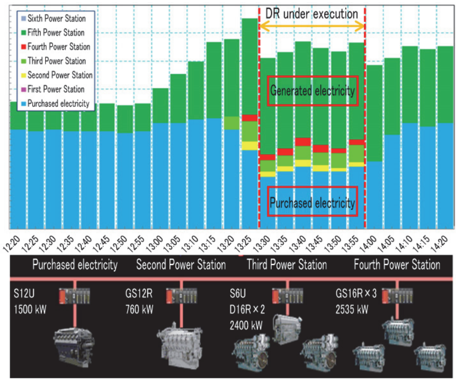
Creating New Value through Private Power Generation Systems in Domestic Power Supply and Demand Balancing Market - Approach to Demand Response at Sagamihara Machinery Works-



HIROYUKI SUZUKI*1 FUJIO EGUCHI*1
YUSUKE ISOBE*2 KEIZO KOSHIMIZU*3
OSAMU NAKAKITA*4

Private power generation systems (including CGS (Note 1)) have been introduced so far mainly for the purpose of being used in the event of a power failure or for energy cost saving such as power peak cuts in summer. However, the rise of fuel prices following the rise of crude oil prices in the Middle East has been a hindrance to the promotion of the introduction or the regular operation of private power generation systems, even while the adoption of CGS has been advanced. Therefore, Mitsubishi Heavy Industries Engine & Turbocharger, Ltd. (MHIET, our company) proposes to customers new methods for utilizing private power generation systems, that recognize the advantages in introducing them through the approaches to demand response (hereafter DR) and the open market of balancing power described below. Under the reform efforts of the domestic power transmission and distribution system, a new power supply and demand balancing market was established, and our company has also been promoting entry into the market with the aim of creating new value of private power generation systems.

1. Introduction

Under the electricity system reform efforts led by the Ministry of Economy, Trade and Industry, the electricity retail market was liberalized in 2016 and the open procurement of balancing power began in fiscal 2017. **Figure 1** shows the milestones of the electricity system reform efforts. Through these efforts, the open procurement of reserve capacities for power supply and demand balancing(Note 2) that have been exclusively dominated and managed by large electric power companies was added, and at the same time, negawatt trading(Note 3) was developed. Consequently, in addition to power generation, the reduction of power demand (hereafter, demand) is now also regarded as reserve capacity for power balancing.

There are various methods for reducing demand. Among them, DR using private power generation systems is expected to be the main power supply source with a stable and large capacity in negawatt trading. **Figure 2** depicts an overview of DR trading and demand control[1]. DR trading is generally performed among electric power companies which request DR, aggregators who serve as commanders, and consumers who execute DR. By controlling the demand in accordance with requests, electric power companies can save the cost for the maintenance and operation of facilities for reserve capacity, and they pay incentives (rewards) to aggregators and consumers in return.

*1 Engine Technology Development Department, Engine & Energy Division, Mitsubishi Heavy Industries Engine & Turbocharger, Ltd,
*2 Manager, Engine Sales Department, Engine & Energy Division, Mitsubishi Heavy Industries Engine & Turbocharger, Ltd,
*3 Production Department, Production Division, Mitsubishi Heavy Industries Engine & Turbocharger, Ltd,
*4 Deputy Director, Engine Technology Development Department, Engine & Energy Division, Mitsubishi Heavy Industries Engine & Turbocharger, Ltd,

There are three kinds of demand controls. As of 2019, Power source I'll describe later was operated by "Down ward DR." Consumers control the demand by predetermined methods such as turning off air conditioners and/or lights, the suspension of the operation of production equipment , and the operation of generators or batteries.

