STUDY OF MODULAR DATA CENTRE DESIGN AND OPTIMIZATION OF CONVERGENCE DATA CENTRE POWER DISTRIBUTION

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A project report submitted in partial fulfilment of the requirements for the award of Master of Engineering (Electrical)

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December 2021

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been duly acknowledged. I also declare that it has not been previously and concurrently submitted for any other degree or award at UTAR or other institutions.

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APPROVAL FOR SUBMISSION

I certify that this project report entitled **"STUDY OF MODULAR DATA CENTRE DESIGN AND OPTIMIZATION OF CONVERGENCE DATA CENTRE POWER DISTRIBUTION"** was prepared by **TOO XIAO YE** has met the required standard for submission in partial fulfilment of the requirements for the award of Master of Electrical Engineering at Universiti Tunku Abdul Rahman.

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ACKNOWLEDGEMENTS

I would like to thank everyone who had contributed to the successful completion of this project. I would like to express my gratitude to my research supervisor, Dr. Chew Kuew Wai for his invaluable advice, guidance and his enormous patience throughout the development of the research.

ABSTRACT

Data centres are the backbone of internet such as web hosting, e-business and trading, and social networking. Today, modern business operations rely heavily on the internet and services IT. The increasing demand of is challenging the data centre operators to manage the data centre resources. The increasing trend of energy consumption in data centre comes from the IT systems such as server, storage, network and from the non-IT systems such as cooling system and power system.

The development of modular data centres has attracted a lot of attention due to their excellent stability, scalability and economic feasibility. This particular design meets the business requirements such as flexibility, shorter deployment time, high efficiency and effectiveness, and lower capital investment. This research paper focuses on the modified feature of mobility and modularity by data centres without any negative impact on the availability, capacity, efficiency, performance, and security function of data centres.

With the increasing workload of data centres, the power consumption is also increasing rapidly. Therefore, optimised power management for cooling system and power distribution in data centres is an extremely rewarding research area, especially for cooling system.

This paper is an overview of the evolution of data centre design, mechanical and electrical infrastructure of data centre, standards and compliance of different redundancy level of data centre, comparison of traditional data centre and modern modular data centre, as well as flexibility and scalability of modern data centre. In addition, several current challenges and future work in the data centre modular system are described.

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LIST OF SYMBOLS / ABBREVIATIONS

ATS	Automatic Transfer Switch
BMS	Building Monitoring System
CCTV	Closed Circuit Television
CFD	Computational Fluid Dynamics
CRAC	Computer Room Air Conditioning
CRAH	Computer Room Air Handler
DC	Data Centre
DCIM	Data Centre Infrastructure Management
EPO	Emergency Power Off
EMS	Environment Monitoring System
ESD	Electrostatic Discharge
FAT	Factory Acceptance Test
HVAC	Heating, Ventilation and Air Conditioning
IP	Internet Protocol
IT	Information Technology
LED	Light Emitting Diode
NFPA	National Fire Protection Association
NVR	Network Video Recording
ODF	Optical Distribution Frame
PDU	Power Distribution Unit
PUE	Power Usage Effectiveness
PVC	Polyvinyl Chloride Plastic Pipe
SPD	Surge Protection Device
STS	Static Transfer Switch
TVSS	Transient Voltage Surge Suppressor
UPS	Uninterruptible Power Supplies
VESDA	Very Early Smoke Detection Apparatus
VRLA	Valved Regulated Lead-Acid

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CHAPTER 1

INTRODUCTION

1.1 General Introduction

Data centre is a room space that been used to house the IT server racks and data. Its design is based on a storage resources and computing equipment that enable the process and connecting of shared technology information and data.

Data centre consists of routers, firewalls, servers, switches, information store system, and application controllers. That includes network infrastructure, storage infrastructure and computing resources.

The most common applied standard for a data centre infrastructure and design is Uptime Institute, organizations who owned data centre will normally aimed for compliance with one of four categories of data centre tiers rated for fault tolerance and redundancy level for their marketing purposes.

Modern data centres design is quite different and well developed as compared to decades ago. Also, the infrastructure has shifted from last time on-premises servers to virtual networks that support applications and usage across lots of physical infrastructure and into a multi-cloud environment.

With the rise in of energy costs and consumption, the efficiency of data centre solutions has become of great importance to businesses and developers. Due to the complexity of logistics and the high capital investment required to build a traditional data centre, this solution will no longer be able to keep up with the industry’s growth rate. Therefore, modular power construction is becoming the first choice for data centre expansion. It enables companies to keep up with the growth of the industry in a more efficient way.

Most of the types of data centre, regardless the size, or different requirement of availability, they are benefits from modularity.

1.2 Importance of the Study

The typically problems of data centres are the speed and budget for deployment. The traditional brick and mortar data centre takes higher capital cost and consume longer time to build, and the faster pace of evolution of supporting technologies has forced the organizations to work with scalable and fast modular designs.

The important of this study is to show the advantages that tagged along with the deployment of modular data centre in terms of design and construction, power density and PUE, scalability, efficiency, mobility and placement, as well as commissioning and operation, etc. that is able to lead the evolution and change of data centre industry from traditional to modern and easily deployable infra.

These modular facilities have also been improved so to provide cost-effective storage as well as comprehensive data management solutions for enterprises.

1.3 Problem Statement

Deployment of modular data centre in Malaysia is still yet popular compared to traditional data centre due to the limited choices in the market is available. The price of modular data centre is controlled by the limited suppliers. Also, the benefits of modular data centre are yet realized by developers and end users.

Lack of investigation and study to shows the comparison between modular data centre and traditional data centre has also led the lack of confidence to deploy modular data centre due to some of the accessories and equipment are mostly propriety by the sole manufacturer and the maintenance can be costly as well.

Hence, this study will focus on the benefits and advantages to employ modular data centre and comprehensive of data centre infrastructure will be introduced.

1.4 Aims and Objectives

The objectives of the project are to study the historical development of data centre, the main infrastructures in a data centre, and to evaluate current design of different types of modular data centre available. Besides that, the studies will mainly focus on the low power distribution for data centre as well as optimization of convergence data centre power distribution.

This study will cover evaluation of the evolution of the modern data centre power supply system and to study the modern busway system for Data Centre.

This research shall be focusing on low voltage power distribution for data centre to meet Uptime Tier I, II, III, and IV requirement and modular data centre.

1.5 Scope and Limitation of the Study

The scope of this study includes the mechanical and electrical infrastructure of a data centre, the importance, evolution and different types of data centres, from traditional to modern. It also discusses standards and requirements for data centres and explains them with real-world examples.

In general, the design of a data centre is determined by its components, and the power load profile also depends on the type and consumption of the components. For example, the overall power model and profile of a cooling system differ from a CRAH to a CRAC design. The location of the data centre also affects the overall design. If a data centre is located in a cold area for and uses natural cold air for heat transfer, the cooling system may only consist of a few fans for ventilation.

As with the majority of studies, the design of the current study is subject to limitations. Firstly, due to the limitation of time for this study and lack of actual information and resources of the actual user feedback on the modular data centre, the data collection and actual user feedback to have a comprehensive understanding how modular data aids and benefits the organizations versus the traditional data centre is difficult to be accessed and is extremely limited.

Secondly, limited access to various products detailed design and information has also limiting the expansion of this study. The scope of the discussions is large, and due to lack of experience in the field, I am also not in a position to independently research and write academic papers of such scope. Therefore, the scope and depth of the discussion in this paper will be limited on many levels as compared to the work of more experienced scholars.

1.6 Contribution of the Study

The purpose of this study is to gain an in-depth understanding on what is a data centre and what is the modern design of data centre.

Data centres are facilities with high increasing of demands as well as significant contribution to the world's power consumption. Deep study and fully understand the components within a data centre and their energy consumption is very vital to achieve better efficiency of their consumed energy within the data centre.

As businesses become more data-driven, demand for ready access to computing power continues to expand. Due to this climate, data centres are in extremely high demand. However, setting up a data centre is not a trivial task. In addition to constructing a secure building, the developer has to install cooling systems, wiring, redundant power, high-speed data connections, and more, the business may be losing its competitive edge due to lack of access to critical data and analytics if the developers are waiting for that "new" data centre. Hence the shorter the period to start up a data centre, the sooner the business can make data-driven decisions. This is the main reason modular data centre come in place.

Modular data centres deliver the same quality and capabilities at a lower cost, and in a fraction of the time. That's why more businesses are adopting prefabricated modular data centres for business-critical applications.

This is descriptive research, with this research, importance of data centre, importance of power distribution within a data centre and the modern expectation of deployment a data centre by an organization will be brought out.

1.7 Outline of the Report

In Chapter I, general introduction of the research with the importance of this study, problem statements, aims and objectives as well as scope and limitation of the study will be introduced. The key contribution of this study arises from the application and refinement of data centre in order to understand the interplay between traditional data centre and modular data centre at the design stage and deployment stage.

In Chapter II, the literature review will introduce the abstract of this study, emphasizing of the importance a data centre to modern days will be interpreted as well. When comes to Chapter III, the research methodology and work plan will be identified. This chapter also outlined the evolution of data centre, types of modern data centre, main infrastructure of data centre, data centre Tier Topology and standards, data centre standard and compliance. Chapter III also discuss the power usage efficiency of a data centre, in this chapter, calculation of PUE will be discussed and demo.

The case study with Uptime Institute Tier Topology and modular data centre continued with the topic of Chapter III. In Chapter IV, a data centre with total 10 nos. of 3kW racks will be used as based design to implement the calculation and design of the power and cooling infrastructure of a data centre. With this case study, a deep understanding between traditional data centre design compared to modern type of modular data centre. In-depth discussed of benefits of modular data centre will be analysed as well. The findings of the case studies were interpreted and results of comparison between different Tier of data centre and modular data centre will be discussed

At the final part of this report, conclusion and recommendation will be presented in Chapter V.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The rapidly growth of the use of internet throughout the world has also increase the demand of the support infrastructure of Internet Technology. While data centre is the scaled infrastructure that house all the equipment and servers of IT system, optimize the design and usage of data centre is become knowingly important and interesting.

Optimize the total efficiency and spaces to build a data centre has become the main concern of a developer throughout their planning to build a data centre is made to serve their business purpose. This paper has reviewed and discussed the evolution of data centre, types of modern data centre, main infrastructure, standard and topology of a data centre design, as well as case study to compare the traditional data centre compared to the modern type of data centre. This report will conclude that the evolution of data centre from the traditional to the latest modern type has bring benefits to the data centre industry and it is believed that further improvement and enhancement of the design will still be brought to the industries and user.

2.2 Literature Review

The importance of computers has initiated the observers to investigate the unintended consequences of their use. It is found that the amount of electricity used by computers and related IT equipment has caused severe environmental impact compared to other factors.

Data centres are typically designed based on peak workload but actually run at lower capacity most of the time. As the actual usage can be varies daily, weekly, monthly, and even yearly. It is abnormal the data centre will run at their highest capacity; the traffic normally can be satisfied by the portions of the network links and switches.

Modular data centres are a portable and convenient solution for increasing data processing capacity as and when they are required, in the meantime they deliver huge power availability within a relatively small footprint and within a short timeframe. Besides that, a quality of a modular data centre is controlled as they are built and tested within a controlled environment and will be shipped to site and ready for immediate installation.

Building modular data centres off-site has significantly shortened project lead times because all systems can be pre-assembled and tested simultaneously during construction of the developer's building.

In addition to the relatively short lead time, another significant advantage of modular data centres is that they are cost effective, due to their flexibility, simplicity, and security.

It is concluded that the efficiency achieved by the modular data centres simply cannot be compete with traditional brick and mortar construction. The flexibility and benefits of modular construction can simplify and shorten the timeline of data centre projects from planning to commissioning.

2.3 What is Data Centre?

A data centre is a building, a space used to house technology systems and associated accessories such as telecommunications, storage as well as IT system. Data centre operations generally include compute, storage and networking from IT.

Compute is defined as the storage and processing power to run the applications, while the storage of important business data is done one media such as tapes or drives. Last but not least is the network that provides the connections between the data centre components and the outside world, including switches, routers, application delivery controllers, and more.

An IT system needs these to shop and manage the critical resources that are essential to the continuous operation of a business. Because of these functions, data centre reliability, efficiency, security, and continuous evolution are top priorities.

The power consumption of a super-scale data centre can be as high as that of a small town.

2.3.1 Importance of Data Centre

Nowadays, as the world moves towards to the web, fast information is needed by users and businesses. As compared to just a few decades ago, when the society was entertained with just old television broadcasts with not many channels to select, even communications between people are as simple as snail-mail is well accepted. However, due to the rapid improvement nowadays, fast and quick information is demanded.

Nowadays as internet became an everyday necessity, most of the people spent most of their waking hour connected online. It can be for work, interaction and communication, this is why the demand for real-time data transmission is a lot higher than former time. This is one of the reasons of catalyst for the evolution of modern data centre.

It is noticeable that the closer a company is to a data centre, the higher the performance of the service. The distance between a data centre and the businesses or users can vary depending on the type of business. Some data centres, such as those for gaming or financial trading, need to be close to the user or business. Other data centres may be located in the Arctic Circle etc., to take advantage of lower energy costs for cooling.

CHAPTER 3

RESEARCH METHODOLOGY AND WORK PLAN

3.1 Research Methodology

This research will be based on existing information that is available online, products brochure that are commonly used in Malaysia, case study the design of a data centre based on different Uptime Tier Standard, and the PUE comparison between a traditional data centre compared to a modular data centre.

The research method includes but not limited to desk research, surveys, case studies, and so forth. The scope of this research will cover the importance of data centre, evolution of data centre, types of data centre, main infrastructure, mechanical and electrical services in a data centre, as well as comparison of traditional data centre versus the modern type of modular data centre.

A case study will be used to describe the different Tier standard of data centre and compare to a modular data centre. As case study research design is good for describing, comparing, evaluating and understanding different aspects of different standards and types of data centre.

Upon completion of this research, reader will have an overall comprehensive understanding of what to be considered before a data centre is being deployed.

3.2 Research Work Plan

	May 21	Jun 21	Jul 21	Aug 21	Sep 21	Oct 21	Nov 21	Dec 21
Research & Review Evolution of DC								
Analysis & Evaluate Current Design of Different Types of Modern DC								
Research & Review of Overall Main Infrastructure of DC								
Research & Study DC Tier Topology & Standard								
Research & Study PUE of DC								
Research & Study Modular DC								
Case Study of DC Design based on different Tier Topology								
Research & Study Comparison of Traditional vs Modular DC								
Conclusion and Recommendation								
Report Writing								
Review and Improvement of Report with Supervisor								

3.3 Evolution of Data Centre

In 1942, the first electronic digital universal computer was born. Before 1990, data centres were mainly used for government and scientific research applications, but seldom for commercial application. Data centres were large yet few.

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

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

Within the period of year 2000-2018, at the beginning of the period, it was realized that major parts of maintenance issues are due to the low power efficiency of a data centre. High power is demanded by the data centres. This started the research to improve the efficiency of the devise reduce consumption.

In 2002, Amazon launched its AWS web services, which include cloud computing, storage and more. Ten years later, 38% of Amazon's business was already in the cloud.

Since 2012, the data centre has been evolving into a new client-server model based on a subscription called cloud services. This model is preferred by small business or enterprises as it can minimise their capital costs. Here, a third party is responsible for the maintaining and upgrading the hardware resources and providing IT support. So, the company does not have to invest in expensive hardware and does not have to upgrade its own data centre or server rooms regularly.

The application and widely use of cloud computing promote the transformation of data centre construction, operations management, and service modes. Cloud computing enables flexible expansion, dynamic allocation, and centralized management and control of data centres. The construction of cloud data centres creates new growth points and promote industry adjustment, transformation, and upgrade.

Small and medium data centres are constructed to be simple, easy to use, reliable, and controllable in operation and maintenance. Compared with traditional data centres, modular data centres have unparalleled advantages in four aspects.

Besides able to construct quickly and have low requirements on the deployment environment, modular products can be pre-integrated and pre-commissioned in the factory in advance. They also provide the intelligent management function.

For large data centres, the power density of information IT equipment is increasing. Modular data centres adopt in-row closely coupled cooling, which greatly improves the cooling efficiency. This adapts to the development trend of high-power density.

As the power consumption of data centres increase, a more efficient and energy-saving cooling system is required. With the rapid development in informatization, the construction of global data centres is accelerated. Their power consumption accounts for 1.1% to 1.5% of the global total.

Besides that, use of clean energy, such as wind and solar energy, is increasingly used in data centres. There is a call for saving energy and reducing consumption to reduce PUE of data centres. Inefficient data centres lead to high cost, and DCIM is of vital importance.

Manage and monitor IT equipment, facility equipment, and IT processes in a unified manner. Support resource management and asset management. Support technologies such as real-time information, simulation, and remote monitoring.

3.4 Types of Modern Data Centre

The types of modern data centre nowadays can be categorized into few and will be further elaborate.

3.4.1 Hyperscale Data Centre – Cloud Data Centre

A hyperscale data centre is a facility owned and operated by the company that supports it. Most well-known companies like AWS, Microsoft, Google, and Apple own their own hyperscale data centre.

