Fujitsu’s Approach to Energy-Saving Data Centers

● Hiroshi Nagazono

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Global environmental problems have become a matter of increasing concern in recent years, and even Fujitsu’s outsourcing business that runs large-scale Internet data centers cannot ignore the need to deal with environmental problems. At Fujitsu, a green Internet data center (Green-IDC) must (1) operate in a stable manner, (2) contribute to a better environment, and (3) make that contribution visible. Various technologies are needed to construct a data center that satisfies these three conditions, and the basis for all of them is visualization technology. In pursuit of Green-IDCs, Fujitsu has created a Total Technology Framework Toward Green-IDC to establish a comprehensive technological system including visualization for making the Green-IDC concept a reality. This paper describes the basic ideas behind this framework and its individual technologies.

1. Introduction

With the G8 Summit in Toyako, Hokkaido completed, discussions are being held in the post-Kyoto Protocol period (post-Kyoto negotiations) on a framework for reducing greenhouse gas emissions (mainly CO_2) that cause global warming. CO_2 emissions have usually been associated with the transport and steel industries, but today, with the volume of information increasing dramatically with the worldwide spread of information technology (IT) services, the amount of power consumed by IT equipment is reaching a level that can no longer be ignored. According to the Ministry of Economy, Trade and Industry (METI), the amount of power used by IT equipment in Japan will increase by about five times from 2006 to 2025. Under these conditions, even Fujitsu’s outsourcing business that runs large-scale Internet data centers (IDCs) cannot ignore the need to deal with environmental problems.

This paper describes Fujitsu’s approach to achieving data centers with environmentally conscious designs while providing high added value (referred to as Green-IDCs below). It introduces energy-saving technologies that are already being applied or are scheduled for use.

2. What is Green-IDC?

Fujitsu has established the following conditions for a Green-IDC.

1) Operate in a stable manner

IT systems have become indispensible to corporate business. For a corporate customer, the purpose of outsourcing one’s IT assets is to guarantee business continuity. The value that the customer wishes to receive consists of comprehensive measures against disasters, all necessary security measures, and uninterrupted system operation. Providing this value on an ongoing basis is the reason for a data center’s existence. Thus, if one moves forward blindly on energy-saving measures, one might get one’s priorities wrong because it could hinder on-site work or degrade the quality of operations. The ideal state is one in which efforts to tackle environmental problems also contribute to improved operation quality.

2) Contribute to a better environment

In addition to providing value as described above, a data center—as a building—must be environmentally friendly. For the same provided value, a data center must reduce the amount of consumed energy (mainly electric power) as much as possible, and for the same amount of consumed energy, it should use as much clean energy as possible to contribute to the environment. Moreover, when we view environmental problems from a broader perspective, we find many issues that data center design must take into consideration, such as refraining from the use of substances that destroy the ozone layer, refraining from the use of lead compounds, and using appropriate methods for treating waste oil, waste water, noise, trash, etc.

3) Visualize environmental contributions

Until recently, customer satisfaction was based on the degree to which value, i.e., stable operation, could be provided continuously in a highly professional manner. From here on, though, it is clear that dealing with environmental problems will be an important management issue for both Fujitsu and customer companies. If customers understand that outsourcing a data center will enable them to contribute to the environment more than operating IT equipment themselves, the data center will take on new value. Green-IDC is the first approach to data centers that will not only achieve energy savings, but also provide ongoing proof to both customers and society that energy savings are being achieved.

3. Green-IDC technologies

Technologies and measures for achieving Green-IDC come in two types: those that contribute directly and those that contribute indirectly to energy savings. The former includes the deployment of high-efficiency uninterruptible power supplies (UPSs) and high-efficiency chillers, while the latter includes technology for optimal control of facilities and technology for assisting efficient operations. It is important that technologies of both types be skillfully combined to produce overall energy savings. Fujitsu's total technology framework for achieving Green-IDC is shown in **Figure 1**.

3.1 Basic ideas

The basic ideas presented in Figure 1 are summarized below.