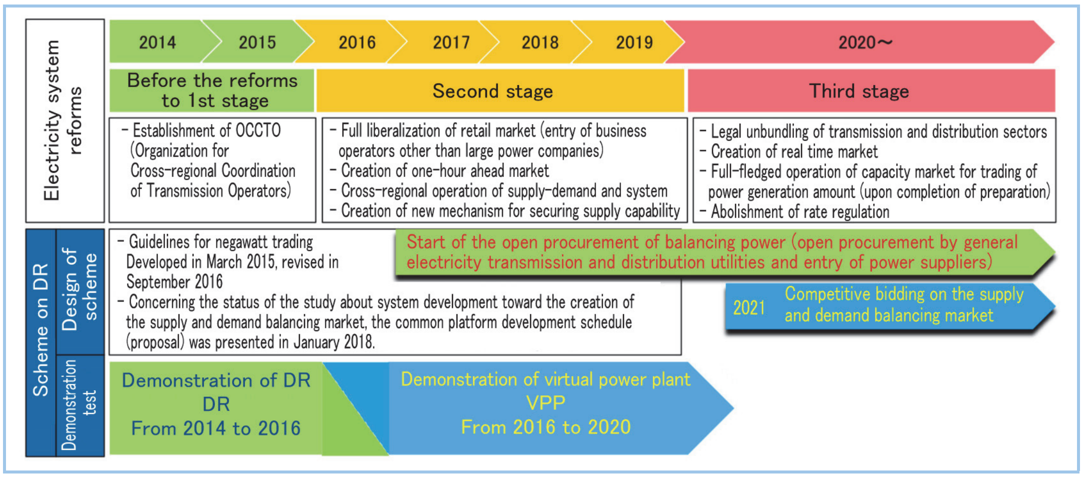


Figure 1 Milestones of electricity system reform efforts

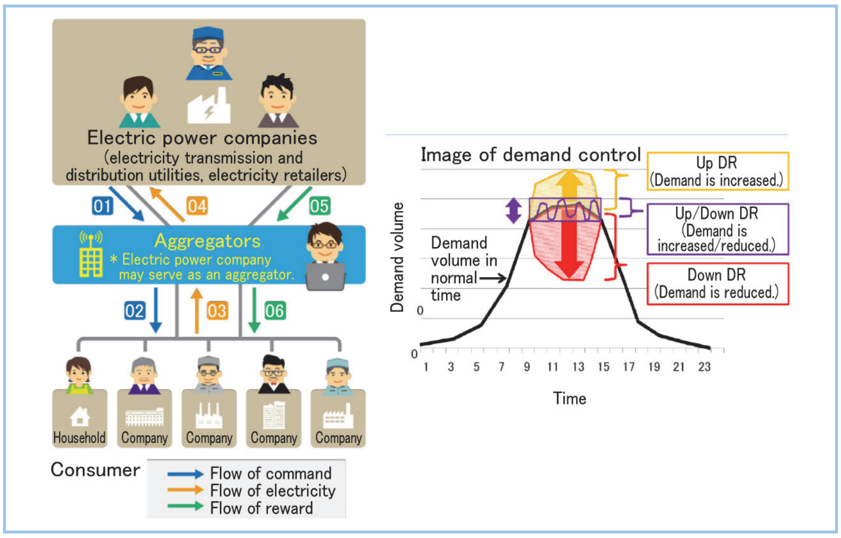


Figure 2 Image of DR trading and demand control

2. Approach to demand response at Sagamihara Machinery Works

2.1 Start of approach to DR

The Sagamihara Machinery Works experienced four times rolling blackouts and operational suspensions after the Great East Japan Earthquake in 2011. Utilizing this experience, the fifth power station with six gas engine generator sets of 1500 kW output, which were the latest model at that time, was constructed to enhance BCP(Note 4), and in 2014, the adoption of CGS in these engine generator sets was completed. **Table 1** gives the configuration of the private power generation systems in the factory. Electricity purchased from the electric power company is still used and the fifth power station in which CGS was adopted is preferentially operated to supply energy to the factory. As a result, a cost advantage has been obtained, and nine engine generators of the first to fourth power stations have been used less frequently. Coincidentally, the DR demonstration started in 2014, and our company decided to join the DR demonstration as a consumer. We were searching for new methods for utilizing the private power generation systems, and we tried utilizing them for power supply and demand balancing and obtaining incentives. This was the start of our current approach to DR.

