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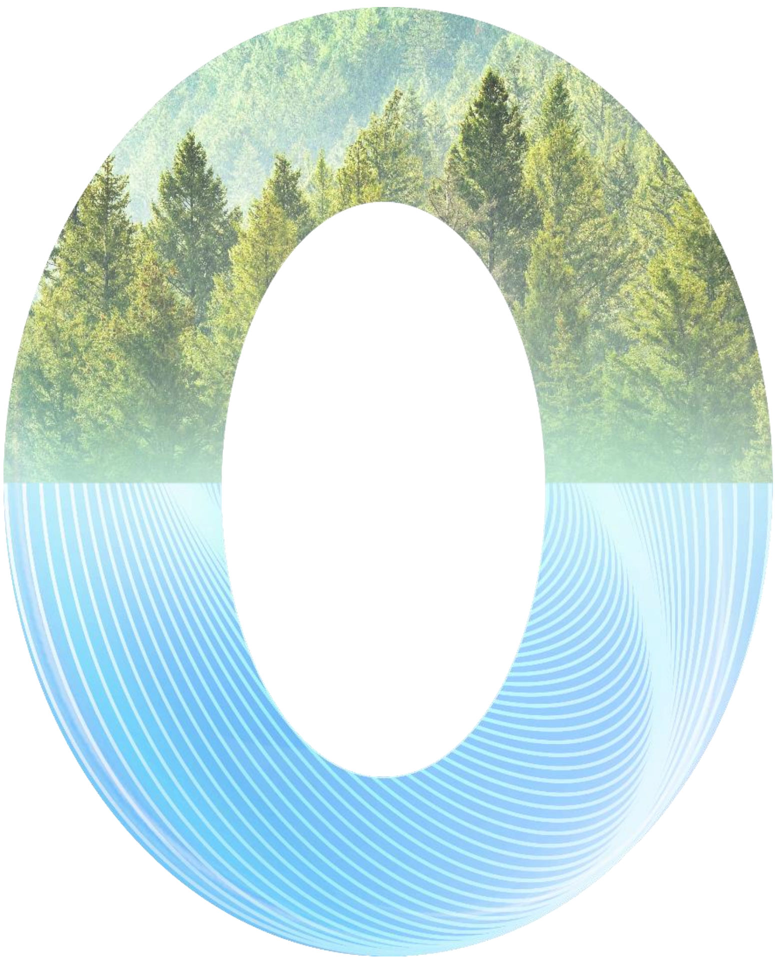
New-Generation Prefabricated Modular Data Center White Paper



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1. Preface

As an important carrier of next-generation information and communication technologies such as 5G, artificial intelligence (AI), and cloud computing, data centers have become the foundation of the digital economy era and have an unprecedented strategic position. Data centers function as an engine of the digital economy with an increasing significance in national economic systems. As technology-intensive emerging business, data centers provide infrastructures that support the digital, networked, and intelligent development of the society while boosting the digital economy. In particular, with the development of 5G and industrial Internet, the Internet and traditional industries are further converged. Data centers have become digital infrastructures that support industry development, digital governance, and socio-economic development.

Governments in various countries have launched digital strategies to drive digital transformation. For example, China has launched the "new infrastructure construction" strategy to promote digital infrastructure construction and build a foundation for the digital economy. In the Middle East, major countries have proposed their national strategies, such as Saudi Arabia's Vision 2030, UAE's AI strategy and Cloud First strategy, and Qatar's National Vision 2030 to promote national digital transformation, bringing a large number of data center construction requirements. Furthermore, with the advent of the digital sovereignty era, more countries are building sovereign clouds and local data centers.

Countries have also set their carbon neutrality and carbon peak goals, which raise higher requirements on data centers to reduce energy consumption. Going green and low-carbon has become an urgent task for data centers.

Driven by policy support and technological innovation, the data center market is booming and ushering in a new golden era of development, but the contradictions also increase. Traditional data center construction solutions face various challenges, such as long construction period, high construction uncertainty, high energy consumption, difficult capacity expansion, and low intelligence, making it impossible to meet the development requirements of data centers in the new era. Next-generation prefabricated modular data centers have emerged to address these challenges. The data centers boast advantages such as short construction period, high quality, good performance, low carbon, and full-lifecycle digitalization while delivering equivalent reliability and user experience as traditional building data centers. They effectively reduce uncertainties in data center planning, construction, and operation, helping customers build future-proof data center facility.

To better promote prefabricated modular data center technologies, we hereby prepare the Next-Generation Prefabricated Modular Data Center Solution White Paper, which describes the construction concepts and technical features of next-generation prefabricated modular data centers, providing reference for personnel across the industry.

CONTENT

2. Glossary

Data center

A building that provides an operating environment for electronic information devices that are placed centrally. It can be one or more buildings or part of a building, and consists of a computer room, auxiliary area, support area, and administrative area.

Prefabricated modular data center

Data center facility subsystems, such as the building structure system, power supply and distribution system, heating, ventilation, and air conditioning (HVAC) system, management system,lighting system, lightning protection and grounding, and integrated cabling, are pre-integrated into pre-fab. modules. All pre-fab. modules are pre-commissioned in the factory and constructed like Lego building blocks.

Hot aisle/cold aisle

A layout of server racks and other computing devices in a data center. Two adjacent rows of racks are placed face-to-face and back-to-back for front air intake and rear air exhaust. The air intake vents of the two rows of racks form a cold aisle and the air exhaust vents form a hot aisle. Hot-aisle/cold-aisle construction is designed to conserve energy and reduce cooling costs by managing airflow.

Seismic intensity

The severity of earthquake's influence on the ground and buildings (or the extent of earthquake impact and damage). It is a macro scale based on people's feeling during an earthquake or the degree of the response of objects after an earthquake, the degree of damage or destruction of buildings, and the changes of the ground when no meters are available.

Category-C environment

According to ISO 9223, atmospheric corrosivity is classified into six categories: C1 - very low; C2 - low; C3 - medium; C4 - high; C5 very high; CX - extreme

Weathering steel

A series of low alloy steel between ordinary steel and stainless steel. The weathering steel is made of common carbon steel together with a small amount of copper, nickel, and other corrosion-resistant elements. It has the characteristics of high-quality steel, such as toughness, plastic extension, molding, welding, cutting, abrasion, high temperature resistance, and anti-fatigue. The weathering steel is antirust, and it improves the corrosion resistance and service life of components.

One floor one DC

Core areas such as the white space area, power distribution area, and cooling area are deployed on the same floor. The power supply and cooling systems of each floor are independent. Each floor is independently deployed as a data hall.

Bottom-to-module (BM) plate

A kit that connects the foundation of a prefabricated modular data center to the module on the ground floor.

Module-to-module (MM) plate

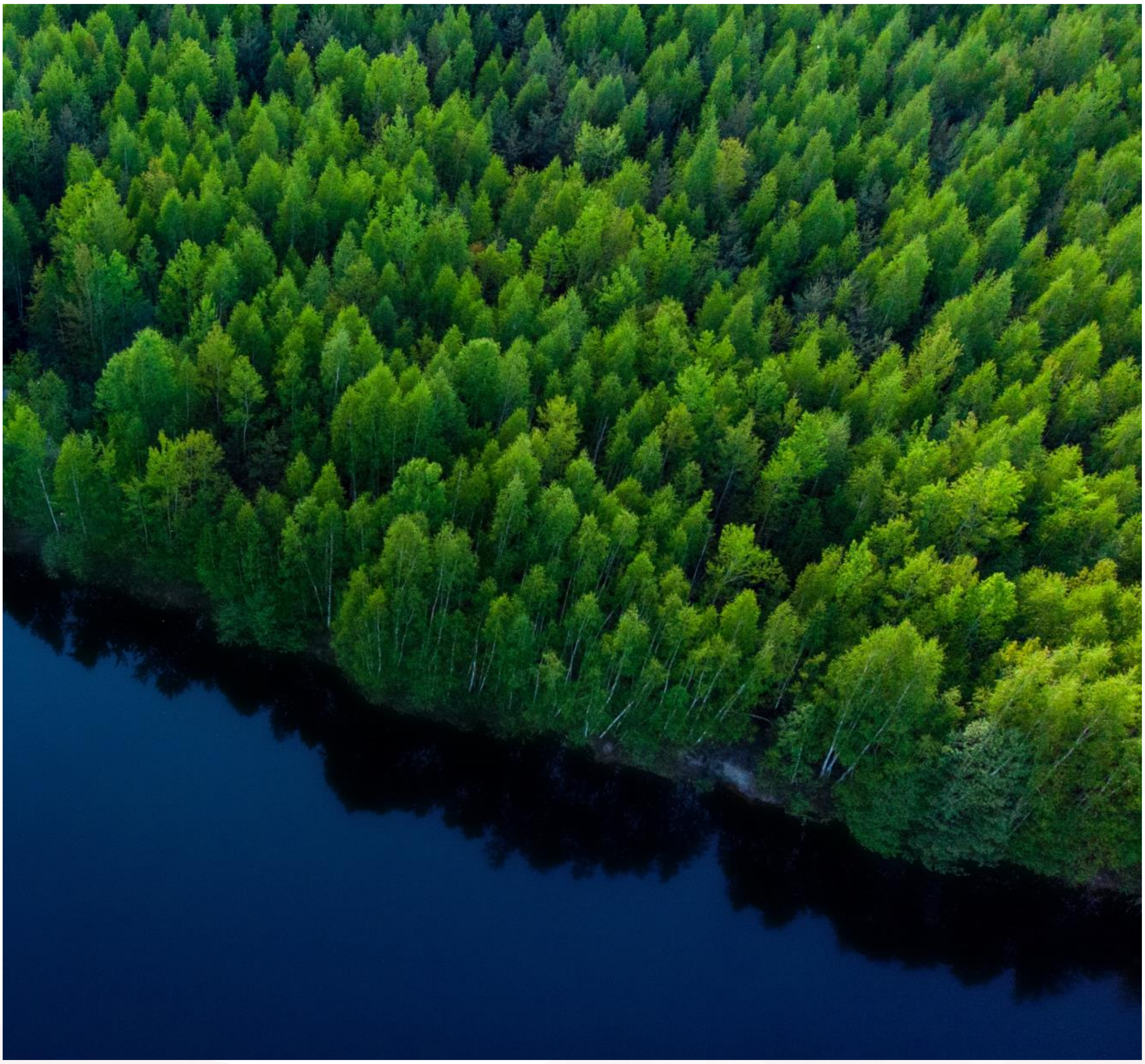
A kit that connects modules of a prefabricated modular data center between floors.

Building information modeling (BIM)

A digital representation for physical and functional characteristics of construction projects and facilities throughout their life cycle, as well as the collection of processes and results of design, construction, and operation based on the digital representation.

Indirect evaporative cooling (IEC) system

An air handling unit that adopts the IEC technology, uses air or water as the working medium and air as the production medium, and provides air circulation, air filtering, cooling, humidity control, and auxiliary cooling sources.



3. Trends and Challenges of the Data Center Industry

3.1. Data Center Development Trends

Zero-carbon data center

"Carbon neutrality" has become one of the primary issues concerning our planet today, and the data center industry will undergo a profound transformation. Building green and low-carbon data centers has become an inevitable direction. Green prefabricated buildings will be widely used in data center construction to reduce carbon emissions of data center buildings. Green power, such as wind and solar energy, will be more widely used in data centers, saving resources such as energy, land, water, and material to the maximum extent during the entire lifecycle of data centers. In the near future, new data centers will be controlled at the 1.0x level. Zero-carbon data centers will emerge.

Quick deployment

Internet and cloud services surge unexpectedly over a short period of time. Due to the ongoing COVID-19 pandemic, service data and traffic requirements have increased sharply, calling for fast deployment. Data centers will shift from a support system to a production system. They need to meet the requirements of cloud applications. Faster service rollout means earlier return on investment (ROI). In the future, the time to market (TTM) of data centers will be shortened from 12–18 months to 3–6 months.

Simple architecture

To address the disadvantages of traditional data centers such as slow construction and high CAPEX, simplified system-level and data center-level architectures will become the mainstream. The power and cooling architectures of data centers will evolve from traditional distributive solution to integrated ones. Data centers using prefabricated and modular design boast advantages such as fast deployment, elastic capacity expansion, simple O&M, and high energy efficiency.

More lithium, less lead

In traditional data centers, power supply and distribution systems are silo-like, complex, bulky, and difficult to locate faults. As lithium batteries continue to replace lead-acid batteries and lithium battery costs decline further, lithium batteries will be more widely used in data centers. Lithium batteries have twice the lifespan of lead-acid batteries and have advantages in physical footprint, O&M efficiency, service life, and safety. They reduce the footprint by 70% and allow for high-density and modular power supply.

Fully digitalized

As digital transformation accelerates innovative applications of digital, communications, and AI technologies increase, digital twin technologies will become more widely used and integrated into data center planning, construction, O&M, and optimization. This will result in visible, manageable, and controllable data centers capable of delivering excellent experience throughout the data center lifecycle.

AI enabled

With the continuous improvement and widespread application of IoT and AI technologies, repetitive tasks, expert experience, and business decision-making will be gradually replaced by AI. Data centers will evolve from single-domain intelligence of O&M, energy saving, and operation to digital and autonomous driving throughout the lifecycle, encompassing planning, construction, O&M, and optimization. Intelligent features will include AI energy efficiency optimization, real-time parameter adjustment, AI O&M, 24/7 inspection, predictive maintenance, AI operation, online simulation, and automatic service design.

3.2. Challenges Facing Data Center Construction

Long time to market(TTM) of traditional data centers cannot meet requirements for fast service rollout.

With the trend of digitalization and cloudification, fast rollout of data center services have become a rigid demand. Quicker rollout of data centers means earlier ROI. However, the construction period may be delayed in practice due to uncertainties such as the impact of weather and design changes. Lengthy construction, long period of return on investment (ROI) have a negative impact the profitability and business monetization of data centers. In the cloud era, the computing capability of data centers will double every year, and IT devices will be upgraded every three to five years. Traditional construction mode is time-consuming so data centers cannot be updated to new-generation technologies in time.

