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FEATURED TOPIC

Smart Power Supply Systems (SPSS) to Support Sustainable Growth

Motonobu FUJIWARA, Yasuhiro TANAKA, and Nobuhiro KURIO

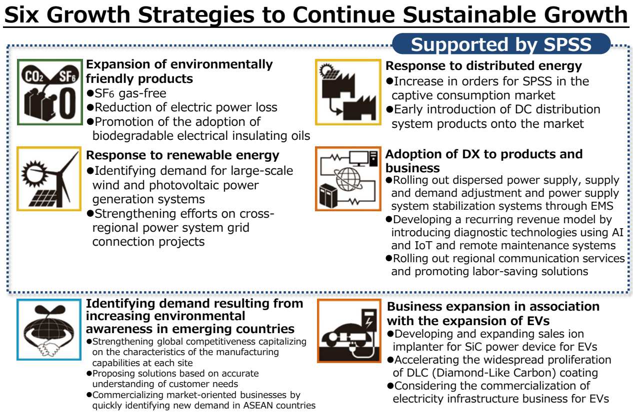
With efforts to realize a carbon-neutral and sustainable society accelerating on a global scale, Nissin Electric Co.,Ltd. has launched a new medium- to long-term plan, VISION 2025, aiming to contribute to "the realization of a sustainable global environment and a society in which anyone can play an active role" through six growth strategies. Among them, Smart Power Supply Systems (SPSS) are a solution business that supports our growth strategies in the environment and energy fields. This paper introduces the recent efforts for SPSS.

Keywords: renewable energy, grid connection, direct-current (DC) distribution, power wheeling, energy management

1. Introduction

In response to the need for a shift toward a new society that uses energy in a manner friendly to the earth's environment, various initiatives are under consideration, including shifting renewable energy produced by, among others, photovoltaics (PV) and wind power generation to a main power source and the construction of a next-generation power network designed to continuously incorporate renewable energy on a massive scale. On the consumer side, businesses are facing the need to achieve carbon neutrality, as a new corporate management challenge. They are required to introduce equipment with high energy consumption efficiency, improve their use of equipment, and implement energy management measures.

Under these circumstances, to provide solutions to the various needs of its customers—such as stable electricity supply, energy conservation, cost reduction, and carbon dioxide (CO_2) emissions reduction—Nissin Electric Co., Ltd. has pursued a project under the title of Smart Power Supply Systems (SPSS), as well as the traditional sale of equipment. For the purpose of SPSS, the Company combined its years of experience in substation system technology and grid connection technology with software and network technologies, joining components, sensors, systems, and expertise.


Six Growth Strategies to Continue Sustainable Growth

Supported by SPSS

Expansion of environmentally friendly products
- SF_6 gas-free
- Reduction of electric power loss
- Promotion of the adoption of biodegradable electrical insulating oils

Response to distributed energy
- Increase in orders for SPSS in the captive consumption market
- Early introduction of DC distribution system products onto the market

Response to renewable energy
- Identifying demand for large-scale wind and photovoltaic power generation systems
- Strengthening efforts on cross-regional power system grid connection projects

Adoption of DX to products and business
- Rolling out dispersed power supply, supply and demand adjustment and power supply system stabilization systems through EMS
- Developing a recurring revenue model by introducing diagnostic technologies using AI and IoT and remote maintenance systems
- Rolling out regional communication services and promoting labor-saving solutions

Identifying demand resulting from increasing environmental awareness in emerging countries
- Strengthening global competitiveness capitalizing on the characteristics of the manufacturing capabilities at each site
- Proposing solutions based on accurate understanding of customer needs
- Commercializing market-oriented businesses by quickly identifying new demand in ASEAN countries

Business expansion in association with the expansion of EVs
- Developing and expanding sales ion implanter for SiC power device for EVs
- Accelerating the widespread proliferation of DLC (Diamond-Like Carbon) coating
- Considering the commercialization of electricity infrastructure business for EVs

Fig. 1. Six growth strategies

This project is in line with the following of the six strategies set out in Nissin Electric's medium- to long-term business plan Vision 2025: *expansion of environmentally friendly products, response to renewable energy, response to distributed energy, and adoption of digital transformation (DX) to products and business* (Fig. 1).

This report describes the current state of the full-scale demonstration of SPSS and our approaches toward energy management (EMS), wind power interconnection, and DC distribution systems as focused SPSS-based solutions.

2. Full-Scale SPSS Demonstration Overview

In 2011, as full-scale SPSS demonstration projects, Nissin Electric introduced a 110 kW PV system to its Head Office and Works and began to make power consumption visible at the works and office buildings. The project scale expanded later to demonstrate SPSS at the Maebashi Works.(1)

With the aim of utilizing diverse distributed energy resources in a stable, efficient, and economical manner, with a distributed energy society in mind, the Maebashi Works constructed a full-scale system combining 66 kV extra-high-voltage substation equipment with a 550 kW PV system, a 700 kW cogeneration system (CGS), a 96 kWh battery energy storage system (BESS), and an EMS. This demonstration project was launched in March 2014. Furthermore, the ENERGYMATE-Factory (ENERGYMATE-F), an EMS that controls these distributed energy resources in an optimal way, was developed(2) and incorporated into the full-scale demonstration. For optimization computation, ENERGYMATE-F uses the energy management system *s*EMSA of Sumitomo Electric Industries, Ltd. Since the start of practical operation in April 2016, ENERGYMATE-F has been operating successfully for more than five years.

