“System UPS” That Uses Consumer Power Resources for Peak Shaving and Business Continuity Plan

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The “System UPS” is an energy solution system that achieves both peak shaving and business continuity plan (as a countermeasure for instantaneous voltage drop and blackout). It combines battery energy storage systems with emergency generators on the consumer side. Aiming to present a solution that offers new customer value as part of our SPSS (Smart Power Supply System) business, we are conducting verification at Maebashi Factory of Nissin Electric Co., Ltd. We report on the development progress and demonstration results of the System UPS.

Keywords: emergency generator, battery energy storage system, peak shaving, BCP, VPP

1. Introduction

After experiencing the Great East Japan Earthquake and a subsequent power supply crisis, Japan has entered an era of a paradigm shift in the electricity market, as exemplified by the fast-paced introduction of photovoltaic power generation and other renewable energy sources, and an increase in the number of new power businesses due to the liberalization of the retail electricity market. Electricity supply-and-demand management services known as virtual power plants (VPP*[1]), which draw on consumer-end power resources, and other similar services have come into use as a coordination capacity adaptable to the introduction of renewable energy. In line with this shift, Nissin Electric Co., Ltd. has been testing and proposing a solution known as smart power supply systems (SPSS).

This paper reports on the development concept and progress of an integrated uninterruptible power system (System UPS) that combines emergency generators and a battery energy storage system*[2] for the user to ensure both peak shaving and its business continuity plan (BCP*[3]).

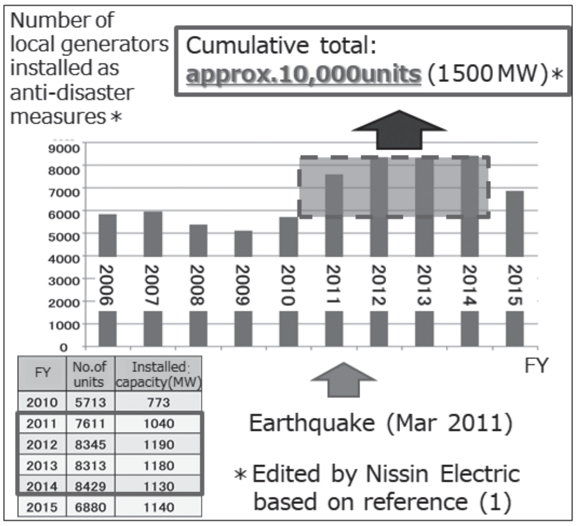


Fig. 1. Estimated number of unutilized generators

2. System UPS

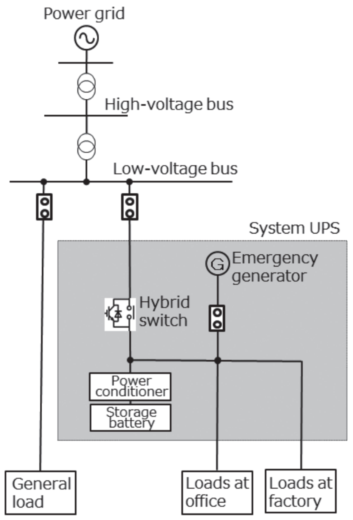
2-1 Development concept

The development concept of the System UPS was to combine a battery energy storage system with unutilized emergency generators owned as consumer-end power resources for use as a system to enable peak shaving and to counter instantaneous voltage drops and blackouts. After the earthquake, nuclear power plants were shut down and a tight situation occurred in electricity supply and demand. As a solution to this situation, rolling blackouts were implemented. Unutilized generators refer to emergency generators introduced as reserve power supplies to address such rolling blackout. The number of emergency generators introduced during the four years from 2011 to 2014 is estimated at approximately 10,000, as shown in Fig. 1.[(1)]

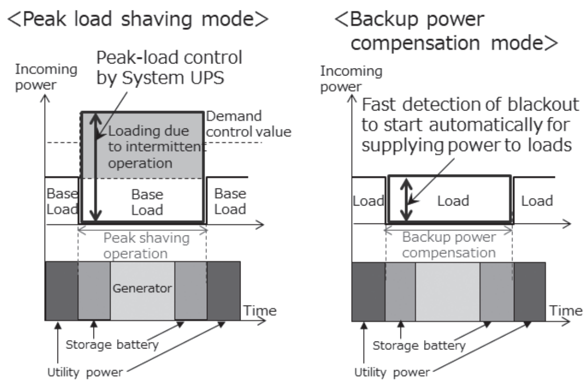
2-2 Configuration and operation of System UPS[(2)–(4)]

Figure 2 presents an example configuration and operation of the System UPS. A battery energy storage system consisting of a power conditioner*[4] and a storage battery, an emergency generator, and a hybrid switch are used to construct a passive standby UPS. At normal times, the System UPS supplies utility power to the load. When an instantaneous voltage drop, blackout, or demand alarm occurs, the hybrid switch continues to supply power to the load using the battery energy storage system and emergency generator, separating the load from the power grid. The emergency generator takes time to start (about 10 to 40 seconds). Using the battery energy storage system to supply power during this duration, it is possible to continue supplying power seamlessly. This system is expected to provide the following benefits.