Traditional data centers with low scalability .

Traditional data centers require one-off planning and investment and high CAPEX. Construction planning does not keep pace with service changes, resulting in a waste of investment. When new services emerge, the capacity cannot be quickly expanded so customers may miss business opportunities.

The operational PUE is far from design PUE and the power consumption remains high in traditional data centers.

Traditional data center systems are complex. They are constructed in segments and many parts need to be integrated onsite. Each segment is independent of each other. Cooling and power supply are separate, failing to ensure end-to-end (E2E) performance and bringing in many quality uncertainties. The PUE design deviates greatly from the actual PUE, and the power consumption remains high. How to achieve "deliver as design" is a common challenge for data centers.

O&M is difficult to traditional data centers due to a low level of intelligence.

With the application of new technologies, data centers are becoming more complex. Traditional manual O&M is difficult to ensure data center reliability and efficiency. In addition, data centers require high O&M skills. However, market research shows that 61% of data centers lack qualified O&M personnel. The utilization of data center resources, such as power, cooling, and space, is unbalanced and fragmented, causing a waste of resources. The intelligence level of data centers needs to be improved.

4. Features of Next-Generation Prefabricated Modular Data Centers

4.1. Definition of Prefabricated Modular DC

A prefabricated modular data center converge the civil work (L0) and facility（L1）of the data center. The prefabricated modular data center solution integrates the prefabricated modular building and modular data center facilities. The entire data center takes modular design. All functional areas including the building are composed of prefabricated modules. Subsystems such as the structural system, power supply and distribution, HVAC system, management, lighting, lightning protection and grounding, and integrated cabling are pre-integrated in prefabricated modules. All pre-fab. modules are prefabricated and pre-commissioned in the factory. The prefabrication is synchronized with the civil work. The prefabricated facilities are delivered to the deployment site by module. All prefabricated modules are deployed by simple hoisting and Lego-like construction，which dramatically reduces the onsite civil work. The data center can be quickly constructed and service will rollout much quicker than the concrete building.

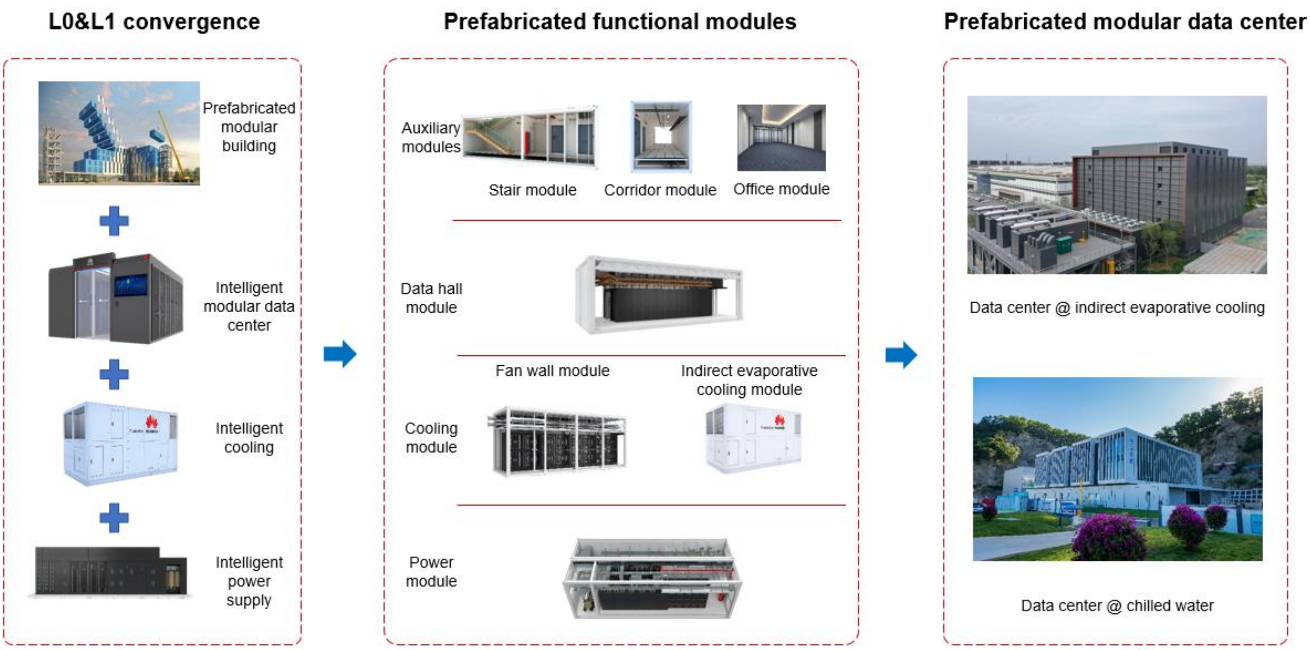


Figure 4-1 Convergence of Prefabricated modular DC

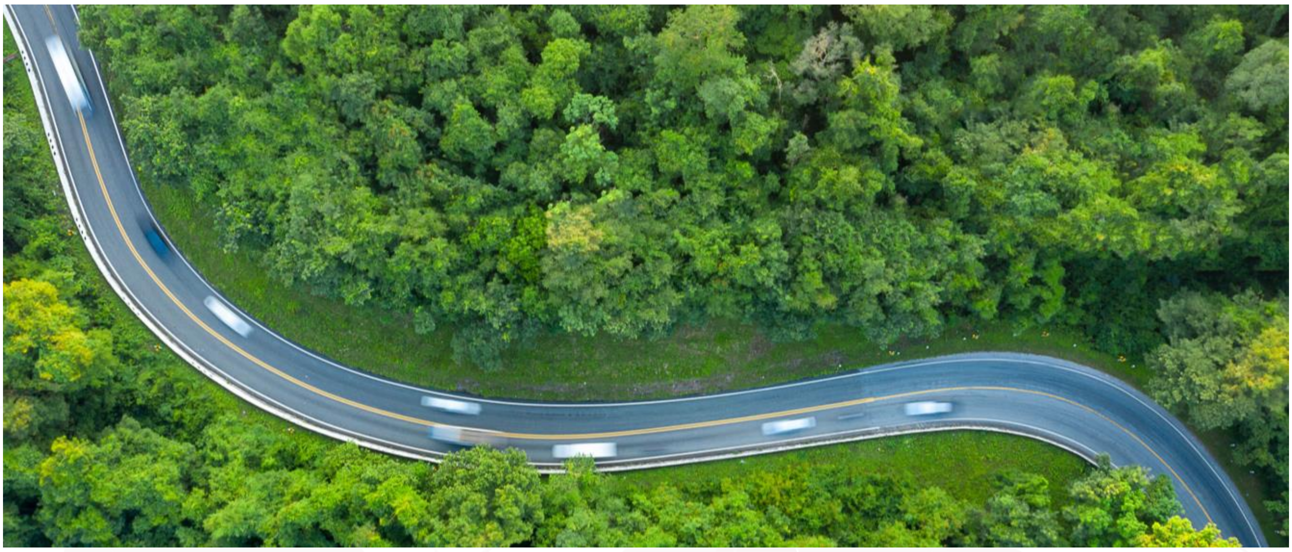


Figure 4-2 *Module prefabrication*

Figure 4-3 *Module pre-acceptance before delivery*

Figure 4-4 *Onsite module hoisting*

4.2. Development Trends of Prefabricated Modualr DC

The prefabricated modular technology has been applied in the data center industry for several years. Early prefabricated data centers used the ISO standard 40ft or 20ft container and adopted the all-in-one deployment. The data center subsystems were integrated and deployed as a complete set of equipment to meet the requirements for rapid deployment and emergency construction of small-scale data centers.

Based on the all-in-one prefabricated data centers, industry players have gradually achieved modularization in some core areas, such as the data hall area and power distribution area. Traditional prefabricated modular data centers emerged, where modules of the IT and power areas were prefabricated, assembled, and deployed on a single layer or stacked on two or three layers. However, the traditional data center could not provide same reliability and using experience as the building DC. Due to restrictions in reliability, space, container appearance, and standardization, traditional prefabricated modular data centers were used only in small-scale and specific scenarios.

With the maturity of the prefabricated modular concept and the development of modular data centers, prefabricated building technologies and modular data centers are deeply integrated, improving the reliability and user experience of prefabricated modular data centers. In the prefabricated modular data centers, the main structure reliability, space, and internal and external using experience are on a par with the building DC. The IT, cooling, power distribution, and auxiliary functional areas are modularized, standardized, and can be expanded on demand, achieving high-level, multiple-layer and large-scale cluster applications. As innovative applications of digital, communications, and AI technologies increase and converge, prefabricated modular data centers are progressing toward intelligence and full-lifecycle digitalization. In-depth integration of prefabricated modular buildings, modular data centers, and intelligent and AI technologies enables prefabricated modular data centers to evolve from temporary and container-level to permanent building-level facilities.

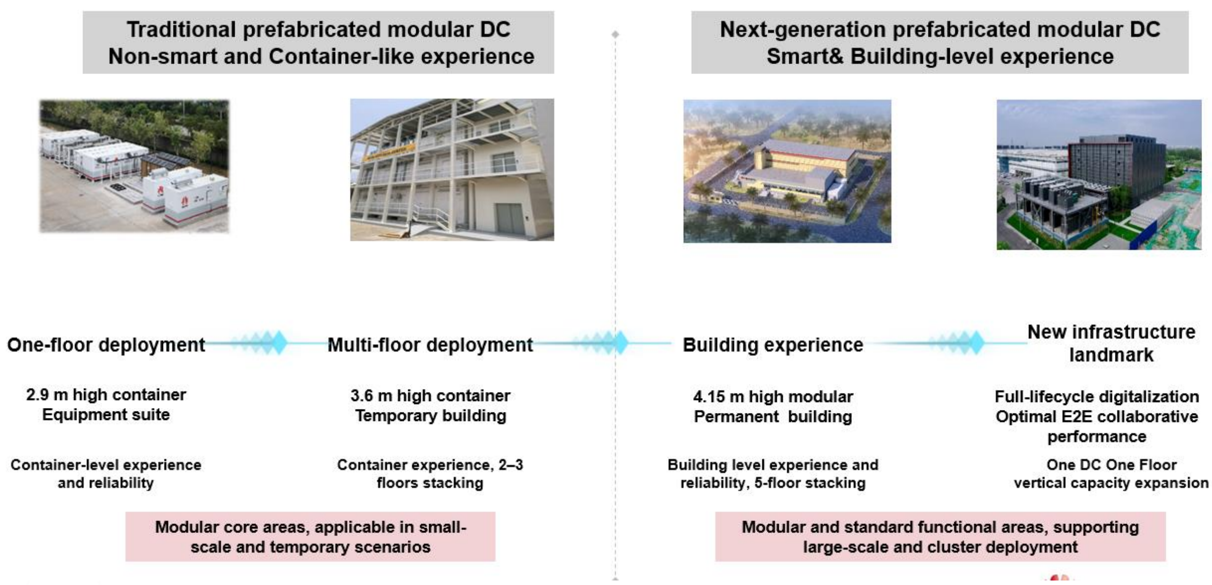


Figure 4-5 Evolution of Prefabricated Modular DC

4.3. Charactistics of Next-genearation Prefabricated Modular DC

To adapt to the development trends of the data center industry and meet the construction and usage requirements of high-level data centers, the next-generation prefabricated modular data centers will have the following characteristics:

① **All-modular design:** The next-generation prefabricated modular data centers adopt modular design for all functional areas, floors, and data center buildings. The data hall, cooling, power supply, corridor, and office areas are composed of pre-fab. modules and can be quickly set up in Lego mode. Standard modules enable the "one floor one DC" design architecture and on demand deployment. Standard and modular POD can be fast replicated.

② **All-prefabricated delivery:** Key functional modules are prefabricated in the factory. The building and internal facilities of the data center can be prefabricated in the factory. In addition, key systems of functional modules are pre-commissioned before delivery to reduce the onsite commissioning workload.

③ **High integration of pre-fab. modules:** The building structure system of a data center is deeply integrated with subsystems such as the power supply and distribution system, HVAC system, management system, lighting system, lightning protection and grounding system, and integrated cabling system. All these subsystems are pre-integrated into pre-fab. modules, minimizing onsite construction.

④ **On-demand deployment:** Data center buildings with standardized design enable fast replication, capacity expansion, and flexible upgrade of power density. The "one floor one DC" design support vertical expansion and on-demand deployment.

⑤ **Structural reliability complying with permanent building standards:** Both reliability and design life of single-layer and multi-layer prefabricated modular data center can meet national and local building design codes and construction standards. It delivers good fireproof, waterproof, windproof, and seismic performance, and have good environmental practicability. The data centers can be directly used in desert, cold, and humid and high-attitude environments.

⑥ **MW-level and large-scale cluster application and stacking of multiple layers:** The next-generation prefabricated modular data centers takes standard design with high reliability. They can be rapidly replicated to construct a large-scale DC complex.

⑦ **Equivalent using experience as traditional buildings:** Both space and layout in the pre-fab modular data center meet the design requirements of high-class data centers as specified in the TIA 942 or Uptime Tier standard. The data center appearance is not like container any more. With the external façade, it provide same appearance as traditional building.

⑧ **Full-lifecycle digitalization:** Wide range of digital technologies, like BIM digital design, digital production, integration of AI and digital twins technologies, and digital O&M are applied to the prefabricated modular data center and enable full-lifecycle digitalization.

4.4. Application Scenarios

In early stages, prefabricated modular data centers were mainly used as small- and medium-sized data centers, such as edge data centers, private small-sized data centers, and disaster recovery data centers, to meet customers' requirements for rapid deployment and simple replication. With the convergence of modular building technologies and modular data centers, the solution reliability and using experience are greatly improved. Next-generation prefabricated modular data centers are being applied as medium- and large-sized data centers. Prefabricated modular data centers can be used in all type of mainstream data center scenarios, such as colocation, cloud data centers, carrier central DC facilities, core data center of governments and enterprises, disaster recovery data centers, and AI and HPC data centers, etc.

