An increase in the use of solar power generation, storage batteries and other distributed energy resources is posing a range of problems on the grid. The virtual power plant (VPP) is a technology designed to centralize supervisory control based on information communication technology (ICT) for controlling and utilizing these items like a single conventional power source.

Hitachi is conducting demonstration operations of the VPP with the use of electric vehicles in the US state of Hawaii and with heat pumps in the UK city of Manchester*. In both locations, they are adopted as energy sources that are distributed to consumers and integrated into the grid. These systems are studied as a means of stabilizing the grid according to the fluctuations in the output of renewable energy in Hawaii and as a commodity to be traded in the power trading market in Manchester.

In Japan as well, a negawatt power trading market will be established in 2017. This fiscal year, the Ministry of Economy, Trade and Industry (METI) embarked on the virtual power plant construction and demonstration project.

* A demonstration project commissioned by METI and by the New Energy and Industrial Technology Development Organization (NEDO).

Microgrids are connected to the power grid to make the most of distributed power sources. On microgrids, it is vital to optimize the demand-supply balance of heat and electric power and to minimize operation costs. Amid the emergence of the impact of distributed power sources on the existing grid, the compatibility of microgrids with the power grid and with other microgrids is essential for their continuous operation.

The multiple microgrid operation and management solution is designed to implement integrated management and the operation of multiple microgrids to open the way for energy transfer between microgrids and to reduce the total cost of operating multiple microgrids.

In addition, it helps create posiwowatt and negawatt power and stabilize the power grid, thereby maximizing the value of microgrids. Adopting international
standard communication protocols, the solution facilitates communication with systems on the utility side and with other microgrid systems, and ensures scalability.

With the use of the high reliability power control technology that has been nurtured by Hitachi and the Internet of Things (IoT), the solution achieves the continuous minimization of expenses and the stable supply of energy.

**Power Storage Solution**

Maintaining a stable supply of high-quality electricity is becoming an urgent issue as larger amounts of variable renewable energy like photovoltaic generation are being introduced to the power grid. Hitachi has been working towards the commercialization of a new hybrid battery energy storage system that combines lead-acid batteries and lithium-ion capacitors as safe and economical battery energy storage systems to provide a solution for this challenge. Hitachi is aiming to cover the range of control from the adjusting capacity of the inertial body of the power generator to the automatic frequency control (AFC).

For this purpose, Hitachi co-developed a 1.5 MW hybrid battery energy storage system with a group company, Shin-Kobe Electric Machinery Co., Ltd. (now Hitachi Chemical Company, Ltd.), as part of project subsided by NEDO. The demonstration project on Izu Oshima Island began in 2015 and has entered into a new stage as a joint research project with TEPCO Power Grid, Inc. The companies have been evaluating the efficacy of the monitoring control system and its effects on the operation of existing power plants.

Hitachi is aiming for the commercialization of the system by 2018 to contribute to stabilizing the supply of power for island regions.
The Organization for Cross-regional Coordination of Transmission Operators, Japan (OCCTO) is a new organization that was established in April 2015. It plans to construct power transmission networks that are necessary for the extensive utilization of power sources, monitors the supply-demand conditions of individual electric power suppliers and provides instructions on electric power supply from one power supplier to another when the supply-demand balance is tight. The OCCTO system collaborates with general electric utilities, power producers and suppliers and Japan Electric Power Exchange (JEPX) to monitor the supply-demand balance and the grid condition, manage reserve capacity and the use of interconnection lines, adjust wide-area frequency and publish grid information. The OCCTO system commenced operation in April 2016.

The main features of this system are as follows.

(1) A triplex hot standby system involving a geographical distance of hundreds of kilometers is introduced to the main site and the backup site.

(2) The leading model in the power grid system complies with IEC 61970-301 (common information model) and thereby achieved linkage with different systems and higher compatibility with package products, as well as a high level of scalability.

(3) The screen is designed with a focus on people to achieve the human machine interface (HMI) featuring the enhanced visibility of the position of electric power equipment located in an extensive space and the area where it belongs.

(4) Unauthorized intrusion is blocked by security measures that comply with different security guidelines.

In the future, Hitachi will continue to offer solutions in line with the progress of power system innovation.

Following the addition of 500 kV power extraction equipment to the Kihoku Converter Station due to the south grid reconstruction, the supervisory control
The supervisory control server, the online information server, the operation console server, the system monitoring server, the maintenance server and other upper-level systems were replaced while the lower-level systems’ central processing unit (CPU) control terminal station and terminal equipment were retained for continued use. Part of the terminal equipment was shifted to the remote station (RS).

