is called storage battery or secondary cell.

Main rechargeable batteries in the market include nickel metal hydride batteries, lead-acid batteries, lithium-ion batteries, and lithium polymer batteries.



Lead-acid battery



Lithium-ion battery

6.2.3 Function

Storage battery are sound DC power sources and are stable in voltage, free of fluctuation, and easy and reliable to use. Therefore, storage battery are widely used in the communications systems. Storage battery can be backup power sources for the AC UPS and DC power system, the startup power source, and the DC operation and control power source in the high-voltage power distribution system.



6.2.4 Technical Specifications

Rated capacity: refers to the nominal capacity, which indicates the minimum capacity that can be discharged according to standards or industrial standards.

Actual capacity: refers to the capacity that can be discharged after a fully charged battery is discharged to the specified end-of-discharge (EOD) voltage under certain discharge conditions. The unit is Ah or Wh.

Discharge rate: For example, C10. C indicates the capacity, and 10 indicates the number of hours for the battery to discharge to the specified voltage at a certain current. The rated discharge current can be obtained by dividing the capacity by the number of hours.

SOH: State of health, refers to the Percentage of actual capacity to rated capacity.

SOC: State of charge, refers to the Percentage of current remaining capacity to actual capacity.

Rated voltage: refers to the approximate value used to identify the voltage of a battery type. For example, the rated voltage of a single VRLA battery is 2 V.

Open-circuit voltage: refers to the terminal voltage of a battery in the open-circuit state. The open-circuit voltage of a battery is equal to the electric potential difference between the positive electrode and the negative electrode when the battery is open-circuited (that is, when no current passes through the two electrodes).

EOD voltage: indicates the voltage when a battery is used up. If the voltage decreases due to continuous discharging, the battery will be damaged. EOD voltage is the protection voltage set to prevent battery overdischarge. When the voltage reaches the value, the discharging should be terminated.

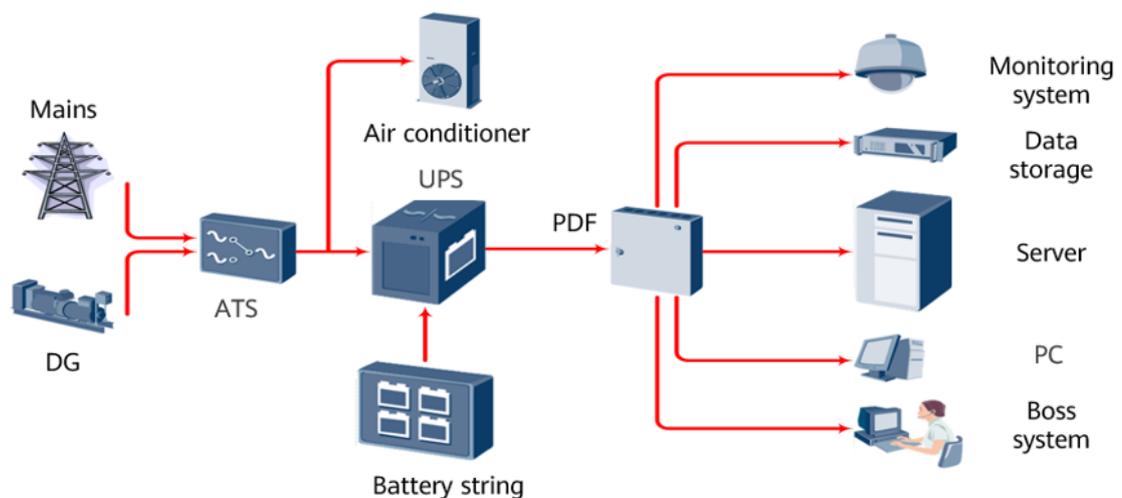
Equalized charging: During the use of batteries, battery voltages are unbalanced due to the individual difference and temperature difference of batteries. To avoid the deterioration of this imbalance trend, the charge voltage of the battery string needs to be increased to activate the batteries. In this way, characteristics of each battery in the battery string are balanced.

Float charging: To balance the capacity loss caused by battery self-discharge, batteries need to be charged at a constant voltage for a long time.

Depth of discharge (DOD): indicates the percentage of battery discharge capacity to rated battery capacity. Generally, when the discharge capacity of a battery exceeds 80% of its rated capacity, it is considered that DOD is achieved.

6.2.5 Application in Data Centers

In a data center, batteries are installed at the end of the UPS. When the mains fails, batteries supply DC power to the UPS, and the UPS converts the DC power into AC power required by loads to ensure continuous operation of devices.



6.3 Lead-acid Battery

6.3.1 Overview

6.3.1.1 Definition

VRLA battery is a battery improved in material, structure, and process based on the common anti-acid and explosion-proof lead-acid storage battery.

The basic feature is that the battery does not need to be maintained by refilling acid or water during operation. Thanks to its sealing structure, the battery does not leak acid or exhaust acid smog.

On the battery cover is a one-way exhaust valve (safety valve), which automatically exhausts the excessive gas in the battery when the internal battery pressure increases to the threshold and automatically closes itself after the exhausting to avoid gas entry.



6.3.1.2 General Category

Based on electrolyte: acid battery and alkaline battery

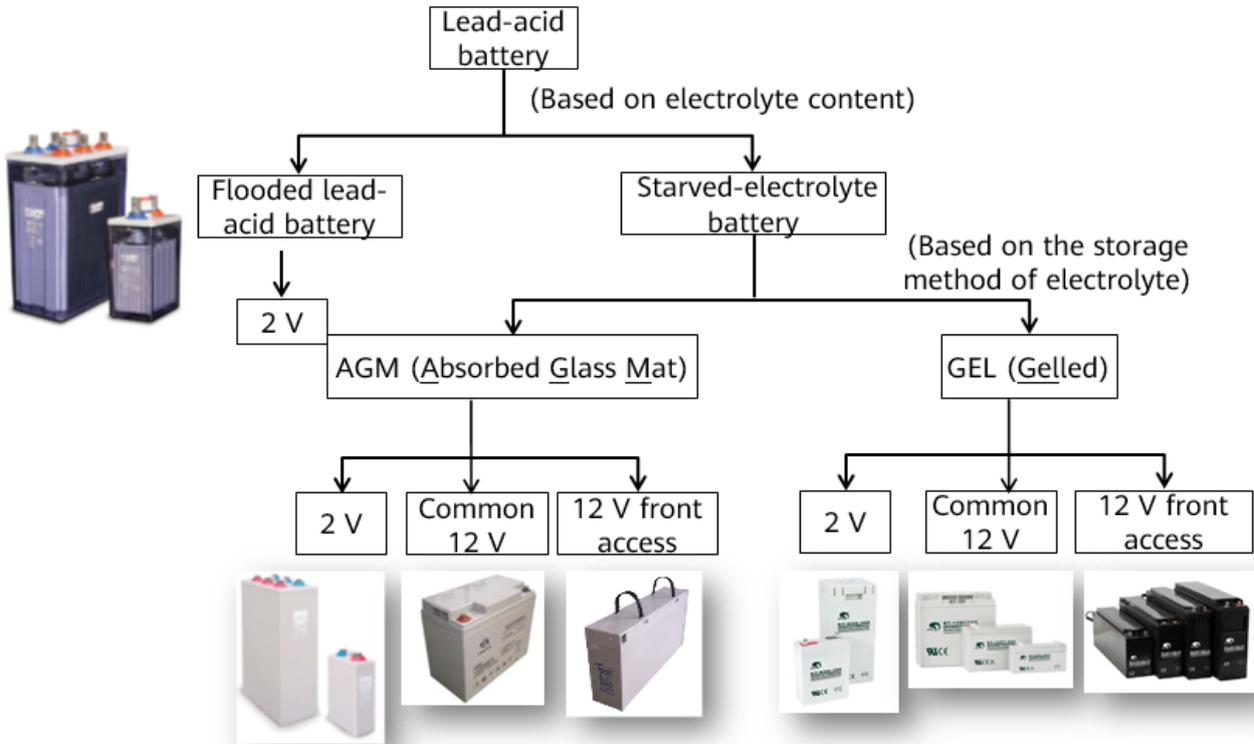
Based on electrolyte content: flooded battery and starved-electrolyte battery

Based on vent plug structure: open-type battery, vented battery, and acidapray-proof battery

Based on cell voltage: 2 V battery, 6 V battery, and 12 V battery

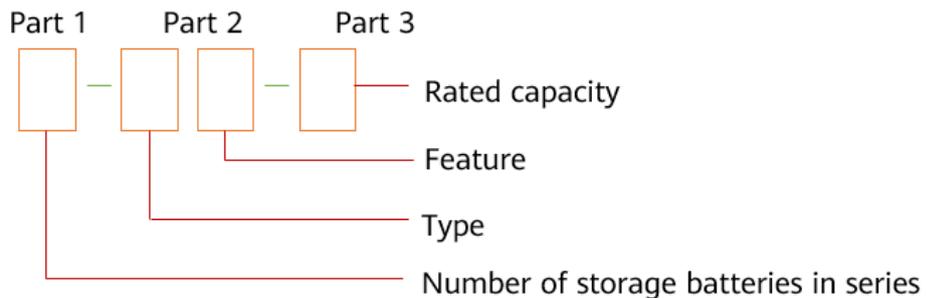
Based on purpose: stationary battery, mobile battery, starter battery, traction battery, railway battery, motorcycle battery, coal mine battery, energy storage battery, and battery for other purposes

6.3.1.3 Battery Classification in ICT



6.3.1.4 Naming Rule

The model number of the lead-acid battery is composed of three parts. Part 1 indicates the number of storage battery in series; part 2 indicates the type and feature of the storage battery; part 3 indicates the rated capacity of the storage battery. Other codes can also be added on the right after the rated capacity if necessary.



6.3.1.5 Examples

GFM-1000: a stationary valve-regulated sealed lead-acid battery, rated capacity 1000 Ah (common in ICT scenarios).

6-GFM-100: six stationary valve-regulated sealed lead-acid batteries in series, rated capacity 100 Ah (common in ICT scenarios).

6-Q-150: a lead-acid battery string of six batteries in series for startup, rated capacity 150 Ah.

No.	Battery Type (Purpose)	Code	No.	Battery Feature (Purpose)	Code
1	Starter	Q	1	Sealed	M
2	Stationary	G	2	Maintenance-free	W
3	(Electric) Traction	D	3	Antiacid	F
4	Valve-regulated	F	4	Gel electrolyte	J
5	Energy storage	U	5	Air-tightness	Q

6.3.2 Battery Structure

6.3.2.1 Main Components

Take the most widely-used AGM lead-acid battery for example, its main components include the positive plate, negative plate, electrolyte, battery separator, battery chute, and other parts, such as the terminal, busbar, and safety valve.



6.3.2.2 Safety Valve

The safety valve is a key component of VRLA battery. The quality of the safety valve directly determines the lifespan, performance uniformity, and safety of the VRLA battery. The function of the safety valve is:

- To automatically exhaust the excessive gas in the battery to lower the internal battery pressure when the internal pressure increases to the threshold.
- Unidirectional exhausting means that air cannot enter the battery, which avoids battery self-discharge.



6.3.2.3 Plate

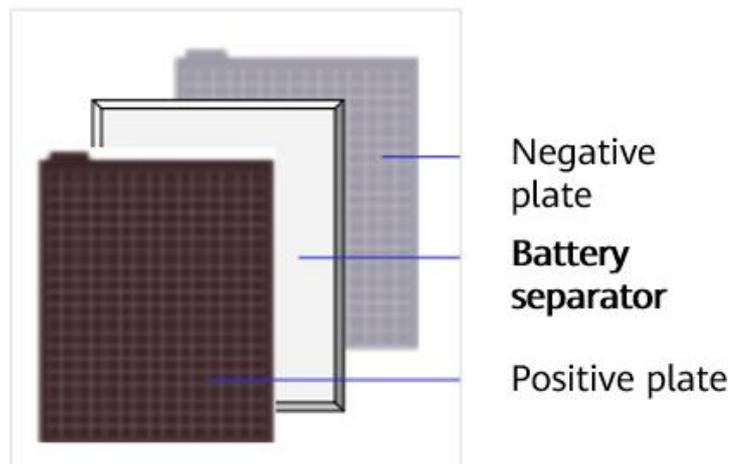
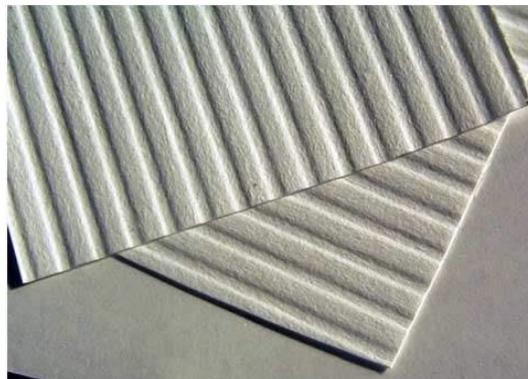
The battery plate can be positive or negative. Battery plates are composed of active substances and plate grids, and there is a separator between the positive and negative plates, as shown in the following figures. Active substances for the positive and negative plates are lead dioxide (PbO_2) and gray sponge lead (Pb) respectively.



6.3.2.4 Separator

The battery separator has the following functions:

- Keeps the positive and negative plates insulated from each other.
- Absorbs electrolyte, and ensures that the electrolyte does not flow and that the negative plate is damp.
- Serves as the gas channel. Many holes in the battery separator facilitate the oxygen moving from the positive plate to the negative plate.
- Slows the disconnection of active substances.



6.3.2.5 Battery Structure – Electrolyte

The electrolyte, composed of pure concentrated sulfuric acid and pure water, is absorbed in the separator to conduct electricity and participate in electrochemical reaction. The post terminal is the external terminal. The safety valve is used to unidirectionally adjust the internal pressure of the battery to prevent air from entering the battery.

In a VRLA battery, the electrolyte does not flow, that is, the electrolyte is absorbed by active substances on the plate and the separator film, and the saturation degree of the electrolyte is 60% – 90%.

When the saturation degree of the electrolyte is lower than 60%, it indicates that the battery loses electrolyte seriously, and the active substances on the plate cannot fully contact the electrolyte. If the saturation is higher than 90%, the diffusion channel of the oxygen from the positive electrode is blocked by the electrolyte, which affects the diffusion of the oxygen to the negative electrode. In addition, the gel electrolyte does not flow.

6.3.2.6 Container and Cover

The battery chute houses the electrolyte, battery plate, battery separator, and accessories. For example, there are the positive terminal, negative terminal, and exhaust unit in a VRLA battery. The battery chute must be made of corrosion-, vibration-, and high/low-temperature-resistant materials.



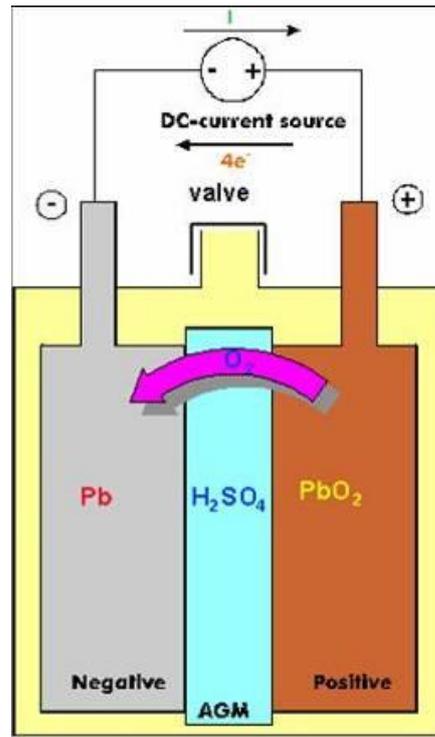
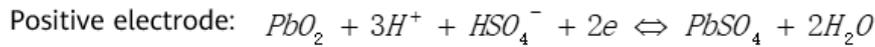
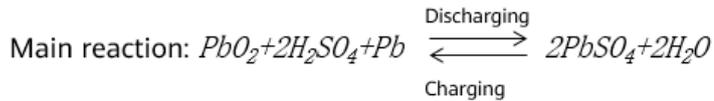
6.3.3 Working Principle

6.3.3.1 Working Principles – Main Reaction

Double-sulphate theory

- This theory can be described as follows: When a lead-acid battery is discharged, the active substances at the positive and negative electrodes change to lead sulfate (PbSO₄). After the battery is charged, the active substances return to the original state. That is, the active substances at the positive electrode change to lead dioxide (PbO₂), and those at the negative electrode change to sponge lead (Pb).

The main reaction constitutes a chemical system of 2 V electromotive force for a single cell.



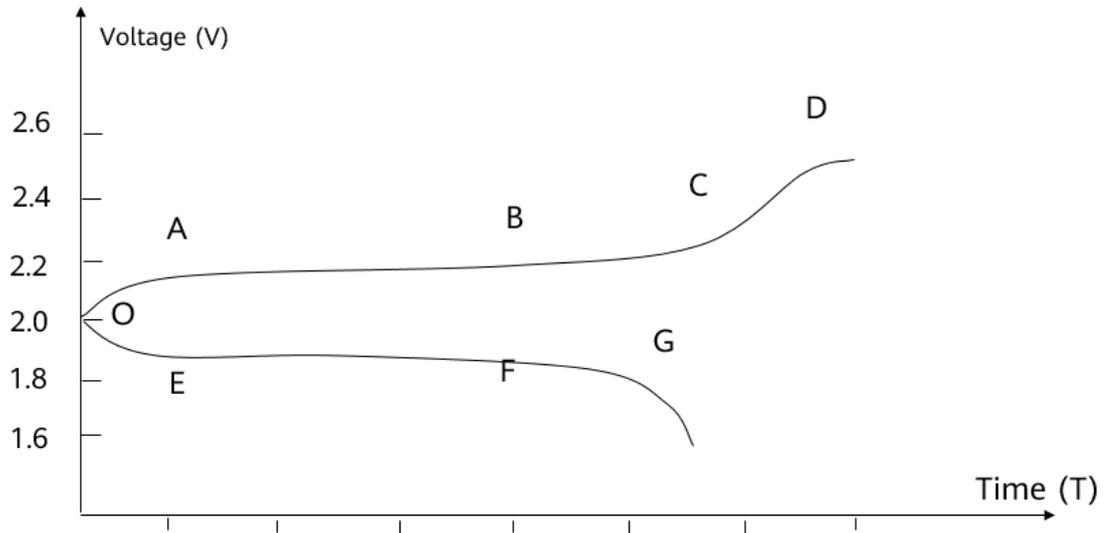
6.3.3.2 Working Principles – Side Reaction



At the end of charging and during overcharging, in addition to the reaction of active substances, the preceding two reactions occur at the positive and negative electrodes. At this time, PbSO_4 is almost completely converted to PbO_2 and Pb in charging state. The potential of the reaction increases. The side reactions including oxygen evolution reaction (OER) and hydrogen evolution reaction (HER) will dominate.

Therefore, overcharging may cause battery swelling due to the side reactions.

6.3.3.3 Working Principle – Terminal Voltage Changes During Charging and Discharging



6.4 Lithium-ion Battery

6.4.1 Overview

6.4.1.1 Definition

Lithium-ion batteries are secondary batteries developed based on lithium batteries.

- The positive electrode material of lithium batteries is manganese dioxide or thionyl chloride, and the negative electrode material is metal lithium. After a battery is assembled, the battery has voltage and does not need to be charged.
- In the early 1990s, Sony invented batteries with carbon materials as the negative electrode and lithium compounds as the positive electrode. In the process of charging and discharging, lithium ions, instead of lithium, exist. These batteries are called lithium-ion batteries.

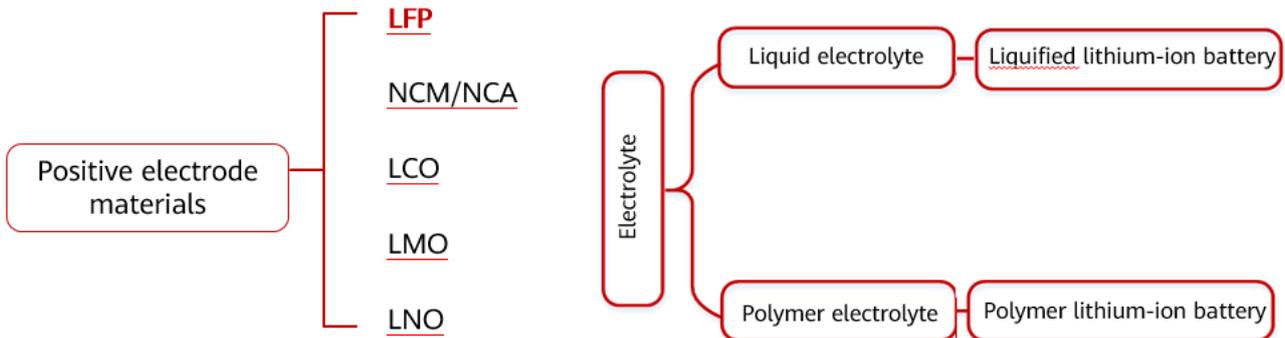


6.4.1.2 Classification

Lithium-ion batteries use positive electrode materials such as lithium cobalt oxide (LCO), lithium nickel oxide (LNO), lithium manganese oxide (LMO), lithium nickel manganese cobalt oxide (NCM)/lithium nickel cobalt aluminum oxide (NCA), and LFP.

Based on the electrolyte form, lithium-ion batteries are classified into liquified lithium-ion batteries and polymer lithium-ion batteries.

LFP batteries with liquid electrolytes are commonly used in data centers.



6.4.2 Battery Structure

6.4.2.1 Internal Structure

Positive electrode: transition metal oxides (containing lithium) with a conductive agent and an adhesive, coated on an aluminum foil to form a positive plate

Negative electrode: formed by coating a laminated graphite with a conductive agent and an adhesive on a copper foil

Electrolyte: composed of electrolyte and organic solvent

Separator film: composed of a polyethylene (PE) or polypropylene (PP) microporous film. It isolates the positive and negative electrodes, preventing the passage of electrons while allowing that of lithium ions.

Shell: aluminum foil (pouch), steel shell, or aluminum shell.

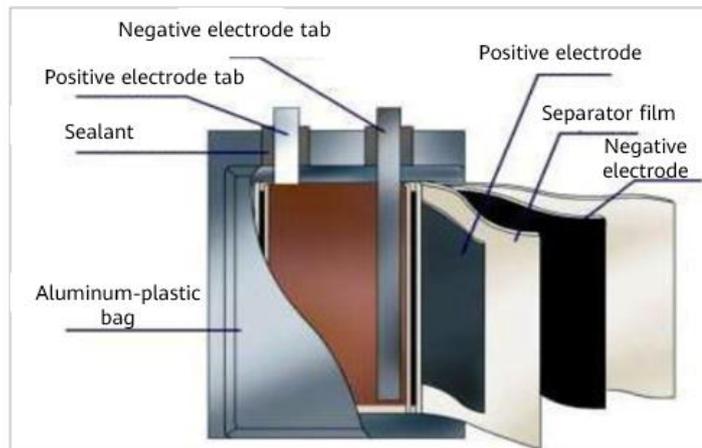
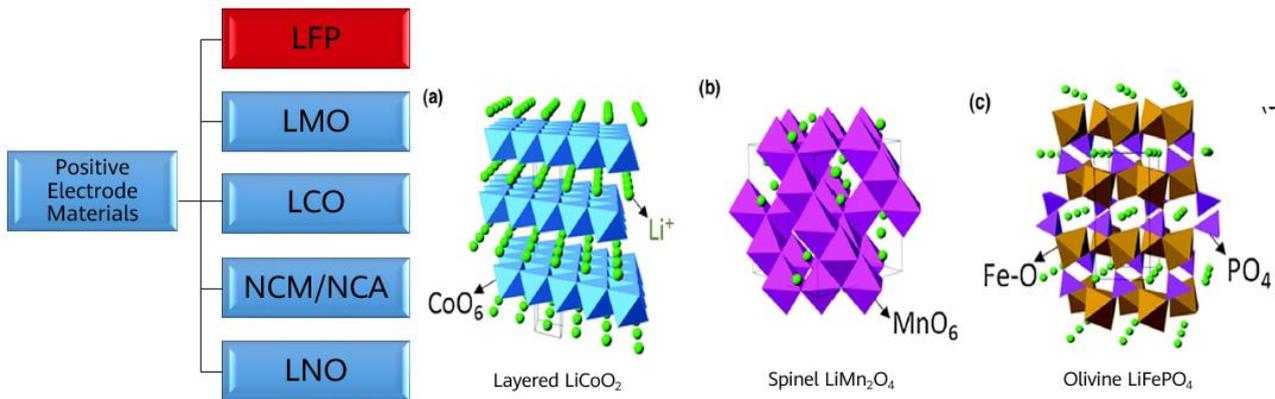


Figure 6-1 Structure of a lithium-ion battery

6.4.2.2 Positive Electrode Materials

Positive electrode material: Positive electrode materials include transition metal oxides or polyanionic compounds containing lithium and have a layered, spinel, or olivine structure. The materials provide a lithium source and have a stable lithium deintercalation capability, which determines the lower limit of safety of a lithium-ion battery.



6.4.2.3 Negative Electrode Materials

Requirements for negative electrode materials:

- Electronic conductivity and ion conductivity are excellent.
- Intercalation and deintercalation reactions of lithium ions in carbon are fast.
- The existence of lithium ions in electrode materials is stable.
- A compact and stable solid electrolyte interphase (SEI) can be generated on the negative electrode surface to prevent the electrolyte from continuously reducing on the surface.
- In the charge and discharge cycle of the battery, the volume of the carbon material at the negative electrode changes slightly.

Common negative electrode material: graphite

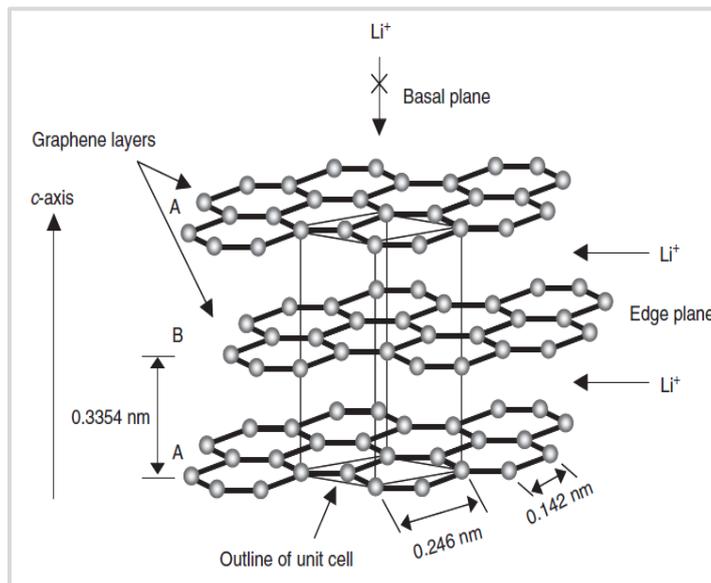
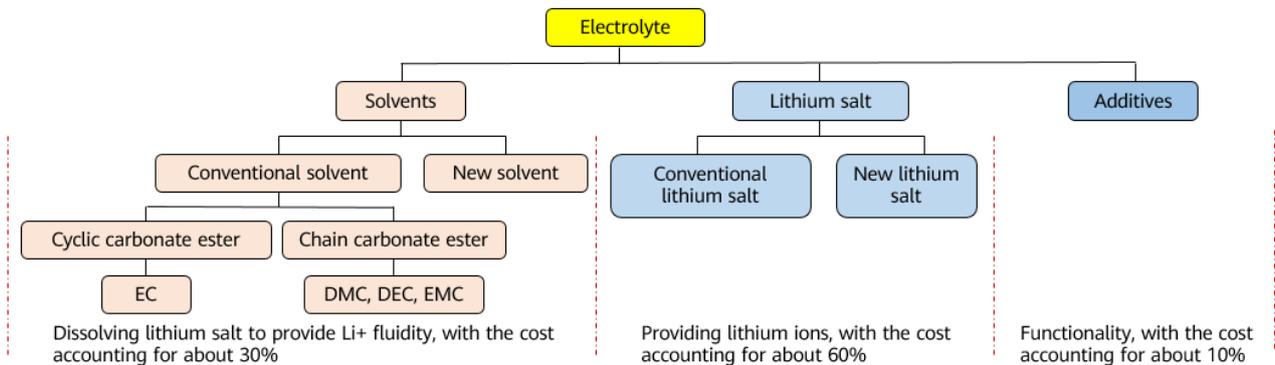


Figure 6-2 Graphite molecular structure

6.4.2.4 Electrolyte

Electrolyte:

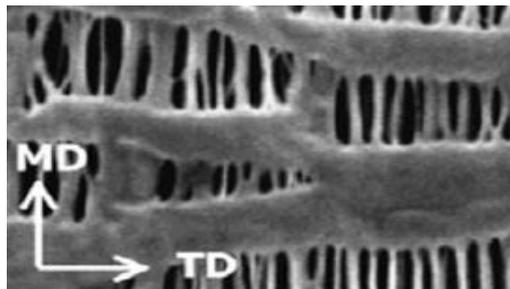
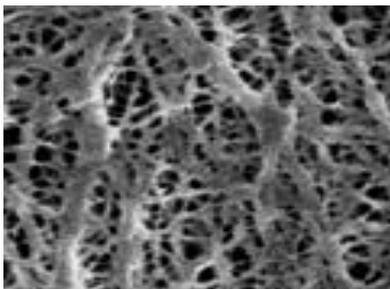
- Provides a medium for rapid conduction of lithium ions, and requires lithium ions (dissociating lithium salts).
- To dissolve the preceding lithium salt and additives, a solvent is required, which determines a lower limit of high and low temperature characteristics of batteries.
- To protect the reaction interface, a protective film (SEI) is formed on the (positive) negative electrode surface, and a film additive is required. The additive determines the interface of the material and the upper limit of the battery cycle.



6.4.2.5 Separator Film

The separator film must meet the following requirements:

- Has direct contact with the positive and negative electrodes (high and low potentials) as well as the electrolyte, requiring electrochemical stability (against electrochemical and other corrosion).
- Provides physical barriers between positive and negative electrodes to prevent short circuits, featuring insulation (separating electrons) and strength against puncture. Allows lithium ions to pass through. Currently, a micro porous structure is used to absorb the electrolyte.
- Provides an automatic shutdown mechanism with low shutdown temperatures and high rupture temperatures, ensuring good protection performance.
- Determines the lower limit of the battery safety, does not provide active substances. A thinner separator film is better in terms of energy density.
- A thin separator film requires a ceramic coating for separation; to ensure that the positive and negative electrodes are adhered to each other, glue is required sometimes.



6.4.3 Working Principle

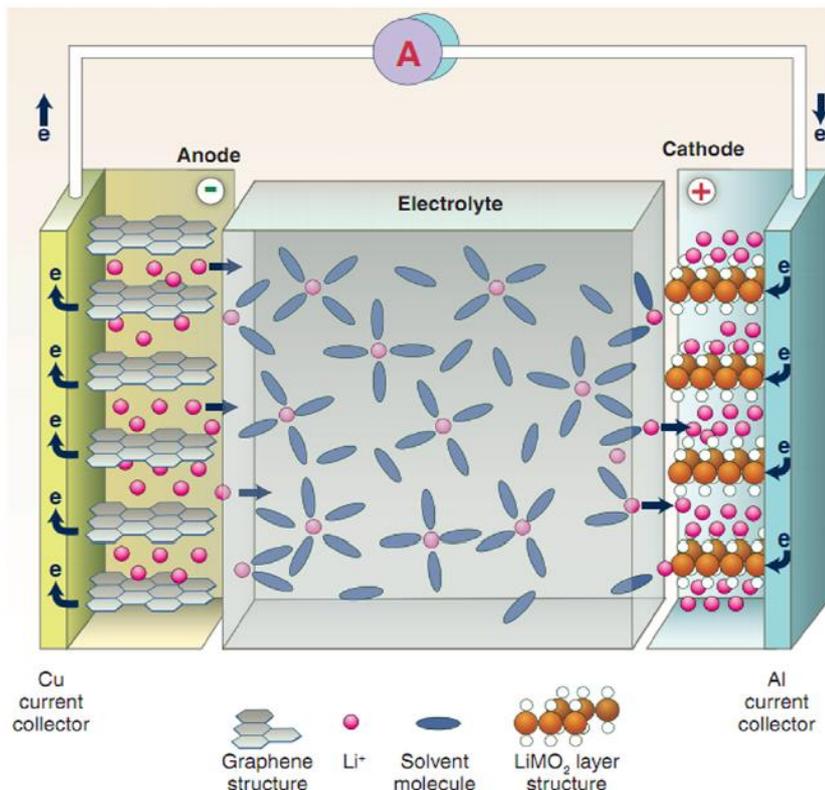
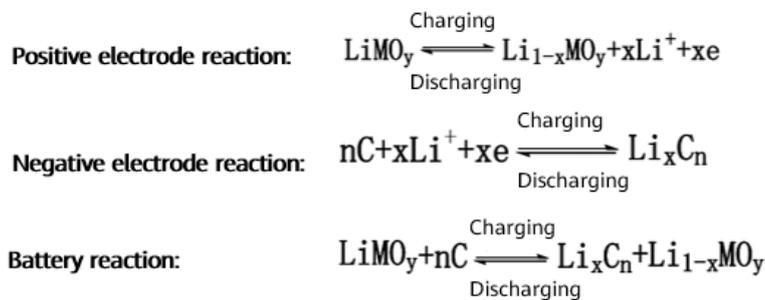
6.4.3.1 Working Principle

Li⁺ intercalation and deintercalation repeatedly occur at the positive and negative electrodes.

During charging, Li⁺ is deintercalated from the positive electrode and intercalated into the negative electrode (obtaining electrons).

During discharging, Li⁺ is deintercalated from the negative electrode and intercalated into the positive electrode (obtaining electrons).

Use compounds that can be intercalated into lithium ions as the positive and negative electrodes, so that the flow of lithium ions changes from uncontrollable to controllable after guidance.



6.4.3.2 Charging Management

The CC-CV two-stage charging method is used. In the CC charging stage, the 0.5C–1C charge current is used.

