SUMITOMO ELECTRIC
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**Innovative Development,
Imagination for the Dream,
Identity & Diversity**

Feature

Supporting Renewable Energy

The Mission of Redox Flow Energy Storage Batteries

SUMITOMO ELECTRIC GROUP

In November 2021, the 26th UN Climate Change Conference (COP26) was held in Glasgow, UK. Previously, the 2015 Paris Agreement had aimed to hold the global average temperature increase to not more than 2°C above pre-industrial levels and introduced the ambitious goal of limiting warming to 1.5°C. COP26 was a continuation of efforts to limit the temperature rise, and the global climate target has been set even further from 2.0°C to 1.5°C. To achieve this target, a global agreement on “decarbonization” or net-zero greenhouse gas emissions by 2050 is necessary. Minimizing the use of fossil fuels is extremely effective for realizing a decarbonized society. To that end, it is essential to expand the use of renewable energy, such as solar and wind power.

However, there are some key issues. The power generation amount of renewable energy, which depends on natural phenomena, cannot be controlled in keeping with demand. Since the frequency fluctuates due to excess and shortage of generated power in a short period, stable power supply is difficult. Great expectations are placed on storage batteries, which can offset these disadvantages.

Sumitomo Electric began developing large-scale storage batteries about 40 years ago. The initial aim was to level the power load that fluctuates with time periods. As renewable energy has been increasingly introduced around the world, we have promoted the development of large-capacity redox flow storage batteries with the aim of ensuring grid stabilization. Hokkaido Electric Power Network, Inc. (HEPCO Network) started full-scale operation of a redox flow battery system in 2022. We have also conducted a large-scale demonstration project in California, USA, and made solid achievements. This issue reveals all the facts about redox flow storage batteries that support renewable energy.

Large-Capacity Energy Storage Battery for Realizing a Decarbonized Society

– To Accelerate the Widespread Use of Renewable Energy –

Minami-Hayakita Substation, HEPCO Network

Long-Life and Safe Energy Storage Battery in Pursuit of Usability

– Redox flow, collecting knowledge of Sumitomo Electric –

Revolutionary large energy storage battery using ionic oxidation-reduction reactions

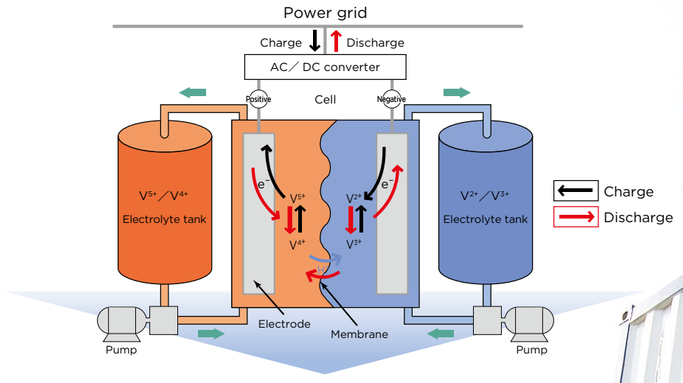
First, we look at the principle and configuration of a redox flow battery. The word redox of a redox flow battery is a combination of reduction and oxidation of active material (material that produces electricity during its chemical change), and the word flow indicates the circulation of an active material solution that is stored in external tanks. As the name suggests, a redox flow battery is a large energy storage battery that circulates an electrolyte by pumps, and charges and discharges electricity by ionic oxidation-reduction reactions. It has a very simple configuration, consisting of basic devices, such as cell stacks (stacked liquid-reflux-type cells), an electrolyte in which an active material is dissolved, and tanks, pumps, and pipes for storing and circulating the electrolyte. Vanadium sulphate aqueous solution is used for the electrolyte. When an electric current passes in a redox flow battery, a battery reaction takes place in accordance with the changes in valence (the number of charges on an ion) of vanadium ions at both the positive and negative electrodes. To adjust the amount of electrons at the positive and negative electrodes, protons move through the membrane that separates both electrodes, resulting in current flows.

Semi-permanently reusable electrolyte

Popular large-capacity batteries include lithium-ion batteries and sodium sulfur (NaS) batteries. In particular, lithium-ion batteries are widely used for consumer products, such as smart phones, personal computers, and electric vehicles. On the other hand, since redox flow batteries are large due to their large tanks and pumps, they have been mainly provided for stationary energy storage systems.

One of the advantages of a redox flow battery is its longer service life than other batteries. Since it uses ionic oxidation-reduction reactions not at electrodes but in the electrolyte to charge and discharge electricity, degradation of the electrodes and electrolyte is very small. The electrolyte can be used semi-permanently. Its design life is more than 20 years. The lifetime does not depend on the number of charging and discharging times, and the number of charging and discharging times has no limit.
The second advantage is its higher safety. Since the electrolyte uses non-combustible aqueous solution and facilities consist of flame-retardant materials, combustion risks are extremely low. The third advantage is its higher degree of freedom of design. Since the discharging amp-hour depends on the amount of the electrolyte while the output depends on the number of cell stacks, the output specification and the capacity specification can be designed independently of each other. In addition, since the electrolyte is supplied from the same tank to each cell, the state of charge of each cell is always the same, leading to easy operation. Moreover, since electromotive force of a redox flow battery can be measured even during charging/discharging operations, redox flow batteries are used as countermeasures against unstable output from renewable power plants and are suitable to stabilize grids with complex charging/discharging patterns. Consequently, redox flow batteries allow the optimum design for various needs for storage batteries.

