Case Study: Smart Community Demonstration Project in Oshawa, Canada

1. Introduction

From 2015 to 2017, a demonstration project about systems consisting of solar panels, battery storage, and hybrid inverter was conducted in the city of Oshawa, Ontario, Canada, an area with unstable power supply. This demonstration project was launched as one of the “Smart Community International Demonstration Projects” of NEDO. It is the verification for the sake of power grid stabilization to introduce and operate power storage systems, and to make use of the systems which can be used as emergency power sources in the area with unstable power supply.

This demonstration was conducted by Tabuchi Electric Co., Ltd. (hereinafter called “Tabuchi Electric”) from Japan, a Canadian corporation Oshawa Power & Utility Corporation (hereinafter called “OPUC”) and the city of Oshawa. NEDO concluded MOU (Memorandum of Understanding) with the city of Oshawa and OPUC. Tabuchi Electric also concluded ID (Implementation Document) with OPUC to build cooperative framework of the project. Panasonic Eco Solutions Canada (hereinafter called “PESC”) concluded a contract for maintenance and inspection with Tabuchi Electric to support participating residents of the demonstration, and made procurement and installation of the systems (Figure 1).

In this case study, we summarize the results of the demonstration of power storage systems, value of emergency power source, suggestions on the future smart community market and power supply systems, and social significance of a demonstration.

2. Background of the demonstration

In Canada, in addition to energy targets and policies set by the government, each province has its own energy policy. A great effort was made to introduce renewable energy in Ontario, and a feed-in tariff (FIT) was first introduced there in North America in 2009 (* As of March 2020, and it is already discontinued.) at the time of the demonstration. Nuclear energy accounts for about 60% of the energy mix in Ontario, but decommissioning of large reactors is imminent, so that alternative energy sources are required. Although thermal power generation is not acceptable in view of the global trend toward decarbonization, renewable energy faces significant challenges in its variability as well as competitiveness against thermal plant in cost, so that the introduction of technology to stably operate power grid systems is unavoidable.

It is also important for Oshawa city to implement measures against power outages, where power outages occurred 204 times in 2013. Especially in winter, the temperature often falls below minus 10 degrees Celsius in the city where there are many elderly, therefore stable power supply is strongly desired from the viewpoint of citizens' health and safety.

Japan's technology matched this situation. In Japan, FIT scheme was established after the Great East Japan Earthquake in 2011, and it has led to the explosive spread of renewable energy. The introduction of battery storage into households has also made great strides in response to heightened awareness of disaster prevention. It is great opportunity for Oshawa to benefit from the technologies developed in Japan, and this is the way the international project was realized.

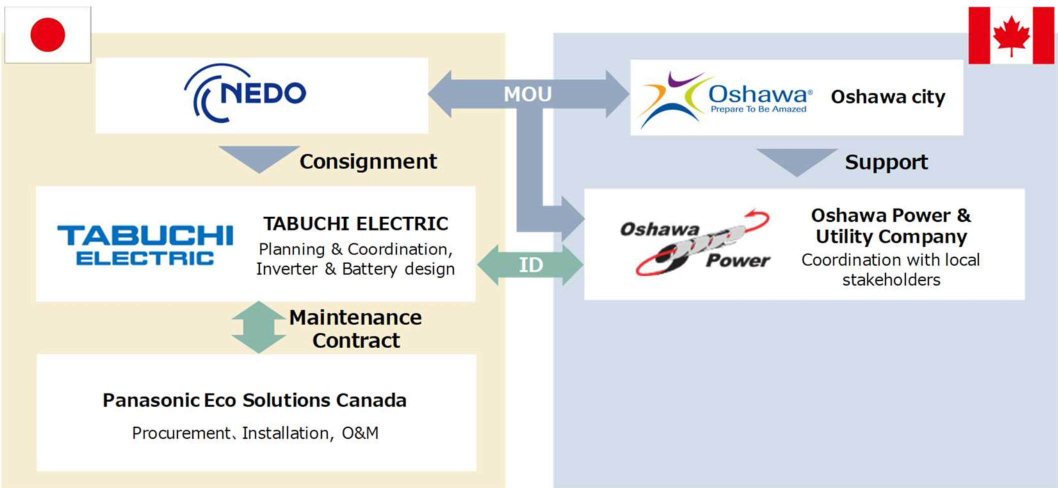

Figure 1 Demonstration stakeholders

3. Outline of the activities in this demonstration

In this demonstration, a system mainly consisting of solar panels, battery storages, and hybrid inverters was installed in 30 houses of OPUC electricity power users (Figure 2).

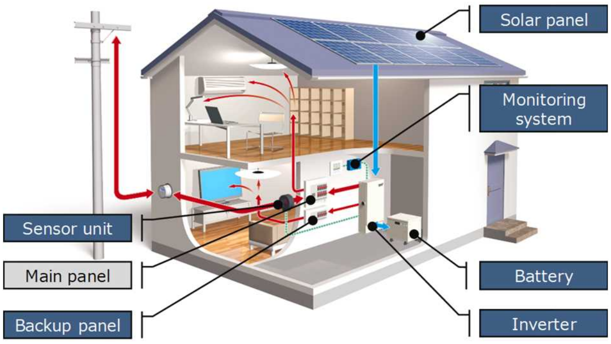

Figure 2 Demonstration system image

The demonstration was based on the following three themes.