- The basis of all technologies and measures is visualization technology. Visualization clarifies current energy usage and air conditioning conditions [1) in Figure 1].
- Visualized information promotes efficient use of power and minimal power consumption [2)].
- Visualized information also promotes optimal control of air conditioning and minimal power consumption [3)].
- Use of clean energy [4)]
- Energy savings through building-related measures [5)]
- Hardware performance and power consumption of computers are always improving and virtualization and other software technologies are continuously evolving. A data center should deploy the optimal platform for its time [6)].
- As a medium- to long-term measure, power microgrids that promote power interchange with other data centers or nearby facilities should be studied [7)].

3.2 Individual technologies

This section describes key technologies in each of the above catetgories, using Figure 1.

1) Pre-construction visualization [1)-a]

An optimal layout for server racks and air conditioning facilities inside the machine room must be determined at the design stage when a new data center is constructed or an existing one is upgraded. Unlike IT equipment, such data center facilities cannot easily be replaced or modified once construction has been completed. It is therefore important to use IT to visualize the state of air conditioning under various layout configurations and find an optimal layout before construction. Thermal current simulation is an elemental technology for this purpose.

2) Everyday visualization [1)-b]

This consists of routine monitoring operations. Existing data centers constantly monitor the state of power usage, temperature, humidity, and air flow and store the collected information. In the case of power, for example, the monitoring system collects and stores the amount of power used at all points from the extra-high-voltage substation to the terminal breaker. As for temperature, the system measures intake temperature and exhaust temperature for each rack at various points. Although monitoring in itself is not connected directly to energy savings, it provides an accurate understanding of current conditions and enables changes to be detected quickly and improvements to be made, thereby providing a basis for establishing energy-saving measures. Elemental technologies for everyday visualization include a sensor network architecture for flexible support of new measurement points, sensor technology such as real-time multipoint temperature measurement using optical fibers, virtual integrated database technology, and analysis techniques.

3) Expansion visualization [1)-c]

The effects on power supplies and air conditioning of installing a certain number of new units of equipment must be clarified beforehand. Once a data center starts operating, it will continually be accommodating new IT equipment that