■ Principle of a redox flow battery



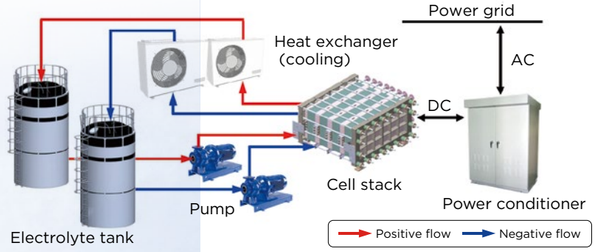
Full-scale market cultivation in 2022

The configuration of a redox flow battery is simple, but it is not easy to ensure the reliability for an extended period of 20 years. Sumitomo Electric has applied our accumulated knowledge, such as the development of 20-year leakage-free cells, a structure design to stack around 100 cells made of thin-walled, large-area flat panels, and functional materials for electrodes, membranes, and bipolar plates that make up cell stacks. We started developing redox flow batteries in 1985, commercialized practical products in 2001, and installed them at consumers' sites one after another. Consumers have reduced electric charge costs by storing inexpensive power during nighttime and discharging the power during daytime peak hours, and power suppliers have gained the benefits of leveling the electric power load. It was from around 2010, when renewable energy began to be introduced worldwide as a measure against global warming, that the importance of large-capacity storage batteries was emphasized like today.

Storage batteries have an advantage in stabilizing the output fluctuation of renewable energy. The use of storage batteries absorbs the fluctuations and smooths the output. Moreover, it is effective for frequency regulation. In response to supply-demand fluctuations, storage batteries are controlled to instantaneously balance supply and demand and keep the frequency at the standard value.

Rapid and enthusiastic development of redox flow batteries was observed in Europe and China. However, Sumitomo Electric already accumulated knowledge from fieldwork. The redox flow battery business of Sumitomo Electric reached a milestone in 2015, when large-scale demonstration projects started in Hokkaido and California, USA. Currently, these demonstration projects have been completed, and the systems have entered the commercial operation phase. In other words, full-scale market cultivation activities for redox flow batteries have started with thorough preparation.

■ Configuration of a redox flow battery



Sales expansion of redox flow batteries in Japan and abroad

The Energy Systems Division manages the redox flow battery business of Sumitomo Electric. The division aims to "develop and commercialize products and solutions for a new energy market that will expand in accordance with the introduction of renewable energy," said Takashi Yano, General Manager of the division. Above all, the primary mission is the commercialization of redox flow batteries. What is required for that?

"When storage batteries are evaluated on a conventional scale of kWh, an energy storage battery is simply a cost because it does not generate electric energy. However, in accordance with the introduction of renewable energy, maintaining the balance between power supply and demand on power networks becomes difficult, and the introduction of storage batteries becomes essential.

Against this backdrop, the top priority of manufacturers is the reduction of energy storage battery costs. In addition, we must uncover the value of balancing power supply and demand and new usage of storage batteries, as well as actively define our role under the power market and its regulations with stakeholders. In the long run, we must obtain understanding and agreement on the purposes and costs of their introduction from users. Since storage batteries for power grids are infrastructure used for a long time, we can develop not a one-time-fee business model but a service model as a service provider like a PPA (power purchase agreement) service for solar power generation facilities. In fact, the batteries are being provided overseas as an energy storage service. We want to create new usage and value from a box of batteries," said Yano. What is the marketing strategy envisioned?

"In Japan, we are focusing on electric power providers that have introduced much renewable energy and consumers that are actively introducing renewable energy. The first overseas target is North America, the largest market in the world. We have already completed a demonstration project in California and started commercial operations. Many power companies are interested in batteries that can be used for a long time, and we feel their great expectations for long-life and safe redox flow batteries. In particular, since an electrolyte can be used semi-permanently, not only costs but also environmental burden can be reduced as it is used for a long time. We also provide redox flow batteries while building a local partnership in Australia, which is one of the world's largest vanadium producers under the concept of local production for local consumption. Australians have high awareness of the environment and are making efforts toward decarbonization, and job creation is also important to them. They fully expect vanadium-related industries to be candidates that will offset the job losses in the declining coal industry in the long run. In Europe, we have also delivered redox flow batteries to a plant in Belgium. We aim to expand sales in European countries. We will reduce costs of redox flow batteries so that they can be used in networks around the world, thus contributing to a decarbonized society," said Yano.

A redox flow battery consists of three devices: positive and negative electrolyte tanks installed on the first floor and cell stacks with electrolytic baths installed on the second floor.

Takashi Yano
General Manager, Energy Systems Div.

40-Year Enthusiasm for Energy Storage Batteries

– The Struggle to Develop Redox Flow Batteries –

(Left) Internal demonstration facility installed at the Yokohama Works (since 2012)
(Middle) A project for John Cockerill in Belgium (2019)
(Right) UNIDO Morocco Project in Morocco (2019)

Development of redox flow batteries starting from the 1980s

The principle of a redox flow battery was first proposed in 1974 by NASA, USA. Almost at the same time, the National Institute of Advanced Industrial Science and Technology*1 (AIST) launched basic research in Japan. Around 1980, the difference in demand for electricity between day and night started to emerge as an issue with the growing proliferation of air conditioners in Japan. A proposed measure was load leveling, storing oversupply power in the nighttime and using it in the daytime. A national project, the Moonlight Project, was started to develop four advanced energy storage batteries, including redox flow batteries. In this period, Sumitomo Electric was looking for new themes to overcome the tendency to rely on the power cable business. One of the new themes was an energy storage battery. In addition to power generation and transmission, energy storage was thought to be necessary in the future. Thus, a redox flow battery was chosen as a new development theme, which had development issues in materials. It was in 1982 that Toshio Shigematsu, a newcomer at that time, was assigned to develop the battery.