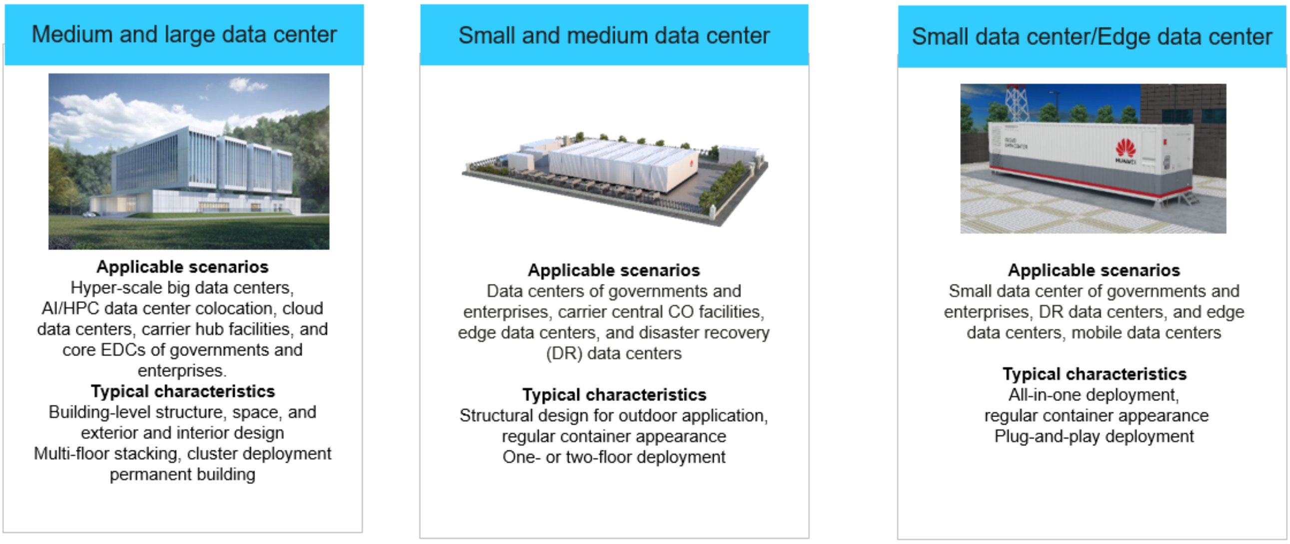


Figure 4-6 Application Scenarios

4.5. Standards Compliance

To ensure that prefabricated modular data centers are safe, reliable, stable, and replicable, it is necessary to confirm the compliance with mainstream national and international codes and standards on data center design and construction design. It includes but limited to following standards：

- TIA 942-2017 Telecommunications Infrastructure Standard for Data Centers
- ASCE 7 American Society of Civil Engineers. 2010. Minimum Design Loads for Buildings and Other Structures.
- AISC 360 American Institute of Steel Construction. 2010. Specification for Structural Steel Buildings.
- AISC 341 American Institute of Steel Construction. 2010. Seismic Provisions for Structural Steel Buildings.
- EN 1990 Basis of structural design
- EN 1991 Action on Structure
- EN 1993 Design of Steel Structure
- EN 1998 Earthquake resistance
- NFPA 72 National Fire Alarm and Signaling Code
- NFPA 75 Standard for the protection of information technology equipment
- NFPA 101 Life Safety Code
- NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems
- NFPA 76: Standard for the Fire Protection of Telecommunications Facilities
- IEC 60364-1-2005 Electrical installations of buildings - Part 1: Fundamental principles, assessment of general characteristics, definitions
- IEC 60364-4-41-2005 Low-voltage electrical installations - Part 4-41: Protection for safety - Protection against electric shock
- IEC 60364-5-51-2005 Electrical installations of buildings Part 5-51:Selection and erection of electrical equipment - Common rules
- IEC 60364-5-52-2001 Electrical installations of buildings Part 5-52: Selection and erection of electrical equipment –Wiring systems
- IEC 60364-5-523 Current-carrying capacities in wiring systems
- IEC 60364-5-54:2011 Low-voltage electrical installations - Part 5-54: selection and erection of electrical equipment - Earthing arrangement and protective conductors
- ASHRAE TC9.9 Data Center Power Equipment Thermal Guidelines and Best Practices
- ASHRAE Standard 90.1-2010 Energy Standard for Buildings Except Low-Rise Residential Buildings
- MCC Video Surveillance Systems Standards 5.0_2017

5. Technical Features of Next-Generation Prefabricated Modular Data Centers

5.1. Site Selection Requirements

To ensure safe and stable operation of prefabricated modular data centers, the overall site selection requirements must meet the requirements in Appendix E of TIA 942. The following site selection requirements must be met:

- The geological conditions are stable and the site is away from risky areas such as seismic zones, debris flows, and landslides. Make sure that the foundation is firm and reliable.
- Keep away from flood- and lightning-prone areas, substations, and transmission lines.
- Keep away from dust, oil fume, air pollution and other sources of corrosion. Ensure compliance with C2, C3, and C4 environment requirements specified in ISO 12944. Keep 3760m away from coastlines, garbage disposal sites, and rivers.
- Keep away from the storage and production sites of inflammable and explosive materials.
- The ambient temperature is within the range of –40°C to +55°C.
- Keep away from areas with strong electromagnetic interference.
- Ensure that the field is broad and there are no obstacles within 10 m of the construction site to allow for the hoisting and construction of lifting equipment.
- Ensure that the site provides good conditions for road transportation. The surrounding roads should allow container vehicles (3495 mm x 4150 mm x 12192 mm) and at least 250-ton cranes to easy pass and hoisting.
- Ensure that the local power supply is sufficient and reliable, and that the communication and network facilities are effective.

5.2. Data Center Layout

The next-generation prefabricated modular data center should adopt the "one floor one DC" architecture. The data hall, power distribution area, and battery area should be deployed on the same floor. Single-floor or multi-floor deployment is supported.

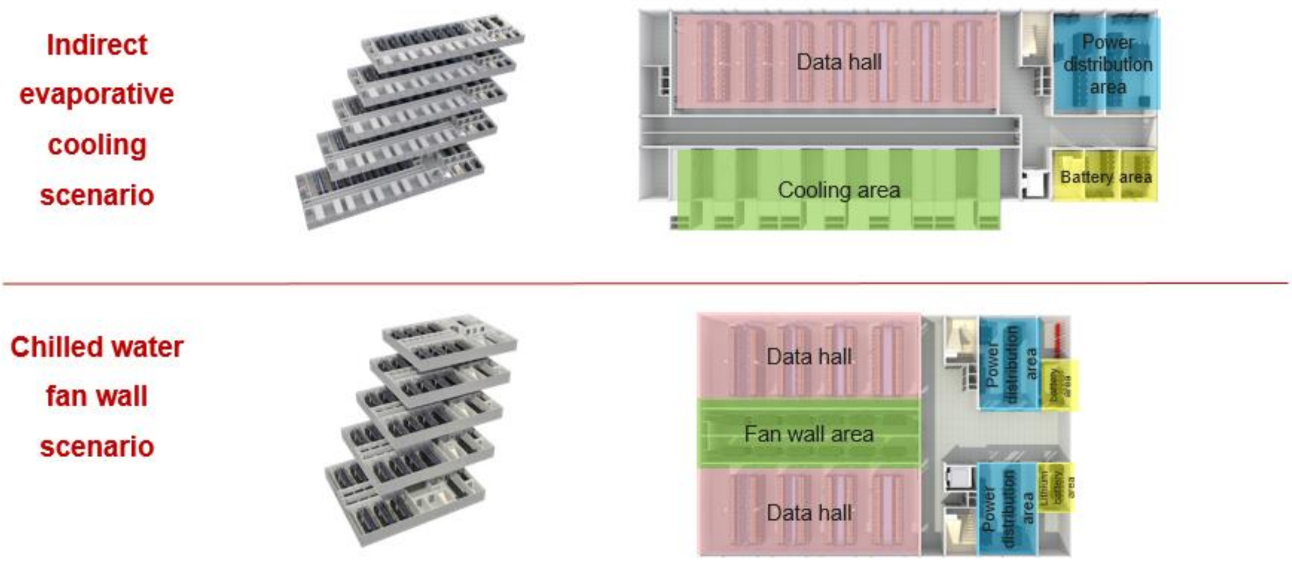


Figure 5-1 *Typical floor layout*

5.3. Classification of Prefabricated Modules

5.3.1. Overview of Prefabricated Modules

Based on the operation characteristics of data centers, prefabricated modular data centers can be divided into three types of pre-fab. modules: core module, auxiliary functional module, and peripheral power module. Core modules include the data hall module, power module, battery module, and MEP module. Auxiliary functional modules include the corridor module, office module, stair module, and elevator module. Peripheral power modules include the hydronic module (chilled water) and genset module. To reduce the onsite workload, equipment in pre-fab. modules must be prefabricated and precommissioned in the factory.

5.3.2. Data Hall Module

The data hall module is a prefabricated module that integrates:

- Racks (optional), aisle containment, smart busbars, dense busways, power distributions units, lighting fixtures, sockets, and power distribution boxes
- Monitoring devices, such as IP infrared cameras, access control, water sensors, collectors, and temperature and humidity (T/H) sensors
- ESD floor, various supports, electric and extra low voltage (ELV) cable trays, fasteners, aluminum baseboards, aluminum slide rails, grid cable trays, and optical fiber cable troughs

Figure 5-2 *Data hall module*

Module dimensions (L x W x H): 12192 mm x 3495 mm x 4150 mm or 12192 mm x 2438 mm x 4150 mm

Compatible rack dimensions: 2000 mm/2200 mm x 600 mm x 1200 mm

5.3.3. Power Module

The module is a prefabricated module that integrates:

- Transformers, IT low-voltage switchgear/bus-tie cabinet, modular UPS, input and output cabinets, busways, lighting fixtures, sockets, cables, busbars, and wiring terminals
- ELV devices such as IP infrared camera, access control, and T/H sensor
- ESD floor, various supports, electric and ELV cable trays, fasteners, aluminum baseboards, and aluminum slide rails

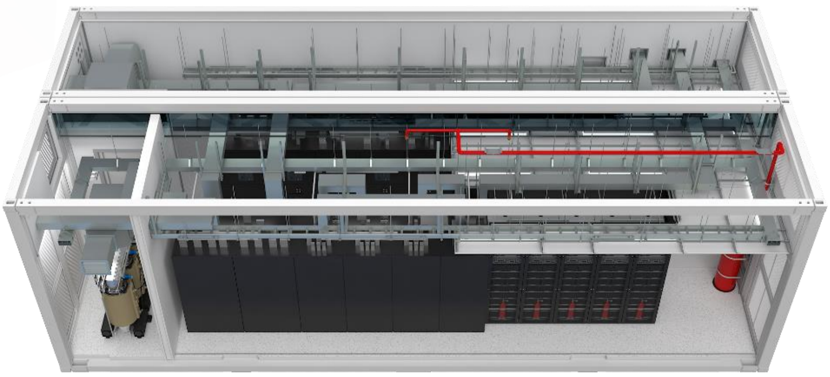


Figure 5-3 *Power module*

Module dimensions (L x W x H): 12192 mm x 3495 mm x 4150 mm

5.3.4. MEP Module

The module is a prefabricated container that integrates:

- Chilled water MEP units or indirect evaporative cooling (IEC)units, cooling pipes, water supply and drainage pipes, and dense busway distribution units
- Auxiliary ELV devices such as cameras, T/H sensors, and fire control devices
- ESD floor, various supports, and electric and ELV cable trays

Figure 5-4 *Chilled water MEP module*

Module dimensions (L x W x H): 12192 mm x 3495 mm x 4150 mm (chilled water fan wall module)

6058 mm x 243 mm x 4150 mm (IEC module)

5.3.5. Battery Module

The module is a prefabricated module that integrates:

- Lithium battery cabinets, switch boxes/cabinets, lighting fixtures, sockets, cables, busbars, and wiring terminals
- ELV components such as IP infrared cameras, card readers, and T/H sensors
- ESD floor, various supports, electric and ELV cable trays, fasteners, aluminum baseboards, and aluminum slide rails

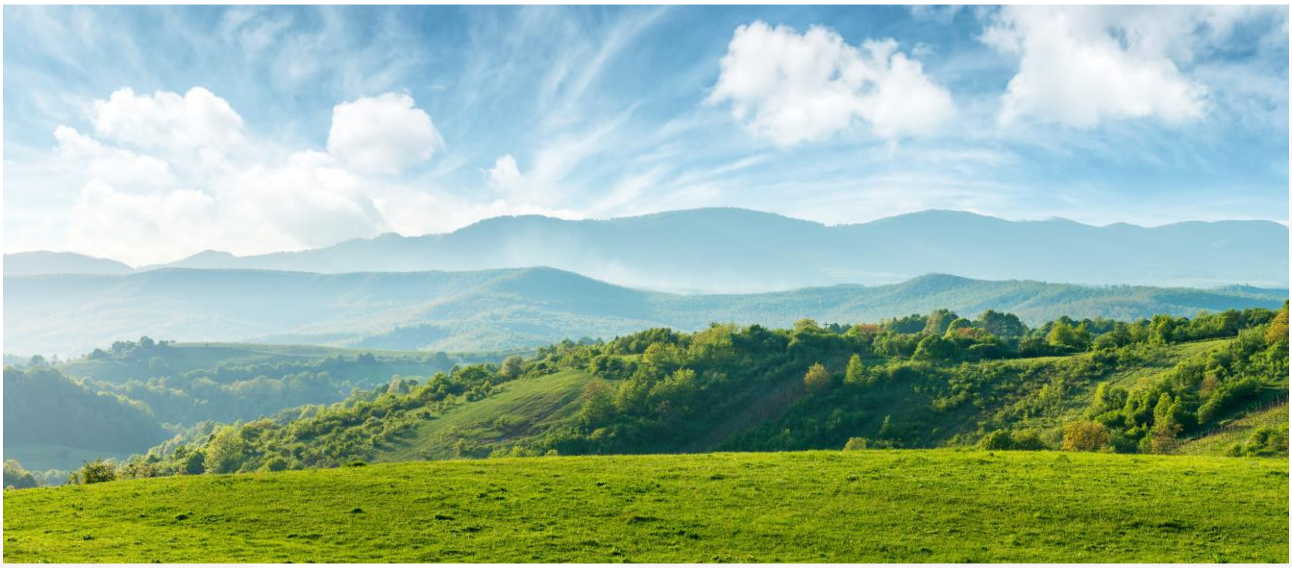
5.3.6. Corridor Module

The module is a prefabricated module that integrates:

- Power distribution: intelligent lighting, lighting fixtures, sockets, cables, and wiring terminals
- ELV: IP infrared cameras, access control, unshielded signal cables, and accessories
- Structure: ESD floor, various supports, electric and ELV cable trays, fasteners, aluminum baseboards, aluminum slide rails
- HVAC: smoke exhaust pipe, refrigerant pipes and their components

Figure 5-5 *Corridor module*

Module dimensions (L x W x H): 12192 mm/6058 mm x 3495 mm x 4150 mm



5.3.7. Office Module

The module is a prefabricated module that integrates:

- Power distribution: intelligent lighting, lighting fixtures, sockets, cables, and wiring terminals
- ELV: IP infrared cameras, access control, unshielded signal cables, and accessories
- Structure: ESD floor and various supports

Figure 5-6 *Office Module*

Module dimensions (L x W x H): 12192 mm x 3495 mm x 4150 mm

5.3.8. Staircase Module

The module is a prefabricated module that integrates:

- Power distribution: emergency lighting distribution box, emergency lighting centralized control box, office floor distribution box, elevator distribution box, lighting fixtures, sockets, cables, and wiring terminals
- ELV: IP infrared cameras, access control, unshielded signal cables, and accessories
- Structure: ESD floor, stairs, various supports, electric and ELV cable trays, and fasteners

Figure 5-7 *Stair module*

Module dimensions (L x W x H): 12192 mm/6058 mm x 3495 mm x 4150 mm

5.3.9. Elevator Module

The module consists of a prefabricated elevator shaft and related supporting facilities. The elevator shaft is prefabricated in the factory and the elevator is installed onsite.

Figure 5-8 *Elevator module*

5.4. Building Structure System

5.4.1. Building Structure Seismic Resistance

The modules should meet the seismic requirements of Zone 3 (equivalent McIntensity 9) or Zone 4 (equivalent McIntensity 11) specified in GR–63–CORE Network Equipment-Building System (NEBS) Requirements: Physical Protection.

The overall building structure should meet the seismic requirements of the American standard IBC 2009: Ss = 0.1, S1 = 0.05, Importance factor I = 1, Soil type = B, Design category = A.

The building structure should meet with the seismic requirements of the European standard EN 1998: Country = CEN default, Ground acceleration ag/g = 0.1, Spectrum type = 1, Ground type = B, Behavior factor q = 2, Correction factor lambda = 1.

5.4.2. Pre-fab. Module Dimensions

To facilitate transportation, the module should be certified by the classification society. The length of the pre-fab. modules should meet the ISO requirements on dimensions of standard 40-foot containers. The length of a core module should be 12,192 mm. In addition, considering the functional layout and O&M space requirements of data centers, the height of all modules should be 4150 mm. The width of the power module, data hall module, and IEC module should be at least 2438 mm, and that of the chilled water MEP module should be at least 3495 mm.

5.4.3. Aisle and Cabinet Deployment

To improve cooling efficiency, aisle containment should be deployed inside a prefabricated modular data center.

In the hot aisle containment scenario, the width of the hot aisle should be at least 900 mm, and the width of the cold aisle should be at least 1500 mm.

In the cold aisle containment scenario, the width of the cold and hot aisles should be at least 1200 mm.

The floor-to-ceiling height of data hall should be at least 3700 mm, and the net clearance under the cable trays should be at least 2600 mm.

The width of the aisle for maintenance and facility transfer should be at least 1500 mm.

5.4.5. Internal Seismic Resistance

Internal equipment should meet the anti-seismic requirements of equipment in telecommunications rooms. The equipment installation base should be integrated with the pre-fab. module frame. Steel beams should be welded. Frame beams should be used for equipment installation. Bolted structures should be used to connect equipment to the beam frame.

5.4.6. Load and Stress Capacity

The structural load of pre-fab. modules should meet the requirements of TIA 942, American standard ASCE7, and European standard EN 1991. The standards are as follows:

Table 5-1 *Live-laod performance*

Area	Live Load in a Prefabricated Modular Data Center
Battery room	12kN/m^2
Power room	12 kN/m^2
Data hall area	12 kN/m^2
Loading bay /Storage area	12 kN/m^2
Gas cylinder room	12 kN/m^2
Corridor and staircase	5 kN/m^2
Top mount	2.4 kN/m^2
Roof without personnel	0.75 kN/m^2

5.4.7. Fireproof Design

The enclosure structure of a prefabricated modular data center should be made of high-density rock wool with a flame retardant rating of A1. The main structure should be coated with fireproof paint to meet the fire resistance requirements of 2 hours for load-bearing beams and columns, 90 minutes for external walls, and 60 minutes for internal partition walls. Fireproof doors should be used as the main entrance doors and inward-opening emergency doors, meeting the 90-minute fire resistance requirement.

5.4.8. Wind and Snow Resistance

The design should meet the maximum value requirements of the American standard ASCE7-05 Minimum Design Loads for Buildings and Other Structures. The top of the pre-fab. modules should support the snow load of 0.718 kN/m2.

Single-floor and multi-floor prefabricated modular data centers should be able to resist winds of scale 12 (wind speed: 32.6 m/s).

5.4.9. Dust and Water Resistance

The automatic welding process should be used to ensure the general waterproof and dustproof capabilities of the entire containers.

To ensure container tightness, water leakage tests should be performed on the top of the modular before delivery.

To ensure the overall waterproof and sealing performance of the building, the top of modules between floors, the top of the modules on the top floor, joints between floors, and external elevation joints of the modules should be waterproofed and sealed according to the building waterproofing standards.

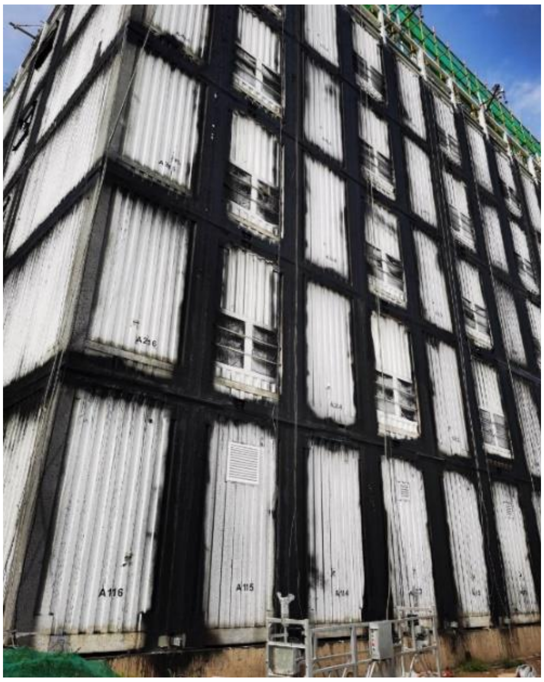


Figure 5-9 *Waterproof Layer*

5.4.10. Corrosion Resistance and Structure Life

To support the long-term operation of a data center, the main body of the prefabricated modular data center structure should meet the life requirements specified in the local building design and construction codes. Pre-fab. modules should be coated with multi-layer anti-corrosion materials such as zinc-rich primer, epoxy intermediate paint, and polyurethane topcoat to meet anti-corrosion design requirements in different environments.

The salt spray test for standard module coating should meet the 1440-hour requirements in ISO 12944. According to ISO 12944, the service life of prefabricated module should be at least 25 years in C3 and C4 environments. After additional anti-corrosion treatment, the main structure of the prefabricated module should meet the requirements for 50-year service life in the C3 environment and 40 years in the C4 and C5 environments.

5.4.11. Exterior Decoration

The next generation prefabricated modular data centers should be locally installed with the external facade to meet the campus and landscape design requirements. The façade should consist of exterior decorative plates and the keel supporting structure. The facade on the exterior of the prefabricated modular data center are simple but elegant, and are easy to install and replace.

Figure 5-10 *Façade of Prefabricated Modular DC*

5.4.12. Internal Decoration

A prefabricated modular data center should be equipped with decorative walls, ESD steel floors, and suspended ceilings. The walls of the prefabricated modular data center should be covered with the rock wool insulation layer and fireproof panels.

ESD floors should be prefabricated and installed in the factory.

5.4.13. Foundation Treatment

The foundation load and depth should be determined according to the actual geological survey report and the local hydrological conditions of 50 years. The strength should meet the requirements of local architectural design and construction specifications.

Common types of foundation for prefabricated modular data centers include strip, independent, raft, and box-type shallow foundations and pile foundations. A shallow foundation usually has a buried depth of less than 5 m.

Figure 5-11 *Foundation work*

5.4.14. Hoisting and Securing

The pre-fab. modules on the ground floor should be secured to the foundation using pre-buried steel plates, BM plates, and bolt assemblies.

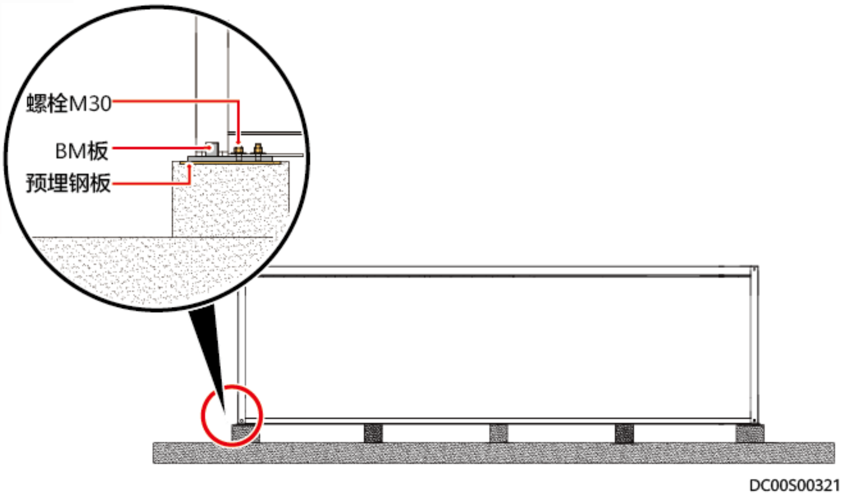


Figure 5-12 Securing a pre-fab. module at the bottom

The pre-fab. modules on adjacent layers should be secured together using MM plates and high-strength bolt assemblies.

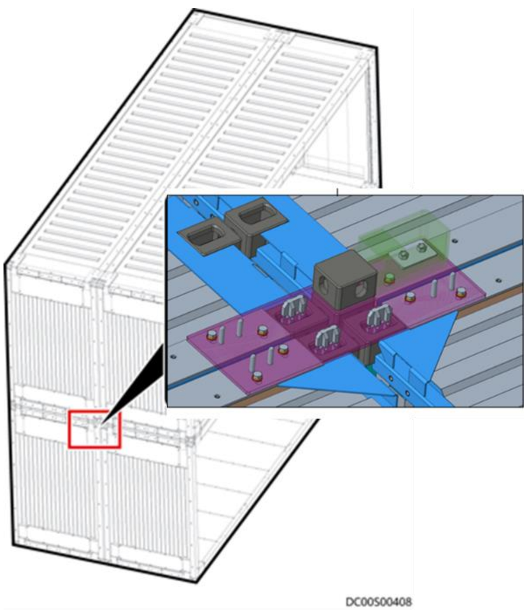


Figure 5-13 Securing stacked pre-fab. modules

5.4.15. Roofing System

The roofing system should be locally installed and made of light steel roofing and adopt the modular design. The system should meet the requirements of light weight and high strength, have good impact resistance and wind pressure resistance, and reduce the load of the building structure. The materials used should be weathering materials, meet the seismic requirements of the building, and have necessary fireproof and waterproof characteristics.

A waterproof sealing roof should be set on the top of the pref-fab. modules on the top floor, and a parapet wall and roof drainage gutter should be also set.

5.5. Power Supply and Distribution System

5.5.1. Power Supply and Distribution Architecture

A prefabricated modular data center should adopt the mains+UPS power supply mode and use the 2N or DR power supply architecture based on application scenarios.

The integrated power module should be used for the low-voltage power supply and distribution system. All low voltage power facilities such as the 10 kVA transformer, the UPS, input/output cabinet, and SVG cabinet are integrated into the one prefabricated module. Compared with the traditional distributed UPS architecture, the integrated power module reduces the footprint of power room by 30% .Meanwhile, it provides the highest link-level efficiency. The built-in intelligent features greatly improves the reliability of the power supply and distribution system.

Figure 5-14 *Integrated power module*

The power module should be connected to the data hall module through busways, which can be prefabricated or installed onsite.