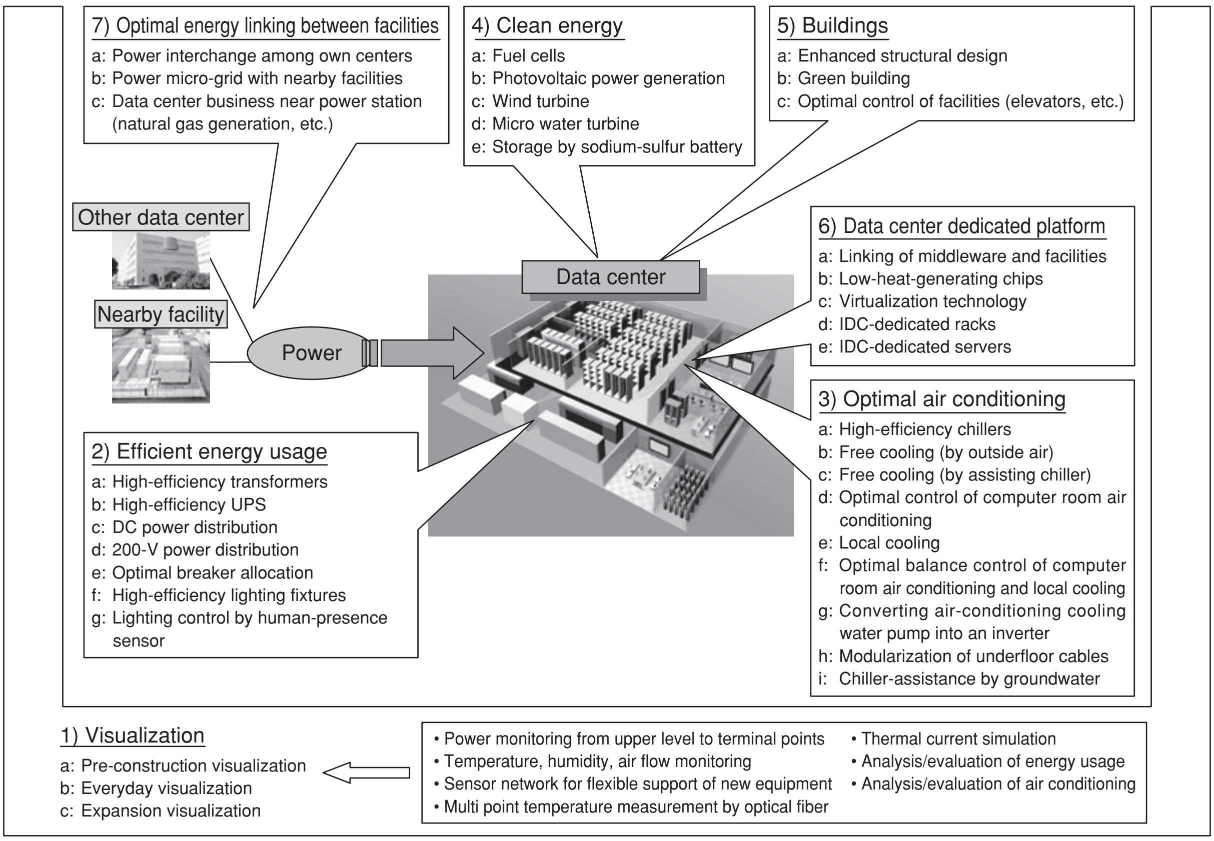

Figure 1
Total technology framework for Green-IDC construction.

will inevitably change the power-supply and air-conditioning conditions within the machine room. Installing new equipment in the wrong place could result in insufficient power supply capacity in some locations and the generation of cold or hot spots in the room. This, in turn, could produce problems with power consumption and stable operation. The place for installing new equipment has usually been decided by experienced on-site personnel, but the needs of the future call for saving power and enhancing quality by utilizing IT. The approach here will be to combine technologies like thermal current simulation and optimal breaker allocation in item 2)-e based on collected information.

4) High-efficiency UPS [2)-b]

For a UPS, a constant-voltage system that controls only voltage features less power loss and higher efficiency than a constant-voltage/constant-frequency system that controls both voltage and frequency. The choice of which to use should be made according to the application. In addition, a typical UPS demonstrates the catalog-indicated efficiency only under high load. In a data center, however, UPSs used for IT equipment have a redundant configuration, so the load applied to individual UPSs is actually only about 50–70%. For the future, we need products whose efficiency drops as little as possible under low-load conditions.

5) DC power distribution [2)-c]

Supplying power to IT equipment by DC reduces the number of AC/DC conversions, thereby decreasing conversion loss. For long transmission distances, however, DC power distribution requires a high voltage, which can present problems in terms of safety and stable provision of power. Moreover, few IT devices currently support DC. Nevertheless, DC power distribution is considered to be an important means of using power efficiently, so some companies have begun work on its partial application. Fujitsu is also investigating its application.

6) 200-V power distribution [2)-d]

In Japan, the power-supply voltage for ordinary households is 100 V while that for IT equipment is either 100 or 200 V. Existing data centers therefore require two types of large step-down transformers and two types of power distribution units for 100- and 200-V use. In recent years, however, the ratio of 200-V IT equipment has increased, making it possible for data centers in Japan to have uniform power distribution at 200 V. This can decrease the power loss associated with voltage conversion. However, 100-V devices still exist among some network equipment and equipment held directly by customers. Such equipment can be supported on an individual basis by a small rack-mount 200→100 V step-down transformer.

7) Optimal breaker allocation [2)-e]

This is a software technology used in combination with "expansion visualization" in item 1)-c to provide advice on optimal installation locations. It extracts the number of free breakers that must be allocated according to basic decision-making criteria such as whether any free breakers exist in a power distribution unit or whether a certain increase in power lies within the capacity of a power distribution unit. Looking forward, such advice should be based not only on basic decision-making criteria as described above, but also on custom policies such as allocating breakers that are as close to each other as possible to the same customer.