"The Sumitomo Electric Group had no experience in developing a battery and was a complete novice. We were feeling our way in the dark. In this same time period, Kansai Electric Power Co., Inc. also chose a redox flow battery as a research topic and started a joint research and development project with our group. We selected the iron-chromium system as an electrolyte and produced a prototype of mini-cells (with an electrode area of 10 cm^2) by following the example of others. When we scaled up the prototype, various problems, such as electrolyte leakage and poor performance, occurred. In 1989, we produced a 60-kW redox flow battery (with an electrode area of 3,000 cm^2); however, it generated hydrogen gas, which decreased the battery capacity, and the performance could not be maintained in the long run. We could not help but admit that commercialization was difficult in that stage," said Shigematsu.

However, Shigematsu and other development members did not give up. They tried to use a vanadium electrolyte, which an Australian university proposed. When the developed battery was tested, it achieved high performance in an instant with the help of accumulated cell material techniques. The electromotive force was 1.4 times as large as that of the Fe-Cr electrolyte, the output was doubled, and the energy density was almost tripled.

Assembly process for cell stacks

The generated hydrogen gas was extremely decreased. A gleam of light was seen on the way toward commercialization.

*1 Then the Electrotechnical Laboratory

The project returned to life

The circumstances had changed in the latter half of the 1990s, when electricity deregulation had developed and the power rate decreased. Electric power companies changed their course of action. They were installing energy storage batteries at customer sites to sell inexpensive nighttime electricity in terms of effective use of nighttime power. In response to this need, Sumitomo Electric began to deliver redox flow batteries to universities and plants in 2001. However, Shigematsu's and other members' hopes were shattered. The redox flow batteries at that time had low durability and suffered from repeated troubles, such as the leakage of an electrolyte. It was difficult to solve these problems, and top management decided to withdraw from the redox flow battery business in 2005. After that, the members had to focus on troubleshooting.

The tide began to turn in 2009. The US proposed the Green New Deal initiative, and large-capacity storage batteries were required to store renewable energy. In Japan, a movement toward renewable energy was growing. While winding down the business, such as removing facilities, they were trying to find the causes of past problems and implement measures. Katsuya Yamanishi said that he felt the time was ripe.

Toshio Shigematsu
Fellow and Chief Engineer, Frontier Technologies Laboratory and Power Systems R&D Center

"Withdrawing from the redox flow battery business was nothing more than frustration. While the circumstances surrounding energy had greatly changed, we continued to appeal to top management to resume the redox flow battery business, saying that it would contribute to the business expansion of Sumitomo Electric. As a result, the redox flow battery business was started again, and we resumed full-scale research and development in 2009. The most important research topic was to maintain the long-term reliability of cell stacks. We had developed materials to exploit the full potential of the batteries, as well as eliminated the electrolyte leakage," said Yamanishi.

Developing a new electrolyte to achieve higher output

In 2012, a 1,000-kW test system was constructed at the Yokohama Works, and verification tests of developed techniques were conducted.

Katsuya Yamanishi
Manager, Flow Battery System Development Dept., Energy Systems Div.

The facility was well received and encouraged dialogue with the markets. This verification led to a real-scale demonstration test at Hokkaido Electric Power Co., Inc (HEPCO) in 2015, funded by the Agency for Natural Resources and Energy, a demonstration project, the New Energy and Industrial Technology Development Organization (NEDO) project in California, USA, and adoption of redox flow battery systems by HEPCO Network.

Aggressive attempts to improve redox flow batteries are still being made at the same time. The most serious issue is a price that customers can accept. To reduce the costs, they are trying to increase output and energy density and are developing an inexpensive electrolyte.

The important factor in cost reduction is output power improvement. The key is cell stacks. The aforementioned Yamanishi and other members are making efforts to increase output power for performance improvement.

"We are improving materials for electrodes and membranes and developing a cell structure that can reduce pressure loss during electrolyte circulation to increase output power. Electrolyte development and higher output power are two sides of the same coin. We aim to develop materials for cell stacks and a structural design that are optimum for the characteristics of an electrolyte. In addition, it is necessary for cost reduction to downsize the container, considering the whole system in the big picture, such as an integrated storage system for components. We also aim to develop a system using a total optimization method," said Yamanishi.

Tou Youyou
Manager, Electrolyte Development Group, Energy Storage Systems Dept., Power Systems R&D Center

They are also concentrating on developing an inexpensive new electrolyte for next-generation systems. Tou Youyou has been developing a new electrolyte since joining the Company.

"Currently used vanadium is expensive and has various issues, such as a price fluctuation risk and uneven resource distribution. We are striving to produce a high-performance redox flow battery comparable to a vanadium-system battery, using less expensive and reliably available materials for an electrolyte," said Tou.

The quest for redox flow batteries is endless.

Closely check completed cell stacks

Grid Storage Batteries for Power Supply Stabilization

– Minami-Hayakita Substation, Hokkaido Electric Power Network –

Minami-Hayakita Substation HEPCO Network.

The meaning in introducing grid storage batteries

Abira-cho, Yufutsu-gun, Hokkaido: the operation of grid storage batteries (redox flow batteries) was started in April 2022 at the Minami-Hayakita Substation of HEPCO Network.
A broad field having dimensions of about 150 m × 45 m and bristling with around 40 redox flow battery facilities is spectacular. The capacity is 17 MW × 3 hours = 51 MWh. It is one of the largest redox flow battery systems in the world.

Since the amount of renewable energy generation from solar and wind farms reached the interconnectable capacity in Hokkaido, many renewable energy companies have installed storage batteries at their sites to independently decrease the output variations of wind and solar power generation. However, these batteries were installed on the power grid side by the power grid company. The installation of large storage batteries on the grid side is economically rational because each power provider does not have to install its own storage batteries and the number of storage batteries in a single grid can be reduced. Moreover, since power providers do not have to reduce output variations, they have a large advantage in that the load of operation management will be reduced.