Table 1 Configuration of private power generation systems in the plant

Name	Kind	Number of units	Automatic DR
First power station	Diesel engine	1	Available in 2017 at the earliest
Second power station	Gas engine	1	Available
	Diesel engine (for emergencies)	1	Not available
Third power station	Diesel engine	3	Available
Fourth power station	Gas engine	3	Available
Fifth power station	Gas engine (cogeneration)	6	Not available
Sixth power station	Gas engine (cogeneration)	1	Not available
Seventh power station	Gas engine, etc.	1	Not available

2.2 Steps of the demonstration

Table 2 shows the planned DR demonstration guideline for each year. In our company, conventionally, a monitoring person has been stationed full time and operated the generators so that the power generation amount does not exceed the contract power under the supply and demand contract with the electric power company.

In fiscal 2014, under the 30-minute advance notice demonstration, there was a sufficient allowance of time left, and even if a larger amount of power than planned was generated, the kWh reward was obtained. Therefore, when a request was received by telephone or e-mail, the monitoring person operated the necessary number of generators at 100% output.

Table 2 DR demonstration guideline each year

		FY2014	FY2015	FY2016	FY2017	FY2018	FY2019
DR scheme		Demonstration project			Open procurement of balancing power		
DR contract amount (%) (suppression amount/ contract amount of power supply and demand)		47.6%	35.3%	37.5%	56.3%		
Advance notice of DR command issue		30 min. before issue	30 min. before issue	10 min. before issue	30 min. before issue		
Number of commands		7 times/4 months	12 times/4 months	16 times/5 months	12 times max.		
Command transmission method	Power company → Aggregator	Phone/ e-mail	Online	Online	Phone/e-mail/on-line		
	Aggregator → Consumer	Phone/ e-mail	Online	Online	Online		
Criteria of judgment for success or failure		——	70% or higher	90 to 110%	80% or higher		90% or higher

In fiscal 2015, the scheme design was developed and the criteria of determining success or failure in demand response were set. **Figure 3** illustrates the baseline(2) and the target receiving power, and **Figure 4** provides an example of the determination of success or failure(2). "High 4 of 5," which is the average demand in 4 highest-demand days out of the last 5 weekdays, was set as the demand baseline and the amount of electric power reduced from the baseline was evaluated. As a result, even if a larger amount of power than the contract reduction amount is generated, it is hard to obtain additional incentive. In addition, as the demand itself largely fluctuates as a result of production variation, etc., at factory, the power generation amount is controlled according to the receiving power in real time. It is difficult for the monitoring person to operate power generation amounts of multiple generators at the same time. Therefore, in fiscal 2015, an automatic DR control system was implemented.

In fiscal 2016, the demonstration was conducted to meet the strict criteria, within ±10% to determine success or failure with 10 minutes advance notice. The start-up time of the gas engine generator was shortened to about 8 minutes, and the result demonstrated that the scheme was capable of quick DR and controlling the receiving power, assuming that the 30-minute balancing rule was applied.

In fiscal 2017, the public procurement of balancing power, rather than a demonstration, began, and our company made a contract for Power balancing capacity I' for extreme weather, emerging continued in 2018. We will continue to provide power balancing capacity on DR in fiscal 2019 as well.

