Recent Developments in Virtual Power Plants and Demand Response

EV and solar photovoltaic after FIT have great potential. ICT will support popularization.

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1. Introduction

Aiming to achieve the 2030 energy mix, Japan, with incentives from the Feed-in Tariff (FIT) mechanism, is increasing the penetration of power from renewable energy (“renewables”) with a major emphasis on solar photovoltaics. Although the cost of renewable power generation in Japan is still higher than in many other countries, solar photovoltaic systems for household use have reached grid parity (i.e. the cost of power generation using them is similar to the retail price of grid power).[i] Solar photovoltaics for non-household use may reach grid parity in the near future, too. However, further increasing the penetration of renewables will face more visible grid-side restrictions, which may drive up the cost of grid enhancement. Potential measures to address this issue have been discussed within the committees of the Ministry of Energy, Trade and Industry (METI) such as the Subcommittee on Mass Introduction of Renewable Energies and Next-Generation Electricity Networks. There have also been discussions on approaches to power trading based on concepts such as the capacity market, supply-demand adjustment market and indirect transmission rights, along with discussions on the scheme of efficiently using transmission networks based on “Japanese-style Connect & Manage”.

As one of the measures, the virtual power plant (VPP) and demand response (DR) may be wisely employed for improving cost-effectiveness, and this is identified by a METI committee as a next-generation approach to supply-demand adjustment. DR is already used in the event of a critical supply-demand imbalance. In one recent case, DR was used for several days from January 22 this year in the Tokyo Electric Power Company (TEPCO)s power grid area to cope with a critical supply-demand imbalance. In that case, DR is estimated to have helped save capacity equivalent to a medium-size thermal power plant, demonstrating its capability to contribute to supply-demand stability.

VPP is still in the demonstration phase in Japan, but some VPP initiatives have started on a commercial basis in Western countries. This article outlines the current situation on the use of VPP and DR in Japan and abroad, recent developments, and global examples, with a review of the literature.

2. VPP and DR

2-1 Definitions of VPP and DR

According to a document prepared for the sixth meeting of the Committee for Discussion on Energy Resource Aggregation Businesses held in September 2017, DR is defined as "changing the pattern of electricity demand by controlling demand-side energy resources (DSRs[1]) by DSR owners or by a third-party". VPP, on the other hand, is defined as "providing a function equivalent to that of a power plant by controlling distributed energy resources (DERs[2]) (including the control of reverse flows from DSRs) by DER owners or a third party" (see Figure 1).

It is generally considered that DR is a demand-side initiative and VPP is a supply-side initiative. Yet, incentive-based DR (like negawatt power trading) may be regarded as a hybrid between DR and VPP. In this article, tariff-based DR and incentive-based DR are referred to as DR while other approaches such as reverse flow control and output control are referred to as VPP.

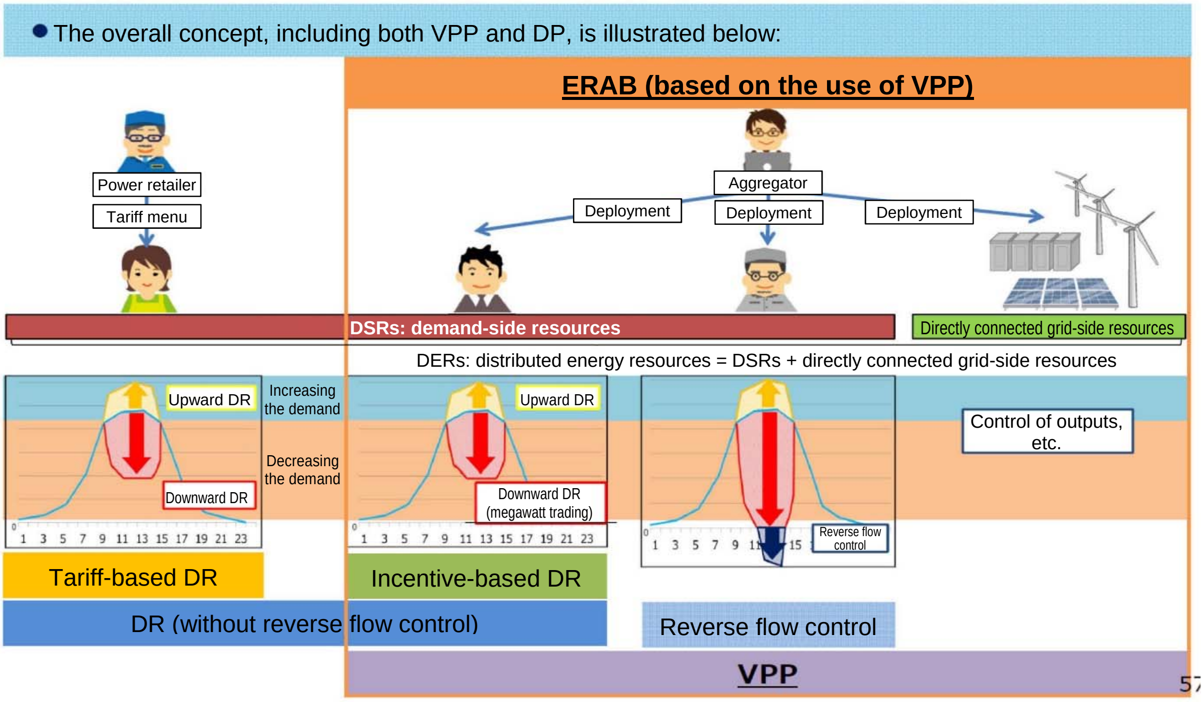


Figure 1. Distinction between VPP and DR

Source: Document prepared for the sixth meeting of the Committee for Discussion on Energy Resource Aggregation Businesses

2-2 Sizes of VPP/DR Markets in the World

In Europe where progress is being made in the deployment of renewables, the size of the

[1] The term applies to all energy resources in general (power generating devices, batteries and power consuming devices) that exist on the demand side behind the meter.