(1) Peak shaving for reduced contract demand
(2) Ensuring BCP (against instantaneous voltage drops and blackouts)



(a) Example system configuration



(b) Example operation

Fig. 2. Configuration and operation of System UPS

2-3 Features of System UPS as compared with conventional schemes

(1) Low-loss, fast-opening operation

Common mechanical switches are slow in opening, taking tens of milliseconds (ms), although power loss attributable to them is virtually 0%. In contrast, electronic switches are subject to large power loss although they open within 2 ms. The System UPS incorporates a hybrid switch combining a mechanical switch and an electronic switch. The combination of their advantages provides the following benefits and features.

(a) Low loss: Power loss ≈ 0% (when in normal operation mode)

The control and auxiliary power sources have a standby loss rate of not higher than 1%. The System UPS is expected to provide energy-conservation effects compared with conventional double conversion UPSs (loss rate: 5%) and passive standby UPSs incorporating an electronic switch (loss rate: 2%).

(b) Fast opening: Opening within 2 ms

The System UPS helps achieve seamless transfer of power supply to the load in the event of an instantaneous voltage drop, blackout, or demand alarm.

(2) Reduced equipment size and running costs

Concerns about UPSs include degraded stability and reliability during long-term operation due mainly to aging storage batteries. The Japan Electrical Manufacturers' Association has guidelines for storage batteries, according to which they have a service life ranging from five to six years, requiring periodic replacement of storage batteries. The System UPS requires a storage battery discharge time of less than 1 min as a sum of durations required for starting the generator and reestablishing interconnection of the power grid. Consequently, the System UPS adopted a lithium-ion battery capable of quickly outputting power for a short period of time of 1 min to provide the following features.

(a) Reduced size: 50% reduction or more in terms of footprint

Compared with UPSs that come with the same capacity of lead-acid battery, the System UPS is expected to be space saving.

(b) Reduced running cost: No battery replacement required for 15 years

The storage battery is designed to have an expected service life of 15 years when used for peak shaving once a day in an installation environment of 25°C ambient temperature. It is not necessary to replace the battery during this period, helping to substantially reduce the maintenance costs (running costs).

2-4 Operating principle of hybrid switch

The hybrid switch has an opening sequence as illustrated in Fig. 3. States (1) to (4) are involved in the opening operation, thereby enabling low-loss and fast-opening operation.

State (1) At normal times, power is supplied to the load via the mechanical switch. In this state, the electronic switch is OFF.

State (2) Upon receipt of a peak shaving operation command, instantaneous voltage drop detection signal, or blackout detection signal, the mechanical switch opens and the electronic switch turns ON concurrently.

State (3) While the mechanical switch is open, the load current is communicated to the electronic switch.

State (4) The hybrid switch completes its opening operation by turning OFF the electronic switch.

Furthermore, by commencing to supply power to the load from the battery energy storage system in state (4), the System UPS achieves seamless transfer to supply power to the load.

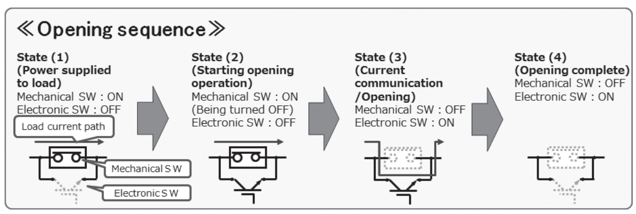
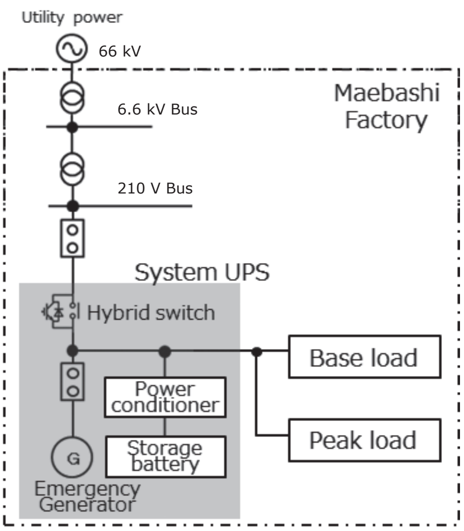


