Realization of a Net Zero Factory Utilizing Vanadium Redox Flow Battery and Energy Management System

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The Sumitomo Electric group aims to reduce greenhouse gas emissions by 30% compared to fiscal 2018 levels by fiscal 2030 and to achieve carbon neutrality by fiscal 2050. At the Matsusaka Factory of SWS West Japan, Ltd., we leveraged our product, the "Vanadium Redox Flow Battery," and the energy management system "sEMSA" to commence operations of the first Net Zero Factory in our group in August 2025. This article reports on the initiatives taken at the Matsusaka Factory of SWS West Japan, Ltd. towards achieving Net Zero status. Finally, we introduce our group's efforts to promote Net Zero status in all our factories.

Keywords: Net Zero Factory, vanadium redox flow battery, energy management system, self-wheeling, renewable energy

1. Introduction

The Paris Agreement adopted at the 21st Conference of the Parties (COP21) sets out the goal of keeping the rise in global surface temperature well below 2°C above pre-industrial levels, and preferably, the limit of the increase should only be 1.5°C. Viewing challenges related to global warming and climate change as the most important management issues, the Sumitomo Electric Group has set a goal of reducing its greenhouse gas emissions by 30% compared to fiscal 2018 levels by fiscal 2030 and achieving carbon neutrality by fiscal 2050 to align with the levels required by the Paris Agreement. In line with these goals, the Group is addressing challenges such as energy saving through improved productivity and the introduction of new technologies, energy creation involving green energy generated from solar power and other sources and other means, and energy purchase through procurement of renewable energy.

With the intention to achieve carbon neutrality by fiscal 2050, Sumitomo Electric Industries, Ltd. plans to gradually turn each of the Group's plants, numbering about 270 in total, into a Net Zero Factory, which is defined as a plant whose annual greenhouse gas emissions are not higher than zero and whose initiatives include promoting energy saving and creation at a normative level. This paper reports on a forerunner example of the plan, focusing on the Matsusaka Factory of SWS West Japan, Ltd. (hereinafter referred to as the SWS-W Matsusaka Factory), which commenced operations in August 2025, as the first Net Zero Factory of the Group.

2. Example Initiatives at the SWS-W Matsusaka Factory

2-1 Initiatives overview

The SWS-W Matsusaka Factory was selected as the first candidate Net Zero Factory of the Group because at the factory the effect of introducing relatively low-cost solar power generation as a means of reducing its greenhouse gas emissions is significant in proportion to the plant size (power consumption), and emissions reductions are compatible with economic efficiency.

In August 2025, the SWS-W Matsusaka Factory commenced operation as a Net Zero Factory without recourse to energy purchase, utilizing Sumitomo Electric's vanadium redox flow battery (hereinafter abbreviated as the VRFB) product and Sumitomo Energy Management System Architecture (*s*EMSA).

2-2 Overall configuration

The factory's renewable energy-based power sources consist of solar power generation equipment (panel capacity: 450 kW) installed on the factory's roof and a solar power plant located outside the factory's premises. Power from the off-the-premises solar power plant was introduced in the form of an off-site power purchase agreement (PPA)*1 jointly with Sumitomo Wiring Systems, Ltd. (Sumitomo Wiring). To ensure balance between power production and consumption at the factory, a VRFB was installed and charge-discharge control implemented through *s*EMSA achieves optimal operation. Surplus electricity is sent to the Yokkaichi Plant of Sumitomo Wiring by way of wheeling. The environmental value created therein is used by the SWS-W Matsusaka Factory to

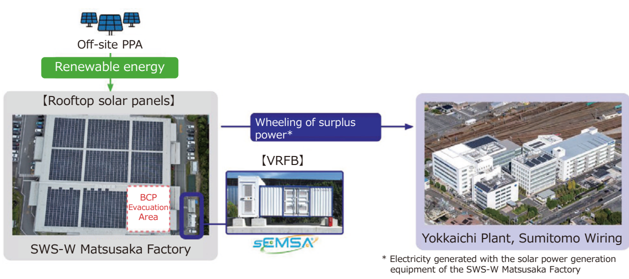

Fig. 1. System configuration at the SWS-W Matsusaka Factory

achieve net zero emissions.

