Current Status and Future Outlook

Power Supply Systems Contributing to Stable Power Supply and Energy Saving: Current Status and Future Outlook

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1. Introduction

Investment in substations, data centers (DCs), and other social infrastructure is continuing to grow in Japan, North America, Europe, and other countries where economic growth is expected to be strong in the medium to long term, including those in Southeast Asia, India, and the Middle East. It is against this backdrop that demand for substation equipment, switchgear, and controlgear has remained steady as a means of supplying stable power. In particular, there is an increasing number of large-scale DCs being constructed in the DC market due to growth in IT system cloud computing, e-commerce, and content distribution services, as well as the spread of the Internet of Things (IoT) technologies driven by the expansion of 5th generation cellular network system (5G) communication networks. As a result, there is growing demand for smaller, more efficient, and higher capacity uninterruptible power systems (UPSs) to contribute to the stable supply of electric power.

In the Japanese market, transformers, switchgear, and other substation equipment that were installed in steel, chemical, and other material plants and railway companies in the 1970s and 1980s are increasingly being replaced due to aging. This investment is primarily being made to prevent accidents and improve both remote and on-site maintenance efficiency.

In addition, the need for plant-wide energy visualization and optimization is increasing to reduce CO_2 emissions and save energy from the perspective of decarbonization and energy cost control. It is expected that opportunities will increase not only for products that have high power conversion efficiency, but also for energy management systems (EMSs) that provide optimal energy supply and demand control.

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In this paper, we describe the current status and future outlook of power supply systems that contribute to stable power supply and energy saving in accordance with Fuji Electric's technological initiatives.

2. Power Supply System That Contributes to Stable Power Supply for Data Centers

2.1 Promoting "Proposal of comprehensive electrical equipment"

There is growing demand for DCs to be built on a larger scale, but with shorter delivery times. At the same time, system designs are becoming more diverse and sophisticated to deliver, for example, initial configuration that facilitates efficient future system expansion completed within a short period of times after the start of operations.

Along with this trend, there is also strong demand for power supply system equipment that not only achieves high reliability and stability, but also realizes larger capacities and better future scalability within shorter construction periods. In order to meet the above needs, Fuji Electric offers "Proposal of comprehensive electrical equipment" which include extra-high-voltage receiving and transforming equipment, emergency power generation equipment, substation equipment, and UPS systems, in addition to standalone products. The solutions optimize systems, reduce installation footprints, and shorten construction periods.

Figure 1 shows a typical power system configuration for a large-scale DC. Substations are facilities that receive extra-high-voltage utility power and convert it to high-voltage. Their configuration is determined according to cost and reliability. In general, it is often configured with a "main line and backup line." These two lines are used to receive utility power and convert it to high-voltage. Emergency power generation equipment is used to supply power to loads during prolonged utility power outages. Substation equipment is installed in each building or floor to supply power to each zone. A UPS system is a piece of equipment that enables a continuous supply of power in the event of a power