Fig. 3. Hybrid switch opening sequence

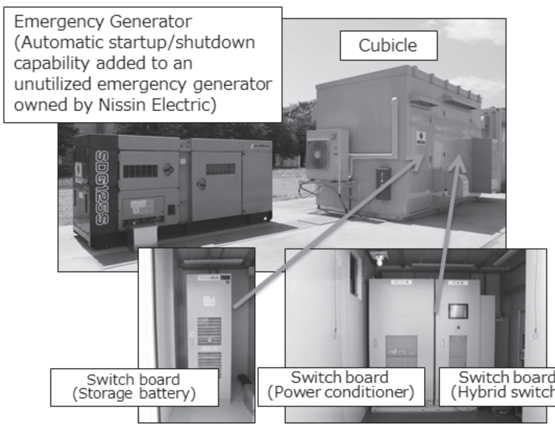
3. Verification of System UPS in Demonstration Facility

3-1 Demonstration facility construction

Figure 4 presents the installation of a pilot System UPS plant constructed at Maebashi Factory of Nissin Electric. The demonstration facility consists of a battery energy storage system incorporating lithium-ion batteries, a power conditioner, and a switchboard incorporating a hybrid switch installed in a cubicle. The generator was prepared by providing additional automatic startup/shutdown capability to an unutilized emergency generator owned by Nissin Electric.



(a) Facility configuration



(b) Installed facility

Fig. 4. Configuration and installation of demonstration System UPS facility

3-2 Test results

A backup power compensation test and a peak shaving operation test were conducted to check the operation of the System UPS.

(1) Backup power compensation test

Figure 5 presents backup power compensation operation results obtained by simulating a blackout by opening a circuit breaker located upstream from the System UPS facility shown in Fig. 4. The grid voltage and current represent the voltage and current waveforms of the system located upstream from the System UPS. The figure also shows the output current waveforms of the battery energy storage system and the voltage and current waveforms of the load for which backup power is to be compensated. Meanwhile, the instantaneous root-mean-square (RMS) value is the result of calculation using the equation below, on the assumption that the RMS value of the rated three-phase integrated voltage is 100%.

$$\text{Instantaneous RMS value} = \sqrt{(Vuv^2 + Vvw^2 + Vwu^2)/3}$$

According to Fig. 5, after the occurrence of a blackout, the load voltage remained below 80% of the rated voltage for 1.5 ms, while the target set for the development was power supply transfer (backup power compensation) within 2 ms.[5]

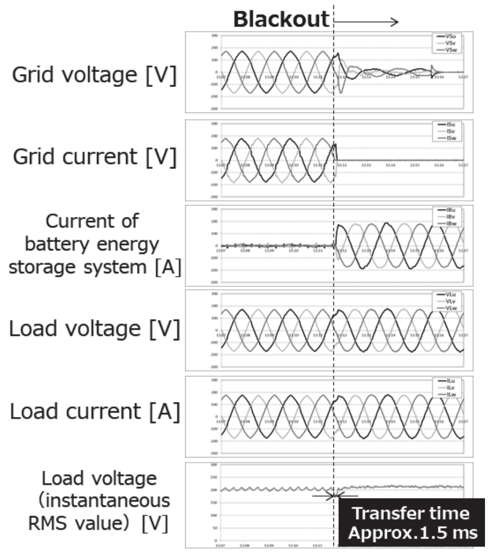


Fig. 5. Results of backup power compensation operation

(2) Peak shaving operation test

When a demand monitoring system issues a demand alarm, responses are made to conduct demand control (peak shaving) generally in two phases. In the first phase (alert), the use of electric appliances that do not affect the users' business is reduced. In the second phase (limit alarm), power to unnecessary electric appliances is shut off. Other methods used to ensure peak shaving without shutting down electric appliances include using a normal service generator (e.g. monogeneration and cogeneration systems) and using a battery energy storage system with a long time capacity. However, with soaring fuel prices, normal service generators exclusively used for peak shaving have become cost-ineffective in terms of total energy cost. Moreover, when an instantaneous voltage drop or blackout occurs, they are shut down or continue running while being isolated from the power grid and/or from the load equipment. Accordingly, it is inevitable for power supply to the load to be temporarily shut off. Meanwhile, battery energy storage systems with a long time capacity require substantial initial and running costs for storage batteries, limiting the number of consumers who are capable of adopting them from the perspective of cost effectiveness.