3.1. Theme 1: Validation of the system's effectiveness.

Theme 1 aims to verify the effectiveness of system operation from two standpoint, the one is in continuous operation under normal circumstances, and the other is in stand-alone operation in the event of a power outages. During normal operation, the following three operation modes are optional for participants in the demonstration.

- Max Power Export mode (priority on bill saving)(Figure 3) : Charging with inexpensive power at night and discharging after the evening to reduce peak power consumption. Selling electricity from solar power generation is prioritized.

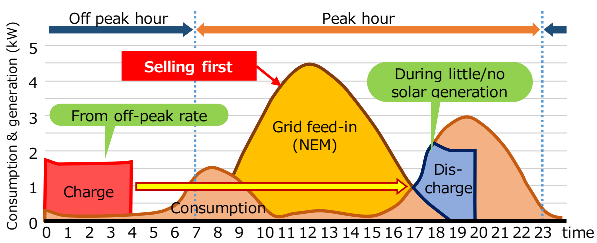

Figure 3 Operation of Max Power Export mode

- Economy mode (priority on self-consumption) (Figure 4) : Electricity is charged from solar power generation during the day and discharged in the evening or at night when solar power is not generated so as to trim the purchase of electricity.

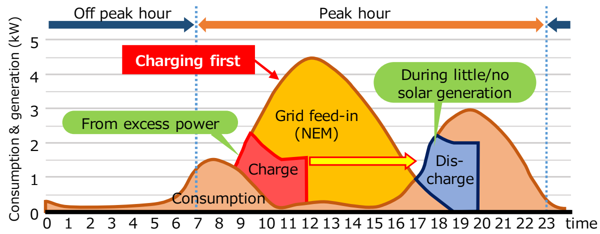

Figure 4 Operation of Economy mode

- Home Backup mode (standby for power outage) : Keep the battery fully charged in case of power outage during a disaster.

3.2. Theme 2: Central control demonstration

In theme 2, the demonstration was aimed to prove that OPUC was able to shift peak power demand and contribute to system stability by centrally controlling the battery operation (charge and discharge) of the demonstration system according to a predetermined schedule (Figure 5). In this demonstration, the operation was verified when 2 sites (2 battery storages) were centrally controlled. After this demonstration period, OPUC took the lead to centrally control 20 sites (20 battery storages).

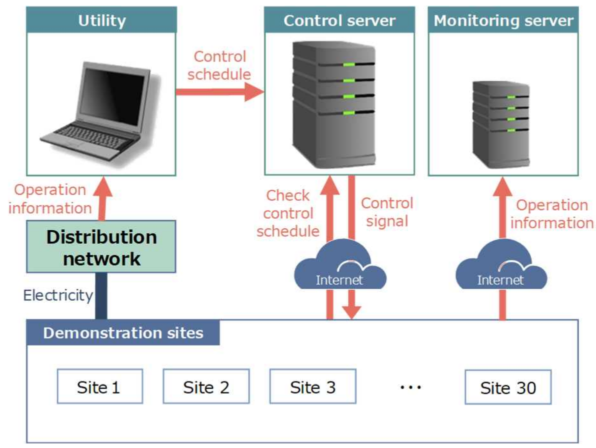

Figure 5 Central control system

3.3. Theme 3: Examination of business models

In Theme 3, business models for deployment and expansion of this system were examined in light of the situation in Oshawa City and OPUC. Since the high initial cost was a bottleneck for users, 2 types of "third-party 's ownership models" were examined, namely a lease model and a PPA model.

4. Construction of demonstration system

30 sites of participants were chosen from OPUC electricity users so that the participants were homogeneously distributed in the area.

The basic components of the demonstration system included solar panels, battery units, and hybrid inverters. PV system consists of 21 or more solar panels, depending on installation conditions such as roof size, and the average output of all the 30 sites were 6.3kW. The battery unit is manufactured by Tabuchi Electric and equipped with a lithium-ion battery cell with a rated capacity of 9.89 kWh/effective capacity of 5.93 kWh. The hybrid inverter is manufactured by Tabuchi Electric and has a rated output of 5.5 kW and can input 6.45 kW of solar panel (3 strings of 2.15 kW). The hybrid inverter also incorporates a charge/discharge circuit for a battery storage in itself, and it can control both the solar panels and the battery storage with one unit.

The solar panels and battery storage units were connected to inverter, which supplied electricity to household appliances through a power distribution board in the home (Figure 6). Surplus power from solar panels could feed into the power grid, but power charged in the battery storage could not because of Ontario grid connection requirements. This control was realized by a hybrid inverter using reverse flow prevention control, patented technology of Tabuchi Electric.