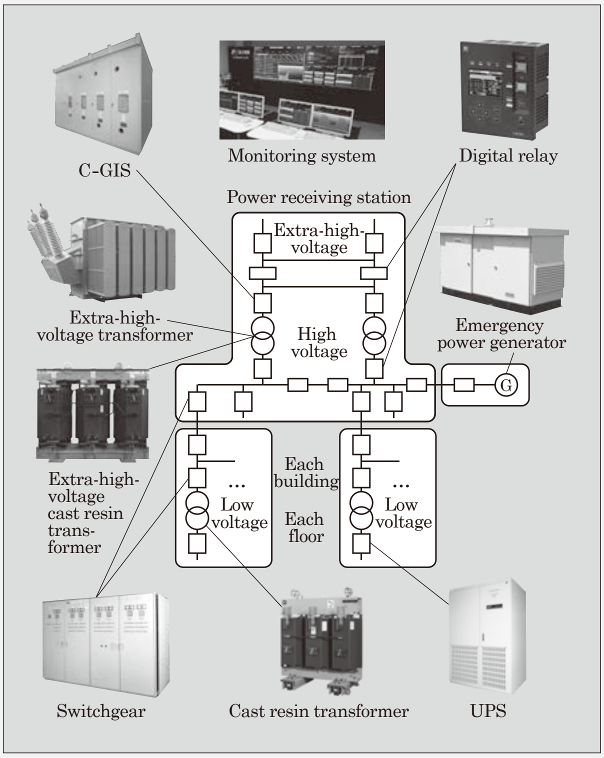

Fig.1 Typical power system configuration for a large-scale DC

outage until switching over to an emergency power generator. Each system has a redundant configuration that ensures a continuous and stable supply of electric power in the event of equipment failure or at times of power supply maintenance.

The most basic requirement of power supply systems for DCs is to improve reliability. The important measures to meet this requirement include building reliable systems in terms of maintenance inspections and recovery operations during unexpected equipment failures, as well as stable operation during regular operations and backups during power outages. Fuji Electric has leveraged its rich experience in supplying power supplies to DCs to create system construction technologies that enable it to offer its customers a wide line-up of power supply systems to meet their requirements (Refer to "Power System Construction Technology with Improved Redundancy and Maintainability" on page 14).

The increase in the scale of DCs has also increased the capacity of their transformers for UPS input. To respond this trend, Fuji Electric offers rectangular large-capacity 5-leg type MOLTRA "V-ECO MOLTRA" that has reduced height dimensions to fit into a standard transformer panel while maintaining the same installation footprint as conventional products in the large capacity range exceeding 1,000 kVA. (Refer to "Rectangular Large-Capacity 5-Leg Type MOLTRA to Meet the Needs of Energy Saving and Downsizing" on page 27).

2.2 UPS technology supporting power supply systems

Large-capacity UPSs are core systems to stabilize the power supply in large-scale DC systems. They are required to achieve higher capacities and energy saving, while facilitating shorter construction periods and overall system downsizing in terms of peripheral equipment, such as input transformers.

In order to improve the system's energy efficiency, a 3-level converter circuit using reverse-blocking IGBT (RB-IGBT), which is Fuji Electric's proprietary technology, has been adopted in rectifiers and inverters in UPSs to achieve the industry's highest level of efficiency as a continuous inverter power supply system. It also has a function to control the number of units to stop several power modules at low load factor so that the power conversion module can be operated with optimum efficiency. Furthermore, during normal operation, it reduces power loss by supplying power from the utility power supply. If there is a utility power supply failure, its high efficiency mode (HE mode) instantly switches to the battery to supply power. This enables power to be supplied with a high efficiency of 98.4% when the voltage and frequency are stable in the power supply.

Moreover, the UPS system has a reduced installation footprint and shortens installation work periods by using a structure that enables installation with rear-facing alignment and internal wiring between I/O panels and transformer panels.

Figure 2 shows the "UPS7500WX" high-capacity UPS for large-scale DC applications. It features the technologies described above (Refer to "High-Capacity Power Supply System That Contributes to Stable Power Supply for Data Centers" on page 9).

The 2N system is the most reliable system configuration in DCs. It makes the whole system redundant. Although this type of system is highly reliable, it requires a static transfer system cabinet

Fig.2 "UPS7500WX"

to switch systems. Its reliability greatly affects the overall reliability. To meet this need, Fuji Electric offers a high-reliability static transfer system cabinet. While improving the reliability of switching, the static transfer system cabinet uses the UPS synchronization function to shorten switching times and improve voltage stability during switching (Refer to "Static Transfer System Cabinet for Data Centers That Contributes to Stable Power Supply" on page 21).

Moreover, not only DC but also general factories, broadcasting and communication facilities, require a medium capacity UPS of 200 V system, and there are various kinds of capacity needs for the UPS alone. To respond to this need for various capacities, we have developed the "UPS6600FX" as a 200-V UPS capable of diagnosing component failures using an abnormal sign detection function. This UPS facilitates replacement work with its reduced installation footprint and improved equipment stability (Refer to "Medium-Capacity Uninterruptible Power Systems with Improved Replaceability and Stable Operation" on page 45).

