Realization of Energy-efficient, Green Data Centers

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The energy consumption of data centers has been increasing with the growth of cloud computing services. There has thus been a growing interest in the environmental performance of data centers. Fujitsu Group added the target of "achieving green data centers" to the Fujitsu Group Environmental Action Plan in 2012 and established the Green Datacenter (GDC) Committee in pursuit of lowering the environmental load of data centers in Japan and abroad. First, we benchmarked 34 major data centers and identified key challenges for short- and mid- to long-term periods. Second, we prepared guidelines specifying improvement measures for these data centers as a basis for action. For this, we created a dashboard that enables the user to determine the results of measures in terms of energy consumption and efficiency. Concurrently, a collaboration system was developed that enables the results to be promptly shared among members of the GDC Committee in order to promote this initiative. We have also been working on a number of long-term projects such as an innovative air conditioning technology using artificial intelligence and a submersion liquid cooling system for servers. This paper reports Fujitsu's various efforts to realize green data centers.

1. Introduction

The amount of energy consumed by data centers is on an upward trend driven by the growth of cloud computing, and as cloud-related businesses expand, CO_2 emissions are predicted to increase. Recognizing these trends, the Fujitsu Group treats the development of green data centers (GDC) as a key social responsibility as well as an important theme to be adopted to solidify its business platform over the long term.

Data centers were responsible for 27% of all CO_2 emissions in the Fujitsu Group in FY2012, and the rate of increase in CO_2 emissions at Fujitsu's 19 major data centers in Japan was 8.1% for the three-year period from FY2010 to FY2012. Against this background, the Fujitsu Group established the GDC Committee in FY2012, declared "improvement in the environmental performance of major data centers" as part of Stage VII (FY2013–FY2015) of its Environmental Action Plan and undertook the task of making 34 of its data centers both inside and outside Japan energy efficient. As a result of these efforts, improvements were made in air conditioning systems, led by a reduction in the energy needed for cooling server rooms while power usage effectiveness (PUE)[note 1)] was improved at an annual average rate of only 2% or more for this period.

These activities began with a focus on configuring the data center environment to achieve improvements in energy efficiency. The Data Center Maturity Model (DCMM) Equalizer provided by The Green Grid (TGG) international industry consortium was used to determine each data center's level of maturity and to identify targets for improvement. To optimize such improvements in the short term, the operational know-how of each data center was shared with the members of the Fujitsu Group GDC Committee, which compiled that know-how and drew up guidelines. Additionally, a dashboard for visualizing the energy efficiency of a data center was developed so that improvement effects and activity status could be shared in real time. In Stage VIII (FY2016–FY2018) of its Environmental Action Plan, the

note 1) An indicator of energy efficiency in data centers: ratio of power consumption of entire data center to that of information and communications technologies (ICT) equipment.

Fujitsu Group declared "achieve an improvement of 8% or greater in data center PUE by the end of FY2018 relative to FY2013" as a target. Activities toward meeting this target are now in progress.

This paper describes Fujitsu Group activities for developing green data centers and achieving the targets set out by the Environmental Action Plan (Stage VIII).

2. Activities at data centers outside Japan

In this section, we describe activities toward green data centers at Fujitsu Australia and other locations outside Japan.

2.1 Achieving energy-efficient data centers

Data centers outside and inside Japan account for 60% and 40%, respectively, of the total amount of power used by Fujitsu Group data centers. Overseas efforts are therefore especially important to achieve the PUE improvement target set by the Environmental Action Plan (Stage VIII). Activities toward improving PUE had, in fact, already been taken to meet the target set by the Environmental Action Plan (Stage VII), and as a result of that effort, the Fujitsu Group succeeded in improving PUE by about 6% relative to FY2012. To improve upon this, even more effort is needed in Stage VIII.

In FY2015 as well, measures were taken for making improvements in both server rooms that control ICT equipment and facility rooms having air conditioning and power supply facilities. The data centers at Fujitsu Australia account for more than 50% of all power consumed by data centers outside Japan, and measures to improve air conditioning efficiency by using a new aisle-capping method are being tested in some of the server rooms there. In this method, the top panel of each rack is left open in both cold and hot aisles, and cooling and heating are clearly separated. For a cold aisle, where providing an excess amount of airflow (wind pressure) to ICT equipment prevents the mixing-in of generated exhaust heat (internal circulation), this method suppresses a rise in pressure within the aisle by discharging excess intake air from the opened top panel.