In addition to this, we are constantly making progress, including the launch of a solution business as SPSS by utilizing the technology obtained through full-scale demonstrations and the development of virtual power plant (VPP*[1]) demonstrations.

Then in June 2019, a demonstration project was launched at Nissin Electric's training facility Nissin Academy Training Center to prove a captive consumption PV system and a DC distribution system to create new SPSS solutions for increased use of renewable energy.

Figure 2 depicts an overview of the full-scale SPSS demonstration. The demonstration project pursued at the Training Center will be described in the following chapter.

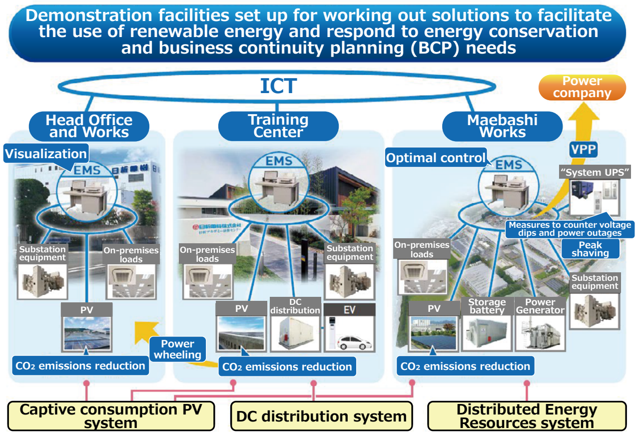


Fig. 2. Overview of full-scale SPSS demonstration

3. New Full-Scale SPSS Demonstration at Training Center

Figure 3 shows the configuration of the SPSS demonstration system introduced to the Training Center.

The captive consumption PV system utilizes surplus PV power by means of captive consumption PV and power wheeling.*[2]

The Training Center has a PV system rated at 92.4 kW installed and uses PV power for captive consumption during weekdays; however, during holidays and other light-load periods, surplus PV power is produced. By wheeling the surplus power to the Head Office and Works, it becomes possible to make efficient use of PV power. Consequently, the CO_2 emissions reduction attributable to the PV increases to 38.7 t-CO_2/year (trial calculation) from 27.1 t-CO_2/year on a captive consumption only basis. Thus, the reduction of environmental impact by using power wheeling is 1.4 times greater than without it.

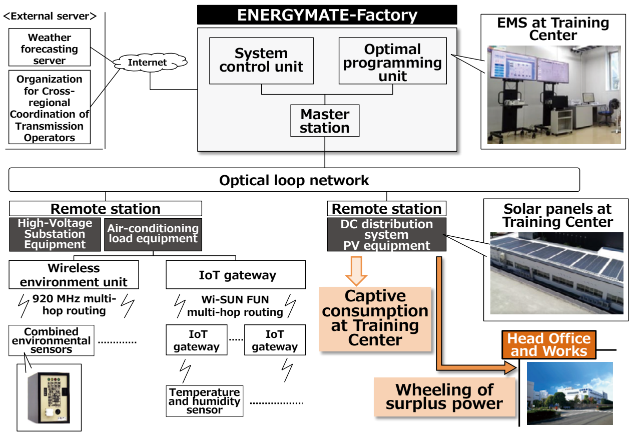


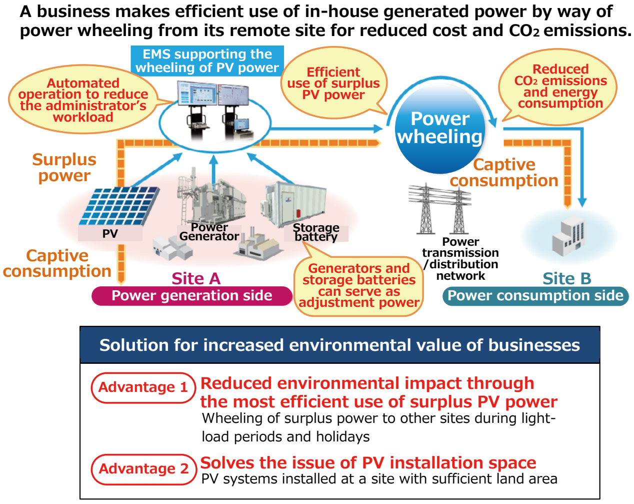
Fig. 3. Configuration of SPSS demonstration system at Training Center

The wheeling of PV power is an unmanned operation automated by an EMS, as detailed in Chapter 4. A detailed description of the DC distribution system will be given in Chapter 6.

4. EMS for Wheeling of PV Power

As described previously, the introduction of a captive consumption PV system involves matters such as surplus power produced during holidays and other light-load periods, provision of an installation space when installing solar panels at an existing factory, and the load-bearing capacity of the roof. As a solution to these matters, there is a program under which solar panels are installed at a remote site and PV power is wheeled to and consumed at the existing factory.