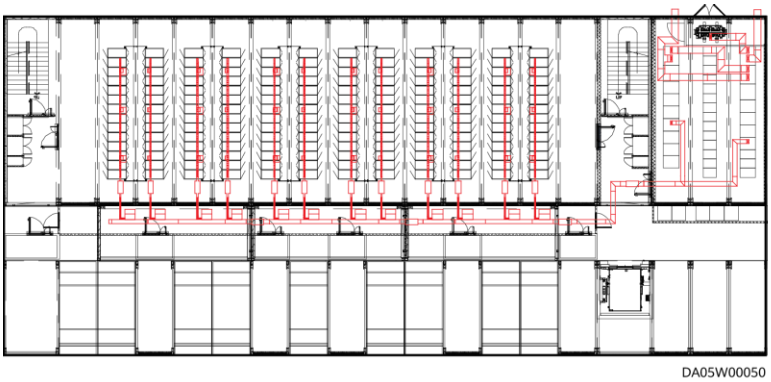


Figure 5-15 *Busway layout in the IEC reference scenario*

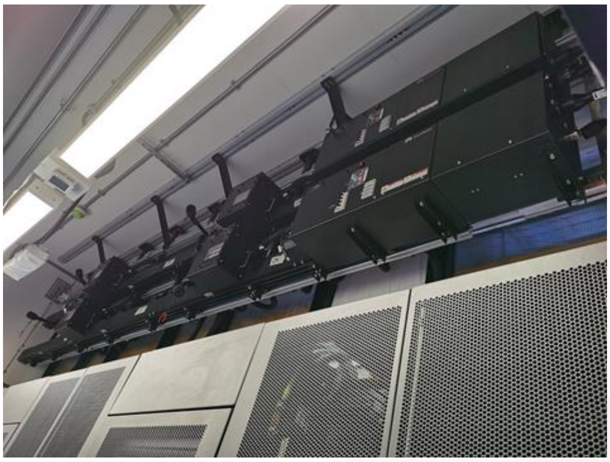


Figure 5-16 *Smart busbars*

5.5.2. UPS

The intelligent modular UPS should be used. The power, bypass, and control modules are hot swappable, facilitating maintenance. In addition, on-demand smooth expansion is supported, which effectively reduces the Day-1 investment in the UPS and improves the UPS operating efficiency. The UPS power and control modules adopt full redundancy design, eliminating single points of failure and improving system reliability.

The high-density power modules are used in the UPS to reduce the footprint.

High efficiency is ensured even with a low load rate. If the load rate is extremely low, the intelligent rotation hibernation technology ensures redundancy and improves the UPS efficiency.

5.5.3. Battery System

Smart lithium iron phosphate (LFP) batteries are recommended for the next generation prefabricated modular data center. Smart lithium batteries have twice or triple the lifespan of lead-acid batteries. They adopt modular design to simplify lifetime maintenance, and support mixed use of old and new batteries, reducing the CAPEX in the battery system.

Figure 5-17 *Lithium battery room*

Smart busbars should be used for data hall modules, and industrial connectors should be used to connect racks to supply power to IT racks.

Figure 5-18 Smart Busbar connection

5.5.4. Genset Platform

Due to the limitation of the pre-fab. module size, a separate genset platform should be deployed accordingly. The genset platform can be a steel-framed platform (single-layer or double-layer) that accommodates outdoor gensets, or an independent utility building that houses indoor gensets.

Outdoor Steel Platform + Outdoor Diesel Generator **Utility Building + Indoor Diesel Generator**

Figure 5-19 *Genset platform*

5.6. Cooling System

5.6.1. Data Hall Cooling System

5.6.1.1. Cooling Solution Selection

Either chilled water or indirect evaporative cooling solution is adaptive for the next generation prefabricated modular data center. The cooling architecture should be configured in N+1 mode.

The next generation prefabricated modular data center should adopt diffuse air supply and aisle containment design without raised floors. Cold and hot air flows should be completely isolated. The airflow distribution should be downflow air supply and upflow air return to increase the return air temperature and prolong the air duct heat transfer and free cooling duration, thereby improving the cooling efficiency.

5.6.1.2. Chilled Water Solution

The high-temperature fan wall is recommended for the chilled water solution. The supply and return water temperatures should not be lower than 15°C to increase the cooling efficiency and free cooling duration. Comparing to the traditional chiller water solution, the free cooling duration of fan wall solution is 18% longer, chiller efficiency is 15% higher and cooling efficiency is 50% higher, which will reduce PUE of data center.

The supply air temperature of a single fan wall should be 24°C and the return air temperature be 36°C. The intake air temperature for equipment should be in the range of 15°C to 32°C.

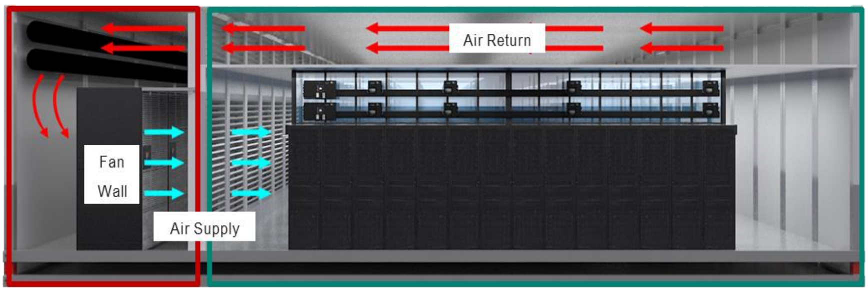


Figure 5-20 *Airflow of chilled water fan wall solution*

5.6.1.3. Indirective Evaporative Cooling(IEC) Solution

The IEC solution is recommended for areas with proper climate conditions. An IEC unit shall operates in dry mode, spray mode, or hybrid mode. The operating mode will be switched flexibly according to temperature, humidity and the IT load. It provides on-demand cooling and maximize freecooling usage and energy saving. The operating conditions are as follows:

① When the outdoor dry bulb temperature is less than or equal to 16°C, only the outdoor fans of the unit are started for heat exchange to fully use the free cooling source.

② When the outdoor dry-bulb temperature is greater than 16°C and the wet-bulb temperature is less than or equal to 19°C, the outdoor fans and cooling water sprinklers exchange heat together to sufficiently use the free cooling source.

③ When the outdoor wet-bulb temperature is greater than 19°C, the fans, cooling water sprinklers and refrigeration compressors work together in heat exchange to partially use the free cooling source.

* The cooling capacity of a single IEC unit should be at least 210 kW @24°C for supply air and 36°C for return air.

The cold aisle temperature range should be 24°C/36°C, with the default temperature rise of 12°C.

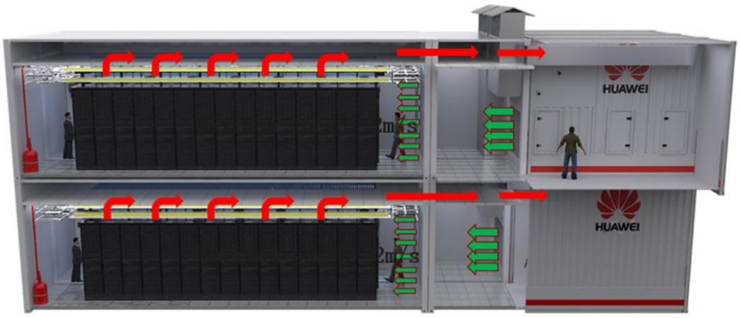
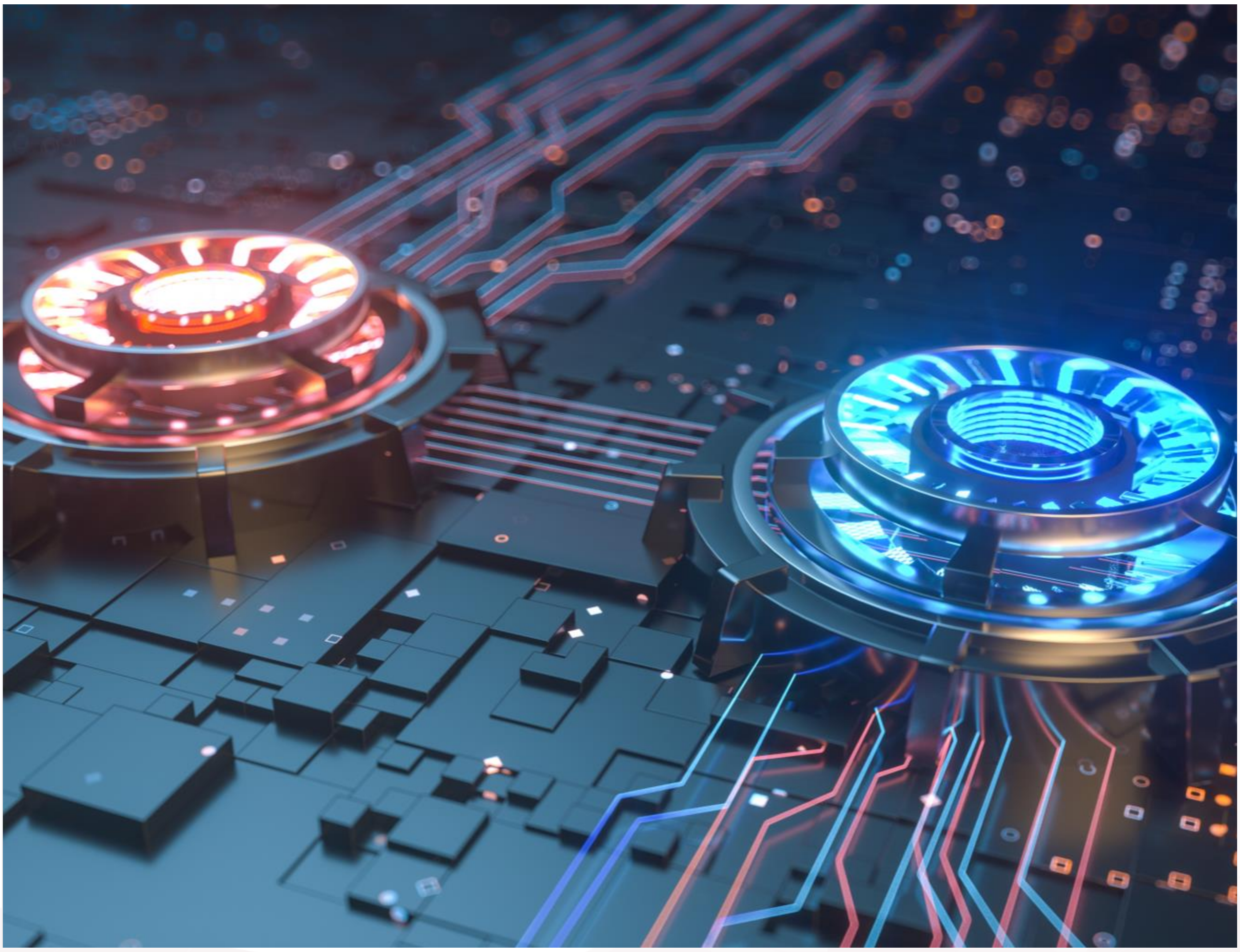


Figure 5-21 *Airflow of indirect evaporative cooling solution*

5.6.2. Power Area Cooling System

Air-cooled direct expansion (DX) air conditioners can be used in the power area. The airflow distribution of the power area should be top air supply through caps and bottom air return on the side of air conditioners. The air conditioners for the power equipment room should be equipped with noise-absorbing caps and double-layer louvered air vents.



5.8. Lighting System

The minimum illumination in each area should comply with the CIBSE standard. The data hall module meets the illumination requirements of 500 lux. The power module and cooling module meet the illumination requirements of 300 lux. The corridor module and staircase module meet the illumination requirements of 150 lux.

Intelligent lighting is provided for data halls, corridors, and staircases. The lights in a pre-fab. module turn on when people come in to the module and turn off when people walk out. The lights in the power module are controlled by panel switches, instead of intelligent lighting.

Intelligent lighting in a data hall is implemented by the module-level ECC800. Aisle lights are controlled under camera linkage. When the camera in the data center detects people, the intelligent lights are steady on. If the camera detects no person in the data center, the intelligent lights are off. You can set the delay time to turn off the lights.

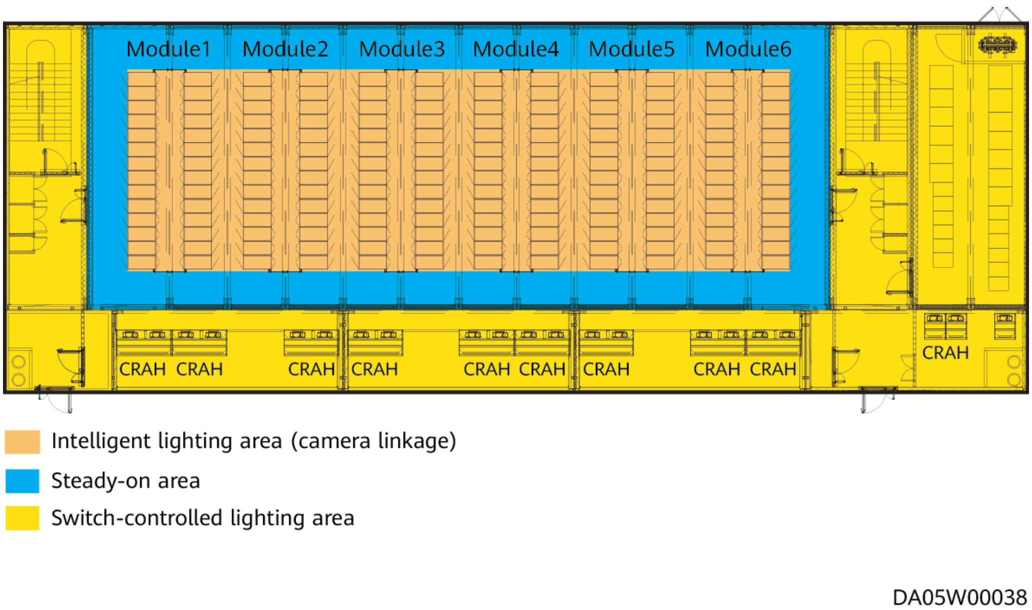


Figure 5-22 *Lighting in the chilled water fan wall scenario*

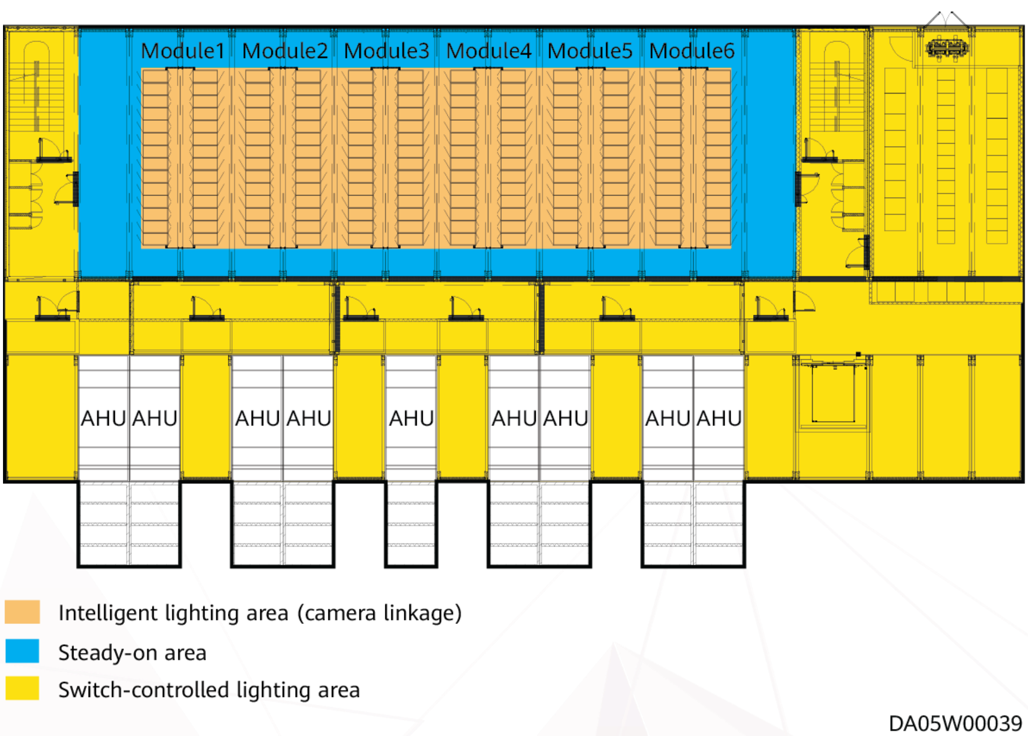


Figure 5-23 *Lighting in indirect evaporative cooling scenario*

5.9. Lightning Protection and Grounding

5.9.1. Building Lightning Protection

Foundation piles should be used as ground electrodes, and foundation reinforcement meshes should be used as equipotential bonding conductors. The hot-dip galvanized flat steel should be laid along the outer wall as the lightning protection downleads that are properly connected.

