VPP: New Stage in Energy Management Smart Utilization of Self-Generation Facilities with Automated DR System

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Along with the expansion of renewable energy, balancing capability for stabilizing the electricity system is required. For the utilization of consumers' self-generation facilities as this balancing capability, verification experiments and commercial transactions of demand response (DR)[*1] *have been actively carried out. Furthermore, in future domestic electricity system reform, self-generation facilities are expected to be important elements in establishing VPP (Virtual Power Plant)*[*2]*. Therefore, Mitsubishi Heavy Industries, Ltd. (MHI) has been promoting effective use of self-generation facilities targeting consumers to optimize energy supply and demand, and we developed an automated DR system so that they can be utilized as electric power for supply and demand balancing in cooperation with the electricity market. This paper presents technical results thereof.*

[*1]*: Suppression of power receiving of consumers upon request from Transmission System Department through control of electricity demand and output of their self-generation facilities.*
[*2]*: Integrated control of distributed energy resources to use them as a single power plant.*

1. Introduction

As part of domestic electricity system reform, electric power retailing was fully liberalized in 2016. Power transmission and distribution business operators started public offering of electric power for balancing supply and demand in 2017, and various verification experiments and trading of negawatt power are becoming active among power transmission and distribution business operators (manage and operate electricity system), aggregators (collect electric power suppressed by consumers), and consumers. The transmission and distribution department is planned to be legally separated in 2020, and the effective utilization of consumers' self-generation facilities in the future is expected.

Furthermore, the Japanese cabinet decision for the basic policy on the expansion of renewable energy and the decentralization of balancing capability supply and system functions in the future was made in the 5th Strategic Energy Plan.[(1)] In this plan, it is expected that as renewable energy rapidly spreads, the market value of kWh (energy quantity) will decrease, on the other hand, the market value of ⊿kW (balancing capability) for stabilizing unstable electrical network will increase, so the future supply-demand balancing market will grow.[(2)] Therefore, the importance of utilizing consumers' self-generation facilities will further increase.

In addition, there is increasing demand from consumers who want to make more effective use of their self-generation facilities with a low capacity utilization rate or large redundant power generation capacity.

Under such circumstances, as one of the menu items of the ENERGY CLOUD™ Service

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targeting the improvement of the business value of consumers, MHI supports the operation of self-generation facilities for the optimization of the energy supply and demand of consumers, and have developed an automatic DR system in response to the above market trends and consumer needs.

2. Outline of DR system

2.1 Background of DR utilization in balancing of domestic power supply and demand

DR is used to suppress the amount of electric power that consumers receive from electrical network by power transmission and distribution business operators requesting that consumers conserve electricity for a certain period of time or operate their self-generation facilities, etc., during a time period when power supply and demand becomes tight. Tightness of domestic electricity supply and demand may occur during summer days when the cooling demand is high, on winter mornings and nights when the heating demand is high or in the evening when the output of photovoltaic power generation suddenly drops.

Under the current system, power transmission and distribution business operators are responsible for constantly conforming to the supply and demand of electric power on the basis of the principle of balancing them at a certain point of time, plan the supply amount according to the amount of demand and invest in power generation facilities. However, it is predicted that if electricity procurement from the supply-demand balancing capability market is institutionalized in the future, DR implemented by effectively utilizing consumers' self-generation facilities is more economical than introducing new facilities or restarting existing facilities not in operation to deal with the peak demand of electric power, so it is expected that the utilization of DR will increase.

For consumers with self-generation facilities, it is important to examine the implementation of DR with an understanding of the following items, which are described later.

(1) DR transaction flow
(2) DR success/failure evaluation method

2.2 DR transaction flow

Figure 1 shows the DR transaction flow. An overview of DR is described below.