They offer reliable and scalable applications and storage to individuals or businesses. A hyperscale data centre has a few hundred cabinets or more in an area of at least 10,000 square feet.

It usually has a minimum of thousands of servers connected to a high speed, fibre-optic count network.

3.4.2 Colocation Data Centre

A colocation Data Centres is a data centre that is owned by one owner but sells space, power and cooling to multiple business and hyperscale customers in its building or location. Colocation data centres provides a link interconnection to software as-a-service or platform as-a-service. This allows companies to grow and scale their business with minimal complexity and at a low cost.

Colocation companies offer technical advice to developers who are technically unsure of what they actually need or who are looking for a low-risk solution. Other forms of colocation facilities may have a slightly different pattern, with selected integrators providing technical design, guidance and specification for migrating customers. Depending on the size of the network requirement, the tenant may rent from one to hundreds of cabinets. A colocation data centre can house up to hundreds of individual customers.

3.4.3 Wholesale Colocation Data Centre

Wholesale colocation data centres consist of an owner selling space, power, and cooling to enterprises and hyperscale company, as with standard colocation. For this scenario, any interconnection is not an important requirement. These facilities are only used by hyperscale or large enterprises to house their IT equipment.

In most cases, wholesale colocation provides the space, power and cooling. A number of wholesale colocation companies also include standard colocation in the same locations in their portfolio when possible. Wholesale colocations typically serve fewer customers; depending on the size of the data centre, this can typically be fewer than 100 tenants.

3.4.4 Enterprise Data Centre

An enterprise data centre is a facility owned and operated by the enterprise. It is often built-on site but may also be located off-site. It may be that certain sections of the data centre are divided among different parts of the company.

An enterprise data centre is usually contracted to maintain mechanical and electrical services, but they operate the white space themselves by hiring their internal IT team. However, they hire other companies to do the setup and network installation before they are maintained by the internal setup team. An enterprise data centre can scale from ten cabinets up to as big as 40MW in size.

3.4.5 Telecom Data Centre

A telecom data centre is a facility owned and operated by telecommunications or service companies. This type of data centre requires high connectivity as they are built to deliver content, mobile services, and cloud services.

Generally, this type of data centre uses 2-post or 4-post racks for telecom. Telecom data centres hire their in-house maintenance team for installation and site management. However, some telecom companies choose to operate their data centre in a colocation data centre.

3.4.6 Edge Data Centre

Edge data centre is the new and latest classification of data centres. It supports systens for the Internet of Things, autonomous vehicles, and moving data and information processing closer to users. As 5G networks are the latest and emerging technology, supporting 5G networks requires much higher data transport. However, it is too prelim to predict the exact shape and scale of edge computing, but it is clear that there will definitely be a lot of fibre involved.

The main requirement of the varying network architectures is nothing but needing for higher speed, better performance, higher efficiency and flexibility to scale up or down. This is to serve the purpose for greater technologies, whether it be automation, artificial intelligent, social media, as well as streaming services. It will hence continually be pushing data centres to be more innovative and grow in order for us to continue move into a more inter data linked world.

3.5 Main Infrastructure of Data Centre

A data centre will include redundant components and infrastructure for power supply as IT operations are crucial for business availability. To support the full IT operations of a company or business, data centre will also associate with various data communication connections, environmental controls for example cooling system, fire protection system as well as various types of security devices. Besides that, power subsystems, UPS, backup generators and cabling works are also mandatory.

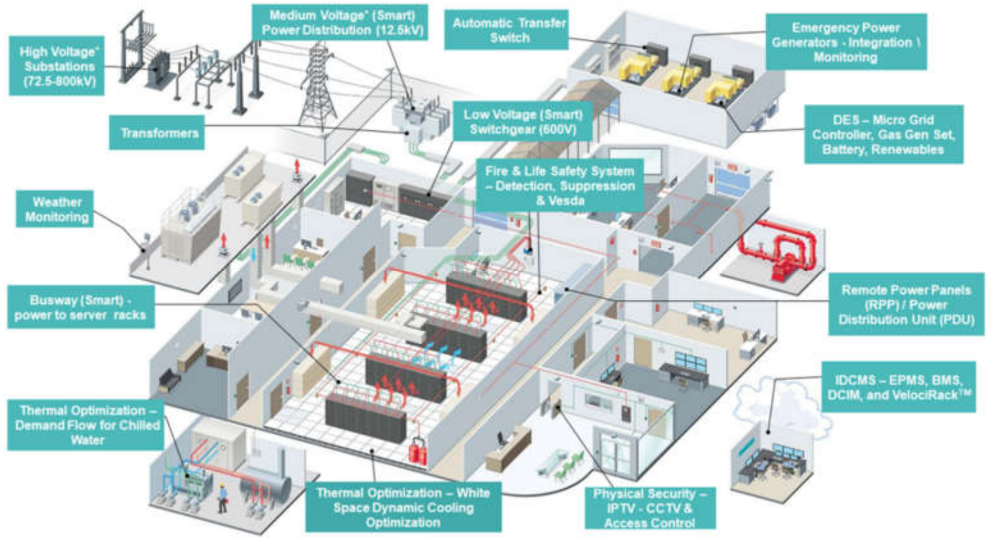

Figure 3.1: Layout Example of Traditional Data Centre

3.5.1 Power Supply System

The utility provides the primary electrical power source for the data centre. Ideally, more than one utility feeds should be given from different sub-stations or utility grids, this provision facilitate the power back-up and redundancy.

An emergency generator can be positioned to bear the load of data centre components, also all essential support equipment in case of power disruption.

A PDU is a device that distributes electric power by usually stepping down high voltage and amperage to the common rating required by the server racks. It is widely used in data centres. Some PDUs are equipped with remote monitoring, and control down to plug level features.

3.5.1.1 Diesel Generator and Automatic Transfer Switch

Standby generator is one critical equipment component that will electrically back up the system from power failure. A standby generator system consists of engine, prime mover, alternator, starter, and control and distribution panel that will be mounted together to form a single equipment.

ATS is one of the major components of a generator system. Besides that, generators also include a fuel tank and are equipped with a battery and electric starter.

Figure 3.2: Indoor Generator Set

An automatic transfer switch is applied to automatically switch to alternative power source in case of any power disruption from the original path. For example, if the existing utility fails, the automatic transfer switch will swap the incoming to be from generator power immediately within few seconds.

3.5.1.2 Uninterruptible Power Supply (UPS)

An UPS is a system that able to keep the continuity of power supply to the essential power load that can’t afford any interruption or shut down. It is installed between a primary power source and the primary power input of equipment that need to be protected. With the features of UPS, the sensitive equipment can be protected from any negative effects of any power outage or transient anomalies.

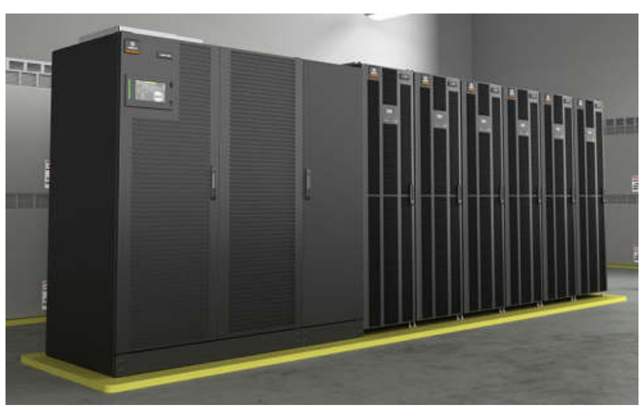

Figure 3.3: Uninterruptible Power Supply

An UPS is equipped with a Static Transfer Switch (STS), it is able to transfer critical loads between two independent power sources without interruption to the sensitive equipment.

3.5.1.3 Back Up Battery

The two common types of batteries that apply for an uninterruptible power supply are either Valve Regulated Lead-Acid (VRLA) or Lithium-Ion Battery.

VRLA is by far the most common found in UPS systems especially in Malaysia. They are typically designed for 5 or 10-year service life and need to be stored in a low humidity and temperature-controlled room. VRLA batteries are sealed inside a moulded case which come with built-in valve that will be able to release redundant gas when the internal casing pressure increase. Besides that, no direct maintenance is required for this kind of battery.

While Lithium-Ion batteries have commonly been used in all kinds of electronic devices such as smartphone, laptops, etc. But recently it is developed to take over VRLA batteries for data centre’s usage due to the inherit advantages such as higher reliability than traditional VRLA batteries because of built-in battery monitoring and management systems to update real time batteries performance, also smaller and lighter due to their high-power density. Besides that, faster charging time, longer cycles has caused the use of Lithium-Ion become more welcomed in data centre industries.

3.5.2 Cooling System

Heat is being generated whenever electrical power is being consumed. Especially in a data centre, mass quantity of heat is being generated by the IT equipment racks. Hence, it causes potential of significant downtime, the heat is needed to be removed from the space. In addition, inadequate cooling will also dictate the lifespan and availability of any IT equipment.

A typical data centre has six to eight times of the heat density of a normal office space, and the temperature can differ dramatically throughout that space. In addition, while a normal office space may require two air changes per hour to maintain temperature, a high-density data centre may require up to thirty air changes per hour. Humidity and temperature levels outside the recommended range can rapidly deteriorate sensitive components inside the computers making them vulnerable to future failures. The concept of proper cooling not only includes the supply of adequate cool air, but also should consider the distribution of that cool air, and the removal of hot air.

3.5.2.1 Precision Air Conditioner

Precision Air-Conditioners is cooling system that control the temperature, humidity more precisely than comforting cooling. It poses higher sensible heat factor that normally exceed 90%.

Precision air conditioners have higher cfm per ton compared to comfort cooling system, as well as higher sensible heat ratio, that is normally greater than 0.90. The system is designed for running 24 hours continuously, 365 days per year. Further to that, precision air conditioners come with inbuilt heater and dehumidifier to provide precise control over temperature and humidity in a data centre. It also comes with controllers for real time monitoring and temperature and humidity regulator. Last but not least, precision air conditioners are normally have higher efficiency of air filtration.

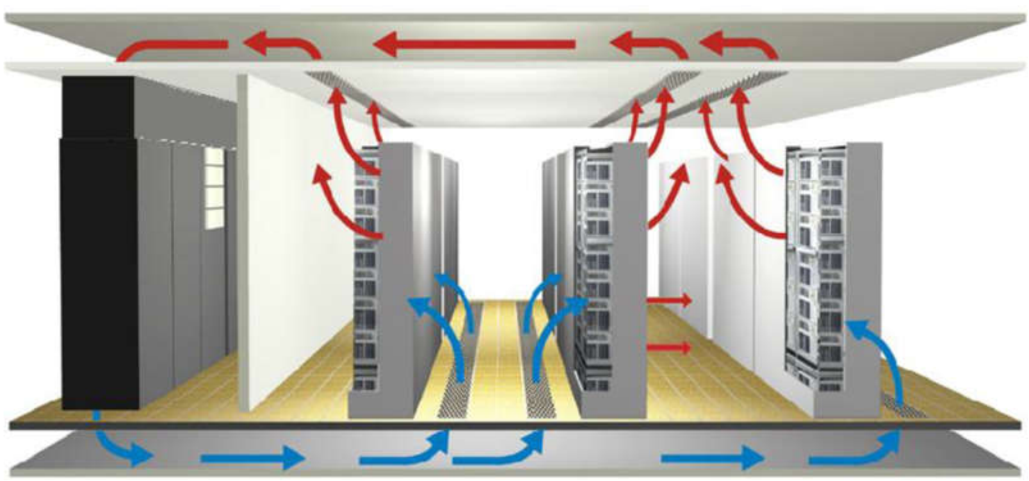

Figure 3.4: Downthrow Room Precision Air Conditioner

3.5.2.2 Ventilation System

Data centres and server rooms hardly need any ventilation. However, as they are operating daily, great amount of cooling is required. Since air represents the carrier medium for cooling, high ventilation is required to bring the cool air within the data centres.

Therefore, it is a need to plan for redundant cooling system for servers and data stations in order to maintain necessary temperatures with appropriate air flow. This is to prevent the disaster of the temperature rises to an unacceptable level for data storage devices.

With proper planning of an energy-cooling system, a great potential for saving energy can be anticipated without affecting the cooling efficiency of the data centre existing air-conditioning system.

3.5.3 Fire Fighting System

The primary goal of a data centre fire protection system is to contain a fire without endangering the lives of employees and to minimise any downtime. The primary goal is to detect the potential presence of a fire before it occurs and then notify authorities and occupants of the threat. The final phase is to suppress the fire and limit the damage. Data centres fall under Fire Class C, and Class C fires involve live electrical equipment.

3.5.3.1 Fire Detection System – Smoke / Heat / Flame Detectors

To protect a data centre, smoke detectors serve as an advance warning system to actively detect if there are flames or smoke in the data centre before the actual disaster occurs. Smoke detectors are more effective in protecting data centres because, compared to heat and flame detectors, they are able to detect fires in their early stages, providing early warning.

There are two common types of smoke detection systems in data centres, namely smart point detectors and air sampling smoke detectors. Both are much more sensitive than a conventional smoke detector. It uses a laser beam that is able to scan particles that pass through the detector. The laser beam can distinguish whether the particles pass the detector or not.

The smoke detection system for air sampling is usually called a high-power photoelectric detector. This system consists of a network of pipes connected to a LED or laser detector while it continuously draws in and samples air with a built-in fan. The pipes can be any type of PVC pipe. This system also uses a laser beam that is much more accurate to detect combustion by-products. If any particles pass the detector, the laser beam can detect them as dust or combustion by-products.

In addition to the detector, a complete fire detection system also consists of signalling and notification devices and control systems.

3.5.3.2 Fire Extinguishing System – Fire Extinguishers and Total Flooding Fire Extinguishers System

Fire extinguishers are by far the most reliable form of firefighting. Because they are one of the fastest solutions for fire suppression, they are extremely valuable in data centres. With fire extinguishers, a potentially dangerous situation can be remedied immediately, before more drastic or costly measures are required.

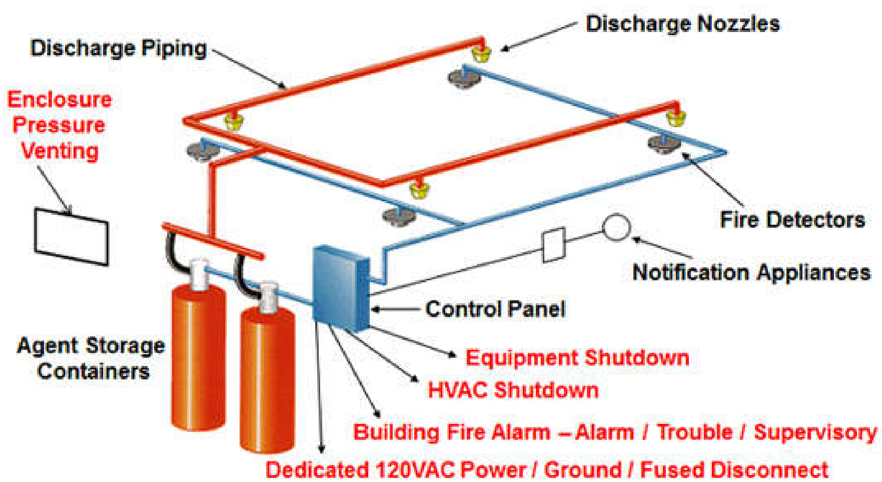

Figure 3.5: Fire Suppression System

The Total Flooding fire suppression system is a more sophisticated form of fire suppression. It consists of a series of high-pressure vessels filled with an extinguishing agent or an equivalent gaseous agent. The main purpose of the gaseous agent is to extinguish the fire by removing either oxygen or heat or both. In an enclosed, well-sealed space such as a data centre, gaseous extinguishing agents are very effective in extinguishing a fire without leaving a residue in the space. Inert gases and fluorine-based compounds are the most commonly used gaseous agents for data centre applications.

3.5.4 Surge Protection System

SPD is designed to limit transient and divert current waves into the earth, hence it is able to trim down the amplitude of any overvoltage to a smaller value that will not harm the electrical installation or IT equipment.

SPD eliminates overvoltage in both common mode and differential mode. Common mode is referring to the voltage different between phase and neutral or earth, while differential mode is the voltage different between phase and neutral.

3.5.4.1 Ground Protection System

Grounding is principally a safety measure to protect against person from electric shock. The grounded wire will be connected to the exterior of metal cases on that electrical equipment to protect against a hot-wire short inside the appliance. If a short occurs, the ground wire will limit the touch voltage to less than certain voltage and will also provide a return path for the excessive current to trip the branch circuit breaker. Ground loops occur when there is a varying quality of connections to the earth at different points in an electrical installation. The result is that current may flow in unexpected loops between ground connections. Ground loops are a potentially hazardous situation. The solution to stopping ground loops is to confirm the quality of ground connection at all points in an electrical installation.

3.5.5 Cabinet System

3.5.5.1 Precision Air Supply Cabinet

There are several types of precision air conditioning system that commonly used in data centre for example room, row, and rack-based cooling precision air conditioning system.

The conventional room-based approach has remains effective as well as practical solution for low density installation or applications where almost none IT technology changes will be made.