Restricted voltages in the CC charging stage are as follows:

- When LiFePO_4 materials are used for the positive electrode, the maximum value is 3.650 V. If 16 lithium-ion batteries are cascaded, the maximum value is $3.650 \text{ V} \times 16 = 58.40 \text{ V}$.
- If the positive electrode material is not LiFePO_4 , the maximum value is 4.100 V. If 16 lithium-ion batteries are cascaded, the maximum value is $4.100 \text{ V} \times 14 = 57.40 \text{ V}$.

Charging termination conditions in the CV charging stage are as follows:

- At the end of the CC charging stage, when the battery voltage reaches the charge voltage limit, the CV charging mode is used. The charging stops until the charge current is less than or equal to $0.01C$, and the entire charging process is complete.

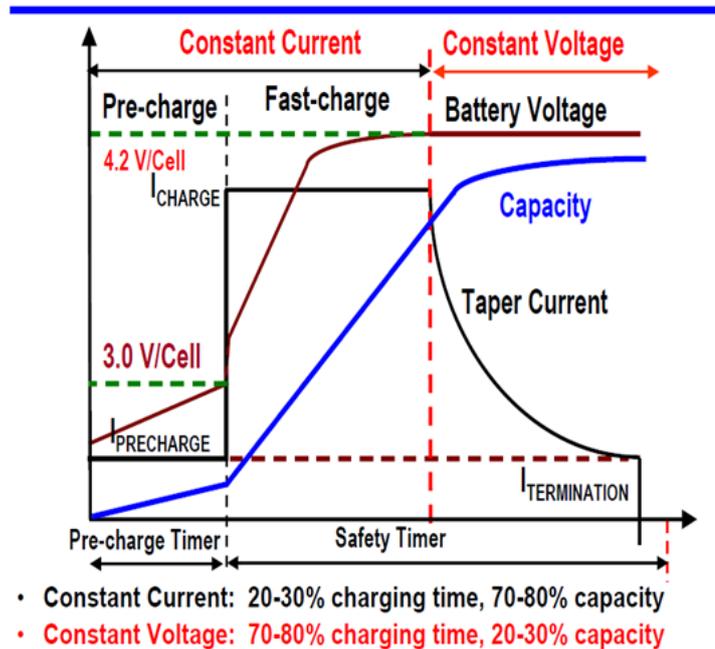


Figure 6-3 Lithium-ion battery charge curve

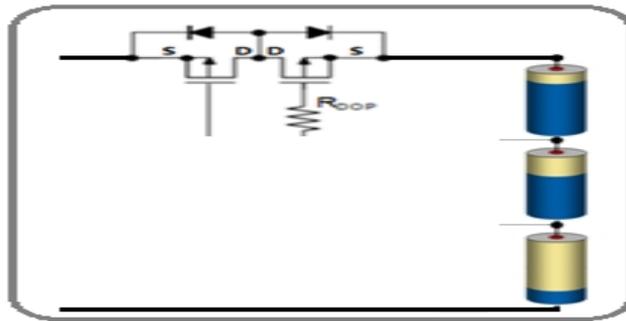
6.4.3.3 Balancing Problems

The most difficult problem of lithium-ion batteries is inconsistency. The causes of inconsistency are as follows:

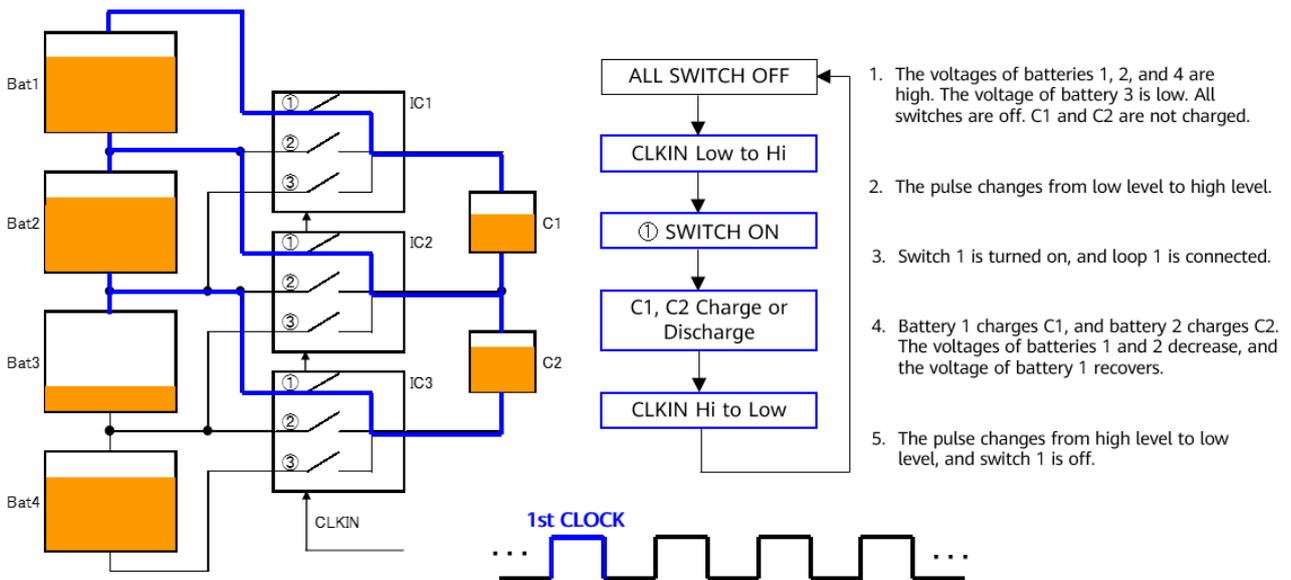
- Internal causes: material or manufacturing difference, capacity, internal resistance, self-discharge and cyclic attenuation rate
- External causes: temperature, charge current, and discharge current

Solutions:

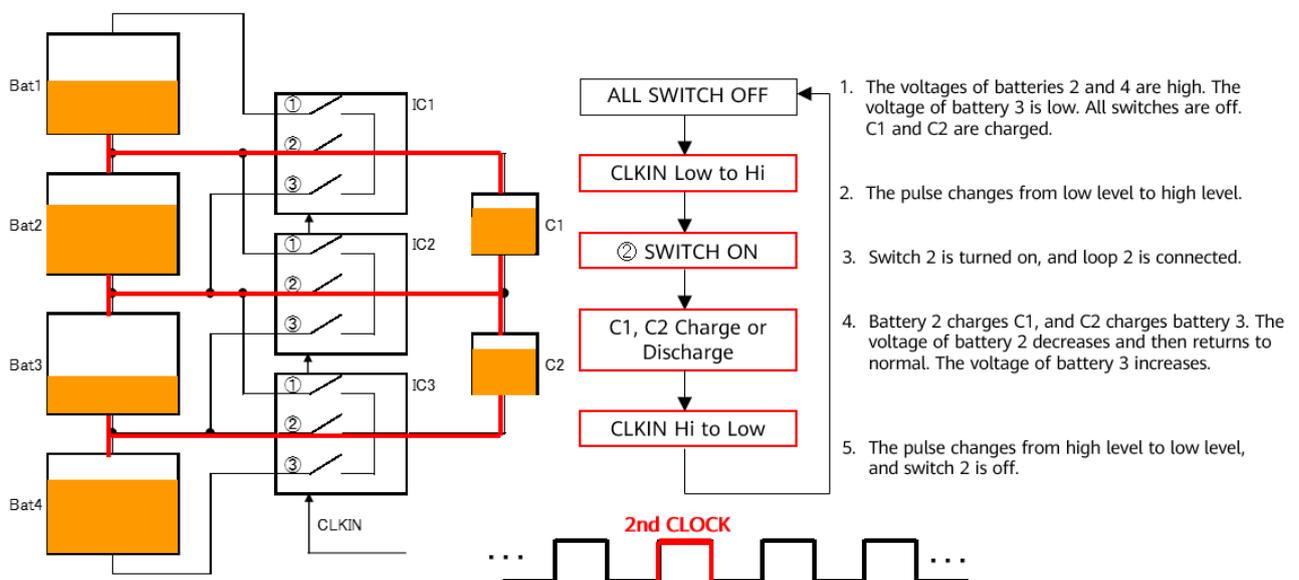
- Remove the first and last batteries.
- Perform balancing management.
- Form battery groups.



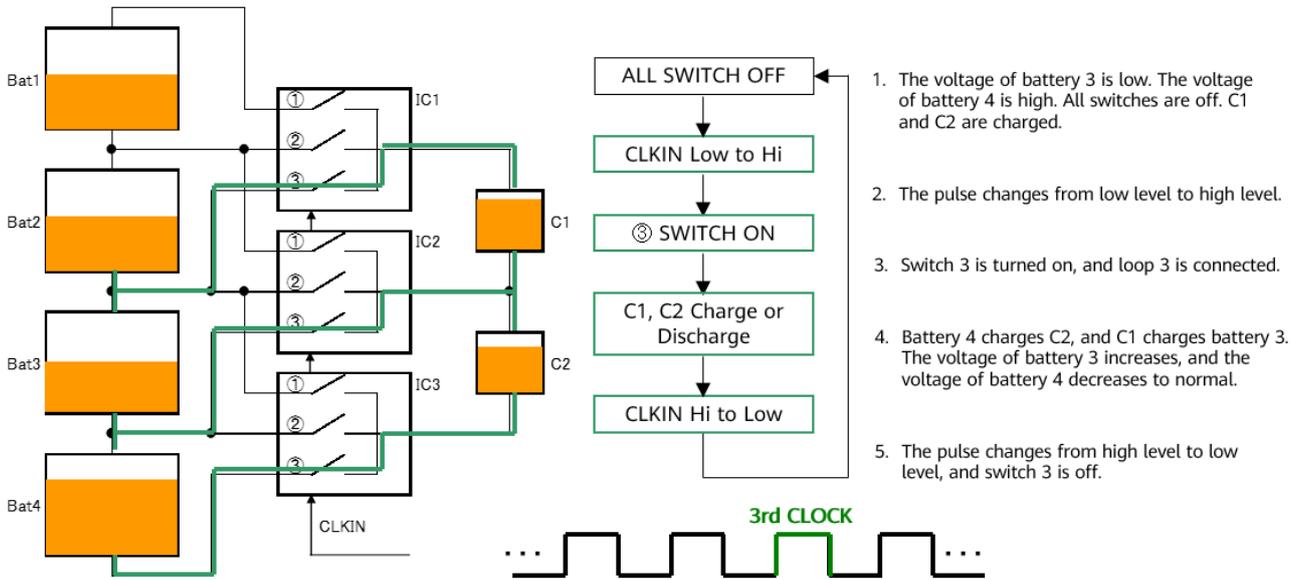
6.4.3.4 Balancing Management (1)



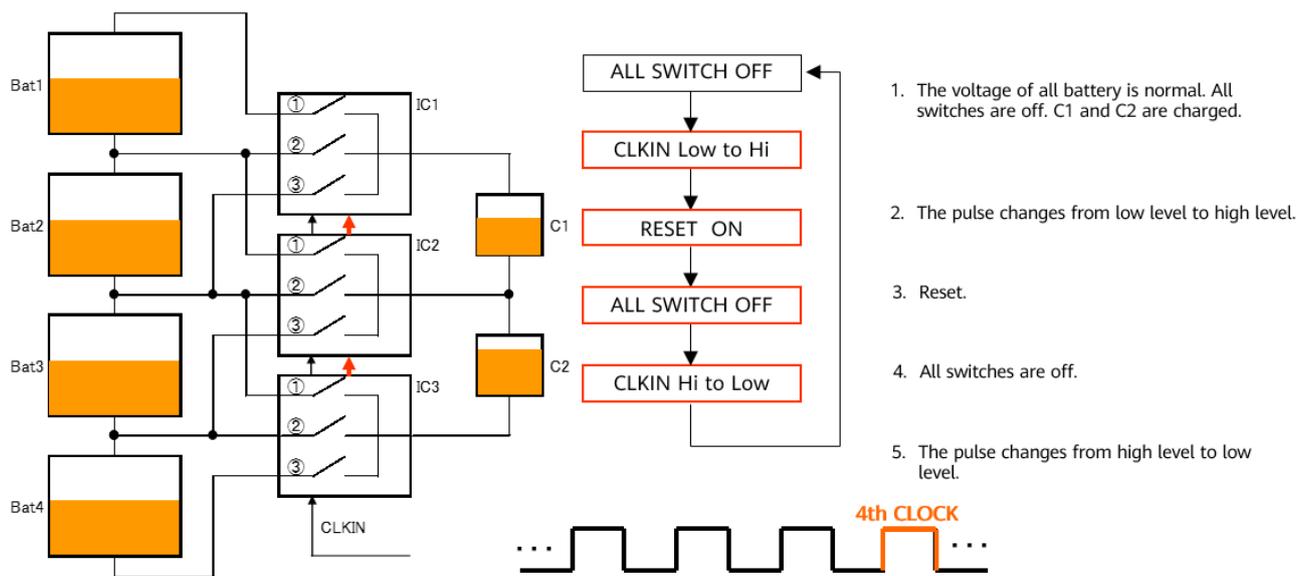
6.4.3.5 Balancing Management (2)



6.4.3.6 Balancing Management (3)



6.4.3.7 Balancing Management (4)



6.5 Comparison Between Lead-acid Batteries and Lithium-ion Batteries

6.5.1 Cycle Life

Lithium-ion battery

- 100% DOD: up to 3000 cycles; deep discharge: at least 3000 cycles.

- 50% DOD: up to 6000 cycles; shallow discharge: at least 6000 cycles.

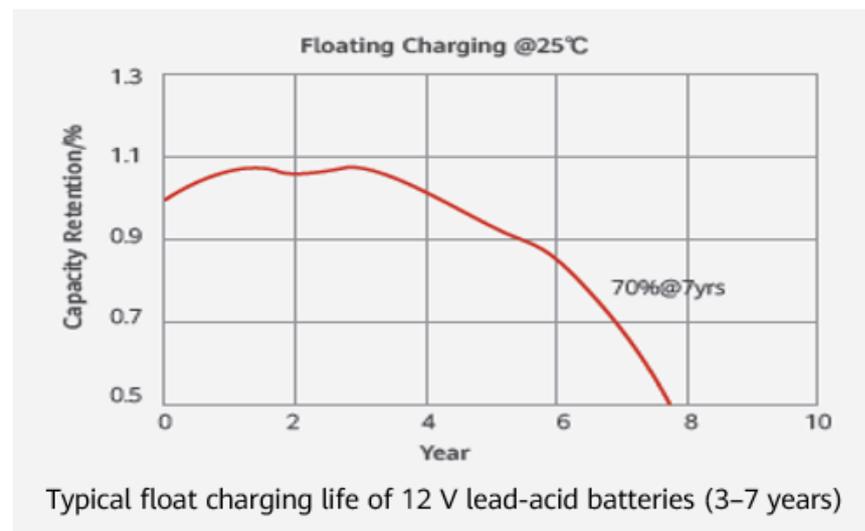
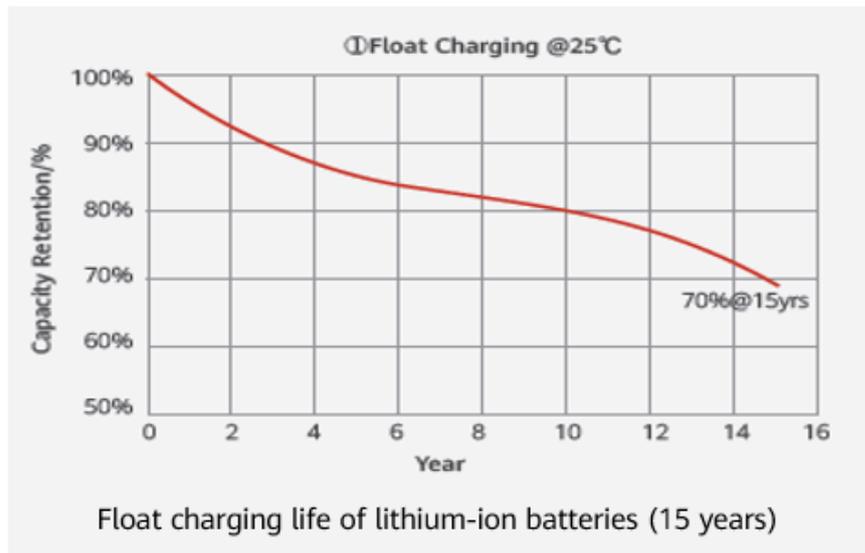
Lead-acid battery

- 100% DOD: about 150 cycles; deep discharge: frequently replacing lead-acid batteries in case of poor grid power.
- 50% DOD: about 600 cycles; shallow discharge: frequently replacing lead-acid batteries in case of poor grid power.

6.5.2 Float Charging Life

70% EOL float charge at 25° C for lithium-ion batteries: up to 15 years; no need to replace within the life cycle of 15 years if grid power is good.

70% EOL float charge at 25° C for lead-acid batteries: up to 7 years; need to replace every 3 – 7 years even if grid power is good; labor-intensive and high battery cost.



6.5.3 Discharge Characteristics at Different Rates

Short-time discharge at a high rate for lithium-ion batteries: More energy is discharged. As the discharge rate increases, the discharge capacity remains stable and can exceed 90%.

Short-time discharge at a high rate for lead-acid batteries: Less energy is discharged. As the discharge rate increases, the discharge capacity decreases rapidly. More batteries are required to offset the disadvantage, which increases the battery investment.

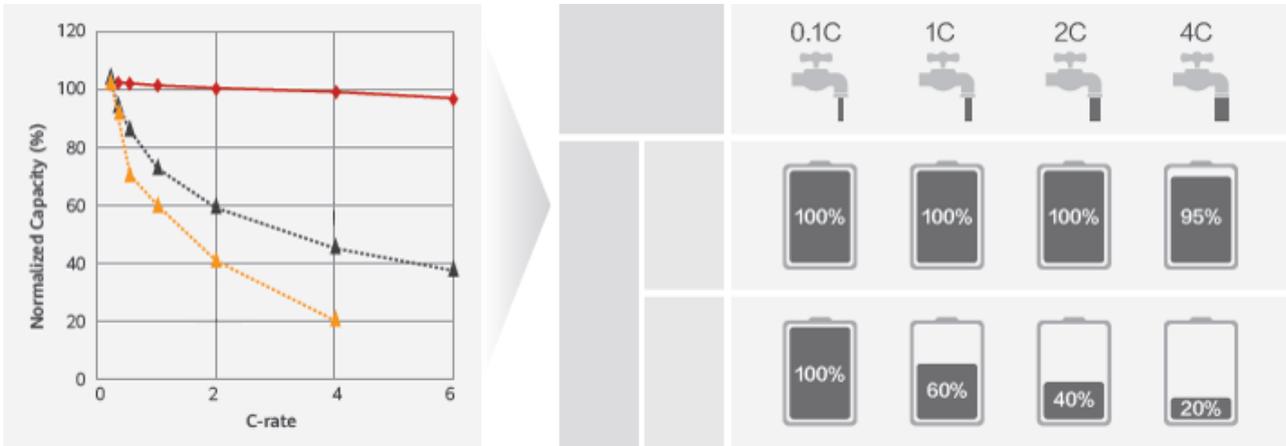


Figure 6-4 Comparison of discharge characteristics between lead-acid and lithium-ion batteries at different rates

6.5.4 Footprint and Bearing Capacity

Weight/Energy density (Wh/kg) ratio: 3:1

- Lithium-ion battery: 100–150; lead-acid battery: 30–50

Volume/Energy density (Wh/L) ratio: 3:1

- Lithium-ion battery: 200–300; lead-acid battery: 60–90

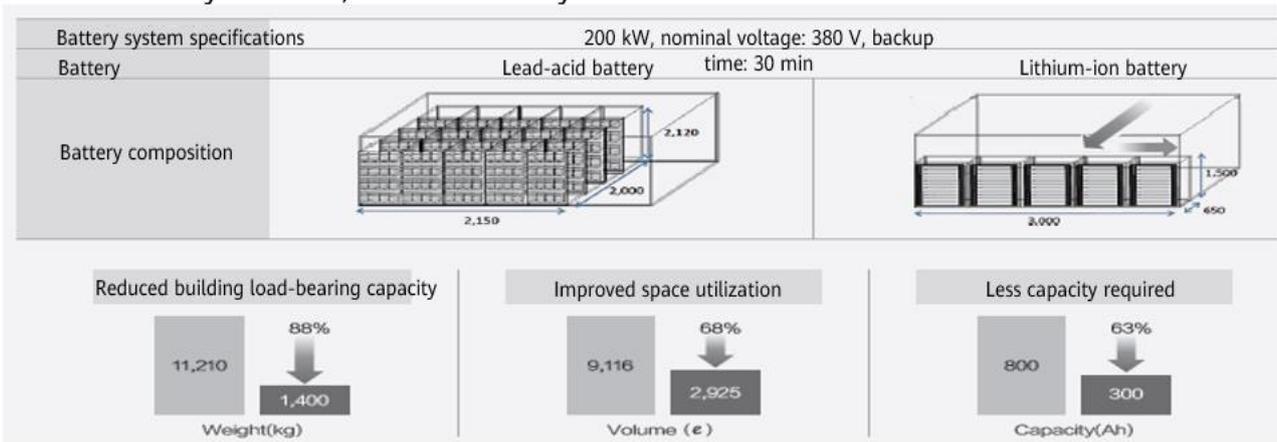


Figure 6-5 Footprint and bearing capacity comparison between lead-acid batteries and lithium-ion batteries

6.5.5 Storage Environment Requirements

For a data center that requires high availability, a small number of spare batteries are required for backup to shorten the maintenance preparation time. These batteries must be stored according to the requirements of the battery manufacturer.

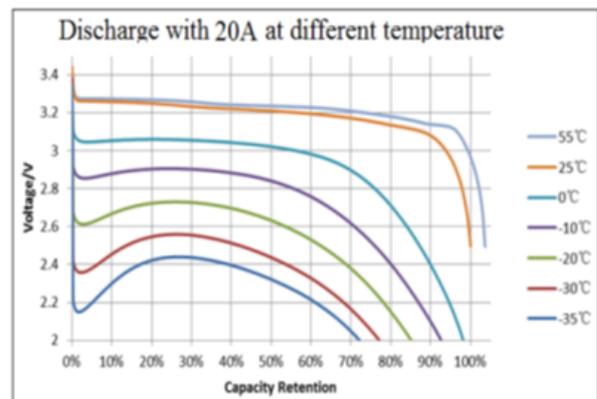
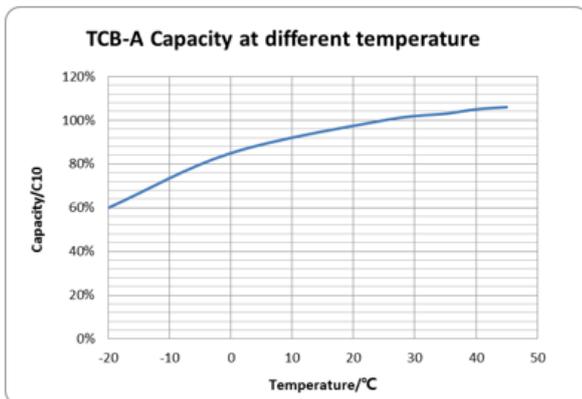
Item	Lead-acid Battery	Lithium-ion Battery
Ambient temperature	5–40° C (recommended temperature: 20–30° C)	0–40° C (recommended temperature: 20–30° C)
Relative humidity	≤ 95%	
Others	The environment is dry, ventilated, and clean. Batteries must not contact with corrosive or organic solvents. Keep batteries away from direct sunlight and at least 2 meters away from heat sources.	

6.5.6 Operating Temperature

The operating temperature of common lithium-ion cells ranges from -20°C to +55°C. Therefore, no air conditioner is required.

- When the temperature is low, the dynamics deteriorates, and lithium plating tends to occur during charging. Generally, only discharging is performed.
- The oxidation-reduction reaction on the surface of the positive and negative electrode material is more intense at a higher temperature.

The operating temperature of lead-acid batteries ranges from 15°C to 25°C. Therefore, air conditioners are required.



6.5.7 Safety Comparison

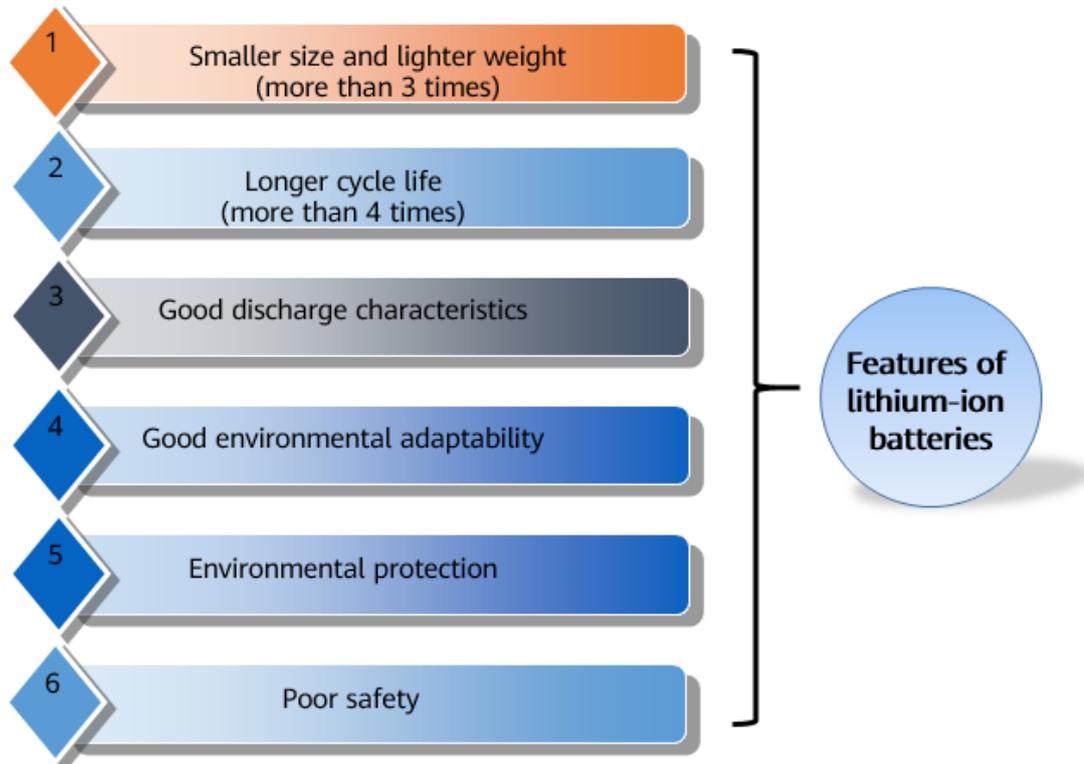
Our pursuit is to maximize stored and released energy and meet high energy density requirements within a safe and controllable range during the life cycle. With existing technology, a lithium-ion battery can be safe and controllable. From this perspective, a current lithium-ion battery is a relatively ideal battery product.

Table 6-1 Safety comparison between lithium-ion batteries and lead-acid

	Lithium-ion battery	Lead-acid battery
Positive and negative electrodes	LFP, NCM, and graphite materials are combustible and flammable.	Pb and PbO ₂ are flame retardants.
Electrolyte	Non-aqueous organic solvent, flammable	Sulfuric acid solution, non-flammable
Barrier	Separator film, PP/PE, flammable	Grid, non-flammable
	10–20 μm thick, easy to be pierced by dust and crystal dendrites. Internal short-circuits are easily caused by heat shrinkage.	3–5 mm thick, difficult to be pierced; no heat shrinkage
Combustion	Internal short circuit, combustion, and explosion	Shell combustion

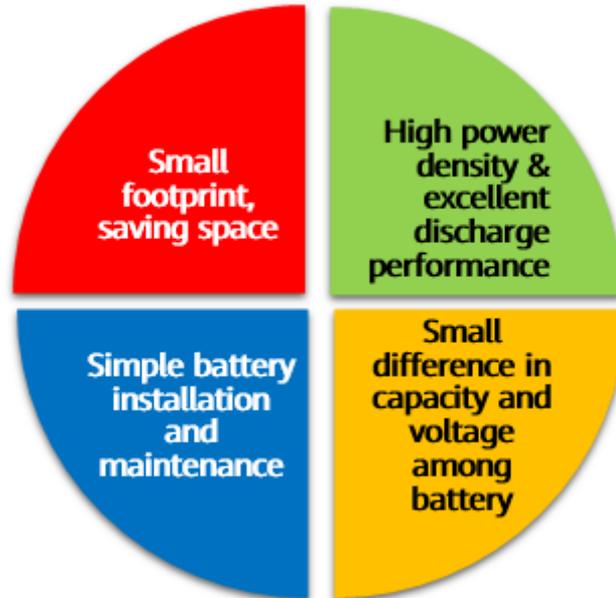
batteries

6.5.7.2 Summary



6.5.7.3 Battery characteristics for Data Center

In recent years, with the rapid development of the Internet industry, many IT companies, such as Baidu, Alibaba, Tencent, Google, and Microsoft, are building more and more large data centers for the new network services. Geographical centralization and size expansion are the transformations facing data centers. High density and high reliability are the higher demands posed on storage battery.



6.6 Quiz

- (Multiple) Based on the electrolyte content, what types can storage battery be classified into?
 - Flooded lead-acid battery and Starved-electrolyte battery
 - AGM and GEL storage battery
 - Lead-acid and alkaline storage battery
 - Primary and secondary storage battery
- (Single) Which of the following components is responsible for exhausting the excessive gas in the battery?
 - Battery chute
 - Battery plate
 - Safety valve
 - Electrolyte
- (Short Answer Question) What does a lithium-ion battery consist of?
- (Short Answer Question) What are the common positive electrode materials for lithium-ion batteries?
- (Short Answer Question) What is the working principle of lithium-ion batteries?

6.7 Summary

- Basic Knowledge of Batteries
- Knowledge About Lead-acid Batteries
- Knowledge About Lithium-ion Batteries
- Comparison Between Lead-acid Batteries and Lithium-ion Batteries

7 Air Conditioning System Introduction

7.1 Introduction

7.1.1 Foreword

This chapter describes working principles of an air conditioning system, classification of air conditioning system, common air processing devices.

7.1.2 Objectives

On completion of this course, you will be able to:

- Understand working principles of air conditioning systems;
- Understand classification principles and types of air conditioning systems;
- Have general knowledge of some common air handling equipment;
- Understand basic knowledge of air conditioning ventilation systems;
- Understand common air conditioner terms.

7.2 Working Principles of Air Conditioning System

7.2.1 Development History of Air Conditioning Systems

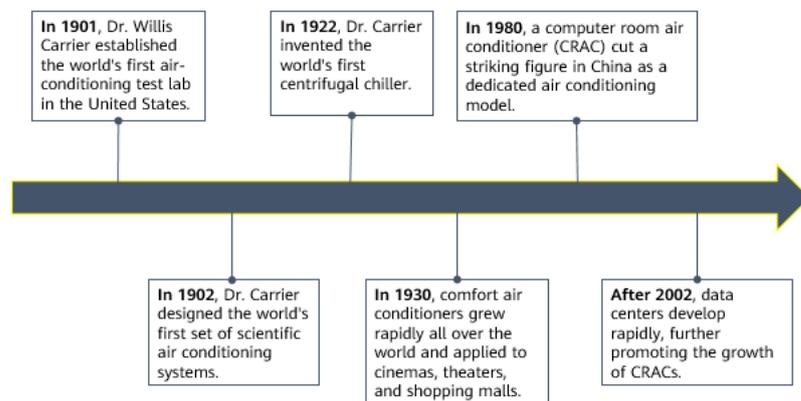


Figure 7-1 Development History of Air Conditioning Systems

7.2.2 What is an Air Conditioner?

An air conditioner performs air conditioning;

The following indicators are designed for air: temperature, humidity, and cleanliness;

An air conditioner is designed to adjust the temperature, humidity, and cleanliness of air, with the goal of creating a comfort living and working environment.



Figure 7-2 Comfort air conditioner



Figure 7-3 Precision air conditioner

For comfort air conditioners, ensure that the following indoor parameters that are designed for thermal comfort and health purposes meet requirements: temperature, humidity, fresh air volume, wind speed, noise level, and indoor air dust concentration. For data center air conditioners, there are no specific requirements for the fresh air volume, wind speed, and

noise level, because data center air conditioners primarily serve devices. However, these three aspects need to be considered if someone is on duty in a data center.

7.2.3 Refrigeration Principle

If being classified by refrigeration principles, many refrigeration methods are available, for example, steam compression refrigeration, lithium bromide absorption refrigeration, steam jet refrigeration, air expansion refrigeration, and electrochemical refrigeration. Air conditioners using artificial cold sources primarily use the steam compression refrigeration method and the lithium bromide absorption refrigeration method. Comfort and dedicated air conditioners primarily use the steam compression refrigeration method. The lithium bromide absorption refrigeration method is used only in areas without sufficient power supply. Therefore, only the steam compression refrigeration method is described in this slide.

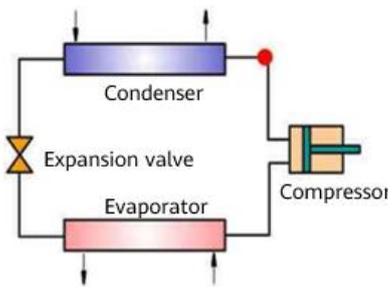


Figure 7-4 Refrigeration Principle (1)

After absorbing the heat of substances to be cooled in an evaporator, a liquid refrigerant vaporizes and becomes low-pressure and low-temperature steam. After being absorbed and compressed by a compressor, the steam becomes high-pressure and high-temperature steam. Then, the steam enters a condenser and discharges heat to cooled substances, and is condensed into a high-pressure and medium-temperature liquid. After passing a throttling device, the liquid becomes the low-pressure and low-temperature liquid refrigerant. The liquid refrigerant then enters the evaporator. As such, cyclic refrigeration is realized.