[2] The term applies to DSRs plus all the power generation and batteries connected directly to the grid.

power supply-demand adjustment market, which is equivalent to the size of the VPP and DR market, is reported to have reached 547 million euros in Germany in 2015[ii], and 565 million pounds in the United Kingdom in 2015/2016[iii] (equivalent to 70 to 90 billion yen). According to some forecasts (Figure 2), the size of the global VPP market (excluding energy storage) may reach 2.1 billion USD/year by 2025. Although this estimated market size in 2025 is not so large, the VPP markets are expected to continue growing quickly in the future in North America, Europe and Asia as the use of renewables expands. Since renewables are expected to continue growing globally after 2025, the VPP markets, helped by the falling cost of introducing renewables, may continue to grow rapidly.

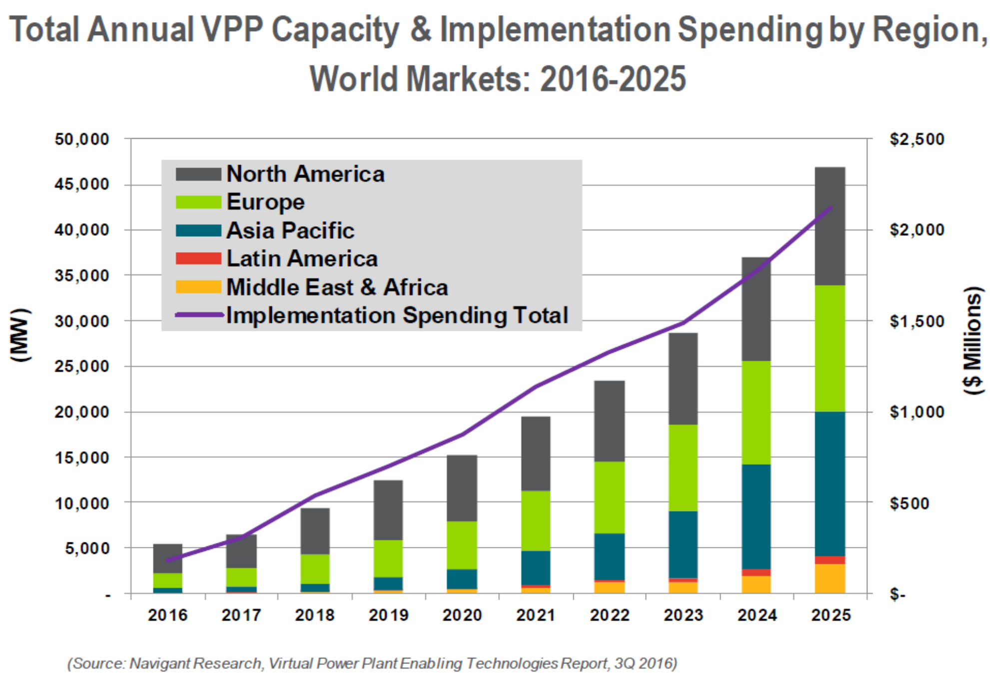


Figure 2. Example forecast on the global VPP capacity and market size

Source: Navigant Research

2-3 VPP Capacity and DR Potential in Japan

VPP and DR have the merit of enabling the power supply-demand to be adjusted at low cost using existing facilities. In public invitations for offers for power supply-demand adjustment capabilities, the average price of DR offers was more than 30 percent lower than that of power supply offers for two consecutive years (Table 1). As a result, the contracted capacity won by DR offers was more than twice as large as that by power supply offers for two consecutive years.

Table 1. Average contracted price of DR offers in public invitations for offers on power supply-

demand adjustment capabilities in FY2018

Average price

(Yen/kW)	Previous FY	Present FY	Changes
Total	4,415	4,085	−330
Power supply	6,165	5,210	−954
DR	3,753	3,661	−92

*The average price was calculated as a weighted average by the Subcommittee secretariat by dividing the total of the contracted prices of power supply offers, etc. by the total of the contracted capacities.

Offered/contracted price

	Previous FY		Present FY		Changes	
	Number of offers	Capacity (x 10MW)	Number of offers	Capacity (x 10MW)	Number of offers	Capacity (x 10MW)
Capacity acquired by public invitations for offers	−	132.7	−	132.2	−	−0.5
Offered capacity	63	165.4	55	175.4	−8	10.0
Power supply	6	54.2	7	59.3	1	5.1
DR	57	111.2	48	116.1	−9	4.9
Contracted capacity	41	132.0	46	132.2	5	0.2
Power supply	5	36.2	7	36.1	2	−0.1
DR	36	95.8	39	96.1	3	0.3
●Offers by parties other than the former general T&D operators (power generation/retail sector)						
Offered capacity	43	40.3	46	50.4	3	10.1
Contracted capacity	22	27.1	37	36.8	15	9.7

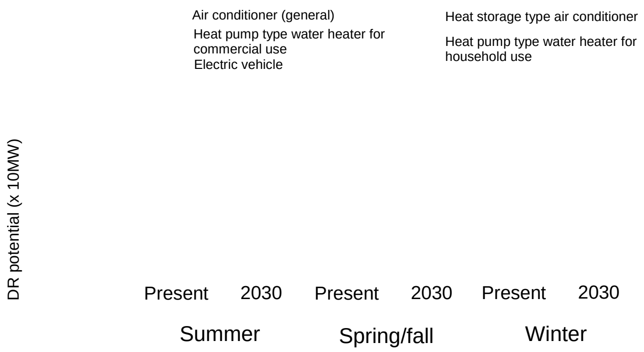
Source: Excerpted with partial editing from Document 4 prepared for the 25th meeting of the Institutional Design Expert Meeting on January 30, 2018