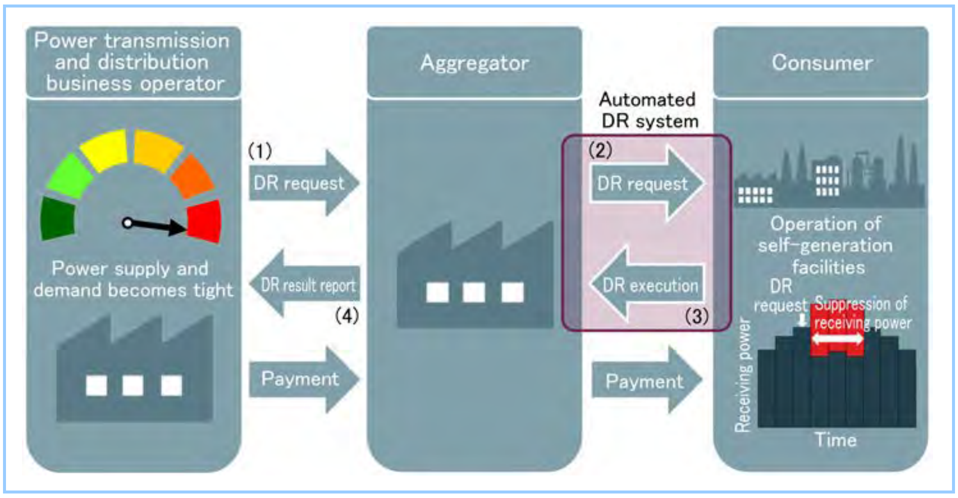

Figure 1 DR trading flow

(1) When power supply and demand is tight, the power transmission and distribution business operator makes a DR request to the aggregator.
(2) The aggregator issues a DR request to consumers.
DR requests include information such as DR start time, DR duration time, target receiving power, etc.
(3) The consumers that received the DR request suppress the amount of electric power indicated and carry out DR by operating their self-generation facilities.
Specifically, they collect information on the receiving power of the factory, the operating conditions of each engine, etc., determine the engine to be activated and the power generation output, and issue command signals to each engine.

(4) The aggregator collects the receiving power suppression amount of each consumer and reports the DR implementation results to the power transmission and distribution business operator.

In the case of the automated DR system presented in this paper, procedures (2) and (3) are performed automatically.

2.3 DR success/failure evaluation method

Figure 2 presents the DR success/failure basis concept and **Figure 3** gives a summary of balancing on the day. The power value that is a criterion for suppressing power reception is called the baseline and is calculated as follows based on the High 4 of 5 method[*3] described in the Guidelines for Trading Negawatts[(3)] issued by the Agency for Natural Resources and Energy.

(1) Calculate the average value of the difference between the actual receiving power from 5 hours before to 2 hours before the DR execution time and the baseline (without balancing on the day) obtained by the High 4 of 5 type calculation.

(2) Add the value calculated in (1) to the baseline (without balancing on the day) after the start of DR, and set this value as the final baseline (with balancing on the day).

The value obtained by subtracting the contract power suppression from the baseline (with balancing on the day) is the target receiving power.

The value obtained after subtracting the power obtained from multiplying the contract power suppression by the coefficient determined in the contract with the aggregator from the baseline (with adjustment on the day) is the criterion for the success/failure determination. If this success/failure criterion is satisfied, DR is successful.

In the case of the automated DR system described in this paper, the actual receiving power is controlled so as to follow the target receiving power.

[*3]: A method using demand data of 4 days with a high average demand amount out of the last 5 days.

