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The method to secure scalability and high density in cloud data-center

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A R T I C L E I N F O

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A B S T R A C T

Recently IT infrastructures change to cloud computing, the demand of cloud data center increased. Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared computing resources that can be rapidly provisioned and released with minimal management effort, the interest on data centers to provide the cloud computing services is increasing economically and variably. This study analyzes the factors to improve the power efficiency while securing scalability of data centers and presents the considerations for cloud data center construction in terms of power distribution method, power density per rack and expansion unit separately. The result of this study may be used for making rational decisions concerning the power input, voltage transformation and unit of expansion when constructing a cloud data center or migrating an existing data center to a cloud data center.

1. Introduction

Cloud computing refers to both the applications delivered as services and the hardware and infrastructure in the data centers. Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared computing resources that can be rapidly provisioned and released with minimal management effort. It relies on sharing of resources to achieve coherence, economics of scale, and business agility [2,5].

Generally, cloud computing is based on metering, making the consumer pay for the usage, refers to the ability of an ICT organization to track and measure the ICT expenses per business unit and charge them back accordingly. To provide cloud computing service, the data center has to change to get flexible, efficient resource allocation, and rapid change management. That is, the cloud computing providers cannot estimate the customer's demand, so they will expand the resource from demand.

Data centers providing the variable cloud computing service need to secure scalability as the ICT service demand changes[1,7,8]. The most basic element of data center operation is the power, and the power is eventually consumed by the servers. Therefore, the power supplied at high voltage by the power plant must be transformed to the low voltage so that it can be used by the ICT equipment. Such transformation can occur differently at the

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Table 1
Comparison of traditional data center and cloud data center.

Items	Traditional data center	Cloud data center
Power density	Low density (1–3 kW/Rack)	High density (10 kW/rack or higher)
Data center architecture	Difficult to expand the facility	Flexible architecture to support expansion of ICT infrastructure (modularized architecture)
Operation	Independent management of ICT infrastructure and facility	Integrated management for stability and cost efficiency

isolated steps from the power reception unit to server in the data center, and each method has the strengths and weaknesses according to the power amount, wiring, power factor, etc.

This study describes the factors – separated to power supply method, power management unit and expansion unit – to be considered to construct a data center with consideration to scalability according to cloud computing demand. Particularly, it categorizes the types of the transformation steps of supplying the power from the power plant to the data center and to the server then presents the power distribution method most appropriate for the cloud data center to help administers determine the power density of the cloud data center which requires the large capacity power.

2. Features of cloud data center

Due to the characteristics of cloud computing service, it is difficult to determine the capacity of the ICT infrastructure after predicting the demand since which services will be provided are not known. Since it is inefficient to own a large scale ICT infrastructure right from the beginning, a cloud service provider generally starts with a small capacity and gradually expands it as there is the need for additional capacity. As such, a cloud data center must be designed and constructed to quickly enable expansion of the center and subsidiary equipment as the ICT infrastructure is expanded [3,4].

As most cloud computing is deployed with the virtualization technology using the low-priced Intel based x86 servers, it requires more servers than using the mainframe or Unix server and thus the power density per rack is relatively high. Therefore, the number of servers installed on a rack must be reduced in order to support cloud computing with the data center equipment which conventionally has low power density per rack. In that case, larger data center space is needed and price competitiveness decreases due to the higher operating cost. Thus the trend is to deploy cloud computing in high density.

Since the cloud users would prefer the service providers offering the good quality services at lower prices, the cloud service providers have the intention to lower the operating cost. Moreover, it is essential to provide the uninterrupted service stably as the IT service trend is changing from owning the ICT infrastructure and data center to cloud computing environment using the ICT infrastructure of the service provider. Therefore, the operation paradigm must be changed to enable operating optimization while providing the stable service and integration of the ICT infrastructure and data center systems is more beneficial for that. In other words, an integrated operation measures of flexibly operating the power and HVAC according to the ICT infrastructure utilization to ensure cost efficiency and surveying the impact of ICT infrastructure problem for each element and planning the countermeasures in advance to minimize the impact of the data center equipment fault is needed.

A data center supporting cloud computing must have the equipment supporting the high density as the ICT infrastructure is advancing to high density environment, the architecture to support flexible expansion of ICT infrastructure to cope with external environment, and operation system enabling service stability and cost optimization in order to increase the cost competitiveness of the cloud service [6] (Table 1).