3. Energy Storage Technology (VRFB)

3-1 Principle and structure of the VRFB

VRFBs are electrolyte circulation-type batteries that store an electrolyte solution—vanadium, the active material, dissolved in dilute sulfuric acid—in external tanks. This electrolyte is supplied to the cells via pumps for charging and discharging. Figure 2 shows the principle. The battery reaction of the VRFB involves only valence number change of vanadium ions in the electrolyte; hence, the battery is less prone to deterioration of both the electrolyte and electrodes over the number of charge-discharge cycles.

The VRFB installed at the SWS-W Matsusaka Factory in this project has a power output of 40 kW and a discharge capacity of 159 kWh. A configuration diagram of the battery is given in Fig. 3, with the battery consisting of cells, pumps, and other electrical equipment placed at the center of the container, and positive and negative electrolyte tanks on either side. It is a VRFB whose structure houses all its components within one container.

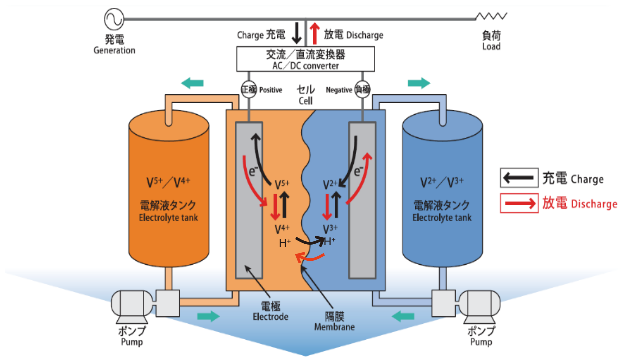

Fig. 2. Principle of the VRFB

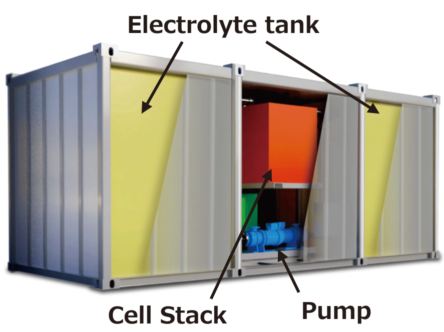

Fig. 3. VRFB configuration
(of the model installed at the SWS-W Matsusaka Factory)

3-2 Features of the VRFB

The VRFB features high level of safety, a long life, and eco-friendliness. Its major features are described below.

(1) High level of safety

The electrolytes are nonflammable aqueous solutions free of self-ignition. The other components are made of non-flammable or flame-retardant materials, posing very low risks of fire, and do not fall into the category of dangerous goods stipulated in the Japan's Fire Service Act. Accordingly, the VRFB does not require permission from the competent fire department or a fire prevention supervisor to be appointed in Japan. It can be installed with the provision of the minimum required fire-fighting equipment (ABC fire extinguishers).

(2) Long life

According to its principle, the battery system has a durability of 20 years or more because the number of charge-discharge cycles is not a factor of deterioration. Additionally, because the number of charge-discharge cycles is not limited, the battery is suitable for multi-use applications, offering supply and adjustment capabilities for the capacity, electricity wholesale, and supply-demand adjustment markets, as well as storing energy when renewable energy sources produce surplus power and discharging when demand for electricity increases.

(3) Eco-friendliness

The battery is an environmentally friendly product, producing virtually no industrial waste when discarded, with the electrolytes being usable semi-permanently and the other battery components mostly being reusable or recyclable.

3-3 Operation of the VRFB at the SWS-W Matsusaka Factory

The VRFB was introduced to the SWS-W Matsusaka Factory as equipment for achieving some of the initiatives at the factory to enable net zero emissions, namely, compensation of forecasting errors for self-wheeling (to avoid imbalance*2), efficient use of renewable energy, and BCP*3 applications. Energy remaining in the VRFB after compensation of power forecasting errors for self-wheeling during daylight hours is consumed to meet the in-house demand at the SWS-W Matsusaka Factory during the nighttime, thereby ensuring waste-free use of renewable energy and the capacity of the VRFB. Since the commencement of operation in August 2025, the VRFB has been continuously and stably operating. Actual compensation of forecasting errors and stable operation during summer in August and thereafter are reported below.