The hybrid inverter and battery storage unit were installed indoors in consideration of the constraints imposed by the Canadian Building Code and the harsh winter environment（Figure 7, Figure 8）. Since a hybrid inverter was able to control both the solar panel and the battery storage unit by itself, it also had the benefit of space-saving to install the equipment indoors.

Figure 7　Hybrid Inverter

Figure 8　Battery storage unit

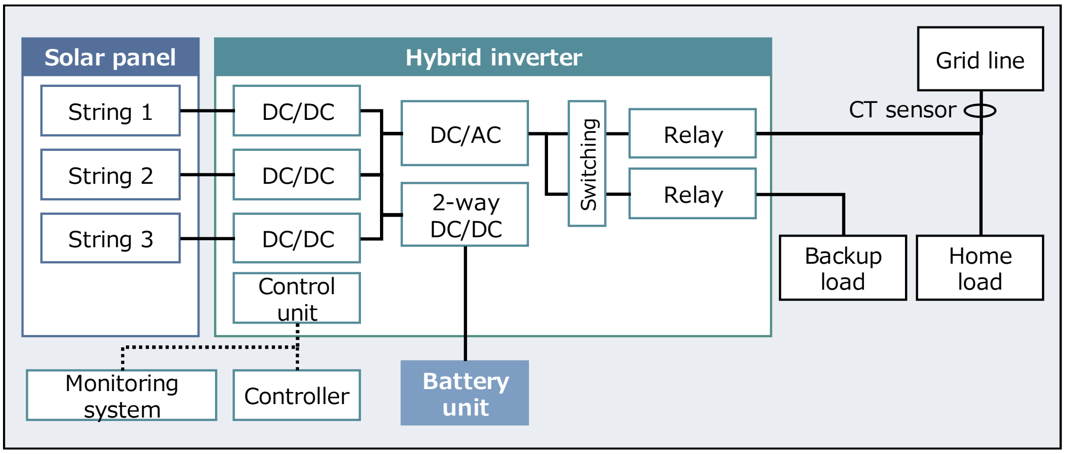

Figure 6　Demonstration system configuration

The equipment used in the stand-alone operation was selected by the users. There are many needs for heating and electric hot water tank, representing the characteristics of areas which have severe cold weather (Figure 9). However, since the specification of the stand-alone operation voltage/output is only AC120 V and up to 2 kVA, AC240 V equipment and the one with an output exceeding 2 kVA cannot be used. This problem was improved as described later in Chapter 6"Key Findings".

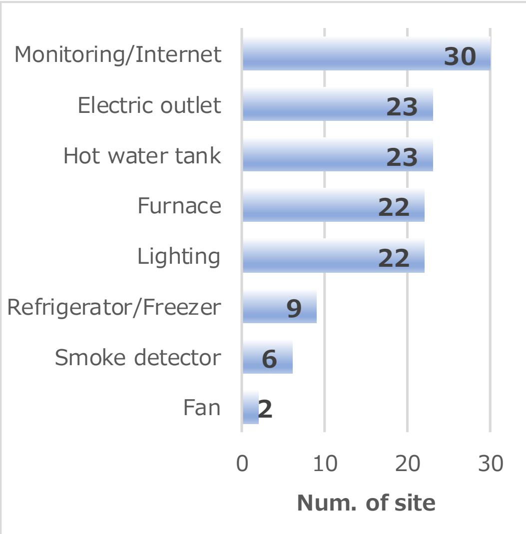

Figure 9 Selected equipment for stand-alone operation

5. Results of the demonstration

5.1. Theme 1 : Validation of the system's effectiveness

The effectiveness of the system installed in Oshawa city was verified in theme 1. Not only the verification of the system operation during power outages, but also collection of continuous operation data over a year was made, so that information leading to analysis of the system's economic benefit was obtained

First, normal operation of the system was verified. It can be confirmed that the system operates without any problem in any season including winter (Figure 10). The continuous operation data was collected for a year. The average annual power generation from solar power systems at all sites was 6.28 MWh in FY 2017. Since the CO_2 emission coefficient of Ontario at the time of the demonstration was 17.96 g CO_2/kWh, the reduction of greenhouse gases at all 30 demonstration sites was 3.39 tons of CO_2 emissions per year. In Ontario, the CO_2 emission coefficient is lower than that of Japan because nuclear power and hydroelectric power generation account for more than 80% of the total power supply.

The electricity self-consumption rate (= power generation by solar system/ power consumption) of the demonstration system was 60% per year on average at all sites. The self-consumption rate exceeded 80% from April to September and reached to highest rate 102% in May. It shows that the installed capacity of solar power generation was adequate. On the other hand, the self-consumption rate was low in winter when the solar generation was decreased. Especially in December, when generation from solar panel was low due to snow cover, the self-consumption rate was 9% (Figure 11).