In FY2016, the above approach was continued and expanded while uninterruptible power supply (UPS) and air conditioning equipment was upgraded as part of a high-efficiency energy savings model to achieve further improvements. From here on, it will be important to determine the limits of PUE improvement and to pursue highly focused improvement activities.

2.2 Use of renewable energy

While the use of renewable energy is attracting increasing attention around the world, Fujitsu Finland has been using renewable energy for 100% of its energy needs in both offices and data centers since 2014. The source of this energy is hydroelectric power.

3. Constructing an environment for improving energy use in data centers

The following describes a method for testing the effects of improvement measures.

3.1 Existing problem

Improving the energy efficiency of a data center requires that improvements be made in the efficiency of all facilities. Improvement measures executed up to now have targeted a broad range of items from server rooms to facility rooms. Among these, raising the air conditioning temperature within server rooms is an effective measure for saving energy in air-conditioned facilities, but it can affect the smooth operation of ICT equipment. It is therefore important to perform testing after implementing a measure and to monitor items for which data change or are expected to change after making improvements.

Up to now, the main approach to performing such measurements and tests has been to use a building management system. This type of system displays operating conditions for air-conditioning-related facilities and temperature conditions for server rooms on a category-by-category basis. However, such a system is not oriented to measuring and testing the effect of energy-saving measures. In particular, it is incapable of simultaneously observing multiple parameters as the need arises. In the case of measures applied to a variety of equipment and facilities, reducing the energy consumed by a specific piece of equipment does not necessarily mean that the energy consumed by the entire data center building will be reduced.

As an example, we can look at the relationship between a chiller and cooling-water pump. A chiller produces the cold water needed for server cooling, and the power it consumes decreases as the temperature setting for the cooling water is increased. However, this increases the amount of cooling water required for the server room, thereby increasing the power consumed by the cooling-water pump. This means that the screens of a building management system corresponding to different categories cannot be easily used to check for temperature changes in a server room after implementing a measure or to examine various types of energy data at a glance.

3.2 Problem solution by preparing consolidated screen

At Fujitsu, we have been working since FY2012 to improve air conditioning operations in our major data centers. One means of solving the above problem associated with the use of a building management system is to use the Plant Information (PI) System provided by OSIsoft, LLC in the United States. The PI System performs real-time data and event management, and in our case, we decided to use the PI ProcessBook function of this system. This function facilitates the creation of a monitoring screen by enabling the real-time data obtained from a building management system or similar product to be arranged in any way on a customized screen. It enables the display of current and historical numerical data, graphs, and figures. With these capabilities in mind, we used PI ProcessBook to create a consolidated screen of measures taken to improve air conditioning operation (**Figure 1**).

3.3 Benefits of consolidated screen

The consolidated screen provides three benefits.

1) Determination of results over entire system

Consolidating the display of power consumed by equipment and facilities on a single screen in relation to a measure taken makes it possible to determine the change in power consumption over the entire system as opposed to a single piece of equipment and to identify the actual energy reduction effect.

2) Tuning to maintain cooling quality of server room

A consolidated screen enables the user to determine the power consumed by chillers and pumps in a server room as items related to energy-saving effects while simultaneously checking air conditioner supply temperature, humidity, etc. as indicators of cooling quality. With this information, the user can