However, due to technological change, the latest variable and high-density IT devices have created the conditions that traditional data centre cooling was never intended to solve, resulting in either oversized, inefficient, or even unpredictable cooling systems. Therefore, row and rack based cooling methods were developed to solve these unforeseen problems.

The main goal of air conditioning systems in a data centre is to minimise air mixing. The two most important functions of data centre air conditioning are to provide adequate and redundant cooling capacity and to distribute cooled air to server equipment on average.

The main difference between room-based, row-based, and rack-based cooling is the distribution pattern of cooled air to the loads. Since the airflow is constrained by the room layout and the actual airflow is not visible and can vary between different installations, the main objective of the different approaches to the cooling system is to control the airflow.

Room-based cooling is influenced by the shape of the room and works simultaneously to manage the total heat load of the entire room. Room-based cooling can consist of multiple air handling units that deliver cooled air without being obstructed by ducts, dampers, or vents. The supply and return air from the units may be partially confined by a raised floor system or an overhead return plenum.

Row-based cooling is a design having a row-based configuration in which the cooling units are arranged in the same row of server racks and are assumed to be associated with a row for design purposes. Compared to traditional room-based cooling, the airflow paths are shorter and more clearly defined. In addition, airflows are much more predictable, and the entire rated capacity of the cooling units is utilised, resulting in higher power density.

Rack-based cooling units, on the other hand, are connected to a rack and are assumed to be dedicated to that particular rack. The units are mounted directly to or within the IT racks. This assignment within the racks makes the airflow paths even shorter and well-defined, and the airflows are completely confined to the specific racks and immune to any installation variations or space limitations. The entire rated capacity of the cooling units can be fully utilised, and the highest power density is achieved.

3.5.5.2 IT Device Cabinet

The enclosure should be universal, modular, organised, and scalable. The EIA-310 standard is published by the Electronics Industries Association to ensure physical compatibility between racks, enclosures, and rack-mounted equipment internationally. This standard is intended to standardise dimensions to ensure compatibility and flexibility within the data centre. EIA-310 is applied to standard 19-inch rack-mounted equipment worldwide.

In addition, EIA-310 also defines Rack Unit (U) as the usable vertical space for a rack-mounted device. A U is equal to 1.75 inches. When a rack is described as 10 U, it means that there is 17.5 inches of vertical space inside for mounting equipment.

Server applications in Malaysia typically use 42U high x 600mm wide x 1070mm deep. Since physical considerations of rack layout are very important when designing a data centre, racks are usually designed to alternate hot and cold aisles between rows. When selecting a rack, it is important to choose the appropriate dimensions that work well with the layout.

3.5.6 Supporting Facilities of Data Centre

Various areas of the data centre facility should work in harmony, separation is the best, combinations are possible and acceptable depending on the Uptime requirements and constraints of the building.

3.5.6.1 Holding Area

The purpose of a holding area is aimed at providing an area where equipment can be received, unpacked, physically inspected, and prepared for movement into the staging area. It must however be spacious enough to handle the equipment. There shall not be any unpack and put any boxes in the data centre itself as it will spread dust.

A holding area shall be easy access for external supply for example, loading bay and route to staging area. Security guards or CCTV camera's that overlook the area shall be considered, if possible, to enhance the overall security of the area.

3.5.6.2 Staging Area

Staging area is an area where equipment can be unpacked, inspected, configured and safely tested to ensure for deployment readiness. It shall be a separate and secure space, separate network, if possible, separate Power Distribution Unit (PDU), environmentally controlled and monitored and equipped with fire protection and other safety measures.

Once unpacking of the equipment is completed, it can be moved to the staging area. This area should be separate from the holding area and is a place where the equipment can be acclimatized.

3.5.6.3 Computer / Server Room

Computer or server room provides a safe production environment where equipment can be expected to run on 24 hours and daily basis with minimal risk of interruption. It requires to be separated and highly secured space including protection and control of power quality, environmentally controlled and monitored, low Electro Magnetic Field (EMF) radiation levels, fire protection and other safety measures.

High level EMF will cause interruptions of IT server, hence, the electrical equipment that will cause high level EMF such as transformers, UPS or vented cell batteries shall not be placed in computer rooms.

3.5.6.4 Media Storage Area

The purpose of media storage area is to provide a safe, secure and conditioned environment where media such as documentation, magnetic tapes, CD-ROMs etc., can be stored in a controlled manner.

This room also needs to be separated and secured, environmental controlled and monitored, fire protection system such as highly sensitive smoke detection systems, sheltered, etc.

Ideally, the media storage area will be in a totally different building or on a different floor. Back-up tapes should be stored off site to mitigate site issues and to facilitate for disaster recovery in case of a severe disruption of the business.

3.5.6.5 UPS Room

UPS room provides a safe, secure and conditioned environment where power protection and conditioning systems can operate on twenty-four hours on daily basis. Similar with other rooms, it shall be a separate and secure space, also environmental controlled and monitored and fire protection. In some cases, a small rating UPS could be located within the computer room.

UPS systems emit EMF which could affect the IT systems. If install UPS systems in the data centre, it shall have at least 2 or 3 rack space units occupied between the UPS systems and ICT equipment.

3.5.6.6 Battery Room

Battery room is where the batteries can be stored in a safe, secure and conditioned environment. Ideally it shall be separated from UPS room. Battery room shall be equipped with environmental controlled and monitored, fire protection and other safety measures, also be vented if required.

The flooded cell, also known as wet cell or vented cell battery, is always stored in a separate room due to issues with hydrogen. Hydrogen gas is highly explosive and if a spark occurs an explosion may appear.

Other type of batteries, such as Valve Regulated Lead Acid (VRLA) requires an environmental controlled area to meet the designed life span.

3.5.6.7 Service Corridor

A service corridor provides a secure area where supporting facilities can be serviced and monitored daily without disturbing the computer room. It shall be separated and secure space, environmental controlled and monitored, equipped with fire protection and other safety measures.

A service corridor will provide a proper separation between facilities, such as air-conditioner and ICT equipment. However, a service corridor can be an expensive option due to the amount of floor space required. To service the air-conditioner the service engineers need to access the computer room, whereas ideally one tries to minimize human traffic in the computer room.

3.5.6.8 Standby Generator Set Room / Area

A standby generator set room provides a safe and secure area where the standby generator set can be located to allow for safe operation with minimal disturbance.

It shall be a separate and secure area, equipped with fire protection and other safety measures, fuel tanks could be located underground or above ground.

The location of where the generator is placed is not restricted as long as one makes sure that it is in a secure environment so that only authorized individuals can access the units. The unit itself should not create any hazard and or problems to the building and people working inside so vibration measures as well as the exhaust of the unit shall be considered. Regular inspection should take place.

Fuel tanks need to be sized and stored based on the local regulations. In most countries there are restrictions in terms of where the fuel tanks can be placed.

3.5.6.9 Meet-Me / Entrance Room

A Meet-Me or sometimes called Entrance Room provides a safe environment where the service provider provides a handover point equipment. Sometimes it is located within the computer room.

Besides that, this room should have proper power protection and air conditioning in place.

Sometimes the hand-over point is in the basement and could be owned by the building owner. The meet me room should have proper power protection and air conditioning in place should be monitored as it is often in a remote location.

3.5.6.10 Security Room

A security room provides a secure area where security functions can be undertaken on a daily basis. It shall be a separate and secure space, protection and control of power quality, equipped with fire protection and other meant of safety measures.

As security guards should be in a fully enclosed room in order to protect themselves from external attacks. Having security personnel at an open counter or desk is not always appropriate as security could easily be compromised in this case.

If security monitoring equipment is placed in the same room, ensure that there is adequate power quality and capacity at hand.

3.5.6.11 NOC (Network Operations Control)

A NOC room provides a secure area where the IT infrastructure and supporting facilities can be monitored and controlled anytime. It is sometimes combined with the security room.

This is where the engineers monitor the environment of the whole data centre, and it should never be in a computer room. As nobody should sit in computer rooms as computer rooms have extreme cold and abnormal humidity levels. It is a matter of health and human safety as well security that may be compromised. However, for the works that needs to be done inside the computer room shall be limited as much as possible. With the current technology available, most of the operation can be performed remotely.

3.5.6.12 Raised Floor

A raised floor system is built around two inches to four feet above final finishing level of the floor. It creates a “duct” that normally been allowed for cooling, mechanical services as well as electrical services.

In data centres, raised floors will be used for distributing cold air from the precision cooling unit. With the use of raised floor system, facilities will be able to reduce the amount of air needed to cool equipment as well as less energy is required and hence improve the temperature distribution among the server racks. It was proven by research that the presence of a raised floor is able to reduce the cooling load by nearly 40 percent of a space.

Figure 3.6: Raised Floor System

Some of the floors are actually filled with wood, but this is no longer available in the market apart from certain countries. The advice is not to use them. Traditional raised floor tiles used for data centres are covered with a vinyl finishing which is a sort of plastic finishing. This is often referred to as HPL which is the acronym for high pressure laminate.

3.5.6.13 Lighting

The lighting of work-areas must facilitate an effortless recognition of visual objects. Lux is the most recommended unit of measure in data centres and is measured one meter above the raised floor. In computer rooms it is recommend having a minimum of 500 lux available. This is very bright light but that is a requirement to make the data centre safe to work in and to make sure that mistakes are minimized.

The lights in the data centre shall be placed aligned with the aisles. As fluorescent lights create a lot of electronic distortion and that is something that one cannot accept on the output of the UPS, lights shall be connected to the raw main supply where in case of the maintenance or a failure of the grid it is supported by generator set.

In case of power failures or unforeseen circumstances one needs to rely on emergency lights. The standards of lux intensity vary from 1 lux to about 15 lux.

LED is preferred to be used, the main advantages of use of LED include they consume less electricity, generate less heat as well as dimmable. Other benefits of using LED are since they are lower in wattage, since every three watts reduced in lighting, one-watt reduction in HVAC load can be anticipated. Hence, with the combination of better efficiency, lower maintenance costs, and declining prices, LED lights are always the first choice for data centres.

3.5.7 Security System

Security components in a data centre must be considered separately but at the same time follow one holistic security policy. Physical security includes the processes, strategies, and systems that are used to protect the data centre from outside interference.

Access into a data centre facility shall be fairly limited to only authorized person. A data centre shall not have any exterior windows or more than minimum required entry points by the local fire authorities. Surveillance cameras shall be making use to assist the security guards inside the building to monitor for suspicious activity. While card or biometric access system will help to eliminate entering of unauthorised parties into the data centres.

3.5.7.1 Access Control

Physical security means keeping unauthorized personal out of places that they do not belong, such as a data centre or other locations that may contain critical physical infrastructure.

One of the common ways to identify the level of protecting a premises is to create a conceptual map of the premise and locate the areas that need to be secured, by classify them accordingly to the strength or level of security.

For a data centre, server rooms shall stand at the innermost depth of security because they house critical IT equipment. The security map shall include areas that containing the functional IT equipment of the facility, as well as areas containing elements of the physical infrastructure that could result in disruption if they are compromised, for example, HVAC, UPS and Battery Room, Fire Protection Equipment Room, etc.

Physical security identification methods and devices e.g., card access system, biometric access system, password access system, etc. Other physical security methods such as data centre position, steel doors, wall, sensors, exteriors, sight lines, concealment, ducts, avoid clutter, locks, plumbing, etc, will also aid in enhance the physical security of the data centre.

3.5.7.2 CCTV Closed-Circuit Television

CCTV is video surveillance that helps to provide interior as well as exterior monitoring and post-incident review. There are several common types of cameras can be chosen for example fixed, rotating, or remotely controlled.

Data Centre that equipped with video surveillance will definitely help to increase the security of the data centre. CCTV should be designed as digital video surveillance system that works live 24/7, network-based for all recorded monitoring. It is mandatory to have CCTV system in place in a data centre.

Figure 3.7: CCTV System

Generally, basic CCTV requirement of a data centre would be IP based CCTV and cover point of entry for all rooms and full coverage of data hall and network rooms. The NVR storage be sized to at least 30 days recording and depends on user's requirement.

3.5.8 Management and Monitoring System

DCIM is the convergence of IT and building facilities functions within a data centre. The purpose of a DCIM is to provide an comprehensive monitoring of a data centre's performance so that energy, equipment and floor space can be planned and welly used as efficiently as possible.

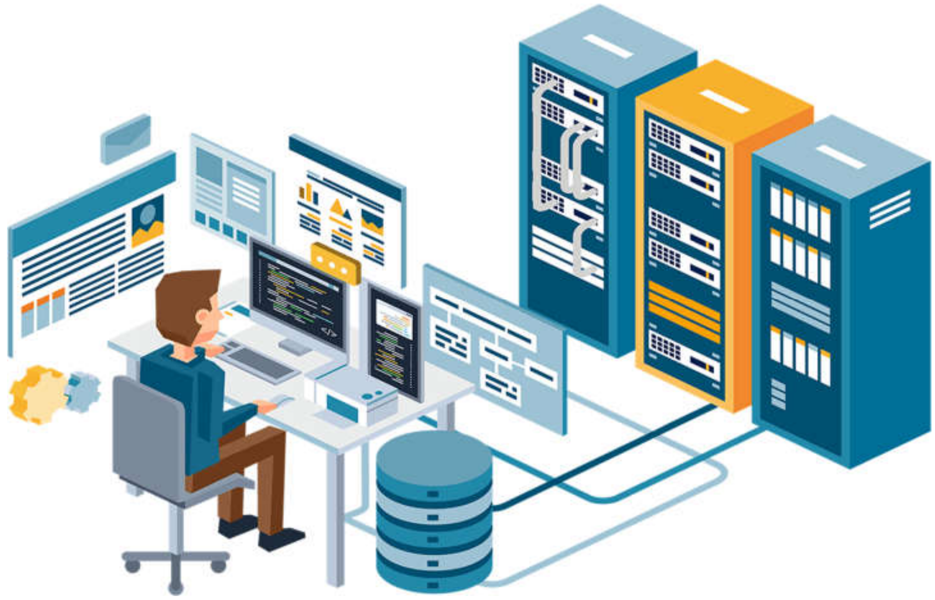

Figure 3.8: Management and Monitoring System

3.5.8.1 Infrastructure Management

An EMS handle "device centric" information, based on individual network IP addresses. EMS information may be the status of a single server, a networking device, or a storage device and is communicated over an existing IT network. EMS has better visibility across an entire network.

A BMS handle "data point centric" information. BMS information does not monitor the condition of a device, itself, but rather monitors the information that a device report. For example, if the BMS device is a temperature sensor, the BMS does not monitor how well the sensor, itself, is doing, but rather monitors the temperatures that the sensor reports. A BMS typically uses its own serial-based network, using either proprietary communication protocols, or some level of standard protocols, such as MODBUS.

Physical Infrastructure management ties traditional facility responsibilities and IT department responsibilities together within an organization, any Physical Infrastructure management solution must be able to support both EMS and BMS architectures. It is difficult to integrate these two management architectures, however, the management strategy must be able to provide device-level summary information for the IT package while providing a level of data point to enable integration with the facility package at the same time.

3.5.8.2 Power and Environment Monitoring

In a data centre, it’s crucial to monitor all environmental variables for each piece of equipment. This enables the technical team to implement immediate preventive measures if something goes wrong. Proper utilization of environmental monitoring sensors is essential to this ability.

The use of monitoring tools can help to maintain the prime condition of a data centres. The monitoring tools are specific to environmental factors such as:

(i) Temperature – Overheating is one of the main risks for servers in a data centre. It will cripple the data centre’s operation. Temperature control is necessary to check if the equipment is operating within the recommended temperature range. A comprehensive approach to temperature monitoring uses many temperature sensors. They are strategically located to provide a holistic temperature reading to facility personnel to make sure the data centre is maintained within its critical temperature parameters.

(ii) Humidity – High humidity can be corrosive to the hardware while low humidity levels lead to issues with static electric arcing. Humidity control goes hand in hand with overseeing the temperature levels. Regulating both environmental factors should be complementary.

(iii) Air Flow – Monitoring of airflow is vital. Observing cooling fans ensures that proper airflow passes through the structure. Devices to measure the presence of airflows can aid in monitoring controls. These sensors detect airflow to avoid safety errors. It prevents the rise of moisture levels by dissipating heat.

(iv) Power – Sudden bursts of static electricity are a choke point for data centres. Erratic volt discharge can ruin a data centre’s performance. It is crucial to ensure an uninterrupted power supply to a data centre. A consistent supply limits electrical failure. Power monitoring will inhibit sudden electrical problems. Energy monitors can spot irregular electricity flow. Through checking of electrical current, the need to power boot the IT equipment is organized. The monitors will prevent power failure and decreases the risk of damage to the IT equipment. Other than that, the monitors also help inefficient power consumption.

3.5.9 Structured Cabling System

MDA is the area where the main cross-connects, switches as well as routers are located. The active devices are not disturbed when replicating active ports.

By using a structured cabling system, adding new hardware to the system takes less time than traditional point-to-point connections. Because the cables are neat and tidy, there is less confusion and it is unlikely that the wrong cable will be accidentally disconnected during changes, moves, or additions.