(1) Compensation of forecasting errors by means of charge-discharge operation of the VRFB

Figure 4 presents a schematic diagram of the configuration of the system installed at the SWS-W Matsusaka Factory and used for power wheeling. Employing control provided by Sumitomo Electric's energy management system *s*EMSA—described later—the charge-discharge cycles of the VRFB are used to compensate for errors deviating from the wheeling plan.*4

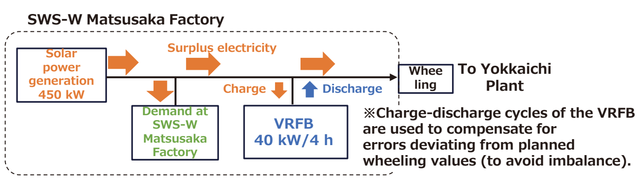

Fig. 4. Schematic diagram of system configuration

Figure 5 illustrates sample data of a typical day. During the daylight hours, errors deviating from the planned values regarding transmitted power are more suppressed in the case with the VRFB (solid blue line in Fig. 5) than those in the case without the VRFB (solid light blue line in Fig. 5) owing to operation following battery charge-discharge commands issued by *s*EMSA.

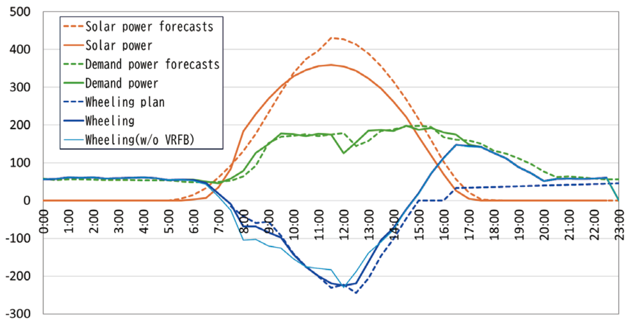

Fig. 5. Typical Example of different types of power values

(2) Stable operation of the VRFB during summer

To maintain battery performance and quality, the VRFB is designed to keep the electrolyte temperature within a certain range by means of an air-cooled system taking in outside air. When the temperature exceeds the threshold, the battery determines it to be a thermal error and shuts down automatically. Despite the situation that, in recent years, in the summer season in particular, abnormal air temperatures have been observed consecutively, the VRFB has continued operating stably without any thermal error-triggered shutdown since commencing operation in August 2025, including the date that recorded the highest air temperature this summer (as of November 2025).

4. Energy Management Technology (*s*EMSA)

4-1 *s*EMSA Basics

Based on Sumitomo Electric's proprietary demand and solar power generation forecast technologies, *s*EMSA formulates an optimal power source operation plan for up to 48 hours ahead by using a mathematical planning method. The management system has a mechanism that enables itself to draw up a highly precise operation plan by incorporating various restrictions associated with storage batteries and other resources subject to control. Moreover, it very accurately follows control command values sent from a host system owing to Sumitomo Electric's proprietary real-time feedback control technology, which monitors the amount of electricity at the power receiving point in the order of seconds and compensates for errors deviating from the plan.

Using three sequences of (1) forecasting, (2) optimal planning, and (3) real-time control, *s*EMSA implements optimal control of the amount of electricity at the power receiving point. In recent years, due to this control technology, the application of *s*EMSA has been increasing in operation systems intended for the supply-demand adjustment market, which requires extremely accurate control technology. This paper reports on how *s*EMSA was applied to the project described in this report, which marks its first self-wheeling solution.