The efficient use of surplus PV power by way of power wheeling is effective for further reducing CO_2 emissions and power cost, thereby improving the environmental value of businesses. Even if the area of a business's land is too small to install power generation equipment, the business can install power generation equipment in a large remote place and use power wheeling. Figure 4 shows how power wheeling is effectively used.



Solution for increased environmental value of businesses

Advantage 1 **Reduced environmental impact through the most efficient use of surplus PV power**
Wheeling of surplus power to other sites during light-load periods and holidays

Advantage 2 **Solves the issue of PV installation space**
PV systems installed at a site with sufficient land area

Fig. 4. Effective use of wheeling of PV power

However, to make effective use of power wheeling, it is necessary on a daily basis to plan the power to be wheeled in units of 30 min, which should be notified to the transmission/distribution operator every day. In addition, various operations are required to follow the planned power wheeling. This requires much labor if an operator does the job. As a solution to this challenge, Nissin Electric equipped ENERGYMATE-F with functions designed to automate all operations involved in the wheeling of PV power.(3),(4)

4-1 EMS system overview

Figure 5 presents an overview of the EMS tailored to the wheeling of PV power. The functionality of the system is roughly made up of prediction, planning of power wheeling, and balancing control.

Prediction is the function designed to determine surplus power by predicting the amount of PV power generated at and the amount of power demanded at the power generation site. Planning of power wheeling is the function designed to formulate a plan for power wheeling based on the surplus power and notifies the Organization for Cross-regional Coordination of Transmission Operators of the formulated plan for power wheeling. Balancing control is the process of performing control to achieve balancing with respect to the planned value.

The newly developed ENERGYMATE-F automatically carries out the above-described operations related to power wheeling.

In the automated operation of the wheeling of unstable PV power, the key engineering points are the plan for power wheeling and balancing with respect to the planned value. The power wheeling planning function and planned value-based balancing function of ENERGYMATE-F are explained below.

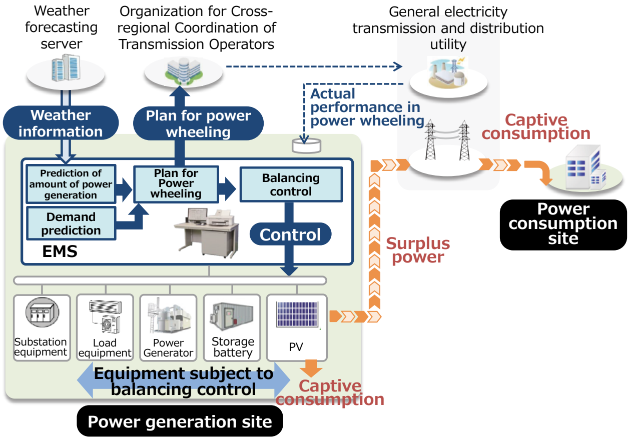


Fig. 5. System overview

4-2 Function for planning power wheeling

When formulating a plan for power wheeling, the amount of surplus PV power is determined based on the prediction of the amounts of PV power generation and power demand. The wheeling of PV power is prone to imbalance*3 because the amount of power generation heavily depends on the weather. Accordingly, power wheeling is planned with the level of potential imbalance taken into account.

ENERGYMATE-F can use power wheeling solely for PV power generation. For this purpose, the power wheeling planning algorithm plans the amount of power wheeled to be lower than the predicted amount of surplus power. With PV, the output can be reduced, but cannot be raised. To address this issue, Nissin Electric's proprietary algorithm is used, which, within the extent of demand for power wheeling planned in advance for the immediate 30 min, assumes abrupt decreases in the amount of PV power as risks.

Power wheeling is planned every 30 min, which is the planning unit. Moreover, the plan is corrected according to the amounts of PV power and power demand predicted immediately before the deadline for submitting the plan in order to improve the level of prediction accuracy and reduce the level of potential imbalance.

4-3 Planned value-based balancing function

Using distributed energy resources and loads as adjustment power, control is performed to achieve balancing in the actual performance in power wheeling relative to the submitted plan for power wheeling. Power wheeling reduction and raising control is performed. When the actual performance in power wheeling is predicted to exceed the planned value for power wheeling, the power wheeling reduction control will be performed; when power wheeling is expected to be lower than the plan for power wheeling, the power wheeling raising control will be performed. ENERGYMATE-F has the optimal control function for distributed energy resources, which makes it adaptable to various equipment configurations used by customers. Table 1 lists equipment that can be controlled as adjustment power to achieve balancing. The power wheeling reduction and raising control functions are described in detail below.

Table 1. Equipment Subject to Balancing Control

Equipment subject to control	Manner of control
PV equipment	Output reduction
CGS and other in-house power generation equipment	Output reduction/raising
Storage battery	Charge/discharge
Air-conditioning and other load equipment	Connecting (increased load) /disconnecting (reduced load)

(1) Power wheeling reduction control

When it is determined that the actual performance in power wheeling will early exceed the plan for power wheeling within a 30 min unit period for which a plan has been submitted, power wheeling reduction control will be performed. The power wheeling reduction control charges storage batteries, reduces the output from the CGS, reduces the PV output, and connects a captive consumption load(s). For these control processes, priority setting can be altered. Control is performed in accordance with the established priority setting.