The upper part should be welded with the roof lightning strip, and the lower part should be welded with the ring grounding flat steel and grounding test point. All the steel structures of containers should be reliably connected to form an electrical path.

The ground resistance should be at least 10 ohms.

5.9.2. Indoor Grounding

The main earthing terminal (MET) installed in the power module is connected to the ground grid outside the data center over ground downleads.

Racks should be equipped with ground busbars. The busbars should be connected to the MET through ground cables. The ground cables of the racks should be at least 16 mm2.

Smart cooling products and PDFs should be connected to ground busbars over ground cables.

Equipotential bonding should be applied for non-live metallic components such as doors, cable trays, and ESD floor supports in the smart modules, using equipotential cables with a cross-sectional area of at least 6 mm2.

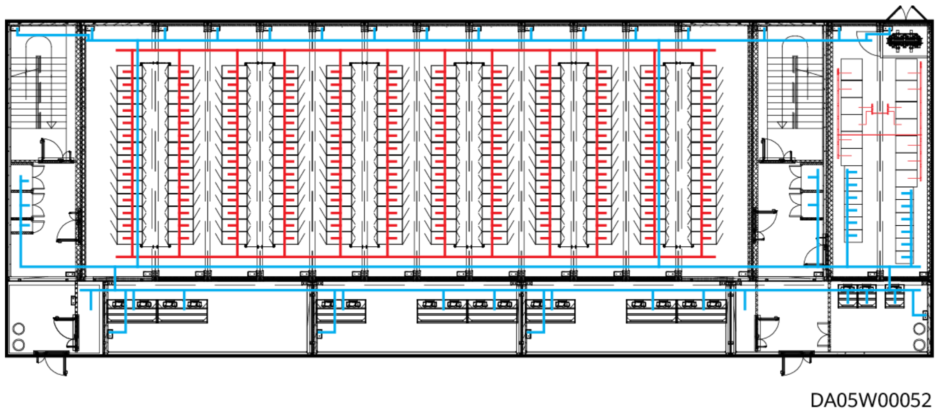


Figure 5-24 *Grounding system layout in the fan wall scenario*

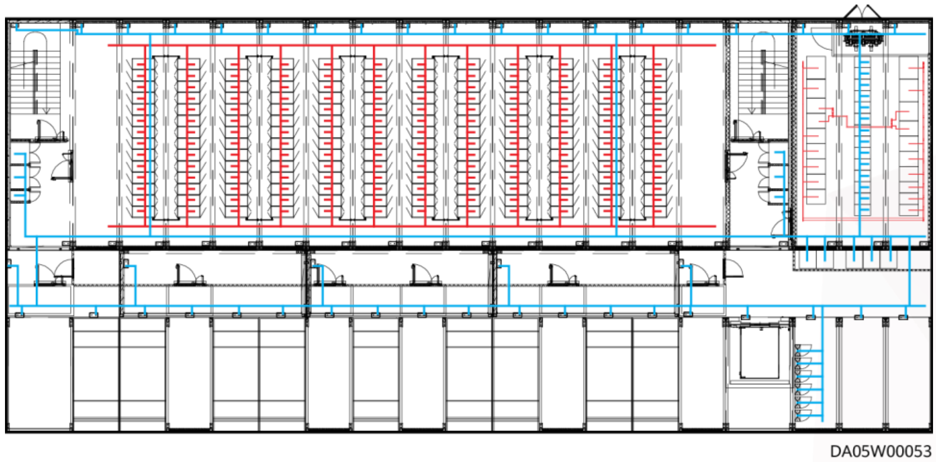


Figure 5-25 *Grounding system layout in the IEC scenario*

5.10. Cabling

Cable trays on the top of a prefabricated modular data center should be separate from cabinets, and can be moved horizontally along the width direction on the top of pre-fab. modules. Cables in the data center should be suspended overhead. Electrical and ELV cables should be separately routed. The electric cables should be arranged on cable trays, optical fiber cables on optical fiber troughs, and ELV network cables on enclosed cable troughs or mesh cable trays.

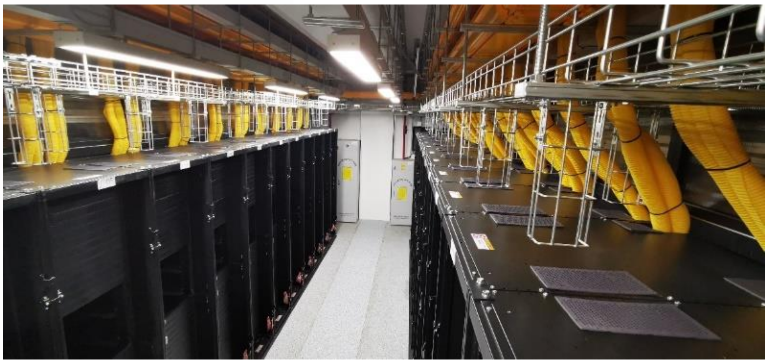


Figure 5-26 Cable Tray

Figure 5-27 Bus way

The racks and smart busbars should be interconnected using industrial connectors, which are plug-and-play and easy to maintain.

The electrical and ELV cable trays and busbars should be prefabricated in the factory. The electrical cable work is implemented onsite. The ELV cables such as network communication cables and optical fiber cables are deployed onsite.

5.11. Capacity Expansion

5.11.1. Basic Principles

The modular design of next-generation prefabricated modular data centers enables flexible and fast capacity expansion and on-demand construction, effectively reducing the Day-1 investment and OPEX and minimizing the waste of resources caused by excessive configuration.

The next generation prefabricated modular data centers support both horizontal and vertical capacity expansion. When designing a data center project that requires capacity expansion, it should consider the initial capacity and reserve space for the subsequent capacity expansion.

5.11.2. Horizontal Capacity Expansion

If the campus size permits, it is recommended to expand the capacity in horizontal way and by phase. Each data center POD works as an independent Phase. The standard POD can be rapidly replicated to implement capacity expansion and build a data center complex.

Figure 5-28 Horizontal capacity expansion

5.11.3. Vertical Capacity Expansion Scenario

When local government regulation permits and engineering ability allowshe next-generation prefabricated modular data center support vertical capacity expansion with architecture of One DC One Floor. Each floor works as an independent DC. It expand the capacity by adding floor without interrupting the existing service running.

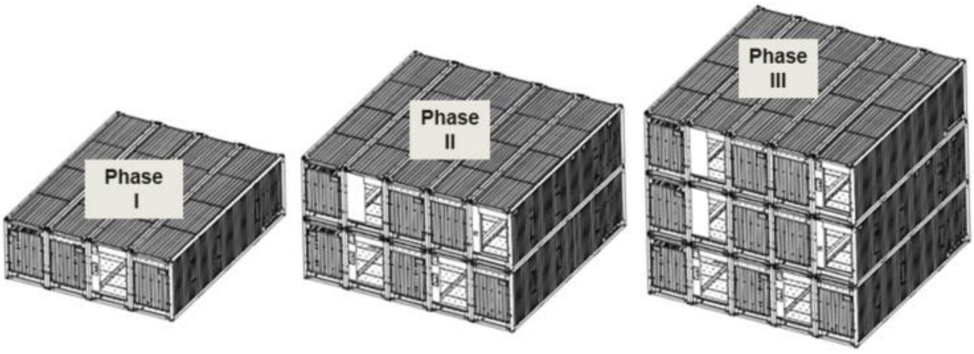
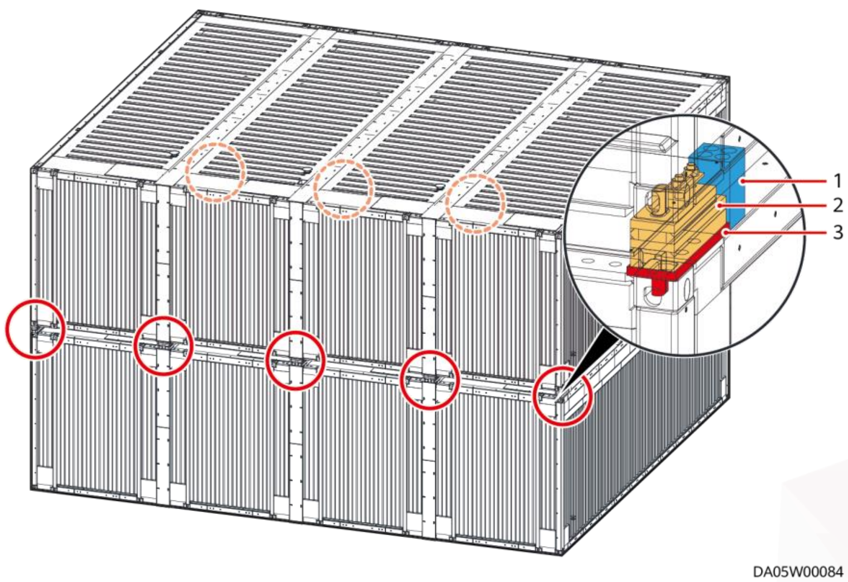


Figure 5-29 *Vertical capacity expansion*

If the data center requires vertical expansion by adding floors, the future equipment weight and foundation bearing capacity should be considered in the initial design . The height of the platforms, staircases, and elevators of the new floors as well as the top awnings of pre-fab. modules should also be considered.

Sufficient space should be reserved for adding pipes and cables. For example, space for cable trays and troughs or cabling paths should be reserved for new cables in the power system. Pipes and ports should be reserved in the HVAC system.

For vertical capacity expansion, special capacity expansion kits should be installed for hoisting pre-fab. modules. Capacity expansion kits allow modules to be quickly hoisted and connected while reducing hoisting shocks during vertical expansion. Lower-layer devices are not interrupted during the expansion.



(1) Capacity expansion kits - buffer (2) Capacity expansion kit- connecting piece (3) MM plate

Figure 5-30 *Vertical capacity expansion*

The power module and IT equipment area are deployed on the same floor. The gensets are deployed close to the power module. Power supply is provided for the data center on each floor. Each floor is equipped with a centralized ELV room, which is connected to the network management center by floor.

5.12. Full-Lifecycle Digitalization

The next-generation prefabricated modular data center pre-integrates various intelligent sensors and monitoring facilities. BIM ,DCIM, digital twins and AI technologies a are deeply integrated. Such integration enable the intelligent planning and design, prefabrication, construction, delivery, O&M, and optimization and brings digitalization throughout the entire lifecycle.

5.12.1. Digital Design

5.12.1.1. BIM 3D Design

Data center is complex and involve a variety of devices. The BIM 3D design leads to digital and visualized design, dramatically improving design efficiency. 3D visualization design facilitates collaborative development and data correlation and visibility across different domains. The solution detailed design, layout, piping, and cabling routes become fully visible. The solution presentation become more intuitive and efficient, and information can be transferred more accurately. The design quality is significantly improved compared with the 2D design.

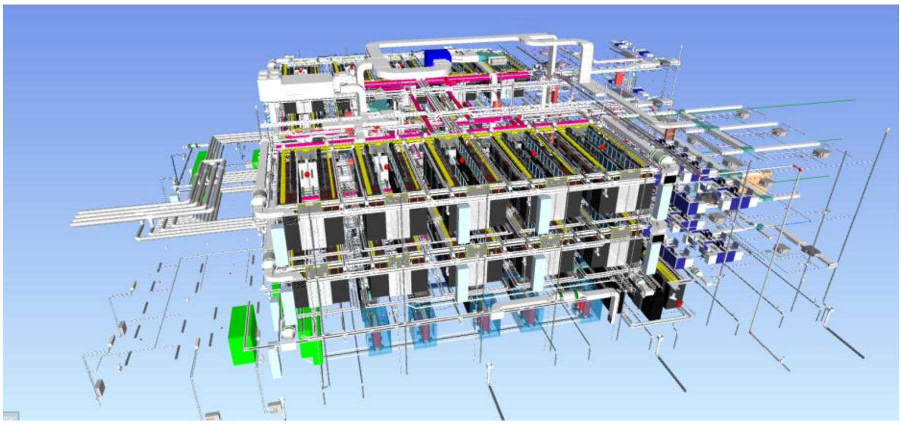


Figure 5-31 BIM Application

The BIM design can accurately locate devices, cable trays, and pipelines in the design phase, identify cabling routes and piping interference, and assist in design optimization. BIM design will reduce the potential design change dramacitally. It will then reduce construction rework and rectification, avoid the waste of materials and labor, and minimizes cost increase and schedule delay due to design changes.