Structured cabling systems are well planned and organized and allow for smaller cable channels, reducing the overall amount of cable and decreasing the risk of blocked airflow or cable pinching.

It is also scalable due to its modular design and additional patch panels to create new connections are very easy as the footprint is already there.

A suitable structured cabling system can reduce operating costs for heating, cooling and power, as well as installation and maintenance time.

3.5.9.1 Cable Management System

Good cable management in data centre can prevent unsafe environments that caused by the restricted of airflow to cabinets. Tracking Excel spreadsheets also becoming more challenging as rack densities increase, more time and resources in the planning, implementation, and ongoing maintenance are required especially if the cables within a data centre is poorly managed.

Good practices are encouraged in order to optimize the design of cabling system as well as easing of maintenance and tracing problem. That include but not limited to designing the network and structured cabling infrastructure prior the installation, documenting all new patch cabling installations, determining the length of cable needed before installation to minimize redundancy and cable dangling, creating precise instruction for installation to maintain the consistency of installation, validating connections with using testing equipment before actual cabling works, tracking connectivity reports and dashboards, as well as planning for future including provision for new equipment.

3.5.9.2 Copper Cables

Copper cabling has been widely used to provide connectivity in almost every office, commercial, data centres and other types of installations. It is a reliable material for transmitting information over relatively short distances. However, its performance is limited to only up to 100 meters between devices, including structured cabling and patch cords at both ends.

Copper cables used to connect data networks consist of a few pairs of wires twisted along the entire length of the cable.

The classification of copper cables, patch cords and connectors is based on their performance characteristics and the applications that are used. In general, they can be divided into two main categories: Solid cables, which offer better performance and are less susceptible to interference, and stranded cables, which are more flexible and cheaper and are typically used only for patch cords.

3.5.9.3 Fibre Optic Cables

Fibre optic cables are another common medium for connectivity. The central part of the cable, called the core, is a hair-thin thread of glass that transmits light. This core is then encased in a thin layer of slightly purer glass, called gladding, to reflect the transmitted light. Another layer of core and cladding glass is covered with a layer of plastic to protect the inner layer from dust or scratches. On the very outside, all of these materials are encased in plastic, which serves as the cable jacket.

Fibre optic cables are able to transmit signals over a greater distance than copper cables because they use light to transmit signals. The greatest distance a signal can travel over a fibre optic cable also depends on the capabilities and relative location of the transmitters.

Aside from distance, fibre optic cables have several advantages over copper cables: they allow faster connection speeds, are not susceptible to electrical interference, are thinner and lighter, and have low signal loss over distance.

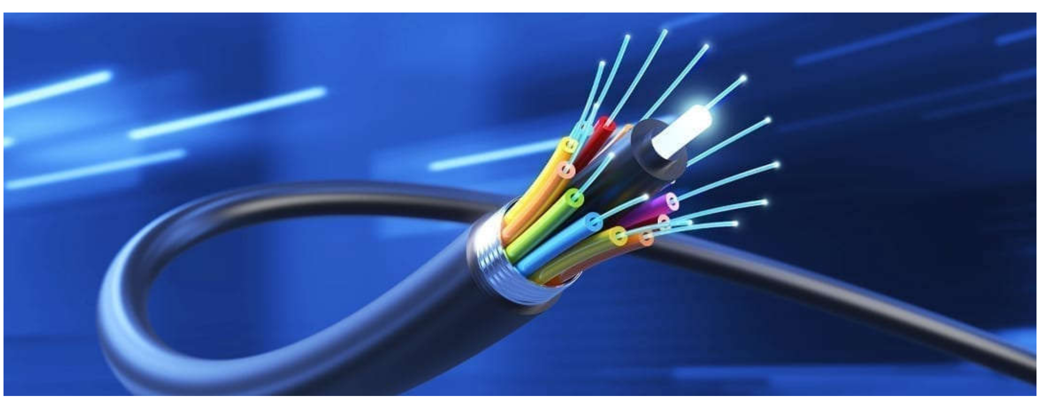

Figure 3.9: Fibre Optic Cable

There are two types of fibre optic cables, namely multimode fibre optic and single mode fibre optic. Multimode fibre optic cables are typically used to provide connections over medium distances, such as between rooms within a single building. Single mode fibre optic cables, on the other hand, are used for longer distances, such as between buildings or sites.

Copper is typically the more cost-effective cabling solution for shorter distances, e.g., the length of rows of servers in data centres, while fibre is more economical for longer distances, e.g. connections between buildings on a campus.

3.6 Data Centre Tier Topology and Standard

3.6.1 Data Centre Tier Topology

Data Centre Uptime is the guaranteed annual availability of a data centre and offering Uptime is one of the core business goals of a data centre. To achieve these uptime goals, a lot of time and cost on redundancy, processes and certificates are required from the data centre providers.

Uptime Institute Tier Standard is the definition of how often a specify resource is available during all the minutes of seconds of a year in a data centre. It is a basis for overall comparison of data centre infrastructure design including their functionality, capacity, availability or performance against others.

The tier topology classification for an entire data centre is limited by the classification of the weakest subsystem that will impact the operation of the entire site. For example, a site with a Tier IV UPS configuration combined with a Tier II chilled water system is defined as a Tier II site rating. The Tier rating is based on the lowest rating of each subsystem.

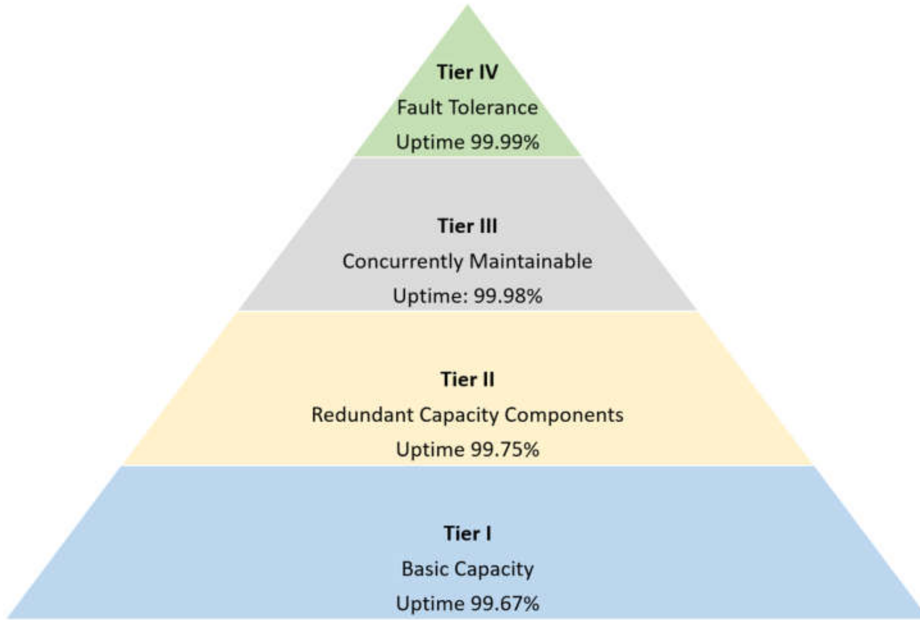

Figure 3.10: Uptime Institute Tier Topology

3.6.2 Uptime Tier I – Basic Data Centre Site Infrastructure

3.6.2.1 Fundamental requirement:

A basic Level I data centre has no redundant capacity components and a single, non-redundant distribution path that powers the entire data centre. It includes a dedicated room for IT systems, a UPS, a dedicated cooling system, and also on-site power generation, such as a generator, to protect IT functions from sudden power outages. For on-site power generation, a 12-hour fuel storage must be available.

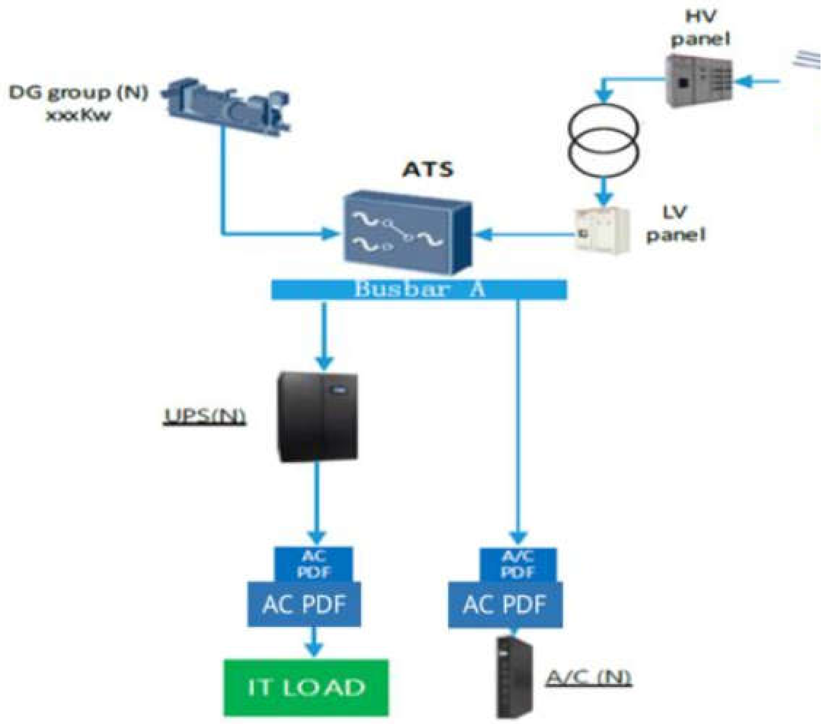

Figure 3.11: Power Distribution Topology of a Tier I Data Centre

3.6.2.2 Performance confirmation test:

(i) Sufficient minimum capacity to meet the lowest demand of the data centre.

(ii) Preplanner work is required because most or all of the site's infrastructure systems will need to be shut down, affecting the entire environment, systems, and end users.

3.6.2.3 Operational impacts:

(i) The site operation will be disrupted no matter planned or unplanned activities. Operation and human errors of site infrastructure components will cause disruption of the data centre with no delay.

(ii) Any sudden failure or malfunction of capacity of any components, or distribution element will impact the overall critical environment.

(iii) The site infrastructure must be completely shut down in order to perform preventive maintenance and repair work. Urgent situations may require more frequent shutdowns. Failure of regularly maintenance will increases the risk of unplanned disruption as well as the severity of the consequential failure.

3.6.3 Uptime Tier II – Redundant Site Infrastructure Capacity Components

3.6.3.1 Fundamental requirement:

A tier II data centre that consists of components with redundant capacity and a single, non-redundant distribution path that powers these IT devices. Redundant components include on-site supplemental power generation, UPS modules and energy storage, and fuel tanks. Twelve hours of on-site fuel storage is required for the base capacity.

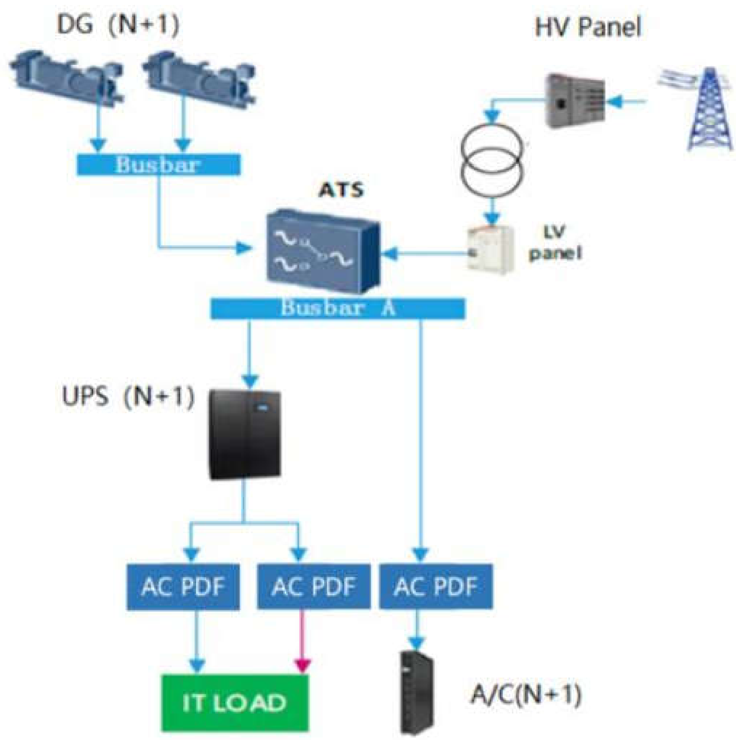

Figure 3.12: Power Distribution Topology of a Tier II Data Centre

3.6.3.2 Performance confirmation test:

(i) Redundant components may be disconnected from service, provided these activities are scheduled, without shutting down the critical environment.

(ii) Disconnection of distribution paths for maintenance or other activities requires a shutdown.

(iii) There is sufficient redundant capacity to meet the needs of the site when the redundant components are removed from service.

3.6.3.3 Operational impacts:

(i) The site may be disturbed by planned or unplanned activities. Operation and human error of the site's infrastructure components may cause disruption.

(ii) Any unplanned failure of capacity components may affect the operating environment. And any unplanned failure or breakdown of a capacity system or distribution element will impact the critical environment.

(iii) The site infrastructure must be completely shut down annually for preventive maintenance and any type of repair work.

3.6.4 Uptime Tier III – Concurrently Maintainable Site Infrastructure

3.6.4.1 Fundamental requirements:

A Tier III data centre is concurrently maintainable and equipped with redundant capacity components with multiple independent distribution paths serving the critical environment. Only one distribution path is required for the power and mechanical distribution path to serve the critical environment at any given time.

The power system is defined as the power distribution path from the output of the power system to the input of the IT UPS and the power distribution path that supplies the critical mechanical equipment.

All equipment from IT is dual powered. Switching devices, such as point-of-use switches, shall be designed for critical environments that do not meet this requirement. Basic capacity must be stored on site for a minimum of twelve hours.

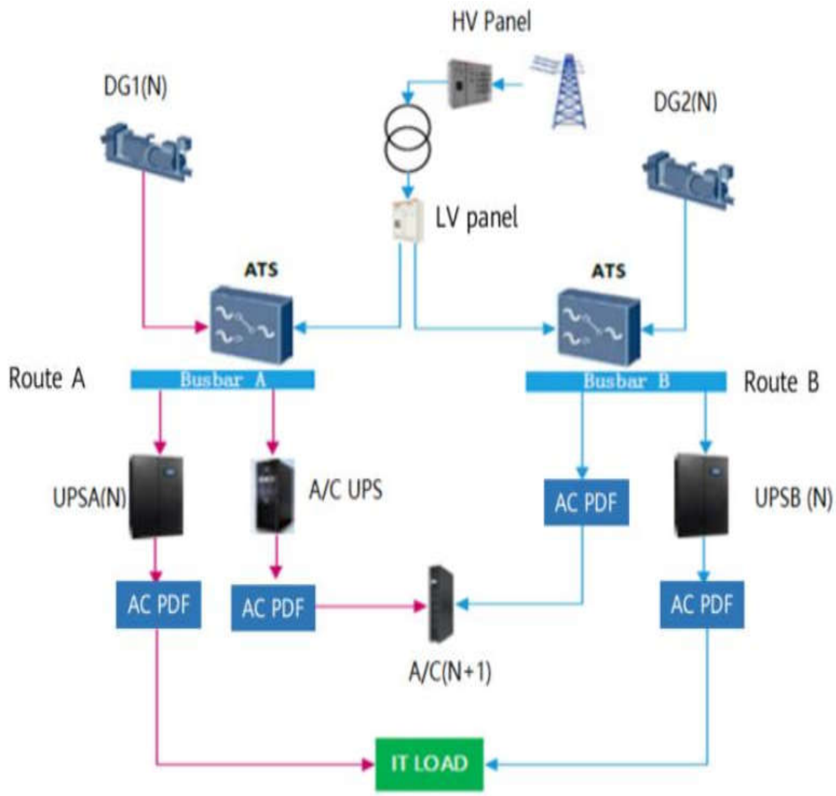

Figure 3.13: Power Distribution Topology of a Tier III Data Centre (Architecture with active-active routes and 2N DG)

3.6.4.2 Performance confirmation test:

(i) The maintenance team can remove every component and element in the distribution paths on schedule without affecting the critical environment.

(ii) There is sufficient fixed capacity to meet site requirements if any of the redundant components and distribution paths are taken out of service for any reason.

3.6.4.3 Operational impacts:

(i) Any disruption or unplanned activity may not impact the site, but the site cannot afford operational failures of site infrastructure components as this may cause computer disruption.

(ii) The critical environment will be disrupted by an unplanned outage or failure of a capacity system.

(iii) The facilities team can perform maintenance with planning, using the redundant capacity components and distribution path to work safely on the remaining equipment.

(iv) The risk of a failure may be increased if the facility team maintains and services the equipment.

3.6.5 Uptime Tier IV – Fault Tolerant Site Infrastructure

3.6.5.1 Fundamental requirements:

A fault tolerant data centre is equipped with multiple and physically isolated systems that provide redundant capacity components and multiple and different active distribution paths that simultaneously serve the critical environment. The redundant capacity components and the various distribution paths are configured to provide power and cooling to the critical environment with a minimum capacity of 'N' in the event of an infrastructure failure.