Since the scale of the grids in Hokkaido is primarily smaller than that of power companies in other areas, expansion of the amount of renewable energy raised the problem of limited control capability before. Thus, HEPCO Network have phased in an interconnectable capacity for renewable energy. This introduction of grid storage batteries is an effective solution to the issue. Ryosuke Nakamoto, who was in charge of grid plans and engaged in the energy storage battery introduction project at HEPCO Network recounted the details.

"Hokkaido has enormous potential for renewable energy, such as wind power generation. HEPCO Network has made efforts to phase in the introduction of renewable energy. However, our control capacity was reaching the limit, so we requested wind farms to satisfy new requirements for output variation mitigation. In other words, we required each farm to install storage batteries to level output variations. While the number of wind farms has increased, however, a national committee submitted a report stating that central operation of storage batteries on the grid side is efficient. We solicited wind farms to participate in the large energy storage battery installation project on a cost-sharing basis and have determined to introduce the large energy storage batteries," said Nakamoto.

Taking the initiative, HEPCO Network started a grid energy storage battery project in which wind farms jointly participated.

Construction during COVID-19 pandemic and frigid, inclement weather

Sumitomo Electric conducted a large-scale demonstration test of redox flow batteries with HEPCO at Minami-Hayakita Substation for three years from 2015. Since then, Shuji Hayashi, the manager of the 1st Energy Storage Engineering Group, Flow Battery System Engineering Dept., has been in charge of technical aspects.

"We have established stable and safe operations of grid storage batteries by trying to develop optimum control and operation techniques that mitigate the impact on the grid due to power fluctuations of renewable energy and maximize the efficiency and lifetime while evaluating the performance of redox flow batteries. In 2019, HEPCO decided to introduce and operate grid storage batteries and launched a solicitation process for procurement. We took part in the solicitation," said Hayashi.

Although jointly conducting the demonstration, Sumitomo Electric did not have any advantage.
The solicitation process was totally fair and transparent. Makoto Hashimoto, the manager of the Hokkaido Branch Office, looked back.

"The greatest problem was the cost of redox flow batteries.
We understood the price disadvantage; however, we received favorable feedback on and gained their confidence in our technological prowess through communication with HEPCO. I felt a sense of great relief when hearing their decision. I also felt tense with a renewed awareness that we were just at the starting line of actual operations," said Hashimoto.

Thus, the construction of the redox flow battery system was started in July 2020. After that, Hayashi managed the project as a project manager. He reduced time and costs by cutting waste in all processes. However, the COVID-19 pandemic blocked the project. Kazutoyo Mitani faced the construction work as a deputy at the site.

"The COVID-19 pandemic stopped port functions, prevented goods transportation, and limited the number of construction workers.
The construction work was delayed from the beginning, and the deadline of March 2022 was approaching.
I struggled with the construction, feeling anxiety. When winter came, it became frigid at the construction site. The construction work started in the early morning at a temperature of −25°C. We suffered from troubles, such as the highest accumulation of snow ever recorded and a rainstorm like a typhoon. We carried on the struggle to catch up on the construction progress," said Mitani.

To increase the potential of renewable energy in Hokkaido

The construction work was almost completed in November 2021, and then tests were conducted until the time of handover. Shohei Fukumoto was charged with the tests. Fukumoto had studied storage batteries at university and mainly taken charge of overseas redox flow battery projects in Morocco, Taiwan, and Belgium since joining the Company. During the tests, problems related to the power conditioning system (PCS) occurred.

"The PCS is a device that converts direct current to alternative current so that the electricity can be used for home appliances. The role is to convert generated electricity to connect a power grid. The PCS is the most important device in a redox flow battery system. The problems caused unstable operations of the system. Since it was made by an overseas manufacturer, we asked them to come to Japan for adjustment, but they could not come due to the pandemic. I clearly remembered that we communicated with each other online to solve the problems," said Fukumoto.

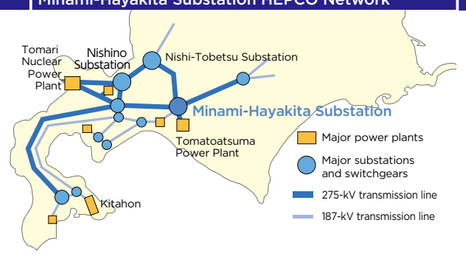
In combination with the efforts of Fukumoto and other members, the construction work was completed as planned on March 31, 2022. It seemed to Mitani a miracle that the construction was completed by the deadline. The project manager Hayashi said that he was moved to tears when the energy storage battery system was connected to the grid. "We made the most of the collective strength of Sumitomo Electric in this project," said Hayashi. Thus, the redox flow battery facility was handed over to HEPCO Network. The aforementioned Nakamoto said in acknowledgment, "I felt the staying power of Sumitomo Electric when the project was completed as planned even during the COVID-19 pandemic."

In this project, HEPCO Network installed grid storage batteries and (about 90% of) the incurred construction costs are shared with wind farms. HEPCO Network first commenced the solicitation process for wind power generation utilizing grid storage batteries (phase I).
The solicitation approved 15 priority grid interconnection companies totaling 162 MW. Nakamoto talked about future development as follows.

"To gradually expand the interconnection amount of wind power generation while checking the impact on power grids, HEPCO Network launched the solicitation process in two phases. The solicitation capacity of phase I is 600 MW, which is a capacity that can assure technical reliability. The remaining capacity is 438 MW, and an additional solicitation process is underway. We will introduce more storage batteries to exploit the maximum potential of renewable energy in Hokkaido," said Nakamoto.