3. Measures to construct high density data center

For data center operation, it is the most critical to stably supply the power to the ICT systems. The high voltage power supplied by a power plant goes through the power receipt unit, UPS and power distribution unit before it reaches the ICT system. A large scale data center is typically organized of two power lines to supply the power to dual powered CIT system to ensure the stability of the power supply so that the IT services can be provided uninterrupted even when there is a problem with the main line or the equipment is changed.

The high voltage power supplied by a power plant must be transformed to the low voltage power to be used by the ICT systems. Such transformations can be combined into different sets at the various isolated steps in the data center, and each method has the strengths and weaknesses according to the power amount, wiring, power factor, etc. Unlike the conventional data centers, a cloud data center requires the variable attribute thus must consider the expansion unit when there is the need for additional demand.

Therefore, the elements that must be considered to construct the high density data center with scalability are separated into the power distribution type, power density per rack for power management, and expansion unit settings (Fig. 1).

3.1. Power distribution type setting

The most important factor for data center safety and efficiency is utilization of the power supplied by the power plant, and the location of the voltage transformation to supply the power to ICT systems determines wiring and power efficiency. To minimize the waste and reduce the

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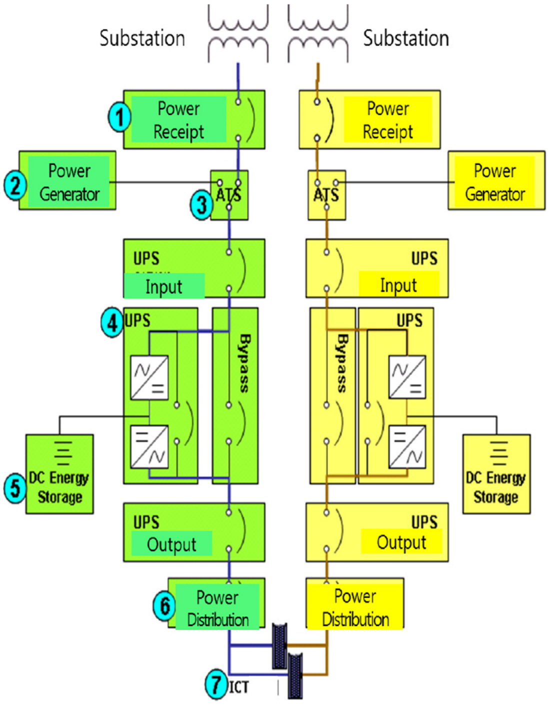

Fig. 1. Power system organization – 2N architecture.

wire size during power distribution, 6.6 kV high voltage is more efficient than 380 V low voltage. Power (unit: W) consumed by an ICT system, generally called load, can be expressed as "P (power)$=V$ (voltage)$\times A$ (current)$\times pf$ (power factor)". The formula indicates that, assuming that the power is constant, the current increases when the voltage decreases. Current increase means the wire must be thicker.

In the traditional method, 380 V power output of the transformer is distributed to each space, and that required the use of thick wires and even bus duct depending on the capacity. The problem with such low voltage power distribution is the voltage drop across the distance and power quality degradation due to the noise (CMN: common mode noise). The wire thickness also becomes an important factor that cannot be ignored.

In the case of '2 step, low voltage UPS, and centralized distribution' method (Fig. 2), all power receipt and distribution units are installed in a same location and the power is distributed to each room at a low voltage of 380 V. In that case, there can be the problems of voltage drop, noise increase, wire thickness increase, etc. described above.

In the case of '2 step transformation, high voltage UPS, and zone distribution' method (Fig. 4), both input and output of UPS is set to the medium voltage of 6.6 kV. The large capacity UPS are installed in a space near the power room. Most medium voltage UPS have the large capacities of 1500–3000 kW. In that case, the flexibility is degraded as the UPS expansion unit capacity is too large.