(2) Power wheeling raising control

If the predicted amount of power for wheeling for the remaining time of a 30 min unit period for which a plan was submitted goes below the power wheeling raising line, or the threshold, ENERGYMATE-F determines that the planned value will not be reached and performs power wheeling raising control. The power wheeling raising control discharges storage batteries, raises the CGS output, and disconnects the load(s) in accordance with the predetermined priority. Figure 6 illustrates power wheeling reduction and raising control.

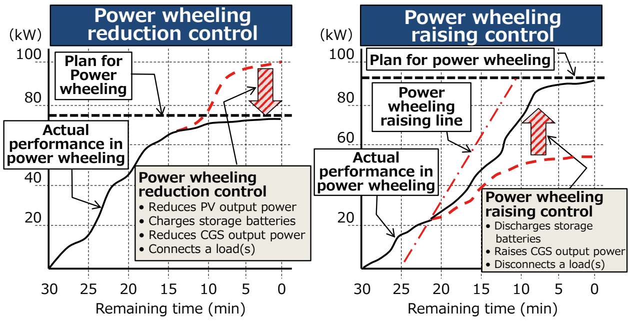


Fig. 6. Power wheeling reduction and raising control

4-4 Evaluation of full-scale operation at Training Center

In November 2019, Nissin Electric began wheeling surplus power from the captive consumption PV system rated at 92.4 kW installed at the Training Center to the adjacent Head Office and Works. For this power wheeling, ENERGYMATE-F described in this chapter plays its role in unmanned automated operation without administrator intervention.

Figure 7 presents an example of operation evaluation, showing the amount of PV power and the plan for and actual performance in power wheeling for one day. Balancing is almost achieved enabling the actual performance in power wheeling to follow the plan in units of 30 min.[5],[6]

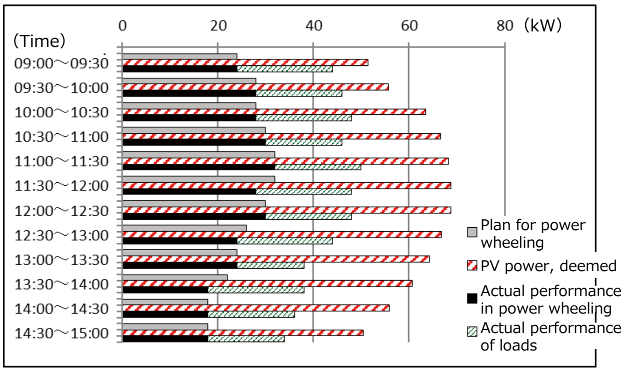


Fig. 7. Amount of PV power and a plan for and actual performance in power wheeling for one day

4-5 Future tasks

This chapter described the EMS capable of performing automated wheeling of PV power. The present operation cuts the amount of surplus power by controlling the PV output power so as to avoid imbalance. Tasks ahead include reducing the cut amount of power.

For the creation of a carbon neutral society, it is essential to further boost the incorporation of renewable energy. To achieve this goal, a new approach aside from the feed-in tariff (FIT) scheme will play an important role, like the power wheeling described in this chapter. Nissin Electric is continually committed to creating products, services, and business models that will contribute to carbon neutrality.

5. Wind Power Interconnection System

5-1 Packaged system of SPSS wind power generation

While wind power has been widely introduced at a rapid pace in recent years, it is often the case that areas benefiting from good wind conditions are located far from existing substations of power companies, necessitating the use of long power transmission lines. Consequently, those who deploy what is known as the "producer-owned and operated line scheme" are increasing.

Off-shore wind power plants are also increasing. An increasing number of power producers are expected to install long producer-owned and operated lines.

Regarding producer-owned and operated lines, overhead power transmission involves issues such as the provision of land for electricity pylons, maintenance of electricity pylons and transmission lines, and snow accumulation and lightning risks. As a consequence, the use of long underground cables for power transmission is increasing due to simple maintenance and it barely detracting the landscape.

Meanwhile, a thorough preliminary study is required before the application of high-voltage, long alternating current (AC) cables for power transmission because abnormal circuit phenomena can occur due to the electrostatic capacitance of the cable.

In addition, when connecting a large transformer to a power grid with low short-circuit capacity, it is necessary to take measures against voltage drops caused by magnetizing inrush current and against output power variation.

With the aim of supporting the growth of large-scale wind power generation systems and helping reduce CO_2 emissions, Nissin Electric provides a packaged system of SPSS wind power generation (Fig. 8), which combines the following into one package:

① Provision of power transforming equipment for interconnection
② Analysis of grid phenomena and working out solutions
③ Provision of countermeasure equipment

The package is based on the Company's long track record in interconnection equipment rated at more than hundreds of megawatts, as well as in system analysis technology.