Physical isolation shall exist between complementary systems and distribution paths to prevent a single event from impacting both systems and distribution paths simultaneously.

Continuous cooling is required to provide a stable environment for all critical spaces within the ASHRAE maximum temperature change for IT equipment. In addition, the duration of continuous cooling should be sufficient to provide cooling until the mechanical system provides rated cooling at the extreme ambient conditions. For base capacity 'N', fuel must be stored on site for a minimum of twelve hours.

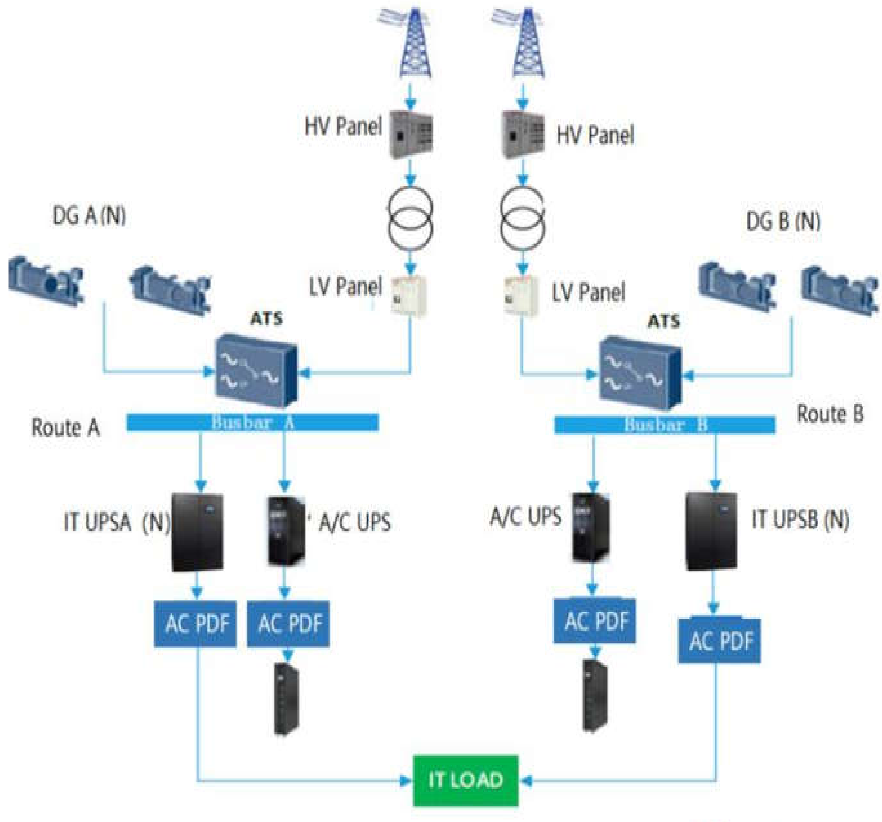

Figure 3.14: Power Distribution Topology of a Tier IV Data Centre

3.6.5.2 Performance confirmation test:

(i) The critical environment is not affected by a single failure of a capacity system, a capacity component, or distribution elements.

(ii) The infrastructure must be able to integrate the system to respond to any failure while maintaining the critical environment.

(iii) The facilities team can schedule and decommission each capacity component and element in the distribution paths without impacting the critical environment.

(iv) Sufficient capacity must be provided to meet the site's needs if redundant components or distribution paths are taken out of service for any reason.

(v) It shall be possible to detect, isolate and contain any potential fault while maintaining N capacity for the critical load.

3.6.5.3 The operational impacts:

(i) A single unplanned event will not affect the site operations.
(ii) Planned work activities will not affect the sites.
(iii) The facilities team will be able to perform regular maintenance using the redundant capacity components and distribution routes.
(iv) There is only an increased risk of interruptions during maintenance activities if redundant capacity components or a distribution path are shut down. However, this maintenance configuration does not affect the Tier rating achieved during normal operation.
(v) However, the operation of the fire alarm, fire suppression, or emergency power function may cause an interruption to the data centre.

3.6.6 Data Centre Standards and Regulations

The first and the current only official accredited data centre standard is the ANSI/TIA-942.

Being said that the more commercial and often being applied as a reference and guideline is Uptime Institute Standard Topology. Uptime Institute Standard will be used throughout this research as the guideline.

Both ANSI / TIA – 942 and Uptime Institute standards are the standards and regulations for the redundancy, reliability, and availability of the data centre, while there are no specific standards that exist only for sub-components that can be used to evaluate the individual or sub-components that exist within the data centre. Hence, the standards for sub-components shall comply to the national or local country standards that applied for building and industrial mechanical and electrical system. These standards are not always specific for data centres and hence more strict requirements may need to be applied when it comes to data centre usage.

Below are some of the standards for the sub-components of data centre that commonly been applied and complied in Malaysia.

Table 3.1: Standards of Sub-Components of Data Centre in Malaysia

Services	**Standards**
Electrical	MS IEC 60364, MS 1979, MS 1936, EN 50160, EN 61000-3-2, EN 61000-3-3, EN 55011, IEC-61643-1
Earthing	BS 7430, MIE-REBT-039, EN-60310

Electromagnetic Field	EN 61000-4-8, EN 55022, EN55011
Lighting	EN 12464-1, light and lighting – lighting in workplaces
Emergency Light	BS-5588 / 5266, EN 50172 and EN 1838 – light at escape path. (min. 1 lux, recommend 15 lux)
Distribution Board	EN 60439-1 (Form 1, 2, 3 & 4), EN 60439-1
UPS	IEC 62040-3, EN50091-3
Environmental	IEC-61340-5-1, ASHRAE
Networks	ISO-11801, EN50173, TIA-568
Fire protection	NFPA-75, NFPA-2001
Rack	ANSI/EIA RS-310-D, IEC 297-2, DIN 41494, IEC 60297
Raised Floors	BS/EN 12825, UK-PAS MOB PF2, IEC-61000-4-2 (anti-static properties), NFPA 251 (fire resistance for at least 1 hour)
Suspended ceiling	EN 13964, BS 476 part 21, 22, 23 (Acoustic attenuation, fire resistance, etc)

3.7 Power Usage Efficiency (PUE)

PUE is a ratio that describes how efficiently a data centre uses energy, specifically, how much energy is used by the computing equipment.

PUE is the ratio of total amount of energy used by a data centre facility to the energy delivered to computing equipment.

$$PUE = \frac{Total\ Facilty\ Energy}{IT\ Equipment\ Energy} = 1 + \frac{Non\ IT\ Facility\ Energy}{IT\ Equipment\ Energy}$$

One drawback of the PUE value is that it does not take into account the climate in the area and location where the data centres are built. So it does not take into account the different ambient temperatures outside the data centre. A colder climate results in lower energy requirements for the cooling system. And cooling systems consume about 35-50 percent of the energy consumed in a data centre, while almost 50 percent goes to the data centre equipment. Therefore, even a data centre with a higher PUE value can operate more efficiently than a data centre with a lower PUE value.

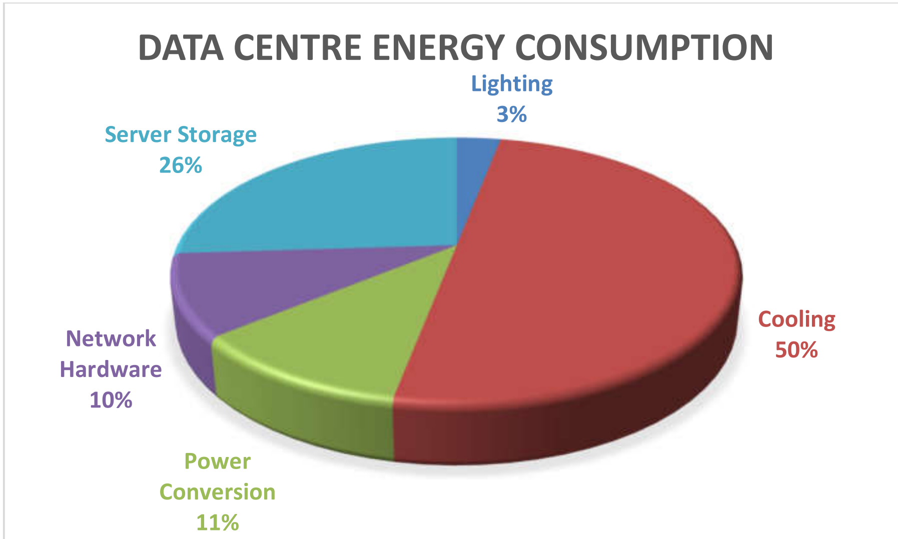

Figure 3.15: Data Centre Energy Consumption

However, PUE metric is still the most common and acceptable method of calculating energy efficiency by comparison to other metrics, and it will be a good reference and guide for one data centre to overview the effectiveness of the equipment over time. To be more precisely and have true real time value, measurement of PUE should be measured on a regular based on different times of the day and week.

There are several important benefits by benchmarking a PUE of a data centre. First, the calculation can be continued over time for a single data centre, allowing the organizer to notify the changes of the data centre throughout the years. Based on this information, the organization will be able to gauge how more efficient practices affect the overall usage. Last but not least, the organization can then make use the PUE as a marketing tool when they are promoting their data centre.

3.7.1 Calculation of PUE

PUE is the ratio of the amount of power needed to operate and cool the data centre versus the amount of power drawn by the IT equipment in the data centre. Hence, power consumption of both facility and IT equipment are required to facilitate the calculation.

For facility, engagement of private utility meters to allow data centre operators to track the total power utilization has commonly been applied instead on depending on the monthly utility bill.

For IT equipment, power data collected from the rack with offered meter down to the individual outlet level providing insights into the efficiency of individual equipment. Some data centres will collect this information from the UPS instead.

With the aid of Data Centre Monitoring System, the data will be collected and send over to the DCMS system and the PUE will be auto generated with the predefined equation.

All facility that is serving the IT equipment shall be taken into consideration when doing PUE calculation, that includes but not limited to:

(i) Lights and utility plugs that serving the data centre and their dedicated mechanical room.

(ii) Cooling, includes the power used by fresh air or exhaust fans, associated with outdoor cooling equipment. The data centre tower filter pump power is also captured as cooling load.

(iii) Water pumps that are used to pump water in the data centre and also capture power used by the boost pumps that circulate water through the fan walls.

(iv) Heating, ventilation, and air conditioning that serving the data centre electrical rooms and other make-up air unit.

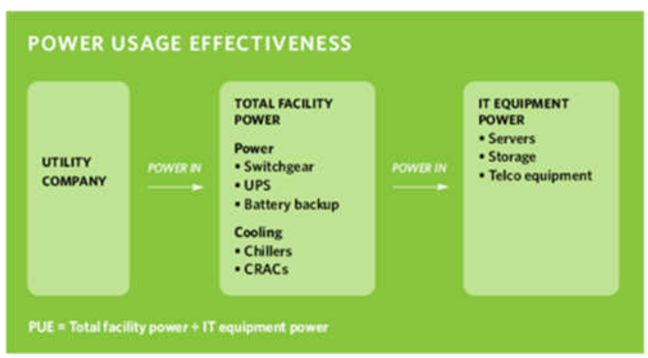

Figure 3.16: Calculation of PUE

Uptime estimates most facilities could achieve 1.6 PUE using the most efficient equipment and best practices.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Case Study of Uptime Institute Tier Topology

Based on Uptime Tier Topology below are the case study to showcase how the power and cooling redundancy are being implemented based on different Tier Standards.

Assumption is made to design basic mechanical and electrical infrastructure to a small data centre with 10 nos. of 3kW IT server racks.

Table 4.1: Design Criteria of Case Study

IT Load	10 nos. 3kW server Rack
Total IT Load	**30kW**

Table 4.2: Sizing of UPS

Total IT Load	30.0 kW
Add 35% (peak load and UPS in-efficiency)	10.0 kW
Total UPS power supply (1)	**40.0 kW**

Table 4.3: Power Consumption of Lighting and Cooling Equipment

Lighting (0.02 x 50 m²)	1.0 kW
Cooling requirement (Total UPS Power x 1.2 for DX-Cooling)	48.6 kW
Total Raw Electrical Supply (2)	**49.6 kW**

Table 4.4: Estimate Total Power Consumption in Data Centre

Add 25% safety norm ((1+2) * 0.25) **(3)**	22.5 kW
Total Electricity supply (1+2+3)	**112.6 kW**

Table 4.5: Sizing of Generator Set

UPS Load x 1.8	73 kW
Cooling & Light Load x 1.5	74.5 kW

Total Genset Capacity	**147.5 kW**
0.8 power factor	**185 kVA**

Table 4.6: Equipment Selection

Equipment	Brand and Model
DX PAC (Cooling Equipment)	Vertiv, Liebert PEX4 P1050
Genset (12 hours)	Erga, ERI-200S
UPS	Vertiv, Liebert EXS 40kVA/kW
UPS Battery (15 mins)	MSB 12-55 Ultra
PDU	ABB

Table 4.7: PUE Calculation (Traditional Data Centre)

Equipment	Electrical
DX PAC (Cooling Equipment)	17.18kW
Lighting	1.0 kW
General Power	1.0 kW
IT Load	30.0 kW
Total Power Consumption	49.18kW
PUE (30.0kW / 19.18kW)	**1.64**

Based on the above design criteria, below study will be brought to compare different redundancy based on different Tier Standards.

4.1.1 Uptime Tier I – Basic Data Centre Site Infrastructure

Table 4.8: Schedule of Main Equipment (Tier I)

Item	Capacity	Qty	
DX PAC	45kW	1	N
GenSet (12 hours)	200kVA (Prime Rated)	1	N
UPS	40kVA	1	N
UPS Battery (15 mins)	55Ah	40 nos.	N
PDU	80A TPN	1	N

A Tier I data centre is the basic capacity level with infrastructure that supports IT racks for an office environment and beyond. The requirements for a Tier I facility include:

(i) A UPS to maintain power quality in the IT server racks.

(ii) A designated area for IT equipment and racks.

(iii) A dedicated cooling system that operates outside office hours.

(iv) An engine generator to serve as an emergency generator in the event of a power outage.

Tier I do not expect failure, redundant equipment capabilities include chillers, pumps, UPS modules, and motor generators. Operators must schedule preventive maintenance and repairs that require a complete shutdown of the facility.

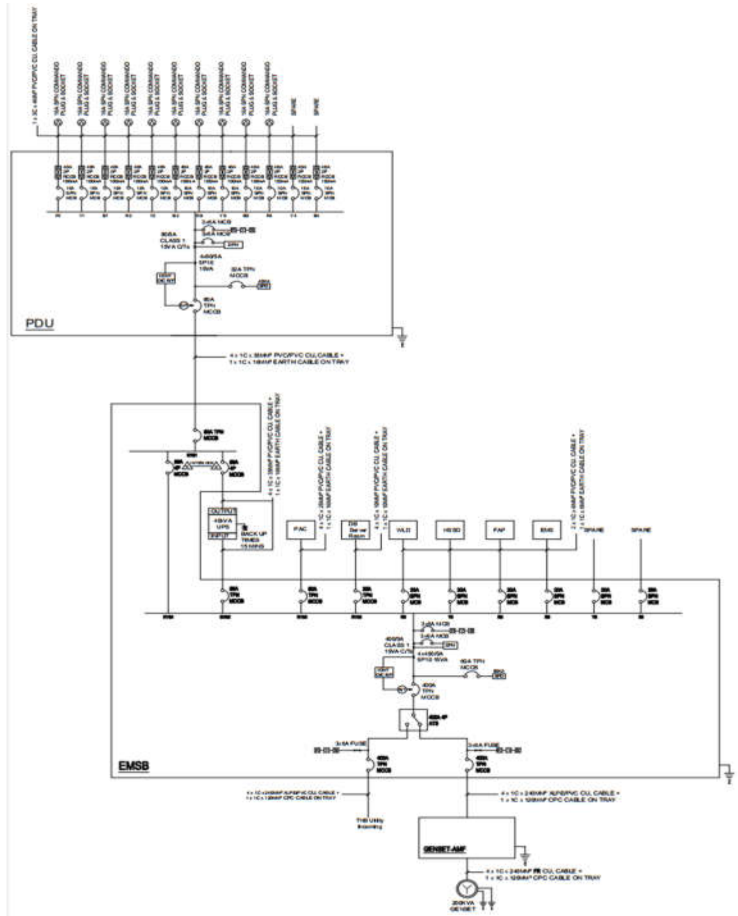

Figure 4.1: Single Line Diagram base on Uptime Tier I

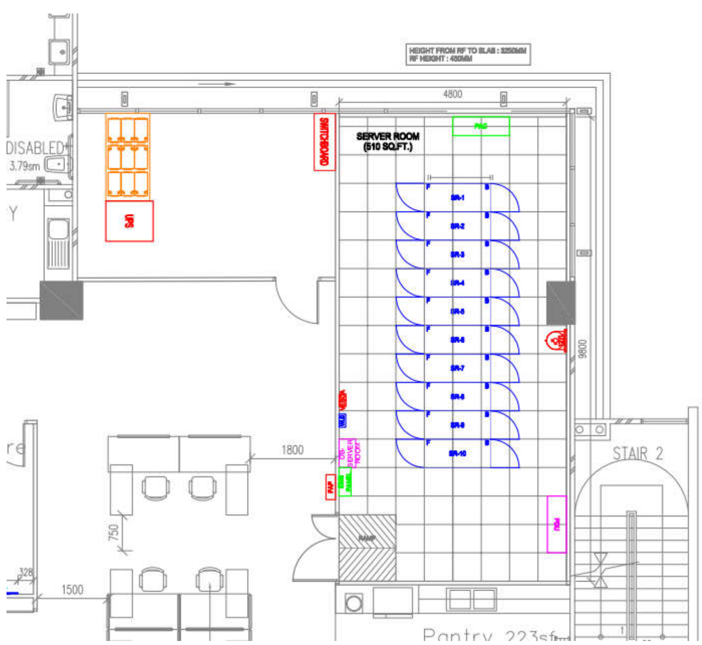

Figure 4.2: Data Centre Layout base on Uptime Tier I

4.1.2 Uptime Tier II – Redundant Site Infrastructure Capacity Components

Table 4.9: Schedule of Main Equipment (Tier II)

Item	Capacity	Qty	
DX PAC	45kW	2	N+1
GenSet (12 hours)	200kVA (Prime Rated)	1	N+1
UPS	40kVA	2	N+1
UPS Battery (15 mins)	55Ah	40 nos.	N
PDU	80A TPN	1	2N

The Tier II data centre has redundant capacity in components, particularly power and cooling, to provide better maintenance planning and security against unplanned disruptions. Components with redundant capacity include motor generators, energy storage, chillers, cooling units, UPS modules, pumps and fuel tanks.