Source: Document prepared for the fourth meeting of the Subcommittee on Mass Introduction of Renewable Energies and Next-Generation Electricity Networks

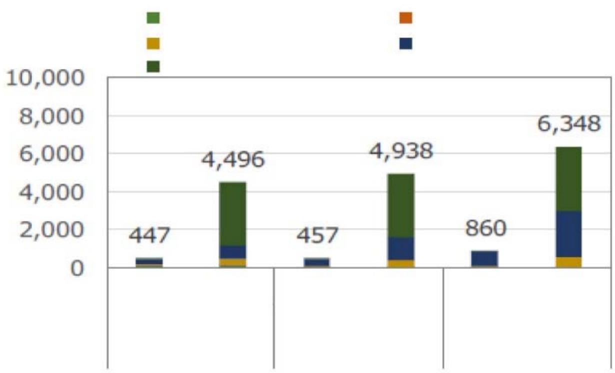
Next, let us look at the DR potential in Japan. The FY2016 Report on Consigned Researches on Mid- to Long-Term Measures for the Expanded Use of Renewable Energy published by the Ministry of the Environment identifies electric vehicles (EVs) as well as heat pump type water heaters and air conditioners for household and commercial use as highly flexible DR resources. As DR resources with less flexibility, the report identifies electric furnaces (arc furnaces), electrolytic cells, water supply and sewage systems, refrigerated warehouses, vending machines, showcases at commercial facilities, and so on. DR may be achieved by controlling the optimal combination of these resources using telecommunication technologies (such as the blockchain technology described later).

Highly flexible DR resources are expected to have the potential to reduce demand by 45 to 63 gigawatts by 2030 (Figure 3). Among the different types of highly flexible DR resources, the contribution of EVs is expected to be the greatest. Presently, the peak electricity demand is around 50 to 60 gigawatts in TEPCOs power grid area, around 160 to 170 gigawatts in Japan. In view of this, DR has huge potential and may offer very great supply-demand adjustment capabilities at low cost. Restrictions arising from the permissible duration of demand control were considered in making the estimations presented here. However, this report also gives estimations on greater demand control based on the full use of average potential.

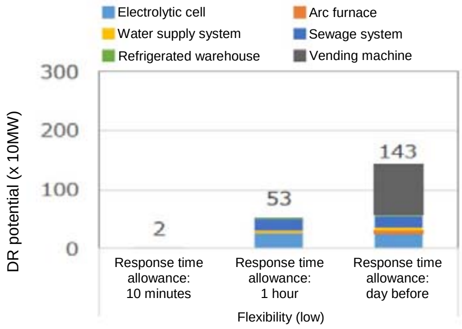
【Potential of highly flexible DR resources (from present to 2030)】



Demand control potential from demand response
(duration of demand control under consideration)



【 Potential of less flexible DR resources (at present) 】



Demand control potential from demand response
(duration of demand control under consideration)

Figure 3. Demand control potential of DR resources in Japan

Source: FY2016 Report on Consigned Researches on

Mid- to Long-Term Measures for the Expanded Use of Renewable Energy from the Ministry of the Environment

Next, let us look at the VPP potential in Japan. From the installed capacity of DERs (renewables + CHP), in-house consumption, FIT sales, etc. are subtracted to estimate the potential capacity from VPP resources (Figure 4).

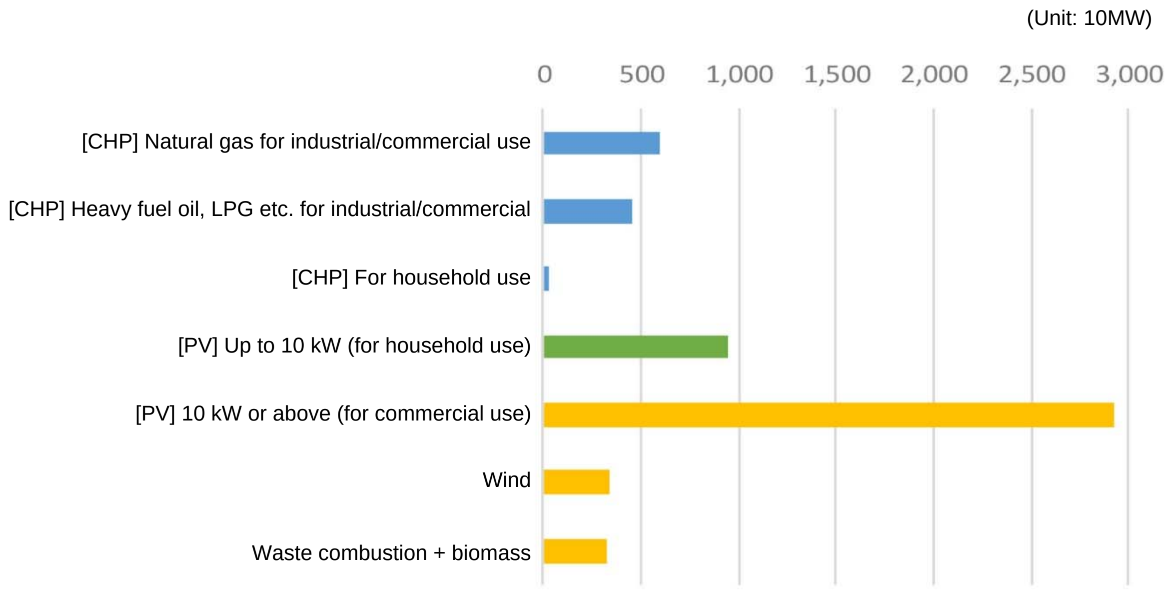


Figure 4. Cumulative installed capacity of DERs (renewables + CHP) in Japan, end of March 2017

Note: The blue bars in the chart represent capacities that are outside the scope of FIT; the green bar represents capacities covered by FIT for 10 years (gradual expiration from 2019); the yellow bars represent capacities covered by FIT for 20 years (gradual expiration from 2032).