3. Power Supply System That Contributes to Stable Equipment Operation

3.1 Energy management system

(1) Responding to trends for energy resilience through distributed grids

(a) Market trends

In response to international calls to address environmental issues through the Sustainable Development Goals (SDGs) and Environmental, Social and Governance (ESG) investment, the Japanese government announced in October 2020 that it will aim to become carbon neutral by reducing its overall greenhouse gas emissions to zero by 2050.

Companies in the market are quickly considering switching to renewable energy sources for their electricity consumption. Furthermore, solar power generation for in-house consumption and self-wheeling (transmission of power generated at the company's own power plant to its own equipment through its transmission and distribution network) and the power purchase agreement (PPA) models*1 are also gaining attention.

As a result, it is expected that renewable energy will continue to expand, but it is essential to strengthen the power grids that receive renewable energy.

At the same time, it has become a major issue in recent years to strengthen resilience against long-term energy supply disruptions caused by large-scale disasters such as torrential rains and earthquakes.

To expand renewable energy and strengthen resilience, the Japanese Diet passed and enacted the "Act of Partial Revision of the Electricity Business Act and Other Acts for Establishing Resilient and Sustainable Electricity Supply Systems" (Energy Supply Resilience Act) in June 2020. The Act went into effect in April 2022. The Energy Supply Resilience Act is a revised law to ensure a resilient and sustainable electricity supply system that can cope with frequent natural disasters, widespread expansion, and the transition to renewable energy as the main power source. The key points of the revision include developing disaster-resistant distributed power sources and grid infrastructure capable of supporting expanded use of renewable energy. This includes legislatively positioning power distribution businesses so that they can operate as standalone networks in the event of an emergency, while also allowing them to operate distribution networks that includes small distributed power sources in their respective regions.

Amidst these circumstances, there are various regions where distributed grids are being considered, with regional distributed power sources as the core. In the future, it is expected that technological verification and business profitability will be examined.

(b) Fuji Electric's initiatives

Fuji Electric has been contributing to the expansion of renewable energy and strengthening of resilience by developing and verifying relevant technologies and providing operational systems in demonstration projects such as remote island microgrids and regional energy management. Figure 3 shows the overall view of the local microgrid offered by Fuji Electric.

Local microgrids aim to reduce CO_2 emissions through localized energy optimization, maintain energy supply in the event of a disaster, and make effective use of local energy resources. To achieve these goals, Fuji Electric has developed and offered the following products and technologies.

(i) Community energy management system (CEMS)

CEMS predicts local energy demand and renewable energy output, and then creates optimal power generation plans to manage energy.

***1 PPA model:**
A model in which power consumers provide power generation facility installation sites to power purchase agreement (PPA) business operators, and the PPA business operators install, operate, and maintain the power generation facilities free of charge, and bill the power consumers for the electricity generated.

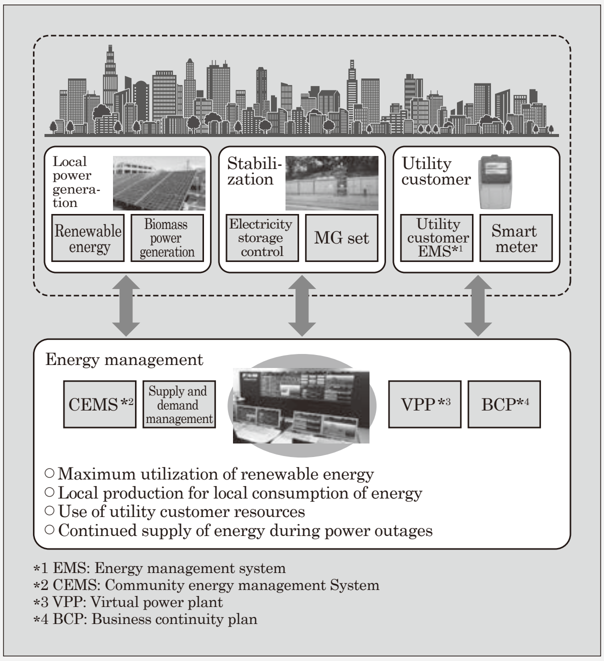

Fig.3 Overall view of the local microgrid offered by Fuji Electric

Demand response is also used to adjust demand.