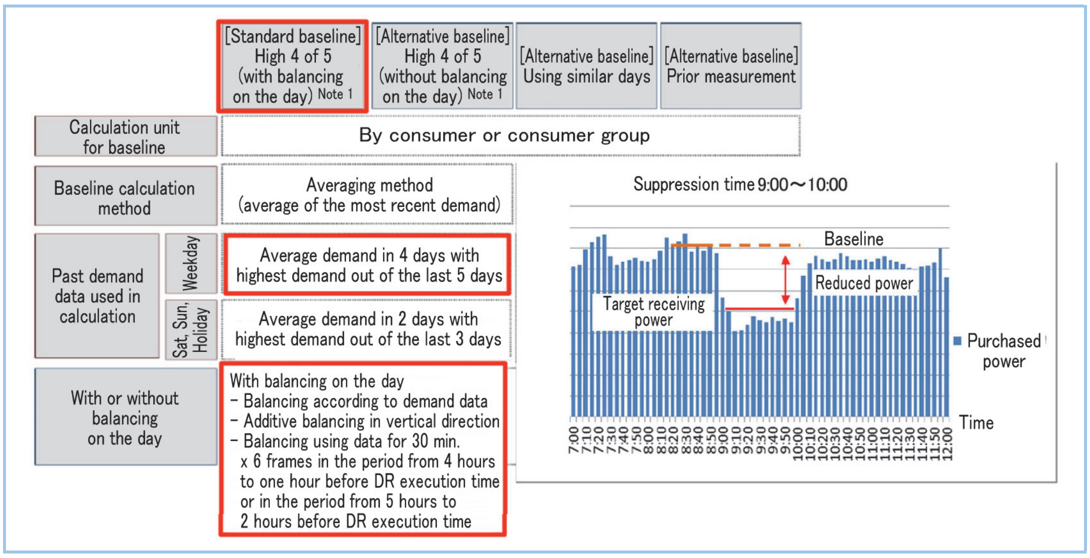


Figure 3 Baseline and target receiving power

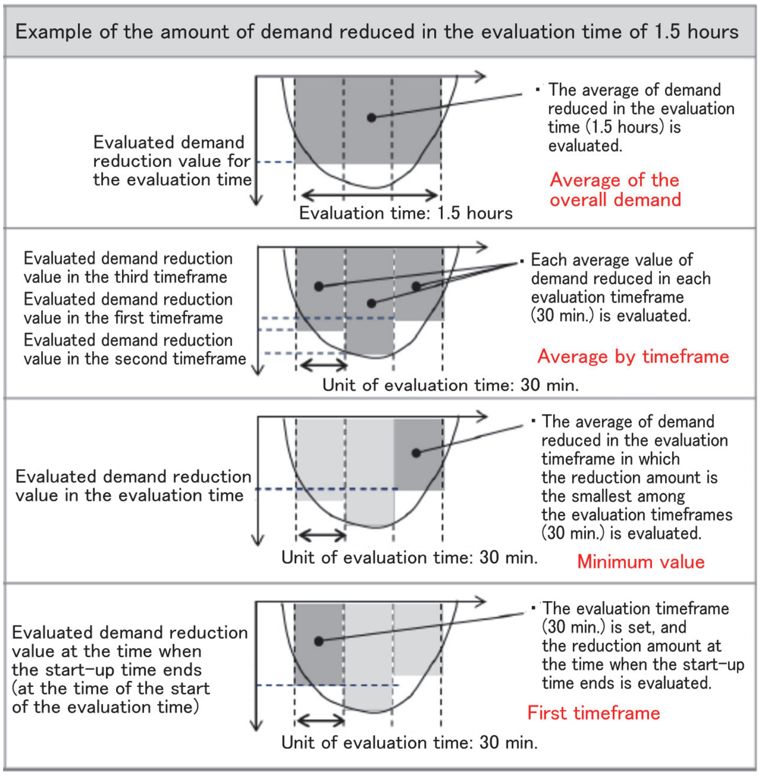


Figure 4 Example of determining success or failure

3. Automated DR system

3.1 System configuration and command transmission flow

Figure 5 is the system configuration and the command transmission flow in the DR system. The resource aggregator (hereafter, RA) and the Sagamihara Machinery Works communicate with the DR gateway which is installed in our factory, through the aggregator DRAS. When DR is ordered, the command is received concurrently. At the same time, the monitoring person is notified by e-mail or phone. The actual receiving power amount data is sent from our factory to the RA in real time to be used in the calculation of the baseline. The final determination of success or failure is made using a verified watthour meter for electricity charge settlement which was installed by the electricity transmission and distribution utility.

Table 3 lists the functions and control items of each device. The scheme of the DR system commenced in 2015, but the RA changed every year and so the system configuration has been somewhat updated. In fiscal 2015 and fiscal 2016, the RA at that time took charge of the functions of the DR gateway and DR controller, and therefore, for security reasons, the system on the RA side and the system on the factory side were separated by the PLC gateway. But it was difficult for the RA to control the engine generators in full consideration of engine characteristics. So, the DR controller was manufactured, and since fiscal 2017, the start/stop of the engine generators and the power generation amount allocation to each power station has been controlled on the factory side.