4-2 Self-consumption solution

Self-consumption of solar power generation refers to the consumption at a facility of solar power generated at the facility. Reducing the amount of electricity purchased from external parties translates to reduced electricity bills and an improved renewable energy utilization factor. One systemic challenge to the implementation of this mechanism is to configure the mechanism so that it keeps the power generated within the facility from flowing to the power grid. In particular, it is necessary to shut down the power output from solar power generation and prevent the power from flowing into the power grid (reverse current) when the power generated by solar panels at the facility exceeds the electricity demand of the facility. *s*EMSA has functions to monitor fluctuations in the power output of solar power generation and electricity demand in intervals of seconds and to curtail the power output of solar power generation when a reverse-current risk arises.

In the case of the SWS-W Matsusaka Factory reported in this paper, permission was granted to implement self-wheeling, by which surplus power otherwise resulting in a reverse current is sent to another business site of the Group, thereby maximizing the power consumption of solar power generation within the Group by avoiding curtailment of power from solar power generation.

4-3 Self-wheeling solution

Self-wheeling is an arrangement by which a company transmits power generated within its facilities to another business site of its group or the like via the power transmission/distribution network of a power company. This arrangement offers advantages such as reduced electricity bills and maximized efficient use of power derived from renewable energy.

To implement self-wheeling, a system carries out the following: (1) forecasting on the previous day the amount of electricity for wheeling on a certain day in 30 min intervals and formulating a wheeling plan and (2) ensuring on the planned day that the actual amount of power wheeling accurately follows the wheeling plan. The determinant factors of the amount of power wheeling are the amount of power from solar power generation and the amount of electricity demand. Therefore, it is important to forecast these two factors and implement prompt recovery measures in the event of an error deviating from the forecasts.

*s*EMSA has functions to forecast the amount of power from solar power generation and the amount of electricity demand and to formulate a future 48 h wheeling plan on the previous day. According to the wheeling plan, for operation on the intended day, *s*EMSA monitors power generation and electricity demand in real time and, in the event of a discrepancy from the plan, controls the charge-discharge cycles of the storage battery to compensate for the discrepancy and ensure reduced imbalance.

4-4 Composite solution

Figure 6 depicts the configuration of the *s*EMSA system at the SWS-W Matsusaka Factory. The system consists of a *s*EMSA server on the cloud and *s*EMSA-FactoryLite installed at the business site. The *s*EMSA server forecasts the amount of power from solar power generation and the amount of electricity demand, drafts a wheeling plan, and submits the wheeling plan to the Organization for Cross-regional Coordination of Transmission Operators (OCCTO)*[5] and to electricity retailing companies. The wheeling plan formulated by the *s*EMSA server is sent to *s*EMSA-FactoryLite, which monitors the amount of power from solar power generation and the amount of electricity required by on-premises loads and sends charge-discharge control commands to the storage battery. These operations of monitoring the amounts of electricity and issuing control commands are implemented in 1-second intervals to compensate for discrepancies between the planned values and actual values in real-time.