Therefore, the '2 step transformation, low voltage UPS, and zone distribution' (Fig. 3) method is recommended when considering the expansion in steps and power source

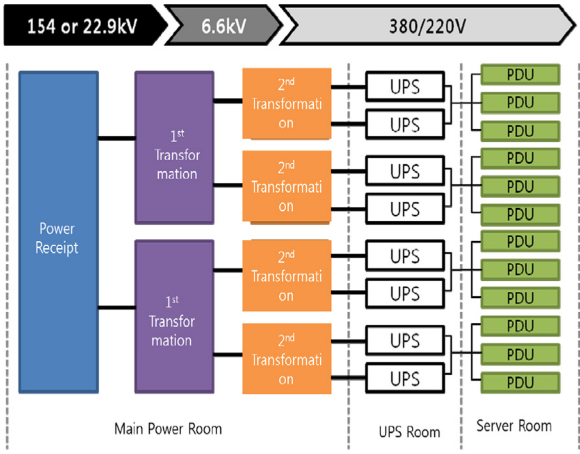

Fig. 2. Data center power distribution method – 2 step, low voltage UPS, and centralized distribution method.

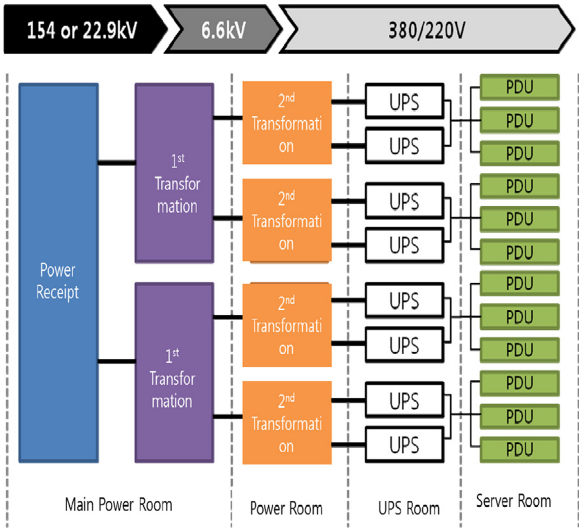

Fig. 3. Data center power distribution method – 2 step transformation, low voltage UPS, zone distribution method.

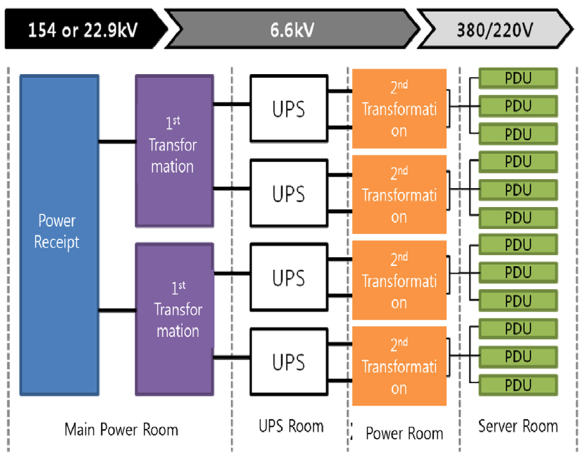

Fig. 4. Data center power distribution method – 2 step transformation, high voltage UPS, and zone distribution method.

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quality which are two of the most important requirements of cloud data center. This method has the high voltage part of the power receipt/distribution facilities in the main power room and the power is distributed in the medium voltage of 6.6 kV to each computer room or module. The low voltage transformer is installed in a location closest to the computer room. Since the UPS and transformer can be expanded in the same step as the space expansion, the scalability and flexibility are higher.

3.2. Power density per rack setting

For the power to the data center, the operating cost should be considered as much as the availability. Therefore, a cloud data center must be expanded in steps. For expansion, the power density of the data center must be properly managed. The power density can be calculated by consumed power per unit area or consumed power per rack.

– *Calculation of power consumption per unit area*: There can be deviations according to the basis for unit area. For example, the power density per m² of a thermo-hygrostat can vary widely according to the installation area and warehouse or other space is included.
– *Calculation of power consumption per rack*: Since it is calculated using the final unit of power consumption, overall power consumption can be calculated relatively accurately when the rack capacity is determined regardless of the space configuration or shape.

Although the power density was managed in unit area in the past, most data centers constructed recently calculate the overall capacity based on the power consumption per rack and applies the hybrid method which configures the power density per rack according to the space usage. Therefore, the unit of expansion in a cloud data center is rack, and the basic unit of power calculation and management is the power density per rack. However, the power density per rack is the most difficult to decide although it is the most basic issue of determining the data center capacity. That is because configuring the power density per rack is the most basic issue of determining the data center capacity, and, if the power density per rack is wrong, it can greatly change the overall facility capacity and affect the overall construction cost. While the existing low density data center required 2 kW/rack, the high density environments like a cloud data center requires 15 kW/rack or higher.