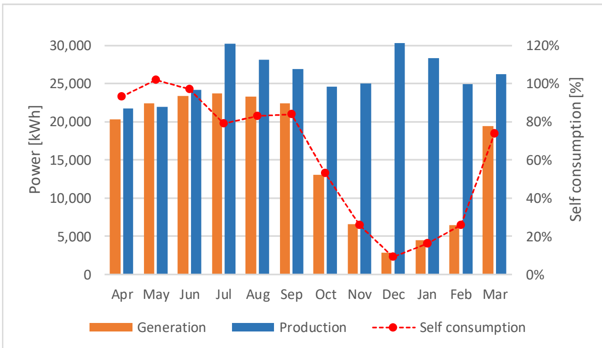

Figure 11 Self-consumption rate

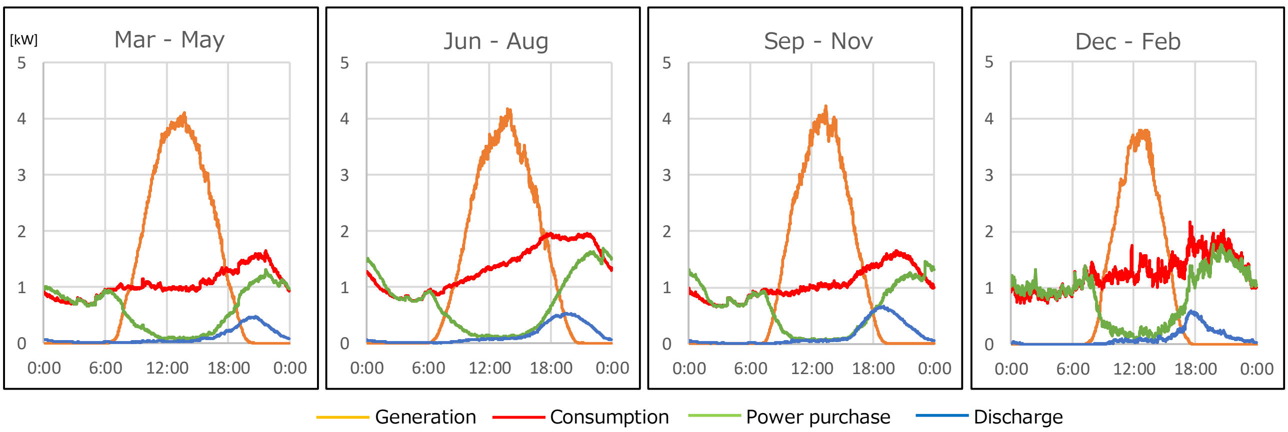

Figure 10 Operation data for each

5.1.1. Normal operation

Although operation mode can be freely set by the participants in the demonstration, 20 out of 30 participating households selected the Max Power Export mode (priority on electricity bill saving). It is clear that power storage systems as emergency power sources are valuable in the event of a disaster or power outage but having a direct effect on electricity bill saving is more attractive in daily usage for users.

The economic benefit on this system was also clarified from the continuous operation data. Users could reduce the electricity purchasing from OPUC by the volume of generation from solar panel. When converted at the electricity rate at the time of the demonstration ($0.077 CAD/kWh), this was equivalent to saving of $470 CAD/year ($1 CAD = 85 yen approx. at the rate as of February 2020). However, the savings alone was not enough to cover the cost of the system, even if 10 years of payback time was considered. Further cost reduction is required in order to spontaneously popularize the energy storage system on the premise of economic efficiency in this region.

At the same time, there are external environmental challenges, such as the electricity rate system in Ontario. Due to the constraint of the Ontario rating system, TOU (Time-of-use) rate is not applied to the consumers who utilize Net metering from solar panel. This problem hinders not only this demonstration, but also the introduction of demand response, V2X, and other innovations. It is desired this problem will be solved as soon as possible. When using TOU rate, it was estimated that an additional benefit of $150 CAD/year in energy bill could be obtained by controlling the charging at a time when the electricity rate is low and discharging at a time when the rate is high.

Although there was no problem with the operation of the system itself, there were cases that the operation stopped due to troubles caused by external factors. At four sites, small animals (squirrels) bit and damaged electrical wires from a solar panel to a house. At three sites, operations were resumed by repairing wire coverings of the cables, but at one site, a wire covering was completely bitten off, causing damage to the cable core, necessitating replacement of the solar panels (Figure 12). The latest Canadian electrical standard (Canada Electric Code: CEC), which was updated after the demonstration, requires the installation of guards on solar PV systems to protect from rodents. Similar trouble has recently occurred in Japan, and a same kind of the measure is needed.

Figure 12 Wire damage due to small animals

5.1.2. Stand-alone operation in the event of a power outage

It was also verified in this demonstration that the power storage system effectively operated during a power outage. All 30 participants experienced power outages, and the cumulative number of power outages resulted in 116 times during the period of the demonstration (Figure 13). The maximum number of power outages per site was 14 times. It is confirmed that stand-alone operation properly functioned in all these cases.

