UPSs for Hyper Scale Data Centers

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ABSTRACT

Data centers (DCs) for storing big data are increasing in size year by year. Uninterruptible power systems (UPSs) are indispensable in stabilizing the operation of DCs and are required to have a large capacity and high efficiency. Fuji Electric has added new functions to UPSs for DCs, including control of the number of operating units to pursue the maximum system efficiency and a continuous commercial power feeding to reduce power loss during stable commercial power supply. We have also developed a module UPS, one unit of which consists of several panels, and a compact, lightweight battery panel equipped with lithium-ion batteries, allowing DCs to improve operational efficiency.

1. Introduction

The Science and Technology Basic Plan of the Cabinet Office, Government of Japan has proposed "Society 5.0," a people-centered society intended to achieve both economic development and solutions to social problems through the use of X-Tech (Cross Tech), a system that merges virtual and real spaces together.

Achieving the goal of Society 5.0 requires communication infrastructure capable of exchanging data from numerous and various sensors connected to the Internet through the Internet of Things (IoT) and data centers (DCs) with high availability for collecting such data.

One important piece of equipment supporting the availability of DCs is an uninterruptible power system (UPS) that supplies stable power continuously even in case of a problem with the power supply. The number of hyperscale (ultra-large size) DCs has been increasing in recent years and they consume a huge amount of electricity. UPSs used in such facilities are also required to have large capacity and high efficiency to save energy. This paper describes UPSs for hyperscale data centers that support the high-capacity electricity infrastructure of hyperscale DCs.

2. Current Status of the DC Market

The costs of electric power for running a DC place a heavy burden on DC operators. The power usage effectiveness (PUE) of a DC can be shown with Equation (1).

$$\text{PUE} = \text{Power consumed by entire DC} \,/\, \text{Power consumed by IT equipment} \quad \cdots\cdots (1)$$

To improve this index, it is essential to reduce the power consumed by items other than IT equipment.

Moreover, one of the factors considered to be important in DC operation is availability, which indicates the percentage of the period for which the system can continue its operation. It can be shown with Equation (2).

$$A = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} \quad \cdots\cdots (2)$$

A : Availability
MTBF : Mean time between failures
MTTR : Mean time to recovery

Uptime Institute, LLC categorizes the quality of DCs from Tier I to Tier IV (top level). The operating rate A for Tier IV is as high as 99.99%[(1)]. This is equivalent to a system where operations may be suspended for four hours only once in five years. It is an important issue for DC operators to increase availability by using a redundant system and improving maintenance in addition to enhancing the reliability of the equipment itself.

The smaller is the installation space for equipment other than IT equipment, the more the number of IT equipment can be installed. A smaller installation space has a trade-off relationship with higher system redundancy for ensuring availability. DC operators consider system configurations that maintain availability while reducing the installation space.

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3. UPS Efficiency Improvements

3.1 Non-insulated UPS

Some transformers for voltage change or isolation are needed on the feeding route from a power receiving point to loads. Increasing the number of transformers increases loss. Consequently, a non-isolated UPS with no internal transformers has been used widely in recent years. Using this non-isolated UPS makes it possible to optimize the number of transformers in the feeding route.

3.2 Three-phase, four-wire, 400-V power feeding system(2)

A three-phase, four-wire, 400-V UPS will output a voltage of approximately 230 V across the neutral phase and another phase. Since this voltage is within the operating range for typical 200-V load equipment, there is no need for stepping down from 400 V to 200 V, reducing the loss incurred by transformers.

If, however, one-line ground fault (interphase short-circuit) occurs on the load side, the ground-fault current is not isolated but reaches the output side of the UPS. When this condition continues, the UPS may stop. In order to prevent such a problem, the feeding circuit must be designed to have an appropriate load branch breaker and design the feeding circuit so that a ground fault at one point will not affect the feeding of other systems.

3.3 Using low-loss devices

The UPS uses a three-level conversion circuit in the pulse width modulation (PWM) converter for AC-DC conversion and the inverter for DC-AC conversion, and the circuit uses Fuji Electric's proprietary reverse blocking-insulated gate bipolar transistors (RB-IGBTs) and power modules dedicated to three-level conversion. This has reduced switching loss that is produced when the device turns on or off, and lowered the ripple current to reduce loss also in the filter circuit. Moreover, Fuji Electric has selected a silicon carbide (SiC) device for the free wheeling diodes (FWDs) of the PWM converter. Compared with conventional silicon (Si) devices, SiC devices offer lower switching loss and conduction loss, allowing the UPS to reduce loss.