8) Free cooling [3)-b, 3)-c]

Free cooling can generally be achieved in two ways:

- By introducing cold outside air directly into the machine room
- By using cold outside air to assist the heat exchanger in the chiller

Either approach can make a big contribution to energy savings. Fujitsu data centers are achieving considerable reductions in air conditioning power usage through free cooling that exploits local characteristics. Deployment of free cooling is an issue that should be studied when constructing a new data center. It must also be kept in mind that optimal humidity control by either removing or adding humidity will be needed when outside air is used directly. Filters must also be used to remove dust in the air.

9) Local cooling [3)-e]

This is technology for pinpointing limited areas that need to be cooled on individual racks or in rack aisles. Various types of local-cooling equipment are available such as the ceiling-overhead type, in-row type installed between racks, and installed-on-rack-back type. The cooling system may be air-cooled (refrigerant type) or water-cooled.

10) Optimal balance control of computer room air conditioning and local cooling [3)-f]

Local cooling equipment can often be used for all air conditioning needs in the case of a small-scale modularized machine room or rack aisles that have been partitioned into units of a certain size by dividers. In the case of a large-scale machine room, however, it would be difficult to handle all exhaust heat by only local cooling equipment considering the cost of initial investment.

It is for this reason that all air conditioning in large-scale data centers has usually been achieved by computer room air conditioning. But from here on, we can expect local hot spots to occur as rack installations become increasingly dense due to the proliferation of blade servers. In that case, eliminating a local hot spot by controlling the room's air conditioning could lead to cold spots in other areas, making for an inefficient scheme overall. An effective means of dealing with this predicament is to combine both of the above approaches, that is, to process a fixed heat load by room air conditioning while performing pinpoint cooling by local cooling equipment for hot spots. This solution can ease temperature-setting requirements in computer room air conditioning and reduce the amount of energy consumed by air conditioning.

There is therefore a need for software-based operation control to achieve an optimal balance between computer room air conditioning and local cooling. We can consider a reactive system that controls operations and achieves an optimal balance based on temperature-monitoring information from within the machine room and a proactive system that links central processing unit load information from IT equipment with the operation of local air conditioning. Fujitsu is in the process of developing an interworking function between server operation-control middleware and facility control.

11) Fuel cells [4)-a]

The use of fuel cells is spreading and there are many types of small fuel cells designed for general households and automobiles. However, fuel cells of this size are unsuitable for use in data centers. Large fuel cells in the 100–200 kVA range do exist, but their capacity would have to be increased for them to be suitable for use in data centers. Nevertheless, we can expect fuel cells to be used in data centers as a source of clean energy once capacity has been increased, an infrastructure for stable provision of hydrogen has been established, and operational costs have come down to current electric-power levels.

12) Photovoltaic power generation [4)-b]

The use of photovoltaic power generation, which is a typical technology associated with clean energy, is spreading rapidly throughout the world. It has begun to be used on a partial basis at Fujitsu data centers, and the plan is to introduce greater amounts in the years to come. However, the total energy needs of a large-scale data center cannot be met solely by photovoltaic power generation. Applications for photovoltaic power generation as a source of clean supplementary energy especially for data centers need to be found. Manufacturers of photovoltaic power generation equipment must propose total solutions for data centers that include greater power-generation efficiencies, storage technologies, and effective applications.

13) Enhanced structural design [5)-a]

When a data center is being designed and constructed (as opposed to leased), energy-saving measures can be taken from the perspective of a new building. In the case of a seismically isolated building, for example, the building's structure can be utilized by implementing free cooling with fresh air cooled within the seismic isolation pit. Moreover, if the building is to be used specifically as a data center, windows can be eliminated, entrances and exits can be minimized, etc.

14) Optimal control of facilities [5)-c]

This consists of energy-saving measures for ordinary buildings such as optimal operation of elevators and establishing energy-saving office space.

15) Virtualization technology [6)-c]

Virtualization technology is said to be effective in reducing the cost of managing IT assets and in shortening the time for constructing a new system. It is also attracting attention as an energy-saving technology. It contributes to energy saving in two ways.

- Reduced power consumption through server consolidation

The number of actual servers can be reduced and power consumption lowered by using virtualization technology to consolidate multiple servers in one server unit.