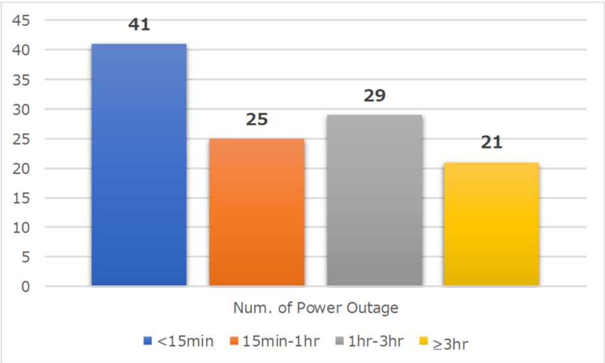

Figure 13 Power outage record

A long-time power outage occurred over a wide area in the northern part of Oshawa City due to a transformer burnout at the substation operated by OPUC on November 14, 2016. In the circumstances, the stand-alone operation functioned at the 14 participating sites for more than 3 hours to provide electricity during power outages in the demonstration. Although available equipment was limited compared with normal times, equipment such as electric water heaters and heating systems was accessible during power outages as well as normal times, and users fully benefited from the system.

5.2. Theme 2: Central control demonstration

In theme 2, the demonstration of a central control was conducted. OPUC, as an electric power company, was most interested in this activity. A control signal is sent from the control server to the remote controller of each demonstration system in accordance with the control schedule set by OPUC to remotely control the battery charging/discharging operation of the demonstration system, which is also called demand side management.

The demand-side management offers power companies a variety of benefits. Peak-shift (peak-shaving) is one of them. OPUC does not have its own power plant and purchases electricity from power producers. The demand charge (the fee according to peak demand) paid for the power producers can be reduced by promoting discharge from the battery storage during peak hours. That an investment in the transmission and distribution lines with low operation rate which are used only during peak hours can be reduced or deferred by load leveling is also one of the benefits. As the other benefit, reducing the strain on the power grid can increase the installation of renewable energy sources such as residential solar power generation. In Canada, a carbon tax set by government of Canada is applied where each province government does not introduce a carbon tax (this applies to Ontario). This carbon tax starts at $20 CAD/tCO$_2$ in 2019 and increases by $10 CAD/tCO$_2$ per year until 2022. Making an increase of renewable electricity in itself is valuable. The widespread use of distributed energy resources also effects on reducing the transmission electricity loss from a distant power plant. The demand side management is expected to play an important role to reform the electric power system in the future in terms of realizing power grid system stabilization and expansion of renewable energy introduction.

As a demonstration test, a trial to centrally control two sites was conducted. When the central control was not performed, the battery was charged during the hours of 9pm to 8am and discharged during the hours of 8am to 9pm. On the other hand, when the central control was performed, the battery controlled that the operation of "charging during the hours of 10am to 2pm, discharging during the hours of 5pm to 9pm" was performed. It is designed to solve the duck curve problem by effectively using the power from the battery storage when power consumption increases in the evening, and by charging the battery storage when solar power is generated. In the trial test, it was confirmed that the batteries operated as the setting at both sites, and the peak demand was shifted (Figure 14). The charging/discharging operation of the battery storage during the execution of the central control was controlled according to the setting by the electric power company regardless of the intention of the participants of the demonstration and the operation mode setting as described above. However, this did not affect the lives of the residents and their electricity use at all. These results suggest that it is possible to contribute to stabilizing grid power system by effectively making use of the assets (battery) set on the consumer side. That may affect the electric power system's course in the future.

After the completion of the demonstration period, OPUC took the lead in the central control demonstration at 20 sites. This demonstration indicated the performance of 0.15 MW peak shaving. If battery storages were installed at 20,000 sites for the central control, the performance of 150 MW peak shaving could be achieved.

Although the system can be controlled properly as long as the signal is received, the problem was found that the system was not able to receive the signal due to the Internet network issue. It is necessary to establish a highly reliable communication method in order to utilize the central control in the actual operation.