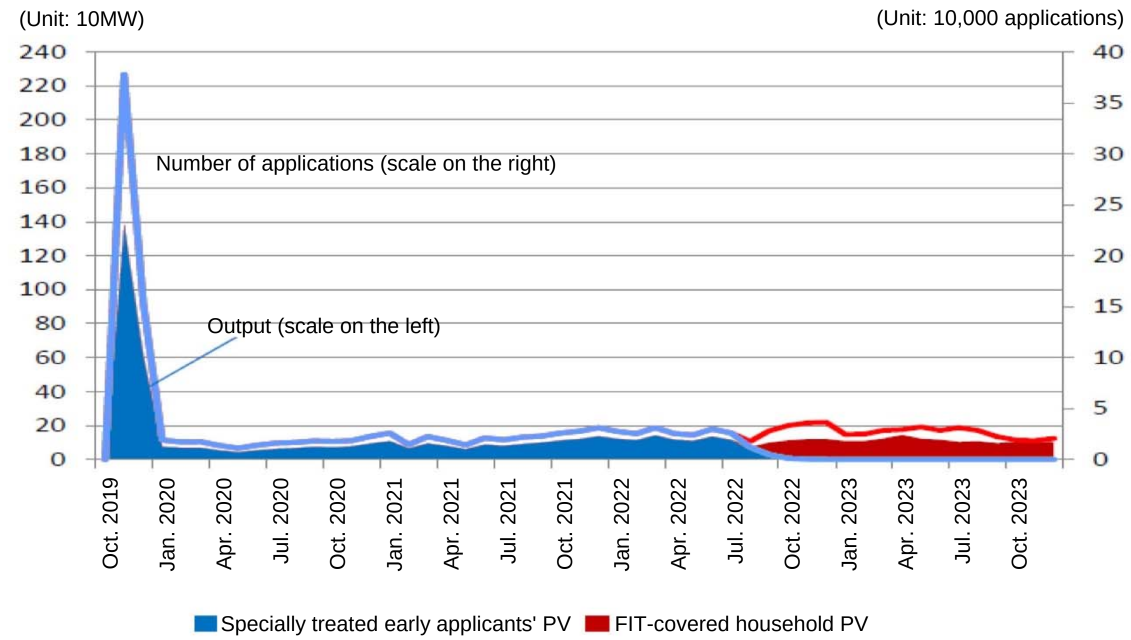
Source: Compiled by the author based on information from "CHP Deployment Report" from the Advanced Cogeneration and Energy Utilization Center, Japan, METI website, "EDMC Handbook of Japan's World Energy & Economic Statistics" from the Energy Conservation Center, Japan, etc.

Among these different types of DER, CHP and "waste combustion + biomass" require fuel, and therefore there is a marginal cost when power is generated using them. Solar photovoltaics and wind, on the other hand, theoretically can generate power without any marginal cost, and therefore, after the period covered by FIT (by which the initial cost will have been recovered), may effectively be used in the market as very competitive power sources. Solar photovoltaics for household use may begin to serve as VPP resources from around FY2019 when they begin to come out of the 10-year FIT coverage period. Wind as well as the solar photovoltaics for commercial use which are volume zone solutions, may begin to serve as VPP resources from around FY2032 when they begin to come out of the FIT coverage period of 20 years. Therefore, the full-scale deployment of VPP based on the use of existing facilities is expected to start in or after 2032 when solar photovoltaics for commercial use, which are volume zone solutions, begin to come out of the 20-year FIT coverage period one by one. However, the deployment of VPP may begin faster depending on factors such as the timing at which the generation cost achieved by newly-built renewable power generation facilities drops to the Mid- to Long-Term target (e.g. 7 yen/kWh in 2030 by solar photovoltaics for non-household use), making them more competitive than existing thermal power plants, and the speed at which the use of EV and other battery systems expands.

The installed capacity of solar photovoltaics for household use reached about 9 gigawatts at the end of March 2017. According to Figure 5, around 2 to 3 gigawatts out of this total capacity will come out of the FIT coverage period in FY2019; for several years thereafter, about a gigawatts will additionally come out of the FIT coverage period each year. Solar photovoltaics for household use, unlike those for commercial use, involve in-house consumption in principle. The scale of in-house consumption is affected by the extent to which excess power is stored using batteries (including EVs) for household use. If it is more economically reasonable to use stored power to satisfy in-house demand, then in-house consumption will increase. If the reverse is true, the power will be sold, potentially contributing to the increase of VPP resources.

While the generation capacity from renewables like mega-solar projects is distributed mostly in rural areas, about three-quarters of CHP is concentrated in the three large metropolitan areas of Japan where electricity demand is large. For a considerable time in the future, natural gas fired CHP systems in particular are likely to serve as promising VPP resources because of their moderate environmental impact and their capability to meet high-volume demand. Although CHP operation is restricted by the need to consider heat demand, CHP offers a greater degree of freedom in adjusting the power generation output compared with variable renewable energy (VRE: solar photovoltaics and wind power) the outputs from which change with natural environmental conditions. However, there is an issue with CHP that it may not always prove to be superior to conventional thermal power generation in terms of generation cost (after taking account of heat demand) depending mainly on oil prices (and associated LNG prices). Moreover, since the generation capacity of each CHP system, when launched, is generally determined in conjunction with the expected heat demand, the operation will in principle be performed within the range that permits the effective use of generated heat.

Thus, these different types of DR and VPP resources may be optimally combined, by making good use of renewables coming out of the FIT coverage period, in order to produce power supply-demand adjustment capabilities in a cost-effective manner.