3.3. Expansion unit setting

A cloud data center assumes expansion as demand increases in order to support variable demand of cloud computing. Expansion unit is generally set based on the partitioned spaces and affected by the power density of the partitioned space and quantity of the receiving racks. Components added when a data center is expanded in step include the transformer, power generator, UPS, battery, PDU, freezer and thermo-hygrostat. It is recommended to adopt a method to enable easy expansion and reduce the investment for each component.

– *Transformer*: Since the reception capacity must be considered in the case of 2 step transformation type mentioned above, the capacity of the first tier transformer (22.9–6.6 kV) is determined on the basis of the overall capacity than the expansion of the step while the capacity and quantity of the second tier transfer (6.6 kV to 380 V) are determined based on the expanded capacity of the step. Because of the nature of the transformer, it may be a problem in terms of space of efficiency if the capacity is partitioned into too small pieces. Thus it may be recommended to configure a transformer to support the multiple spaces.
– *Power generator*: The capacity and quantity of an emergency power generator can vary greatly according to the building shape. To operate a power generator at an appropriate capacity for a long period, inhalation, exhaust, gas duct, and fuel tank should all be considered and the appropriate capacity must be calculated by reflecting the building shape and space size so that these considerations can be satisfied. Like the transformer, a power generator may not be effective if it is divided into too small capacities. A generator capability is generally divided into 3 levels of emergency > prime > normal, and the inhalation/exhaust volume and fuel consumption are generally calculated in the basis of the prime level.
– *UPS/battery*: A dedicated UPS is generally configured to suit the expanded capacity of the step. Modularized UPS is recommended so that it can be quickly added as the ICT system capacity is expanded.

4. Conclusion

As the ICT services become more common and demand for cloud computing increases, the interest on data centers to provide the cloud computing services economically and variably is increasing. For cost saving, which is the ultimate goal of cloud computing, it is essential to construct the high efficiency data center using the high integrated architecture, and cooling performance enhancement and energy efficiency improvement are needed to cope with higher power density in order to achieve such goal.

This study analyzes the factors to improve the power efficiency while securing scalability of data centers and presents the considerations for cloud data center construction in terms of power distribution method, power density per rack and expansion unit separately. Moreover, it describes the factors and expansion unit, which must be considered when changing the data center power management from unit area basis to rack basis for the cloud environment, in terms of the transformer, power generator and UPS/battery separately. Particularly, it categorizes the types of voltage transformation in different steps of supplying the power from the power station to the data center and then to the server then presents the power distribution method most suitable for the cloud data center.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.is.2014.05.013.

References

[1] Michael Armbrust, Armando Fox, Rean Griffith, Above the Clouds: A Berkeley View of Cloud Computing, EECS Department, University of California, Berkeley, 2009.

[2] Rajkumar Buyya, Chee Shin Yeo, Srikumar Venugopal, Market-oriented cloud computing: vision, hype, and reality for delivering it services as computing utilities, in: Paper read at International Conference on High Performance Computing and Communications, 2008.

[3] HP, Optimizing facility operation in high density data center environments technology brief. 〈http://h20000.www2.hp.com/bc/docs/support/SupportManual/c00064724/c00064724.pdf〉 (accessed 22.08.13).

[4] IBM, Modular data centers: providing operational dexterity for an increasingly complex world. 〈https://www950.ibm.com/events/wwe/ca/canada.nsf/vLookupPDFs/Modular_data_centres_-_providing_operational_dexterity_for_an_increasingly_complex_world/$file/Modular%20data%20centres%20%20providing%20operational%20dexterity%20for%20an%20increasingly%20complex%20world.pdf〉 (accessed 22.08.13).

[5] NIST Special Publication 500-293, US Government Cloud Computing Technology Roadmap, 2011.

[6] SangHak Lee, YoungJin Choi, JinHwan Kim, YongJu Kim, HyeonGyu Pak, GyuYoung Moon, JongHei Ra, Yong-Gyu Jung, Cloud data-center with scalability and high density, in: Proceedings of the International Symposium on Advanced and Applied Convergence, 2013.

[7] L. Vaquero, L. Rodero-Merino, D. Mor, Locking the sky: a survey on IaaS cloud security, Computing 91 (2011) 93–118.

[8] Wang Tao, Marcel Kunze, Scientific cloud computing: early definition and experience, in: Paper read at 10th IEEE International Conference on High Performance Computing and Communications, HPCC'08, 2008.

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