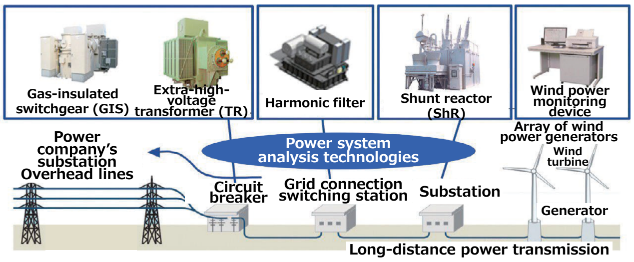


Fig. 8. Packaged system of SPSS wind power generation

5-2 Technical challenges involved in grid interconnection and solutions(7)

The technical challenges involved in grid interconnection include specific phenomena caused by the line-to-ground capacitance of the cable in long-distance AC cable power transmission. An example of the specific phenomena and solution development is described below.

(1) Solution to voltage fluctuations

The charging capacitance (Q_c) of the long power transmission cable increases and the active power that the cable can transmit decreases with increasing voltage of the transmitted power. As a solution to this challenge, it is a general practice to install a shunt reactor (Photo 1), which compensates for the reactive power generated by the cable by consuming the reactive power.

Photo 1. Shunt reactor

The normal voltage fluctuation range is stipulated by power companies to be within ±1% to ±2%. These limits may be exceeded by voltage fluctuations occurring when a long cable system is opened or closed, due to the charging capacitance of the cable (leading current). An effective solution to this matter is to install the above-mentioned shunt reactor or a static VAR compensator (SVC) to cancel the charging capacitance of the cable (Fig. 9).

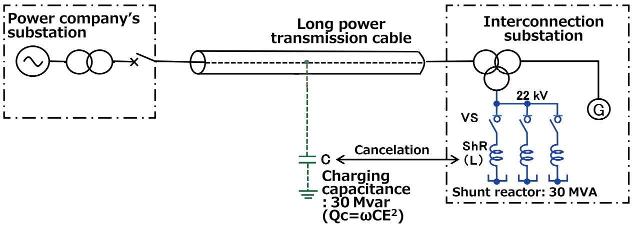


Fig. 9. Solution to voltage fluctuations by shunt reactor

(2) Measure for discharging residual charge of cable

When a circuit breaker opens in a long cable system, the peak voltage may remain in the cable's electrostatic capacity (C). If under this condition the circuit breaker closes, an overvoltage may occur, potentially damaging the equipment. To avoid this, the method of discharging the residual charge to the ground via the windings of a voltage transformer (VT) is employed.

However, the applicable standards do not describe any duty for discharging the residual charge of the cable. Consequently, the VT's insufficient withstand current rating may lead to burnout potentially causing a ground fault or the like. For this reason, it is important to check the VT's withstand current rating and the thermal and mechanical performance of the VT needs to be verified (Fig. 10).

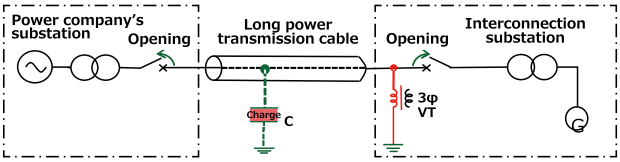


Fig. 10. Measure for discharging residual charge of cable

(3) Solution to zero-missing phenomenon

When, at power-on or in the event of a ground fault, a voltage is applied to a neutral grounding reactor, an inrush current (lagging current + DC component) occurs. Of the rush current, the lagging current is canceled by the cable charging current (leading current), resulting in the appearance of a duration with no zero point of current. If in this duration a grid failure occurs, the circuit breaker may fail to open (Figs. 11 and 12).

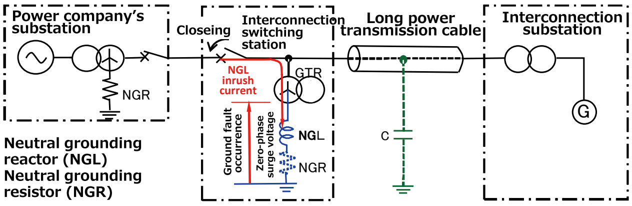


Fig. 11. Solution to zero-missing phenomenon

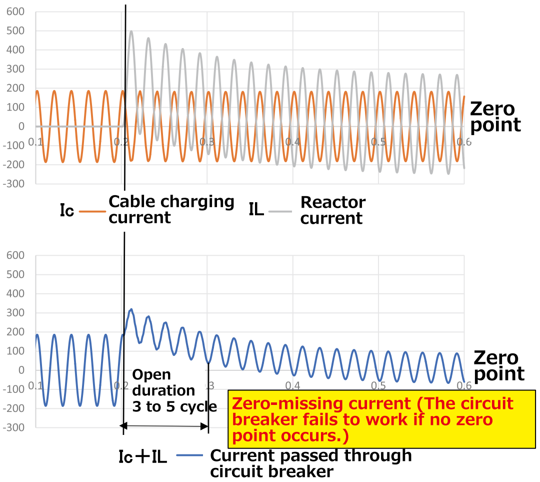


Fig. 12. Zero-missing phenomenon

As a solution to this matter, it is necessary to reduce the rush current of the reactor, insert a neutral grounding resistor, or take other measures that will make the operation suitable for the grid configuration.

(4) Measure for reducing inrush current occurring when connecting a large-capacity transformer

When connecting a large-capacity transformer to the grid, the grid voltage may sharply decrease due to excessive magnetizing inrush current of the transformer. It is necessary to consider the use of the following measures for reducing the inrush current according to the equipment configuration.