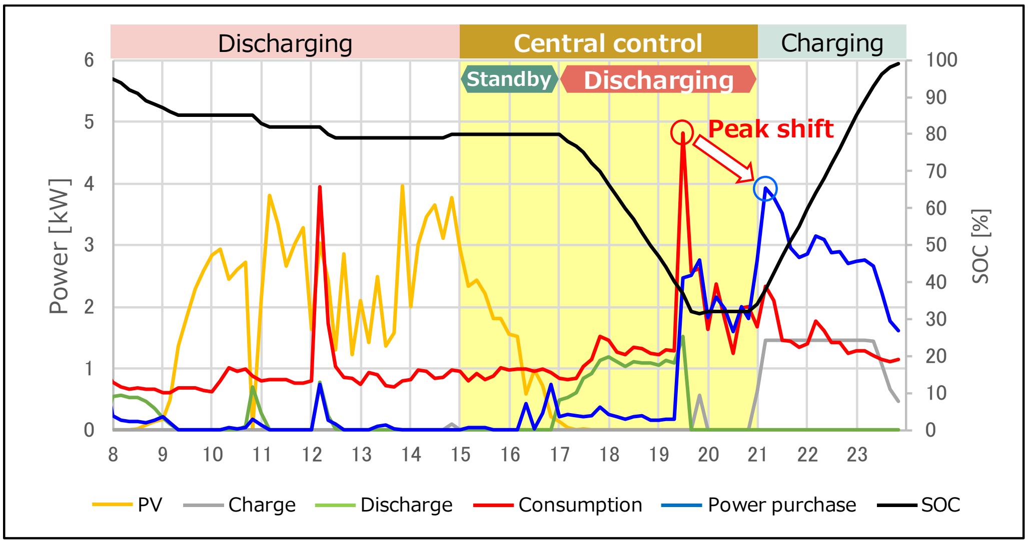

Figure 14 Operation data under the central control

5.3. Theme 3: Examination of business models

In theme 3, the "Lease" business model and the "PPA" business model, the ownership of the system was a third party, were examined as the methods for spreading and expanding the systems that had been used for the demonstration.

5.3.1. Interviews with participating users

Interview survey was conducted with the participant of the demonstration to collect information for the business model consideration. As answers of the reasonable system price, the largest number of participants responded that the energy storage system introduced in this demonstration was valued at $20,000 CAD (Figure 15). In addition to its value as an emergency power source in the event of a power outage, it is also expected to have the value of electricity bill saving by solar power generation.

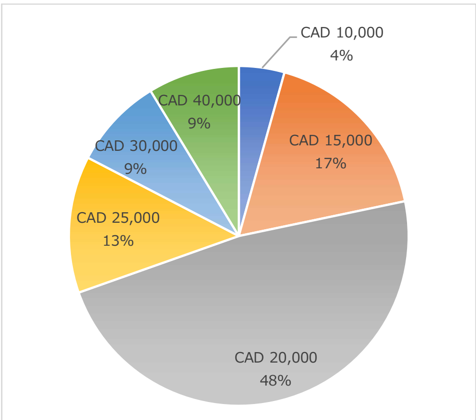

Figure 15 Reasonable system price (Interview result)

The participants' motives for the demonstration were also investigated in this interview survey, and more than 90% of the participants cited "reduction of electricity bills" as the motive, followed by "emergency power supply in case of a power outage".

5.3.2. Examination of specific business models

Although it is a valuable emergency power source for users, its high initial cost is a bottleneck to promote the spread of the system. Therefore, a business model utilizing "third-party ownership model" in which an electric power company owns a system and provides services to users was examined (Figure 16).

The first is the "Lease" business model. Electric power companies own the equipment and lease it to users in this model. The users pay the lease fee for electric utilities, instead of paying the initial cost. The users can benefit from the reduction of electricity bills and an emergency power source in the event of a power outage.

The second is the "PPA" business model. In this model, the equipment is owned by an electric power company as well as the "Lease" model. The difference from the "Lease" model is that the "PPA" model does not lend the equipment, and the electric power company keeps holding the equipment. Users can reap the basically same benefits as installing the systems by themselves by paying for the electricity bill of PPA (for solar power generation) and the backup power usage fee. On the other hand, since electric power companies technically keep owning the equipment by themselves, the cost of its installation can be depreciated, and they can obtain a CO_2 reduction effect and utilize the equipment for power grid system stabilization.

The results showed that a further reduction of initial costs such as the equipment and installation cost was indispensable for the establishing both business models on the premise that is in Oshawa City (Ontario). Although the prices of solar system and battery storage are rapidly declining worldwide, the current cost structure is not sufficient to run the business considering its value as only simple emergency power sources. However, the PPA model has the potential to establish a business model by incorporating the effects of power grid system stabilization of electricity companies into economic efficiency.

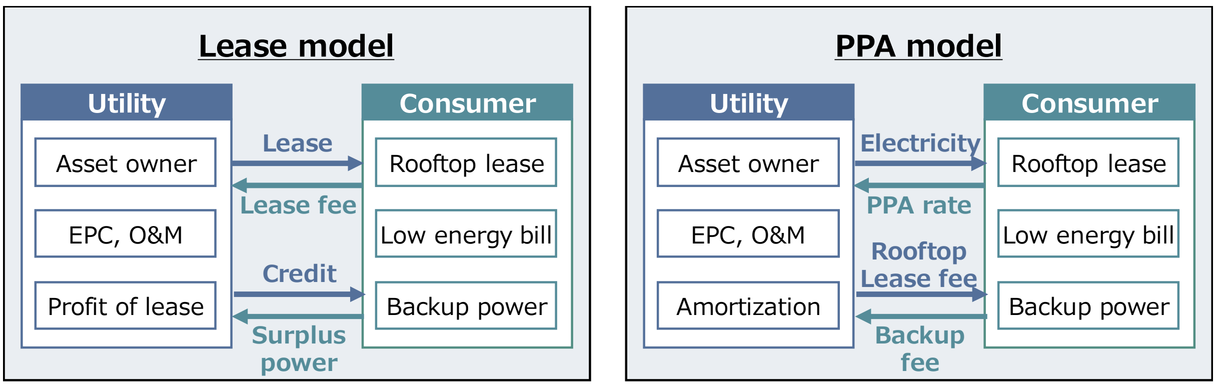

Figure 16 Business Model Overview

6. Key Findings

The important results and suggestions obtained through this demonstration project were summarized from the following three viewpoints.