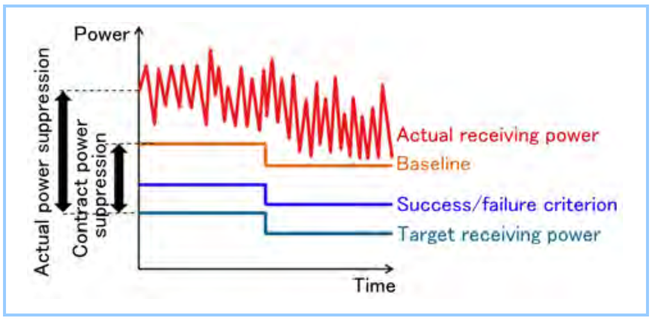

Figure 2 DR success/failure basis concept

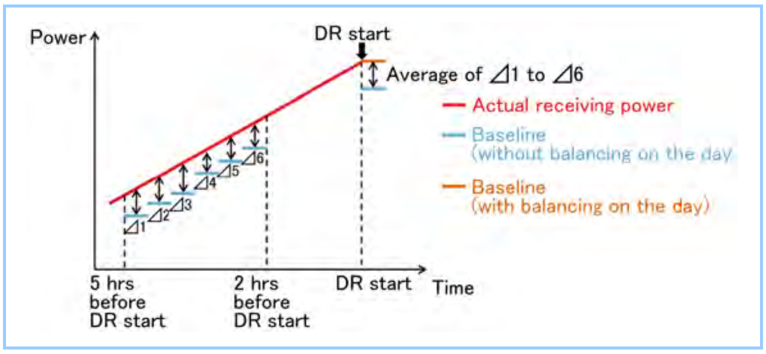

Figure 3 Summary of balancing on the day

3. Developed automated DR system

3.1 Characteristics of automated DR system

Figure 4 depicts the configuration of the automated DR system, and **Figure 5** is a photograph of its external view. The automated DR system adopts DIASYS Netmation™, which is a plant control system produced by Mitsubishi Hitachi Power Systems, Ltd. and has abundant sales results and high reliability in more than 2,000 projects.

For consumers with self-generation facilities to make DR contracts with aggregators and maximize revenue, the following items are important. The characteristics and verification experiment results thereof are described later.

(1) Automated control with high followability
(2) Short DR reaction time
(3) Reverse power flow prevention function during DR

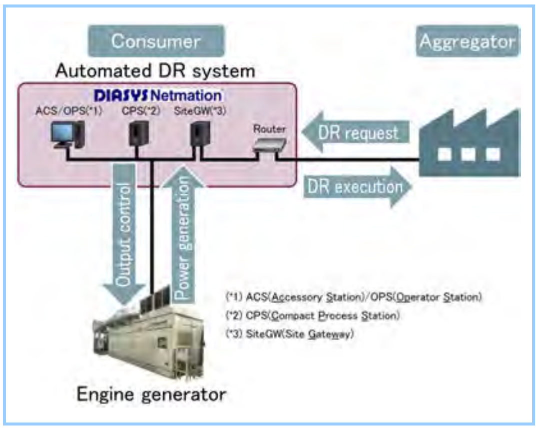

Figure 4 Configuration of automated DR system

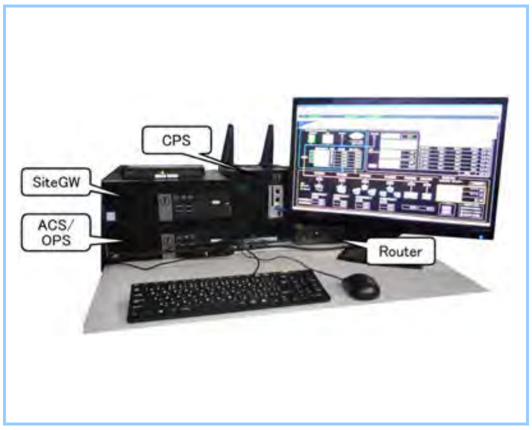

Figure 5 Photograph of external view

3.1.1 Automated control with high followability

For automated control of the DR system, the output control expertise on engine generators that Mitsubishi Heavy Industries Engine and Turbocharger, Ltd. (hereinafter MHIET), which manufactures and sells engine generators, has accumulated over the years is utilized.

When evaluating DR implementation results, the amount of electricity exceeding the contract power suppression is out of the scope of the compensation, so it is desirable to deal with DR at the minimum energy cost. For this reason, we realized automated control that always follows the receiving power with fluctuation and can achieve the standard with less excess and fewer deficiencies. **Figure 6** illustrates an image of automated control with high followability.