(ii) Virtual power plant (VPP) resource aggregator

A VPP resource aggregator collectively manages consumers' resources (large storage batteries) and controls the battery system in response to various requests.

(iii) Supply and demand management

Supply and demand management predicts demand and creates power generation plans. The necessary power is then purchased on the electricity wholesale market based on the drafted power generation plan. It also acquires actual demand results and manages the supply-demand balance situation.

(iv) Storage battery control

Storage battery control regulates the charge and discharge of storage batteries in order to stabilize renewable energy generation and ensure efficient operation of generators. It also stabilizes the frequency of independent power systems in the event of an emergency.

(v) Storage battery-driven MG set

A storage battery-driven MG set is a power supply system that combines a storage battery-driven motor and generator. It contributes to controlling renewable energy fluctuations and to stabilizing independent power systems.

(2) Improved power management system functionality

System-based management is essential to ensure a stable supply of electricity. Fuji Electric uses the most advanced network technologies to offer power management systems with enhanced reliability, operability, and maintainability to meet the needs of replacement (Refer to "Electric Power Management System Contributing to Safe and Stable Railway Transportation" on page 32).

(3) Future developments

(a) Regional microgrid simulator

The building of microgrids based on distributed power sources, including renewable energy, require advance capacity designs for major power generation equipment, such as renewable energy equipment, cogeneration systems, and power storage equipment, on the basis of demand projections. In addition to normal operations, when considering operations during bulk power system outages, it is difficult to find optimal solutions because of the complex interaction of factors. Fuji Electric is developing a microgrid design support simulation system to solve this difficulty, based on its cultivated power simulation technologies. It will reduce the burden on designers and assist them in optimizing the design of operation-ready microgrids.

(b) EMS for business continuity plan (BCP) compatible EMS

Local microgrids need to ensure power supply to important facilities (evacuation centers, hospitals, etc.) through distributed power sources in preparation for long-term power outages due to disasters.

During small-scale operations, such as supplying power to single facilities or adjacent facilities, power can be restored according to defined procedures. However, when the scale of operations is extensive, restoring power using renewable energy generation requires sophisticated operations, such as gradually expanding the scope of restoration while balancing supply and demand. Fuji Electric is developing a restoration support function that can be integrated into CEMS by utilizing power simulation technologies.

3.2 Power receiving and transforming equipment technology supporting power supply systems

Power receiving and transforming equipment, such as transformers and switchgear, are core components of power grids that support power systems. Continuous efforts are being made to develop these technologies further. In addition to downsizing, higher efficiency, higher reliability, and maintenance-free operation, mainstream technological developments in recent years have been increasingly focused on digitization and reduction of environmental impacts. There has been increasing application of the international communication standard IEC 61850 to monitoring, control, and protective equipment of power receiving and transforming equipment, as well as to monitoring systems for transformer in-oil gas analysis and switchgear partial

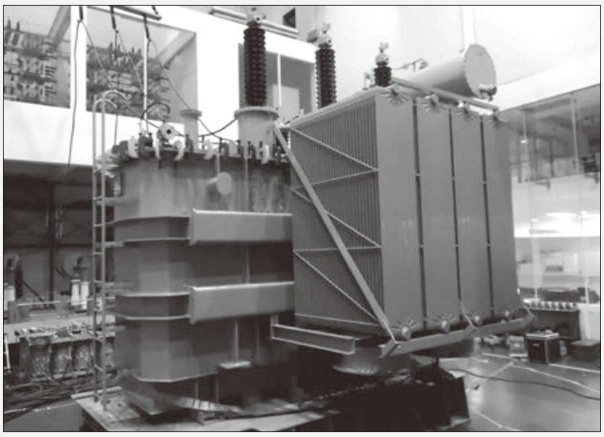

Fig.4 Globally compatible 115-kV, 50-MVA transformer

discharge and gas density.