- Dynamic control of exhaust heat

Server virtualization technology enables switching between processing servers without halting the system. With this function, the location of exhaust heat produced by a concentration of processing in a certain device can be controlled by distributing the processing load among various devices and making generated heat from those devices uniform. Linking exhaust-heat dynamic control technology and the air conditioning control system can achieve optimal air conditioning for a given amount of processing and save energy. As a result, this approach is more suitable to a utility-type service that provides resources from a large server pool than to ordinary services characterized by a one-to-one relationship between customer and equipment. The next generation of data centers is likely to be based on this kind of utility-type service and we expect the dynamic control of exhaust heat to be applied in earnest in those data centers.

3.3 Application to new data centers

A breakdown of power consumption in existing Fujitsu data centers is shown in **Figure 2**.

Power usage effectiveness (PUE) is an index of energy usage efficiency in data centers. It indicates the ratio of power used for the entire data center to power required by IT equipment. A lower value for this index means a higher percentage of power used for IT equipment and better energy usage efficiency for the data center. The usefulness of this index has been questioned because it does not consider energy other than electric power and cannot express performance improvements in IT equipment. On the whole, however, it is very easy to understand, which probably explains its extensive use. From Figure 2, the PUE of existing Fujitsu data centers comes to about 2.2.

At Fujitsu, the Tatebayashi No. 2 Data Center (provisional name) is scheduled to be completed in autumn 2009. A variety of novel technologies like the ones described above are being actively applied to this new data center. Ongoing

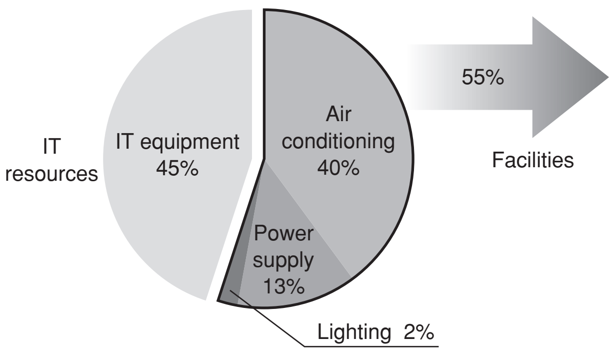

Figure 2
Breakdown of power consumption in Fujitsu data centers.

improvement of the PUE is considered to be important for future data centers. The main technologies scheduled to be applied to the Tatebayashi No. 2 Data Center are listed below.

1) Visualization
- Thermal current simulation
- Visualization of power usage from extra-high-voltage substation to the terminal breaker
- Visualization of temperature, humidity, and air flow
- Sensor network that can accommodate new measurement points

2) Optimal power supply control
- High-efficiency transformers
- High-efficiency UPS
- Optimal breaker allocation assistance system
- Uniform 200-V power distribution

Optimal air conditioning
- High-efficiency turbo chiller
- Free cooling
- Local cooling equipment
- Optimal balancing of computer room air conditioning and local cooling

3) Clean energy
- Photovoltaic power generation

4) Building construction
- Free cooling using fresh air cooled within a seismic isolation pit
- Lighting control based on radio frequency identification (RF-ID)

4. Conclusion

The total technology framework presented here is being applied to the Tatebayashi No. 2 Data Center as an initial target. Plans are being made to expand its use to other Fujitsu data centers and those of affiliated companies. Although this paper focused on energy-saving technology for data centers, there is also a need to visualize energy-saving effects for the customer's benefit. We have begun to address this issue by computing the PUE for each customer. Looking to the future, we will continue in our efforts to attract all of our customers' IT systems to Fujitsu data centers with the ultimate goal of reducing CO_2 emissions and contributing to a better global environment.

Reference

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Hiroshi Nagazono
Fujitsu Ltd.
Mr. Nagazono received the B.S. degree in Business and Commerce from Keio University, Tokyo, Japan in 1988. He joined Fujitsu Ltd., Tokyo, Japan in 1988 and has been engaged in planning and development of information systems. He is currently engaged in research and development of energy-saving technologies for data centers.