*Compiled based on data on applications for subsidies to cost-sharing adjustment organization and published data on applications for facility approval. Some figures were estimated.

Figure 5. Timing of excess power purchase agreement termination and output/performance of specially treated early applicants' PVs and FIT-covered PVs

Source: Agency of Natural Resources and Energy website

2-4 Subsidies Made Available by the Japanese Government

Next, let us look at the subsidies made available by the Japanese government to support VPP demonstration projects.

Through projects launched in the five-year period from FY2016 to FY2020, Japan aims to establish VPP technologies for the control of capacity above 50,000 kilowatts and allocated budget of 4.1 billion yen for use in FY2018 (Figure 6). These subsidies are used for purposes such as supporting domestic demonstration projects described later in this article. Since VPP technologies are mostly still in the demonstration stage in Japan, these subsidies contribute greatly to VPP initiatives in the country.

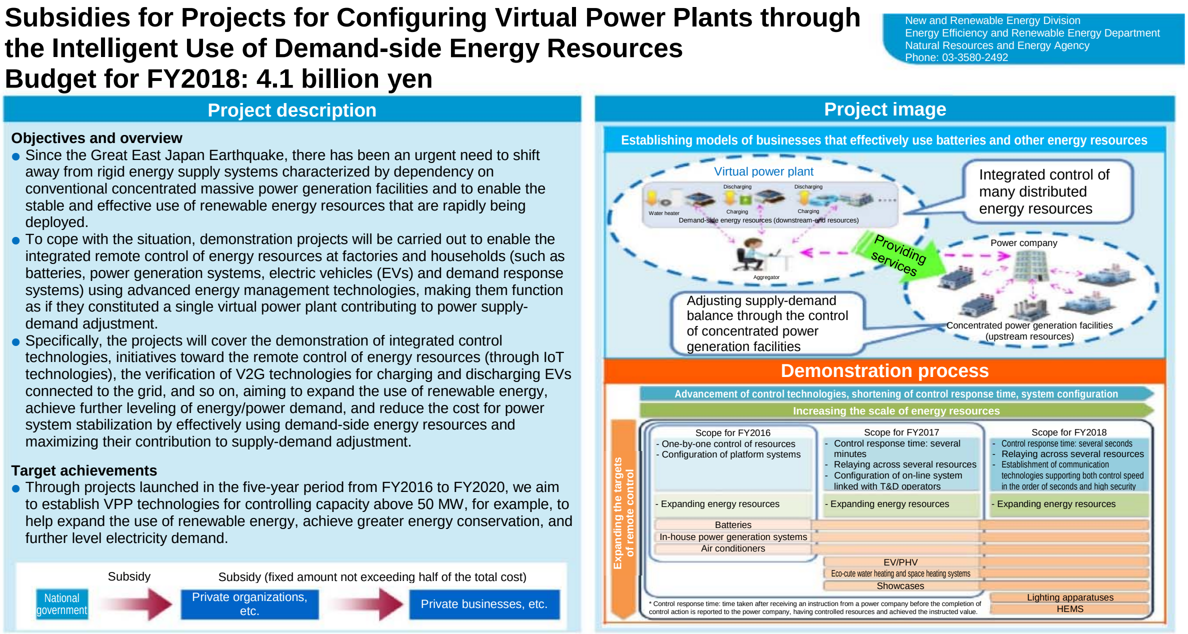


Figure 6. Subsidies for VPP in Japan

Source: Agency of Natural Resources and Energy website

3. Examples of VPP and DR Related Initiatives in Japan and Abroad

From this point on, we shall look at actual examples in Western countries and Japan. In Western countries, VPP is found to be in both the commercial utilization phase and the demonstration phase while in Japan, it is almost entirely in the demonstration phase. DR has begun to enter commercial use in Japan as in Western countries. Most of the VPP and DR resources utilized in Western countries today are owned by power consumers in industry or the commercial sector, and so most of the equipment is up to the high voltage class. Core resources are CHP and renewables in Europe, and batteries combined with DR systems in the United States.[iv] Although resources in the household sector are hardly used at present, their use may expand in the future with progress in the deployment of solar photovoltaic systems for household use.

3-1 Examples of VPP and DR Initiatives Abroad and Recent Developments in the Japanese Market

Next Kraftwerke started up business only recently after the company was established in 2009, but it has already reached the top class in Germany by scale of business in this area, recording annual sales of about 273 million euros in 2015. They earn profit by aggregating renewable energy such as PV, wind, hydro and biomass, and delivering power to power markets and reserve capacities to supply-demand adjustment markets. VPP/DR traders simultaneously take account of various market data and other data in real time to make advantageous transactions based on accurate predictions on prices, maximizing profits by selling capacities to optimally selected markets at optimal timings.[v]

Some Western companies have begun to approach the Japanese market using know-how accumulated in their businesses. In March 2018, ABB Bailey Japan, a subsidiary of ABB, a major European heavy electric machinery company, announced the full-scale entry into the VPP support business in the Japanese market.[vi] They consider that, by aggregating DERs through the use of ABB Ability Virtual Power Pools, a VPP solution, they can contribute to power system stabilization, power quality improvement and CO_2 emissions reduction. In eight European countries, the company has so far configured VPPs with a total capacity of about 4 GW and based on the know-how thus gained, it intends to penetrate the Japanese market. In addition, some other foreign companies, including that funded by Shell Technology Ventures, a group company of Royal Dutch Shell, a British/Dutch oil major, are showing interest in the VPP market in Japan.

As it is difficult to perform metering on VPP resources in Japan, foreign companies are expected to enter the Japanese market in an indirect manner for now, such as by providing Japanese companies with VPP support services leveraging the know-how gained in the markets of Western countries.