The main features are as follows.
(1) Devices constituting the current system that cannot be supplied in the future were replaced with new models.
(2) The new system is configured to accommodate both devices from the conventional system and newly introduced systems.
(3) To improve maintainability, the architecture of servers at power supply stations and electric power facilities was adopted, which is the standard for the control systems of the Kansai Electric Power Co., Inc.

The Izumi Substation faced an issue of addressing the voltage fluctuation that occurs during the start-up in pumping in a neighboring pumped storage power station. As a solution to this issue, a static synchronous compensator (STATCOM) was installed and commenced practical operation.

Prior to this, the voltage fluctuation on the 6.6 kV bus line of the Izumi Substation reached a maximum of 10% at the start-up of the pumped storage power station and around 5% prior to parallel operation. After the installation of STATCOM, the fluctuation is suppressed to ±2% to meet the voltage fluctuation requirement stipulated in the system interconnection regulations. STATCOM’s initial capacity was planned to be 16.5 MVA. In order to avert long-term constraints on pumped storage operation due to the failure of the conversion for transformer, the STATCOM was planned to consist of three 5.5 MVA units of which two units would be constantly required and the remaining would serve as a spare unit. In this project, cooperative tap control that combines the tap control of the 154 kV/6.9 kV transformer was devised to reduce the required capacity to 11 MVA (two 5.5 MVA units). Even in the event that only one unit (5.5 MVA) is operating after another unit has failed, the voltage fluctuation is still within ±2% to satisfy the requirement.

The pulse code modulation (PCM) current differential protection relay equipment for 500 kV power grids originally comprised two-panel configuration, consisting

<table>
<thead>
<tr>
<th>Item</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated capacity</td>
<td>11 MVA (two parallel units of 5.5 MVA each)</td>
</tr>
<tr>
<td>Rated voltage</td>
<td>6.6 kV (three-phase)</td>
</tr>
<tr>
<td>Rated frequency</td>
<td>60 Hz</td>
</tr>
<tr>
<td>Voltage fluctuation suppression</td>
<td>Within ±2%</td>
</tr>
<tr>
<td>Response time</td>
<td>Within 50 ms</td>
</tr>
<tr>
<td>Converter configuration</td>
<td>Parallel quadruplex three-phase three-level converters</td>
</tr>
<tr>
<td>Rated DC voltage</td>
<td>6,000 V</td>
</tr>
<tr>
<td>Main device</td>
<td>3,300 V, 1,200 A, IGBT</td>
</tr>
<tr>
<td>Modulation system</td>
<td>15-pulse multi-carrier PWM</td>
</tr>
<tr>
<td>Cooling system</td>
<td>Circulation water and air cooling</td>
</tr>
<tr>
<td>Harmonic filter</td>
<td>1,010 kVar</td>
</tr>
</tbody>
</table>

IGBT: insulated gate bipolar transistor, PWM: pulse width modulation
of the main panel and the auxiliary panel. However, Hitachi’s latest digital relay unit was applied to make the input auxiliary transformer shared for the main relay and the fault-detecting relay to reduce the number of panels. A slim system with a single-panel configuration was therefore created. In Japan, the protection relay system consists of the main relay and the fault-detecting relay, whose hardware configurations and relay functions are different from each other in order to prevent unwanted operation.

The main features are as follows.

1. The input auxiliary transformer is shared for the main relay and the fault-detecting relay.
2. It offers advanced out-of-step relay using 2-bit data transmission, with excellent selectivity, responding to power swings at high slip frequency.
3. It complies with the immunity standard specified in JEC-2501 (electromagnetic compatibility test on protection relay) in consideration of the latest version of the B-402 Standards (digital protection relay and protection relay equipment).

After undertaking the type test witnessed by the Kansai Electric Power Co., Inc., this equipment was delivered to the operation site and preparations are being made for its operation. Hitachi will continuously develop products to provide a high level of reliability and to fulfill a wide range of needs.
Many of the protective relays used by consumers in their on-site super-high voltage power distribution systems are of the analog type and static relays. Some of these systems have already been in service 30 years or more, and it is time for them to be replaced. For replacement purposes, functionally intensive digital relays, which are today’s mainstream relays, will be introduced. Given that individual electrical rooms have many unique specifications for alarm items and others, Hitachi developed a protective relay unit for on-site super-high voltage power distribution with a standardized digital relay designed to meet individual specifications by means of hardware connection.

The main features are as follows.

1. The power supply, the CPU, the input converter, the input/output circuit and others are housed in a single unit 349 mm wide, 267 mm high and 274.9 mm deep.
2. The protection system of the in-house super-high voltage power distribution equipment is selectable from among the primary protection of the power line (current differential), the secondary protection of the power line, transformer protection and overload protection.
3. For the output of external alarm, an output selection function has been added to enable arrangement for individual electrical rooms.

In the future, Hitachi will endeavor to add functions such as a transfer block function so that the unit can be more widely utilized.