In contrast, in the event of a demand alarm, the System UPS achieves peak shaving without interrupting power to electric appliances. Moreover, it effectively works to counter instantaneous voltage drops and blackouts. Additionally, for the peak shaving capability, the System UPS offers the following two operation mode options, enabling the user to make a selection from among applications.

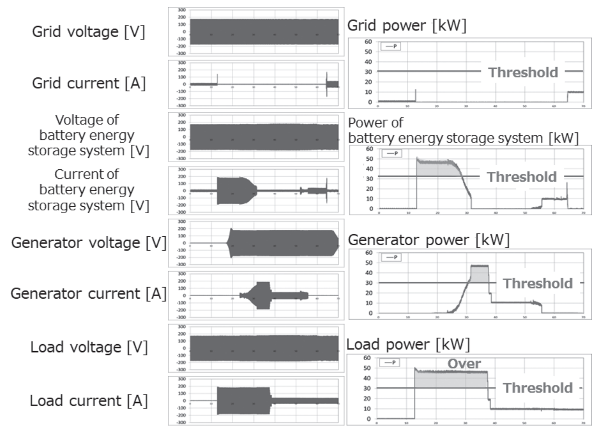
(a) Remote mode: Operation/control from a remote location

When the demand monitoring system issues a demand alarm or in other similar instances, the System UPS in this mode executes peak shaving in response to an operation command from an external source. This mode is used when controlling power demand in general situations (e.g. 30 min power demand).

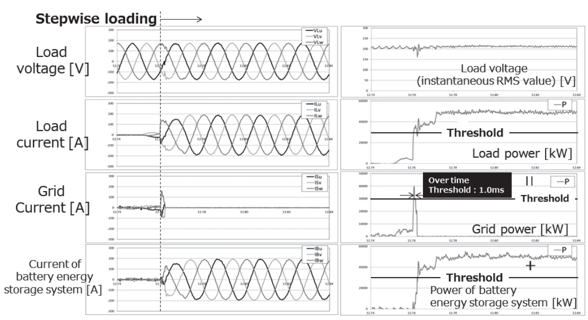
(b) Local mode: Instantaneous power shaving

In this mode, the System UPS conducts peak shaving instantaneously if the load equipment subject to peak shaving exceeds the preset electrical power or current value assigned to it. This mode is used to shave instantaneous power.

This paper reports on the results of demonstration of the local mode (b). Figure 6 provides test results obtained when switching a dummy load (resistor) from 0 kW to 45 kW and to 10 kW, with the preset peak value set to 30 kW in local mode. When, due to stepwise switchover, the load current sharply increased and exceeded the preset value, the power source shifted from the utility power source to the battery energy storage system within 2 ms, thereby achieving instantaneous power shaving. Subsequently, after the generator started up, the sharing of load shifted smoothly from the battery energy storage system to the generator. Conversely, when the load power switched to below the preset value, the sharing of load smoothly shifted from the generator to the battery energy storage system and then from the storage battery to the power grid. It is proved that this smooth shift enables stable power supply to the load without any fluctuation in load voltage, current amplitude, or current phase.



(a) Voltage/current/power



(b) Extended time scale (instant of transfer)

Fig. 6. Results of peak shaving operation

When incorporated, this mode is expected to enable the user to avoid enhancement work (raising the current rating and/or switching over to extra-high-voltage incoming power) otherwise necessitated on the incoming equipment when additionally or newly installing a peak load larger than the base load. Moreover, it is also expected to avoid increasing payments for electricity arising from renewed contract demand (maximum demand).

4. Conclusion

Consumers have emergency generators as power resources introduced after the Great East Japan Earthquake, which have been unutilized thereafter. The authors have developed the System UPS as an energy system solution, which, using unutilized emergency generators, achieves both peak shaving and protection against instantaneous voltage drops and blackouts. The System UPS is currently proposed to our customers. This paper reported that a pilot System UPS plant was constructed at Maebashi Factory of Nissin Electric and it has been undergoing testing. Future tasks include verifying the operation of the system for commercialization, using various loads [e.g. air-conditioners and electric vehicle quick chargers]. Along with this verification, our plans include expanding its applications considering novel customer needs, such as use in electricity supply-and-demand management services in VPP.

Technical Terms

*1 Virtual power plant (VPP): A power plant that combines various power resources.

*2 Battery energy storage system: Storage batteries combined with a power conditioner.

*3 Business continuity plan (BCP): A plan designed for use in the event of a disaster.

*4 Power conditioner: A device used to convert direct-current power into alternating-current power.

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