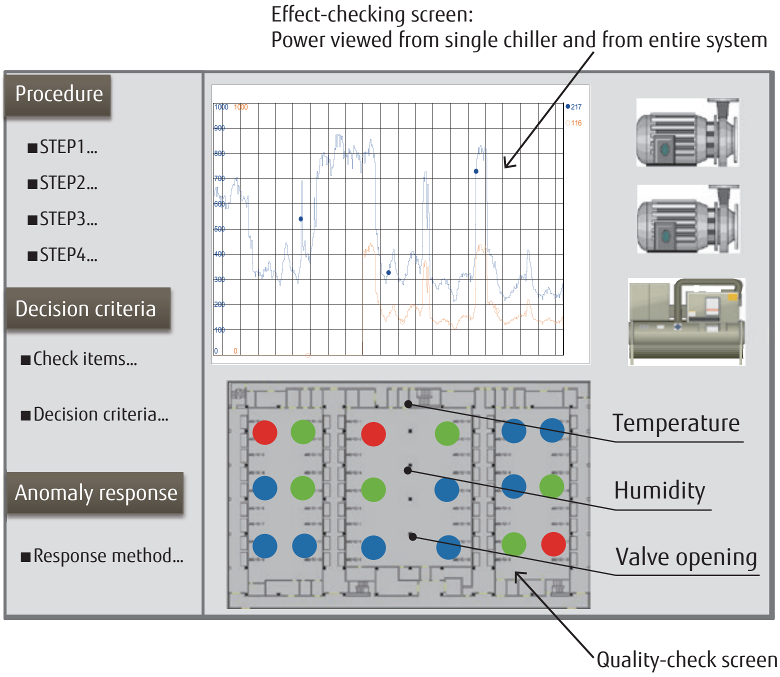

Figure 1
Consolidated real-time display screen created using PI ProcessBook.

appropriately tune the temperature setting of the cooling water. This capability makes it possible to maintain stable operations and identify areas for further improvement.

3) Visualization of know-how

In the past, data to be checked and know-how regarding energy-saving measures such as criteria for executing measures were stored in the heads of engineers. This data and know-how can now be displayed on a screen, which makes for smooth roll out of the developed system to other Fujitsu locations and facilitates the construction of an environment for improving the use of energy.

Departments in charge of data center operations have been using this consolidated screen for studying energy-saving measures and for making improvements in air conditioning operation. As a result of these efforts, data center PUE was improved by approximately 4% in FY2015 relative to the previous year. Going forward, Fujitsu will continue to pursue energy savings while thoroughly checking the effects of measures by using optimal testing methods and monitoring ICT equipment for stable operation.

4. Technical innovation toward environmentally conscious data centers

In this section, we describe efforts toward improving the cooling efficiency of Fujitsu data centers.

4.1 Development of innovative air conditioning control technology

The tuning of air conditioners has traditionally been performed in accordance with specific conditions such as the removal or addition of ICT equipment, the rearrangement of in-service racks, and other activities particular to data centers. To provide flexible support for such tuning operations, we developed air conditioning control technology using just-in-time (JIT) modeling (**Figure 2**). This technology predicts data center temperature and humidity one hour into the future on the basis of temperature, humidity, and power data obtained from various sensors, and it controls the air conditioning system so as to minimize power consumption. A simulation we performed for a data center on a scale of 1,000 racks using actual data for 100 racks showed that a power-saving effect of about 20% could be expected. In FY2016, this technology was applied to an actual data center to assess its effectiveness, and

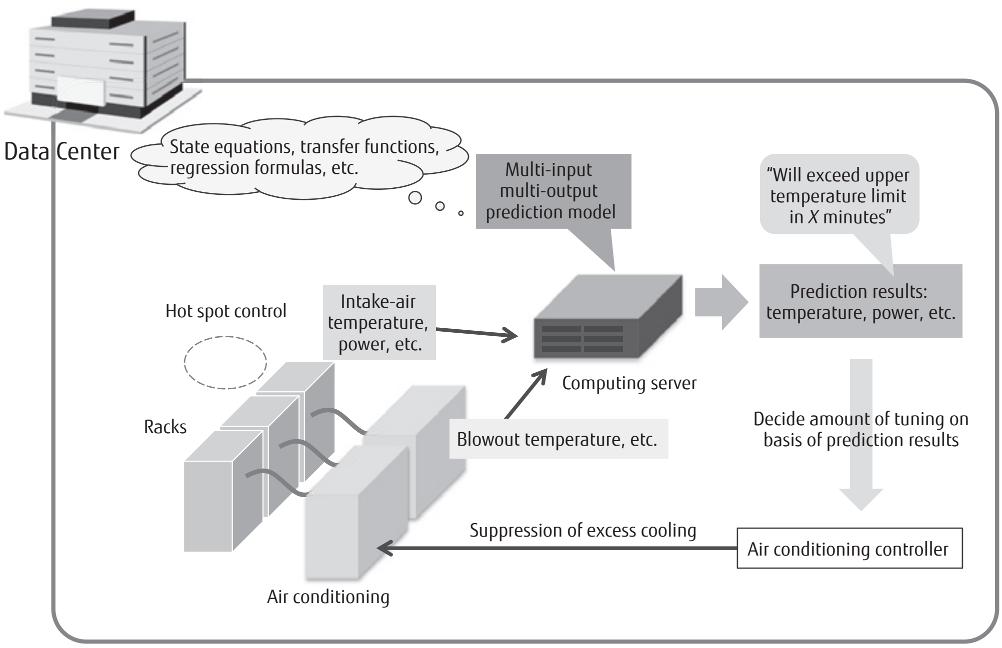

Figure 2
JIT modeling control.

in FY2017, it will start to be rolled out to other data centers.

