HUAWEI

Next-Generation Data Center Facility

White Paper

Foreword

The world is undergoing a rapid digital transformation. Innovative services, such as smartphones, smart homes, smart manufacturing, and autonomous driving, are reshaping our work and life. At the same time, with climate change accelerating and a global consensus on carbon neutrality, the pursuit of green and sustainable development has become a common goal.

Data centers are fundamental for the digital economy. However, data centers are currently attracting much attention from all segments of society due to their high energy consumption and carbon emissions. With surging demand for data center construction, information technology evolution and low-carbon requirements, the data center industry is undergoing profound changes, and its development will enter a new era.

What is a "next-generation data center facility" that meets the requirements of the new era? Huawei has worked with global data center industry leaders and technology experts to conduct an extensive discussion on industry and technology trends, and reached many important consensuses, including the definition of next-generation data centers.

The future is here. It is believed that the next-generation data center facility, defined by the industry's wisdom, will play an important role in the high-quality and sustainable development of the industry.

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Intelligent and Low-carbon Technologies Drive the Rapid and Sustainable Development of Data Centers

Digitalization and low-carbonization are two unstoppable trends in the world. Data centers are the foundation of the digital world. By integrating digital and power electronics technologies, building smart and low-carbon data centers will become the mainstream trend.

1.1 Digital Economy Drives Fast Growth of Data Centers

Currently, digital technologies such as AI, cloud computing, big data, IoT, and 5G are evolving at a fast pace, fueling global GDP growth. According CAICT (China Academy of Information and Communications Technology), the digital economy accounted for 43.7% of global GDP in 2020 and has expanded with astonishing speed.

Major economies like China, the EU, and the USA have released digital economy visions.

China has set the digital economy as the main developing direction in the 14th Five-Year Plan (2021–2025) for National Economic and Social Development.

The European Union has set out digital ambitions for the next decade in *2030 Digital Compass: the European way for the Digital Decade*, which states that by 2030, 75% of European enterprises will use cloud computing, big data and AI; more than 90% of European SMEs (small and medium-sized enterprises) will reach at least a basic level of digital intensity, and Europe will increase investment in renewable energy and digital infrastructure.

In the USA, National Science Board recommended increased investments in data, software, computing, and network to maintain competitiveness in the digital economy in *Vision 2030*.

Nowadays, digital technologies have been evolving and reshaping the way we live and work. In the post-pandemic era, the digital economy has unleashed a powerful force to reshape the global economic structure, and reconstruct the global competitive landscape, data center construction is expected to develop rapidly.

Data has become a key factor of production now, and the data volume keeps increasing dramatically. According to Huawei's *Intelligent World 2030*, computing power will increase ten times, and AI computing power will increase 500 times. The skyrocketing demand for computing power will unlock the significant potential of the data center market. According to report of Synergy Research Group, which was released in March 2022, the number of global ultra-large data centers will be more than 1,000 in the coming three years.

1.2 Carbon Neutrality Raises New Requirements for Data Center Sustainability

With global warming problems, carbon neutrality has become a common mission. Until now, more than 130 countries have declared their commitment to carbon neutrality. Energy conservation and carbon emissions reduction have become key trends across all sectors.

In recent years, the Data Center industry is booming, its market space has been growing rapidly, and power consumption has increased dramatically. According to "*Uptime Global Data Center Report 2021*", from 2014, the PUE of large data centers around the world has remained around 1.6 for seven consecutive years. The resource utilization of data centers is low and needs to be upgraded urgently. To advance the sustainable development of the Data Center industry, a number of countries and international organizations have released Data Center-related policies. For example, the U.S. government adopts the DCOI (*Data Center Optimization Initiative*), which requires that the PUE of new-built data centers be lower than 1.4 and that of upgraded old data centers be lower than 1.5. In "*The Climate Neutral Data Centre Pact*", European data center operators and industry associations have announced that data centers will be carbon neutral by 2030.