(a) Controlling the phase angle for closing the circuit breaker

Measure the remanence of the transformer and control the phase (timing) for closing the circuit breaker.

(b) Resistor connection system

Close in advance a circuit breaker connected in series with a resistance circuit to reduce rush current. Subsequently, close the main circuit breaker.

(c) Deployment of reverse excitation method

Using an emergency generator, apply a gradually increasing voltage to the low-voltage side of the transformer. When the excitation is completed, close the high-voltage circuit breaker in sync with the phase of the grid voltage; then disconnect the generator.

(5) Solution to harmonic resonance phenomenon

When a long power transmission cable is installed entailing high electrostatic capacitance (C), the resonance frequency between C and the grid inductance (L) decreases and specific harmonics are emphasized.

Resonance frequency = $1/(2\pi\sqrt{LC})$

When the resonance frequency decreases, resonance may occur for instance at the fifth or seventh harmonic, potentially resulting in aggravated distortion of the grid voltage beyond the limits specified in the Harmonics Guidelines. This problem can be solved by inserting a fifth or seventh harmonic filter to avoid the resonance (Figs. 13 and 14).

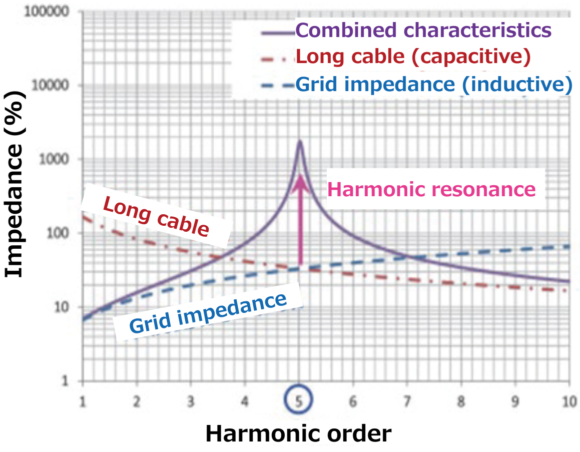


Fig. 13. Frequency-impedance characteristics
Example of harmonic resonance in long AC cable systems

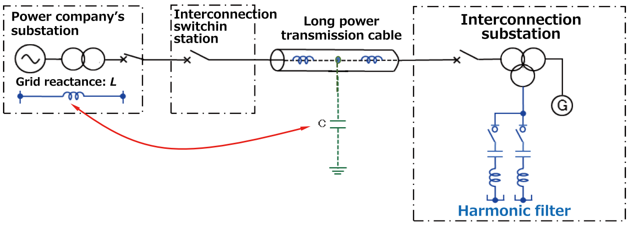


Fig. 14. Example of solution to harmonic resonance in long AC cable transmission

5-3 Future tasks

Grid interconnection of a long AC cable is subject to specific circuit phenomena. The solutions described in this chapter are just a few examples.

Nissin Electric provides the packaged system of SPSS wind power generation to propose systems that will be satisfactory to both power producers and power companies, based on our own knowledge and technologies in the area of power quality solutions.

Nissin Electric is willing to contribute to wider use of renewable energy leveraging its years of experience in grid technology in the area of interconnection equipment for offshore wind power expected to grow in the future.

6. DC Distribution System for Demonstrative Test

This chapter explains the results of the demonstrative test for DC distribution system, Nissin Electric launched in June 2019.

6-1 Configuration and features of the demonstration system(8)

The DC distribution system for demonstrative test is composed of the following DC equipment with the monitoring and control system to operate the optimum management. Figure 15 shows the configuration of the demonstration system.

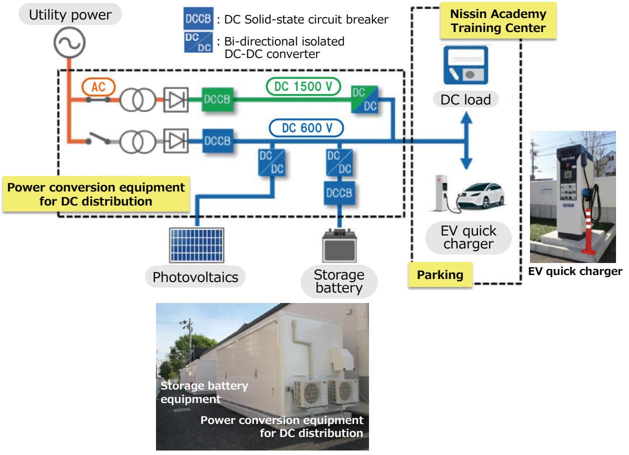


Fig. 15. DC distribution system for demonstrative test

[Main components]

① DC Solid-state circuit breaker (DCCB):
- 1500 V_{dc}, 135 A
- 750 V_{dc}, 135 A

② Bi-directional isolated DC-DC converter:
- 1500/600 V_{dc}, 167 kW (liquid-cooled)
- 600/600 V_{dc}, 100 kW (air-cooled)

③ Photovoltaics panel (PV): 92.4 kW
④ Storage battery (lithium-ion): 27.4 kWh
⑤ EV quick charger (DC input): 44 kW

(1) Features of the demonstration system

Most of the low-voltage DC distribution systems in the world supply electricity at voltages below 380 V_{dc}, which is used at data centers. Our system has adopted two voltage classes: (1) 1500 V_{dc} as the maximum voltage in the low-voltage DC (LVDC) category of the International Electrotechnical Commission (IEC) standards, and (2) 600 V_{dc} in compliance with the low-voltage DC category of domestic standards (Technical Standards for Electric Appliances and Materials). This aims to provide solutions in multiple voltage classes to meet customer needs. Few demonstration reports have been confirmed for voltage classes above 600 V_{dc}, especially 1500 V_{dc}. The reduction of power transmission loss makes the system suitable for high-power applications.