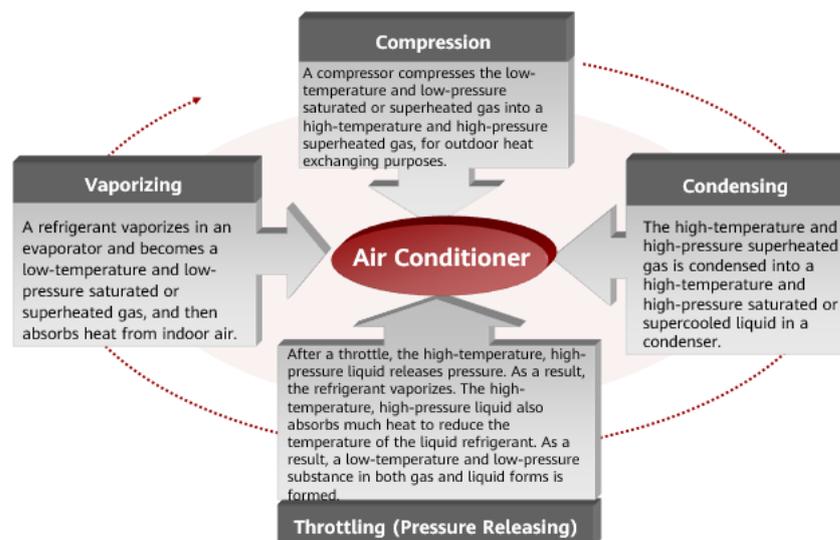


Figure 7-5 Refrigeration Principle (2)

Process 1: Compression process (adiabatic pressurizing) - This is an adiabatic compression process, involving only compression and not involving heat transfer. After low-temperature and low-pressure steam is compressed in a compressor, the steam pressure becomes greater. The outside world performs energy working for the steam in the form of mechanical energy. As a result, the steam obtains energy and its temperature rises. The compression aims to enable the refrigerant to release heat so that the steam temperature becomes higher than the outside temperature and the heat in the system can be released.

Process 2: Heat radiation process (equal-pressure heat radiation) - A condenser condenses the high-temperature and high-pressure steam that comes from the compressor, and releases the heat in the system to the outside world. Then, the temperature of the steam is reduced, but the pressure does not change. As a result, the steam changes to a liquid refrigerant. In summary, this process can be understood as reducing the temperature of the steam that is under normal atmospheric pressure, with the goal of changing the steam to a liquid.

Process 3: Throttling process - The normal-temperature and high-pressure liquid enters a throttle, which is actually a small hole that features dynamic adjustment. After passing the hole, the normal-temperature and high-pressure liquid enters a low-pressure and large-volume refrigerant pipe, forming the throttling effect. With the pressure being reduced, the liquid obtains a greater speed. As the pressure becomes too low, part of the liquid gasifies. As a result, the temperature of the liquid is reduced, and a low-temperature and low-pressure gas/liquid mixture is formed. The throttling aims to reduce the pressure of the refrigerant so that the boiling point of the refrigerant is lower than the indoor temperature and the refrigerant can absorb heat in a room and vaporize.

Process 4: Heat absorption process (equal-pressure process) - The low-temperature and low-pressure gas/liquid mixture from the throttle enters an evaporator and absorbs the heat of the indoor air, so that the temperature of the indoor air decreases. As a result, the room is cooled. After the heat is absorbed, all liquid changes to a gas. The heat absorption is realized because the boiling point of the refrigerant is very low in the low pressure state. When the ambient temperature is higher than the boiling point of the refrigerant, the refrigerant absorbs heat continuously and changes to a gas.

Table 7-1 Major changes in the cooling process

Component	Refrigerant Status	Pressure Change	Temperature Change
Evaporator	Liquid – gas	Low pressure	Low temperature
Compressor	Gas – gas	Low pressure – high pressure	Low temperature – high temperature

Condenser	Gas – liquid	High pressure	High temperature – normal temperature
Expansion valve	Liquid – liquid/gas	High pressure – low pressure	Normal temperature – low temperature

7.2.4 Introduction to the Four Major Components

Compressor:

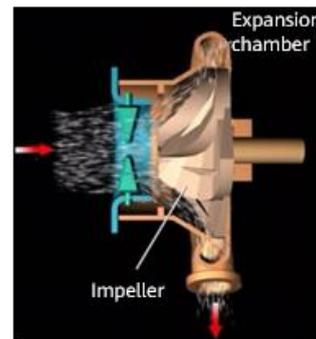
- Being the core of the refrigeration cycle, a compressor is the power device that enables a refrigerant to circulate in the cooling system. The compressor maintains low pressure for the refrigerant in an evaporator and high temperature and high pressure for the refrigerant in a condenser.
- Refrigeration and air conditioning industries use the following five major types of compressors: reciprocal compressor, screw compressor, rotary compressor, vortex compressor, and centrifugal compressor. Reciprocal compressors are most widely used in small and medium commercial refrigeration systems. Screw compressors are mainly used in large commercial and industrial systems. Rotary compressors and vortex compressor are mainly used in household and small-capacity commercial air conditioning units. Centrifugal compressors are widely used in air conditioning systems of large-scale buildings.



Scroll compressor



Screw compressor



Centrifugal compressor

Figure 7-6 Compressor

Condenser:

- Working with a condensing medium, a condenser condenses the saturated or superheated steam discharged by a compressor into a liquid;
- If being classified by cooling media, condensers are available in water-cooled and air-cooled types. Water-cooled condensers use water as a cooling medium, with condensation heat being taken away by a temperature increase in water. Air-cooled

condensers use air as a cooling medium, with condensation heat being taken away by a temperature increase in air.



Water-cooled condenser



Air-cooled condenser

Figure 7-7 Condenser

Evaporator:

- After passing a throttle, a liquid refrigerant enters an evaporator, absorbs heat, and vaporizes. As a result, the temperature of the substances to be cooled decreases, and refrigeration is realized.
- If being classified by media to be cooled, evaporators are available in cooling air-type evaporators and cooling liquid-type evaporators.



Figure 7-8 Evaporator

Throttling device:

- A throttling device performs throttling. Specifically, a throttling device regulates the circulation flow volume of a refrigerant. The throttling device regulates the flow of a high-pressure liquid refrigerant and reduces the pressure of the refrigerant so that the refrigerant can absorb heat and evaporate at the desired low pressure in an evaporator. In addition, the throttling device can automatically adjust the volume of the refrigerant that enters the evaporator based on the change in the heat load of the medium to be cooled.
- Expansion valves are available in two types, namely, thermal expansion valves and electronic expansion valves. A thermal expansion valve can control the amount of liquid to be supplied to an evaporator and throttle a saturated liquid refrigerant. When being classified by structure, thermal expansion valves are available in internal balance

expansion valves and external balance expansion valves. Electronic expansion valves are mainly used in variable-frequency air conditioning systems. An electronic expansion valve adjusts the amount of liquid to be supplied to an evaporator based on a preset program. Electronic expansion valves adapt to the development of mechanical and electrical integrated refrigeration, feature excellent characteristics that thermal expansion valves do not have, and enable intelligent control for refrigeration systems.



Figure 7-9 Throttling device

7.3 Classification of Air Conditioning System

7.3.1 Classification of Air Conditioners - By Application

Air conditioners are classified into the following by application:

- Industrial air conditioner: Selected parameter values must meet requirements of the industrial process for air parameters;
- Comfort air conditioner: Selected parameter values must meet requirements for working conditions and rest conditions of people.

Table 7-2 Air conditioners are classified into the following by application

Type of an Air Conditioner		Adjustment Parameter		Temperature	Humidity	Cleanliness	Airflow Speed	Operating Life
		Temperature	Humidity					
Industrial air conditioner	CRAC (precision)	Constant	Constant	Cleanliness required by data centers	Uninterruptible operation > 10 years			
	Clean air conditioner	Adjustable	Cleanliness required by industrial buildings	Intermittent operation ≤ 10 years				

	Medical air conditioner	Adjustable			Cleanliness required by the medical industry	Intermittent operation ≤ 10 years
Comfort air conditioner	Home air conditioner	Adjustable				Intermittent operation ≤ 10 years
	Commercial air conditioner	Adjustable				Intermittent operation ≤ 10 years
	Central air conditioner	Adjustable				Intermittent operation ≤ 15 years

7.3.2 Classification of Air Conditioners - By Media

Direct expansion air-cooled

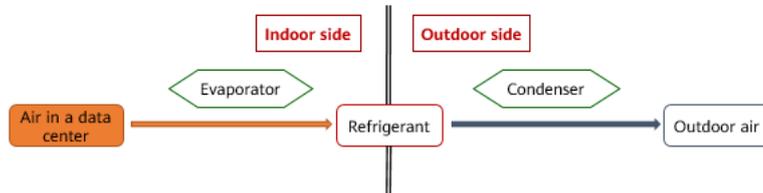


Figure 7-10 Direct expansion air-cooled

Direct expansion water-cooled

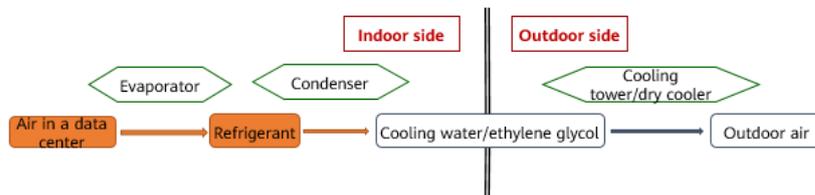


Figure 7-11 Direct expansion water-cooled

Air-cooled chilled water

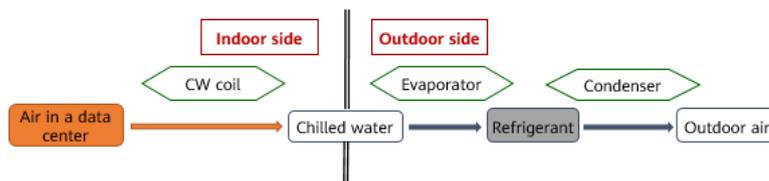
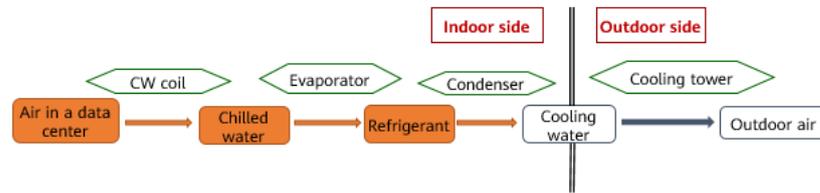


Figure 7-12 Air-cooled chilled water

Water-cooled chilled water


Figure 7-13 Water-cooled chilled water

7.3.3 Classification of Air Conditioners - By Other Criteria

By the concentration degree of air conditioning devices

- Centralized air conditioning system: All air processing devices are installed in a central air conditioning room. Processed air is sent to the air conditioning system in each room using ducts. Centralized air conditioning systems apply to places with a large area, concentrated rooms, and basically the same ratio of the heat load to the humidity load in each room.
- Semi-centralized air conditioning system: A semi-centralized air conditioning system consists of a centralized air conditioning system and end devices that process air. A semi-centralized air conditioning system is complex but achieves higher adjustment accuracy.
- Decentralized air conditioning system: In a decentralized air conditioning system, air processing devices are installed in each room. Decentralized air conditioning systems apply to places with a small area, scattered rooms, and a large difference between the heat load and the humidity load.

By the refrigeration architecture

- In-room air conditioner.
- In-row air conditioner.
- In-cabinet air conditioner.

By the method of adjusting the system air volume

- Constant-air-volume air conditioning system: For an ordinary centralized air conditioning system, the volume of air supplied by fans is constant. The change in the load of an air conditioning zone is accommodated by changing the temperature of the supplied air. As such, the indoor temperature and humidity are adjusted.
- Variable-air-volume air conditioning system: The temperature of supplied air is maintained at a certain degree by changing the volume of the supplied air. As such, the change in the load of an air conditioning zone is accommodated, and desired indoor temperature and humidity are obtained.

7.4 Air Handling Equipment

7.4.1 Classification of Devices That Process Air Heat and Humidity

Direct-contact processing device

- The medium that exchanges heat and humidity with air is in direct contact with air. Specifically, a direct-contact processing device lets air flow on the surface of the medium or sprays the medium into air. Common direct-contact processing devices include water chambers and humidifiers.



Figure 7-14 Direct contact (humidifier)

Indirect-contact processing device

- The medium that exchanges heat and humidity with air is not in direct contact with air. The exchange of heat and humidity between the air and the medium is carried out using the metal surface of the device. Common indirect-contact processing devices include surface coolers, air heaters, evaporators, and condensers.

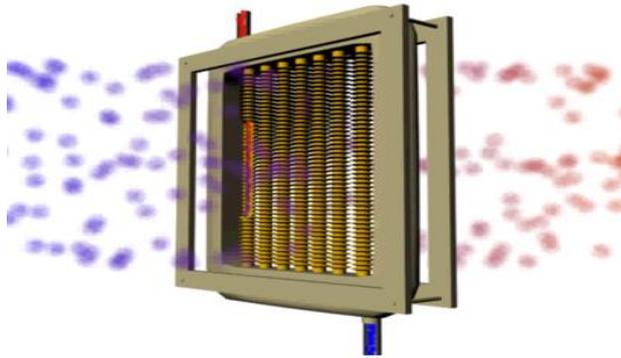


Figure 7-15 Indirect contact (surface heat exchanger)

7.4.2 Surface Heat Exchanger

Surface heat exchangers include air heaters and air coolers.



Figure 7-16 Surface Heat Exchanger

Surface heat exchangers include air heaters and air coolers. A surface heat exchanger enables a heat medium or a refrigerant to flow in the cavity of a metal pipe and the air to be processed to flow on the outer wall of the metal pipe. As such, heat is exchanged, and the purpose of heating or cooling air is realized. Radiators widely used in northern China belong to this type of heat exchangers.

7.4.3 Humidifier

Wet film humidifier

- When water in the tank is conveyed to the sprinkler on the top of a humidifier, the sprinkler sprinkles the top part of the wet film with water evenly. The water permeates through all layers in the wet film and is absorbed by the wet film. Then an even water film is formed. When dry air passes through the wet film, the dry air has a large area of contact with the wet film surface so that a large amount of water evaporates. A lot of water molecules are blown with air into the space that requires humidification to increase its air humidity.
- Huawei precision air conditioners use wet film humidifiers.

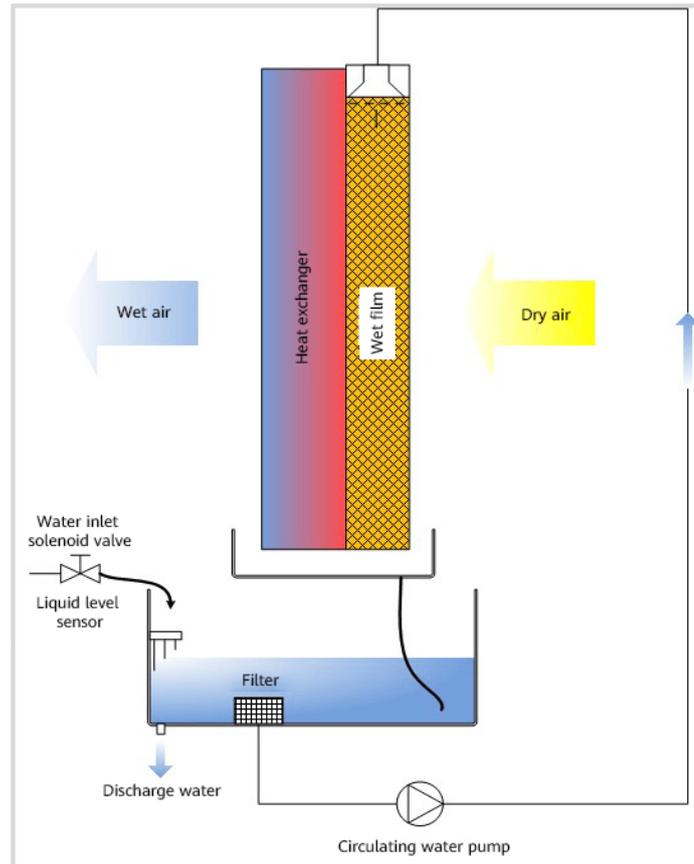


Figure 7-17 Wet film humidifier

Electrode humidifier

- The electrodes of an electrode humidifier form a loop with water in a humidifier cylinder. The electrode humidifier heats the water until the water boils and generates steam. The amount of moisture generated by a humidifier is controlled by adjusting the level of water in the humidifier cylinder in use. The electrode humidifier is safe and reliable. It does not work without water. It controls precision through output power and is free from the impact of scaling. The electrode humidifier features large humidification amount and low acquisition cost. Electrode humidifiers are generally used in in-row precision air conditioners.



Figure 7-18 Electrode humidifier

Infrared humidifier

- An infrared humidifier uses extreme infrared rays to make water vibrate, so that the water obtains heat and then evaporates. An electrode humidifier has high requirements for the water quality, because scale generated in the humidifier cylinder may block the solenoid valve and affect the humidification efficiency. An infrared humidifier does not have this weakness. In addition, an infrared humidifier saves energy. Infrared humidifiers are generally used in in-room precision air conditioners.

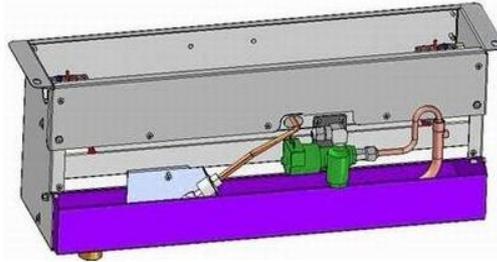


Figure 7-19 Infrared humidifier

High-pressure micro-mist humidifier

- Working principles of a high-pressure micro-mist humidifier: A high-pressure micro-mist humidifier increases pressure on water to 7 Mpa using a high-pressure piston pump, and then sends the pressurized water to a dedicated nozzle using a high-pressure transmission pipeline. The nozzle atomizes the water to generate particles in 3 to 15 μm . The particles quickly absorb heat from the air and then vaporize and diffuse around. As such, the air is humidified and cooled. A high-pressure micro-mist humidifier can reach the humidification efficiency of 166 kg/kWh, which is more than 100 times that of an electrode or infrared humidifier.



Figure 7-20 High-pressure micro-mist humidifier

Dry steam humidifier



Figure 7-21 Dry steam humidifier

7.4.4 Dehumidifying Devices

Refrigeration dehumidifier

- Refrigeration dehumidifiers are usually called dehumidifiers. When coming into contact with the cooling copper fins of a refrigeration dehumidifier, water vapor changes into water droplets. In the entire liquefaction process, the dehumidifier works as a device that converts gaseous water into liquid water.



Figure 7-22 Refrigeration dehumidifier

Rotary dehumidifier

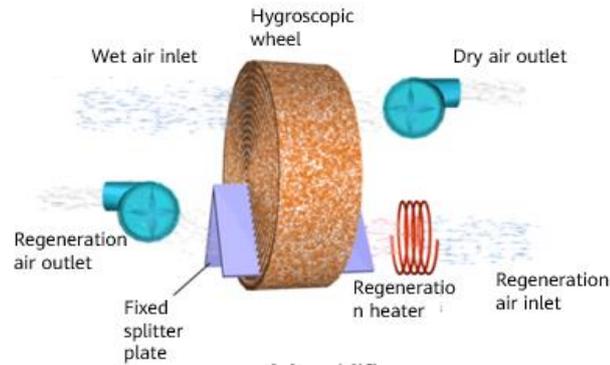


Figure 7-23 Rotary dehumidifier

7.5 Air Conditioning Ventilation System

7.5.1 Functions of Air System

Functions of air system: An air system properly organizes the flowing of indoor air, with the goal of ensuring that the temperature, humidity, speed, and cleanliness of the air in indoor work areas better meet requirements of the production process and human body comfort. The air system of an air conditioning system primarily consists of fans, ducts, air vents, and air valves.

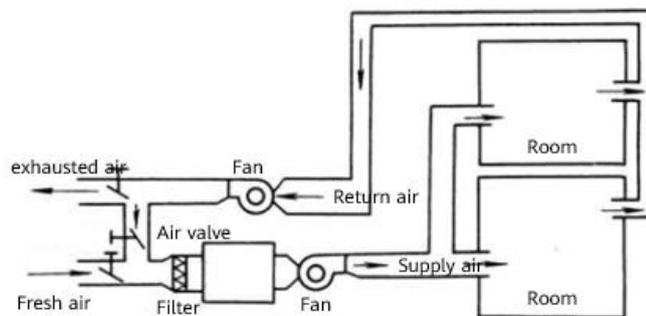


Figure 7-24 Air System

7.5.2 Airflow Forms

Supplying air from the top of room (up supply) and returning air from the bottom of room (down return).

- Air supply vents are located at the top of an air-conditioned room, and air return vents are located at the bottom of the room. The airflow enters the room from the top and leaves the room from the bottom.
- This airflow form applies to industrial air conditioners that require a constant temperature and cleanliness, and also applies to comfort air conditioners that primarily supply hot air and are installed in rooms with a large floor height.

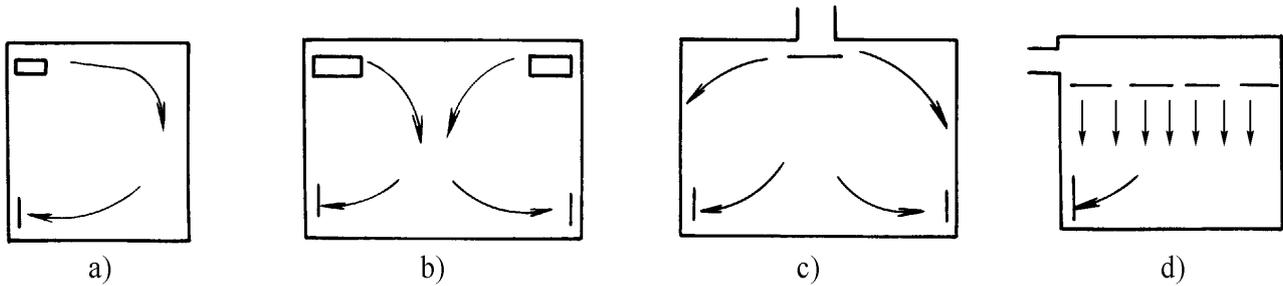


Figure 7-25 Airflow organization forms of up supply and down return

- Airflow organization: Plan air supply vents and air return vents properly for an air-conditioned room, so that after being sent to the room through the air supply vents, air that is purified and undergoes heat and humidity processing can evenly eliminate the excess heat and excess humidity in the room when diffusing and mixing with air in the room. As such, the work area obtains uniform and stable temperature, humidity, airflow speed, and cleanliness, and requirements of the production process and human body comfortableness are met.
- Strengths of up supply and down return:
 - Before entering the work area, the supplied air has sufficiently mixed with the air in the room, facilitating the formation of a uniform and stable temperature field, humidity field, and velocity field.
 - When both air supply vents and air return vents are located on sides, the air supply path is very long. To address the issue, ensure that the difference between the temperature of the supplied air and the temperature of the air in the room is large and that the volume of the supplied air is small.
- Weaknesses of up supply and down return:
 - If air return vents need to be connected to air ducts, installing air ducts is difficult.
 - If centralized air return vents are used, noise in the data center has a significant impact.

Supplying and returning air both from the top of room (up supply and up return).

- When both air supply/return ducts and air supply/return vents are located at the top of an air-conditioned room, the airflow enters the room from the top and leaves the room also from the top.
- This airflow organization form applies to comfort air conditioners that are primarily used to reduce temperature and are installed in rooms with a small floor height, and also applies to rooms where air return vents cannot be provided at the bottom.

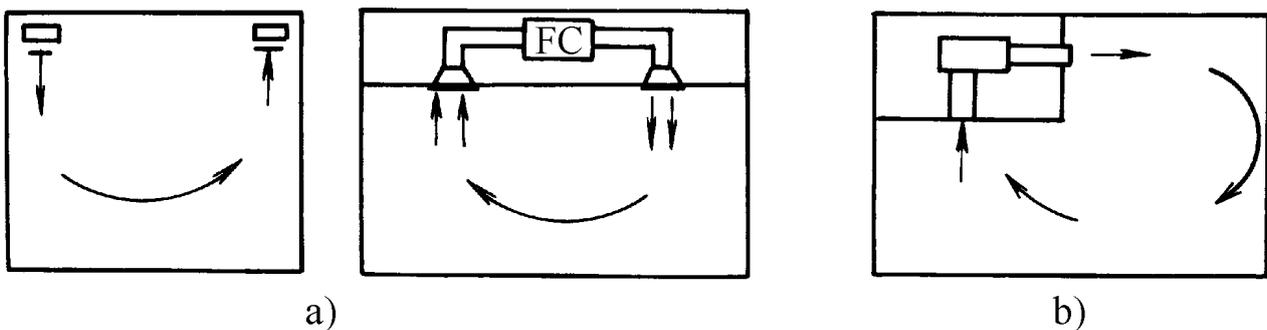


Figure 7-26 Airflow organization forms of up supply and up return

- Strengths of up supply and up return:
 - Air supply/return ducts being installed at the top of a room or hidden in a ceiling do not take up the usage area of the room and easily match the interior decoration.
 - When air return ducts are installed at the top of a room, the return airflow can take away part of heat radiated by lighting devices in the ceiling, reducing the cold load in the work area in summer.
- Weaknesses of up supply and up return:
 - As part of the work area is in the air supply area and part of the work area is in the air return area, it is difficult to form a uniform temperature field, humidity field, and velocity field.
 - If air vents are not properly planned, the air supply/return flow may be blocked, affecting the air conditioning quality.

Supplying air from the middle of side walls of room (central supply).

- Air supply vents are located in the middle of side walls of an air-conditioned room, and air return vents are located at the bottom of the room. The airflow enters the room from the middle of side walls and leaves the room from the bottom.
- For some tall air-conditioned rooms, if the actual work areas are in the lower parts of the rooms, you do not need to control the entire space, and you only need to control the lower parts of the rooms.

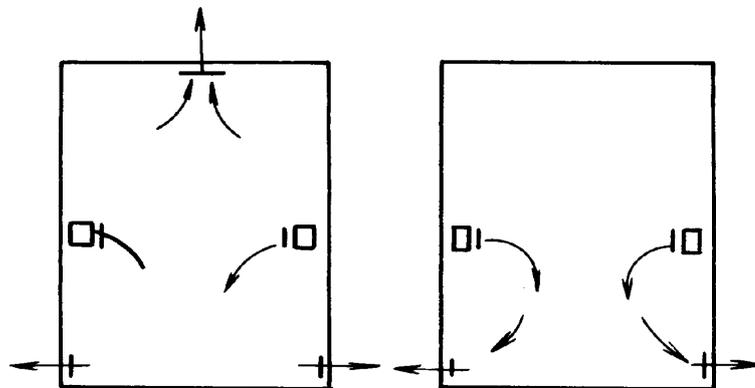


Figure 7-27 Airflow organization forms of central supply

Supplying air from the bottom of room and returning air from the top of room (down supply and up return).

- Air supply vents are located at the bottom of an air-conditioned room, and air return vents are located at the top of the room. The airflow enters the room from the bottom and leaves the room from the top.
- This airflow organization form applies to industrial air conditioners that need to take away a large amount of excess heat in the lower part of an air-conditioned room, and also applies to comfort air conditioners that are installed in crowded public buildings with a large floor height, for example, a theater.

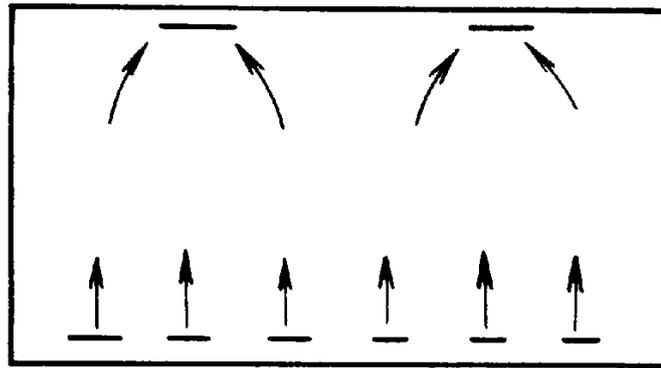


Figure 7-28 Airflow organization forms of down supply and up return

7.5.3 Introduction to Air Vents

Louver

- Louvers are the most widely used air vents in air conditioning projects. Louvers can be installed on walls of air-conditioned rooms or sides of exposed ducts. Besides, louvers can be installed on ceilings of air-conditioned rooms or bottoms of exposed ducts.
- Common louver types: single-layer louver and double-layer louver.



Figure 7-29 Single-layer louver



Figure 7-30 Double-layer louver

Air Diffuser

- Air diffuser is usually installed on the ceiling of an air-conditioned room or the bottom of an exposed. Air diffuser has a nice shape, easily matches the room decoration, and is one of the most widely used air supply vents.

- Common types: down air supply type and horizontal air supply type.
 - After being blown from a down-type diffuser, an airflow directly diffuses into the air-conditioned area, forming a steady, downward, direct airflow. Down-type diffusers are primarily used in scenarios in which the room clearance is very large (3.5 m to 4.0 m).
 - After being blown from a flat-type diffuser, an airflow diffuses around radially along the flat top, so that the supplied air is fully mixed with the indoor air before entering the air-conditioned area, with the goal of obtaining a relatively uniform temperature field and velocity field. Flat-type diffusers generally apply to industrial air conditioners that have requirements for the room-temperature fluctuation range and are installed in rooms with a small floor height, and also apply to comfort air conditioners that are installed in general public buildings.



Figure 7-31 Round diffuser



Figure 7-32 Square diffuser

Vented floor

- Vented floor is generally installed on raised floors in data centers and used as downward air supply vents.
- Common types: mechanical type and electric type.
- Variable-air-volume vented floor panels are available in two types: one type using adjustable air dampers (using physical blocks between openings), and the other type using both dedicated vented floor panels and adjustable fans. A vented floor panel can be mechanically or electrically controlled, but the price of the electrically controlled

type is 10 times or even higher the price of the mechanically controlled type. A mechanically adjusted vented floor panel cannot increase the volume of vented air. In addition, it is difficult to control the adjustment accuracy. That is, the allocation of air in a data center almost cannot be adjusted. An electrically adjusted vented floor panel (adjusted by a fan) is not affected by the floor opening rate. The volume of supplied air is dynamically adjusted based on the rotating speed of the fan. Therefore, electrically adjusted vented floor panels can be used in scenarios in which a large amount of air is required or in data centers that have local hot spots. However, an electrically adjusted vented floor panel is less reliable and more expensive than a mechanically adjusted vented floor panel. The problem of local hot spots can be resolved using other methods, for example, increasing the number of horizontal flow air conditioners. Therefore, electrically adjusted vented floor panels are seldom used.

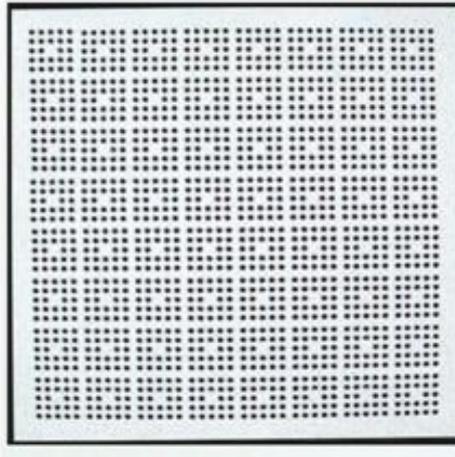


Figure 7-33 Mechanical vented floor



Figure 7-34 Electric vented floor

Other air vents

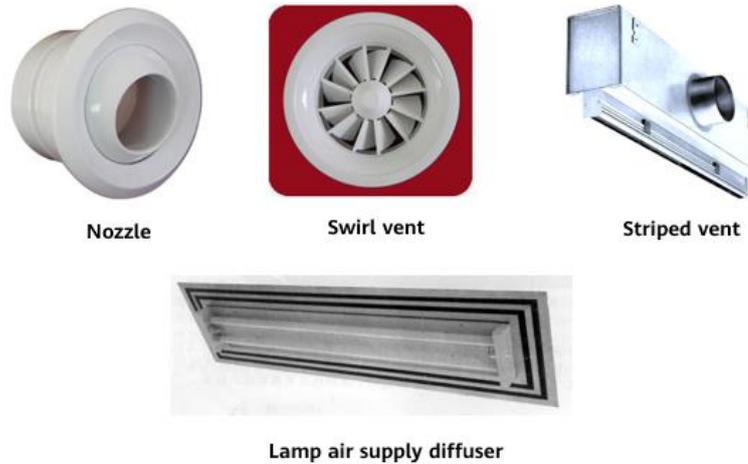


Figure 7-35 Other air vents

7.6 Common Air Conditioner Terms

7.6.1 Cooling Capacity, EER and COP

Cooling capacity:

- Heat absorbed by the refrigerant on the low-pressure side in the evaporator in unit time when the air conditioner is refrigerating or the sum of heat removed from the enclosed space, room or area in unit time. The common unit is W or kcal/h.
- 1 cal is the energy needed for making the temperature of 1g water rise by one Celsius degree. In international unit, energy is expressed by using joule. 1 cal = 4.184 J.
- Refrigeration ton: Refrigeration ton indicates the cooling capacity needed for freezing 1 ton of 0°C saturated water into 0°C ice within 24 hours;
 - 1 US refrigeration ton = 3024 kcal/h = 3.517 KW.

Consumed power:

- Consumed power for refrigeration: total power consumed when an air conditioner is refrigerating (unit: W).
- Consumed power for heating: total power consumed when an air conditioner is heating (unit: W), including power consumed by the electric heater supplementing the heat pump.

Energy efficiency ratio (EER):

- Ratio of cooling capacity to input power under rated and specified conditions when an air conditioner is refrigerating. The value is expressed by using W/W.

7.6.2 Refrigerant and Circulated Air Volume

Refrigerant:

- Refrigerant is also called refrigerating medium. It is an operating substance that circulates continuously in the refrigerating system by changing its state to realize refrigeration. Refrigerant absorbs heat of cooled medium (water or air) in the evaporator and evaporates and then transfers heat to surrounding air or water in the condenser and condenses;
- Common refrigerant: R22 (HCFC-22), R407C (HCFC-32/123/134a), and R410A (HCFC-32/123). R22 will create a greenhouse effect and damage the ozone layer and R407C and R410a will create a greenhouse effect;
- Types of refrigerant oil: R22, R407C, and R410A.