China has released "*Guidance on Accelerating the Construction of Collaborative Innovation System of National Integrated Big Data Center*" to promote the construction of a national integrated big data center. And the "*Eastern Data and Western Computing*" project has been launched to channel more computing resources from the eastern areas to the less developed western regions, which promotes the green and sustainable development of data centers, and accelerates the R&D and application of energy-saving and low-carbon technologies. It is required that the PUE of newly-built large data centers be lower than 1.3 by 2025.

Low carbonization of Data Centers will become an inevitable trend. Large-scale application of clean energy, development of carbon-reduction technologies including PV and energy storage, and waste heat recovery, will effectively advance data centers to achieve sustainable development.

The Next-Generation Data Center Facility

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In the face of the booming development of data centers, green and low-carbon requirements, Huawei and global data center industry leaders and technical experts have conducted in-depth and extensive discussions and reached many important consensuses, summarizing the four characteristics as Sustainable, Simplified, Autonomous Driving, and Reliable.

1. Sustainable: Innovative measures are undertaken to build green and highly energy efficient data centers benefiting the society.
2. Simplified: In response to the increasing scale and complexity of data centers, the architecture and key subsystems are minimalist through hardware convergence.
3. Autonomous driving: Responding to the operation and Maintenance challenges of massive data centers and enabling facility autonomous driving with the help of digital and AI technologies.
4. Reliable: Reliable operation is the cornerstone of a data center. Through modular redundant architecture and AI active prevention, we can guarantee the safety and reliability of data centers at all levels from components, equipment and systems.

2.1 Sustainable

Looking back on the development of global modernization, we went through three industrial revolutions from "Steam Age", "Electronic Age" to "Information Age". These three industrial revolutions mainly relied on fossil energy. With the rapid economic growth, carbon dioxide emissions increased exponentially, which caused global climate change and brought great challenges to the survival and development of human society.

The next-generation data center facility will be an all-green, all-efficient, and all-recycled data center.

All-green: Utilizing Green Source, In Harmony with Nature

Green growth has become a global consensus. It is a sustainable development model based on green, low-carbon and recycling technology, which means that while maintaining sustained economic growth, it can reduce the damage to the environment.

Based on the concept of green growth, the next-generation data center construction must utilize green sources.

Electricity:
Renewable energy should be used on a large scale for data centers. The development and utilization of local PV, wind power and hydropower should be given a high priority in order to reduce fossil energy dependence. In addition, distributed PV can be deployed in the data center campus to fully utilize the rooftop and land resources of the campus. Distributed PV can reduce the carbon emissions of the data center by 1% to 2%.

Water:
The consumption of water resources requires minimal use of clean water, maximum use of reclaimed water, or even without using water. Water resources are increasingly scarce in many areas of the world, and data centers need to conserve precious water resources. For example, all data centers in Ulanqab city of China are banned from using any groundwater for cooling system.

Land:
The data center scale is increasing and the construction will use land resources intensively. Improving land use to generate more computing power from each meter square of land.

Climate:
The data center should use natural resources, such as outside cold air and cold water. We can build a data center in the appropriate area or use technical measures, such as increasing the supply and return temperature to use more outside cold air.

Achieve harmonious coexistence between data centers and nature by utilizing the green resources.

All-efficient: PUE → xUE, One Dimension to Multi-dimensional System

The Green Grid proposed PUE as an indicator to measure the power efficiency of data centers in 2007, it has been widely accepted and used in the industry. However, PUE-only cannot fully reflect the resource utilization of data centers. For example, even with the same PUE, the carbon emissions from thermal power and green power are completely different, and the water resources consumed by chilled water systems and indirect evaporative cooling systems are also different. With a certain grid capacity, the number of IT cabinets that can be deployed varies according to the solutions.

Therefore, the evaluation system of whether resources are used efficiently should be changed from PUE-only to xUE, that is, the multi-dimensional system including CUE, PUE, WUE, GUE, etc.

Carbon Usage Effectiveness (CUE) is a quantifiable indicator for the carbon emissions of data centers. Different energy sources generate different carbon emissions. For example, coal emits 1023 grams of carbon dioxide per kWh, and photovoltaic emits only 30 grams per kWh. Therefore, CUEs of different sources of electricity in data centers vary greatly.