Sumitomo Electric has already started taking on the challenge of establishing the presence of redox flow batteries in Hokkaido.

Minami-Hayakita Substation HEPCO Network



Ryosuke Nakamoto
Power System Planning Group Chief,
Engineering Department, HEPCO Network.

Shuji Hayashi
Manager, 1st Energy Storage Engineering Group, Flow Battery System Engineering Dept., Energy Systems Div.

Kazutoyo Mitani
1st Energy Storage Engineering Group, Flow Battery System Engineering Dept., Energy Systems Div.

Shohei Fukumoto
Assistant Manager, 3rd Energy Storage Engineering Group, Flow Battery System Engineering Dept., Energy Systems Div.

Makoto Hashimoto
Manager, Power System Sales Div., Hokkaido Branch Office

Energy storage battery building

Electrolyte tanks in the building

Battery cubicle

Facility for the large-scale demonstration test of redox flow batteries together with HEPCO in 2015

Redox flow energy storage battery system installed in California: 8,000 kWh (2,000 kW x 4 h)

Using Microgrids to Generate Power for the Wholesale Market

– A Demonstration of VRF Technology with NEDO in California, USA –

Energy Storage Facilities Provide Opportunities to Boost State Grid Reliability

In the United States, California has enacted Senate Bill 100, which sets an ambitious climate goal to reach 100% carbon-free electricity by 2045. California is committed to achieving this target while keeping grid reliability in mind, which includes finding ways to balance energy supply and demand during morning and peak evening hours when photovoltaic power generation is low. One solution was proposed by state law AB 2514, which asks utility providers to help store renewable energy by introducing battery facilities. In addition, a new program was introduced to help the wholesale power market ensure adequate revenues from energy storage facilities.

Against this backdrop, in 2015, NEDO signed a memorandum of understanding (MOU) with the California Governor's Office of Business and Economic Development (GO-Biz). Under this agreement, a demonstration project was initiated to promote the popularization of vanadium redox flow batteries with the selection of Sumitomo Electric as a subcontractor and with cooperation from San Diego Gas & Electric Company (SDG&E), a utility based in San Diego that serves 3.7 million customers. The construction of a flow battery facility started in 2016 and the demonstration began in 2017. Like all major projects between global partners, the path to a successful demonstration created opportunities and also faced challenges.

Kazutoshi Nonami, Senior Vice President of Sumitomo Electric USA, Inc. (SEUSA), explained, "We made contact with NEDO in 2012 and proposed a demonstration project of redox flow batteries in California. After a feasibility study, the proposal was accepted. The contract of the demonstration project required agreement among four companies, Sumitomo Electric, SEUSA, NEDO, and SDG&E. However, as the demonstration project of these batteries was the first, we had no template. We drew up a contract, including business risks and guaranteed performance from scratch and, in the process, realized the promise this demonstration project held."

We started the demonstration project in 2014.

Optimizing operations of the flow battery system in the wholesale market

Yoshiyuki Nagaoka assumed the post of project manager of the demonstration project and shared, "In the first stage of this project, we evaluated the basic characteristics and reliability of the redox flow batteries, using the control mode of the 2,000 kW × 4 hours (8,000 kWh) flow battery installed at SDG&E's substation. The next stage of the project aimed to evaluate system reliability, including making the stored energy of the battery available for dispatch through the California Independent System Operator (CAISO). For that reason, we developed a relationship of mutual trust with SDG&E. It was a pleasure to work with a collaborator like SDG&E on this demonstration project while building a relationship."

The second state of operating the redox flow batteries involved the connection of the battery system to the power market. The wholesale power market calls for supply capacity that provides long-period electrical energy to cope with energy supply time-shifts as well as adjusting capabilities that provide short-period output, such as frequency regulation.

Riich Kitano, who belonged to Innovation Core SEI, Inc. in the U.S. at that time and currently works for the Flow Battery System Development Department, engaged in the operation in the wholesale power market.

"Redox flow batteries feature restriction-free operation in terms of the number of charge and discharge cycles. This implies that the redox flow batteries are suitable for meeting charge and discharge requirements in two modes: instantaneous response and long duration. We verified the optimum operation techniques in specific hours and seasons by flexibly combining multiple trading schemes in the energy market, which provides electric power required in the market, and in the ancillary service market*, which provides frequency regulation and other services." said Kitano.

Toshio Ooka, who engaged in the NEDO project in the Flow Battery System Development Department, supported the demonstration project from Japan with Yuichi Ishiguro, who administered contract and cost management in the Administrative Department.

"I summarized the progress of the demonstration project concerning technical items on the U.S. and Japan sides and reported it to NEDO. I was committed to maintaining NEDO's confidence by reporting demonstration data with accuracy and swiftness. I feel fortunate to have experienced many major milestones with this project, and I look forward to sharing my experience with emerging energy engineers," said Ooka.

"This demonstration project was a large-scale, complex endeavor lasting over seven years. At the beginning, we faced various difficulties, such as delayed execution of the budget associated with the extension of work," said Ishiguro. "However, I facilitated coordination and negotiation with NEDO and our U.S partners successfully. I felt a sense of accomplishment as well as heavy responsibility,"

Microgrid demonstration conducted for the first time in the U.S. and Japan

The third and final stage introduced the world's first demonstration of "dual-use" operation for a flow battery microgrid in both normal and emergency situations. Since it is easy to increase the capacity of redox flow batteries and they are equipped to provide long-time discharge, the batteries were expected to be effective in business continuity planning measures as well as enhance grid resilience for emergency situations. Redox flow batteries make the most of their strengths within a microgrid, which, in this case, provided energy service to pre-determined homes and businesses in the local community.