Circulated air volume:

- Air volume sent to the enclosed space, room or area under rated refrigerating conditions. Unit: m³/h;
- In a room, the air velocity has a great effect on human comfortableness. The air velocity in ordinary working areas is 0.4 m/s.

7.6.3 Sensible Heat Ratio

Sensible heat ratio = sensible heat/total heat = sensible heat/(sensible heat + latent heat)

- Sensible heat refers to heat that can be sensed. It can cause temperature change of a substance but does not change the state of the substance;
- Latent heat changes the state of a substance but does not change the temperature when heat is absorbed or released;
 - Latent heat of fusion refers to the heat absorbed or released when a substance changes from solid state to liquid state or from liquid state to solid state;
 - Latent heat of vaporization refers to the heat needed when a substance changes from liquid state to gas state;
 - Latent heat of liquid refers to the heat released when a substance changes from gas state to liquid state.
- Example of latent heat: 335 J of energy is absorbed when 0°C ice melts into 0°C water.
- Example of sensible heat: 4.186 J of energy is absorbed when 0°C water is heated and becomes 1°C water.

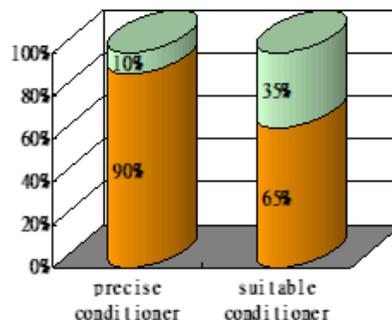


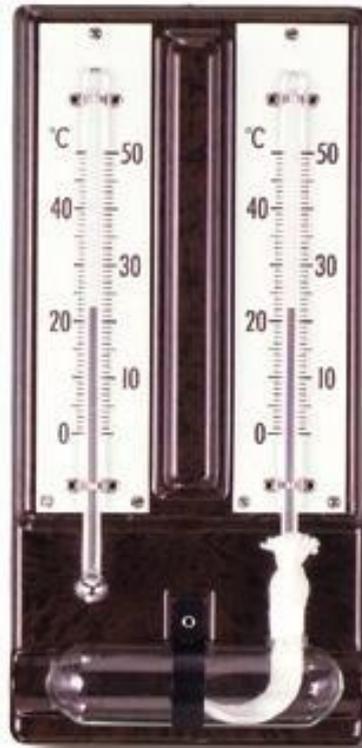
Figure 7-36 Sensible Heat Ratio

7.6.4 Temperature

Dry bulb temperature: temperature measured by using the thermometer not wrapped with wet gauze, as shown in the figure.

Wet bulb temperature: temperature measured by using the thermometer wrapped with wet gauze, as shown in the figure.

- In general, the air is unsaturated and can absorb moisture. In this case, water on the wet gauze absorbs heat and evaporates. Therefore, the wet bulb temperature is generally lower than the dry bulb temperature. The lower the relative humidity of air is, the more water on wet gauze will evaporate. In this case, the wet bulb temperature is much lower than the dry bulb temperature. When the air is saturated, the two are the same.


Figure 7-37 Wet and dry bulb thermometer

Centigrade temperature ($^{\circ}\text{C}$):

- Under 1 atmospheric pressure, the freezing point of water is 0°C and the boiling point is 100°C .

Fahrenheit temperature ($^{\circ}\text{F}$): $^{\circ}\text{F} = ^{\circ}\text{C} \times 1.8 + 32$; $^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 5/9$

Absolute temperature (K): $\text{K} = 273 + ^{\circ}\text{C}$

- The absolute temperature is the thermodynamic temperature, also known as Kelvin, It is one of the important parameters in thermodynamics and statistical physics.

7.6.5 Humidity

Humidity: amount of steam in the air

- The most suitable humidity is 40% to 55% in the computer room.
- Too low humidity will easily generate static electricity; too high humidity will easily generate condensate water and cause short circuit of electric equipment.

Table 7-3 Humidity

Humidity	Definition	Meaning
Relative Humidity	Ratio of the actual amount of steam in the air to the maximum amount of steam that can be accommodated in the air under the same temperature and same pressure. It is expressed by using %.	Drying degree of air. The smaller the percentage is, the drier the air is.
Moisture content	Amount of steam in each kilogram of air (g)	Water volume in unit mass of air

7.6.6 Dew Point

Dew point: temperature when the air becomes saturated.

- Under certain atmospheric pressure and steam content, when the air becomes saturated and continuous cooling will form dew, the temperature at this time is dew point.
- In the air conditioning system, when the surface temperature of the evaporator or surface cooler is lower than the dew point of the air, steam in the air will condense, so as to achieve the objective of dehumidification.
- In a general computer room (24°C, 50%), the dew point is 13.2°C. Below this temperature, the surface of objects will form dew.

Table 7-4 Dew points in common computer room environments

Dry Bulb Temperature (°C)	Relative Humidity	Dew Point (°C)
24	50%	13.2
24	45%	13.1
24	55%	14.6
23	50%	12.4
23	45%	10.6
23	55%	13.7

22	50%	11.3
22	45%	11.1
22	55%	12.7

7.6.7 Cleanliness

Cleanliness: content of dust (including microbes) in clean air.

- Code for Design of Data Centers raises the following requirement for dust concentration in computer rooms: under static or dynamic conditions, the number of dust particles greater than or equal to 0.5um is smaller than 17,600,000 in each cubic meter of air.
- When the air conditioning system in the computer room adopts a cycle generating unit, a primary efficiency or medium efficiency filter should be equipped. A fresh air system should be equipped with a primary efficiency or medium efficiency filter and a sub-high efficiency filter is preferred.

Table 7-5 Comparison table of filter levels

Filter efficiency compare table about China USA and Europe										
China GB/T14295	Roughing				Medium efficiency			High efficiency		
USA ASHRAE	C1	C2,3,4	L5 L6	L7	L8	M9 M10	M11	M12	M13	M14
Europe CEN	G1	G2	G3	G4		F5	F6		F7	F8
Europe EUROVENT	EU1	EU2	EU3	EU4		EU5	EU6		EU7	EU8

7.7 Quiz

1、(Single) Which of the following devices is a direct-contact processing device?

- A Humidifier
- B Evaporator
- C Electric heater
- D Condenser

2、(Short Answer Question) What categories can air conditioning systems be classified into by media?

7.8 Summary

- Working Principles of Air Conditioning System
- Classification of Air Conditioning System
- Air Handling Equipment
- Air Conditioning Ventilation System
- Common Air Conditioner Terms

8

Basic Knowledge of Precision Air Conditioners in Data Centers

8.1 Introduction

8.1.1 Foreword

The slides describe the basic knowledge of precision air conditioners in data centers, as well as the technical principles and main components of the air-cooled precision air conditioner, chilled water precision air conditioner, and indirect evaporative cooling system.

8.1.2 Objectives

On completion of this course, you will be able to:

- Understand the features of data center air conditioners and the differences between data center air conditioners and household air conditioners;
- Understand the basic principles and main components of the air-cooled precision air conditioner;
- Understand the basic principles and main components of the chilled water precision air conditioner;
- Understand the basic principles and main components of the indirect evaporative cooling system;
- Understand the product architecture of Huawei precision air conditioners.

8.2 Overview of Data Center Air Conditioners

8.2.1 Why Do We Use Air Conditioners?

If there are no specialized air conditioners for the computer room:

- Unable to maintain constant temperature - greatly reduce service life of electronic components.
- Partial superheat - sudden shutdown of equipment.
- Too high humidity in computer room - generate condensate water.
- Too low humidity in computer room - generate damaging static electricity.
- Not clean enough - main equipment damage and communication data error.

Table 8-1 ANSI/TIA-942-2-2010 'Telecommunications Infrastructure Standard for Data Centers'

Space	Environmental requirements
<p>Computer rooms, entrance rooms, access provider spaces, and service providers spaces in data centers</p>	<ul style="list-style-type: none"> ● Temperature: 18 - 27°C (64 - 81°F) dry bulb high altitude: reduce maximum dry-bulb temperature 1°C for every 300m (1.8°F for every 1000 ft) above 1800 m (5900 ft) altitude ● Maximum Relative Humidity (RH): 60% ● Maximum dew point: 15 °C (59 °F) ● Minimum dew point (lower moisture limit): 5.5 °C (42°F) ¹ ● Maximum rate of temperature change: 5 °C (9 °F) per hour
<p>Notes: 1. Dewpoint of 5.5 °C - corresponds to approximately 44% RH at 18 °C (64 °F) and 25% RH at 27 °C (81 °F).</p>	

8.2.2 Why Do We Use Precision Air Conditioner?

Advantages:

- High energy efficiency: COP>3.0
- High sensible heat ratio: > 0.9
- High air volume
- Cooling throughout the year
- High precision control over temperature and humidity
- Long service life: > 10 years

Coefficient of performance. Consumed power for refrigeration: total power consumed when an air conditioner is refrigerating (unit: W). Consumed power for heating: total power consumed when an air conditioner is heating (unit: W), including power consumed by the electric heater supplementing the heat pump.



Figure 8-1 Precision Air Conditioner

8.2.3 Application Scenarios

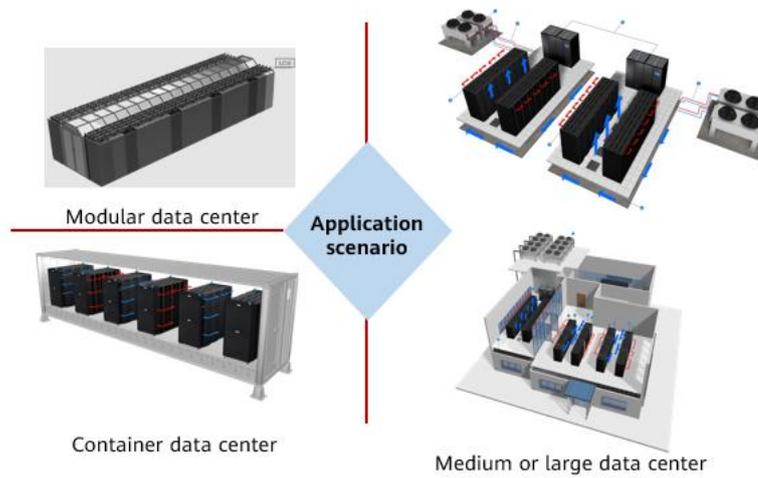


Figure 8-2 Application Scenarios

8.2.4 Classification

The mainstream cooling modes for data centers include mechanical cooling and free cooling.

- Mechanical cooling is implemented by the compressor operation of a cooling device. Direct expansion and water-cooled air conditioners are mainly used for mechanical cooling.
- Free cooling is implemented by free cooling sources to cool data centers. Direct fresh air cooling and indirect evaporative cooling are two major modes.

With the development of technology and energy-saving requirements, many new cooling methods are emerging, such as refrigerant pump cooling, fan wall cooling, heat pipe air conditioning, and liquid cooling.

This course mainly describes air-cooled precision air conditioners, chilled water precision air conditioners, and indirect evaporative cooling air conditioners that are widely used in data centers, and briefly introduces other technologies such as refrigerant pumps.

Classified by indoor unit layout

- To solve the problem of mixing of cold and hot air in the data center, in-room, in-row, and in-cabinet cooling modes are mainly used during data center design. In these modes, the air-conditioning system is integrated with a room, a cabinet row, or a single cabinet to reduce air mixing. This improves predictability, density, and efficiency, and also brings many other benefits. The preceding figure shows the differences between in-room air conditioners, in-row air conditioners, and in-cabinet air conditioners.

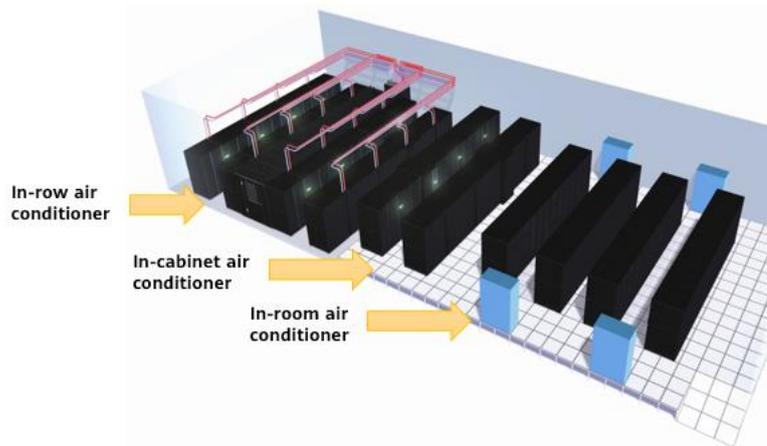


Figure 8-3 Classified by indoor unit layout

Classified by cooling mode

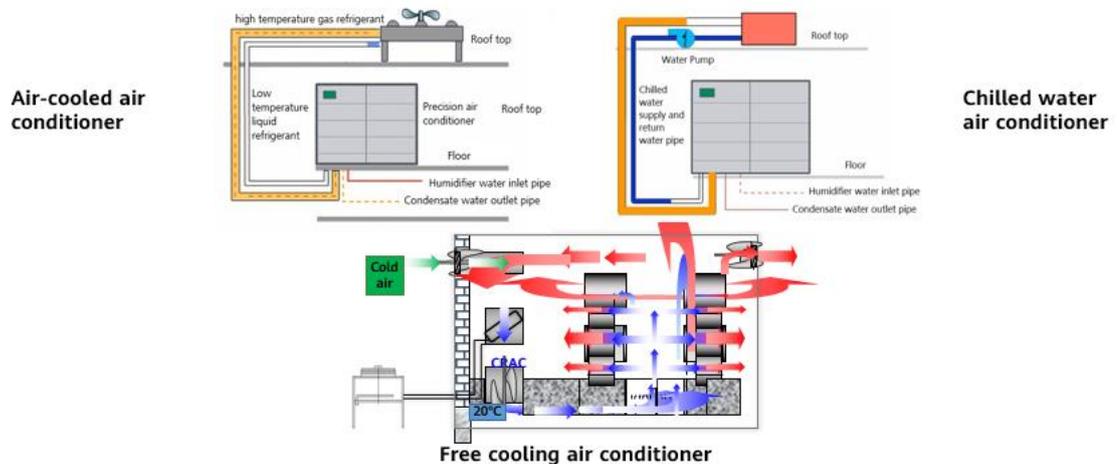


Figure 8-4 Classified by cooling mode

Classified by airflow organization

- Upflow air conditioners can be equipped with the tuyere or air duct for overhead air supply. Air supply with a tuyere applies to small- and medium-sized equipment rooms where the air supply distance of a single air conditioner is less than 15 m and the power of a single cabinet is less than 2 kW. Air supply with an air duct applies to equipment rooms with long air supply distances and low power.
- For downflow air conditioners, the raised floor must be at least 400 mm above the ground. Thermal insulation measures must be taken for the floor. This mode applies to scenarios where the air supply distance of a single air conditioner is less than 15 m. Aisle containment can improve efficiency.
- In-row air conditioners with horizontal airflow apply to high-power equipment rooms and do not require raised floors.

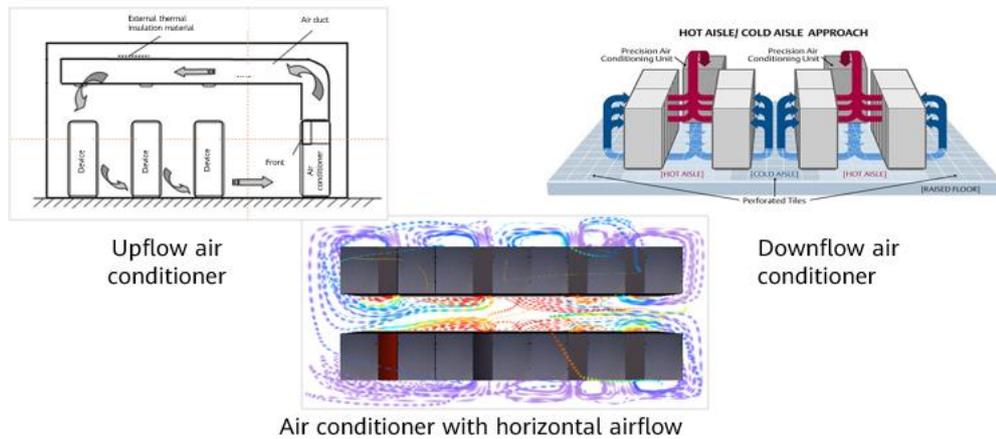


Figure 8-5 Classified by airflow organization

8.3 Air-Cooled Precision Air Conditioner

8.3.1 Basic Principles

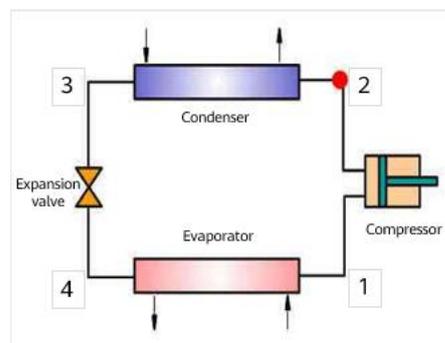


Figure 8-6 Basic Principles

- 1—2: The low-temperature and low-pressure vapor is compressed into high-temperature and high-pressure vapor by the compressor.
- 2—3: The heat of the high-temperature and high-pressure vapor is released by the condenser to form medium-temperature and high-pressure liquid.
- 3—4: The saturated liquid passes through the expansion valve to form a low-temperature and low-pressure gas-liquid mixture.
- 4—1: The gas-liquid mixture absorbs heat through the evaporator to form low-temperature and low-pressure vapor.

Direct expansion air-cooled

- Device refrigerant: refrigerants such as R410A, R407c, and R22;
- Application scenarios: small and medium-sized data centers without 24 h chilled water source (with the cooling capacity less than 500 kW);
- Characteristics:
 - Simple structure, easy and quick installation, and low cost;
 - Relatively small, independent refrigeration cycle, and easy maintenance;
 - Suitable for areas where water is scarce and where a cooling water system is absent;
 - Relatively low cooling energy efficiency ratio;
 - Not supporting long-distance installation. (Because such installation results in heavy cooling loss).

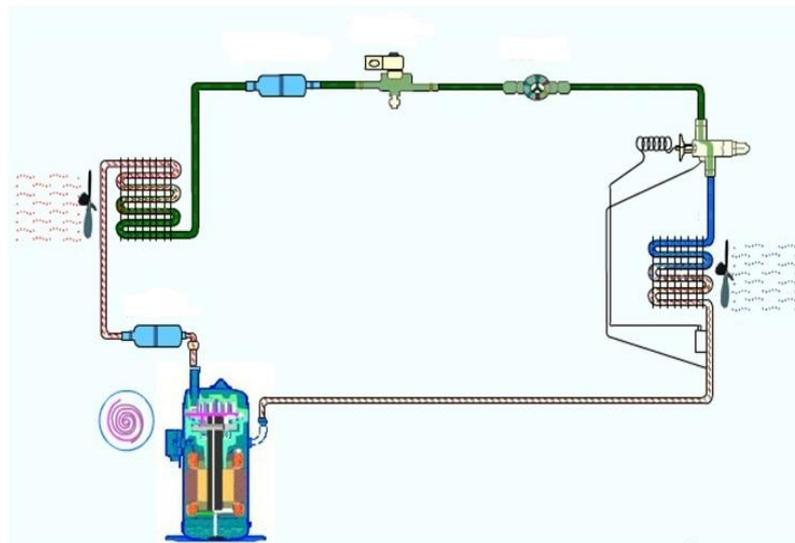


Figure 8-7 Direct expansion air-cooled

Direct expansion water-cooled

- Device refrigerant: refrigerants such as R410A, R407c, and R22;
- Application scenarios: areas with abundant water sources;
- Characteristics:

- Convenient and quick installation; (because refrigerants have been filled in factories);
- Supporting long-distance installation;
- A mixed solution of water and ethylene glycol generally required;
- More suitable for large-scale systems with a cooling tower.

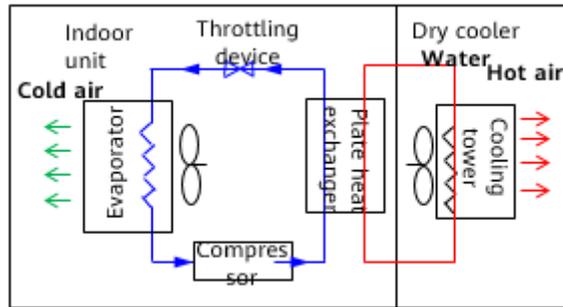


Figure 8-8 Direct expansion water-cooled (1)

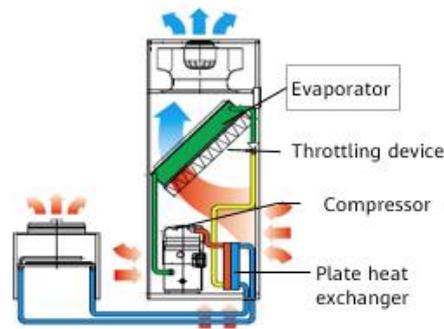


Figure 8-9 Direct expansion water-cooled (2)

8.3.2 Components

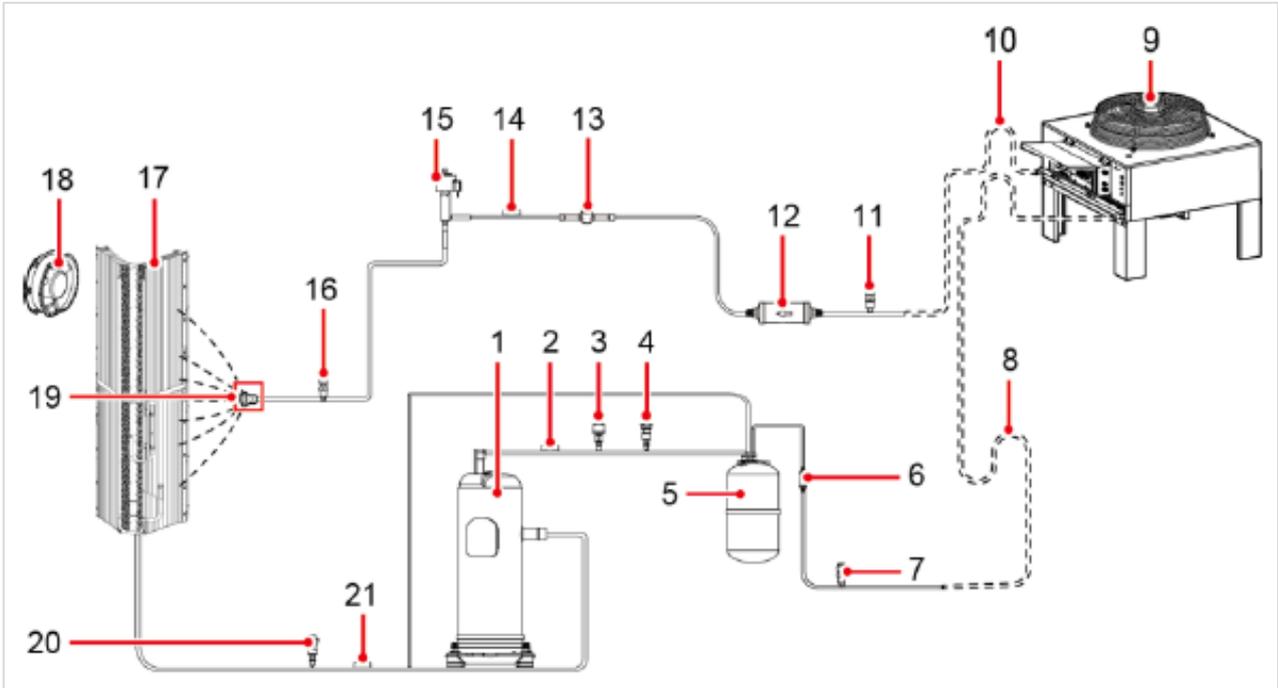


Figure 8-10 Components of a Huawei Air-Cooled Air Conditioner

Table 8-2 Components of a Huawei Air-Cooled Air Conditioner

No.	Name
1	Compressor
2	Discharge temperature sensor
3	High pressure switch
4	High pressure sensor
5	Oil separator
6	One-way valve
7	Exhaust pipe needle valve
8	Oil trap
9	Outdoor unit
10	Inverted U-shaped trap
11	Liquid pipe needle valve
12	Filter dryer

13	Sight glass
14	Liquid pipe temperature sensor
15	Electronic expansion valve (EEV)
16	Low pressure needle valve
17	Evaporator
18	Indoor fan
19	Liquid distributor
20	Low pressure sensor
21	Suction temperature sensor

Four main components of refrigerating system

- Compressor: The compressor is the core of the refrigeration cycle and is a power unit for refrigerant to circulate inside the system.
- Condenser: Under the effect of condensing medium, the condenser liquidizes the superheat saturated steam discharged by the compressor.
- Expansion valve: used for throttling. It is a regulating device for circular flow of refrigerant.
- Evaporator: The liquid refrigerant that is throttled absorbs heat and evaporates in the evaporator to cool down cooled materials, so as to achieve the objective of refrigeration.



Figure 8-11 Four main components of refrigerating system

Common auxiliary parts of refrigerating system

- Oil-gas separator: It is used to separate the lubricant brought out due to exhaustion of the compressor and brings back the separated lubricant to the compressor.



Figure 8-12 Oil-gas separator

- Liquid storage tank: It is used to store excessive refrigerant in the system and guarantee that the refrigerant entering the expansion valve is liquid.



Figure 8-13 Liquid storage tank

- Filter dryer: It is used to absorb moisture and filters out impurities in the refrigerating system.



Figure 8-14 Filter dryer

- Sight glass: It is used to check whether water exists in the refrigerating system and observe the state of refrigerant.



Figure 8-15 Sight glass

- Solenoid valve: It is used prevent slugging due to migration of refrigerant when the air conditioning unit is powered off.



Figure 8-16 Solenoid valve

- Fan: Accelerating the air flow and improving the heat transfer capability of the heat exchanger.



Figure 8-17 Fan

Low temperature components:

- If we use air conditioner in lower temperature environments, we require a low temperature components to improve the continuous low pressure caused by low temperature starting. By adding low temperature components, the air conditioner can operate normally.

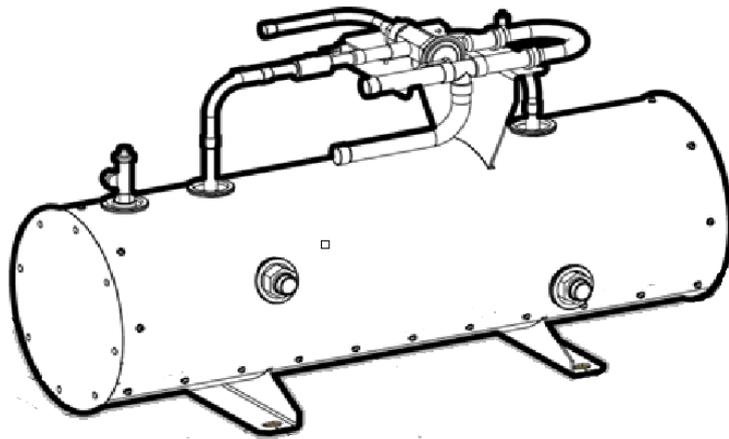


Figure 8-18 Low temperature components

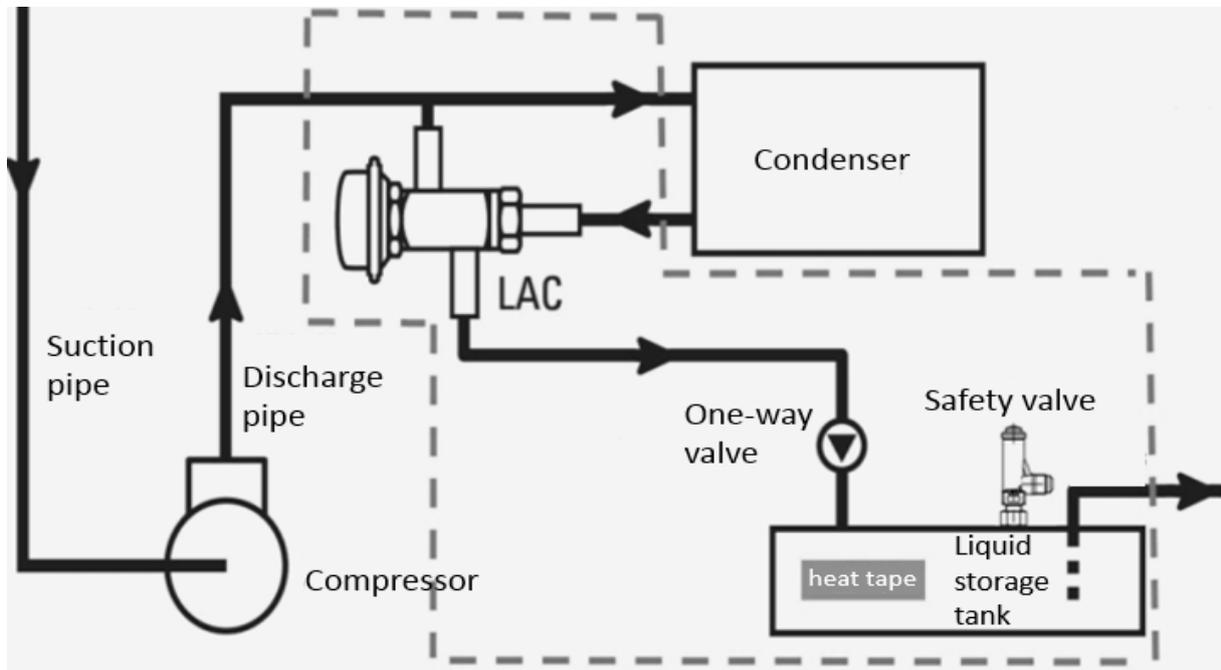


Figure 8-19 Working Principle of the Low temperature Component

8.4 Chilled Water Precision Air Conditioner

8.4.1 Basic Principles

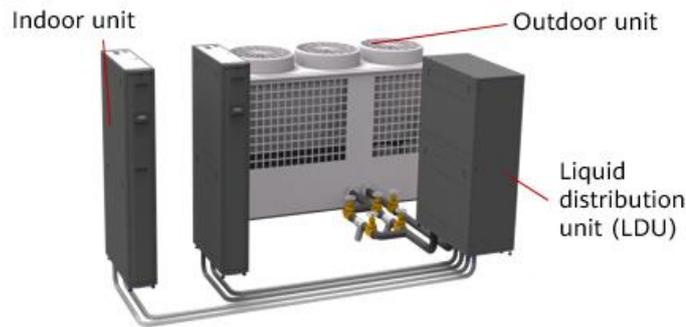


Figure 8-20 Chilled water air conditioning system

The chiller uses the vapor-compression refrigeration principle to produce low-temperature water (called chilled water), and distributes the low-temperature water to the indoor unit (fan coil). The hot air in the room flows through the surface of the fan coil to reduce the temperature.

After heat absorption, the temperature of the chilled water increases and the water flows back to the chiller. The preceding process is repeated.

- LDU: evenly distributes the low-temperature chilled water to each indoor unit. An LDU is required if there are multiple indoor units.

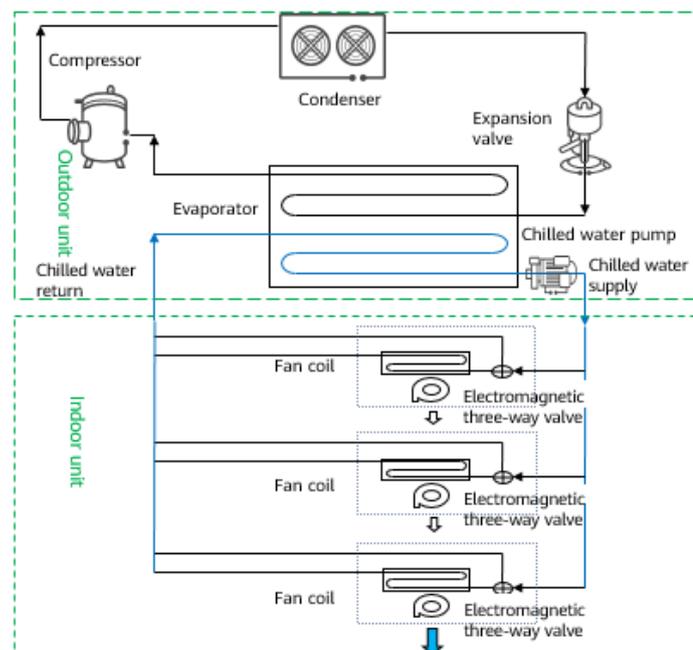


Figure 8-21 Basic Principles

Air-cooled chilled water

- Device refrigerant: chilled water
- Application scenarios: large and medium data centers
- Characteristics:
 - Not requiring a cooling tower, easy to install, easy to move, and suitable for occasions where water is scarce and where a water tower is absent;
 - Low-noise fan motor, excellent cooling and condensation effects, and stable throttling body;
 - High EER value, low noise, and stable operation.

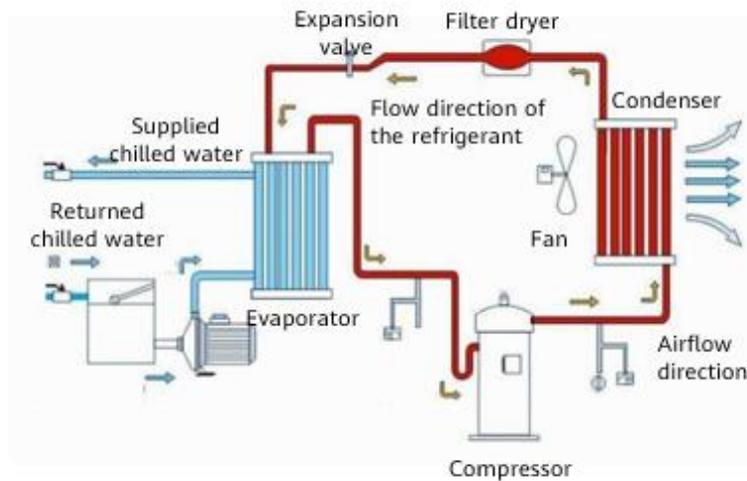


Figure 8-22 Air-cooled chilled water

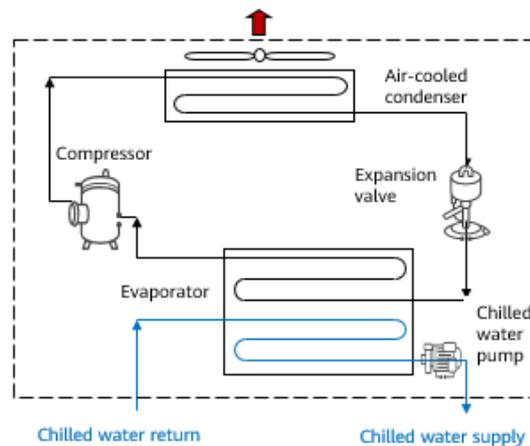


Figure 8-23 Air-cooled condenser

Water-cooled chilled water

- Device refrigerant: chilled water
- Application scenarios: large and medium data centers

- Characteristics:
 - Centralized cooling and high refrigeration efficiency;
 - Efficient heat transfer/exchanging device used, less cold loss, easy oil returning, and heat pipes not easily cracking;
 - Central air conditioning system used, and a need to consider the problem that chilled water cannot be provided in winter.