Water Usage Effectiveness (WUE) measures the water consumption of IT devices in a data center during cooling. It can be used to restrict solutions and products that consume a large amount of water.

Grid Usage Effectiveness (GUE) indicates the maximum number of IT devices that can be deployed with a certain mains capacity. This indicator helps the industry to optimize products and deploy more IT equipment.

Different regions and industries pay different importance to the corresponding indicators. Therefore, each indicator can be measured based on the characteristics of regions and industries, and finally the optimal evaluation scheme can be selected based on comprehensive consideration.

All-recyclable: Maximizing Resource Recovery Throughout the Life Cycle

A data center is a large energy-consuming and heat-generating entity. The energy consumed by the data center is converted into heat and discharged into the air, which is not effectively utilized or recycled. In addition, a hot spot is formed around the data center, affecting the cooling and thus the PUE. Waste heat recovery is an important technology in the low-carbon era and it is one of the important features of next-generation data centers as well.

The European Data Center Carbon Neutralization Convention (CNDCP) has clearly stated that heat recovery is one of the five key measures to achieve carbon neutrality in 2030. The European Sustainable Infrastructure Alliance (SDIA) has put heat recovery on the roadmap, and the proportion of heat recovery in data centers should be greater than 60%. Through heat recovery, the recovered heat can be used for:

(1) The self-use of the data center, for domestic hot water in office areas and heating the diesel generator room.
(2) Ancillary industries around the data center, such as aquaculture or heating of a commercial complex.
(3) Incorporated into the municipal heating network.

In addition to the waste heat recovery of the data center, the recyclability of the data center equipment and the materials of the facilities should be also considered. In the future, more and more regions will promote new prefabricated green buildings, green building materials, and the recyclability rate will exceed 80%. Use lead-free and halogen-free green recyclable materials to replace traditional harmful substances, such as lead in components, boards, and auxiliary materials to achieve a higher recovery rate, and promote a low-carbon circular economy for data centers.

2.2 Simplified

To cope with problems such as slow construction and difficult O&M of traditional data centers, the continuous pursuit of "Simplicity" drives the convergence of components, devices, systems, and data center architectures.

Simplified Architecture Brings Innovative Forms of Buildings and Equipment Rooms

"*Code for Design of Data Centers*" GB50174-2017 defines a data center as a "building that provides a running environment for centralized electronic information devices. It can be one or several buildings or part of a building, including the main equipment room, auxiliary area, support area, and administration area." Data centers are considered to be complex engineering buildings. Traditionally, civil engineering, power supply, and cooling projects are constructed in sequence. The construction process is lengthy. In the actual construction process, the construction period faces multiple uncertainties due to weather and design changes. In addition, different vendors are responsible for the implementation of different procedures. As a result, on-site construction units and construction personnel are complex, which increases on-site management difficulty and makes it difficult to ensure the construction period and final quality.

In the future, with the increasing scale of data centers, no matter the building form or equipment room form, convergence and simplification can meet fast service rollout requirements and meet the industry development trend.

Building prefabrication: The data center is divided into parts, changing the building form and construction mode. The traditional "reinforced concrete + onsite construction" is transformed into "fabricated steel structure building + factory prefabrication". The engineering is product-oriented, enabling data center construction mode from serial to parallel, fast delivery, and on-demand deployment that meets fast service rollout requirements in the cloud data center era.

For the traditional building construction, the whole process includes the construction of foundation engineering, main engineering, decoration, power supply and distribution, heating ventilation & air conditioning (HVAC), fire extinguishing, and monitoring system plus installation and commissioning. The prefabricated modular construction can realize all-round parallel construction, which is embodied in two levels. The first is the parallel construction of foundation engineering and factory functional module manufacturing, pre-integration and pre-commissioning. At the second level, standard modules are used, and multiple modules can be produced simultaneously in the factory. The efficiency is greatly improved through mass production processes. Modules are pre-integrated and pre-commissioned in the factory, which greatly improves the quality and supports quick onsite deployment and joint commissioning delivery.

