Carbon Neutral Solutions to Increase the Value of Independent Power Generation Facility

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In recent years, as the efforts toward becoming carbon neutrality made by various industries in Japan and other countries are getting more active, there is a growing need for carbon neutrality in privately owned and operated power generation systems as well. Having domestically supplied many independent power generation facilities, Mitsubishi Heavy Industries, Ltd. (MHI) offers carbon neutral solutions for these facilities by making full use of our related technologies, products and services. In this report, we propose two carbon neutral approaches for independent power generation facilities: (1) energy balance diagnosis and improvement from a facility point of view, and (2) finding a solution to the needs (pain points) pertaining to the independent power generation facilities, for example, in relation to operators or work processes. Specific examples of these two approaches are also presented. Depending on the medium- and long-term business goals and needs of our customers, we will provide valuable carbon neutral solutions that are tailored to each independent power generation facility.

1. Introduction

In Japan, many of the factories in industries such as petrochemicals, papermaking, iron and steel-making, and cement are equipped with an independent power generation facility wherein boilers, steam turbines and gas turbines function as the major units. Such facility supplies, as a cogeneration system, electricity and heat (e.g., steam) to the production facility side. Over the years, we, the manufacturer, together with our customers (that is, the user), have worked on reducing the generation of CO_2 through improving efficiency and energy conservation by effectively utilizing waste heat, by-product fuel and such like. With recent acceleration and increase of the social demand for carbon neutrality, further reduction of CO_2 generation is required. When supplying heat to the production facility side, a large quantity of high-temperature and high-pressure heat (e.g., steam) is required in many cases. However, the means of supply are often limited to fossil fuel-fired boilers, which is the major bottleneck in the reduction of CO_2 emissions. On the other hand, from the viewpoint of the recent energy crunch and energy security awareness, people are becoming aware once again of the necessity and importance of independent power generation facilities. The importance of effectively using these facilities and achievement of carbon neutrality is thus increasing.

MHI has not only an installation record of many independent power generation facilities in Japan, but also the latest technologies, products and services, and extensive expertise in power generation and heat supply, for achievement of carbon neutrality. By making use of such technologies and expertise, we provide “Carbon neutral solutions” that help customers to achieve carbon neutrality of their independent power generation facilities.

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In this report, we propose two approaches as carbon neutral solutions. The first is “energy balance diagnosis and improvement”, which focuses on the facility itself. In an independent power generation facility, the major input factors are the fuel used and the electricity purchased, while the output is the amount of electricity generated (which is self-consumed or sold) and the amount of heat supplied (the amount of steam sent). The energy balance of this first approach refers to the overall picture indicators of a plant (charts and numerical data) including the efficiency, economy and environmental performance, and the supply ratio of electricity to heat (i.e. thermoelectric ratio) in an independent power generation facility with the aforementioned input/output factors. The second approach is to “find a solution to the needs (pain points) pertaining to the independent power generation facilities”, which focuses on the issues related to the facility operation such as the operators (manpower and passing of technical skills), work processes, and improvement of profitability (**Figure 1**).

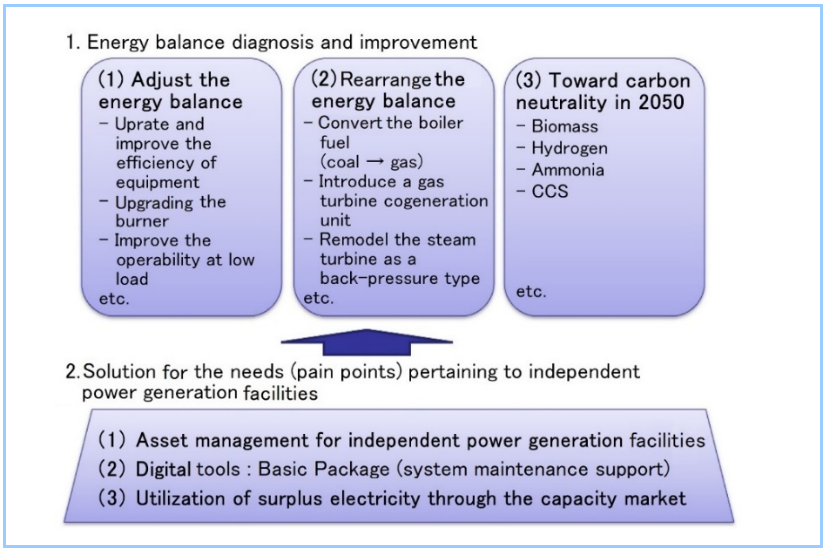

Figure 1 Overall picture of carbon neutral solutions

2. Energy balance diagnosis and improvement

As the global market environment, market needs change and the passage of years from the installation of an independent power generation facility, changes also take place in the electricity/heat demand on the facility, the operating load, required CO_2 reduction, and the applicable technologies that enable meeting these requirements. Facing such challenges, we propose the approach of “energy balance diagnosis and improvement”. This will proceed by repeatedly holding meetings with customers to understand the situation and extract the problems, followed by creating short-, medium- and long-term achievement of carbon neutrality road maps, estimating the operating cost, initial cost and the amount of CO_2 generation, and eventually making a proposal for achievement of future carbon neutrality (**Figure 2**).