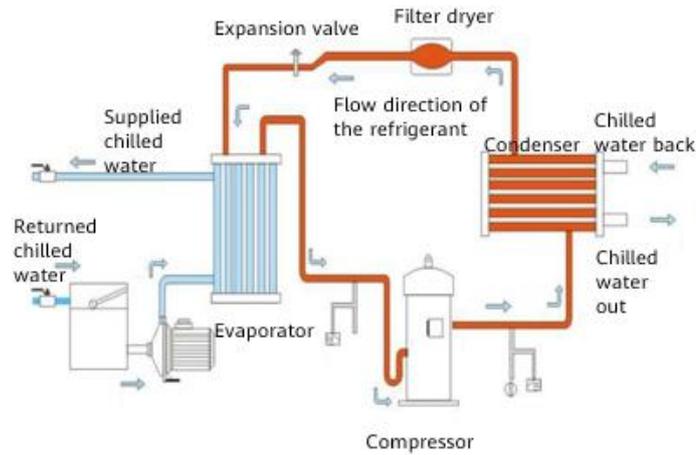


Figure 8-24 Water-cooled chilled water

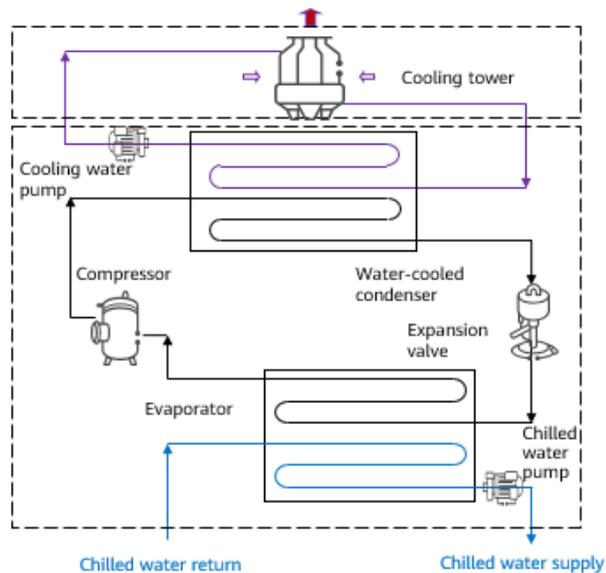


Figure 8-25 Water-cooled condenser

- Cooling tower mode: The cooling water is directly in contact with the air after the water temperature increases. The air absorbs the heat of the water. After the water temperature decreases, the cooling water flows back to the water-cooled condenser and can be used again.

8.4.2 Components

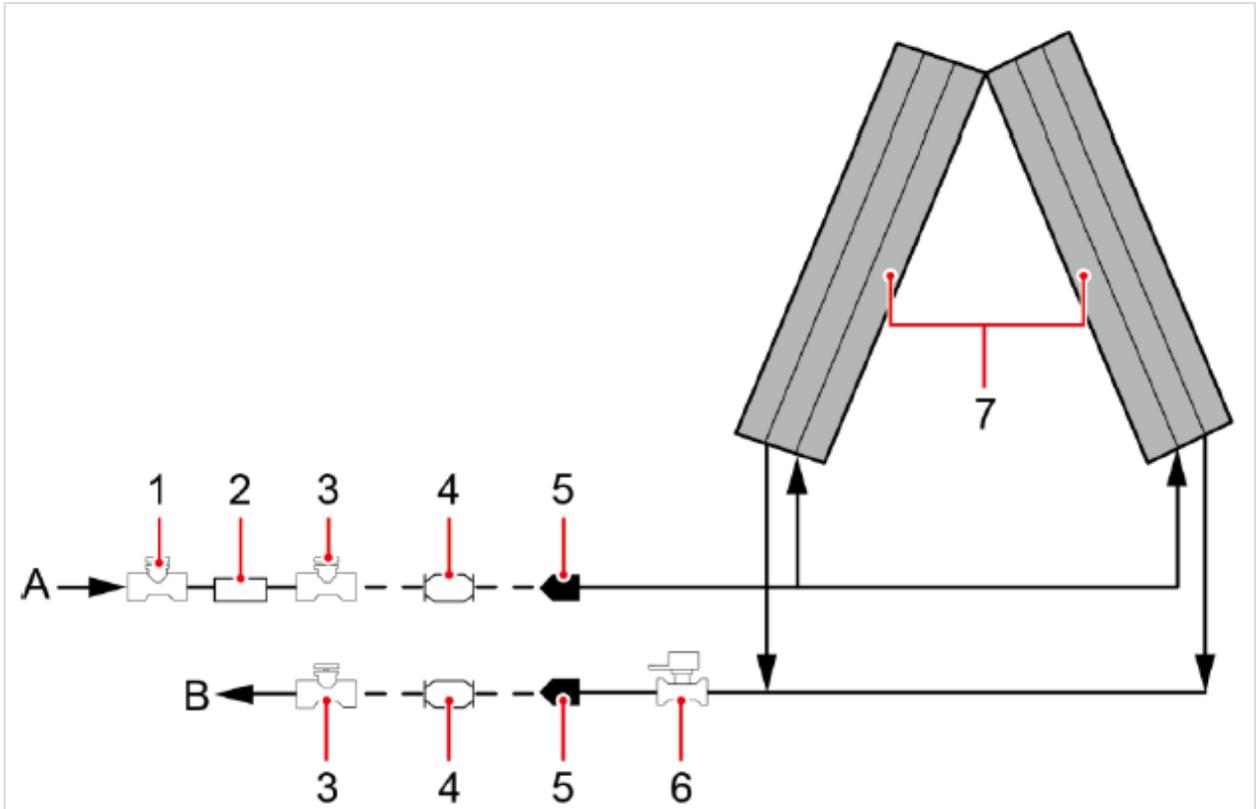


Figure 8-26 Components of a Huawei Chilled Water Air Conditioner

Table 8-3 Components of a Huawei Chilled Water Air Conditioner

No.	Name
A	Chilled water inlet
B	Chilled water outlet
1	Balance valve or isolation valve
2	Water strainer
3	Isolation valve
4	Soft connection
5	Chilled water inlet and outlet pipe connectors
6	Chilled water valve
7	Heat exchanger

Main components of refrigerating system

- Two way valve: The water flow into the air conditioner is adjusted continuously according to the change of the thermal load, and the temperature is accurately controlled;



Figure 8-27 Two way valve

- Fan: Accelerating the air flow and improving the heat transfer capability of the heat exchanger;



Figure 8-28 Fan

- Surface air cooler: A component that controls the indoor temperature and humidity by exchanging heat between chilled water and indoor air.

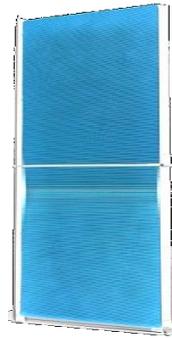


Figure 8-29 Surface air cooler

Common auxiliary components

- Power supply unit: Provide stable power supply to the fan;



Figure 8-30 Power supply unit

- Condensate water pump: Drain condensate water from the system;



Figure 8-31 Condensate water pump

- Float: Used to control condensate water level.



Figure 8-32 Float

Other components

- Water sensor
- Temperature sensor
- Air filter
- Electric heater
- Electrode humidifier

8.5 Indirect Evaporative Cooling Air Conditioner

8.5.1 Basic Principles

Evaporative cooling principle:

- In nature, liquids, such as water, absorb heat from the air during evaporation, causing the air temperature to drop. Water evaporates at any temperature and absorbs heat from the air, causing the air temperature to drop. Evaporative cooling is an isenthalpic process of humidifying and cooling air.



Figure 8-33 Evaporative cooling phenomena

Indirect evaporative cooling process

- In the indirect evaporative cooling process, the cooled air and water obtained by (direct) evaporative cooling are transferred to the air to be processed through an indirect-contact air-to-air heat exchanger, so as to obtain air with temperature reduced but moisture content unchanged. This is an iso-humid process of cooling air.

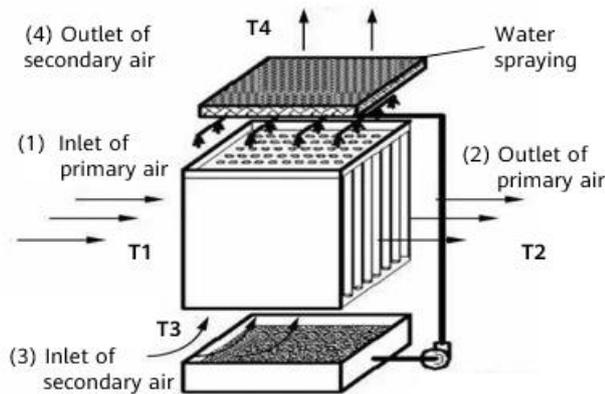


Figure 8-34 Conceptual diagram of an indirect evaporative cooling system

- 1—2: Iso-humid process of cooling, indirect cooling
- 3—4: Isenthalpic process of humidifying, direct evaporative cooling
- Primary air is air that is indirectly cooled.
- Secondary air is air cooled by direct evaporation.

Based on the outdoor fresh air temperature and humidity and IT load, an air conditioner works in three modes to implement on-demand cooling.

Table 8-4 Indirect Evaporative Cooling Air Conditioner Working Mode

Working Mode	Outdoor Ambient Temperature (100% Load)	Fan	Water Pump	Compressor
Dry mode	Dry bulb temperature $\leq 16^{\circ}\text{C}$	ON	OFF	OFF
Wet mode	Dry bulb temperature $> 16^{\circ}\text{C}$; wet bulb temperature $\leq 19^{\circ}\text{C}$	ON	ON	OFF
Hybrid cooling mode	Wet bulb temperature $> 19^{\circ}\text{C}$	ON	ON	ON

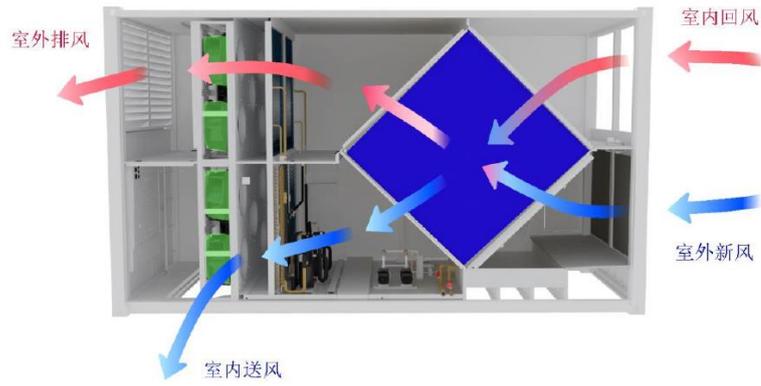


Figure 8-35 Dry mode

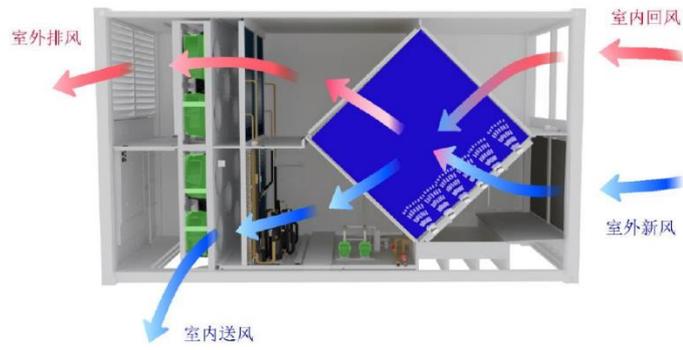


Figure 8-36 Wet mode

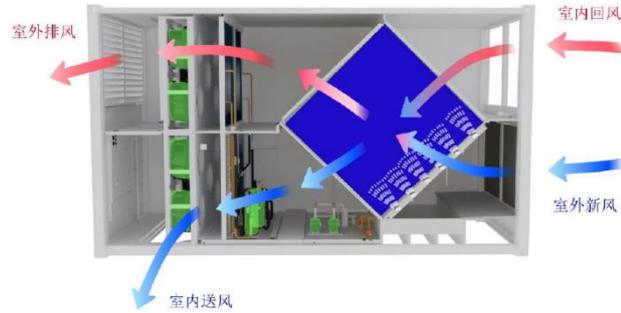


Figure 8-37 Hybrid cooling mode

8.5.2 Components

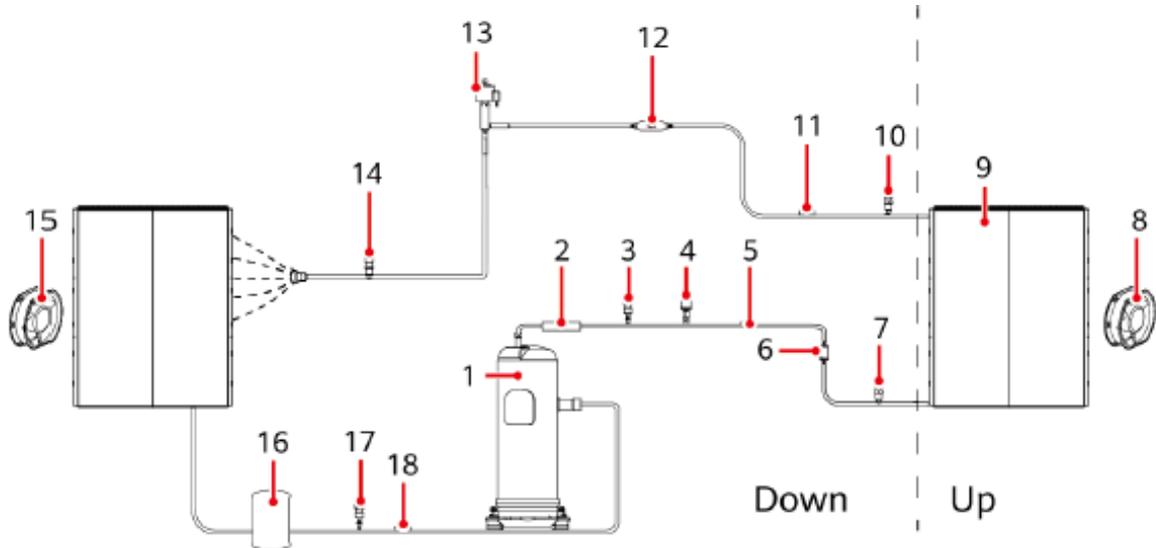


Figure 8-38 Components of a Huawei Indirect Evaporative Cooling Air Conditioner

Table 8-5 Components of a Huawei Indirect Evaporative Cooling Air Conditioner

No.	Name
1	Compressor
2	Shock-absorbing corrugated pipe
3	High pressure sensor
4	High pressure switch
5	Discharge temperature sensor
6	One-way valve
7	Exhaust pipe needle valve
8	Exhaust fan
9	Heat exchanger
10	Liquid pipe needle valve
11	Liquid pipe temperature sensor
12	Strainer
13	EEV

14	Low pressure needle valve
15	Indoor fan
16	Gas-liquid separator
17	Low pressure sensor
18	Suction temperature sensor

Heat exchanger core: cross-flow heat exchanger, improving heat exchange efficiency.



Figure 8-39 Heat exchanger core

Fan: accelerates air flow and improves the heat exchange capability.



Figure 8-40 Fan

Nozzle: ensures the spray pressure and improves the spray effect.



Figure 8-41 Nozzle

Water tank: stores water and provides spray water for a certain period of time.



Figure 8-42 Water tank

Shock-absorbing pipe: reduces pipe vibration to prevent pipe cracks during transportation and operation, improving the unit reliability.



Figure 8-43 Shock-absorbing pipe

Differential pressure switch: detects the differential pressure between the front and rear of the internal circulation air filter to determine whether the air filter is dirty or blocked.



Figure 8-44 Differential pressure switch

Other components include the auxiliary cooling system, pipes, pressure sensor, temperature and humidity sensor, and one-way valve.

8.6 Other Cooling Solutions for Equipment Rooms

8.6.1 Refrigerant Pump Cooling Technology

Refrigerant pump: refers to a pump lined with fluoroplastics, which is widely used in chemical production and transports strong corrosive media for a long time in the environment of -20°C to $+150^{\circ}\text{C}$.

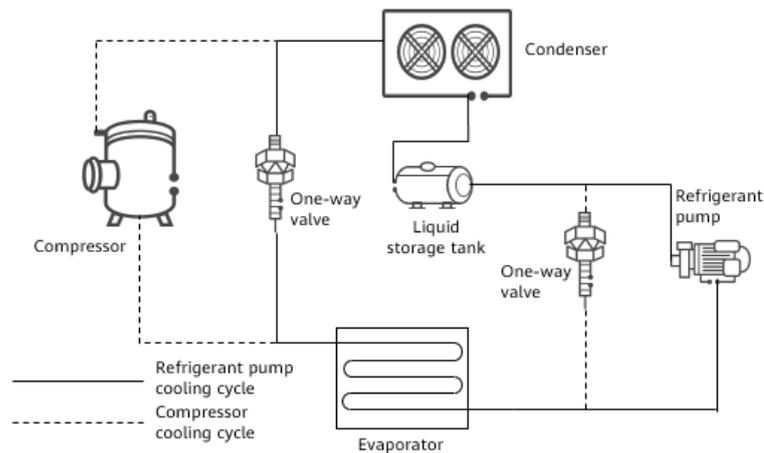


Figure 8-45 Refrigerant Pump Cooling Technology

When the outdoor temperature is higher than 20°C , the conventional mechanical cooling solution is adopted. The compressor works properly and the refrigerant pump does not work.

When the outdoor temperature is lower than 10°C , the compressor stops and the refrigerant pump starts cooling.

When the outdoor temperature is greater than or equal to 10°C and less than or equal to 20°C , the refrigerant pump and compressor start cooling at the same time, enabling the hybrid cooling mode to save energy.

8.6.2 Fan Wall Cooling Technology

The fan wall technology is an energy-saving technology that uses free cooling sources. Based on the indoor and outdoor temperature difference, the outdoor cold air is taken into the equipment room to absorb heat through the process of air intake, pre-processing, fan wall, air exhaust, and air return. In this way, partial or complete free cooling without mechanical cooling is implemented for the equipment room, which saves energy.

The fan wall technology, with multiple small fans arranged in order, replaces a single large fan in a conventional air handler, so that airflow organization is more even and fan energy consumption is lower.



Figure 8-46 Fall Wall

Different vendors may adopt different fan wall modes.

Yahoo's Compute Coop is an early and well-known data center that uses the fan wall technology.

8.6.3 Backplane Heat Pipe Air Conditioner

A heat pipe is a heat transfer element with extremely high thermal conductivity. It transfers heat by evaporation and condensation of liquids in a fully enclosed vacuum pipe. A heat exchanger formed by heat pipes has advantages such as high heat transfer efficiency, a compact structure, and small fluid resistance.

The cooling unit is distributed to the cabinet backplane in the internal area. Based on the heat pipe principle, the liquid working medium absorbs heat at the cabinet backplane in the indoor area and evaporates to gas, which rises to the outdoor condenser. After condensation, the gas working medium releases heat to the outdoor environment and becomes liquid, which flows back to the indoor environment under gravity. In this way, the indoor heat is transferred to the outdoor environment to complete the cooling cycle.

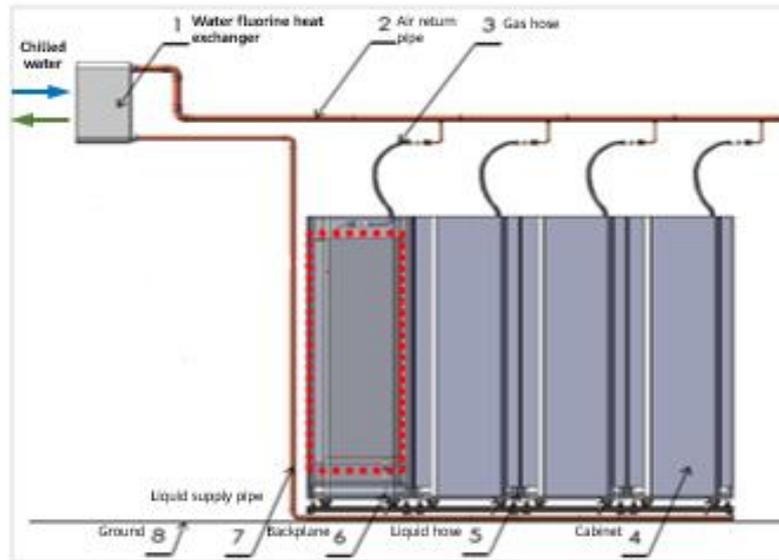


Figure 8-47 Backplane Heat Pipe Air Conditioner

This air conditioner type prevents water from entering the cabinet area and eliminates water leakage risks.

There are a large number of indoor units (backplanes), pipes, and connectors, and the O&M workload is heavy.

8.6.4 Liquid Cooling Technology

Cold plate liquid cooling

- An LDU is configured on the liquid cooling cabinet to provide water inlet and outlet pipes. The LDU is connected to the internal cold plate pipes in the liquid-cooled compute nodes to implement liquid cooling circulation in the compute nodes.

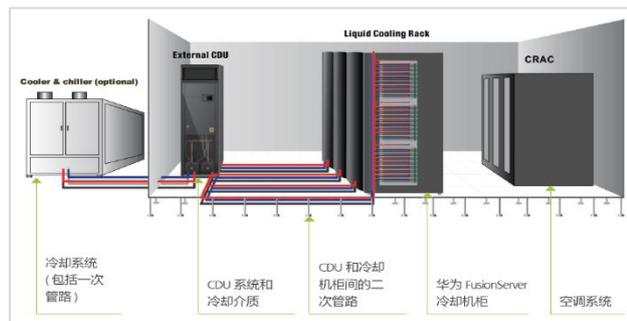


Figure 8-48 Cold plate liquid cooling

Immersion liquid cooling

- Specific coolant is used as the heat dissipation medium. Immerse IT equipment in the coolant to take away heat through coolant circulation.



Figure 8-49 Immersion liquid cooling

Spray liquid cooling

Insulated non-corrosive coolant is sprayed onto the surface of a heating device (or the extended surface in contact with the heating device) through the spray plate on the server box for heat exchange.



Figure 8-50 Spray liquid cooling

Liquid cooling technology features:

- The data center construction cost is reduced by 60%: Raised floors, heat dissipation channels, and server spaces are not required.
- Energy consumption of cooling is reduced by 90%: Fans and heat sinks are removed from servers, and no air conditioner humidifier is required in the equipment room, reducing noise in the equipment room.
- The total energy and maintenance costs are reduced by 50%: The hardware service life is prolonged and the number of components is reduced.
- High reliability is required. Leakage risks exist.

8.7 Introduction to Huawei Air Conditioners

8.7.1 Huawei Precision Air Conditioner Series

In-row precision air conditioner

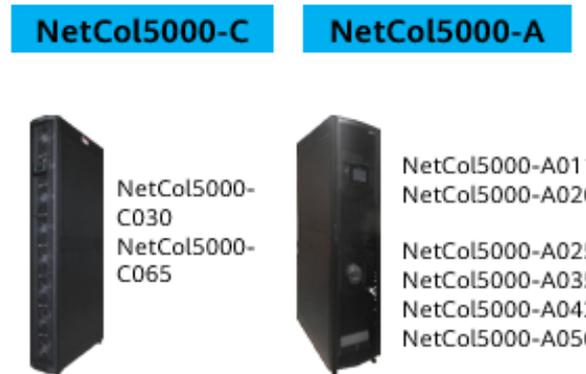


Figure 8-51 In-row precision air conditioner

In-room precision air conditioner



Figure 8-52 In-room precision air conditioner

Indirect evaporative cooling air conditioner



Figure 8-53 Indirect evaporative cooling air conditioner

8.7.2 Huawei Outdoor Unit Series

Main functions

- The outdoor unit controls the fan speed based on the condensing pressure to implement variable frequency speed control.
- The outdoor unit provides protection against overheating for fans.
- The driver provides a screen manipulator for keys and nixie tubes to meet commissioning requirements.
- Indoor and outdoor units are connected using signal cables. The outdoor unit is started or shut down as instructed by the indoor unit.



Figure 8-54 Huawei Outdoor Unit Series

8.8 Quiz

- 1、(Single) Which of the following is not one of the four major components of an air-cooled air conditioner?
 - A Compressor
 - B Evaporator
 - C Fan
 - D Condenser
- 2、(Multiple) Which of the following are the performance features of an air conditioner in an equipment room?
 - A Small air volume and large enthalpy difference
 - B Cooling throughout the year
 - C High reliability
 - D Various air supply modes
- 3、(Single) When the indirect evaporative cooling system works in dry mode, there is an iso-humid process of cooling.
 - A True
 - B False

8.9 Summary

- Overview of Data Center Air Conditioners
- Air-Cooled Precision Air Conditioner

- Chilled Water Precision Air Conditioner
- Indirect Evaporative Cooling Air Conditioner
- Other Cooling Solutions for Equipment Rooms
- Introduction to Huawei Air Conditioners

9 Basic Knowledge of Monitoring Systems

9.1 Introduction

9.1.1 Foreword

This chapter describes basic knowledge about the monitoring system, including interfaces and common protocols of the monitoring system and data center infrastructure monitoring modes.

9.1.2 Objectives

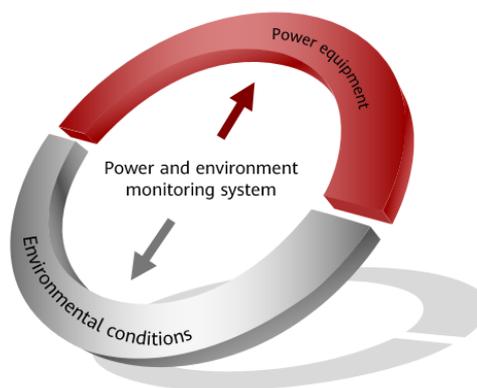
Upon completion of this course, you will be able to:

- Describe basic interfaces and communication protocols.
- Describe the overall architecture of the monitoring system.

9.2 Introduction to the Monitoring System

9.2.1 What is Power and Environment Monitoring System

The power and environment monitoring system is the short name of the power and environment centralized monitoring system.



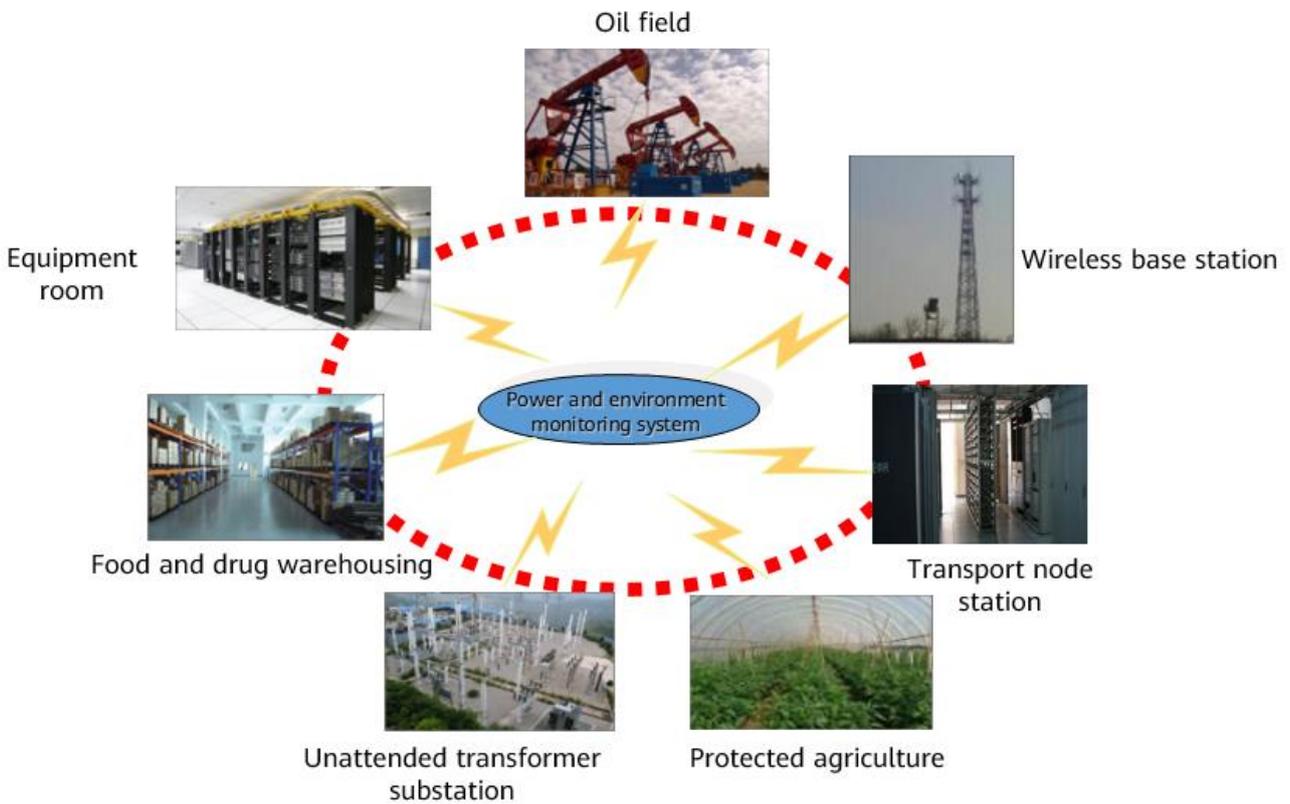
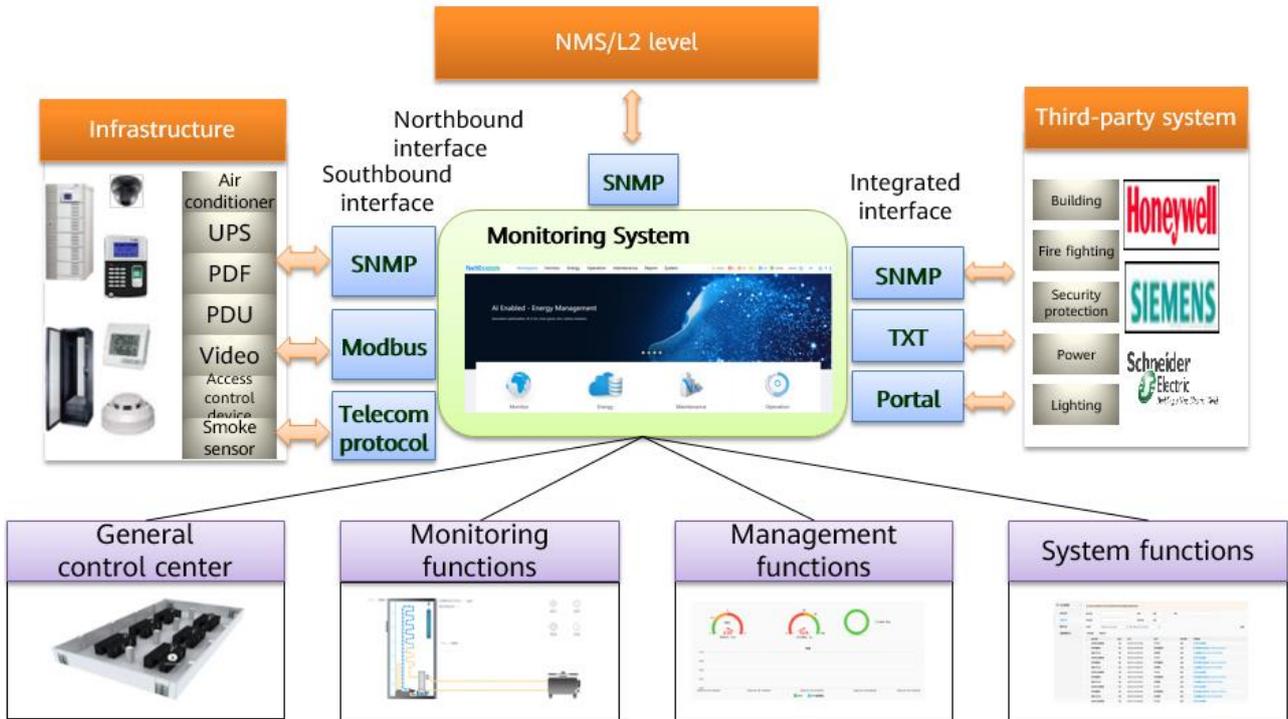
Power equipment

 UPS	 Diesel Generator	 Batteries
 High-voltage and low-voltage power distribution		 Mains power distribution

Environmental conditions

 Audio and video	 Access control device	 Air conditioner	 Smoke sensor
 Temperature	 Humidity	 Infrared sensor	 Water sensor

9.2.2 Overview of the Monitoring System



9.2.3 Application Scenarios of the Monitoring System

9.2.4 Development Trend

With the development of technologies, data center staff want to reduce inspection times of on-duty staff, reduce the workload of data center maintenance and management staff, and improve system stability by monitoring system equipment and environment.

- **Unified monitoring:** The monitoring system of equipment rooms is integrated with enterprise IT operation and maintenance (O&M) management systems (such as systems of service monitoring, server monitoring, and network monitoring) to form a complete management system.
- **AI energy conservation:** drives data center energy efficiency diagnosis and optimization to continuously reduce energy consumption. It saves energy by monitoring and managing IT equipment chips and site environment.
- **Mobile inspection technology:** Scheduled inspection of equipment rooms is one of the most important routine O&M tasks of a data center. Mobile inspection reduces the workload of staff and improves the accuracy of inspection data.
- **Fiber grating temperature measurement technology:** An electrical equipment failure can cause insulation performance deterioration or even breakdown, damaging the equipment. Common measurement methods cannot accurately monitor the equipment operating temperature online. Fibers can overcome this difficulty and ensure equipment security.