A microgrid with redox flow batteries as a power source was tested using a real distribution network that was momentarily disconnected from the commercial power system. SDG&E had confidence in Sumitomo Electric conducting the test, as all possible preparations were made to ease any customer inconvenience. We successfully demonstrated that the system makes it possible to continuously provide power to blackout areas as an independent power source for the first time in the U.S. and Japan. A series of demonstration project stages was completed at the end of 2021, and the system is now being operated by SDG&E.

Laurence Abcede, Distributed Energy Resources Manager of SDG&E, looked back on the demonstration project as follows:

"The redox flow batteries supported our region and state grid with a high availability rate. These batteries also demonstrated grid reliability and resilience during a planned outage to simulate a system failure and test the flow batteries as a microgrid running independent from the larger grid. The demonstration was successful and SDG&E will continue to collect data and optimize operations as we integrate the VRF battery into our overall grid and energy storage portfolio." said Abcede.

Eitaro Omine, an official of NEDO, evaluated the project as follows:

"We successfully completed the project due to the efforts of Sumitomo Electric. We have proved not only the effectiveness of system stability but also the high reliability of the system by the almost 100% availability rate. The success of the microgrid demonstration was an important favorable result. The project also became a good case of cooperation between the U.S. and Japan. For social implementation, We expect Sumitomo Electric to reduce costs of redox flow batteries," said Omine.

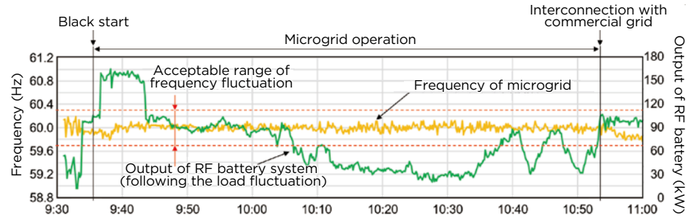
Toshikazu Shibata, General Manager of the Flow Battery System Engineering Department, was in command of the entire project.

"We see the enormous potential of redox flow batteries amid the accelerated introduction of renewable energy. We consider redox flow batteries of Sumitomo Electric to be technologically advanced. Making full use of our redox flow batteries, we will accelerate the introduction of renewable energy and contribute to achieving a carbon neutral society," said Shibata.

It is certain that the dissemination of redox flow batteries of Sumitomo Electric will be a step toward a more sustainable future.

* Ancillary service market: System operators, who are obliged to maintain the frequency of the electric power system, procure the power sources required for frequency regulation through markets. The ancillary service market provides regulation capability and reserve capacity to balance electricity supply and demand.

■ **Microgrid test**
(An example of black start operation: Oct. 22, 2021)



A stable frequency was maintained during microgrid operation.
(It is the first time in the U.S. and Japan that a microgrid has been operated on a commercial distribution network inclusive of real consumers with storage batteries as the main power source.)


Eitaro Omine
Senior Researcher, Smart Community and Energy Systems Dept.,
The New Energy and Industrial Technology Development Organization, Incorporated Administrative Agency (NEDO)


Kazutoshi Nonami
Senior Vice President,
Sumitomo Electric USA, Inc.


Yoshiyuki Nagaoka
Manager, 3rd Energy Storage Engineering Group
Flow Battery System Engineering Dept.
Energy Systems Div.


Riichi Kitano
Assistant Manager, System Design Group,
Flow Battery System Development Dept.,
Energy Systems Div.


Toshio Ooka
Senior Assistant Manager, System Design Group,
Flow Battery System Development Dept.,
Energy Systems Div.


Yuichi Ishiguro
Manager, Administration Group,
Administrative Dept., Energy Systems Div.


Mr. Laurence Abcede
Distributed Energy Resources Manager
San Diego Gas & Electric


Toshikazu Shibata
General Manager, Flow Battery System Engineering Dept., Energy Systems Div.

LIVING IN SAFETY AND COMFORT ON OUR GREEN PLANET

Relentlessly challenging ourselves to use Technology for Good

We have developed the Sumitomo Electric Group 2030 VISION, which describes our basic attitude toward greater contribution to society, as well as a direction for the growth of the Sumitomo Electric Group in a world facing great transformation. The Sumitomo Electric Group will pursue its ambition to achieve a "Green Planet" and a "Safer" and more "Comfortable" Society, relentlessly challenging ourselves to use technology for good.

President & COO
Osamu Inoue

Purpose

Contribute to building a better society by pursuing Top Technology and innovation on a global scale, using the integrated capabilities of the Sumitomo Electric Group.

Direction for the Sumitomo Electric Group in an Era of Great Transformation

This year 2022 has been a turning point in my five years as President. Unprecedented headwinds, such as the COVID-19 pandemic since 2019 and the Russian invasion of Ukraine, have impacted our business. To overcome various difficulties, the members of the Sumitomo Electric Group have strived toward its business operations as a whole for these five years. The Group announced the five-year medium-term management plan "VISION 2022" in 2018. The concept is "Contributing to a better society by leveraging our expertise in connectivity and transmission technologies through concerted efforts of the entire Group," and the strategy to realize the vision is to strive for further growth through enhancement, expansion, and innovation of the five business segments of Automotive, Infocommunications, Electronics, Environment & Energy, and Industrial Materials, aiming to achieve a balanced business portfolio. In FY2021, the total consolidated operating profit of four business segments other than the Automotive segment was a record high, and all businesses grew, nearing the ideal portfolio. In particular, the Environment & Energy segment achieved an all-time high profit with a tailwind of GX*1. We satisfied the requirements of not only customers but also society with our accumulated engineering and sales expertise.