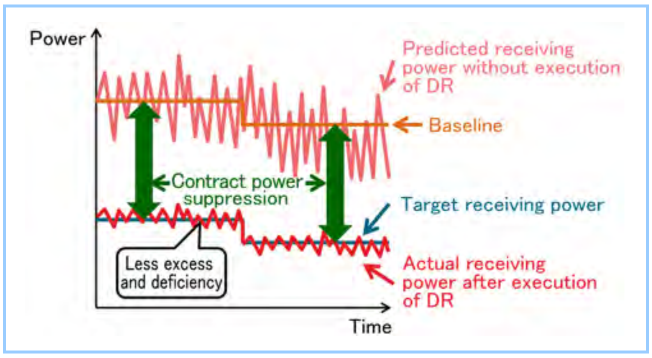

Figure 6 Image of automated control with high followability

3.1.2 Short DR reaction time

The time from a DR request to DR start is called the DR reaction time. The shorter the contracted reaction time, the higher the reward at the time of DR success. Therefore, we implemented output control in consideration of the output characteristics, startup time, etc., of the engine generator, and realized a shortened contracted reaction time. **Figure 7** shows an image of a short DR reaction time.

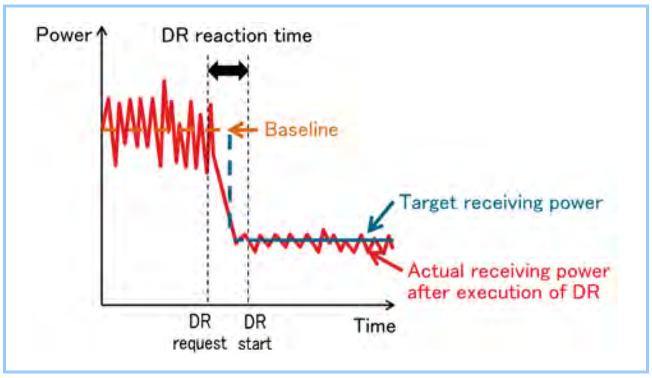

Figure 7 Image of short DR reaction time

3.1.3 Reverse power flow prevention function during DR

In cases where the receiving power suddenly drops due to the suspension of the production facility, etc., a large negative balancing on the day is added to the baseline and the calculated target receiving power may fall below zero. Based on the fact that the current DR is targeted at the negawatt balancing power amount and that some consumers have power contracts prohibiting reverse power flow, a control function to implement DR within the range where no reverse power flow occurs is adopted. When the target receiving power becomes 0 or less, reverse power flow prevention is realized by setting the substitute target receiving power and controlling the receiving power. **Figure 8** presents an image of the reverse power flow prevention function during DR.

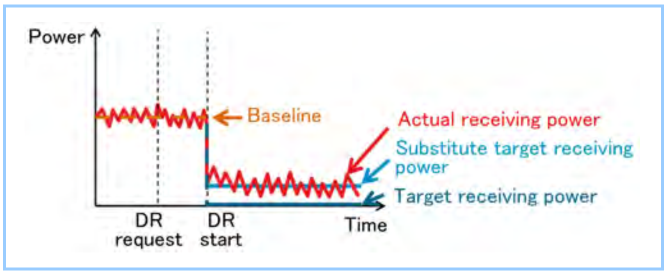

Figure 8 Image of reverse power flow prevention function during DR

3.2 Verification experiment results

The developed automated DR system was installed at our Sagamihara Machinery Works to carry out a verification experiment using engine generator in the factory.

The main items evaluated by the verification experiment are shown below.

(1) Achievement rate*4 of DR requests

(2) Followability of DR control

(3) Reverse power flow prevention function during DR

3.2.1 Evaluation results of achievement rate of DR requests

Table 1 and **Figure 9** give examples of the evaluation results of the achievement rate of DR requests issued by the aggregator during the verification experiment. The achievement rate was good in each time zone and the average receiving power was controlled near the target receiving power. Thus, an automated DR system that could respond appropriately to DR requests was realized.

Table 1 Example of evaluation results of achievement rate of DR requests

Evaluation time*5	0-30 minutes	30-60 minutes	60-90 minutes	90-120 minutes
Achievement rate	105%	105%	107%	106%