9.2.5 Intelligent Building Monitoring System

The main functions of the intelligent building monitoring system are integrated monitoring, linkage, and management of the systems under real-time monitoring system in a building.

The intelligent building monitoring system focuses on the overall management of a building, and the power and environment monitoring system focuses on the management of in-house equipment.



9.3 Basic Interfaces and Communication Protocols

9.3.1 Basic Concepts

Interface: connection mode between two hardware devices.

Protocol: a group of conventions that both parties involved in communication must observe, for example, how to establish a connection and how to identify each other. Both parties can communicate with each other only after they observe the conventions.

For example, mouse and USB drive are devices that use USB ports. These devices must comply with USB port specifications before they can be used over USB ports.

Common interface types

- DB9, RJ45, and cord end terminal.

Transmission modes

- RS232, RS485, RS422, and FE.

Protocol Type

- SNMP, Modbus, telecom protocol, OPC, and other protocols.

9.3.2 Common Protocols and Interfaces

9.3.2.1 Comparison of Common Protocols

Common interface forms:



DB9



DB25



Crimp terminal



RJ45



RJ12

Comparison of Common Protocols : Protocol Type	Feature	Transmission Mode	Category	Applicable Scope
Modbus	Field bus protocol, master/slave mode	Serial transmission, supporting loading of RS232/RS485/RS422	ModBus-RTU ModBus-ASC ModBus-TCP	Air conditioners, UPSs, ammeters, humidifiers, PDUs, and controllers
SNMP	Network management protocol	Used on TCP/IP networks in UDP mode.	SNMPV1.0 SNMPV2.0 SNMPV3.0	Air conditioners, UPSs, and PDUs
Telecom protocol	Field bus protocol, master/slave mode	Serial transmission, supporting loading of RS232/RS485/RS422	Frontend intelligent monitoring equipment communication protocol for power supply, air conditioners, and integrated environment management system of telecommunication offices (sites)	Based station air conditioners and base station power supply

Protocol Type	Advantage	Disadvantage
Modbus	Standard and open, supporting multiple electrical interfaces; the frame format is simple and easy to use.	Master/slave mode, providing low efficiency
SNMP	Complying with the OSI model, open protocol, and implementing management relying on network; the protocol is widely used; security is high.	The number of devices is large and the efficiency of query among much data is low; processing is complex.

Telecom protocol	Open protocol, supporting multiple electrical interfaces	The format is complex and the protocol is not universal.
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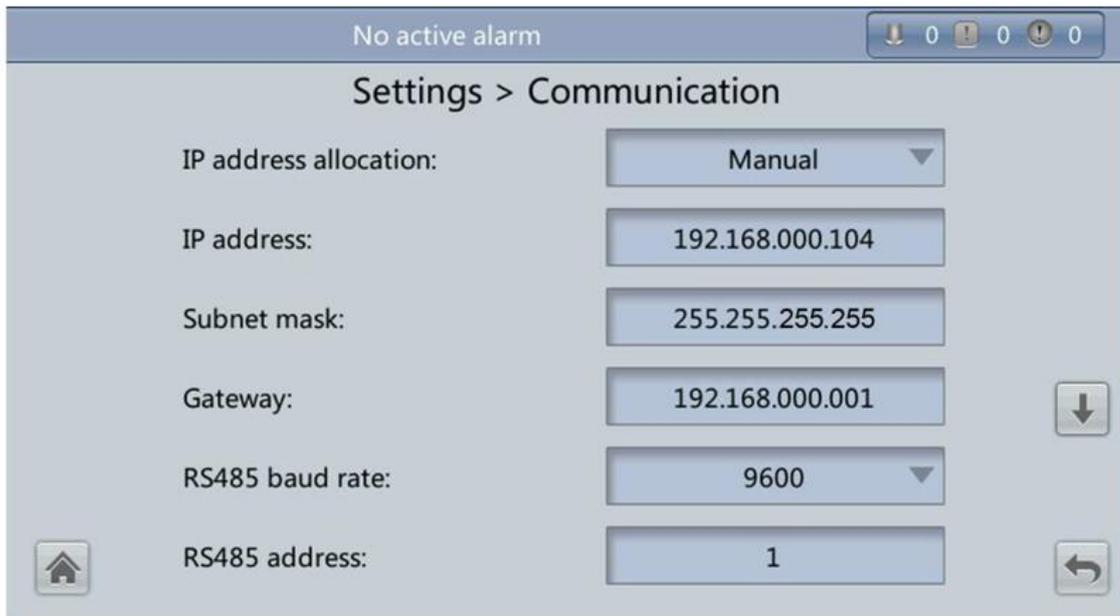
Transmission Mode	Number of Pins	Electrical Characteristic	Transmission Mode	Transmission Distance	Transmission Rate
RS232	Standard 25-pin, common 3-pin	± 15 V	Full duplex, single point	15 m	20 K
RS485	Standard 4-pin and 2-pin, common 2-pin	TTL (± 2 to ± 6)	Half duplex, master/slave	1200 m	10 M
RS422	Standard 4-pin	TTL (± 2 to ± 6)	Half duplex, master/slave	1200 m	10 M
FE	Standard 8-pin	TTL	Full duplex, multi-master	100 m	10 M

Transmission Mode	Advantage	Disadvantage
RS232	It is easy to obtain tools.	The distance is limited, networking is unavailable, and the transmission mode is susceptible to interference.
RS485	2-pin interfaces are widely used, networking is convenient, and the anti-interference capability is provided.	The distance is large and resistance must be matched at a high rate.

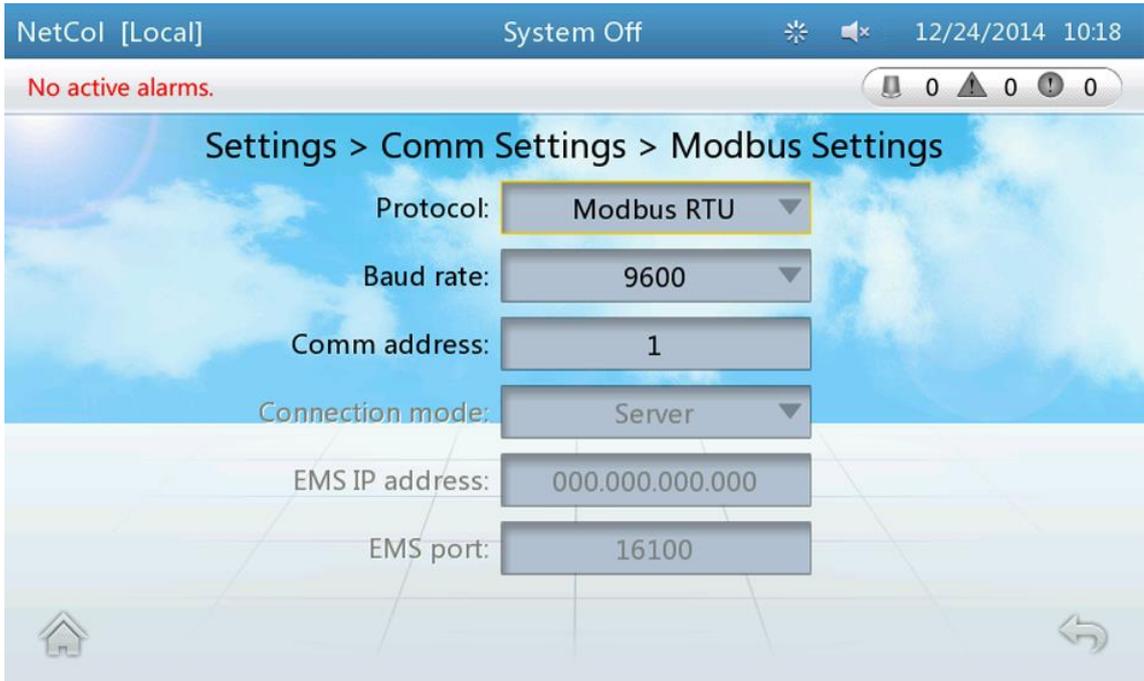
RS422	The anti-interference capability is provided and networking is available.	The distance is large and resistance must be matched at a high rate. The number of slave nodes is 10, which is smaller than that of RS485. The number of cores is greater than that of RS485.
FE	The transmission rate is high, the efficiency is high, and flexible networking is provided.	The networking cost is high.

9.3.3 Parameter Settings of Common Protocols

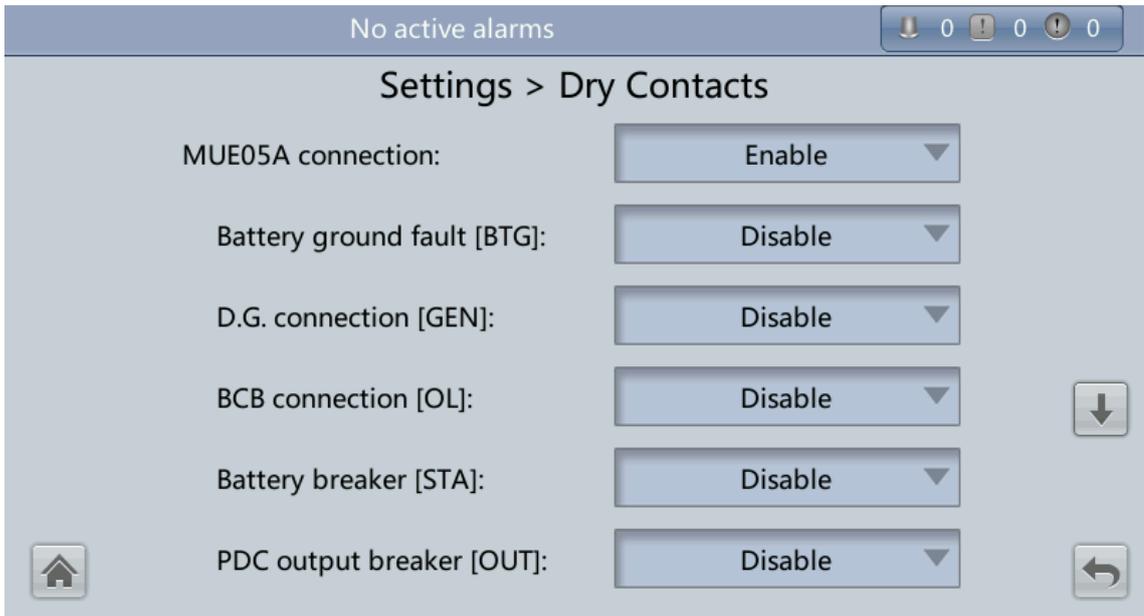
9.3.3.1 Parameter Settings - SNMP



9.3.3.2 Parameter Settings - Modbus



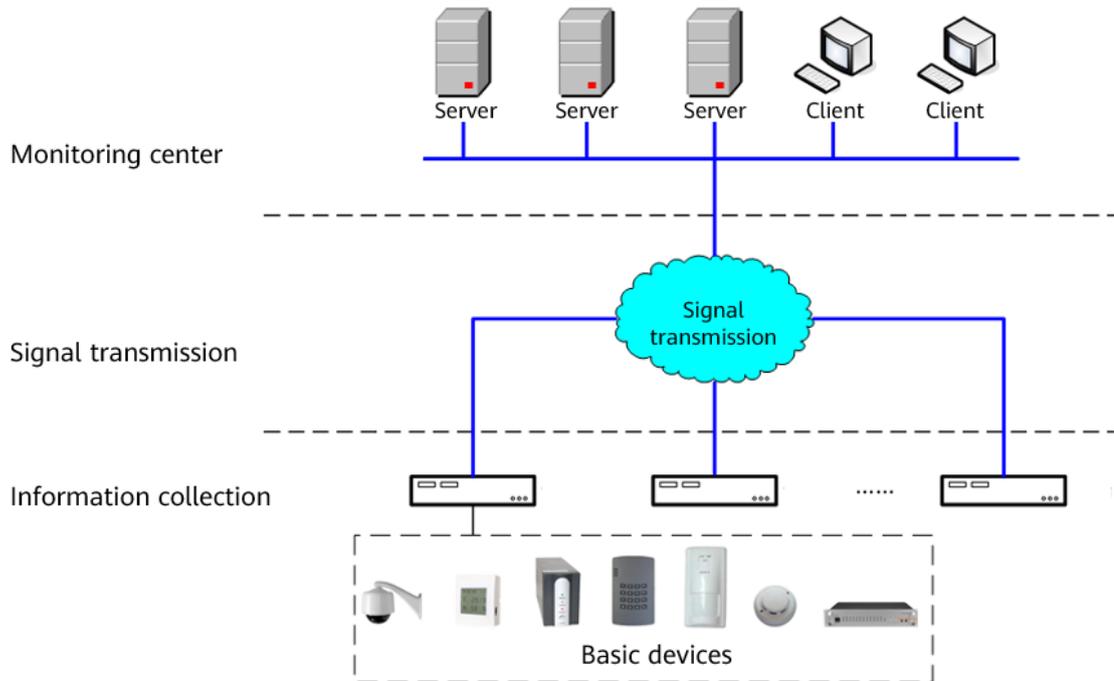
9.3.3.3 Parameter Settings - Dry Contact



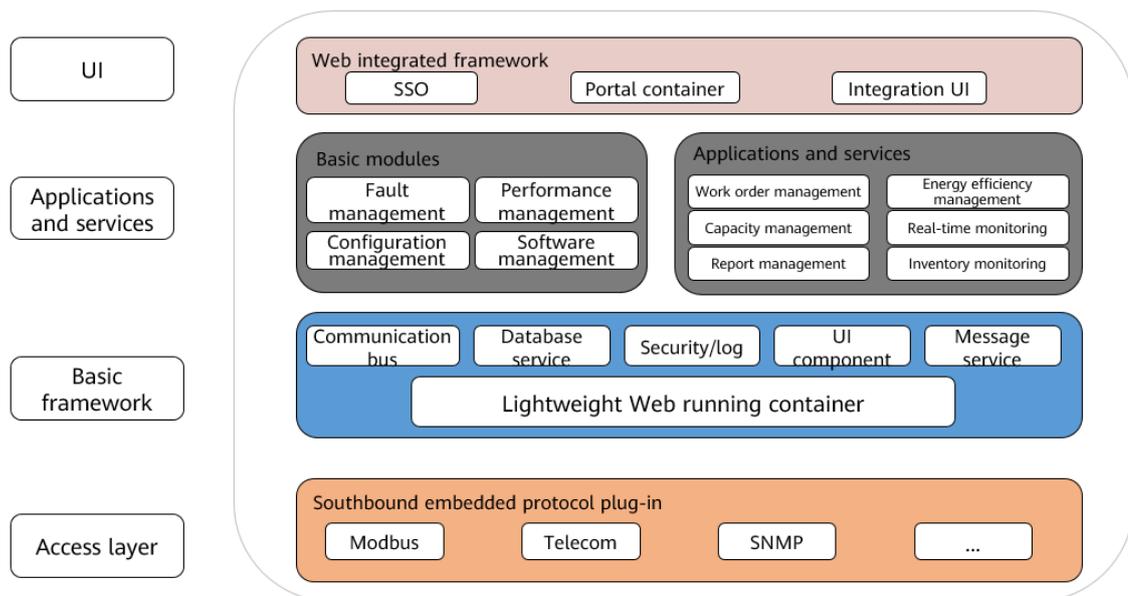
9.4 Introduction to the Data Center Monitoring System

9.4.1 System Architecture

9.4.1.1 Composition of Hardware Devices



9.4.1.2 Software Architecture



9.4.2 Application Scenarios

9.4.2.1 Data Center Application Scenario

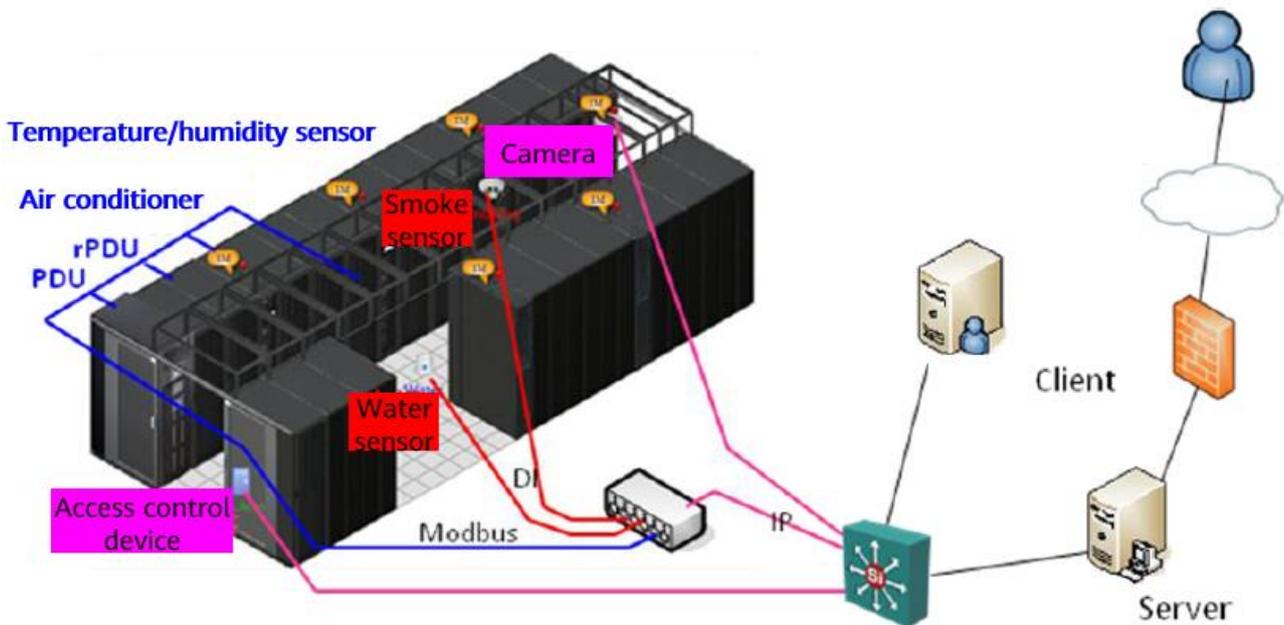
The monitoring system helps users quickly locate faults by monitoring infrastructure of the data center, supports centralized configuration and status monitoring for basic devices in the data center, and implements remote refined management for the data center.

The monitoring system can be deployed in medium and large modular data centers, small modular data centers, and container data centers.



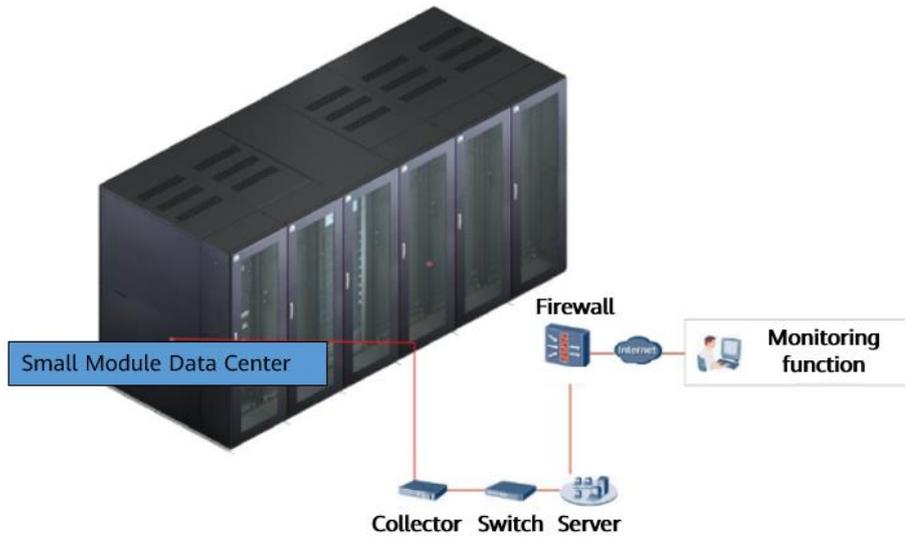
9.4.2.2 Medium and Large Modular Data Centers

Medium and large modular data centers are a series of complete data center solutions. The solutions are applicable to quick deployment of medium and large data centers of operators and large corporate customers.

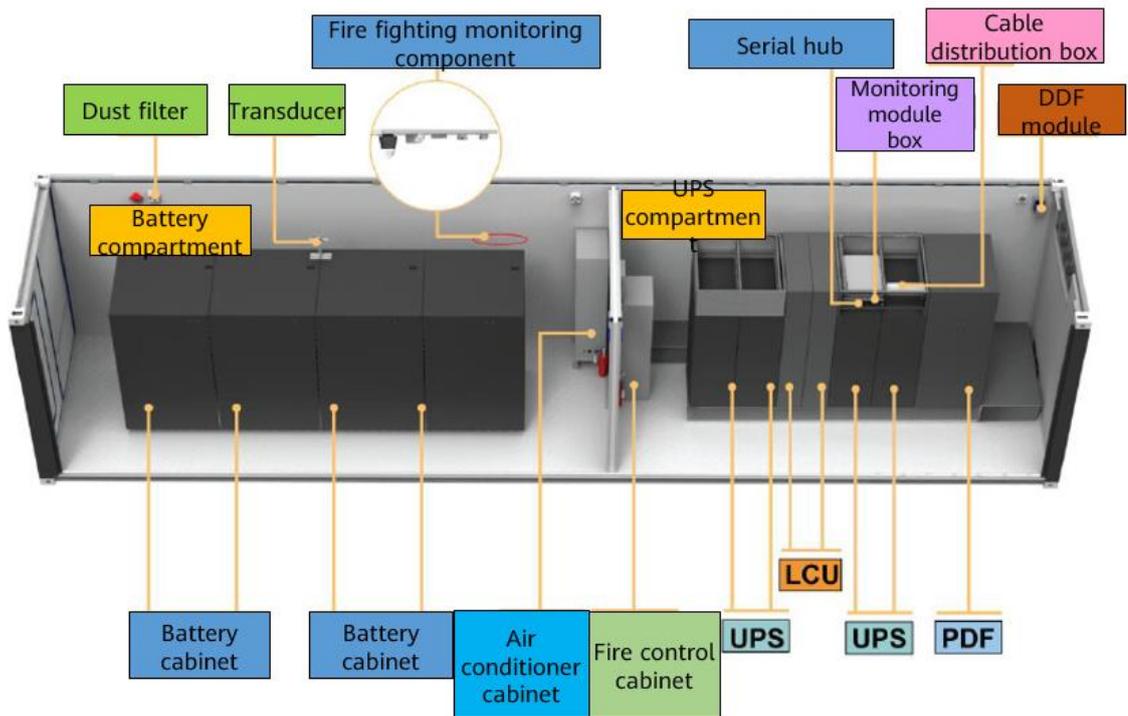


9.4.2.3 Small Modular Data Centers

Small modular data centers are mainly used in cloud hosts in parks, branches of large enterprises, small and medium enterprises, e-government networks, education, healthcare, and data equipment rooms of financial branches.

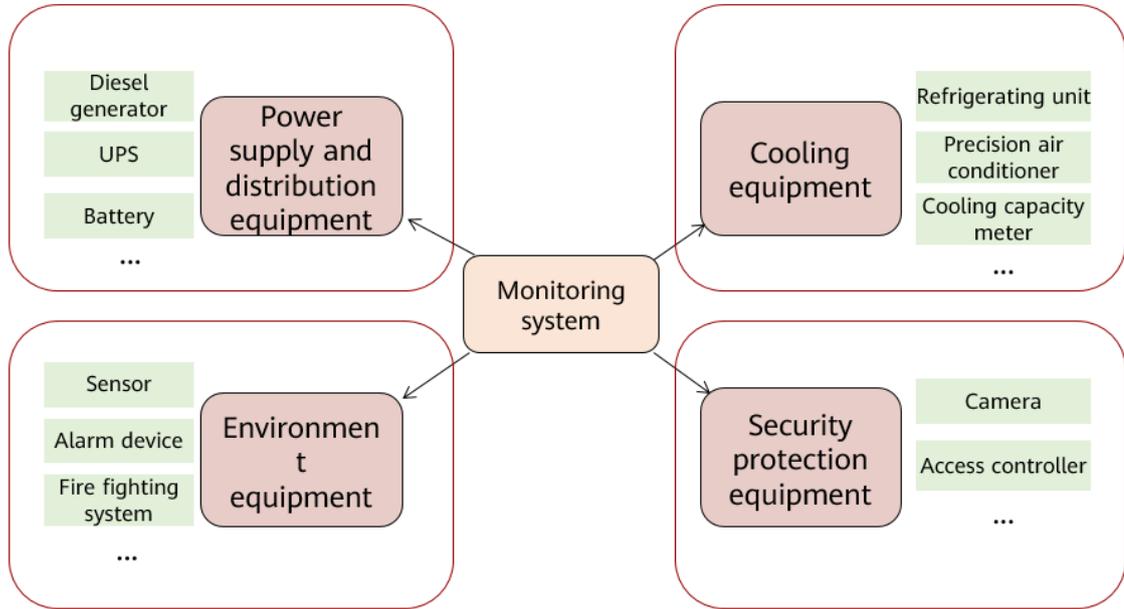


9.4.2.4 Container data center



9.4.3 Monitoring Implementation Mode

9.4.3.1 Subsystem Monitoring



9.4.3.2 Subsystem Monitoring Implementation Mode

Power supply and distribution equipment

Device Name	Object Monitored by NetEco	Monitoring Implementation Mode
Diesel generator	Operating status, operation parameters, alarms, and remote management; operation parameters of remote management provided by protocols for various devices.	Based on different interfaces provided by the devices, the solution provides two network connection modes. 1. Devices supporting Modbus or Telcom protocol are connected to the serial server or monitoring system collector that provides transparent transmission capability over RS485. 2. Devices supporting SNMP are connected to the monitoring system over the FE interface.
ATS and STS		
UPS		
Battery and battery cabinet		
UPS output cabinet		
PDU		
PDB		
RPDU		

Refrigerating equipment

Device Name	Object Monitored by NetEco	Monitoring Implementation Mode
Refrigerating unit	Operating status, operation parameters, alarms, and remote management; operation parameters of remote management provided by protocols for various devices.	Based on different interfaces provided by the devices, the solution provides two network connection modes. 1. Devices supporting Modbus or Telcom protocol are connected to the serial server or collector that provides transparent transmission capability over RS485. 2. Devices supporting SNMP are connected to the monitoring system over the FE interface.
Precision air conditioner		
Cooling capacity table		
In-row air conditioner		
Humidifier		

Environment equipment

Device Name	Object Monitored by NetEco	Monitoring Implementation Mode
Smoke sensor	Monitor the smoke concentration in an equipment room or module.	The smoke sensor is connected to the collector over the DI interface.
Temperature / humidity sensor	Monitor temperature and humidity in an equipment room or module.	The temperature and humidity sensor is connected to the collector over the RS485 interface.
Water sensor	Monitor liquid leakage in an equipment room or module.	The water sensor is connected to the collector over the DI interface.
Audible and visual alarm device	When an alarm is generated in an equipment room or module, the audible and visual alarm device in the equipment room or module produces sound or light, prompting the user to handle the alarm.	the collector over the skylight controller.

Environment equipment

Device Name	Object Monitored by NetEco	Monitoring Implementation Mode
Hydrogen detection system	Monitor whether hydrogen exists in an equipment room or module and prevent safety accidents such as fire due to high concentration of hydrogen.	The hydrogen detection system is connected to the collector through dry contacts.
Fire fighting system	Control fire extinguishing equipment in an equipment room to put out fire.	The fire fighting system is connected to the collector through dry contacts.

Security protection equipment

Device Name	Object Monitored by NetEco	Monitoring Implementation Mode
Camera	Real-time situation in an equipment room or module.	Cameras of the standard configurations are directly connected to a switch over the FE interface and are supplied with power in POE mode to view video information in real time.
NVR	Configure and manage cameras.	The NVR is used to store HD images and provide large-scale storage medium to store videos on a long-term basis. The videos are stored in different files based on time segment.
Equipment room access controller	Control and manage card readers.	Equipment room access controllers are connected to the monitoring system over the FE interface.

9.5 Quiz

1. (Short Answer Question) What are differences between SNMP and Modbus?
2. (Short Answer Question) Which scenarios can the power and environment monitoring system be used in?

9.6 Summary

- Basic Interfaces and Communication Protocols
- Subsystem Monitoring of Data Centers
- Technical Indicators and Environment Standards

10

Functions and Features of Monitoring Systems

10.1 Introduction

10.1.1 Foreword

This slides describe the main features and functions of the monitoring system, including the general control center and monitoring function, management function, and system function.

10.1.2 Objectives

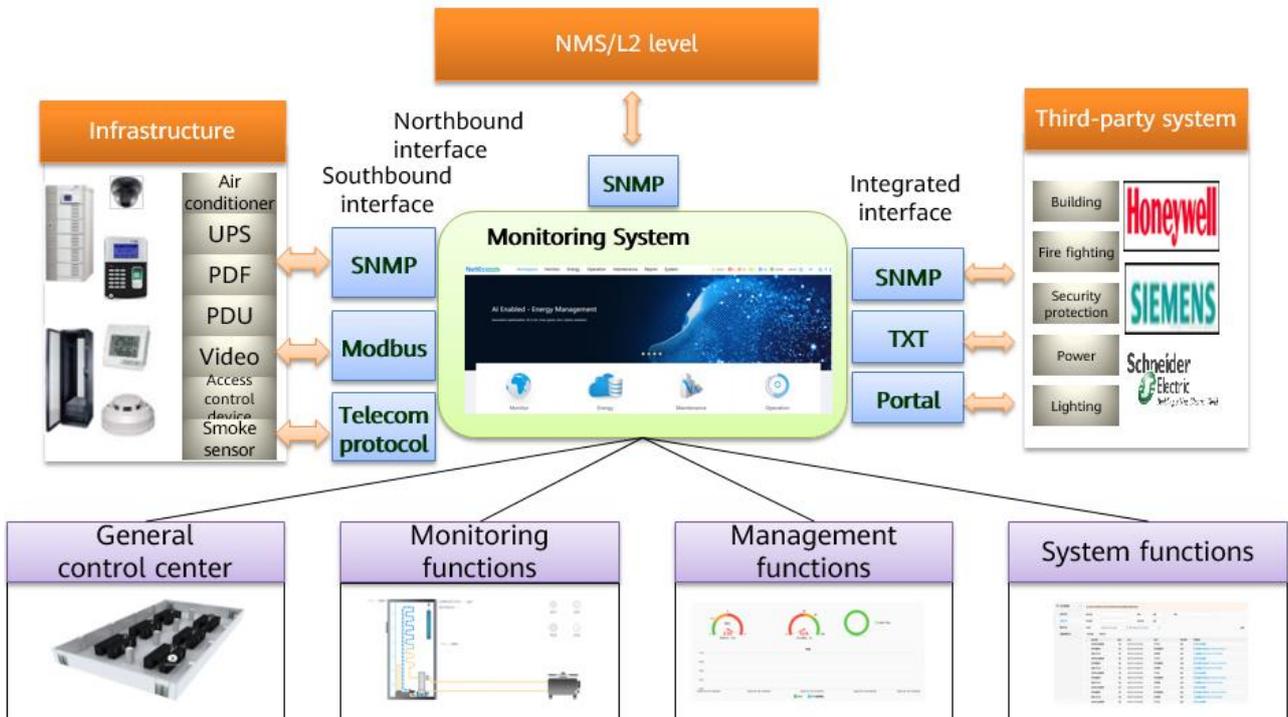
Upon completion of this course, you will be able to:

- Describe the features and advantages of the monitoring system.
- Understand the main functions of the monitoring system.

10.2 Overview of the Monitoring System

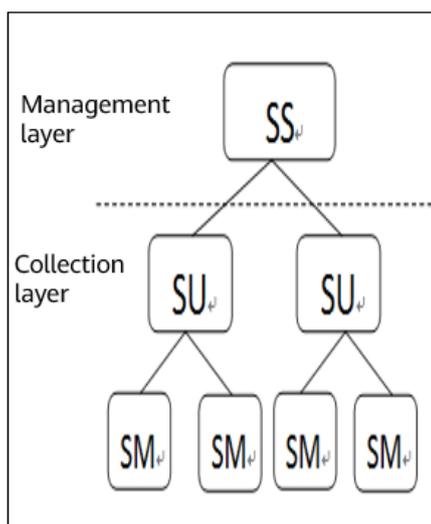
10.2.1 Hierarchical Deployment

10.2.1.1 Overview of the Monitoring System

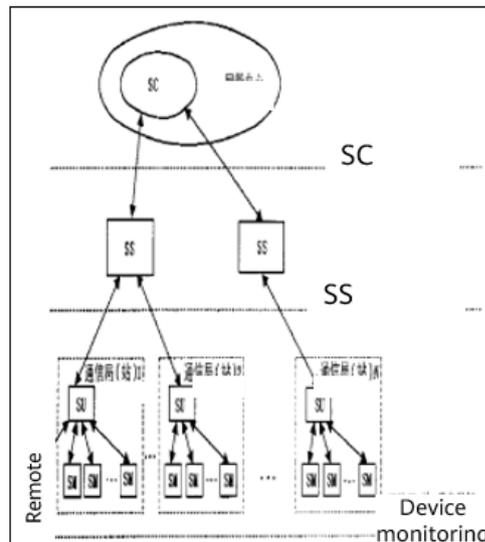


10.2.1.2 Hierarchical Deployment of the Monitoring System

When multiple equipment rooms need to be monitored at the same time, hierarchical deployment is required.