3-2 VPP and DR Initiatives Based on the Use of EVs

Since EVs are equipped with batteries, once there are a number of EVs in use, their power storage capabilities may help to build VPP and DR schemes.

(1) EV-based VPP and DR initiatives in California

According to an analysis up to 2020 conducted by California Independent System Operator (CAISO), the appearance of the "duck curve" in the State of California due to expanded use of solar photovoltaics is expected to worsen every year (see Figure 7). In the daytime, when outputs from solar photovoltaics are large, the supply-demand balance is still disturbed even after suppressing outputs from base power sources to the minimum level, increasing the need to control outputs from renewables.[3] As a countermeasure, excess power should be used to charge EV batteries in the daytime and discharged at night.

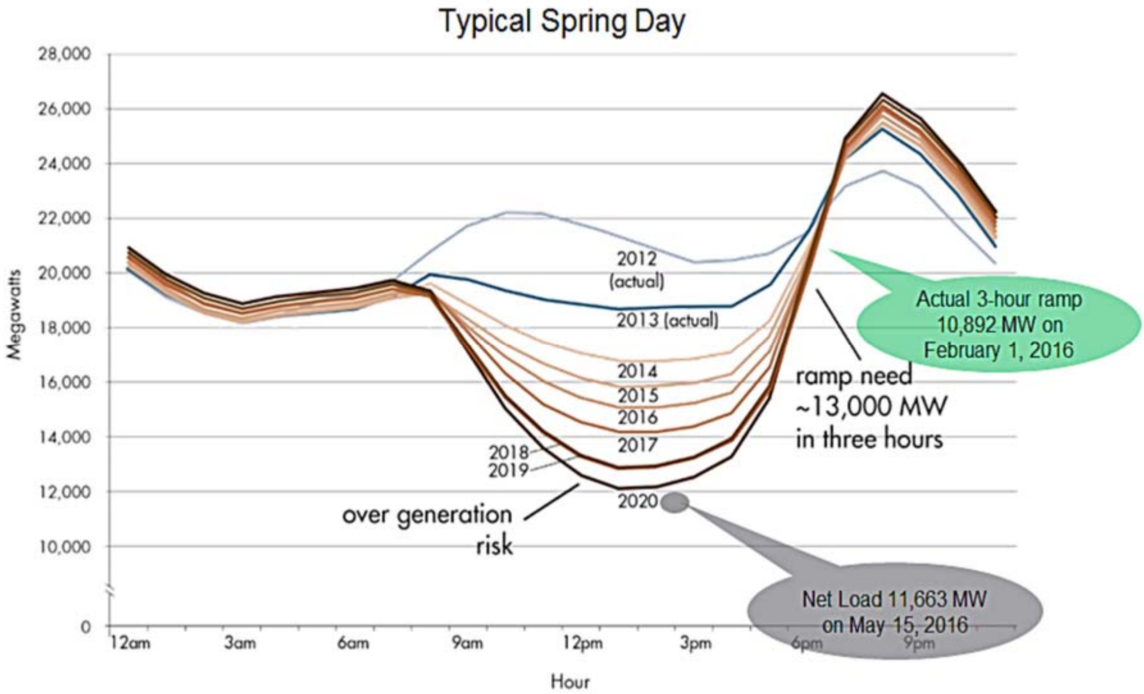


Figure 7. Changes in the shape of the duck curve with notes on predicted values

Source: CAISO, "FAST FACTS: What the duck curve tells us about managing a green grid"

State-level initiatives

The State government has announced the target of increasing the number of zero-emission vehicles (ZEVs) to 1.5 million by 2025. To achieve this target, the ZEVAction Plan was formulated in 2013 and amended in 2016, setting forth approaches to technological development,

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[3] In Japan also, a duck curve has appeared in Kyushu Electric Power Company's service area where the use of solar photovoltaics is expanding. This may happen in other areas as solar photovoltaic systems spread.

infrastructure building, consumer education, etc.[vii] EV owners are now encouraged to charge their EVs in the daytime in parking lots at offices, shopping centers, etc. Individuals seem to follow the pattern of storing excess power in the daytime using batteries at home and discharging the stored power at night.[viii] This alleviates the duck curve by reducing excess power in the daytime, permitting the sustainable expansion of solar photovoltaics.

Corporation-level initiatives

The Sacramento Municipal Utility District (SMUD) in the State of California regards charging of EVs not only as an instrument to compensate for the loss of profits resulting from the expanded use of solar photovoltaics but also as a means for load shifting and overcoming the duck curve. In the past, they drew up various scenarios for different assumptions on the number of EVs in the service areas, and studied the possibility of using them for load shifting and resolving the duck curve. As a result, they concluded that EVs might be used to counter the increase of wind power at night. However, there are concerns about the degradation of EV batteries by using EVs for power system operation. SMUD is examining the intelligent use of EV batteries jointly with automobile manufacturers.[ix]

eMotorWerks, which was established in 2010, sells EV chargers and provides platforms for battery charging services. Since 2014, they have been selling an EV charger, called Juice Box, mainly for household use and have sold more than 14,000 units already (see Figure 8). They also sell Juice Plug, which is plugged into an existing power outlet to serve as an adapter capable of controlling all commonly-used chargers, and Juice Net, which is a software-based platform. In November 2016, they carried out a demonstration experiment that involved supplying EV chargers for free to 1,000 households in California and offering rewards to program participants.[vii] Then, in October 2017, Enel acquired eMotorWerks though EnerNOC, Enel's subsidiary in the U.S. This marked Enel's entry into the U.S. EV market, one of the largest EV markets in the world.