As of 2019, the system has two gateways: the DR gateway between the RA and the factory and PLC gateway between the DR controller and the engine generators.

Table 3 Functions and control items of each device

Device name	Function	Control item
DR gateway	RA-Consumer communication gateway function	
	Calculation of receiving power amount pulse	1-minute integrated receiving power amount [kW・min]
	Relay of DR control signal	Date and time of DR start, duration, target receiving power every 30 min., baseline every 30 min.
DR controller	Calculation of target power generation amount	Target value (from target receiving power and actual receiving power)
		Power generation amount feedback command
	Control of multiple power stations	Generator entry check
		Power station Calculation of power generation amount allocated
		Generator Start-up/stop command
PLC gateway	Power station data summarization and relay	
Each generator	Control of multiple units by common control panel	DR ready status
		Possible power generation amount
		(Effective) power generation amount

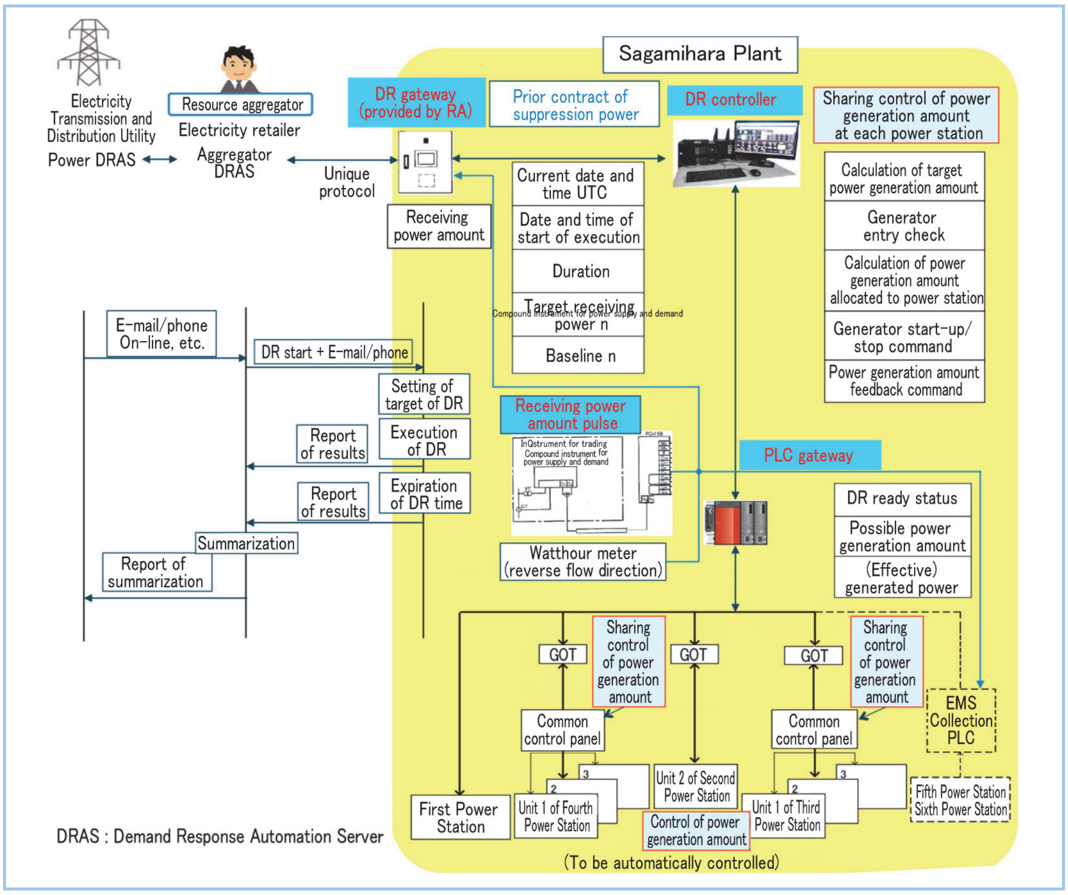


Figure 5 System configuration and command transmission flow

3.2 Allocation control of multiple power stations

Engine generators are designed and developed at the Sagamihara Machinery Works of our company. In all the power stations, the new engine generators at the time were introduced and have been used for the verification test of various issues while being operated. Therefore, the Sagamihara Machinery Works has a larger number of generators installed compared with domestic general customers. The land engine generators are tuned so that the maximum efficiency is provided at 100% rated output, and for long-term operation, 50% or higher rated output is suitable for engine combustion.