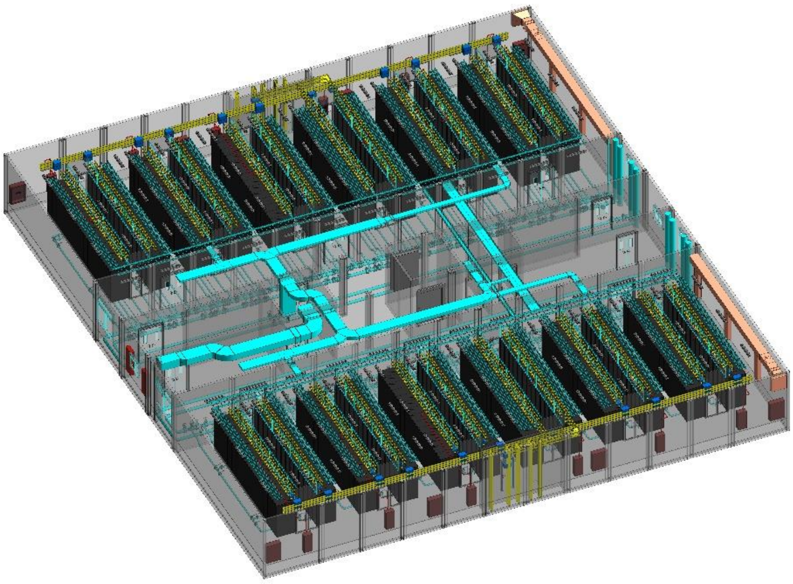


Figure 5-32 BIM Drawing

5.12.1.2. Digital Design PUE Optimization

The next-generation prefabricated modular data center solution adopts specific digital platform to the climate database, device efficiency database, and expert experience database to perform big data analysis, and implements full-scenario simulation calculation based on actual project conditions. The designed PUE can be implemented under different loads and environments, and optimization suggestions are proposed based on online diagnosis by experts. The designed PUE is reliable and feasible.

5.12.2. Digital Production and Delivery

Digital production control is implemented for module prefabrication in the factory. All pre-fab. modules are controlled by the QR code system. Each module corresponds to a code. The whole production system process is monitored. The status and results of production and quality are visible, manageable, and controllable in real time, ensuring high-quality and efficient production and standardized delivery.

Quality check standards, including test reports, certificates, and associated operation guides and process guide photos, are digitalized and template-based. Production management personnel track quality based on the templates to ensure delivery quality.

Figure 5-33 One code for one pre-fab. module, digital control for module prefabrication

Figure 5-34 Production status and process visualization

5.12.3. Digital O&M

5.12.3.1. Digital Twins and 3D Visualization

Based on the digital twins technology, the DCIM performs full-scenario 3D virtual simulation for the physical environment (buildings, equipment rooms, and devices) of a data center. 3D visualization enable to display data center alarms, equipment room capacity, temperature maps, inspection, security protection, low-voltage switchgears, mechanical, electrical, and plumbing (MEP), and network cables in real time.

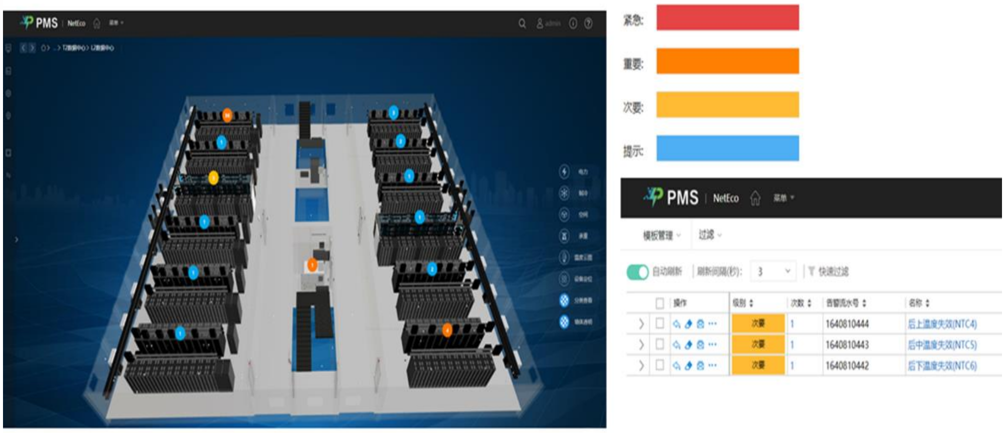


Figure 5-35 *Data center alarm status in real time*

Figure 5-36 *Visualization of power, cooling, space, and load-bearing capacity*

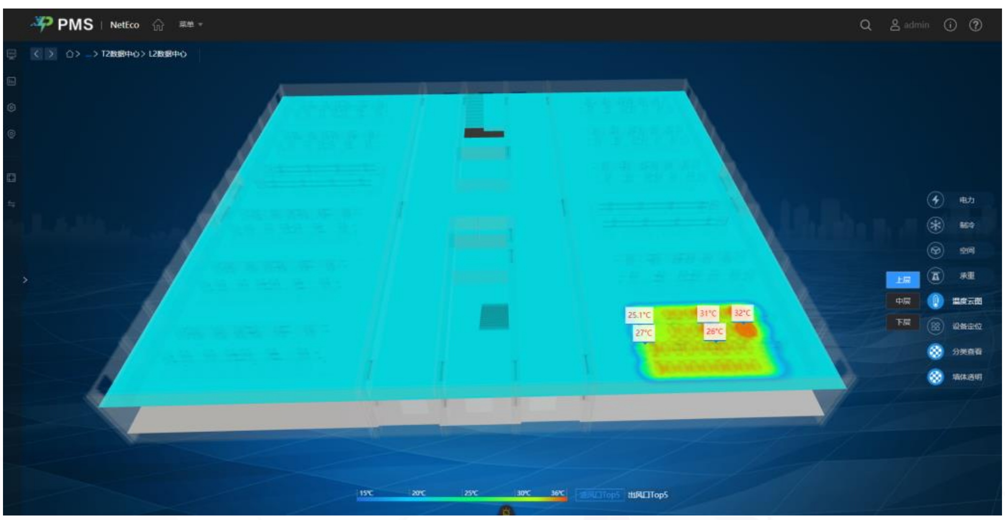


Figure 5-37 *Visualization of power, cooling, space, and load-bearing capacity*

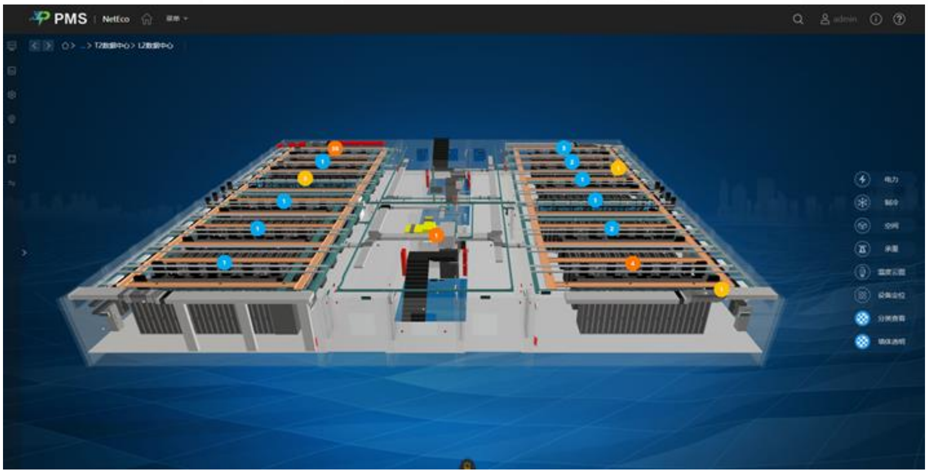


Figure 5-38 Real-time visualization of fire extinguishing pipes, cooling pipes, and power distribution lines

5.12.3.2. Full-Link Visualization

The system displays the topology of key components of subsystems, visualizes all links of the cooling and power systems in real time, and helps quickly locate and analyze faults, improving O&M efficiency and quality..

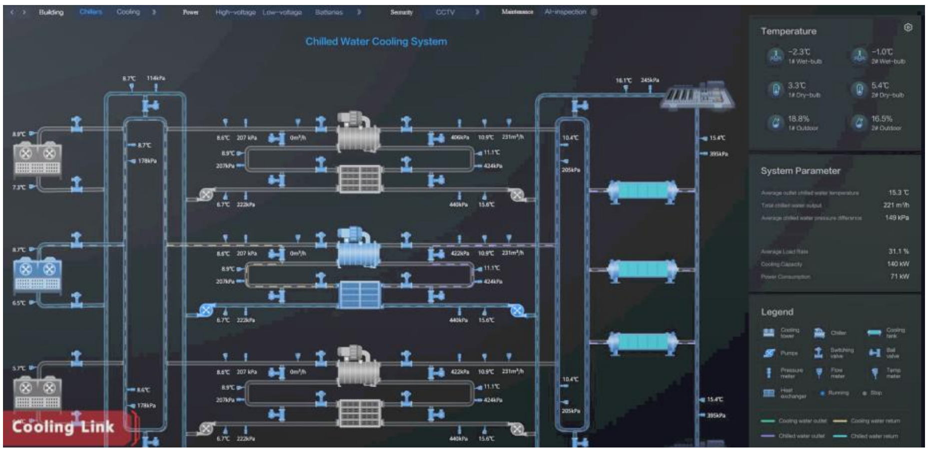


Figure 5-39 Cooling link visualization

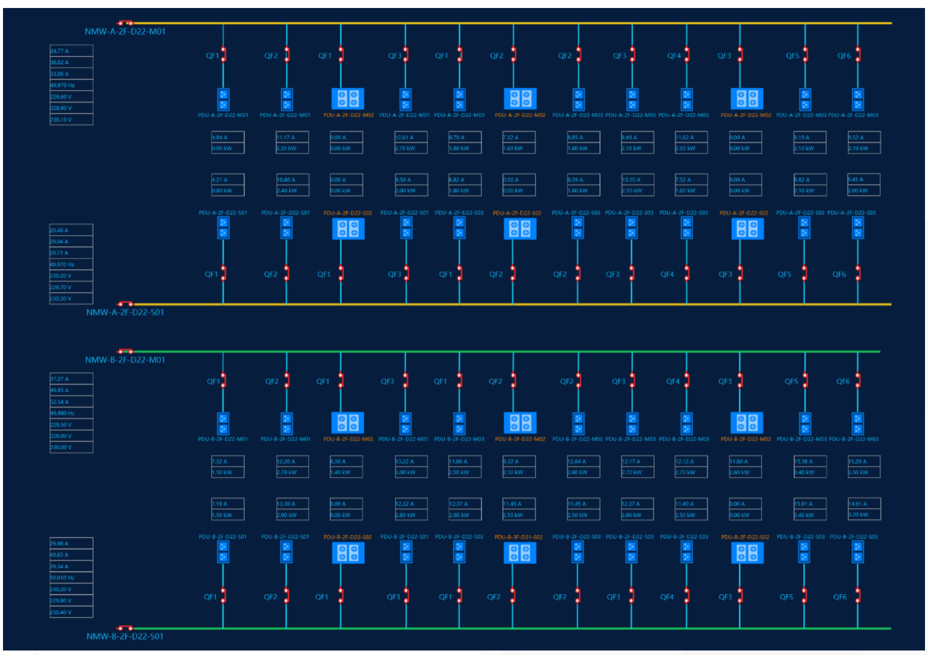


Figure 5-40 Power supply and distribution link visualization

5.12.4. AI-enabled Energy Efficiency Optimization

A prefabricated modular data center uses AI technologies to connect multiple links, such as the cooling source, air conditioner teamwork control system, and IT service system, to implement precise and on-demand cooling, centralized management, optimization control, automatic adjustment, and real-time adjustment of cooling system parameters. In this way, the cooling capacity of the system meets the IT load requirements, and the E2E energy efficiency is optimized in real time. This feature reduces the energy consumption caused by excess cooling, the energy consumption of the cooling system, and the PUE of the data center.

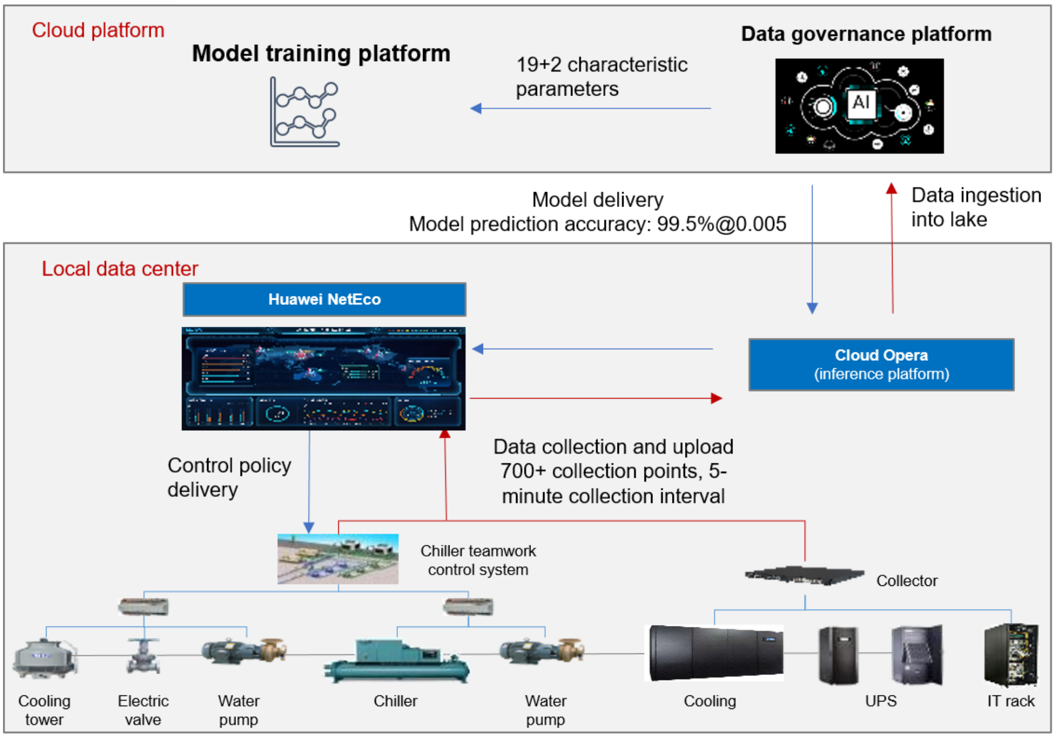


Figure 5-41 AI energy efficiency optimization

5.12.5. AI-enabled Predictive Maintenance

A prefabricated modular data center uses the integrated power module with over 200 built-in temperature measurement points to monitor link operating temperatures in real time. The AI temperature prediction algorithm based on a deep neural network can model multi-dimensional parameters such as IT load, environment parameters, and running status to implement dynamic temperature prediction and warning of key nodes. In addition, all links are visible and manageable. Data such as the logical architecture, switch status, running parameters, and node temperature is clearly displayed. AI-enabled featured are supported to implement predictive maintenance for improving system reliability.