[1] Value of the storage as an emergency power source
[2] Shift from consumers to prosumers
[3] Detailed support and local adaptability

[1] Value of the storage as an emergency power source

Damages caused by natural disasters is increasing worldwide due to extreme weather event triggered by global warming. In Japan, typhoons with unprecedented power frequently land in mainland Japan, causing a variety of damages, including long-term power outages, floods, and landslides. In the discussion of Japanese feed-in tariffs renewal, local use of electricity and heat in the event of a disaster is considered as the requirement of FIT application, and the importance of strengthening resilience is increasing day by day. According to Tabuchi Electric, sales of battery storages have remarkably increased in recent years, and the BCP (business continuity plan) related market will continue to thrive.

With battery storages gaining greater attention, this demonstration showed great results in clarifying the value of the storage system as an emergency power source. After more than two years of demonstration testing, participants rated the system's reasonable value at an average of $20,000 CAD. Some users valued it at $40,000 CAD. As mentioned in the section 5.1, the economic benefit of this system (estimated with $0.077 CAD/kWh electricity rating) is $470 CAD/year, so it takes 42.6 years to payback without considering the deterioration or replacement of the equipment (Figure 17). This is wildly out of line for investment in general. Nevertheless, the reason why this system was worth enough for the purchase is because it is regarded as a valuable emergency power source in the event of a power failure.

Figure 17 Initial cost and payback time

On the other hand, further cost reduction is necessary to achieve the price of $20,000 CAD. Since the equipment used was a demonstration model, it was very expensive. However, the cost reduction can be expected as products are mass-produced. And the cost of solar system and battery storage has been rapidly decreasing year by year, narrowing the gap. A recent analysis by the International Renewable Energy Agency (IRENA) estimates the initial cost of solar system in 2018 to be about $1,000-1,500 USD/kW, although this varies by country. Assuming a 6 kW of solar system, the cost is estimated to be about $8,000-12,000 CAD (converted at $1 CAD = $0.75 USD). According to U.S. research agency GTM Research, domestic power storage systems distributed in North America in 2016 cost between $1,300 and 2,000 USD/kWh. Assuming a 10 kWh of storage system, the price (excluded installation cost) is estimated to be about $17,000-27,000 CAD. Total system costs $25,000-39,000 CAD and is assumed $20,000 CAD cannot be achieved yet, but given the recent trend of sharp cost decline, it is expected that it will be achievable in the near future (Figure 18).

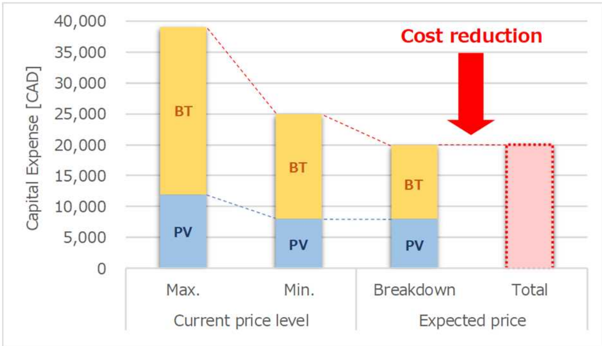

Figure 18 Current price level and expected price

Even if the cost is reduced to an acceptable level, the high initial cost can be a bottleneck for introduction of the system. It is also important to introduce the method such as the third-party ownership model verified in this demonstration.

[2] Shift from consumers to prosumer

In this demonstration, we showed the feasibility that the power storage system can contribute to grid stabilization by the central control of electric power companies. In the future, where variable renewable energy is further introduced, drastic power system transition is required to improve system flexibility, and battery storages are expected to play important roles. Demand response and demand-side management will also be utilized more and more, and it is very important to change the consumer awareness to realize the transition. Both OPUC and Oshawa City stated that one of their major achievements was to have managed to educate their residents through this demonstration.

Oshawa City attaches importance to education aspect and has partnerships with its neighboring universities in environmental education. A series of demonstration efforts were also effective to attract the attention. In addition, OPUC stated, “Option of three operation mode led the users to confirm how much electricity usage is reduced in real time, and it resulted in the major factors to change the awareness of the participant in the demonstration.” Many battery products others sell have no room for a setting or adjustment during operation. Although they are operation-free products, they do not encourage users to take voluntary actions.

Nowadays, the word “prosumer” seems to have become widespread in the energy sector. It means that electricity consumer can be a producer, who produces electricity from distributed energy resources. However, “prosumer” is not instilled in the consumers. Even if the power system transition is made, it will never work if the consumers are left behind. This is because, in places where the power system transition has been realized, active participation of the consumers in the market is a prerequisite.

This demonstration provided great opportunities for consumers to learn “how to reduce electricity usage and bills”, and to take voluntary actions. According to the survey after the demonstration, 58% of participants answered that their approach to energy use was changed. When we visited the participants in the demonstration, they said, "I will show you how much electricity I am using now" and "The monthly electricity bill was only this much", before we asked them.