In China, the prefabricated modular construction mode is used to construct a 1000-cabinet data center. The construction period can be reduced from more than 18 months to 6 to 9 months, shortening the construction period by more than 50%. This difference is more obvious in the Middle East. Due to climate conditions, May to October is the hottest time. Outdoor construction is not allowed from 13:00 to 17:00 every day. The construction time of a large data center is longer than that of other regions. In the Middle East, the construction period of prefabricated modular data centers is shortened by 60% from 30 months to 12 months compared with the traditional construction mode.

The Wuhan AI computing center uses the prefabricated modular data center solution. The main project was completed in four months, and the project was completed in five months. The rollout time was shortened by more than 50%.

DC Modularization: The data center equipment room adopts a modular architecture to reshape the equipment room. In traditional equipment room construction, modules such as cabinets, air conditioners, UPS, power distribution cabinets, batteries, fire extinguishing devices, and cables are purchased, installed, and perform acceptance testing separately, which brings great challenges to early construction, subsequent O&M, and energy efficiency management. The modular architecture integrates the cabinet, cooling, power supply, monitoring, and fire extinguishing subsystems into one module and isolates the hot and cold air. By changing the architecture of the equipment room, the delivery period is shortened, the O&M difficulty is reduced, and the energy efficiency is improved.

Simplified Power Supply: Redefined Components and Links

The trends of data centers are high-density and large-scale. The power supply system is the heart of data centers. To meet the increasing power density and large-scale requirement, the power supply system innovation of data centers in the future is to integrate and innovate on power supply links and enter the era of simplified power supply.

Component integration: In the past, the power supply system of large-scale data centers mostly incorporates the UPS parallel system and lead-acid battery solution. There are many complex devices, which face challenges such as complex onsite installation, commissioning and large footprint. Take a data center with 1500 cabinets and 8 kW/cabinet as an example, the area for power system (including transformers, UPSs, power distribution cabinets, and batteries) is about 1800 square meters, accounting for 15% to 20% of the total data center area.

As the power density of IT cabinets increases in the future, this proportion will continue to increase if the power supply system remains unchanged.

To meet the challenges of large footprint and complex on-site delivery and commissioning, the system space is reconstructed and optimized by all-in-one integration of originally distributed devices and innovative components without changing power supply links. For example, the switch miniaturization technology is used to reduce the number of switch cabinets without reducing the number of switches. On the other hand, the topology pooling and component optimization technologies are used to improve the power density of UPS modules, effectively reducing the footprint and simplifying onsite delivery.

Simplified link: In a carbon neutral environment, clean energy applications, Peak-valley electricity price differential, and virtual power plant (VPP) drive data center require PV and energy storage deployment. In the traditional solution, PV systems (inverters and PV modules) and energy storage systems (converter boxes and energy storage boxes) are deployed on power supply links. More devices increase the complexity of the power supply system, which leads to challenges such as longer links,

The China Transportation Telecommunication Center (CTTC) Cloud uses Huawei's Powerpod solution, which saves the power supply system space by more than 40% compared with the traditional solution, helping customers deploy 350 more IT cabinets and save more than 16,000 meters of power cables.

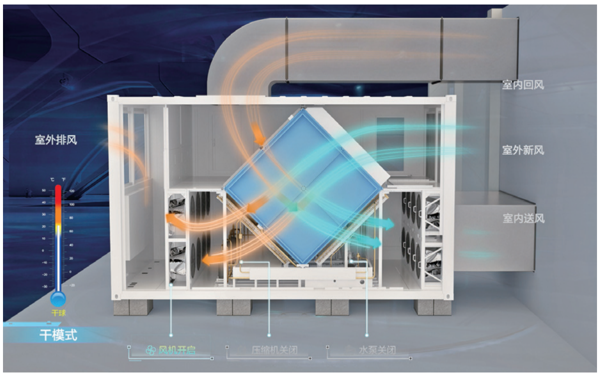
and more difficult maintenance etc. The next-generation data center integrates all power links innovatively to make them simple. For example, the PV inverter and energy storage converter are integrated with the uninterruptible power system to construct a new medium-voltage uninterruptible power system. A single system is used to connect the mains, PV, and energy storage at the same time, and integrates the mains rectifier inverter, PV inverter, and energy storage functions. The complexity of the power supply link is greatly reduced.