Assuming self-consumption of PV power by customers, the use of a diode rectifiers for connection to the utility power simplifies the control operation and reduces equipment costs in comparison with bi-directional inverter interconnection. This system configuration is free of the restrictions arising from the fault ride through (FRT)*4 requirements because with this system no reverse power flow occurs. Consequently, it ensures great flexibility for equipment installation.

Moreover, a storage battery monitor is also installed. This newly developed tool diagnoses battery condition in real time without system interruption. Thus, a demonstrative test is concurrently conducted in order to assist in high-efficiency, long-life operation.

(2) Features of key components

The DC distribution system requires the DC circuit breaker(9) to quickly interrupt fault currents that have no zero point of current. Nissin Electric has newly developed the solid-state circuit breaker (DCCB), which detects fault currents quickly (within 0.02 ms) and interrupts the current (within 2 ms) without arc. This quick interruption technology is intended to improve the safety and reliability of the DC distribution system and downsize the equipment.

Nissin Electric has also developed the bi-directional isolated DC-DC converter(10) of the dual active bridge (DAB) system that transforms DC voltage (step-up/step-down) and ensures isolation. The converter rated at 167 kW is made small and light, including the high-capacity high-frequency transformer (200 kVA) contained in the DC-DC converter, owing to the use of a silicon carbide (SiC) device for high-frequency operation (20 kHz).

6-2 Operational control of the demonstration system

(1) Basic concept

The operational control scheme employed for the demonstration system is such that the respective DC-DC converters for the storage battery and PV constantly monitor the state of the DC voltage of the DC feeder and determine operation autonomously under integrated control of the system.

(a) DC-DC converter for storage battery

The DC-DC converter for the storage battery autonomously operates determining the system operation mode (scheduled or self-sustained operation) according to the AC voltage of the utility power, the DC voltage of the DC feeder, and SOC (state of charge/charging rate) of the storage battery.

(b) DC-DC converter for PV

The DC-DC converter for PV performs autonomous control determining the PV operation mode by detecting the DC voltage of the DC feeder. When surplus power is available from PV, the DC-DC converter for the storage battery detects an increase in the DC feeder voltage and charges the storage battery. When the storage battery is fully charged, the DC-DC converter for PV carries out output control to ensure that the increase in the DC feeder voltage is within the predetermined range.

(2) Demonstrative test

The DC demonstration system performs the operational control as identified above the basic concept. Table 2 shows verification items of the demonstrative test.

Table 2. Verification Items

Maximum use of renewable energy	Effective use of renewable energy by charging surplus PV power in the storage battery and minimizing the amount of utility power purchased
BCP solution	Stability of self-sustained operation in the event of an instantaneous voltage drop or outage of utility power and rapid re-interconnection after voltage recovery
Peak shaving	Effectiveness of power reduction within the contract demand limit by deploying the storage battery for peak shaving against a sudden load such as an EV quick charger
Safety	Ability of quick interruption (to prevent the ramification problem of accidents) by means of the DCCB in the event of short-circuit failure on the DC circuit side
Power interchange	Ability of power interchange between feeders with different voltage (1,500 V_{dc} and 600 V_{dc})

6-3 Example demonstrative test

As an example of the demonstrative test, this section describes the results of self-sustained operation in the event of an outage of utility power.

The following case study is based on the assumption of a utility power outage in the event of a disaster, and confirms that PV and storage battery enable the load to stably supply power. Figure 16 presents the measurement results.

With the DC feeder voltage maintained at the rated voltage of 600 V_{dc} using utility power via the diode rectifier, a resistance load (13 kW) at first, then a constant power load (6 kW) as a DC load was connected.

The DC-DC converter for PV was activated at the point of T = 100 s. By controlling the DC feeder voltage to be slightly higher than the DC output voltage supplied via the diode rectifier, the DC feeder current decreased. It follows that PV power started to supply to the DC load. This operation ascertains that the amount of utility power purchased was reduced and the PV power was given a high priority and was efficiently used.