In contemporary society with increasing globalization in all aspects, imminent risks (such as global warming, COVID-19 and other infectious diseases, natural disasters, the Russian invasion of Ukraine, and other geopolitical risks) will directly and significantly affect business operations, and they will accelerate various types of transformation in personal lifestyles and the global society and industries. Because a precise, prompt, and flexible response to the transformation is required, we have formulated the Sumitomo Electric Group 2030 VISION, which provides a broad direction for the Group, to achieve its ideal future "Glorious Excellent Company" for 2030.

Honoring both the Sumitomo Spirit and the Sumitomo Electric Group Corporate Principles

The Sumitomo Electric Group 2030 VISION consists of Management Policy, Society 2030 & Business Domains, Business Direction, and Business Foundations & Targets.

Management Policy stipulates anew that even in an era of great transformation, honoring both the immutable philosophy of the Sumitomo Spirit and the Sumitomo Electric Group Corporate Principles, we manage the Group based on the spirit of "contributing to the public benefit through business" while striving to ensure mutual prosperity with our stakeholders. Based on these basic beliefs, we summarize the important management policies: pursuing top technology, expanding global presence, diversity & inclusion, and sustainability into purpose.

The Sumitomo Electric Group has provided products and services that contribute to a safer and more comfortable society since its founding. Looking ahead to 2030, it is increasingly important to achieve sustainability for our planet. Therefore, we have added green and environmentally friendly society to Society 2030. To realize Society 2030, we will continue to provide an extensive range of products and services for the development of infrastructure and industries. Acknowledging energy, info-communications, and mobility as our three key areas, and including areas where they are fused, we will unleash all of its capabilities to contribute to the ideal society by capturing various customer needs, such as GX, DX*2, and CASE*3.

Specifically in the field of Energy, it is important to address a further increase in the adoption of renewable energy, such as solar and wind power, for a carbon-free society. Direct-current transmission grids that allow long-distance power transmission between power generation and consumption sites, rechargeable batteries that balance the electricity supply and demand in response to the intermittency issues of renewable energy sources, and integration and control due to the increase of distributed energy sources, such as solar power, rechargeable batteries, and EVs, will be required. The Sumitomo Electric Group will satisfy these needs through its extensive portfolio of products and services, such as power cables, electrical substation equipment, batteries, and engineering.

In April 2022, the large-scale redox flow battery system, which is used for the interconnection between large-scale wind farms and the power system, started operation together with Hokkaido Electric Power Network, Inc. Since vanadium electrolytes in the batteries can be used semi-permanently, the system is an eco-friendly storage solution. We will actively cultivate the market. In addition, we have superiority in the field of high-voltage direct-current cables, which are being introduced at an accelerating pace in the world against a backdrop of increasing needs, such as further introduction of renewable energy, expansion of wide-area power trading, and improvement of the reliability of power supply. We will focus our efforts on this field, including the expansion of our production capacity.

*1 GX: Green transformation, transforming the industrial structure and socio-economy by converting to green energy that does not emit greenhouse gases
*2 DX: Digital transformation, transforming the business process, company culture, or daily life into something better using digital technologies
*3 CASE: Connected, Autonomous, Shared & Services, and Electric, the key trends in the automotive field

2030 VISION (excerpt)

Society 2030 & Aspiration

Since our establishment

Safety

We will supply various products that support infrastructure and industries for a Safer Society.

- High durability
- High strength

Comfort

We will supply high-quality and high-performance products to global markets for a more Comfortable Society.

- High speed
- Large capacity

Further Emphasis

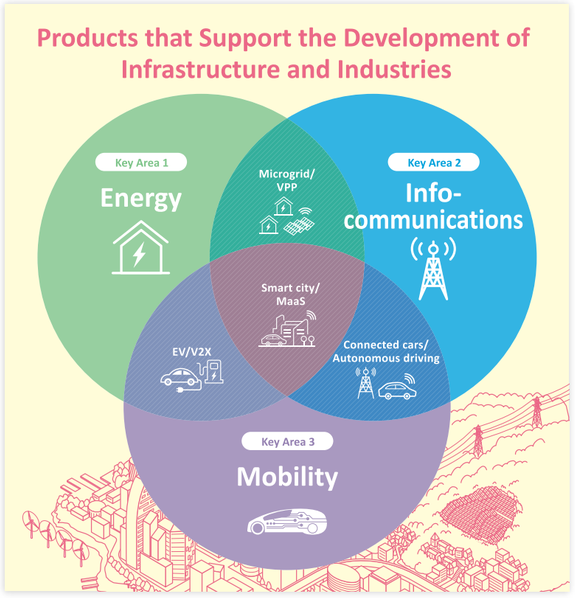
Green

We will achieve a Green Society through company wide efforts to promote our businesses including the carbon-free business.

- High efficiency
- Low loss

→ We will focus on realizing a Green Society that is both Safer, more Comfortable and sustainable.

Business Domains—Key Areas



Not adhering to the profit-first principle, we have provided products necessary for society. We have not changed our corporate principle, satisfying social needs and contributing to society.

In the field of Communications, development of high-speed large-capacity data communications will drive the expansion of wireless and optical networks. It will also lead to the establishment of more data centers, leading to growing demands for reducing their power consumption. While base stations for 5G are being installed around the world, we have started efforts with an eye toward 6G. The Sumitomo Electric Group will continue to meet the challenge to develop innovative materials and devices, such as gallium nitride devices for base stations achieving low power consumption, large-capacity communications, and wide-area coverage; multi-core optical fibers and ultra-high fiber count cables for large-capacity optical communications; and photonics-electronics convergence wiring for power saving in communications.