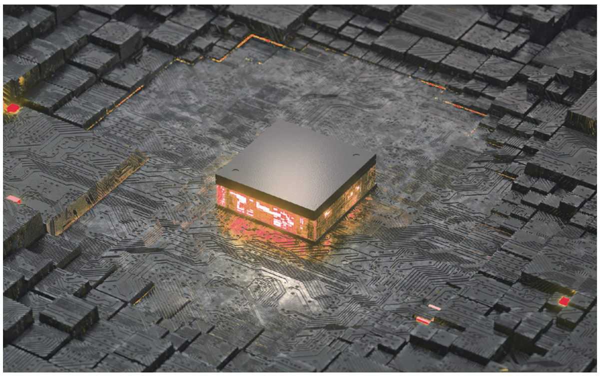
Simplified Cooling, Maximizes Heat Exchange Efficiency

To achieve low carbonization, energy saving and consumption reduction in data centers lies in the minimal integration of cooling system and the maximization of heat exchange efficiency.

Simplified cooling link: In the past, large data centers mainly used mechanical cooling system. Take chilled water as an example, which includes seven devices (chiller, cooling tower, cold storage tank, indoor unit, cooling water pump, plate heat changer, and management system), four times heat exchange take place in whole cooling system. The project delivery period lasts more than half a year which is hard to implement. The construction quality affects the cooling efficiency. In the future, the data center temperature control system integrates multiple components into one module, "One Module, One System", shortening the delivery period and reducing O&M difficulty. In addition, a free cooling mode is available in this system, changing multiple heat exchanges to one heat exchange, shortening the cooling link, and improving the cooling exchange efficiency.

Air-liquid convergence: As the power density of IT devices increases, especially in ultra-high power computing scenarios brought by AI and supercomputing, in another word, the servers and chips require more capability and high efficiency and comprehensive cooling mechanism. Close to heat source refrigeration has become one important trend in the development of cooling system. The cooling mode ranges from traditional room-level dispersion cooling, to closed cold/hot aisle containment module-level cooling, to cabinet-level and chip-level liquid cooling, and finally to direct removal of heat from the chip. In the future, in scenarios where the cabinet power density is more than 20 kW, liquid cooling is used as the primary and air cooling as the auxiliary. Converging air-liquid cooling mode will become mainstream.





2.3 Autonomous driving

As the scale of the single data center is developed from thousands of cabinets to ten thousands of cabinets, the number of devices and their operation status to be monitored are increasing exponentially, causing data center facility management to face great challenges.

1. **Relying on manual inspection mainly.** Generally, 15 to 30 professional O&M engineers are required for a 1000-cabinet data center to perform 6 to 12 on-site inspections every day. The O&M cost is high and the inspection quality is difficult to guarantee.

2. **Passive response.** A data center generates massive alarms every day, including common alarms, redundant alarms, and root alarms. One fault often triggers hundreds of alarms, and root alarms are drowned in them. As a result, fault identification becomes difficult. Traditional data center O&M relies on manual alarm priority identification, alarm root cause identification, and fault analysis, which leads to low O&M efficiency and may cause manual maloperation risks.

3. **High operation gap.** Firstly, the actual operation PUE is not as good as the design PUE, even though the design PUE is attractive. Secondly, the average resource utilization of data centers is usually lower than 65%, causing much resource waste.

To address the above challenges, data centers need more advanced management methods, like systematic, automated, and intelligent methods to improve management efficiency, to realize autonomous driving in the data center, includeing O&M automation, energy efficiency optimization, and operation autonomy.

O&M Automation, Unmanned Inspection

As the scale of the single data center becomes larger and larger, the O&M difficulty becomes bigger and bigger.