Therefore, it has been decided that when DR is executed, the number of engine generators which are started up and operated at 50% of the rated output or higher should be minimized. The first priority of operation was assigned to the first power station which can be remotely controlled only for the rated output operation or stopped, the second priority was assigned to the fourth power station which consists of four gas engine generator sets, the third priority was assigned to the second power station which has one gas engine generator sets, and the fourth priority was assigned to the third power station which consists of three diesel engine generator sets. The necessary number of generators in the order of priorities will be started up. Basically, gas engine generators are started up first, and then, if additional generators are required, diesel engine generators which can start up fast are used. The minimum number of generators is used only at the time of start-up. On the other hand, when in-factory demand is lowered, the number of engines to be stopped is minimized. This is because once the engine stop sequence is started, the load shift, synchronization parallel-off, cooling operation, etc., are performed and it takes six minutes or longer to re-start the engine. Any generator that has been started up for backup of regular demand balancing before DR is executed ,is excluded from the system.

4. Results and issues

4.1 Results of DR by public procurement of balancing power

The DR results of Power balancing capacity I' for extreme weather, contracted in the public procurement of balancing power in fiscal 2017 and fiscal 2018 are shown in **Table 4**. Power balancing capacity I' is used for DR which is executed when the supply-demand balance becomes tight in extreme weather that would only occur once every ten years.

After the public procurement of balancing power commenced, the first DR was ordered at 18:00 on January 22, 2018 and the reduction time was from 18:30 to 20:00. On this day, in the Kanto area, it snowed heavily as once in decades, and all the employees at the factory left work to go home at 15:00. Most production facilities were already switched off, so the demand was low at 16:30, which was 2 hours before the DR order, and in that situation, adjustment on the day was executed. As a result, the baseline became low. The baseline itself was lower than the contract power reduction, and the DR was determined as a failure as a matter of course. This poor result of the first DR due to the extreme weather was the chagrin of the persons concerned.

Table 4 DR results of power balancing by Generator I' for extreme weather

Fiscal 2017

RD execution date	Time	Predicted system reserve rate(3) [%] (Predicted peak time)
January 22, 2018 (Mon)	18.5-20	4.2 (18)
January 23 (Tue)	18-20	4.0 (10)
January 24 (Wed)	09-12	5.9 (19)
	17-20	
January 25 (Thu)	09-12	3.5 (19)
	17-20	
January 26 (Fri)	09-12	5.3 (19)
	17-20	
February 1 (Thu)	09-12	4.6 (18)
	17-20	
February 2 (Fri)	09-12	4.6 (10)
	17-20	
February 22 (Thu)	17-20	4.2 (19)

Fiscal 2018

RD execution date*3	Time	Predicted system reserve rate(3) [%] (Predicted peak time)
August 1, 2018 (Wed)	15-18	8.7 (15)
August 1 (Tue)	15-18	7.3 (15)
August 22 (Wed)	15-18	8.0 (15)
August 27 (Mon)	14-17	8.0 (14)

As of February 15, 2019

Figure 6 is a graph detailing the results of DR on the morning of January 25 when there was sufficient demand in the factory It shows that the purchased electricity in blue, that is, the receiving power, has been controlled well along the target value every 30 minutes. In cases where the demand in the plant is low, we enhanced the function of preventing a reverse power flow from occurring or the receiving power from falling below the minimum receiving power.