3.4 Quantity control

In general, the efficiency of UPSs is low in the light load region and peaks in a specific heavy load region. In a system where several UPSs are connected in parallel, load current flows equally through each UPS. Consequently, when the load is small, the load per unit becomes even smaller, resulting in a significant degradation in the efficiency of the entire system.

To improve the efficiency of the entire system, this UPS changes the number of operating units to make the load on a single operating UPS close to the maximum efficiency by monitoring the load of the entire system, instead of operating all UPSs all the time.

3.5 Continuous commercial power feeding

Large-capacity UPSs used in large-scale DCs generally use normal inverter feeding because it is highly reliable. The reasons why this method is regarded as highly reliable are that it can continuously supply power at a constant voltage and frequency and that the feeding continues without instantaneous interruption in case of a blackout because of the continuous operation of the inverter.

In addition to IT equipment, UPSs in DCs are used for feeding power to air-conditioners and other equipment, and some load may allow voltage fluctuation or instantaneous interruption. Fuji Electric offers UPSs with continuous commercial power feeding, which uses a bypass feeding circuit to reduce power loss.

Continuous commercial power feeding is a method that puts the emphasis on feeding efficiency. When the commercial power supply is normal, power is fed directly to the load from the power supply. During a blackout, the power stored in the storage batteries is fed after the conversion into alternating current by an inverter. Fuji Electric calls this function High Efficiency Mode (HE mode) and has been incorporating it into its latest models. Figure 1 shows a comparison between normal inverter feeding and continuous commercial power feeding(3).

In continuous commercial power feeding, the fluctuation in the AC power supply directly affects the load during normal operation. When a blackout occurs, the output voltage waveform is instantaneously interrupted for about 1/4 of the cycle due to a delay in the detection time. Since this method feeds power to the

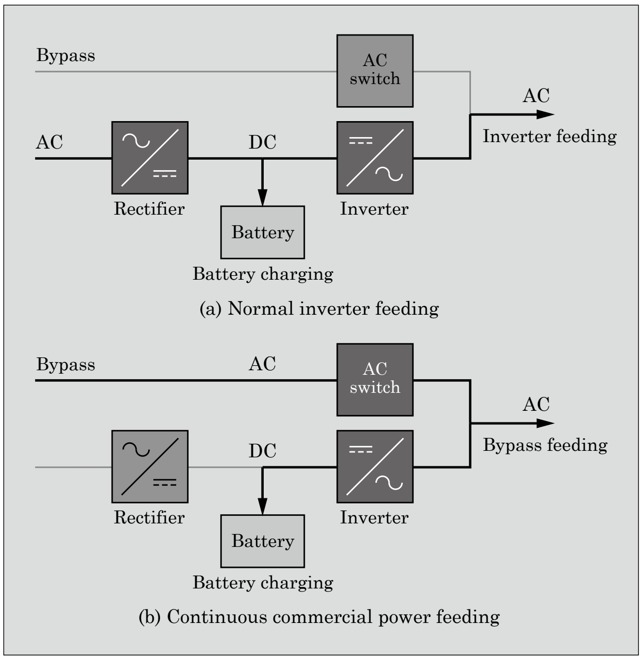

Fig.1 Normal inverter feeding and continuous commercial power feeding

load without using a converter, the power loss is lower than that for normal inverter feeding.

4. Optimization of UPS System Configuration

In addition to the high efficiency described in Chapter 3, UPS systems in DCs are required to deliver: easy equipment maintenance, enhanced maintainability for quick recovery from failure, scalability for phased capital investment, compact size for saving installation space to reduce building costs, and low running costs using long life parts.

4.1 Modular UPS

A module UPS consists of several panels that have respective functions. For example, Fuji Electric's module UPS "UPS7400WX-T3U" is shown in Fig. 2. As shown in Fig. 2, this UPS includes three to four panels: an I/O panel, a control panel and a UPS module panel, installed from the left.

A modular UPS has the following features:

(1) High reliability

Redundant converters ensure continuous inverter feeding even if some of the modules fail.

(2) High maintainability

Inspection and failure recovery are possible on a module basis while the inverter feeding is continued.

(3) High scalability

The capacity can be increased by adding modules.

Fuji Electric has launched the "UPS7400WX Series" modular UPS, having the features described above.

4.2 Use of lithium-ion batteries (LIBs)

Conventional UPSs have used lead-acid storage batteries; however, these batteries have disadvantages of being heavy and large. On the other hand, lithium-ion batteries (LIBs) are compact and lightweight. In recent years, although LIBs have been rapidly expanding in applications, such as electric vehicles and power storage units, their use in large-capacity UPS systems has not been increasing so much. This is because

Fig.2 "UPS7400WX-T3U" modular UPS

UPSs are installed in an electrical room and LIBs use an electrolyte, which is as flammable as petroleum, manufacturers are required to provide a certain fire-prevention measure according to the Fire Service Act.