Figure 8. Products of eMotorWerks: Juice Box (EV charger) and power outlet adapter

Source: eMotorWerks website

(2) EV-based VPP and DR Initiatives in Japan

EV-based VPP and DR initiatives are in the demonstration phase in Japan. Examples are given below:

- In January 2018, Kansai Electric Power started a VPP configuration demonstration project on the charging of EVs by remote control with Sumitomo Electric Industries, Ltd. and Nissan Motor Corporation.[x]
- In December 2017, Tokyo Electric Power Company Holdings started a demonstration project on EV-based VPP with Nissan Motor Corporation.[xi]

Chubu Electric Power is also conducting a demonstration project on EVs, which is described in the next subsection.

(3) Suggested approach for Japan

In Japan, cumulative EV sales is about 100,000 units, with about 10,000 units sold annually. At this level, it is difficult to configure any large-scale VPP or DR based on the use of EVs. When their sales quantity increases in the future, however, EVs are expected to serve as promising VPP and DR resources. Therefore, it is hoped to accumulate know-how on VPP and DR through demonstration projects, etc. Also, when Japanese car manufacturers export EVs in the future, they will surely wish to include know-how and mechanisms for configuring VPP or DR. This may profit both the car industry that may suffer falling sales as EVs have fewer parts than conventional cars and the energy industry that may suffer falling energy demand also because of the reduced number of parts.

With the expansion of solar photovoltaic power, a duck curve is expected to appear more commonly in various parts of Japan; VPP and DR may serve as an effective countermeasure. As foreign companies start entering the VPP market in Japan (as supporters of project implementation), Japanese companies are expected to establish business models through ongoing demonstration projects on EV-based VPP, etc. One possible way to speed up progress may be to take over a promising start-up company in the area of VPP and DR, like in the case of eMotorWerks.

3-3 Potential Acceleration of VPP and DR Initiatives by Blockchain Technology

The blockchain technology may accelerate the deployment of VPP and DR. While the chief feature of VPP and DR is the effective use of excess power and excess capacities by "connecting together" existing resources, the blockchain technology may reinforce this capability of "connecting together" through sharing past records.

Report from a U.S. research company

In February 2018, Frost & Sullivan, a U.S. research company, announced that the introduction of blockchain technology could transform current utilities and consumer business transaction models by enabling "a decentralized energy production model". The company identifies five opportunities for applying the blockchain in the digital grid sector:[xii]

(i) Billing platform for retail sales and net metering
(ii) Platform for direct trading between power companies and customers (P2P: peer-to-peer) [4] and renewable energy certification
(iii) International energy trading
(iv) Vehicle-to-Grid: bi-directional flow of electricity between vehicles and electricity grid
(v) Customer management

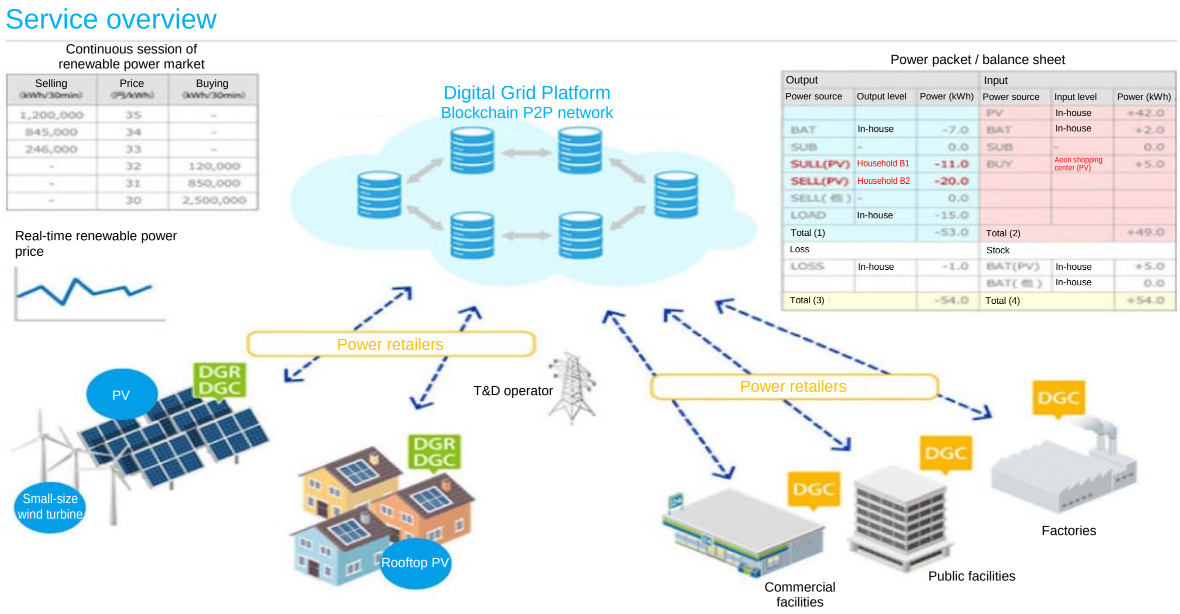
Among the above, (i), (ii) and (iv) may help accelerate VPP and DR initiatives. (i) and (ii) can be a platform business that may be used by households owning an in-house power generation system to sell excess power to households and companies that wish to buy power. For example, one possible business is to provide a blockchain platform with which all transaction details are preserved in chronological order while allowing platform users to make money through transactions. (iv) suggests the possibility of applying the blockchain technology effectively to EV-based VPP and DR initiatives like the ones launched in California.

Examples of initiatives in Japan

Energy trading using the blockchain is mostly in the demonstration phase in Japan, but recently there have been attempts at commercial utilization. Digital Grid Corporation, a company specializing in blockchain VPP and DR businesses, etc. was established in October 2017. As of March 30, 2018, the company is funded by investors such as Tokyo Gas. The company is focusing on businesses around a P2P power trading platform that processes transactions automatically by directly connecting small-to-medium level power demands, aggregated by power retailers, with power sources (Figure 9). This enables the direct trading of power among households and companies.