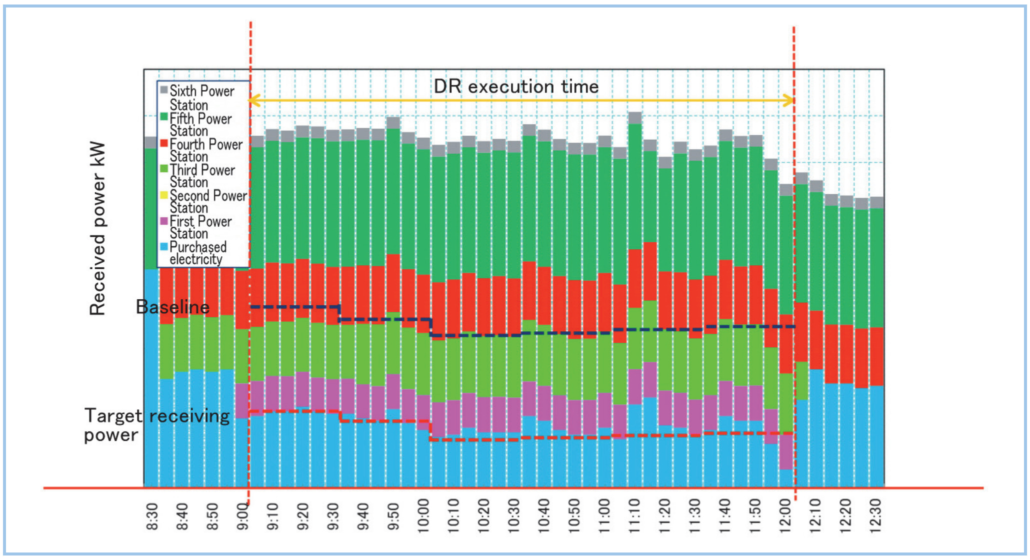


Figure 6 Results of DR on the morning of January 25, 2018

4.2 Issues in operation

The issue found in fiscal 2017 is that there was a mismatch between the contract power reduction value, set based on the factory demand in the peak time zone in summer when a tight supply-demand balance is expected, and the demand in the evening in winter. The contract power reduction should be determined based on the factory demand throughout the year. Another failure example can be seen in the DR in the summer of fiscal 2018. On a day when it was exceptionally hot, the factory demand was extremely high due to the use of air conditioners, etc., and it was necessary to operate the engine generators to keep the receiving power at the maximum power of the supply and demand contract or below. Part of the fifth power station and the sixth power station had not been operated because of maintenance and other reasons, and furthermore the operation of some engine generators for DR had been started as a backup before the DR was executed. As a result, after the DR was executed, the receiving power couldn't be reduced, even while all the operable generation systems were operated to generate electricity. Thus, in preparation for the execution of DR, the consumer needs to keep the receiving power above the contract power reduction level and below the maximum power of the supply and demand contract, with consideration for maintenance plans, weather, etc. However, if the power receiving facility can measure the reverse power (power transmission) amount and the reverse power amount is accepted as part of the power reduction in the DR system, it is not necessary to keep the receiving power at the contract power reduction level or above and the operation can be simplified. In this point, improvement of the DR system is desired.

4.3 Issue in DR system

Looking at Figure 6, we find that there is still an issue. It is especially clearly shown at the point of 11:10, where the demand in the factory fluctuates largely as depicted at the upper edge of the graph, and the receiving power is not fully reduced. The evaluation is based on the average over 30 minutes, and there is no problem in terms of the average value. But if stricter balancing power trading is started, it will be necessary to settle DR within ±10% in a short time.

4.4 Issues in providing the system to customer facilities

The aforementioned issues are from the perspective of a consumer who operates private power generation systems as power sources for power balancing.

From the perspective of a manufacturer who modifies customers' private power generation systems and provides a system that can be used in power sources for balancing power, the following issues were extracted:

(1) If the RA business operator is replaced, the communication interface between the customer side and the RA system is changed;

(2) there is a cost associated with designing a system corresponding to the system configuration

of the generator site; and

(3) modification of the engine generator should be minimized.

We are developing a DR control system for customers that can solve these issues.

5. Conclusion

Our company has improved the DR system, by accumulating operational expertise through 5 years of demonstration tests and DR for balancing power by Power balancing capacity I' at the Sagamihara Machinery Works and obtained findings for optimum proposals to customers.