The Tier II data centre serves a critical environment, requiring the facilities team to shut down components to perform maintenance. However, an unexpected shutdown of a Tier II data centre will disrupt the IT system.

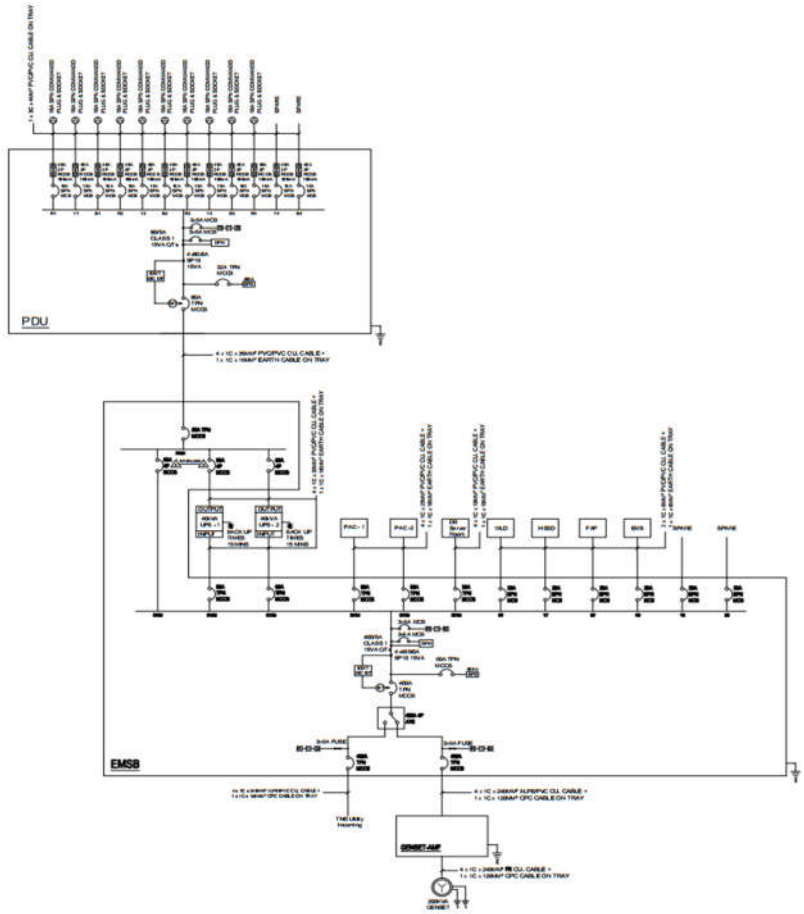

Figure 4.3: Single Line Diagram base on Uptime Tier II

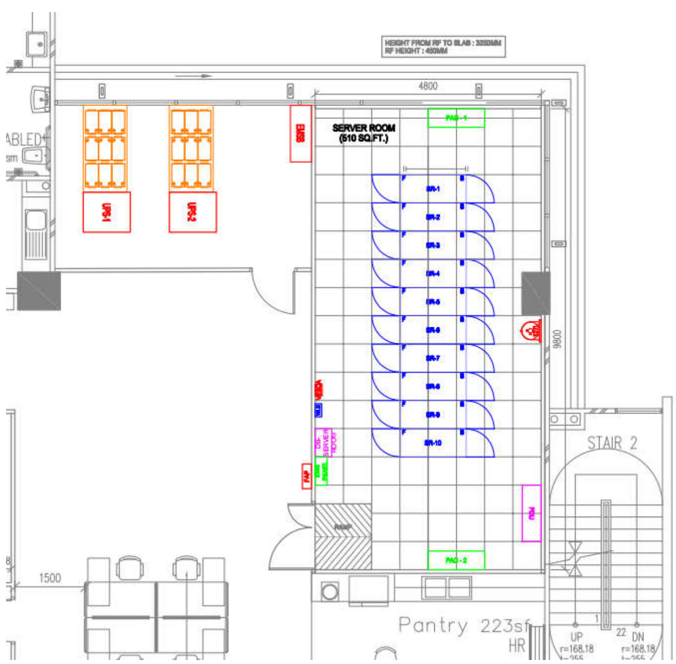

Figure 4.4: Data Centre Layout base on Uptime Tier II

4.1.3 Uptime Tier III – Concurrently Maintainable Site Infrastructure

Table 4.10: Schedule of Main Equipment (Tier III)

Item	**Capacity**	**Qty**	
DX PAC	45kW	2	N+1
GenSet (12 hours)	200kVA (Prime Rated)	2	2N
UPS	40kVA	2	2N
UPS Battery (15 mins)	55Ah	80 nos.	2N
PDU	80A TPN	2	2N

The Tier III data centre is designed for concurrent maintenance with redundant components as well as redundant paths to power the critical environment. Unlike Tier I and Tier II, these facilities do not require a shutdown for maintenance or replacement. Tier III components are added to Tier II components so that any part can be shut down without affecting IT operations.

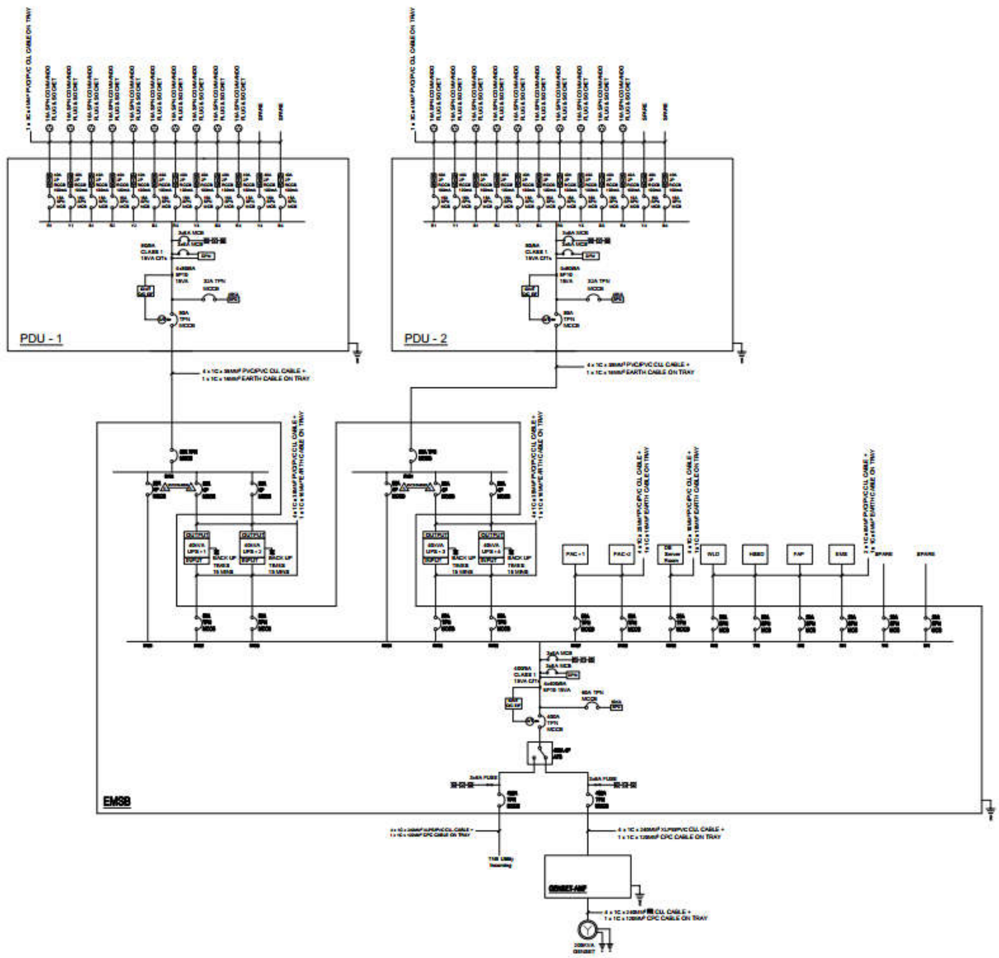

Figure 4.5: Single Line Diagram base on Uptime Tier III

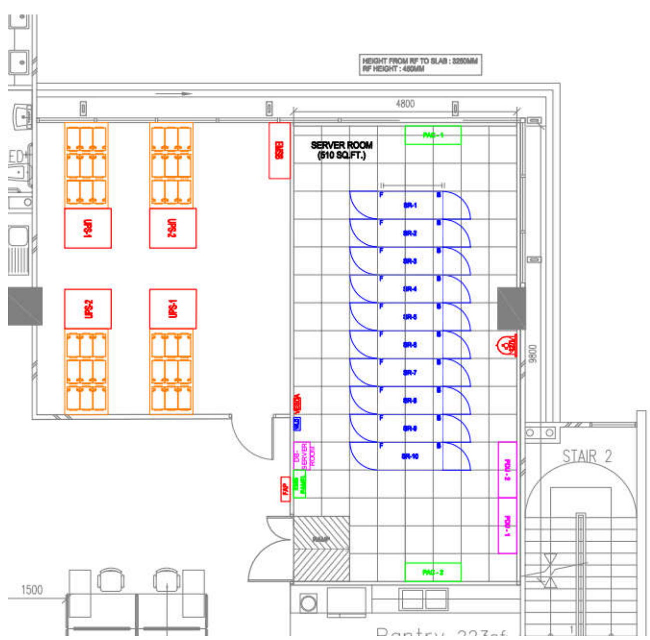

Figure 4.6: Data Centre Layout base on Uptime Tier III

4.1.4 Uptime Tier IV – Fault Tolerant Site Infrastructure

Table 4.11: Schedule of Main Equipment (Tier IV)

Item	Capacity	Qty	
DX PAC	45kW	2	2N
GenSet (12 hours)	200kVA (Prime Rated)	2	2(N+1)
UPS	40kVA	2	2N
UPS Battery (15 mins)	55Ah	80 nos.	2N
PDU	80A TPN	2	2N

A tier IV data centre has multiple independent and physically isolated systems that act as redundant capacity components and distribution paths. The separation is necessary to prevent an event from compromising both systems. Data centre IT operations remain normal during all planned or unplanned events. However, when components or distribution paths are shut down for maintenance, the IT system is at a higher risk of disruption.

A Tier IV facility is designed with a higher fault tolerance than the Tier III topology. The operation of IT will not be affected even if a device fails or an interruption occurs in the distribution path.

In general, all IT devices must have a fault-tolerant power supply design. A Tier IV data centre also requires continuous cooling to ensure that the environment is stable and redundant backup.The redundant euqipment for example, UPS, battery rack and switchboard will be placed in two different rooms and each rooms will be equipped with fire protection system. The purpose of segregation is to mitigate the possible shall there be any room is on fire or beding disturbed or destroyed by any mean.

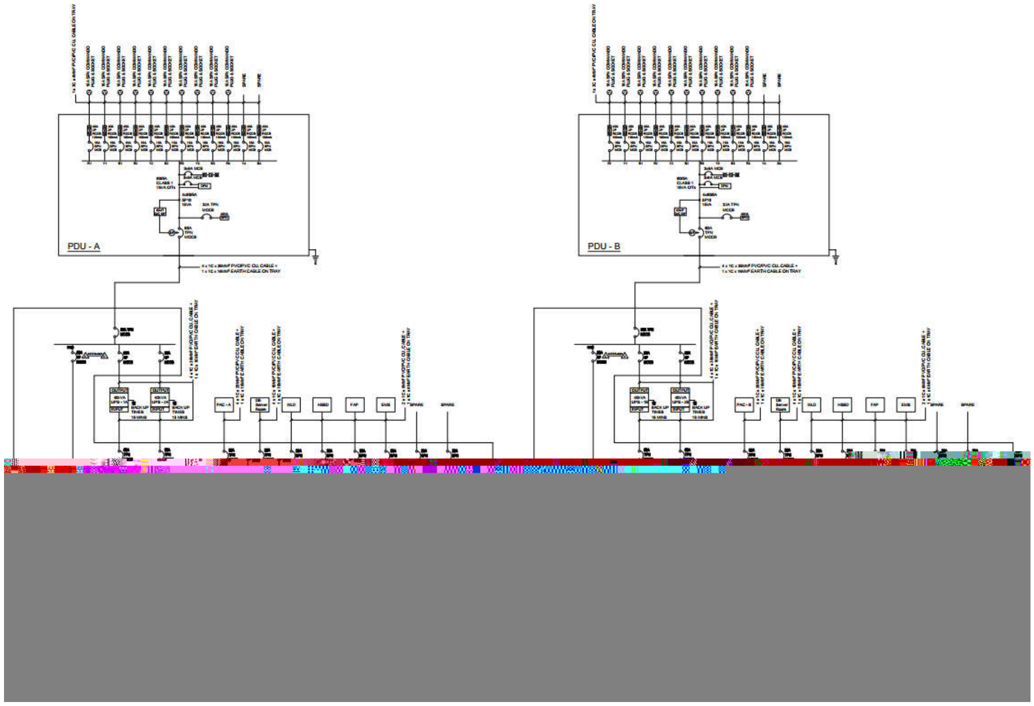

Figure 4.7: Single Line Diagram base on Uptime Tier IV

Figure 4.8: Data Centre Layout base on Uptime Tier IV

4.2 What is the upcoming?

With the rise in energy costs and power consumption, companies are beginning to look for more efficient overall data centre solutions. Since a traditional data centre requires complex logistics and high capital investment when planning to upscale, this solution is no longer compatible with the industry's pace of growth.

As a result, modular design has become the first choice for data centre upgrades. It allows developers to expand their data centre in a more efficient manner in parallel with the industry's growth.

A prefabricated module is also can be well applied in a harsh environment. As they can be configured to withstand different critical scenarios such as high temperature, high humidity, and even dusty locations or areas prone that to earthquakes. It facilitates a great alternative solution compared to building a traditional data centre that need to be built from foundation given an empty space. The modules are pre-assembled in a controlled environment, and it will be more advantage compared to the exist of construction variances when built on site.

4.2.1 Modular Data Centre

Modular Data Centre, sometimes is also called Prefabricated Data Centre, is a data centre that is pre-engineered with its own systems for both hardware and software, where they will be pre-assembled, integrated, and tested in a factory environment before the modular is deployed on site.

The ISO container is one option of prefabricated modular data centre, but modular data centres come in other sorts of shapes and dimensions besides than the container type. It could be either a single rack, or either come with self-contained enclosure that compacts all services and equipment in a closet.

Below describes the common features of prefabricated data centre modules regardless the shape or side.

(i) It provides all the security and resiliency.
(ii) It is flexible and compatible to fit into any environment.
(iii) It is expandable and scalable.
(iv) The same model can be manufactured in bulk, hence giving flexibility to the user to install identical modular in multiple locations and able to provide the ultimate predictability in efficiency, reliability, and

operation since all modular are identical. It will also ease the training and implementation standards by the data centre operators.

Modular data centres are a mobile solution for delivering data processing capacity wherever it is needed, while delivering large amounts of power within a tight timeframe but requiring less space.

It is built and tested under controlled conditions before being delivered to site and ready for immediate installation. The nature of modular data centre design provides a compatible solution for the industry.

4.2.2 Evolution of Modular Data Centre

Similar like every else thing, modular data centre also has been through gradual development before the engineer and technical become mature and well-integrated. From the very initial stage, the idea is just to assembly of the subsystems from multi vendors and the assemble will be on-site. Somehow it results low PUE hence the benefits were being realized. However, the main problem of this method is the difficulty of quality control as well as slow delivery.