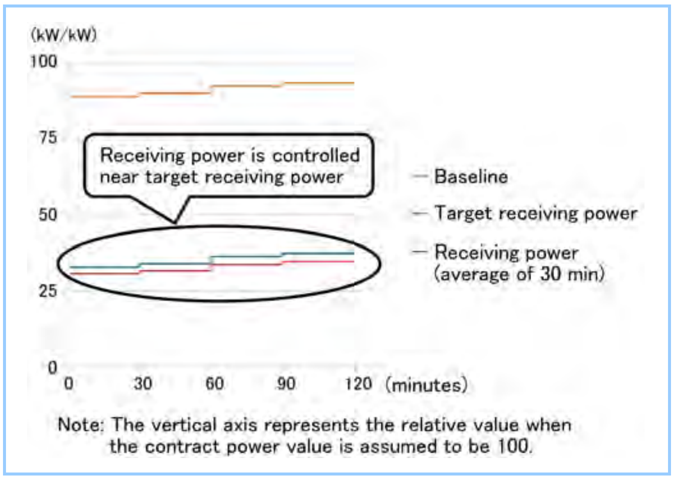

Figure 9　Example of evaluation results of achievement rate of DR requests

3.2.2　Evaluation results of followability of DR control

Figure 10 presents the power trend graphs before and after the improvement of the follow-up control, which indicate the evaluation results of the followability of the DR control. Utilizing MHIET's expertise, the followability of the receiving power to the target receiving power was improved by controlling the engine generator output at a cycle of 5 seconds.

In addition, control was carried out so that the receiving power became the target receiving power at the start of DR in consideration of the output characteristics of the engine generator.

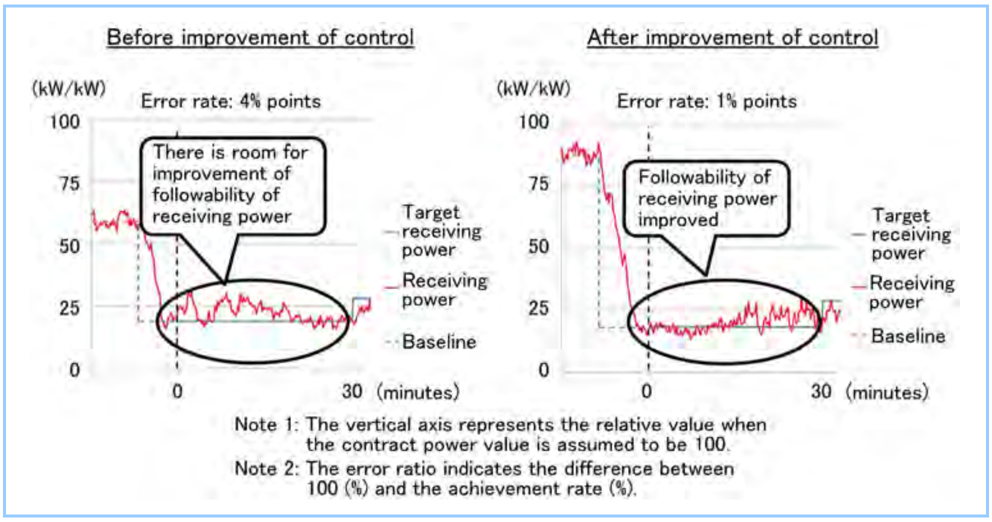

Figure 10　Power trend graphs before and after improvement of follow-up control

3.2.3　Evaluation results of reverse power flow prevention function during DR

It was indicated that even when the target receiving power is 0 or less or there is a possibility that the receiving power may fluctuate below 0 during DR, reverse power flow can be prevented by setting a substitute target receiving power as the new target value to control the receiving power. **Figure 11** depicts power trend graphs of the cases with and without the reverse power flow prevention function. Since there is no measurement data of the electric power of reverse power flow, an image thereof is added to the figure.