Take a data center with 1500 cabinets as an example. There are more than 100 types of devices and most of them are dumb, resulting in huge difficulty for manual inspection and much time cost for fault locating. In addition, O&M relies on labor mainly, leading to the growth of the proportion of labor cost. According to the report of *Uptime Institute global supply-side survey 2021*, the data center O&M labor cost increased from 4.5% in 2015 to 10% in 2020. On the other hand, the aging population of the world is accelerating and the labor force is decreasing, making it more difficult for enterprises to employ proper O&M engineers. According to the above report of Uptime Institute, 47% of data center enterprises have difficulty in finding qualified O&M engineers.

Traditional manual O&M cannot meet complex O&M requirements of data centers. Automatic O&M will become an important data center facility. To build a digital visualized foundation, and apply AI technologies to implement unmanned inspection through intelligent sensing, Sound recognition, and image recognition. In addition, by standardizing the O&M process, by sharing expert experience on the cloud platform and incorporating it into the process, to quickly improve the skills of O&M engineers.

In the past, it took two hours for one engineer to finish an on-site inspection for a data center of 2000 cabinets. In the future, by using automatic inspection methods, such as indicator collection, camera image analysis, and infrared sensing, engineers can complete the inspection of 2000 cabinets in 5 minutes remotely.

Automatic Energy Efficiency Optimization, Enables Smart Cooling

Except for IT devices, the power consumption of the cooling system in the DC is high. The traditional BA (building automatic) system faces a series of challenges, such as less than 10 collection parameters, less than 3 adjustable parameters, slow adjustment speed and poor precision, 2 hours for each optimization, and short adjustment duration. In addition, the traditional BA system relies on manual optimization and relies heavily on expert experience, which requires high skills. For increasingly complex cooling systems, manual adjustment based on expert experience cannot be performed in real time based on environmental parameters (such as temperature, humidity) and IT load. In addition, to ensure system reliability, cooling requirements are often magnified, resulting in energy waste.

In the future, data center energy efficiency optimization uses the AI dynamic modeling technology to build machine learning models between energy consumption and varying parameters such as IT load, climate, and device running parameters. In this way, the energy consumption of each subsystem can be diagnosed in real time while ensuring device and system reliability. It automatically and accurately infers and configures the optimal control logic of the data center, obtains the PUE model through DNN (deep neural network) training, and obtains the appropriate instruction. The optimal cooling policy is inferred from 1.4 million original combinations within 1 minute, delivers the cooling policy, and provides feedback on the effect, achieving optimal energy efficiency of the data center.

Take Huawei Cloud LangFang Data Center as an example. AI energy efficiency optimization is introduced. There are more than 700 collection points. After optimization, the annual average PUE decreases from 1.42 to 1.25, saving 33.36 million kWh and 3.83 million USD ($0.115/kWh).

Operation Autonomy: Maximizing Resource Value

Resource Optimization @AI

During data center operation, with service changes, a large number of devices need to be added, removed or changed which brings great challenges to the management of cabinet space resources in the data center. In the data center, some cabinets are not fully used or even idle, and some cabinets are overloaded. How to manage data center resources more efficiently and maximize their utilization is an issue that needs to be considered in the next generation DC.

The AI-based resource optimization technology manages data center resources throughout the lifecycle, establishes a management model and analysis platform centered on device management, and automatically counts data center resource status through AI simulation and AI service prediction, and accurately locates data center assets based on asset-management. Comprehensively analyze the available SPCN (space, power, cooling, and network), and intelligently recommend the optimal position for devices on the rack. In this way, data center resources can be visualized and managed, preventing capacity stranding. This feature maximizes the utilization of data center resources, improves resource usage, and improves operation revenue.

Energy scheduling @AI

With the increasingly diversified energy input and usage of future DCs, the AI-powered autonomous driving platform, enables flexible scheduling of various energy resources and implements on-demand in terms of green power, stacking, and energy storage, reducing manual computing and operations and maximizing resource value.

2.4 Reliable

The security and reliability of data center infrastructures are still facing great challenges.