On the other hand, under the electricity system reform efforts, the design of a balancing power scheme which will be used more often than Power balancing capacity I' and a demonstration with a frequency adjusting function is under development, as prescribed in the requirements for products(4) in the power supply and demand balancing market in **Table 5**. Conventionally, such a scheme was applied to large thermal power stations, pumped-storage power stations, etc., and not applied to private power generation systems such as engine generators. Going forward, we will promote customer to utilize private power generation systems as stable and large-capacity power sources in DR/VPP(Note 5) operations and plan to enter the capacity/frequency balancing market to create new value through private power generation systems ,by leveraging the strengths of our company as a manufacturer of engine power generation facilities with "engine power generation control technologies and "telecommunication technologies."

Table 5 Requirements for products in the market of power supply and demand balancing

	Primary balancing power	Secondary balancing power (1)	Secondary balancing power (2)	Tertiary balancing power (1)	Tertiary balancing power (2)
English designation	Frequency Containment Reserve (FCR)	Synchronized Frequency Restoration Reserve (S-FRR)	Frequency Restoration Reserve (FRR)	Replacement Reserve (RR)	Replacement Reserve-for FIT (RR-FIT)
Command/ control	Off-line (own-terminal control)	On-line (LFC signal)	On-line (EDC signal)	On-line (EDC signal)	On-line
Monitoring	On-line (partially, off-line available)	On-line	On-line	On-line	Dedicated line: On-line Simple command system: Off-line
Line	Dedicated line (Not required for off-line monitoring)	Dedicated line	Dedicated line	Dedicated line	Dedicated line or simple command system
Response time	Within 10 sec.	Within 5 min.	Within 5 min.	Within 15 min.	Within 45 min.
Duration	5 min or more	30 min or more	30 min or more	Product blocking time (3 hours)	Product blocking time (3 hours)
Parallel required/not required	Required	Required	Voluntarily	Voluntarily	Voluntarily
Command interval	- (own-terminal control)	0.5 to several tens of seconds	Around 1 to several minutes	Around 1 to several minutes	30 minutes
Monitoring interval	Around 1 to several seconds	0.5 to several tens of seconds	Around 1 to 5 seconds	Around 1 to 5 seconds	Not defined
Possible output amount (upper limit to bidding amount)	Output can be changed within 10 seconds (upper limit of GF range on equipment performance)	Output can be changed within 5 minutes (upper limit of LFC range on equipment performance)	Output can be changed within 5 minutes (upper limit of the range adjustable on-line)	Output can be changed within 15 minutes (upper limit of the range adjustable on-line)	Output can be changed within 45 minutes (upper limit of the range adjustable on-line (including the simple command system)
Minimum bidding amount	5MW (1 MW for off-line monitoring)	5MW	5MW	5MW	Dedicated line: 5MW Simple command system: 1MW
Increment (bidding unit)	1kW	1kW	1kW	1kW	1kW
DR category	UP/Down	UP/Down	UP/Down	UP/Down	UP/Down

To that end, in cooperation with major electric power companies and aggregators and also in coordination with the ENERGY CLOUD^{TM}[(5)(Note 6)] Service which has been promoted by the Power & Energy Solution Business Division of Power Systems of Mitsubishi Heavy Industries, Ltd., in the same corporate group,, we will not only sell system equipment alone, but also develop a DR control system with a view to offering a service business allowing RAs and customers to easily enter the power supply and demand balancing market using private power generation systems.

Note 1: Abbreviation for “cogeneration system.” CGS is a system that reuses the waste heat of an engine generator.

Note 2: Power supply or capacity required for the transmission and distribution sector of the electric company to conduct system stabilization operation in a supply area

Note 3: Trading in which the demand reduction amount (negawatt) is regarded as the amount of power to be supplied for power balancing performed by a general electricity transmission and distribution utility, and can be purchased and sold in the same way as generated electric power.

Note 4: Business Continuity Planning: Planning of methods and means for continuing business in emergencies

Note 5: Virtual Power Plant: Controlling a group of small power stations or facilities as if they were a single power station

Note 6: ENERGY CLOUD^{TM} is a registered trademark of Mitsubishi Heavy Industries, Ltd. in Japan and other countries.

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