It is then coming to the intermediate stage, whereby the design of modular has integrate the subsystems as a product. Most of the subsystems will be developed by single vendor, pre-assemble and pre-tested in a factory before they are delivered and deployed on site. By doing this, the quality of the modular can be highly maintained and the speed of deployment is being shorten. However, the intellectualization between these subsystems is yet improved.

As the technology growth rapidly, the current stage of modular data centre is more towards smart data centre solution. It defined that all devices within the modular shall be digitalization, smart controllable and shall have more interaction with the end user meaning ease access from anywhere and any mean to monitor the status of the smart modular system. With these features, the smart DC is anticipated to be more intellectualization, as well as come with software defined auto-management system. The overall availability, reliability, energy saving, and resource utilization of the modular data centre is improved rapidly. It integrates power, cooling, rack, cabling, and management systems within a module, meeting the requirements for quick delivery and on-demand deployment.

4.2.3 Modern Definition / Main Components of Modular Data Centre

A complete design of modular data centre shall consist of:

(i) Critical Incident Early Detection, for example, gas, smoke, water and battery detection and monitoring.

(ii) Energy resiliency and reliability backup power and distributed generation.

(iii) Integration and system health monitoring.

(iv) Disaster management and capability of recovery.

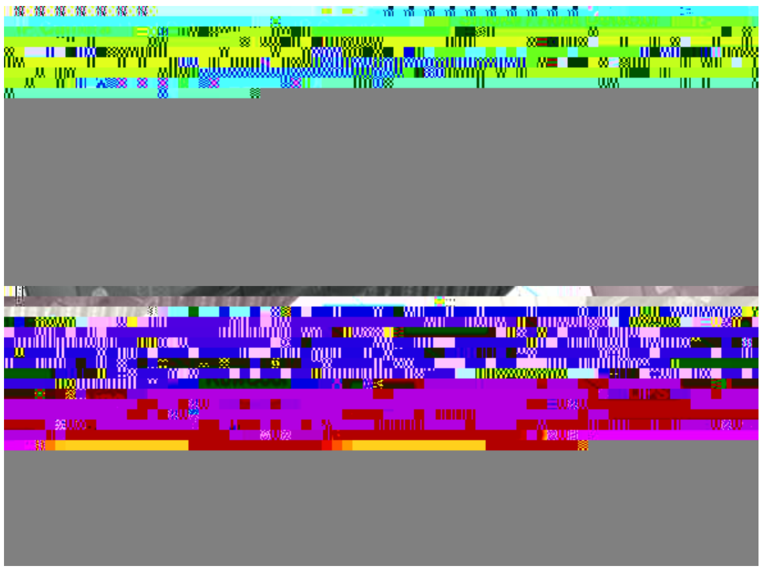

Figure 4.9: Modular Data Centre

Hence, a complete solution of modular data will have cold aisle containment, smoke / heat detector, IP camera, UPS come with battery backup, server racks, row cooling equipment, power distributing equipment, as well as monitoring system.

4.2.4 Comparison of Conventional and Modular Data Centre

Table 4.12: Comparison of Conventional and Modular Data Centre

	Modular Data Centre	**Conventional Data Centre**
Complete, Integrated Infrastructure	A single containment that includes all products including cooling, monitoring, power	Redundant systems where multiple, independent infrastructure components

	distribution and management that work in an integrated manner to provide high efficiency, availability and optimal capacity.	must be ordered and installed, less compatibility and lower capacity.
Incorporate Industry Best Practices	Implements industry best and enterprise-ready practices such as hot and cold aisle separation, high availability and efficiency, minimal footprint, modular and scalable architecture, streamlined monitoring and management.	Infrastructure components may not be designed and configured according to best practices, resulting in low performance and sometimes prioritizing efficiency over availability.
Lower Capital Expense	Cost effective implementation, scalable architecture that eliminates the need to build a larger space for increased capacity, resulting in huge savings.	Additions are needed to increase room-level power, cooling, and distribution to support more IT devices, depending on the degree of scalability.
Lower Operating Expense	Achieve annual savings of more than 30% over conventional designs thanks to high efficiency, integrated cooling, closed-aisle system and effective energy management.	Targeted cooling may be less efficient because the overall room temperature and humidity must be controlled.
Compact Footprint	The sleek design takes up less space and features an advanced power distribution system.	Perimeter cooling and dedicated infrastructure require significantly more space, resulting in less efficient cooling; multiple power distributors are required.

Quick Installation	Easy to order and deploy, lesser time required as compared to conventional data centre build.	Complex installation owing to longer timeframes, and requirement of external technicians.
Simplified Project Management	Well-connected network of data centre experts ensures easy ordering, installation, and servicing.	Service and support require multiple vendors increasing the complexity.
Flexibility	All-in-one architecture with 2-6 racks, 25kW cooling capacity with higher scalability in terms of power, cooling and supervision.	Adding or changing airflow and power capacity cannot be achieved easily.
Monitoring and Management	Built-in monitoring and alarm systems with notifications on power and cooling among other attributes provide enhanced control.	Monitoring and management may not have built-in components and function parts resulting in inadequate control.

4.2.5 Problems that Traditional Data Centres Encounter

4.2.5.1 Long Construction Period

The construction duration including time needed for planning, design and installation of the systems and its operation, the schedule can very lengthily include decision-making, preparation, implementation, and completion phases.

As the business requirements change rapidly, long duration required before deployment of a data centre is neither suitable nor acceptable because the faster a data centre can be built, the more time benefits will be brought to the organizers.

4.2.5.2 Poor Expandability

The expandability is crucial to the adapt the change of a business. A system capacity will normally be designed after considering peak demand scenario and based on estimate future business capacity requirements. With these consideration, excessive capital may be deployed due to the inaccurate and hard to predict the actual needs of the business over the upcoming few years. While on the other hand, if the planning is too conservatively by only in consideration of current requirements without taking the future business growth, the organizer will face more difficulty when they are trying the expand the existing infrastructure due to more physical limitations.

4.2.5.3 High Energy Consumption

When traditional data centres are built, the PUE of many data centres is too high because efficiency has never been prioritised and the equipment that was last equipped with high reliability usually has low efficiency. Some of the PUE values of such data centres can even exceed 2.0 or higher, which means that almost half of the energy consumed in the data centres is not used for the IT load.

4.2.5.4 Difficult Operations and Maintenance of Traditional Data Centre

IT Operations and maintenance have encountered low quality of service, resulting in an unaccountable resource balance. Since the personnel responsible for operations and maintenance usually do not fully understand all the resources of IT as well as the management. Service interface specialists are not available to report and handle incidents. IT personnel need to collect huge data and statistical reports to find out the optimization results of operation and maintenance systems, but routine IT operation, maintenance and management are not capable of collecting these statistical data effectively.

4.2.6 Features and Characteristics of Modular Data Centre

4.2.6.1 Program Timeline

The overall project implementation timeline can be shortened by nearly 50% for deployment of modular data centre. All systems are tested on site at the same time as the construction work, reducing the time required for engineering and testing on site.

Construction work can now be carried out in parallel, with walls and ceilings being erected on site while the self-contained modular data centre equipment is assembled, wired, tested and commissioned in the factory. Once the modules are delivered to the site, the connection work is simple and quick. This parallel construction approach reduces deployment times at a typical site by nearly 50%.

4.2.6.2 Standardization

Quality control is much easier in a factory than on a construction site. Standardization makes costs predictable by minimizing unforeseen changes on the job site. Plans for future expansion are also greatly simplified as standardization leads to improved quality over time.

Standardization also solves the problem of inconsistent expertise among workers in different regions. When similar design, construction and project plans are implemented by experts in factories in all regions, the quality of delivery is more consistent and easier.

4.2.6.3 Flexibility

Increasing the performance capacity of a data centre requires proper space planning to accommodate the new equipment and infrastructure. However, expanding an existing facility or a newly constructed building can be extremely costly. Modular solutions allow companies to increase power capacity incrementally. This helps developers manage their budgets more effectively. With the increase in mega and hyper-scale facilities, phased construction is better suited to better align capital costs with demand.

4.2.6.4 Safety

During the installation phase of a modular data centre, man hours on site can be reduced compared to a traditional installation. This significantly reduces the risk of accidents or injuries on site. In addition, the modular data centre is tested in a controlled environment before being transported to the site for final installation.

This way, the centre's managers can be sure that the entire infrastructure meets the required safety standards, as tested as part of the FAT, without further testing.

4.2.6.5 Installation and Commissioning

On-site integration of a prefabricated modular data centre has now been further simplified compared to traditional integration, as each module is delivered to its destination fully integrated, tested, commissioned and ready to be connected to the power distribution system. This has resulted in the infrastructure being integrated in less time and with virtually no disruption.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The advantages of modular data centre have been discussed and supported with case study in this report. It helps to achieving low PUE, minimize project timeline, design standardization, scalability and flexibility, better safety as well as faster and easier of testing and commissioning.

Besides that, a modular data centre that integrated all the equipment in a form of single containment has also contribute to spacious space saving. By deploying a modular data centre instead of building a traditional data centre, the room or space for UPS, battery, firefighting, service corridor, raised floor etc., has becoming needless as all the testing and commission has been done in factory, connection, security system as well as monitoring system have been integrated into the single containment.

Since the demand on the speed of internet and online is rapidly increase throughout these years, rapid deployment of the backbone of IT, that is data centre is what the market is highly urging for. Next-generation data centres must adapt to changing demands, reliably support high and variable power density, and reduce power consumption.

In addition, the latest modular data centres are now also equipped with the latest technologies, so the overall efficiency of the architecture is now even further improved. This also refers to the use of lithium-ion batteries as well as the latest high-efficiency UPS technology to reduce CO_2 emissions and energy costs.

Prefabricated modules offer benefits beyond speed of delivery. Because they are built and tested in a factory environment, they are flexible and can fit into almost any environment. They are also scalable, so colocation data centres can expand capacity as needed. And they are repeatable, so identical deployments can be installed at multiple sites. This leads to predictability in performance, efficiency, reliability and operations, as well as standardised deployments and training.

When you consider the efficiencies in project lead time, cost, security, installation and commissioning that can be achieved through modular data centre construction, it is clear that the use of modular data centres is much more effective and better than traditional methods for meeting the industry's daily increasing demand for power capacity. It meets the needs of both the data centre and the data consumer.

5.2 Recommendations for future work

The case study is based on the small data centre with 10 nos. of 3kW IT server racks, that is a relatively small scale of data centre. Bigger scale data centre shall be considered in the future to facilitate more comprehensive studies and comparison between traditional data centre and modular data centre, with the higher capacity of power required.

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APPENDICES

APPENDIX A: Vertiv Liebert PEX4 Precision Air Conditioning

VERTIV.

Precision Air Conditioning - Liebert PEX4

Technical Parameters

Parameters	P1035	P1045	P1050	P1060	P2070
Dimensions (W×D×H) (mm)			1330 × 995 × 1975		2430 × 995 × 1975
Operational Weight (kg)	425	430	460	465	750
	Test condition & Loading: RAT 35°C/26%RH, Condensing temp 45°C & 100% loading				
Net Sensible Cooling Capacity (kW)*	36.7	46.2	51.1	61.4	73.0
Air Flow (m³/h)	7400	9500	10600	12200	14800
No of Compressor** & Fan	1	1	1	1	2
EC Fan ESP (Pa)	Available ESP: 20 ~ 200; Standard for down flow: 20Pa & up flow: 50Pa				
Type of filter	Dry media type (G4 rating)				
Electrical Characteristics	380V ~ 415V 3P+N; 50Hz/60Hz				

Parameters	P2080	P2090	P2100	P2110	P2120
Dimensions (W×D×H) (mm)	2430 × 995 × 1975				
Operational Weight (kg)	755	760	780	785	790
	Test condition & Loading: RAT 35°C/26%RH, Condensing temp 45°C & 100% loading				
Net Sensible Cooling Capacity (kW)*	81.6	92.4	101.8	112.3	123.2
Air Flow (m³/h)	16900	19000	21200	22350	24400
No of Compressor** & Fan	2	2	2	2	2
EC Fan (ESP) (Pa)	Available ESP: 20 ~ 200; Standard for down flow: 20Pa & up flow: 50Pa				
Type of filter	Dry media type (G4 rating)				
Electrical Characteristics	380V ~ 415V; 3P+N; 50Hz/60Hz				

Note:

- *Net sensible cooling capacity is calculated at above given condition
- ** Scroll compressor driven by inverter drive; R410A refrigerant based compressor; Fan: EC fan
- 1 or 2 stage heater & Infra red/bottle type humidifier are available on request.
- F5 filter is available on request.
- Specification are subject to change without any prior notice

APPENDIX B: Vertiv Liebert PEX4 Precision Air Conditioning Data Sheet

10/14/2020 Welcome to vertiv rating system! PrintPage [10.163.97.106]

Precision Air Conditioning - Liebert PEX4

P1050DA106 Performance Results

Date: 2020-10-14

Contact email: AriDani.MatZin@vertivco.com

VERTIV

Unit Information

Model Range	PEX3
Unit Model	P1050DA106
Air Discharge	Downflow
System Type	AirCooled
Refrigerant	R410A

Electrical Information

Power Supply	400V/3ph/50Hz+N
System FLA(incl.Cond)(A)	54.17
System total power (incl.Cond)(kW)	17.18

General Input/Output Data

Return Air DB(°C)	24.0
Return Air WB(°C)	17.07
Return Air RH(%)	50.0
Grs Total Cap(kW)	52.5
Grs Sens Cap(kW)	48.8
Net Total Cap(kW)	49.6
Net Sens Cap(kW)	45.9
SHR	0.93
Supply Air DB(°C)	15.1
Supply Air WB(°C)	13.5
Supply Air RH(%)	84.5
Indoor Power(kW)	15.09
Indoor Sens EER(kW/kW)	3.04
Expansion Valve Type	EEV
Width(mm)	1130
Height(mm)	1975
Depth(mm)	995
Weight(kg)	440
Service Space	Front min.1100mm

Indoor Fan

Quantity	1
Total Air Flow(CMH)	15000
ESP(Pa)	20
Total Power(kW)	2.86
FLA(A)	5.5
Fan Material	PP plastic

Condenser

Model	LSF76-R3
Quantity	1
Cond Heat(kW)	64.73
Ambient Temp(°C)	35
Power Supply	380V/3ph/50Hz
Cond Fan Power(kW)	2.09
FLA(A)	6.4
Outdoor LpA(dB(A))	68
Width(mm)	2384
Height(mm)	695
Depth(mm)	1273
Weight(kg)	220

Compressor

Type	Compliant
Total Power(kW)	12.23
FLA(A)	28.6

Heater(Optional)

Type	PTC
Stage	1-Stage
Total Power(kW)	9
FLA(A)	13.67

Humidifier(Optional)

Type	Infrared humidifier
Total Power(kW)	4
FLA(A)	6.1

Connection Details

Liq Return ID(mm)	16
Liq Return Qty	1
Discharge ID(mm)	22
Discharge Qty	1
Humid Supply OD(mm)	6.35
Drain ID(mm)	19

Filter

Grade	G4

1) FLA is full load current.
2) Performance tolerance is ±5%.
3) Declared performances according to GB/T 19413-2010.