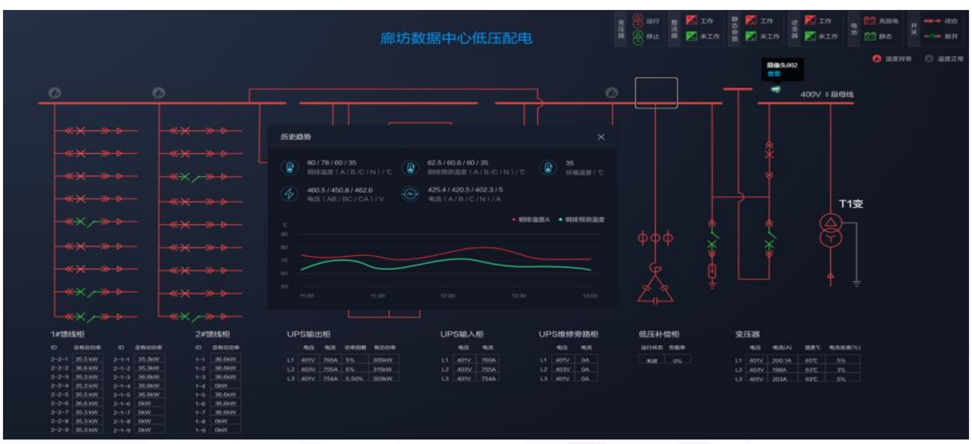


Figure 5-42 AI-enabled predicative maintenance

6. Advantages of Prefabricated Modular Data Centers

6.1. Construction Period

In the traditional construction mode, planning and design are followed by many tasks such as civil construction, external and internal electromechanical installation, subsystem commissioning, system joint commissioning, trial running, and acceptance. The construction period is long. For example, a 1000-rack data center in China is constructed in the traditional way. It takes more than 18 months to complete the while process ranging from planning and design, civil construction to final acceptance (excluding design and government permit application)..

If the prefabricated modular construction mode is used, most of data center facilities are prefabricated in the factory, and onsite civil construction is performed simultaneously, greatly shortening the construction time. In addition, all functional modules are pre-commissioned before delivery, reducing the onsite commissioning time. For a data center of the same size, with reference design of prefabricated data center the design takes 6 to 9 months(excluding design and government permit application). The rollout time is halved.

6.2. Green and Low Carbon

In traditional reinforced concrete construction, a large number of wet-method operations are involved, which wastes much steel and cement onsite, consumes a large amount of resources including construction water, and generates a large amount of dust, waste gas, and construction waste, resulting in a large amount of carbon emissions during construction. In addition, the recovery rate of traditional building materials is less than 30%.

On the contrast, the onsite construction workload of a prefabricated modular data center is only 10% of that of the traditional mode. The construction does not involve wet-method operations and minimizes waste during construction. The field project estimation shows tahts the construction water and waste could by reduced by 80% compared with the traditional mode. In addition, as the main body of the structure is made of steel, the material recovery rate exceeds 80%. The carbon emission of prefabricated modular DC construction is much lower than that of traditional reinforced concrete.

The entire lifecycle of prefabricated modular data centers is digitalized. In the design phase, the designed PUE that can be implemented under different loads and environments is calculated through big data and full-scenario simulation, and optimization suggestions are proposed based on online diagnosis by experts. Meanwhile, optimal piping and cabling routes are designed to reduce the heat loss, and the optimal design scheme is proposed. In the delivery phase, various AI energy efficiency optimization sensors are pre-integrated in advance to support the E2E energy saving solution, achieving high efficiency across all links and a low value of PUE. In the O&M phase, the cooling system parameters are adjusted in real time based on AI algorithms to keep the output cooling capacity of the system consistent with IT loads, achieving better PUE than traditional building data centers and a green and low-carbon level throughout the lifecycle from construction to operation.

6.3. Performance and Quality

Data center systems are complex. The quality of construction and installation has impact on the data center performance. In the traditional construction mode, all systems are integrated onsite, and there are many construction interfaces. Ventilation, fire, water, and power systems are constructed separately. The construction quality depends on the skill level of onsite workers. If the room airtightness deviates greatly from the design and the delivery quality is unstable, the data center performance will be unpredictable. In addition, many design changes affect the subsystem coordination, temperature field, and system operating environment. A number of factors can cause the actual value of PUE to be higher than the designed value. Later system installation and commissioning also affect future intelligent O&M.

The prefabricated modular construction mode implements product-based solutions, E2E system design, and full-scenario digital PUE simulation based on big data. The PUE is reliable and feasible. Prefabricated modular data centers adopt standardized production, product-level dimensional tolerance control, and optimal module sealing and air leakage rate design. Various subsystems are pre-commissioned in the factory, ensuring good system coordination. Prefabrication and standardized design reduce design changes and onsite human interference, improve delivery quality, and ensure overall system performance. In prefabricated modular construction, intelligent sensors for AI energy efficiency optimization can be preintegrated, and intelligent feature optimization tests can be performed in advance to ensure E2E coordination and early optimization. The mode makes performance stable and minimizes the deviation between the actual operation and designed values of PUE.

6.4. Delivery Mode

Traditional data center construction contracting is a kind of fragmented management. The design, equipment and material supply, construction company, supervisor, and owner are all responsible for the finished products of a construction project. The responsibility matrix is complex and the project management workload is heavy. In addition, design, procurement, and construction are separate from each other, and design changes are prone to occur during the construction phase, which increases the cost and project duration and affects the overall delivery quality.

E2E delivery of a prefabricated modular data center minimizes onsite construction and simplifies project management. It effectively overcomes the restrictions of design, procurement and construction, bridges all these processes, and reduces the uncertainty of schedule, cost and quality.

6.5. Quality Consistency

In traditional data center construction mode, the construction quality depends on the technical and management level of the construction company. If multiple data centers are constructed on a campus or in different locations or data centers are constructed in several phases, their construction quality may vary due to different construction quality and many uncontrollable factors. As a result, the quality of the entire campus is not standard, which poses challenges to unified O&M of data centers in the future.

A next-generation prefabricated modular data center is deployed with product-based construction, fully modular design, standardized batch production, digital production, quality control, and unified quality control. Multiple data centers can be built in a standardized manner by replication so that the deployment quality, performance, and O&M of the entire campus and multiple locations can be kept consistent.

6.6. Adaptability to New Technologies

Traditional construction is time-consuming, and infrastructure planning is based on prediction on the development trend of IT and computing power in two to three years. Inappropriate planning will cause a data center to be out-of-date once it is constructed. If there is a need to adapt to new infrastructure technologies, large-scale reconstruction is unavoidable or a new data center need to be built, making it difficult to maintain technological leadership.

Traditional prefabricated data centers are usually constructed using freight containers. Due to space and design limitations, they are mainly used as small- and medium-sized data centers. The cooling solution adopted is air-cooled DX or in-row chilled water. A next-generation prefabricated modular data center integrates prefabricated building technologies. The space and usage experience are similar to those of buildings. It can be adapted to various solutions, such as air cooling, water cooling, in-row cooling, fan wall, and IEC. Industry-leading prefabricated modular data centers have begun to adapt to next-generation power supply solutions, such as lithium batteries and integrated power module, improving the rack availability and technological leadership.

Next-generation prefabricated modular data centers can be deployed 50% faster than traditional ones, minimizing the impact of future technology applications and avoiding uncertainty in planning. In addition, the product solution supports technology iteration that applies the latest technologies rapidly to maintain industrial and technological leadership of data centers.

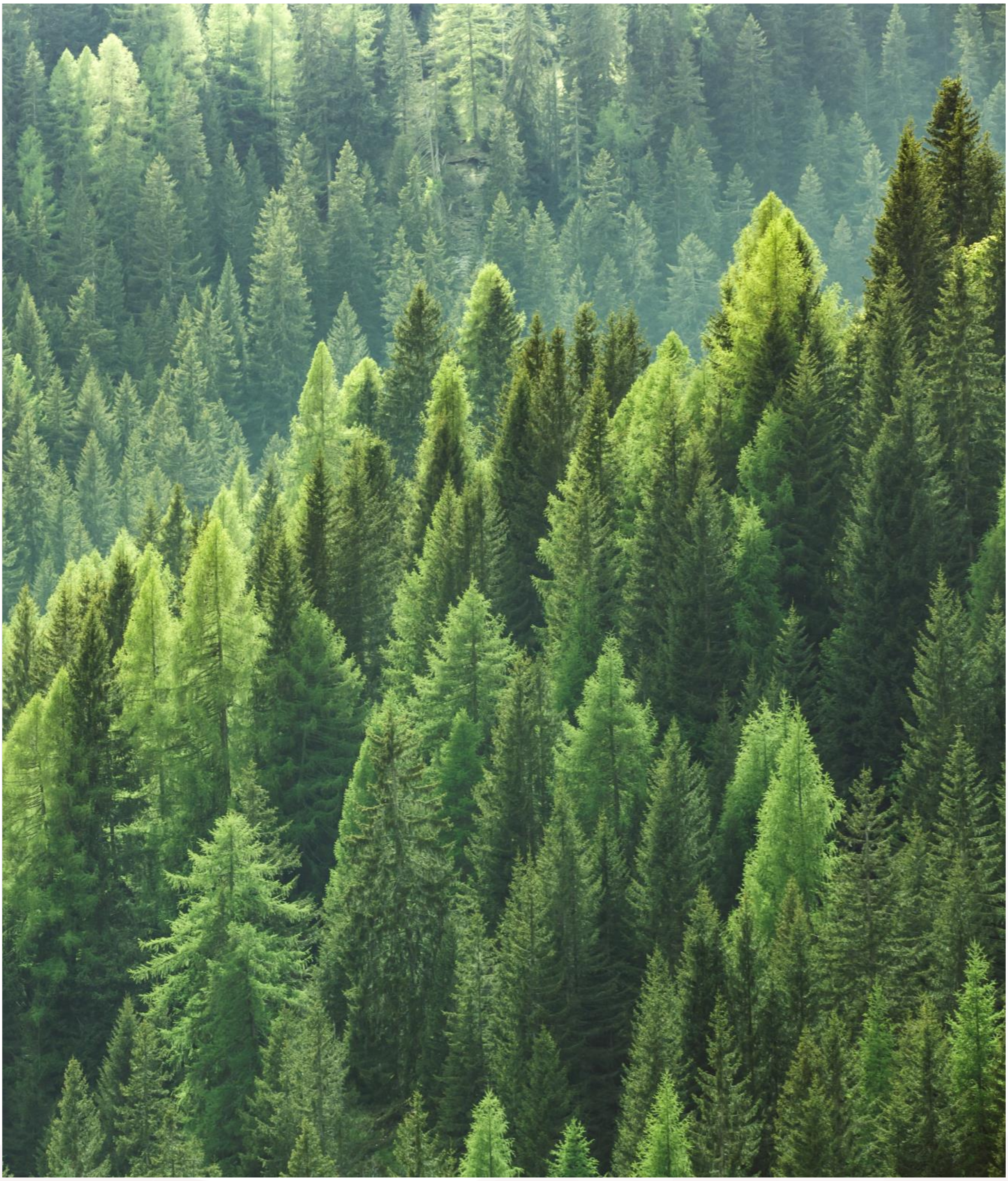
6.8. Rack Deployment Space

The floor height of a traditional building data center is more than 5 m, while that of a prefabricated modular data center is 4.15 m. If the building height is the same, more floors can be built with the prefabricated modular DC solution. For instance, if the building height is limited to 24 meters, a maximum of four floors can be constructed for a traditional reinforced concrete building, but five floors can be constructed for a next-generation prefabricated modular data center, improving land utilization and leaving more space for racks.

In addition, the prefabricated modular data center adapts to integrated power module and lithium batteries, which greatly reduces the footprint of the power distribution area. For example ,for a data center with power density of 6 kW/rack, total floor area of 72,000㎡, and 2N architecture, the rack deployment space is around 1028 racks for 4 floors , but that of a next-generation prefabricated modular data center can reach around 1200 racks with 5 floors , which is 15% higher than the traditional solution.

7. Summary and Prospect

As technologies evolve and converge, prefabricated modular data centers deliver equivalent usage experience as traditional building data centers. Thanks to advantages such as fast construction period, green and low carbon, elastic design, flexible deployment, and full-lifecycle digitalization, prefabricated modular data centers will effectively help customers reduce uncertainties in terms of time, investment, quality, planning, and advanced technology adaptation, and build future-oriented data center infrastructure. With the constant improvement of modularization, standardization, and the industry chain, the next-generation prefabricated modular data center solution will become a mainstream data center construction approach for its widespread value across industries.



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