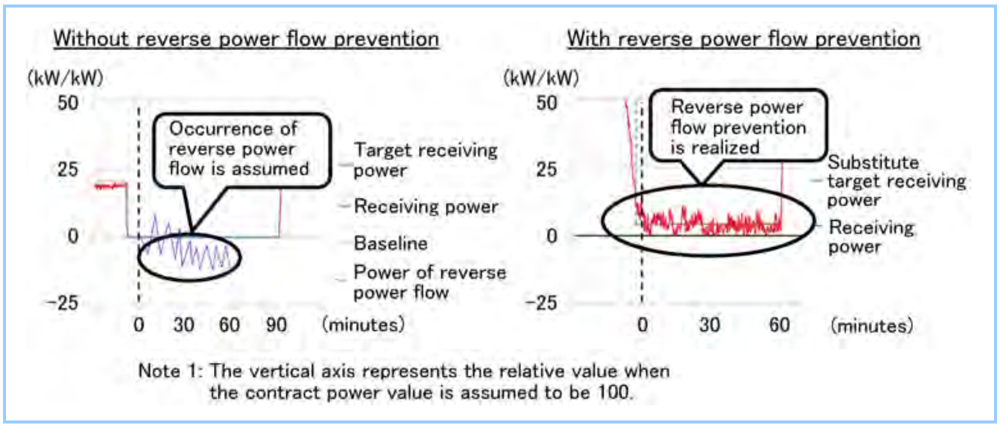

Figure 11 Power trend graphs of cases with and without reverse power flow prevention function

3.3 Development from DR to VPP

Along with the expansion of renewable energy in the future, it is anticipated that the role of DR will further increase as a balancing capability for electrical system stabilization. On the other hand, with the future separation of transmission and distribution, the establishment and operation of VPP that integrates and controls distributed energy resources to use them as a single power plant for electric power supply to the system is expected. DR is supposed to generate no reverse power flow by suppressing the electric power received from the system using self-generation facilities, etc. Also in the case of VPP where reverse power flow occurs, it is expected to effectively utilize self-generation facilities to improve economic efficiency. Therefore, we would like to make use of the developed DR technology for VPP and contribute to further the effective utilization of consumers' self-generation facilities. **Figure 12** is a conceptual diagram of VPP.

[*4]: Achievement rate = (Baseline - Receiving power) / Contract power suppression × 100 (%)

[*5]: Evaluation of the DR implementation results with the evaluation time unit set to 30 minutes.

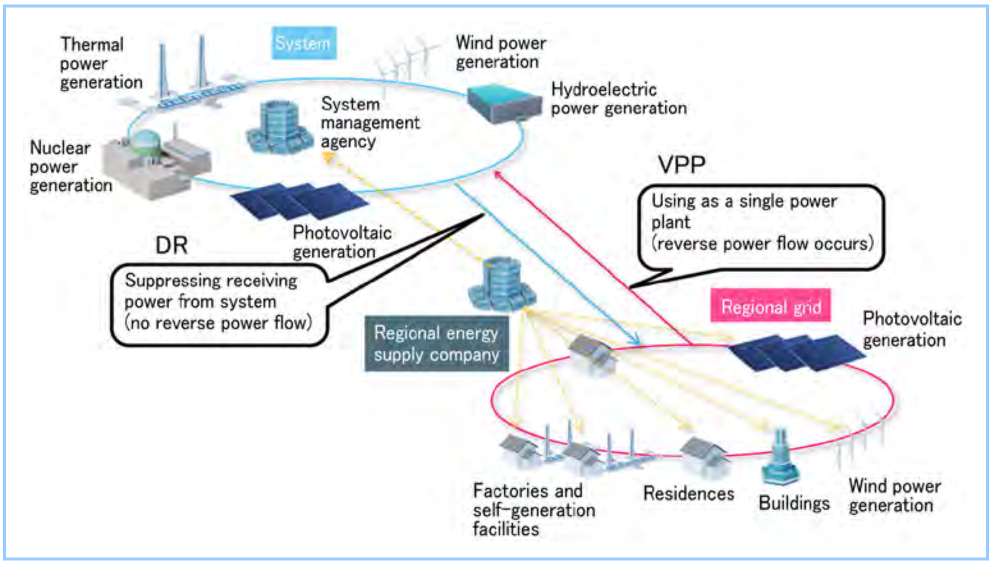

Figure 12 Conceptual diagram of VPP

4. Conclusion

We developed an automated DR system that can utilize consumers' self-generation facilities for supply and demand balancing in the electric power market. Our company aims to optimize energy demand and supply for consumers as part of the ENERGY CLOUD^{TM} Service. On the other hand, it is anticipated that the role of DR will further increase as a balancing capability for electrical system stabilization. Furthermore, self-generation facilities are expected to be an important element of future VPP. Therefore, we would like to contribute to the further effective use of self-generation facilities by using the developed automated DR system.

References

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