4.2 Activities at new annex of Tatebayashi Data Center

Fujitsu has undertaken the introduction of outside-air cooling methods for some time as one example of technical innovation toward environmentally conscious data centers.[1)] For a new building (Annex C) at the Tatebayashi Data Center in Gunma prefecture, which opened in April 2016, we achieved an excellent PUE of 1.2 (design value) in simulations by adopting a new outside-air cooling method and reevaluating server-room air conditioning conditions. Three measures were implemented in a case study.

1) Adoption of mixing-aisle method

The mixing-aisle method adopted in some server rooms mixes low-temperature supply air from a variable speed fan mounted above a cold aisle in a server room and warm air from adjacent hot aisles and adjusts temperature and humidity in accordance with server intake conditions[note 2)] (**Figure 3**). Monitoring the temperature and humidity of the outside air (OA) and supplying low-temperature OA in accordance with current conditions reduces the amount of supply air (SA), thereby decreasing the power needed to transport that air into the room. Compared with a rated ventilation system, the variable speed fan used here can be operated with up to 23% less power on average over one year.

2) Maximum use of outside-air cooling method

The building structure of Annex C at the Tatebayashi Data Center is based on the use of the outside-air cooling method (**Figure 4**). Specifically, this building has an SA duct and an exhaust-air (EA) duct installed vertically from the roof to the server floors between two adjacent server rooms. This scheme reduces air-transport power while mixing OA and EA on the roof, enabling the use of OA without condensation even for OA at low temperatures.

3) Air conditioning conditions for each server room

Tatebayashi Annex C has three types of server rooms: standard rooms, cloud rooms, and premium rooms complying with FISC.[note 3)] Each type operates under different air conditioning conditions (intake conditions for fans installed in servers). For example, the temperature and relative humidity of the premium rooms are kept in the range of 18–28°C and within 20%, respectively, while those of the other types of server rooms are simply kept at values that present no problems to the operation of ICT equipment. This approach can lengthen the effective period of OA cooling (described below) and minimize energy consumption.

This study showed that OA, given the climate of Tatebayashi city in Gunma prefecture, can be effectively used for approximately 7,000 hours annually (about 80% of the year) for cooling.

4) Other measures

- Adoption of heat-source facilities excelling in low-load operation

The thermal load of a data center gradually increases with the addition of ICT equipment requested by a customer, but in the initial implementation period in which the scale of the facilities requested is relatively small, there is a need for operation at low loads. For this reason, we adopted air-cooled modular chillers featuring highly efficient inverter control at times of low-load operation.

- Adoption of wireless temperature sensors

Installing wireless temperature sensors in front of server racks and making accurate measurements of intake temperature enables appropriate control of ventilation temperature and airflow.

Performance testing of the above cooling measures in accordance with the operation of ICT equipment is now in progress at Annex C of the Tatebayashi Data Center. The aim is to achieve an actual PUE of 1.2 as early as possible by optimal setting of automatic control parameters and assessment of various operating conditions through an equipment commissioning process. Going forward, Fujitsu is committed to expanding a safe and secure outsourcing business and contributing to customer solutions through the construction and operation of environmentally conscious data centers.

note 2) Temperature and humidity conditions at a server's installation location as specified by each equipment manufacturer for protecting the product.

note 3) Safety standards required of computer systems used by financial institutions as established by the Center for Financial Industry Information Systems, a public interest incorporated foundation.

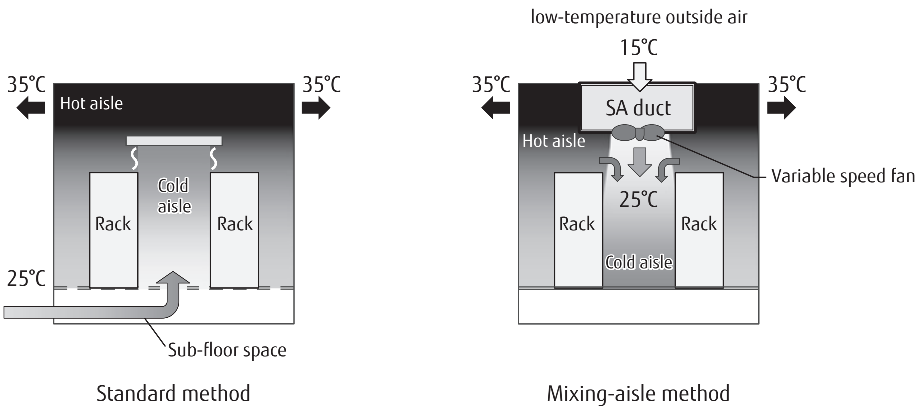

Figure 3
Server-room air conditioning methods.