AC Rating System V4.6.5

APPENDIX C: Vertiv Liebert APM Modular UPS Data Sheet

Liebert® APM™ 250

VERTIV

Modular Uninterruptible Power Supply

Technical Specifications

Nominal Ratings(kVA/kW)	50-250
Input Parameters	
Nominal input voltage(Vac)	380/400/415 (three-phase and sharing neutral with bypass input)
Input voltage range (Vac)	305-478VAC, 228-304VAC with linear derating up to 70% load
Nominal input frequency(Hz)	50/60(Range: 40-70)
THDi (%)	3
Input power factor(kW/kVA)	>0.99
DC Parameters	
Rated battery bus voltage (Vdc)	384-528
Ripple Current (%C_{10})	≤5
Temperature compensation (mV/°C/cell)	-3.0 (selectable from 0 to -5.0 around 25°C or 30°C, or inhibit)
Float Voltage (V/cell)*	2.25 (selectable from 2.2 to 2.3V/cell)
Output Parameters	
Nominal output voltage (Vac)	380/400/415
Nominal output frequency (Hz)	50/60
Steady state voltage stability (%)	+/-1
THDv (%)*	<1 (100% Linear load) & <3 (100% Non-linear load)
Inverter overload capacity	110% for 60 mins; 125% for 10mins; 150% for 1 min
Efficiency	
Online mode efficiency	Up to 96.3%
ECO mode efficiency	Up to 99%
Dimension and weight	
Dimension (W x D x H) mm	1000 x 1000 x 2000
Weight (kg)	583
General	
Nosie at 1 m dB (A)	<70
Altitude	≤1500, derate power by 1% per 100m between 1500-3000m
Relative humidity	0-95%RH, non condensing
Storage temperature	-25 to 55°C
Operating temperature	0 to 40°C
General and safety requirements for UPS	IEC 62040-1
EMC requirements for UPS	IEC 62040-2
UPS classification according to IEC 62040-3	VFI-SS-111
Color	Black ZP7021
Protection degree, IEC(60529)	IP 20

conditions apply

APPENDIX D: Erga Generator Set Data Sheet

IR INDUSTRIAL RANGE DEUTZ

GENSET PRODUCTS

TECHNICAL DATA

MODEL (Open)	MODEL (Soundproof)	POWER R.P.M. 50 Hz 1500 rpm		ENGINE	SERIES REGULATOR	N. CYL	SUCTION	CYL. Liters	Cooling system	Injection	CONSUMTION 75% (Lt/h) 50 Hz / 1500 rpm	OPEN GENSET			SOUNDPROOF GENSET			CONTROL MODULE DSE 7320
		KVA PRP	KVA LTP									DIMENSIONS (mm)	WEIGHT (Kg)	FUEL TANK (L)	DIMENSIONS (mm)	WEIGHT (Kg)	FUEL TANK (L)	
ERD-13	ERD-13S	13	14	F2M 2011	Mechanical	2	Natural	1,55	Oil	Indirect	2,86	1300 x 580 x 1220	450	80	2000 x 950 x 1253	750	85	✓
ERD-20	ERD-20S	20	22	F3M 2011	Mechanical	3	Natural	2,33	Oil	Direct	4,7	1700 x 730 x 1560	540	150	2000 x 950 x 1220	825	300	✓
ERD-30	ERD-30S	30	33	F4M 2011	Mechanical	4	Natural	2,33	Oil	Direct	6,3	1700 x 730 x 1520	640	150	2000 x 950 x 1220	940	300	✓
ERD-40	ERD-40S	40	44	BF4M 2011 C	Mechanical	4	Turbo	3,11	Oil	Direct	8,4	1700 x 730 x 1406	720	105	2000 x 950 x 1953	950	85	✓
ERD-60	ERD-60S	60	66	BF4M 1013 E	Mechanical	4	Turbo-interc	4,04	Oil	Direct	10,6	1900 x 900 x 1625	820	192	2500 x 1100 x 1650	1280	350	✓
ERD-80	ERD-80S	85	95	BF4M 1013 E	Mechanical	4	Turbo	4,76	Liquid	Direct	15	2950 x 1100 x 1759	1680	220	2950 x 1100 x 1759	1680	220	✓
ERD-100	ERD-100S	100	110	BF4M 1013 ECG2	Mechanical	4	Turbo-interc	4,76	Liquid	Direct	19,3	2050 x 930 x 1717	1300	212	2950 x 1100 x 1930	1880	630	✓
ERD-130	ERD-130S	130	145	BF4M 1013 ECG2	Electronic	4	Turbo	4,76	Liquid	Direct	23,5	2250 x 1040 x 1600	1500	250	2950 x 1100 x 1759	1980	220	✓
ERD-150	ERD-150S	150	165	BF6M 1013 EC	Mechanical	6	Turbo	7,15	Liquid	Direct	28,9	2500 x 1035 x 1607	1580	236	2950 x 1100 x 1759	1100	220	✓
ERD-180	ERD-180S	180	200	BF6M 1013 FCP	Electronic	6	Turbo	7,15	Liquid	Direct	34,2	2500 x 1035 x 1840	1800	236	3600 x 1350 x 2040	2960	360	✓
ERD-200	ERD-200S	200	220	BF6MFC G2	Electronic	6	Turbo	7,15	Liquid	Direct	37,7	2500 x 1035 x 1850	1840	300	3600 x 1350 x 2040	3060	360	✓
ERD-250	ERD-250S	200	250	TCD 2013 LO64V	Electronic	6	Turbo	7,15	Liquid	Direct	39,9	3000 x 1200 x 1975	2050	450	3600 x 1350 x 2040	1350	360	✓
ERD-300	ERD-300S	300	330	BF6M 1015 C	Electronic	6	Turbo	4,76	Liquid	Direct	56,9	2750 x 1515 x 2252	2940	562	4200 x 1600 x 2145	4300	534	✓
ERD-380	ERD-380S	380	415	BF6M 1015 CP	Electronic	6	Turbo	4,76	Liquid	Direct	68,1	2750 x 1515 x 2380	3260	562	4200 x 1600 x 2145	4650	534	✓
ERD-430	ERD-430S	430	475	BF8M 1015 C	Electronic	8	Turbo	15,9	Liquid	Direct	75,8	3000 x 1815 x 2406	3700	550	4860 x 2060 x 2630	6000	1000	✓
ERD-450	ERD-450S	450	500	BF8M 1015 C2	Electronic	8	Turbo	15,9	Liquid	Direct	84	3000 x 1815 x 2410	3800	550	4860 x 2060 x 2630	6100	1000	✓
ERD-500	ERD-500S	500	550	BF8M 1015 CP	Electronic	8	Turbo	15,9	Liquid	Direct	93,2	3000 x 1815 x 2406	4030	550	4860 x 2060 x 2630	6380	1000	✓

erga 10

APPENDIX E: MSB VRLA Battery Data Sheet

MSB ULTRA 6V & 12V RANGE

AGM TECHNOLOGY

Discharge Performance (MS12V Ultra)

Constant Power (Watts) Discharge Characteristics @ 20˚C to 1.70 volts per cell (vpc)

Model	Capacity	Time(in minutes)										
		10 min	15 min	20 min	30 min	1 hr	2 hr	3 hr	4 hr	5 hr	8 hr	10 hr
MS 12-18 Ultra	18	62.60	49.10	41.70	32.20	19.90	11.90	8.82	7.17	6.05	4.12	3.44
MS 12-26 Ultra	26	102.10	79.60	66.40	49.70	30.10	17.20	13.10	10.70	8.80	6.03	4.99
MS 12-33 Ultra	33	129.60	101.00	84.30	63.10	38.20	21.80	16.70	13.50	11.20	7.65	6.34
MS 12-40 Ultra	40	137.40	109.90	88.70	68.20	41.20	25.80	19.60	16.00	13.00	9.01	7.64
MS 12-55 Ultra	55	198.80	159.00	128.40	98.70	59.70	37.30	28.40	23.10	18.90	13.00	11.10
MS 12-65 Ultra	65	211.90	179.50	151.40	113.60	67.70	40.40	30.40	25.10	21.30	14.94	12.49
MS 12-80 Ultra	80	271.10	216.80	175.10	134.60	81.40	50.80	38.70	31.50	25.70	17.80	15.10
MS 12-100 Ultra	100	325.30	260.20	210.20	161.60	97.60	61.00	46.40	37.80	30.90	21.30	18.10
MS 12-110 Ultra	110	366.50	307.70	261.80	193.60	115.00	67.60	50.10	41.00	34.80	24.30	20.10
MS 12-125 Ultra	125	433.80	346.90	280.20	215.40	130.20	81.30	61.90	49.20	41.10	28.50	24.10
MS 12-150 Ultra	150	488.00	390.30	315.30	242.40	146.50	91.50	69.60	56.70	46.30	32.00	27.20
MS 12-165 Ultra	165	542.20	433.60	250.30	269.30	162.70	101.70	77.30	61.50	51.40	35.60	30.20
MS 12-200 Ultra	200	650.70	520.40	420.30	323.20	195.30	122.00	92.80	75.70	61.70	42.70	36.20
MS 12-230 Ultra	230	757.80	636.20	527.10	396.50	251.30	146.30	107.00	84.80	70.70	51.00	42.40
MS 12-260 Ultra	260	826.80	722.70	583.80	448.80	271.20	169.40	128.90	105.10	85.70	59.30	50.30

APPENDIX F: ABB Power Distribution Unit Data Sheet

PRODUCT DATASHEET

Cyberex® Power Distribution Unit (PDU)

Power distribution system

Data centers are the essential ingredients that enable individual businesses to have an electronic presence on the Internet. Reliable uninterrupted power is critical to the mission of any organization's data center.

Electrical	
kVA	50 – 800kVA
Input	3-phase, 3-wire + ground
Input voltage	Up to 600V – 60Hz*
Output	3-phase, 4-wire + ground
Output voltage	208/120 VAC*
Transformer type	Copper, delta-wye, electrostatic shielding
Transformer ratings	K-13 (standard) K-4, K-9, or K-20 (optional)
Transformer efficiency	DOE 2016 compliant
Transformer temperature rise	150°C (standard) 115°C or 80°C (optional)
Transformer inrush	8X (standard) 11X or 5X (optional)
Transformer compensation taps	(4) 2-1/2% FCBN, (2) 2-1/2% FCAN
Transformer insulation	220°C (class R)
Neutral rating	200%
Basic metering and monitoring (BMM)	
Cyberex® PowerView Monitoring System	
Metering (RMS): - Input voltage (L-L) - Output voltage (L-L) - Output voltage (L-N) - Output current - Neutral current - Ground current - kVA - kW - kWh - Hz - Power factor (each phase) - % load per phase - Peak demand	
Accuracy	<=1.0%
Operating conditions	
Temperature (operating)	0 to 40°C
Temperature (storage)	-40 to 60°C
Audible noise	NEMA ST20

Dimensions	
PDU 50 – 225kVA and most 300kVA	Height: 77.4" (450.6 cm) Width: 34" (86.4 cm) Depth: 34" (86.4 cm)
PDU 350 – 800kVA	Height: 78" (198.1 cm) Width: 52" (132.1 cm) Depth: 38" (96.5cm)
Sidecars available in 3 widths	10" (25.4 cm) side-facing 24" (61.0 cm) front-facing and/or rear-facing 34" (86.4 cm) front-facing and/or rear-facing
Distribution options (50 – 300kVA)	
Side car is needed for more than 2 panelboards	
I-line panel available	
225A or 400A panelboards available	
Sub-feed brealers available: 100/150/225/400A	
ABB or Square D	
Distribution options (350 – 800kVA)	
Sub-feed brealers available: 100/150/225/400/600A	
ABB or Square D	
General	
Natural convection cooled	
Hinged dead-front panel	
6.5" color touchscreen LCD with integrated unit status LED ring-light	
Single point ground	
Top and bottom entry/exit	
Enhanced options	
Cyberex® PowerView branch and/or sub-feed circuit monitoring with revenue grade accuracy	
Remote emergency power off (EPO)	
Surge protective device (SPD) – primary and secondary sides	
Floor stands	
Input junction box	
Isolated ground	
Standards	
Safety	ETL listed to UL 60950-1 and UL 891 cETL listed to CAN/CSA-22.2 No. 60950-1
EMC	FCC compliant (part 15)
Enclosure	NEMA 1

*Other configurations available as non-standard

APPENDIX G: Huawei Fusion Module 2000 Data Sheet

FusionModule2000

Smart Modular Data Center Solution

INTRODUCTION

Huawei FusionModule2000 is a new generation smart modular data center solution, which dedicated to providing customers with simple, efficient, and reliable data center solutions.

It's a modular-designed, highly integrated solution which comprises power supply, cooling, rack & structure, cabling and management system within a module, meeting the requirements for quick delivery and on-demand deployment.

Furthermore, the Huawei smart module uses the i³ intelligent management to comprehensively improve the reliability and efficiency of power supply and cooling system. This significantly improves data center availability and O&M efficiency.

Standard Dual- row

APPLICATION SCENARIOS

- The FusionModule2000 uses an air-cooled cooling system and is mainly applicable to small- and medium-sized data centers. The solution features simple design and high building adaptability, lowering the requirements of room height and reconstruction. It meets the data center deployment requirements of various sectors such as enterprise headquarters and large branches, bank headquarters and secondary branches, governments, carriers, education, and healthcare.

Standard Dual-row Smart Screen Version*

FEATURES

Simple

- Modular design, one module one DC, on-demand deployment and flexible expansion

Green

- iCooling intelligent optimization*, reducing the energy consumption of cooling system by 8% to 15%
- SmartLi Inside* supports Huawei smart lithium batteries deployed in the module. Compared with traditional lead-acid batteries, footprint is reduced by 70% under the same load and same backup time
- Wet film humidification*: Compared with traditional electrode humidifiers, wet film humidifiers reduce energy consumption by 95%
- Industry's first air-cooled smart modular DC PUE test and certification, the annual average PUE is as low as 1.245 @Beijing

Smart

- iManager: Space, Power, Cooling (SPC) visualization, automatic asset management simplified O&M
- 3D view* clear display of key information and alarms about power distribution and cooling system, automatic management of assets*, automatic asset tracking, and no manual counting
- Local 43-inch smart screen * intuitive display of intelligent features, simplifying O&M

Reliable

- iPower: Visualization of power supply chain, fault auto-locating and auto shutdown for proactive protection
- SmartLi Inside* :Three-layer BMS ensure the reliability of lithium batteries
- Innovative intelligent refrigerant leakage detection prevents cooling capacity decrease or air conditioner breakdown

Simplified Single-row

*Optional Features

SPECIFICATIONS

Item	Specifications	
Micro Module	Dimensions	Single row (with aisle containment) (L × W × H): L × 2400 × 2410mm; L × 1350 × 2000mm; L × 1600 × 2000mm Dual row (with aisle containment) (L × W × H): L × 3600 × 2410mm; L × 3400 × 2410mm; L × 3600 × 2610mm
	Cabinets per module	Single row≤24 cabinets; dual row: ≤48 cabinets
	Power supply	380/400/415VAC, 50/60Hz, 3Ph+N+PE
	Max IT load per module	125kW (with integrated UPS)/ 145kW (with integrated PDC)/ 310kW (with New main way)/ 235kW (with precision PDC)
	Operation condition	Ultra low temperature condition: -40°C to 45°C(Need low-temp kit) T1 condition: -20°C to 45°C; T3 condition: -5°C to 55°C(Need T3 outdoor unit)
	Cable routing	Routed in/out through the top of cabinets
	Installation	Installing on concrete floor or raised floor
Cabinet	Dimensions (H × W × D)	2000mm × 600/800mm × 1200mm; 2000mm × 600mm × 1100mm; 2200mm × 600/800mm × 1200mm
	Space available	42U/47U
	Cabinet Porosity	Front and rear doors: hexagonal mesh door design, porosity rate ≥ 75%
	Protection level	IP20
Air-cooled in-row air conditioner	Cooling capacity	25kW/35kW/46kW
	Dimensions (H × W × D)	25kW:2000mm × 300mm × 1100mm; 35kW:2000mm × 600mm × 1200mm; 46kW:2000mm × 600mm × 1200mm; (Simplified Single-row can only support 46kW)
	Power supply	380/400/415VAC, 50/60Hz, 3Ph+N+PE
	Refrigerant	R410A
Integrated UPS (UPS inside)	Input voltage	380/400/415VAC, 50/60Hz, 3Ph+N+PE
	Input	250A/400A MCCB (single input); 250A/400A ATS (dual input)
	Input power factor	Full load > 0.99, Half load > 0.98
	Output power factor	1.0
	Rated capacity	30~125kVA: IT Load ≤ 120 kW, power modules ≤ 4, the capacity of a single power module is 30kVA IT Load > 120 kW, power modules ≥5, the capacity of a single power module is derated to 25kVA
	Output	IT: 40A/1P × 24 × 2; A/C: 40A or 63A/3P × 8; lighting: 10A/1P × 3
	Efficiency	≥ 96% (Linear Load)
	AC SPD	5kA, 8/20μs
Integrated power distribution cabinet (UPS outside)	Input voltage	380/400/415VAC, 50/60Hz, 3Ph+N+PE
	Input	IT: 160A/250A MCCB; A/C: 160A/250A MCCB (single/dual input)
	Rated input current	IT: 160A/250A, Air conditioner: 160A/250A
	Output	IT: 2 × 24 × 40A/1P; 2 × 24 × 63A/1P;2 × 8 × 40A/3P;A/C: 40A/3P × 8 or 63A/3P × 8 ; lig 10A/1P × 3
	AC SPD	20kA, 8/20μs
Precision power distribution cabinet (UPS outside)	Input voltage	380/400/415VAC, 50/60Hz,3Ph+N+PE
	Input	160A/250A/400A/630A MCCB (single/dual input)
	Output	IT: 40A/1P,63A/1P,40A/3P,63A/3P, max 144 routes
Smart busway (UPSoutside)	Input voltage	380/400/415VAC, 50/60Hz,3Ph+N+PE
	Input	250A/400A/630A MCCB (single input)
	Output	IT: 40/1P, 63A/1P, 40A/3P, 63A/3P (6 branches in one Power Distribution Unit)
SmartLi inside	Single Lithium battery cabinet	Contains 16 battery modules. Two battery strings are connected in parallel, and each battery string contains eight battery modules connected in series.
	Number of Lithium battery cabinets	2N scenario: ≤ 4 battery cabinets; N+1 scenario: ≤ 2 battery cabinets
	Typical backup time	The backup time can be 15 minutes, 30 minutes, or 1 hour

C:\Users

Recommended Configurations—UPS Inside the Module

R24 Dual-Row Module with Lithium Batteries in Row

UPS Inside the Module(Integrated UPS+SmartLi)

R24 Typical Layout of the UPS and Lithium Batteries in Row

IT Load (kW)	Power Supply	Redundancy	A/C Configuration	Battery
30	Integrated UPS	N+ 1/ 2N	25kW × 2	In-row (Battery cabinet)/ Outside Installation
40			25kW × 3	
60			35kW × 3	
80			35kW × 4	
100			46kW × 4	
125			46kW × 5	