In this demonstration, the consumers were able to select only the operation mode, and it may be just a beginning step as a prosumer. However, the first step is meaningful. The Plug-and-Forget style product, in which consumers do not have to do anything while limiting functions and achieving low product costs, is not necessarily incorrect in terms of pursuing the advantages of consumers. However, this does not lead to the consumers action to change their behavior on their own. There will be endless discussion about which is preferable, but the result that consumers' awareness and behaviors have been transformed is significant. It is clear that the demonstration system has advantages in encouraging consumers to become prosumers.

[3] Detailed support and local adaptability

What is the value of Japanese companies in leading these new efforts? OPUC felt the strength of Japanese companies in providing detailed support. For example, Tabuchi Electric acquired safety certification in North America to deploy this demonstration system in Canada. Some other companies have found it difficult to provide such a support. After the installation, the lack of grounding fault protection was pointed out by the local regulatory authority. Although the system modification was required, OPUC believes that it was also promptly applied.

When a product or business is developed overseas, there are always unexpected troubles. In such a situation, the ability to appropriately and promptly respond to them is critical for the success of overseas business development. Unexpected troubles are often caused by the differences in the regulations, standards and the scope of those in different countries. When expanding a business overseas, it is also necessary to thoroughly investigate these areas in advance as much as possible to avoid the problems.

In addition, customs and culture are different in foreign countries, and the same things as in Japan are not accepted. The key to success is how to accommodate local ideas and methods, and how to conform to local requirements and specifications. For example, household electricity consumption in Canada is higher (all sites average: 700-1,000kWh/month) than in Japan. Therefore, it was found that the optimized battery storage for use in Japan ran out of its capacity in Canada. There was a strong demand for heating and water heaters as the equipment for stand-alone operation during a power outage, but there was also a problem that equipment capacity was too large, and the power and voltage of the battery were insufficient under the severe winter in Canada. The capacity required by the consumers was determined based on the operational data obtained through the demonstration, and the improvement was made to double the system output by connecting two battery storages (called as “Stackable”). The available voltage was also modified from only AC120 V to AC240 V for large-capacity electrical products, as well as power systems such as pumps. OPUC evaluated that the design modification has enhanced product appeal in Canada.

These improvements have been applied to the development of new products in Japan. The battery storage unit developed based on the knowledge obtained from this demonstration is a high-capacity and high-output product with an output of 5.5 kVA and a maximum energy capacity of 14.08 kWh. In addition, AC 200 V appliances can be used with it. This is to respond to the prolonged damage caused by recent disasters, and the number of available equipment that can be used in an emergency is increased. In addition, the battery storage unit with 7.04 kWh can be flexibly stacked to 2 units according to demand and life cycle.

What is required in overseas markets is also required in domestic markets in many cases, although part of requirements may be based on regional characteristics to some extent. Companies can improve their competitiveness in the domestic market by sincerely responding to these. This demonstration is a good example of the cycle that overseas achievement lead to the enhancement of domestic products strength. We hope that the products created in this way respond to the user needs and spread widely in the market.

7. Conclusion

Thus far, we have summarized the efforts, results, and key findings from the viewpoints of verifying the operation (effectiveness) of power storage systems in areas with unstable power supply, providing power grid support under central control, and examining business models for dissemination. These results not only represent the introduction of the system but also show how valuable this demonstration was by showing the value of emergency power source, and by shifting consumer awareness which leads to a basis of power systems transition. When renewable energy and distributed energy resources explosively increase in the future, in addition to an increase in the presence of power storage systems for a growing number of disasters, their role will become more important. We hope that the power storage system will become the core of the electric power system by enhancing the added value of the storage and steadily realizing the cost reduction, not satisfied only with the results of the demonstration.

And this demonstration awarded "Honorable Mention" of ISGAN Award 2019, which is held by International Smart Grid Action Network (ISGAN) who promotes smart grid technology worldwide. This is first time for Japanese company to get ISGAN Award. Including this, great results in the dempnstoration were achieved thanks to the tremendous cooperation among relevant stakeholders. Establishing such an excellent cooperation system is critical to smoothly conduct international projects. We hope that the concerned parties in both Japan and Canada, who have successfully led the demonstration project, continue to actively introduce and benefit from these new innovations.

Lastly, Mr. Sakamoto of Tabuchi Electric, who dedicated to lead this project for three years commented on the future of their battery storage business.

Comment by Mr. Yukitaka Sakamoto

NEDO demonstration was the first opportunity for Tabuchi Electric to develop new products overseas, and that was the valuable work. The battery storages lead the current business of Tabuchi Electric, and we make use of the knowledge learned in this demonstration test by NEDO. The new product, released in February 2020, supplies emergency power sources by its increased storage capacity with AC 200 voltage without touching the home's power distribution board. We make use of the know-how acquired overseas project.

Recently, the number of disasters keeps rising around the world, and the battery storage market is rapidly growing. We are aiming for a high market share in the battery storage business

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