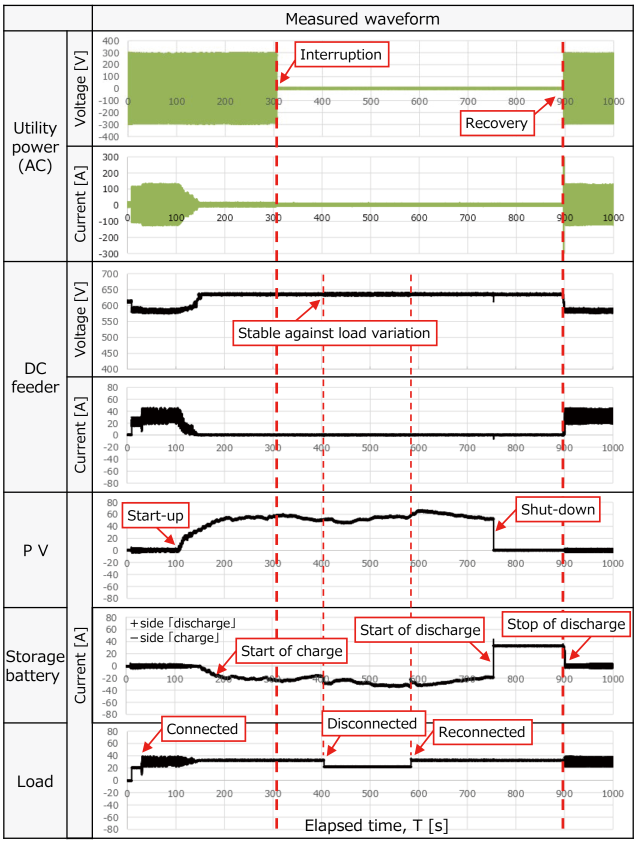


Fig. 16. Measurement results of self-sustained operation by PV and storage battery

At the point of T = 310 s, the AC circuit breaker opened to simulate an outage of utility power. The DC distribution system automatically entered self-sustained operation mode combining the PV and storage battery. The figure reveals that the DC feeder voltage was stably controlled even against output variation of the PV power due to changes in solar irradiation. Moreover, the DC feeder voltage was constantly stable even with disconnection at T = 400 s of the constant power load and reconnection at T = 580 s simulating load variation.

Furthermore, the DC-DC converter for PV was shut down simulating a power decline of the PV output according to rapid fluctuations in insolation at T = 750 s. Nevertheless, the DC feeder voltage drop was controlled to approximately 10 V.

Subsequently, the AC circuit breaker was closed and utility power was recovered at T = 900 s. The figure reveals that DC power supply smoothly transitioned to utility power.

Note that while this test simulated disconnection and outage on the utility power side, even in the event of a power outage due to a short-circuit accident or the like, no reverse power flow will occur to the fault location on the utility power side by virtue of the diode rectifier. The system was verified to stably shift to self-sustained operation.

6-4 Efforts for zero-emission energy

In March 2021, Nissin Electric began its efforts toward zero-emission energy use at the Training Center using surplus PV power, to use the DC distribution system on a daily basis in addition to demonstrative test.

During daytime hours, surplus PV power is charged to the storage battery, which is efficiently used during the night thereby reducing the amount of utility power purchased and improving the captive consumption rate. Currently, the battery charging power is supplied during the night to the Training Center and to the LED lighting at the entrance and front yard of Nissin Electric's welfare facility (Nissin Club Saganoso) adjacent to the Training Center.

6-5 Future tasks

Grid power stabilization and enhanced power resilience are increasing in importance as renewable energy sources are taking the position of the primary power sources and natural disasters are becoming increasingly devastating. To be in line with this trend, Nissin Electric assumes that DC distribution systems suitable for the utilization of renewable energy and storage batteries will come into wider use in harmony with the existing AC systems. Nissin Electric intends to provide the best solutions in the future to fulfill various customer needs with downsized and light equipment applying leading-edge semiconductor devices.

7. Conclusion

The SPSS described in this report is an important growth-strategy product for Nissin Electric to continuously grow, keeping up with major changes in the electric energy-related markets increasingly accelerating owing to the Green Growth Strategy and also intentionally creating changes.

Nissin Electric works on the development of environmentally friendly products and provides solutions for the move toward the use of renewable energy, such as PV and wind power, as main power sources. In addition to these fundamental efforts, it deploys DX-related technologies such as AI, IoT, and energy management and flexibly combines distributed energy resources including PV and storage batteries via AC and DC equipment to offer the latest and optimal solutions for increasingly diverse needs. By doing so, the Company meets the challenge of helping build a sustainable-energy-based society. Nissin Electric is committed to continually making research and development efforts and creating innovative products and services.

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- *s*EMSA is a trademark or registered trademark of Sumitomo Electric Industries, Ltd.
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Technical Terms

∗1 Virtual power plant (VPP): The scheme of utilizing distributed renewable energy-based power plants and storage batteries for ensuring demand and supply balance by controlling them as if they are a single power station.

∗2 Power wheeling: The scheme of transmitting power by which a company transmits electricity generated by in-house power generation equipment to the company's site away from the power generation equipment by way of the transmission network of a power company.

∗3 Imbalance: The difference between planned and actual demand or between planned and actual power generation.

∗4 Fault ride through (FRT): A continuous operation performance requirement for distributed energy resources to ensure power quality against power grid disturbances

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Contributors The lead author is indicated by an asterisk (∗).

M. FUJIWARA*
• General Manager, Nissin Electric Co., Ltd.

Y. TANAKA
• General Manager, Nissin Electric Co., Ltd.

N. KURIO
• Chief Senior Staff, Nissin Electric Co., Ltd.

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