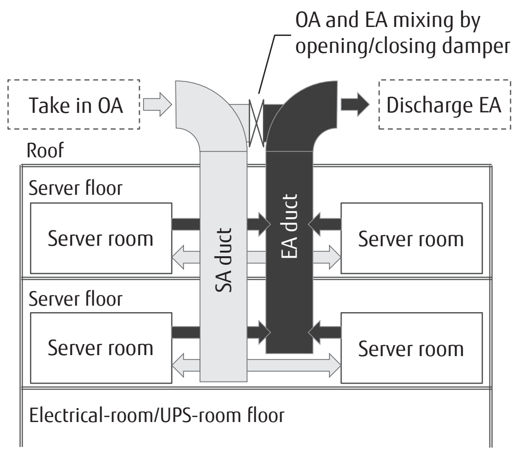

Figure 4
Building structure of Tatebayashi Annex C.

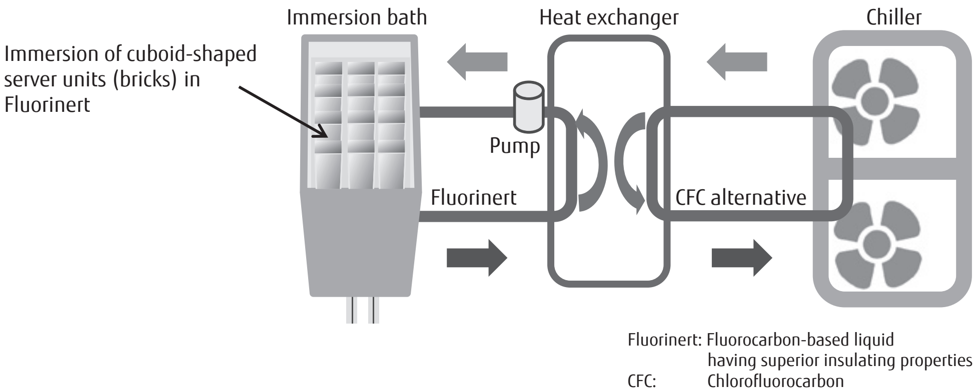

Figure 5
Overview of Fujitsu Liquid Immersion Cooling System.

5. Further pursuits in technology

Finally, we describe two key technologies now under verification.

5.1 Submersion liquid cooling technology

Amid forecasts of expanded energy consumption by data centers driven by the growth of Internet of Things (IoT) business, Fujitsu has formed a capital tie-up with ExaScaler Inc. to develop energy-savings technologies for data centers. As part of this effort, the basic functions, system operation, and cost-saving effects of submersion liquid cooling technology are now being tested. A system implementing this technology cools ICT equipment through complete submersion in a liquid (**Figure 5**). It dramatically improves cooling efficiency compared with the air-cooling method, enabling high-density consolidation of ICT equipment. It also minimizes installation space, reduces the failure rate and leak current in ICT equipment through low-temperature operation, and decreases power consumption through the elimination of internal fans. In this way, the application of submersion liquid cooling technology should enable further cost reductions across an entire data center.

5.2 AI-based learning control technology

Air conditioning control technology for data centers is entering an era of optimization through learning control using artificial intelligence (AI). Using a tested AI model, Fujitsu has established technology for automatically modeling air conditioning characteristics through deep learning, targeting a variety of parameters such as air flow, heat load, outside-air temperature, and ICT equipment load. Going forward, Fujitsu plans to feed back learning results to the control section of air conditioning equipment to achieve more efficient power usage.

6. Conclusion

This paper described environmental configuration methods and the introduction of new technologies for making the improvements needed to achieve green data centers. Looking to the future, we expect the IoT society to evolve even further, resulting in an even greater demand for cloud-based services. To respond flexibly to these developments, the Fujitsu Group will treat high efficiency and high reliability as vitally important, long-term themes.

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