In the field of Mobility, it is expected that by 2030, electric vehicles, including hybrid electric vehicles and plug-in hybrid vehicles, will constitute the majority of new vehicle sales, autonomous driving will develop to level 3, where cars actually drive autonomously under certain conditions, and various forms of mobility, such as ultra-compact mobility and flying automobiles, will emerge. In addition, linkage of vehicles with external services will be expanded.

During these changes in the business environment, we will provide new value through the power of our global manufacturing quality, high-level technological engineers, and skilled workers, which enable the production of the same product with the same quality all over the world, with a focus on wiring harnesses as our core business. Additionally, the Sumitomo Electric Group will endeavor to advance electrification and high-speed communications of automobiles, leveraging the integrated technologies of the Group, such as energy and infocommunications. We will create CASE-related new products, such as high-voltage harnesses for EVs and connectors for high-speed communications. With regard to flat magnet wires for motors in vehicles, we have enhanced production capacity to expand the wires to one of our core businesses like the wiring harness business.

We will expand the sales of these three core fields by 1 trillion yen or more and strive to grow the consolidated net sales to 5 trillion yen or more. In addition, we will review the medium-term business plan every three years to promptly and flexibly respond to the uncertain and unprecedented business environment.

We will also engage in a wide range of activities, such as recycling water resources, effective use of rare metals, and reduction of CO_2 emissions, to achieve a green society.

Devotion to Sumitomo Electric Group 2030 VISION

Since its founding more than 120 years ago, the Sumitomo Electric Group has built up its core business and achieved steady growth in each of the five segments to contribute to society. We will not adhere to the profit-first principle but uphold the corporate principle that we should provide products necessary for society and contribute to society in 2030. While practicing the Sumitomo Electric Group 2030 VISION, we will find a new pillar of business and create profitable products.

We have produced highly evaluated products by improving and refining existing products; however, we will bring entirely new products into the world for business continuity.

The Sumitomo Electric Group has carried out research and development in a wide range of fields, centering on the three R&D centers, including overseas sites. Redox flow batteries mentioned above were invented among them. Other promising businesses include the water treatment business using Poreflon, a special filtration membrane for wastewater purification and recycling. We will satisfy social needs, not only looking into the future from the present but also backcasting or looking back from a carbon neutral society in 2050 to the present.

We have incorporated the determination of the Sumitomo Electric Group to contribute to establishing a better society into the Sumitomo Electric Group 2030 VISION, and to fulfill the vision, the most important thing is the awareness of each employee. It is necessary to understand the corporate principle of the 2030 VISION and its meaning and to get everyone on the same page toward the same goal. I will actively disseminate information to deepen understanding of the Sumitomo Electric Group 2030 VISION in all Group companies and divisions. Each employee's awareness that we work to create a better society will lead to the road to a Glorious Excellent Company.

Sailing into rough-water transformation

After the global financial crisis in 2008, I was appointed as the President of our German subsidiary, which had entered insolvency, and we revitalized the company in a unified effort for three years. After returning to Japan, I launched a new wiring harness project as the President of Sumitomo Wiring Systems, Ltd., a group company. Based on these experiences and as the President of Sumitomo Electric, I believe that it is truly important to build an effective system to respond to changes and make decisions in limited time. To promptly respond to changes, I am trying to constantly collect accurate information. I receive reports from surrounding members on a daily basis and attentively listen to the information, wondering if it is strictly correct or something has been partially omitted, to increase the accuracy of the information. In addition, I talk with members about the information. I believe that the interaction leads to the right decision to address unforeseen or unexpected situations or rapid changes by top management.

The world will increasingly become more uncertain toward the future. I will meticulously and boldly steer the helm of management in the rough water to enhance our corporate value.

A Picture of Sumitomo Electric in Those Days

2019

Construction of the ±400-kV HVDC XLPE Cable System Connecting the UK and Belgium

DC XLPE insulated cables loaded onto the freighter to NEMO Link

Starting the DC XLPE Insulated Cable Project for International Interconnectors

With the increasing capacity of renewable energy sources and construction of power interconnectors between countries and regions, demand for direct current (DC) power transmission cables, which are suitable for long-distance and large-capacity power transmission, is rapidly growing around the world.

The Sumitomo Electric Group jointly developed DC cross-linked polyethylene (XLPE) insulated cable technology with Electric Power Development Co., Ltd.*1 and completed construction of the Hokkaido-Honshu DC Interconnector in 2012. This was the world's first high-voltage direct current (HVDC) power transmission project using XLPE cables and has been accident-free since 2012. In recognition of these achievements, we were selected as the first Asian cable manufacturer to build a NEMO Link*2 interconnector between countries, part of the most important social infrastructure in Europe. The construction completion of the world's highest-voltage DC XLPE insulated cable system boosted the reputation of our DC XLPE insulated cable in Europe in terms of engineering capability and reliability. Since then, we have won contracts for a ±525 kV high-voltage DC power transmission cable system in Germany, an extra-high-voltage DC power transmission system in the UAE, and systems in other regions.

As the only Japanese cable manufacturer with a track record in operation of DC XLPE insulated cables, we will continue to contribute to building important power transmission infrastructure around the world by harnessing cutting-edge technologies refined through many years of research and development and delivering many products.

*1 Electric Power Development Co., Ltd.: Currently J-POWER Transmission Network Co., Ltd.
*2 NEMO Link: UK-Belgium HVDC interconnector system by Nemo Link Ltd., a joint company between National Grid Plc (UK) and Elia Group (Belgium)

Also refer to:
• id vol. 01 Feature: International Submarine Cable Project
https://sumitomoelectric.com/id/project/v01/01
• id vol. 18 Feature: Connecting to the future of a decarbonized society. At the forefront of direct current power transmission cables
https://sumitomoelectric.com/id/project/v18/01

id vol.19

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