In addition to developing technologies that achieve higher voltages and larger capacities in transformers, Fuji Electric has also been developing technologies to achieve downsizing. In 2018, we developed a globally compatible 115-kV, 50-MVA transformer that achieves the world's smallest size, mass, and oil volume, as shown in Fig. 4, by utilizing the latest analysis technology to optimize the core, winding, and cooling unit structure. We are continuing developments so that we can apply this technology to even higher voltage and larger capacity transformers.

At the same time, we have developed and released palm fatty acid ester filled transformers that use plant-derived insulating and cooling media to reduce environmental impacts (Refer to "Palm Fatty Acid Ester Filled Transformer That Contributes to Reducing Environmental Load" on page 50). In addition to reducing environmental impacts, we have developed and released a transformer with enhanced disaster-prevention features using natural esters derived from soybeans, which have a high flash point.

In terms of switchgear, we have a product lineup of gas-insulated switchgear (GIS) for rated voltages up to 300 kV. Figure 5 shows the 145-kV GIS for global markets that we have developed using the latest breaking and analysis technologies to respond to revisions in test standards in the IEC 62271 series, the international standard related to switchgear. We are developing this technology further for higher voltage GIS.

Conventionally, sulfur hexafluoride (SF_6) gas, which has a very high global warming potential, has been used as an insulator and arc interruption medium in GIS. In order to environmental load reduction, the utilization of GIS that use SF_6 alternative gases is progressing in Europe, the United States, and South Korea, where there are evolving regulations on SF_6 gas. In light of these international trends, Fuji Electric is also developing GIS that uses SF_6 alternative gases.

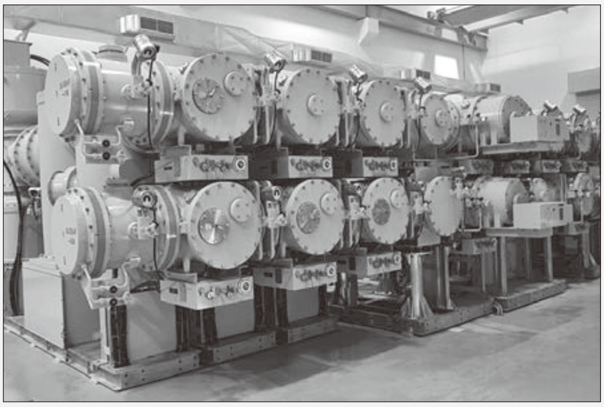

Fig.5 Globally compatible 145-kV GIS

3.3 Industrial power supply equipment that supports stable power supply

Capital investment in the industry of manufacturing materials, such as nonferrous metals, steel, chemicals, and green hydrogen, continues to expand globally. Fuji Electric provides industrial transformer rectifiers used to power electrolysis, melting, and smelting equipment utilized in the manufacture of these material products. In addition to ensuring power supply quality, industrial transformer rectifiers are required to have various features, such as countermeasures against harmonics leaking into grids, downsizing, redundancy, energy saving, high efficiency, and safety in the event of accidents. To meet these requirements, we are making full use of harmonic system analysis and various simulation analyses to provide solutions by taking advantage of our power supply systems along with standalone devices (Refer to "Industrial-Use Power Supplies Contributing to Stable Operation of Material Manufacturing Equipment" on page 39).

4. Postscript

In this paper, we described the current status and future outlook of power supply systems that contribute to stable power supply and energy saving in accordance with Fuji Electric's technological initiatives. Moving forward, we will continue to contribute to society by helping to stabilize and optimize the supply of electric power.

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Innovating Energy Technology