2-level architecture



Multi-level architecture

Abbreviation	Full Name
SC	Supervision Center
SS	Supervision Station
SU	Supervision Unit
SM	Supervision Module

10.2.1.3 Centralized Monitoring

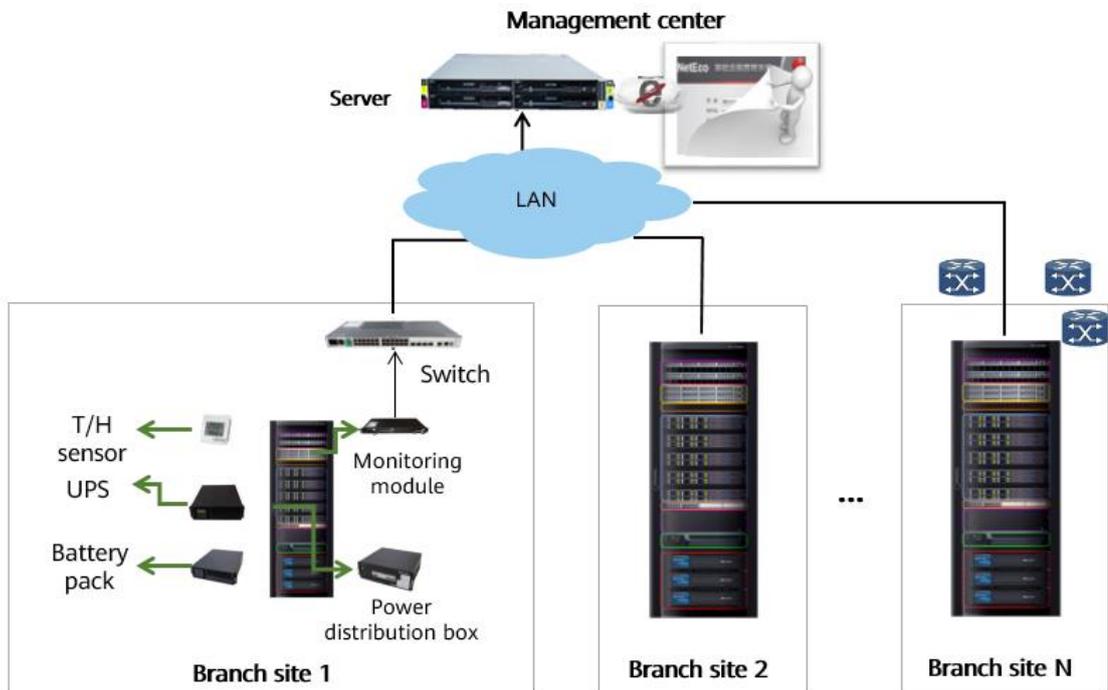


Figure 10-1 Centralized monitoring involves 2-level architecture and multi-level architecture

10.2.2 Architecture Types

10.2.2.1 Double-Layer Architecture

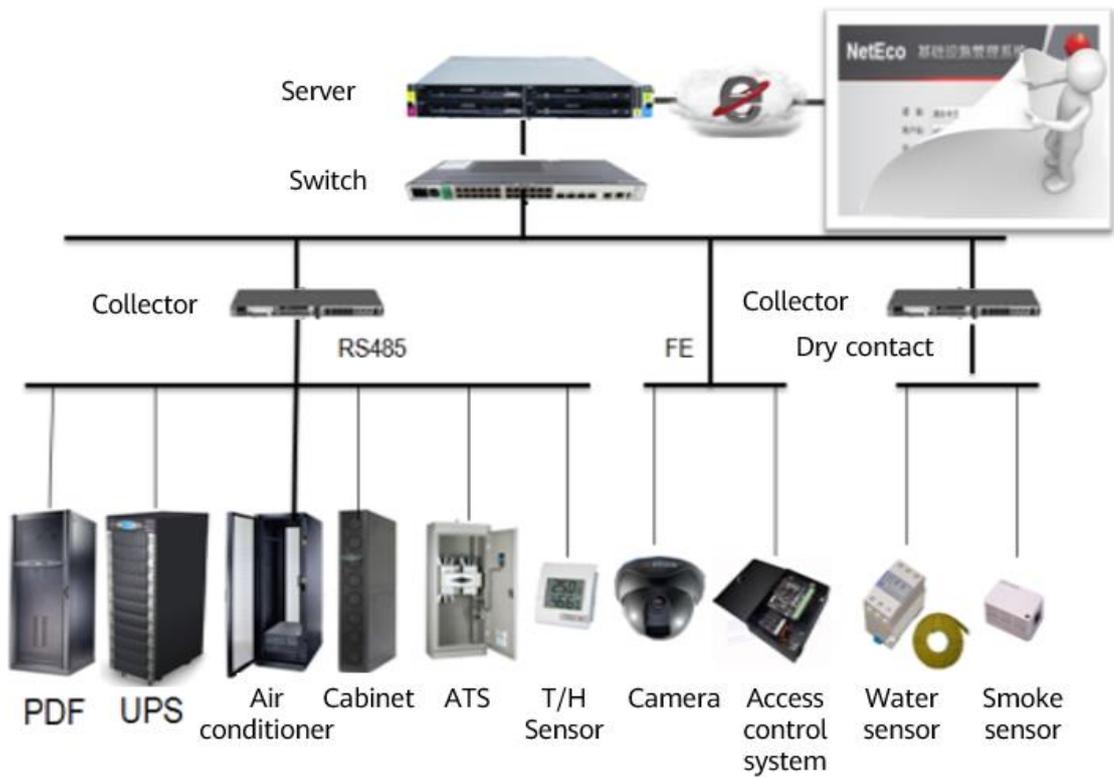
Two levels architecture: that is, management layer + data collection layer

Only one monitoring station is provided.

Multiple modules or equipment rooms are allowed.

The levels of equipment rooms are not differentiated.

This is the most common monitoring system mode.

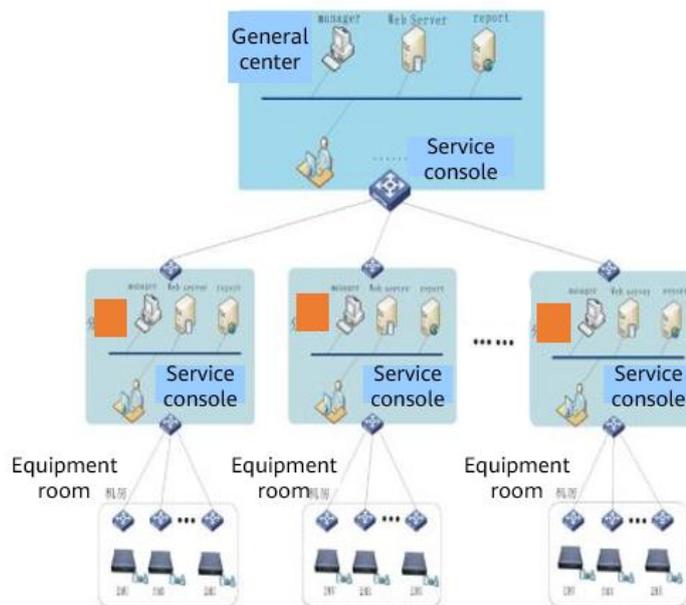


10.2.2.2 Multi-Layer Architecture

Typical 3-level architecture, that is, SC + SS + data collection layer

Typical scenario in which the head office can directly manage branch equipment rooms.

The monitoring management system of a branch center can be relatively independent and is an integral part of the SC.



10.2.3 Monitoring Features

10.2.3.1 Features of the Monitoring System

Flexible infrastructure management capability

- Real-time device monitoring, ensuring device reliability and high utilization.
- Real-time environment monitoring, ensuring environment consistency.
- Robust security protection management, fully protecting security of devices and environments.
- Accurate energy efficiency analysis, providing customizable and diversified energy consumption statistical and analysis methods.

Software and hardware layering

- The monitoring hardware (collector) collects data of infrastructure and sends the data and alarms to the monitoring software.
- The management software is divided into the data collection layer and the management and operation service layer.

Modular design

- Basic modules must be configured.
- Advanced modules can be generally deployed as required or selectively deployed.

Standard network management interface

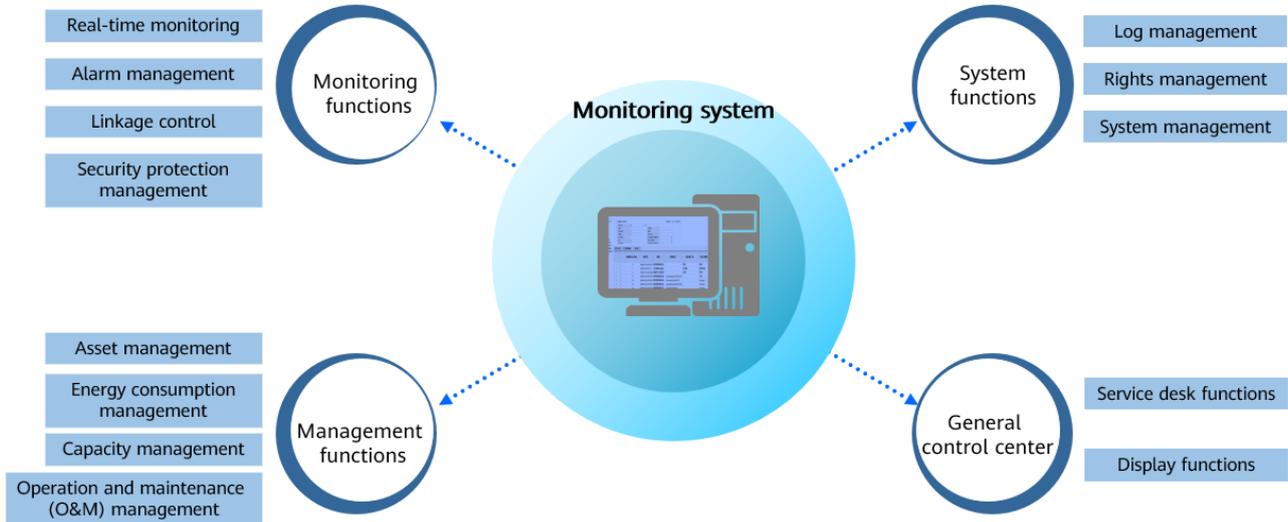
- The monitoring system can provide third-party NMSs with SNMP interfaces to meet information exchange with third-party systems. In addition, the monitoring system can provide a multi-protocol expansion mechanism to meet access of difference devices.

Flexibly configured collector

- Installation on a 19-inch cabinet is supported. The collector can be installed at the back of the cabinet to save space.
- Front and rear installation using mounting ears is supported to meet installation requirements for different product configurations.
- AI/DI expansion cards and serial expansion cards are supported.

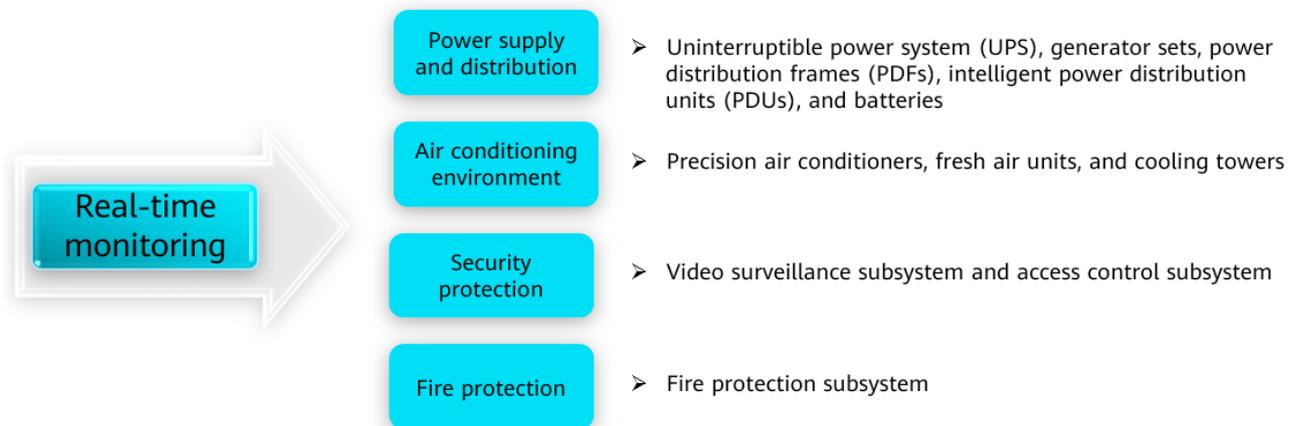
10.3 Introduction to Main Functions

10.3.1 Monitoring System Functions



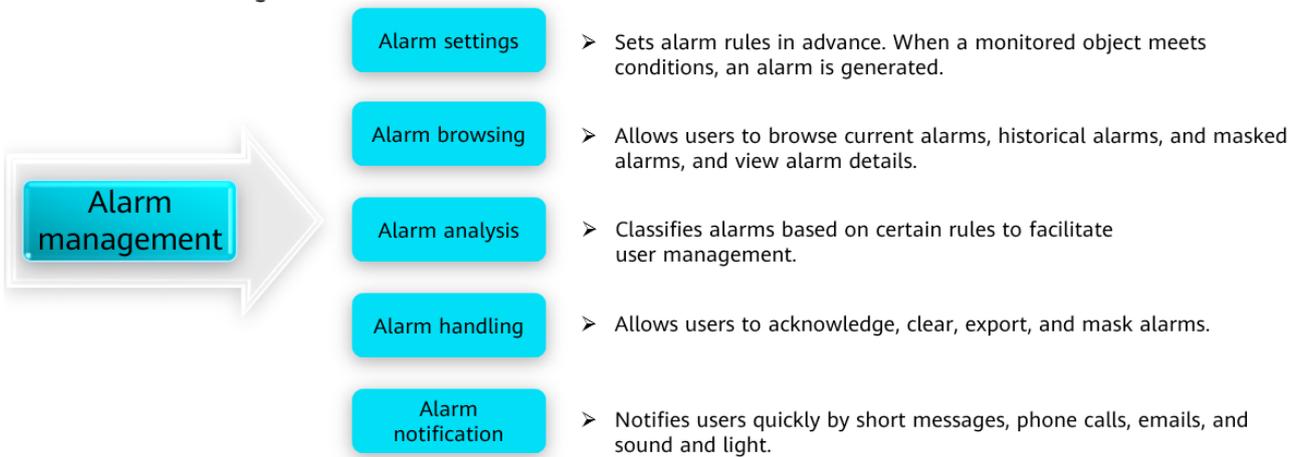
10.3.2 Monitoring Functions — Real-time Monitoring

The system allows users to view the running status of power supply and distribution equipment, air conditioners, security protection equipment, and fire protection equipment.

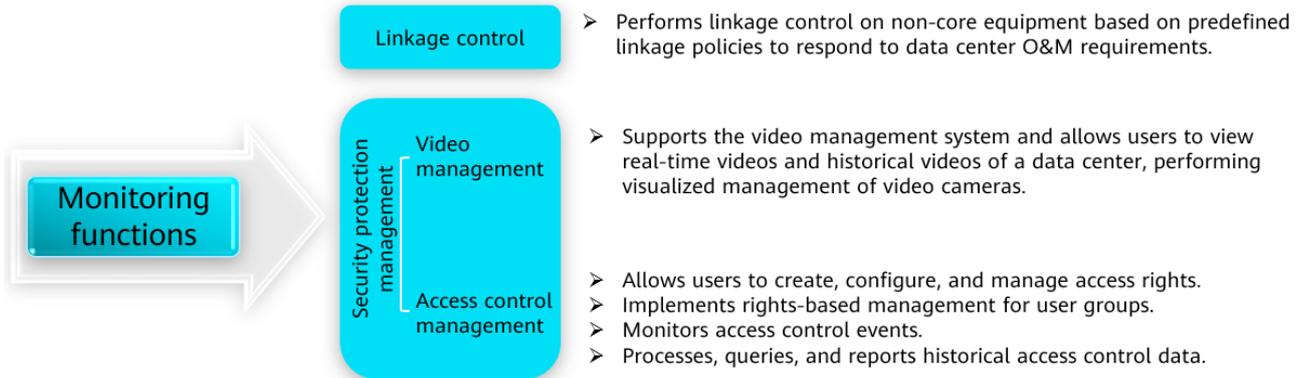


10.3.3 Monitoring Functions — Alarm Management

The monitoring system collects equipment information and generates warning and alarm information respectively before and after a condition is met according to preset alarm rules. Then, it displays and notifies the warning and alarm information to users.

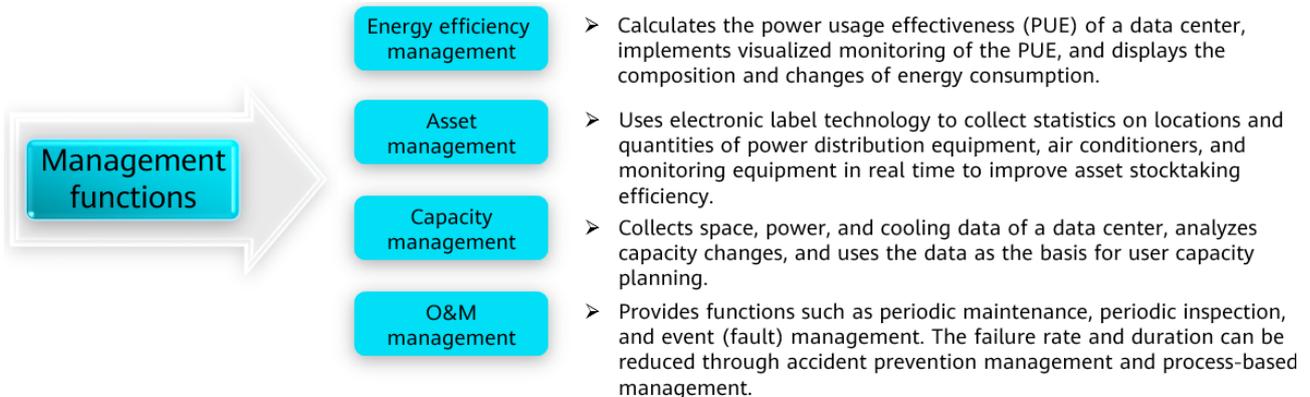


10.3.4 Monitoring Functions — Linkage Control and Security Management



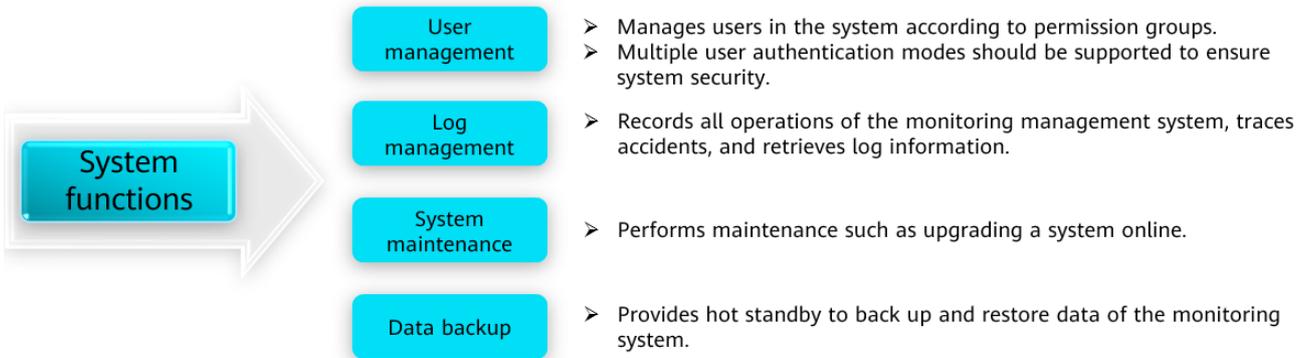
10.3.5 Management Functions

The objective of data center operation management is to achieve high availability of the data center with low operation costs. To achieve this goal, the monitoring management system must have the following functions: energy efficiency management, asset management, capacity management, and O&M management.



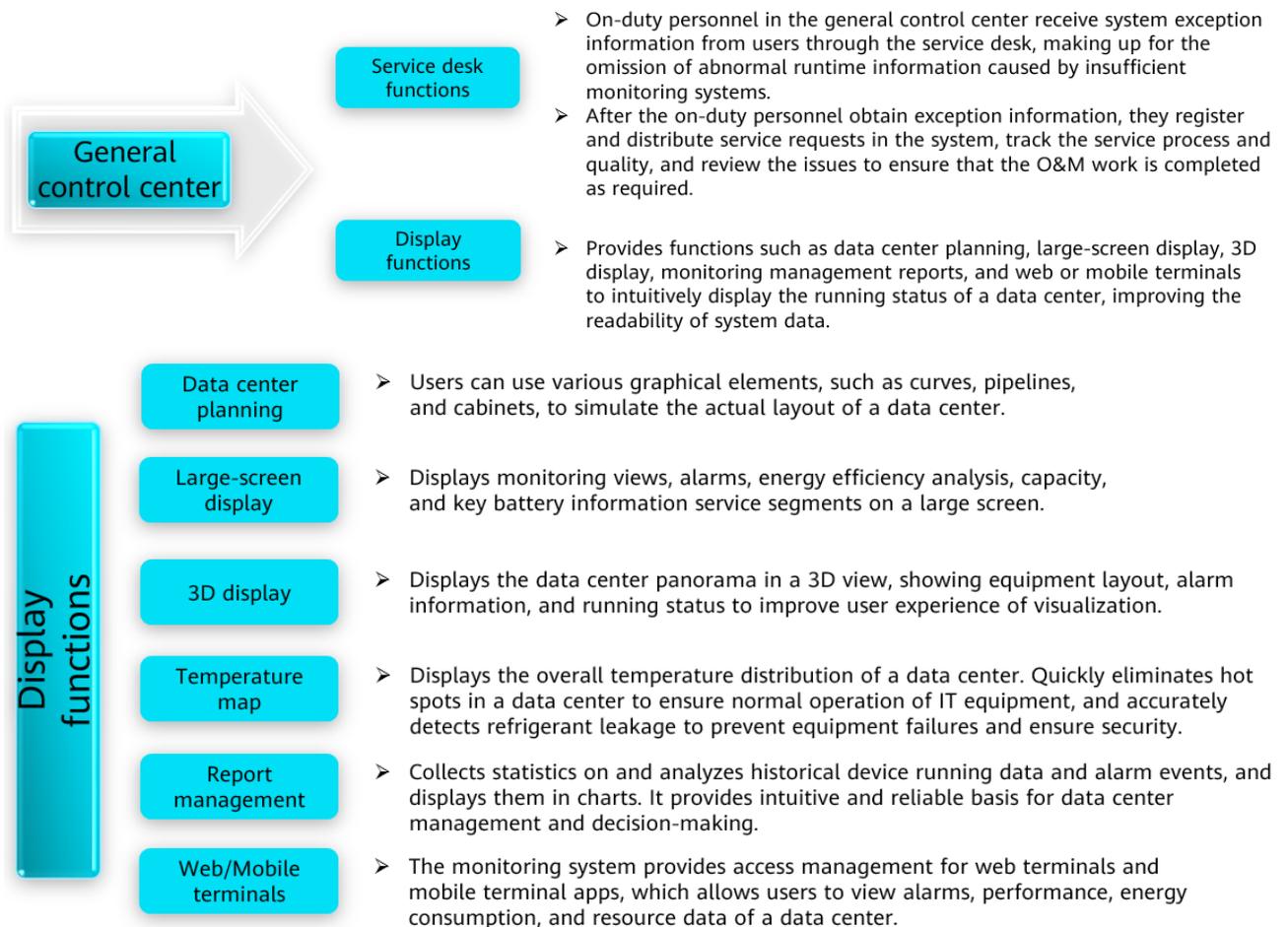
10.3.6 System Functions

The system provides common functions for each module of the monitoring management system, including user management, log management, system maintenance, and data backup.



10.3.7 General Control Center

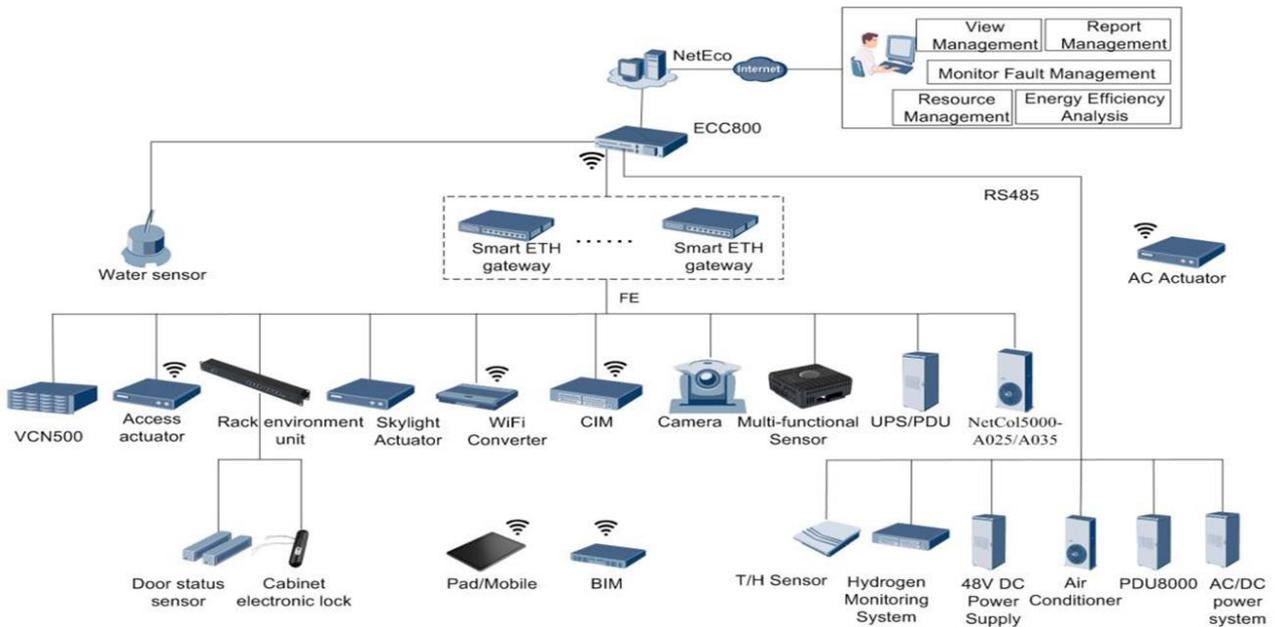
The general control center is an important entry for O&M management driver information. It provides the service desk and display functions and works with the O&M management system to ensure the availability of data centers.



10.4 Introduction to Huawei Monitoring System

10.4.1 Huawei Monitoring Management System

Huawei monitoring management system covers power monitoring, environment monitoring, and security monitoring, provides real-time status of devices inside micro-modules, alarm information, and configuration information for management, and provides visual interfaces.



10.4.2 Functions of Huawei Intelligent Monitoring System



10.5 Quiz

1. (Short Answer Question) What are the differences between 2-level architecture and multi-level architecture for centralized monitoring?
2. (Short Answer Question) What are the main functions of the monitoring system?

10.6 Summary

- Overview of the Monitoring System
- Introduction to Main Functions
- Introduction to Huawei Monitoring System

11

Introduction to Other Systems of Data Center Facility

11.1 Introduction

11.1.1 Foreword

In addition to the power distribution system, cooling system, and monitoring system, the data center facility has many other indispensable systems.

11.1.2 Objectives

On completion of this course, you will be able to:

- Understand systems of fire protection, fresh air, lightning protection and grounding, and integrated cabling in the data center infrastructure;
- Understand working principles and main components of these systems.

11.2 Fire Protection System

11.2.1 Fire Extinguishing System Overview

Functions:

- Fire extinguishing system automatically detects the smoke or hot air produced when a fire happens in the fire detection area, generates audible and visual alarms, and controls the automatic fire extinguishing system. In addition, the fire extinguishing system is associated with the output contacts of other devices, to control emergency lighting, evacuation signs, emergency broadcast/communication, and fire extinguishing water supply/smoke control facilities. This enables automatic monitoring, alarms, and fire extinguishing.

Classification:

- Water fire extinguishing system: Water is the most common extinguishing agent, because it is cheap and provides high extinguishing performance. The fire extinguishing principle is that water cools and penetrates a burning object to extinguishing the fire:
 - Fire hydrant water supply system: indoor and outdoor fire hydrant systems
 - Closed automatic water jetting system: Closed nozzles are used. When a fire happens, the temperature rises, and the glass bead of a nozzle breaks or the

fusible metal drops, enabling automatic water jetting. The system applies to buildings where the indoor temperature ranges from 4° C to 70° C.

- Pre-action water jetting system: The pipe of the system is charged with pressurized or non-pressurized gas during normal operating, without water. When a fire happens, the fire detection system opens the pre-action valve, water is injected into the pipe, and then the closed nozzle ejects water to extinguish the fire. The system applies to buildings where the indoor temperature is below 4°C or above 70°C.
- Automatic drench water jetting system: Open nozzles are used. When a fire happens, all nozzles eject water at the same time to extinguish the fire. The system applies to high-risk buildings.
- Foam fire extinguishing system:
 - Stationary foam fire extinguishing system: The system consists of the stationary foam liquid fire pump, foam liquid cylinder, proportioner, foam liquid transport pipe, and foam generating device. When a fire happens, the fire pump is started and related valves are opened to enable fire extinguishing.
 - Semi-stationary foam fire extinguishing system: Some devices are stationary and can be started in time. Others are non-stationary and are carried to the site when a fire happens, to work with the stationary devices for fire extinguishing.
 - Mobile foam fire extinguishing system: The system generally consists of the water source (outdoor fire hydrant, fire pool, or natural water source), foam fire fighting truck or foam generating device, water band, foam gun, and proportioner. When a fire happens, all mobile facilities are carried to the site and form a fire extinguishing system based on connection of pipes and water bands.
- Gas fire extinguishing system:
 - The extinguishing agent is stored in a pressure vessel in a liquid, liquefied gas, or gas state. During fire extinguishing, the extinguishing agent is sprayed in a gas (steam or mist) state.
 - The gas fire extinguishing system is mainly applied to places with valuable equipment or places where water fire extinguishing is not applicable. Such places and equipment include telecom equipment rooms, radio and television equipment, generator rooms, electrical equipment rooms, transformers, oil circuit breakers, motors, internal combustion engines, electric locomotives, library and archive buildings, scientific experiment buildings, valuable equipment rooms, large ships, and oil product factories.

11.2.2 Structure of the Fire Extinguishing System

The fire extinguishing system consists of the automatic fire alarm system, gas fire extinguishing system, smoke control system, safety evacuation system.

- Automatic fire alarm system: in the early stage of fire, the system converts the physical signals, such as smoke, heat, and flame produced by fire, to electrical signals through the fire detector, and transmits them to the fire alarm controller to trigger relevant linkages so that people may detect the fire and take effective measures in a timely manner.

- Gas fire extinguishing system: The system stores extinguishant in the form of liquid, liquefied gas, or gas in a pressure vessel, and releases the extinguishant in the form of gas to extinguish a fire. The extinguishant diffuses evenly in a protected zone with a regulatory concentration sufficient to put out a fire from all directions.
- Smoke control system: The system exhausts the large amount of smoke produced by fire and prevents the smoke diffusing out of the protected zone to ensure the smooth evacuation and sheltering of people in the building and create favorable conditions for firefighters to put out the fire.
- Safety evacuation system: The system disconnects the non-firefighting power supplies in the case of fire and maintains proper lighting in the evacuation route and other necessary places to facilitate personnel evacuation and accident handling.

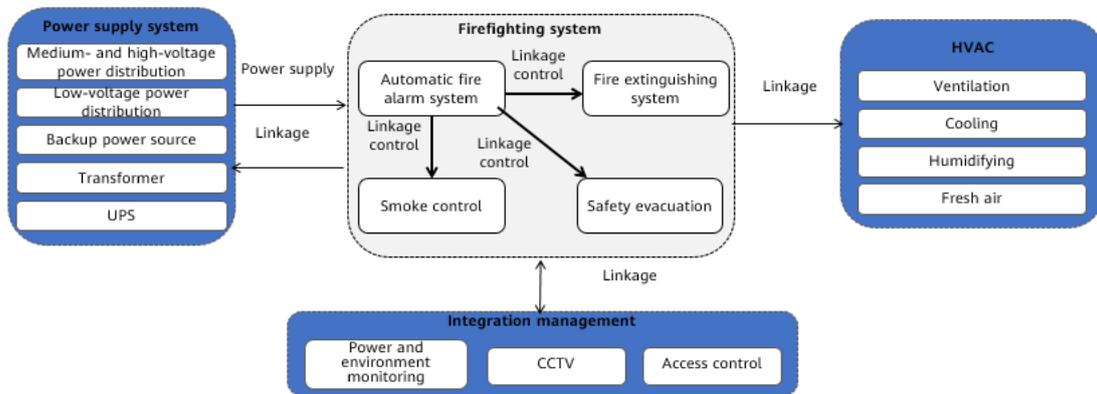


Figure 11-1 Structure of the Fire Extinguishing System

11.2.3 Automatic Alarm System

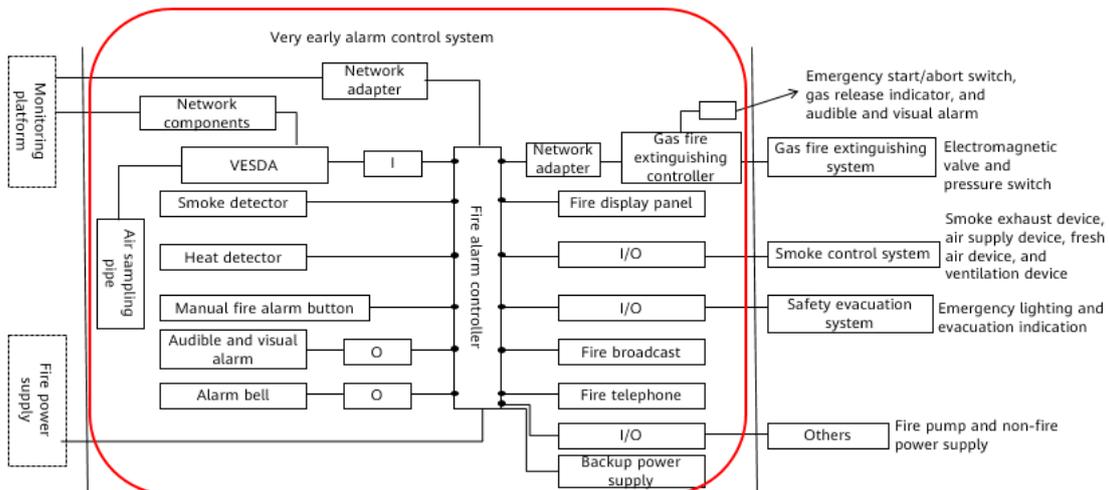


Figure 11-2 Structure of the Automatic Alarm System

The automatic alarm system consists of the VESDA, air sampling pipe, fire alarm controller, smoke detector, heat detector, manual fire alarm button, audible and visual alarm, alarm bell, fire display panel, power supply, control module, fire telephone, fire broadcast, and gas fire extinguishing controller.