In addition, services for EVs are being developed. For example, one service provides EV owners with renewables-based power that is the cheapest at the given time of the day. These are examples of platform businesses enabled by the blockchain described in the report by Frost & Sullivan.

[4] The term peer-to-peer (P2P) refers to the use of a network that does not require centralized management. Here, the term refers to direct power trading between renewables-based energy producers and power consumers.



Power trading transactions are performed automatically between individual power sources and aggregated small-to-medium power demands.

Figure 9. Illustlative explanation of the power retail platform business of Digital Grid Corporation

Source: Digital Grid Corporation website

Japanese companies are accumulating know-how on the processing of energy trading using the blockchain technology:

- In March 2018, Chubu Electric Power . started with Nayuta and Infoteria a project to demonstrate technology for managing historical data concerning the charging of EVs and PHVs using the blockchain technology.[xiii]
- In July 2017, Tokyo Electric Power Company Holdings, Inc. started up a blockchain P2P platform with Innogy, a major German electric power company, to begin businesses in Germany.[xiv]
- In June 2017, ENERES Co., Ltd. started a demonstration project on blockchain DR in Fukushima Prefecture jointly with Aizu Laboratory Inc.[xv]
- In February 2018, Minna Denryoku (MINDEN) began a blockchain direct (P2P) power trading platform simulation project.[xvi]

Blockchain technology is potentially highly compatible with VPP and DR because, when combined with artificial intelligence (AI), it could perform automatic optimization while maintaining security. Japanese companies are expected to establish business models soon through demonstration projects.

However, it is difficult to imagine a quick transition in power trading toward the processing of all trading through P2P transactions managed using the blockchain and other technologies. First, we should distinguish between the *physical aspect* of power exchange and the *information aspect*, that is to say, the control of information on transactions and accounting. Regarding the *physical aspect*, even after the widespread use of DERs such as renewables and EVs (batteries), it will still be necessary to maintain generation capacities from massive thermal power plants at a certain level because of their outputs are adjustable. Hence, the transformation of conventional power networks in their entirety into distributed power networks is unlikely to take place quickly; conventional power networks will continue to be used for a long time.

Regarding the *information aspect*, it is reasonable to exchange information according to the physical exchange of power. That is to say, it is likely that power from DERs will be traded through P2P transactions, managed using the blockchain and other technologies, while the power from conventional massive thermal power plants will be traded by conventional trading systems such as wholesale power markets. Until power networks are wholly transformed into distributed networks, these two modalities of power trading are likely to coexist: P2P transactions managed using the blockchain and other technologies and trading by conventional trading systems.

4. Conclusion

As we have seen, progress is expected in the deployment of VPP and DR as a result of synergy among their constituent technologies in the areas of renewable energy, EVs (batteries) and data communication technology. The widespread use of VPP and DR, in turn, may contribute to the further deployment of renewable energy, EVs (batteries), etc. In the future, when the combination of renewable energy with batteries (EV, for example) attains storage parity, which means when the total of the generation cost and storage cost reaches parity with the power retail price, the momentum towards the commercial utilization of VPP and DR will accelerate. Then, VPP and DR will serve not only as solutions for power system restrictions but also as very cost-competitive providers of power.

VPP and DR businesses in Japan are still in their infancy, and there are diverse business opportunities. The challenge is to find how added value may be created by bringing together what kinds of services in what combinations. VPP and DR businesses permit a wide variety of combinations and there are a multitude of variables; it will be difficult for any single company to address them all. Furthermore, it will be difficult to look ahead because there are so many variables and rapidly-changing factors. It will be necessary to construct a flexible business model through the participation of multiple companies under a partnership agreement, for example, where each company handles its area of expertise.

The widespread use of VPP and DR, in the long run, may contribute to a great change in the energy supply-demand structure. A historical turning point in technology does not happen suddenly; rather, it results from accumulated technologies. For example, AI, which is currently a hot topic, results from the combination of technological developments such as the progress in data collection by the internet, the increase of data storage volumes using cloud technology, etc., the improvement in computing efficiency that speeds up the processing of collected data, and so on. Similarly, VPP and DR are expected to be achieved and become more commonly used by combining the latest technological developments such as the increasing use of renewables for addressing climate change, the resulting increase in the number of DERs, the growing popularity of energy storage systems, and the advancement of information technologies.

[References]

[i] According to an article on the use of solar PV (of less than 10 kW capacity) at households on the website of the New Energy and Industrial Technology Development Organization (NEDO), the cost of solar PV (with the use of output control device) in Japan in 2016 was 18.3 yen/kWh, which is lower than the grid power retail price for households.
[ii] The German Market for System Reserve Capacity and Balancing, September 2015
[iii] THINKING GRIDS
[iv] METI “FY2016 International Energy Usage Rationalization Project, etc. (Survey on Actual State of Virtual Power Plants in Other Countries) Report”
[v] Next Kraftwerke website
[vi] ABB Bailey Japan website
[vii] Ministry of the Environment, Japan “FY2016 Medium- and Long-Term Renewable Energy Introduction Expansion Policy Study for Realization of Low Carbon Society Survey Consignment Business Report”
[viii] “Mega Solar Business” website
[ix] Ministry of the Environment, Japan “FY2015 Medium- and Long-Term Renewable Energy Introduction Expansion Policy Study for Realization of Low Carbon Society Survey Consignment Business Report”
[x] Kansai Electric Power Co., Inc. website
[xi] Tokyo Electric Power Company Holdings, Inc. website
[xii] Frost & Sullivan “Frost & Sullivan Explores Five Different Applications for Blockchain in the US Digital Grid Sector”
[xiii] Chubu Electric Power Co., Inc. website
[xiv] Tokyo Electric Power Company Holdings website
[xv] ENERES Co., Ltd. website
[xvi] Minna Denryoku (MINDEN) website

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