Fuji Electric has solved such a challenge and has used LIBs manufactured by Samsung SDI Co., Ltd. in the large-capacity UPS "UPS7000HX Series" and "UPS6000DX Series."[4]

The advantages of using LIBs are as follows:

(1) The expected lifespan is 15 years so that replacement is unnecessary during the operating period of the UPS (15 years) (the lifespan of lead-acid batteries is 7 to 9 years).
(2) Compared with lead-acid batteries, the footprint is reduced to about half, and the mass is reduced to about 20%.
(3) The backup time is longer than that for lead-acid batteries even at higher temperature.

4.3 Optimization of system configuration

In recent years, the capacity of UPSs has been increasing as the server racks used for DCs are designed to provide larger capacity. Moreover, the use of a parallel redundant system has become common for the UPS systems intended for DCs, so that the capacity of the necessary peripheral equipment should also increase. Although the capacity of an entire UPS system including peripheral panels increases, there is a strong demand for limiting any cost increase.

Fuji Electric's efforts to meet such a demand are described below:

(1) Larger capacity of a single UPS unit

Increasing the capacity of a single UPS unit will cause the following effects:

(a) The number of panels, such as battery panels or peripheral panels, can be reduced, resulting in cost saving.
(b) The reduced number of pieces of equipment also helps lower the failure rate and improve availability.

(2) UPS feeding system

A parallel redundant system has been used in UPS systems to improve reliability. In this case, the output currents from the respective UPS units are aggregated to the output bus, and the bus and switches are required to endure large output currents. Since switches have a limitation to their capacity, UPSs are also limited in terms of their size.

On the other hand, many DCs overseas that are rated as Tier IV class specified by Uptime Institute use 2N systems with static transfer switches (STSs). Figure 3 shows configuration examples of a parallel redundant system and a 2N system.

Like parallel redundant systems, 2N systems can also achieve high availability. Furthermore, when a UPS is assigned to each load equipment of a DC, the output bus capacity can be reduced. Consequently, it will be more important in the future to work in close

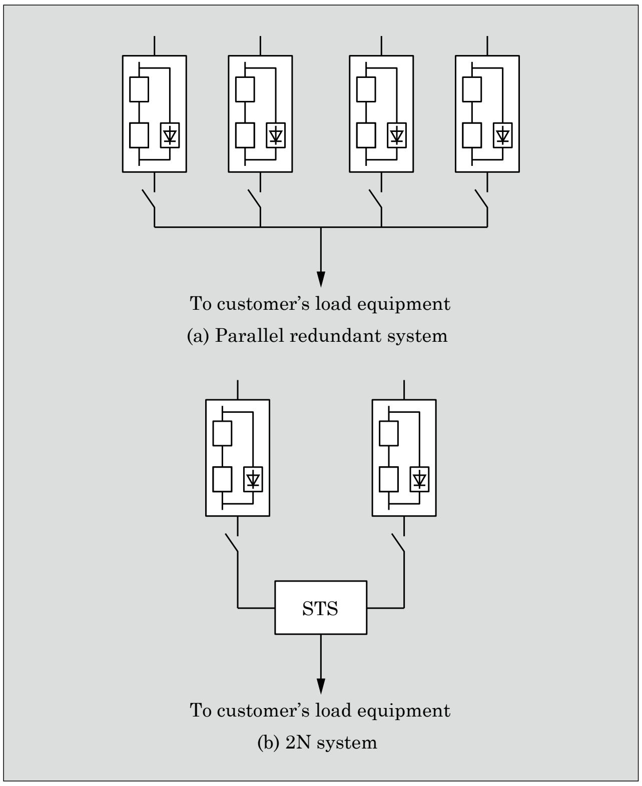

Fig.3 Configuration examples of a parallel redundant system and 2N system

cooperation with DC operators and build UPS systems by not only optimizing the equipment delivered from Fuji Electric but also optimizing the DC as a whole.

Incidentally, Fuji Electric provides a function to enable control in a 2N system to synchronize the outputs from two UPS units.

5. Postscript

This paper described UPSs for hyperscale data centers.

Efficient operation of electric power and the technology for improving the availability of the entire system are essential factors in data center operations. We need to perform product development and present solution proposals for UPSs, which are essential equipment for data centers, on the basis of operating a system including entire peripheral equipment rather than optimizing the unit alone from the standpoint of availability and total cost of ownership of the entire electricity infrastructure.

At Fuji Electric, we are willing to further advance our technology so that we can contribute to Society 5.0 in which people will enjoy new values brought by X-Tech and to data centers that will play the key role there.

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