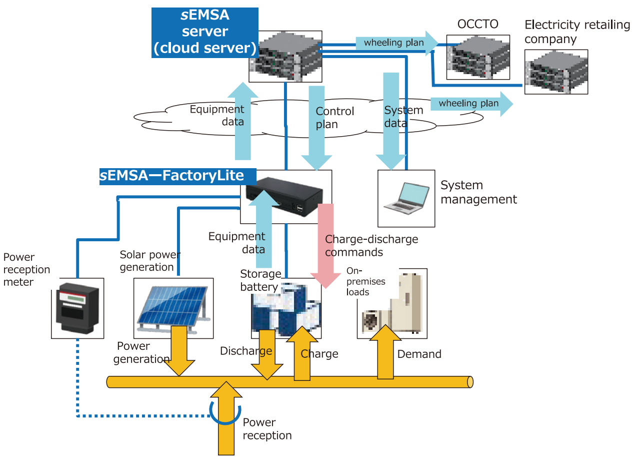

Fig. 6. *s*EMSA system configuration at the SWS-W Matsusaka Factory

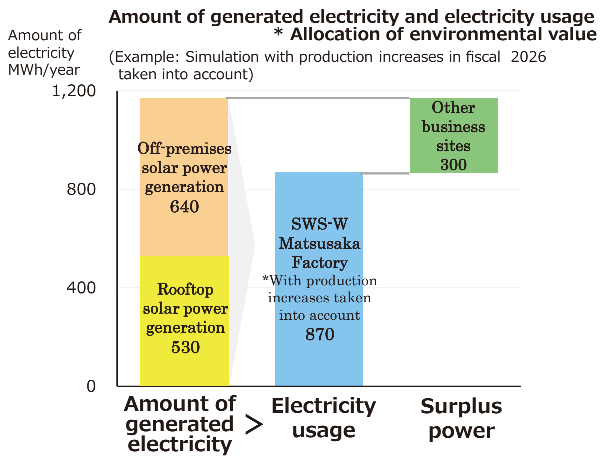

Fig. 7. Amount of generated electricity and electricity usage at the SWS-W Matsusaka Factory

Electricity generated by solar power is supplied to on-premises loads in the SWS-W Matsusaka Factory to maximize self-consumption. In addition, surplus power when the power produced by solar power generation is greater than the on-premises loads is transmitted to the Yokkaichi Plant of Sumitomo Wiring by way of self-wheeling to make the most efficient use of renewable energy created by in-house equipment. *s*EMSA issues charge-discharge commands to control the storage battery to avoid imbalance during wheeling, with charge control implemented to ensure that electricity produced by solar power alone is used for charging. The reason for this is that power from the grid is not allowed to be used for wheeling.

5. Net Zero Emissions Achieved by the SWS-W Matsusaka Factory and In-House Certification

The SWS-W Matsusaka Factory emits no greenhouse gases produced from consumption of city gas, etc. (Scope 1*[6]), so it will achieve net zero emissions if it meets its electricity demand by entirely using renewable energy. The electricity usage by the factory for fiscal 2026 is estimated at approximately 870 MWh/year, with the effects of future production increases taken into account; the sum of generated electricity is designed at approximately 1,170 MWh/year, exceeding the electricity usage, as illustrated in Fig. 7.

Meanwhile, with the aim of turning plants at each business site into net zero emissions at an increased pace with carbon neutrality by 2050 in sight, the Group started its Net Zero Factory certification program in April 2025. The track record regarding greenhouse gas emissions for three months (August to October 2025) was used to check whether the SWS-W Matsusaka Factory passed the criteria, an on-site review was conducted regarding energy conservation and creation requirements, and the factory was formally certified as the first Net Zero Factory in November 2025 (Photo 1).

Photo 1. Presentation of a Net Zero Factory certification plaque

6. Conclusion

In the example of the SWS-W Matsusaka Factory, net zero emissions were achieved by using wheeling to another business site and making efficient use of the surplus power produced by the rooftop solar power generation equipment substantially exceeding the factory's electricity usage during daylight hours. This is a model that could be realized due to the fact that the factory size (electricity usage) is small and relatively large solar power generation equipment could be installed on the premises. For a plant of large size (electricity usage) to achieve net zero emissions, in contrast, it is highly likely that deficiencies in environmental value should be complemented by energy purchases (e.g. with a non-fossil fuel certificate) and a virtual PPA.*7

The Group aims to turn each plant into a Net Zero Factory at all of its business sites by 2050. We will promote our efforts for turning each plant into a Net Zero Factory in a systematic manner on a global scale while sharing the established method of developing Net Zero Factories based on the experience obtained through the example described in this paper and making the progress visible to parties inside and outside Sumitomo Electric.

Technical Terms

*1 Off-site power purchase agreement (PPA): An agreement signed by a company to purchase electricity generated by renewable energy-based power generation equipment installed outside its premises (off-site).

*2 Imbalance: Imbalance refers to a difference between a demand plan and actual demand or between a power generation plan and actual power generation.

*3 BCP: Business continuity planning.

*4 Wheeling plan: A plan that sets out the amount of electricity to be sent by wheeling.

*5 Organization for Cross-regional Coordination of Transmission Operators (OCCTO): The organization that administers nationwide electricity supply and demand.

*6 Scope 1: Greenhouse gases directly emitted by a company.

*7 Virtual PPA: The mode of obtaining a certification for renewable energy-based electricity (environmental value) by an agreement while actually using electricity coming from general transmission networks.

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