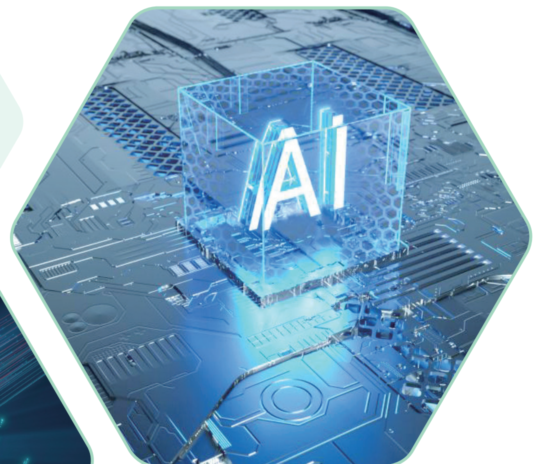
According to the *Uptime Institute global supply-side survey 2021*, failure in the power supply system and cooling system are still the main causes of data center operation interruption, accounting for 57% of them, of which 43% are from the power supply system and 14% are from the cooling system.

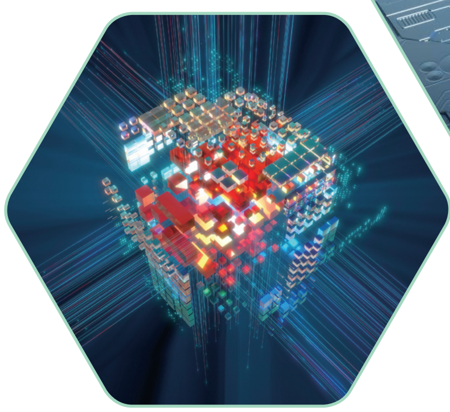
Once infrastructure security problems occur, the consequences and impact will be huge.

For example, in 2021, a fire broke out in the data center of a cloud service provider in Europe. As a result, 3.6 million websites were down and some data was permanently lost, causing huge losses.

The next-generation data center facility features, sustainable, simplified, and autonomous driving, all of which are based on the reliable of data centers.

How to further ensure reliable of the next-generation data center? It can be implemented from two aspects: proactive security and architecture security.





Proactive Security: Early Warning and Quick Fault Closure

Heinrich's rule states: "Any accident can be prevented. Behind every serious accident, there must be 29 minor accidents, 300 attempted foreshadows and 1000 potential accidents."

Based on real-time fault detection, visualized panoramic display, and AI-assisted locating, faults can be quickly detected, analyzed, troubleshot and services can be quickly recovered.

High-level safety and reliability should be prevention before failure happens.

Traditional data center maintenance usually relies on manual passive response, which makes it difficult to detect subtle risks and prevent faults in advance.

Proactive security means using big data and AI technologies to implement predictive maintenance from components to data centers, based on the visibility and perception of all domains in the data center.

For example, for key components and vulnerable components, such as capacitors and fans, big data collection and AI model training are used to predict their service life, calculate the failure time of the components in advance, and remind O&M personnel to replace the components. This can avoid failure and repair in advance.

On the other hand, the fault response mechanism changes from work order-driven manual response to automatic fault response.

Secure Architecture: Safeguards All Ranging from Components to Data Centers

In the future, ICT technologies will be more and more widely used in the data center facility field. They will be deeply integrated with power electronics technologies to ensure reliability at various levels, such as components, devices, and systems, to effectively enhance facility resilience and build a comprehensive security defense line. For example, at the component level, key components are hot-swappable through the modular design to quickly recover from faults. At the device layer, the full redundancy design enables seamless switchover to redundant modules within 0ms after a single point of failure (SPOF), ensuring device runs without any interruption. At the system level, the E2E (end to end) visualizable, manageable, and controllable platform enables the system availability to reach "Five Nines" (99.999%).

To sum up, the architecture-level optimization design reduces energy conversion layers and removes extra components. In addition to reducing fault points, hitless switchover and awareness-free switchover are also implemented, ensuring system always online and architecture security in all aspects and systems.

Summary

In the pursuit of the next generation data center facilities, technological innovation will be a key force in ensuring sustainable development. Looking towards the future, Huawei will keep making breakthroughs in products and technologies through continuous investment in R&D and with the all-round cooperation with customers, ecosystem partners, industry organizations, we can jointly usher in a new era of data center development.

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