VESDA

- VESDA is short for very early smoke detection apparatus.
- Work principle: Sampling pipes distributed in the protected areas collect air samples. A special device filters out the dust in the air samples and transfers the air samples to the laser detection compartment. The laser detection compartment detects smoke particles in the air caused by burning, determines whether a fire happens by using a program, and generates an alarm as required.

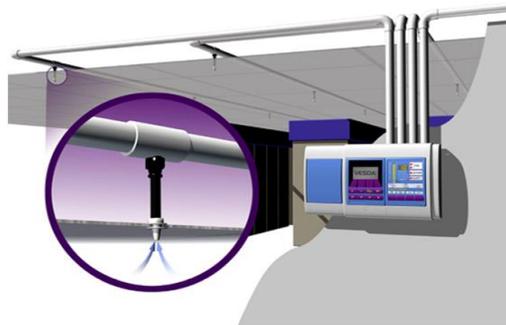


Figure 11-3 VESDA

Air Sampling Pipe

- The air sampling pipe collects air samples for the VESDA. Sampling holes are evenly distributed on the pipe.



Figure 11-4 Air Sampling Pipe

Smoke Detector

- The smoke detector is a fire detector that detects smoke particles caused by burning. Two types of smoke detectors are available: spot-type smoke detectors and line-type smoke detectors. The transmitter and receiver of a spot-type smoke detector are configured on the same device, and those of a line-type smoke detector are separated. Therefore, spot-type smoke detectors are preferred in small space (with a floor height of less than 9 m).



Figure 11-5 Smoke Detector

Heat Detector

- The heat detector detects the ambient temperature based on the temperature sensitivity of thermosensitive components. It is generally used with the smoke detector and especially applicable to places with significant temperature rise in a fire. Spot-type and line-type heat detectors are available.



Figure 11-6 Heat Detector

Manual Fire Alarm Button

- The manual fire alarm button is installed in a public place. When confirming that a fire happens, staff can push down the organic glass sheet on the button, to send a fire alarm signal to the fire alarm controller. After receiving the alarm signal, the fire alarm controller displays the ID or location of the alarm button and generates an audible alarm. Such an alarm is more emergent than a detector alarm and generally requires confirmation.



Figure 11-7 Manual Fire Alarm Button

Audible and Visual Alarm

- The audible and visual alarm is installed onsite and is enabled by the fire alarm controller. After being enabled, the alarm generates strong audible and visual alarms to remind onsite personnel.



Figure 11-8 Audible and Visual Alarm

Alarm Bell

- Similar to the audible and visual alarm, the alarm bell generates fire alarms that are differentiated from the ambient sound and light, to remind onsite personnel to perform safety evacuation and fire extinguishing.



Figure 11-9 Alarm Bell

Fire Display Panel

- The fire display panel is a fire alarm display device designed by using a single-chip microcomputer, and is installed on a building floor or in an independent fire protection area. Digit-based and text-based fire display panels are available. The fire display panel is connected to the fire alarm controller through a bus, and processes and displays the data received from the fire alarm controller.



Figure 11-10 Fire Display Panel

Control Module

- The fire control module, also called an I/O module, is an important component of the fire linkage control system, and is connected to external devices in the automatic fire alarm system, such as smoke valves, air supply valves, and fire valves.



Figure 11-11 Control Module

Fire Telephone

- The fire telephone is used for communication between the fire control center and the site. It enables multi-party calls and can be used to report alarms, check fire information, arrange for rescue, and exchange fault information. Generally, the fire telephone consists of a main phone set and extension telephones.



Figure 11-12 Fire Telephone

Fire Broadcast

- The fire broadcast is used by the fire control center to evacuate personnel. Generally, the fire broadcast consists of the emergency broadcast controller, power amplifier, and sound box.



Figure 11-13 Fire Broadcast

Gas Fire Extinguishing Controller

- The gas fire extinguishing controller automatically controls the start/stop of the gas fire extinguishing system. It can be connected to the emergency start/abort switch, manual and automatic transfer switches, gas release indicator, and audible and visual alarm. In addition, the gas fire extinguishing controller provides electromagnetic valve driving interfaces, to enable gas fire extinguishers.



Figure 11-14 Gas Fire Extinguishing Controller

Fire Alarm Controller

- The fire alarm controller is the core of the automatic fire alarm control system. It receives detection signals, processes alarm information, and provides a linkage alarm platform. Based on the structure, fire alarm controllers are classified into the wall-mounted, cabinet, and table types. A wall-mounted fire alarm controller contains a maximum of two loops and connects a small number of alarm points. A cabinet-type or table-type fire alarm controller contains more loops, has a large capacity, and provides bus and multiline linkage control, meeting the requirements of the complex fire alarm and linkage control system.



Figure 11-15 Fire Alarm Controller

11.2.4 Gas Fire Extinguishing System

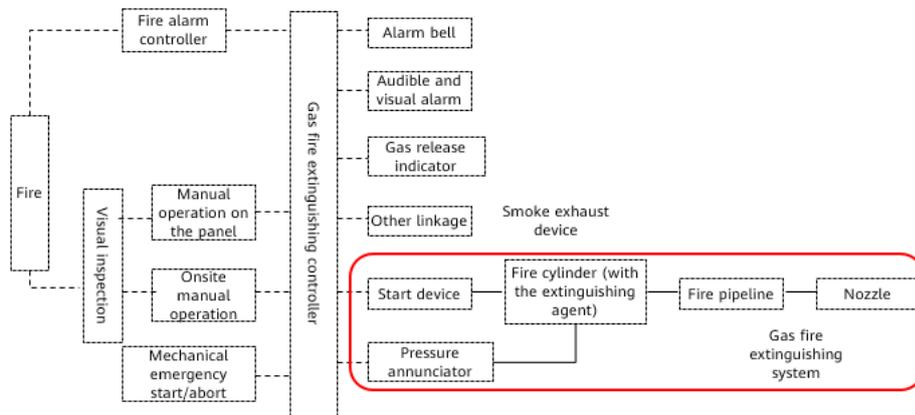


Figure 11-16 Structure of the Gas Fire Extinguishing System

The gas fire extinguishing subsystem consists of the fire cylinder (containing the extinguishing agent, extinguishing agent vessel, and vessel valve), start device (start vessel or electromagnetic valve), fire pipeline, nozzle, pressure annunciator, and other auxiliary devices. The auxiliary devices include the fire cylinder rack, high pressure hose, one-way valve for the extinguishing agent, manifold, start cylinder rack, start pipeline, one-way valve for air flows, selector valve, flange joint, and safety valve.

Heptafluoropropane Extinguishing Agent

- Heptafluoropropane is an environment-friendly extinguishing agent well recognized around the world. It causes no damage to the ozone layer and has the following advantages: superb fire extinguishing performance, no pollution, no conductivity, small storage space, low operating pressure of pipelines, and no slag after fire extinguishing.

The extinguishing agent is stored in a liquid state and released as gas. After discharge, the gas is naturally released or fast released based on a ventilation system. No slag is left onsite.

Fire Cylinder

- The fire cylinder consists of the extinguishing agent vessel and vessel valve. The extinguishing agent vessel is generally a red steel seamless container covered with epoxy painting, and can be recharged with the extinguishing agent. The extinguishing agent is stored in the vessel in a liquid state and is pressurized to the operating pressure by using nitrogen. When a fire happens, control air flows from the start cylinder trigger an action of the pneumatic valve. Therefore, the vessel valve is opened to release the extinguishing agent. When an emergency occurs, staff can remove the manual safety pin and press the manual button. The vessel valve is immediately opened.



Figure 11-17 Fire Cylinder

Start Device

- The start device stores startup gas (high-pressure nitrogen) and can be started electrically or manually. It releases startup gas to open the selector valve and vessel valve and provides the following functions: sealed storage, release, recharge, low-pressure discharge, and pressure display.



Figure 11-18 Start Device

Fire Pipeline

- The fire pipeline transports the extinguishing agent to the terminal nozzle. Generally, main pipelines and branch pipelines are available, with different diameters. The pipeline diameter is designed based on the extinguishing agent flow rate.

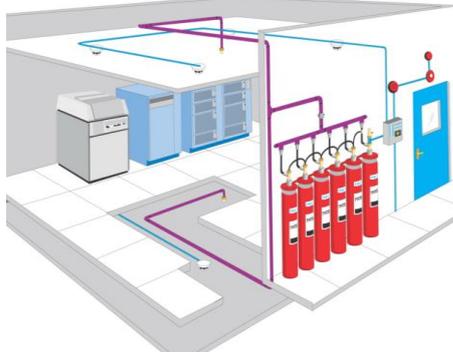


Figure 11-19 Fire Pipeline

Nozzle

- The nozzle ejects the extinguishing agent in a specific jet form. Therefore, the extinguishing agent is quickly vaporized and reaches the extinguishing concentration in the protected space. Generally, seam-type, pipe mouth-type, and atomizer nozzles are available.



Figure 11-20 Nozzle

11.2.5 Smoke Control System

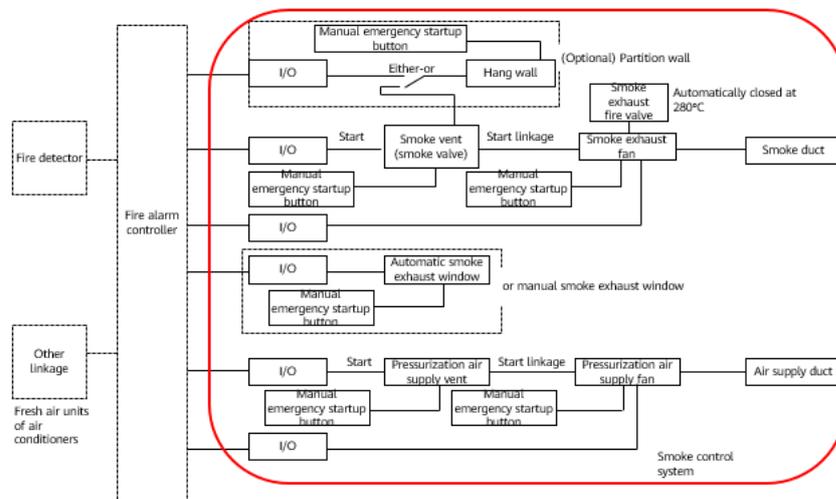


Figure 11-21 Structure of the Smoke Control System

The smoke control subsystem consists of the pressurization air supply fan, pressurization air supply vent, air supply duct, smoke exhaust fan, smoke vent (smoke valve), smoke exhaust fire valve, smoke duct, and auxiliary materials. The auxiliary materials include the hang wall (optional), automatic smoke exhaust window (optional), manual emergency startup button, pipe hangers and supports, power cables, signal cables, and control modules (I/O modules and input modules).

Pressurization Air Supply Fan

- The pressurization air supply fan mechanically supplies air to staircases, elevator lobbies, and other protected areas, to generate positive pressure in the areas and prevent smoke from entering the areas. This ensures personal safety during evacuation. The pressurization air supply fan is generally selected based on parameters such as the air capacity, atmospheric pressure, power, and noise.



Figure 11-22 Pressurization Air Supply Fan

Pressurization Air Supply Vent

- The pressurization air supply vent is also called a positive-pressure air supply vent or a multi-leaf air supply vent. An aluminum alloy air vent is installed in the front of the valve body. The valve body is generally installed on the side wall of an elevator lobby or a staircase. A handling cell is set near the valve body and is configured with a movable door to facilitate operations.



Figure 11-23 Pressurization Air Supply Vent

Air Duct

- The air duct supplies air or exhausts smoke. The cut-off surface of the air duct is a rectangle or circle. Common air duct materials include thin steel plates, plastic, plywood, fiberboards, concrete, concrete and reinforcing steel, bricks, asbestos cement, and slag gypsum boards.



Figure 11-24 Air Duct

Smoke Exhaust Fan

- The smoke exhaust fan exhausts smoke out of a building, to remove smoke, improve the visibility in the building, and facilitate fire extinguishing. The smoke exhaust fan is generally selected based on parameters such as the air capacity, atmospheric pressure, power, and noise.



Figure 11-25 Smoke Exhaust Fan

Smoke Vent

- The smoke vent, also called a smoke valve, is installed on a pipeline of the smoke exhaust system. It is normally closed during proper operating and is opened upon a fire to exhaust smoke.



Figure 11-26 Smoke Vent

11.2.6 Safety Evacuation System

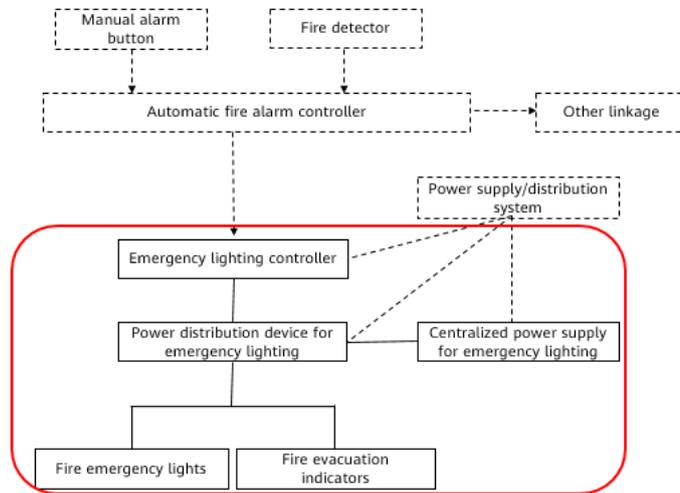


Figure 11-27 Structure of the Safety Evacuation System

The safety evacuation design applies inside data centers and contains two parts: emergency lighting and safety evacuation.

The safety evacuation system consists of the fire emergency lights, fire evacuation indicators, emergency lighting controller, power distribution device for emergency lighting (power distribution box for emergency lighting), and centralized power supply for emergency lighting.

Fire Emergency Light

- The fire emergency lights provide lighting for personnel evacuation and fire extinguishing. Key parameters include the input voltage, luminous flux, light source type, and power.



Figure 11-28 Fire Emergency Light

Fire Evacuation Indicators

- The fire evacuation indicators provide the following functions by using signs or text:
 - Indicate the exit, current floor, and shelter floor (room);
 - Indicate the evacuation direction;

- Indicate the locations and directions to the fire extinguishers, fire hydrant boxes, fire lifts, and stairs for the disabled;
- Indicate the blocked passages and places and the storage locations of hazardous materials.



Figure 11-29 Fire Evacuation Indicators

Emergency Lighting Controller

- The emergency lighting controller controls and displays the operating status of the following components: fire emergency lights, centralized power supply for emergency lighting, power distribution device for emergency lighting (power distribution box for emergency lighting), and other accessories.



Figure 11-30 Emergency Lighting Controller

Power Distribution Device for Emergency Lighting

- The power distribution device distributes power for the emergency lighting and evacuation indication system. Key parameters include the input voltage, output voltage, capacity, and operating time upon power failure.



Figure 11-31 Power Distribution Device for Emergency Lighting

Centralized Power Supply for Emergency Lighting

- When a fire happens, the centralized power supply provides power for the fire emergency lights based on batteries. Key parameters include the power capacity, output voltage, and backup time.



Figure 11-32 Centralized Power Supply for Emergency Lighting

11.3 Fresh Air System

11.3.1 Fresh Air System Overview

A fresh air system refers to delivering the filtered outdoor fresh air indoors and exhausting the indoor stale air outdoors, achieving system balance while exchanging the air. This system makes scientific convection in a closed environment possible.

Functions:

- Maintain the positive pressure difference between the data center and the outside and avoid the entry of dust, ensuring better cleanliness; provide the data center with adequate fresh air, creating a favorable working condition for the personnel; treat the outdoor contaminated air, ensuring the safety of devices inside.

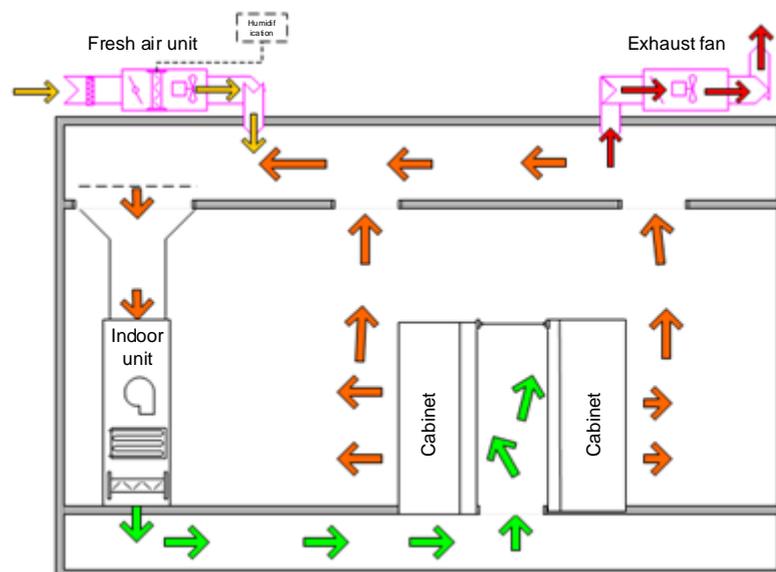


Figure 11-33 Fresh Air System

The fresh air system consists of the fresh air unit (fan, filter, humidifier, pre-cooling and heat reclamation devices), air exhaust pipes, and air exhaust vents. Out of these, the exhaust fan and filter are mandatory for the fresh air unit. The humidifier, pre-cooling and heat reclamation devices, and chemical filter are optional modules.

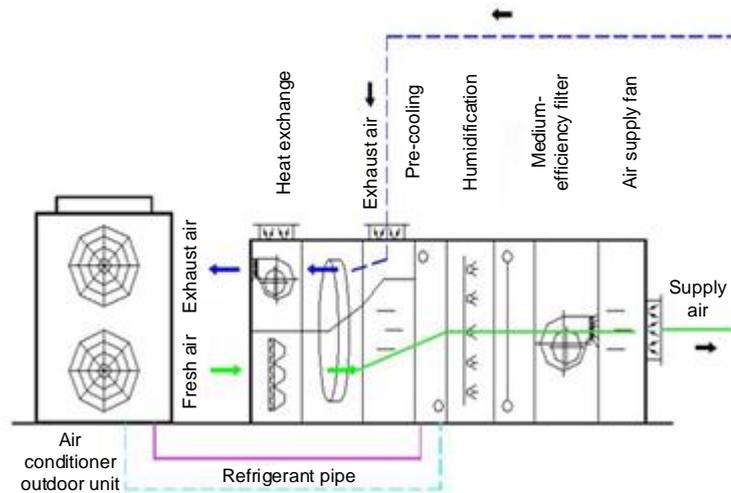


Figure 11-34 Composition of the Fresh Air System

11.3.2 Functions of the Components

Fan

- Fans include the air supply fan and exhaust fan. They are the mandatory items for the fresh air system. They can be variable-frequency and constant-frequency. In general, you are advised to configure a differential pressure controller and select the variable-frequency ones.



Figure 11-35 Fan

Filter

- Filters include the coarse-efficiency filter and medium-efficiency filter. The former is a plate filter and the latter is a bag filter. In general, the coarse-efficiency filter is G3 or G4, and the medium-efficiency filter is F5 to F8 in filtering level. The configuration principle of these two types of filters is that the difference should not be greater than four levels. The higher the filtering level, the higher the filtering efficiency, and the higher the cost. Figures on the right show a coarse-efficiency filter and a medium-efficiency filter respectively.

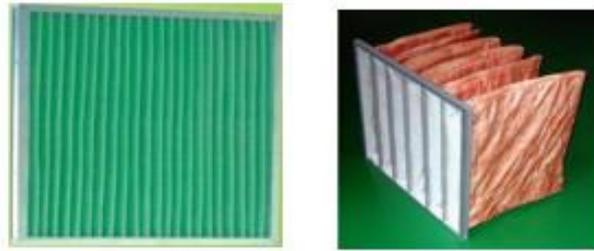


Figure 11-36 Filter

Pre-cooling/Dehumidification device

- When the fresh air is not delivered to the air return vent of the indoor air conditioner (the indoor air conditioner bears the fresh air loads), you need to configure a pre-cooling section to meet the air supply requirements.
- When the humidity control uses the independent fresh air control, and the outdoor humidity is higher than the indoor control target, you need to configure a dehumidification section (the cooling dehumidification is generally adopted).

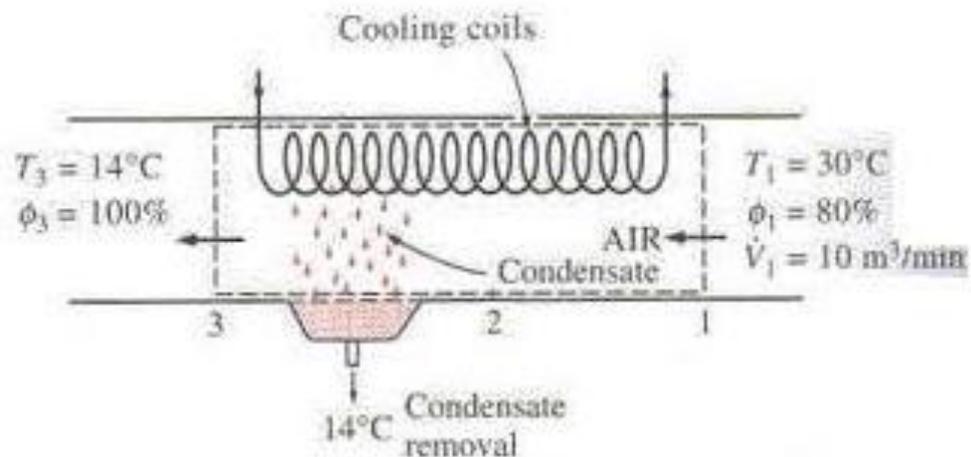


Figure 11-37 Pre-cooling/Dehumidification device

Humidifier

- When the humidity control uses the independent fresh air control, and the outdoor humidity is lower than the indoor control target, you need to configure a humidification section.

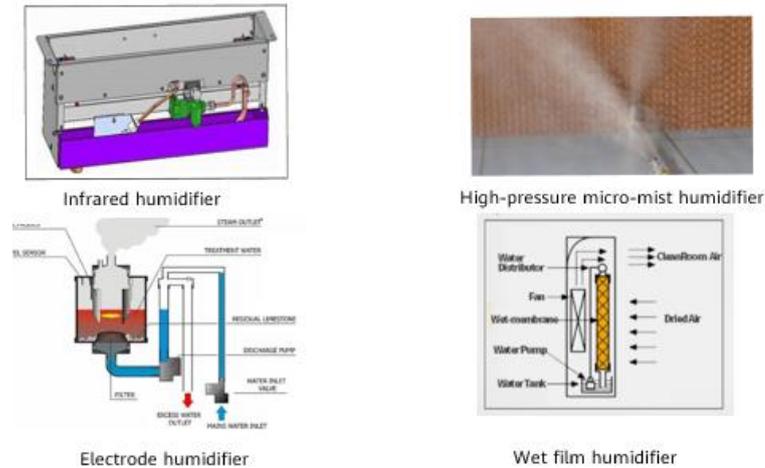


Figure 11-38 Humidifier

Heat reclamation device

- To save energy, you can configure a heat reclamation section, using exhaust air to preheat or pre-cool the fresh air. There are two working modes, namely plate type and rotary-wheel type. The figure on the right shows the rotary-wheel heat reclamation.

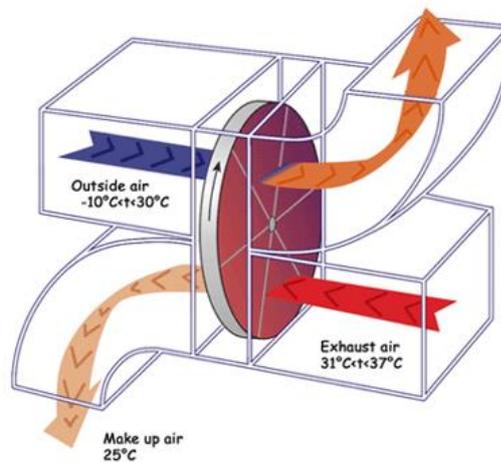


Figure 11-39 Heat reclamation device

Heater

- You need to configure the heating section only when the fresh air unit adopts the constant-temperature and constant-humidity air supply solution.
- After the cooling and dehumidification, heat the fresh air unit to dry bulb working conditions at the air supply vent. This solution is not energy-saving and therefore is not recommended.

11.4 Cabinet System

11.4.1 Cabinet Overview

Standard cabinets are widely used in stacking the integrated cabling and cable distribution equipment, computer network equipment, communications equipment, and electronic equipment. Cabinets are classified into server cabinets, network cabinets, and console cabinets.

Cabinets provide the enhanced electromagnetic shielding, reduce the equipment operating noise, and lower the footprint. Some high-end cabinets have the air filtering function, which improves the operating environment for precision equipment.

Simple in structure, standard cabinets mainly include the basic framework, internal supporting system, cabling system, and ventilation system.

General specifications of cabinets are 600 mm or 800 mm in length, 600 mm, 800 mm, or 1000 mm in width, and 24 U, 36 U, 42 U, or 47 U in height.

- The installation heights of devices in a 19-inch standard cabinet are represented by a special unit, U, which is 44.45 mm.



Figure 11-40 Cabinet

11.4.2 How to Select a Cabinet?

Load-bearing performance: The cabinet must be solid enough to bear the increasingly small-sized, network-based, rack-mounted, and large-capacity heavy IT devices.

Temperature control: The cabinet must have sufficient heat dissipation capabilities.

Cable management: The cabinet must provide sufficient cable channel and support top and bottom cable routing. The cables must be laid out conveniently and orderly. The cabinet

must be close to the cable ports to shorten the cable routing distance and reduce the space occupied by the cables.

Power distribution management: The cabinet must support the vertical installation of a dedicated PDU with two inputs without affecting installation, use, or maintenance of devices. The PDU is often equipped with SPDs.

Protection performance: The cabinet door stile and frame must be reliably grounded. Inside the cabinet there are ground points. The working ground bar and protection ground bar can be connected to the grounding copper bar of the data center. The cabinet is equipped with various monitoring devices for monitoring the temperature, humidity, voltage, current, and smoke.

11.5 Lightning Protection and Grounding System

11.5.1 Lightning Overview

Lightning phenomenon: Lightning is a result of mutual high-speed movements and fierce friction between clouds in the sky, causing the high-end clouds and low-end clouds to be with opposite charge. In the meantime, the low-end clouds also induce a large amount of hetero-charges on the ground to form a tremendous capacitance. When the capacitive field reaches a certain threshold, the ground discharge is generated.

Lightning hazards

- The thermal effects of the lightning current can blow the conducting wires and burn out the electrical equipment.
- The electrodynamic force generated by the mechanical effects of the lightning current can smash the equipment, towers, and buildings, as well as cause injuries to people and livestock.
- The electromagnetic effects of the lightning current can generate overvoltage, break down insulated electrical equipment, and even cause fire and explosion, which may hurt and kill people.

Direct lightning strike: The lightning strikes the electrical devices, cable routes, buildings, and other objects.

Induction lightning strike: Overvoltage is caused by electrostatic induction or electromagnetic induction from the lightning to the cable routes, devices, or other objects.

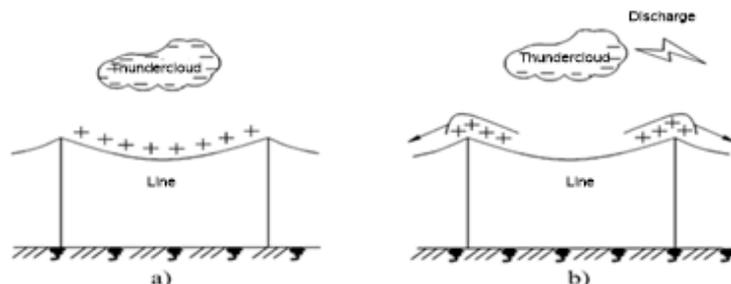


Figure 11-41 Induced overvoltage on the overhead cable routes

11.5.2 Lightning Arrester

The lightning arrester consists of three parts: air-terminal system, downlead, and grounding device.

- Air-terminal system (lightning receiver): It is a metal conductor that receives the lightning current, and normally uses the lightning rod, lightning conductor, or lightning net (belt).
- Downlead: Ensure that the lightning current does not melt the downlead. Generally, the downlead is made of steel tube whose diameter is at least 10 mm or flat steel whose cross-sectional area is at least 80 mm².
- Grounding device: It is a general term for ground conductors and earthing electrodes buried under ground.

11.5.3 Grounding Overview

Grounding refers to connecting certain parts of the electrical equipment or certain points of the power system to the ground to provide a pathway for discharging the faulty current or lightning current, stabilize potential, and provide the zero potential reference point. It ensures the safe operation of the power system and electrical equipment, as well as personal safety.

The grounding function is implemented by the grounding device or grounding system.

11.6 Integrated Cabling System

11.6.1 Integrated Cabling System Overview

An integrated cabling system is the information transmission channel inside a building or between buildings. It connects voice equipment, data equipment, message exchange equipment, and building automation management equipment in a building to provide a unified physical transmission medium for the building. At the same time, it connects information communications equipment in the building to an external communications network.

Features:

- It is a modular and highly flexible information transmission system inside a building or between buildings.
- Its equipment is independent of lines and features flexibility, openness, compatibility, reliability, economy, and advancement.
- It adopts unified design and planning for voice and data signals. Unified transmission lines and information connectors are used to transmit different signals in a standard cabling system.

11.6.2 Composition of the Integrated Cabling System

The Integrated Cabling System is composed of six subsystems: work area subsystem, horizontal subsystem, backbone subsystem, management subsystem, equipment room subsystem, and campus subsystem.

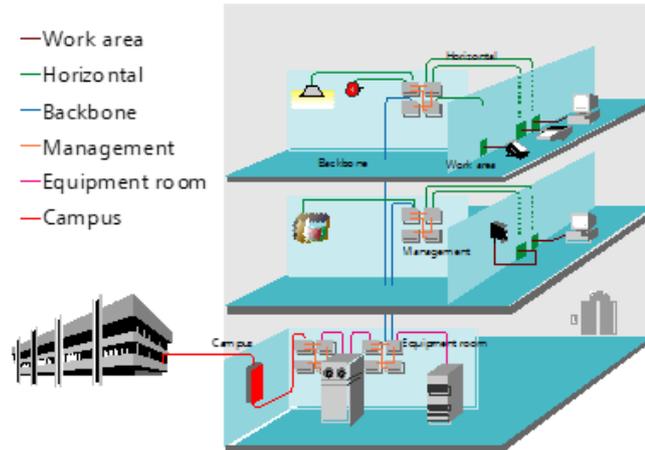


Figure 11-42 Composition of the Integrated Cabling System

11.6.3 Integrated Cabling in Data Centers

The determination of cabling mode is an important step of the data center planning. Ignoring the cabling mode reflects the blindness and confusion of the data center planning.

Cabling modes are classified into overhead cabling and underfloor cabling:

- Overhead cabling: cables laid out in spaces higher than the device height;
- Underfloor cabling: cables routed under the raised floor;
- Cabling on the top of cabinets: troughs for data cables and power cables installed on the top of each cabinet to route cables to each cabinet.



Figure 11-43 Integrated Cabling in Data Centers

Compared with the underfloor cabling, the overhead cabling is a little complicated. This layout generally applies to standard rack-mounted scenarios. Consistent dimensions, especially consistent height, make an appealing appearance. In addition, the overhead cabling usually uses the cable trough or cable tray to support the cables. Cable troughs and cable trays can be further classified into different materials and installation modes. These are the factors that need to be considered in design and planning.

11.7 Indoor Decoration System

11.7.1 Composition of Indoor Decoration System

Acceptance items of the indoor decoration engineering include the decoration of suspended ceilings, partition walls, doors, windows, walls, the acceptance of floors and raised floors, and other indoor operations. All indoor decoration operations and construction should comply with corresponding specifications and standards.

- Electrostatic discharge (ESD) raised floor decoration: As the floor is removable, cable connections, pipe connections, and maintenance are convenient. The ideal height of a raised floor ranges from 18 to 24 inches (46 to 61 cm). The floor of a building should meet design requirements and be clean and dry. When the raised floor space is used as a plenum, the walls and floor should be dust-proof and should not be peeled or cracked. Take protective measures for raised floors when moving or installing equipment on them. After laying out ESD floors, ground them properly.



Figure 11-44 ESD floor

- Ceiling decoration: The area above the suspended ceiling is used as the plenum space for air supply or return in a data center, where ventilating ducts can be deployed. The surface of the suspended ceiling in a computer room should be flat and free from dust, discoloration, and corrosion. Edges should be neat without warping. After edges are sealed, the adhesive should not be peeled off. Thermal insulation and sound insulation materials used for filling the ceiling should be flat and dry, and seams should be wrapped.
- Partition decoration: mainly includes partition walls and wall decoration. It requires sound insulation, thermal insulation, and fire prevention.



Figure 11-45 Suspended ceiling and partition

- Shielding system: It is mainly used for anti-interference and information confidentiality. It not only prevents indoor information from leaking or being detected through electromagnetic waves, but also prevents external electromagnetic interference. Common use cases of shielding systems include rooms shielded with metal mesh or plate and shielded cabinets.
 - Waveguide window: prevents electromagnetic waves from passing through but allows air to flow through.
 - Power filter: Each power cable entering shielded rooms must be configured with a power filter.



Figure 11-46 Shielded room

11.8 Quiz

- 1、(Short Answer Question) Which kind of fire extinguishing system is applied to data centers?
- 2、(Short Answer Question) Why is overhead cabling more popular?

11.9 Summary

- Fire Protection System
- Fresh Air System
- Cabinet System
- Lightning Protection and Grounding System
- Integrated Cabling System
- Indoor Decoration System