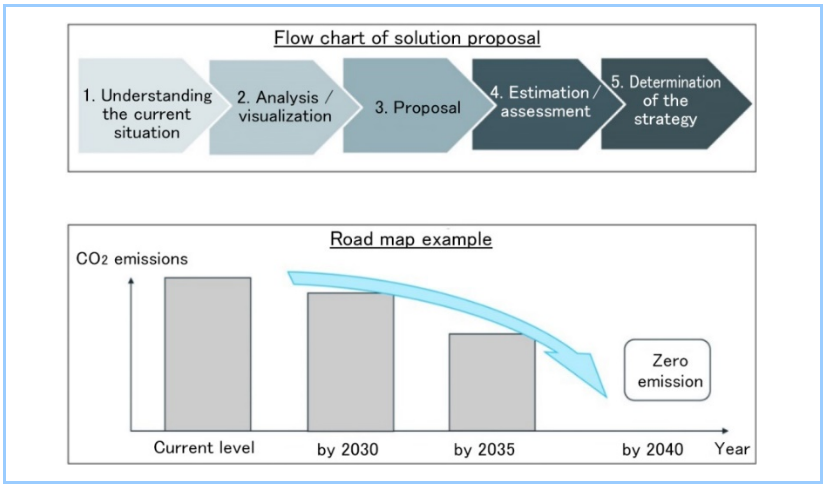

Figure 2 Flow chart of solution proposal and example of road map

2.1 Adjust the energy balance

(1) Energy balance adjustment by small-scale investment

Toward achievement of carbon neutrality of an independent power generation facility, in order to obtain the outcomes in a stable manner within a relatively short period of time with a minimum initial investment (that is, resulting in the improved efficiency and the optimized purchase/sale of electricity), the options to consider are upgrading (revamping) of equipment, and small-scale introduction of new units. Specifically, the former includes recovering performance deterioration, by aging, reviewing to suit current electricity/heat demand and uprating by means of partially applying the latest technologies. For the latter option, the recommended units to introduce are high-efficiency equipment such as a gas engine, ORC (Organic Rankine Cycle) and heat pump (**Figure 3**). The use of such equipment can be expected to contribute to ramping up the power output and energy conservation by a range of several hundred kW to several MW (for the characteristics and development status of each piece of equipment, see the relevant reports in this energy system special edition(1)). These proposals have, in contrast to those described later, the advantage of being relatively unaffected by the restrictions such as the availability of fuel or site and causing less impact on the overall thermoelectric ratio. However, there is also a possibility that these measures may only be effective for a short while. It is therefore critical to formulate measures and road maps from a comprehensive perspective with a medium-to-long time span, in order to make the investment continue to be effective with a vision toward the goal (achievement of carbon neutrality). We help customers study and plan the steps toward achievement of carbon neutrality from both short and medium-to-long perspectives.

(2) Improvement of operational efficiency and CO_2 reduction: energy management

The energy-saving measures implemented in each unit of the independent power generation facility are already at advanced levels in Japan. However, we consider that there is still room for further energy conservation, because the individual units to supply energy such as electricity and steam are handled separately. That is to say, in other words, with the overall optimization including multiple energy supply units being considered, the energy demand required for the production processes in a factory can be fulfilled in such a way as to be optimized over the course of time according to the daily fluctuations of energy demand. There is a growing need for energy management at the production site in which complicated processes are executed against a dynamically changing external environment. The use of the energy management guidance provided us makes it possible to maximize the economic effect, because it enables, for example, the load distribution among the energy supply units to be determined based on the factory’s electricity or steam demand that fluctuates daily, as well as fuel procurement and the prices for buying/selling electricity.

Let us suppose an independent power generation facility in which the units such as the boiler, gas turbine, condensing extraction turbine, and back pressure turbine are incorporated. Their rated outputs, minimum loads, and efficiencies are all different, with each using a different type of fuel such as heavy oil, coal and by-product fuel. Based on the production plan variable on a daily basis, this independent power generation facility is to supply electricity and low-, medium- and high-pressure steam to production processes that are in need of it, and, if electricity shortage occurs, electricity is purchased from the spot market. To examine which unit should be operated at what load in order to achieve the best economy, it is required to consider not only the amount of by-product fuel to be fed, and the prices for fuels or buying/selling electricity, but also the applicable range of load on each unit, and how the unit efficiency can be changed by the load applied. Finding the right answer to these questions must be difficult, unless you are an engineer with years of experience. With our energy management guidance, however, these questions can be handled in the form of mathematical expressions such as objective functions and constraint conditions for mathematical optimization algorithms, leading to the optimal solution. The obtained result is presented as the “optimal operating conditions”. The optimal load distribution is simulated considering the changing demand, fuel prices and such as the variable factors. This enables the achievement of further energy conservation and operation optimization, while minimizing the losses caused by supply and demand mismatch including the loss by steam released into the air, and the procurement cost to compensate for the shortfall of electricity.

Other actively ongoing projects in recent years are the introduction of solar power generation facilities and battery storage systems, and wheeling of electricity in which power generated by an independent power generation facility is transmitted to multiple geographically remote sites through existing distribution or transmission networks. In this case, the factors to consider for energy management become more complicated because of the additional conditions such as weather and power demand at remote sites. To handle such needs, we are accelerating our efforts to make it possible to offer the Energy Management System (EMS) enabling optimal load distribution among the independent power generation facility units in a timely manner by connecting our proprietary intelligent solution TOMONI®.

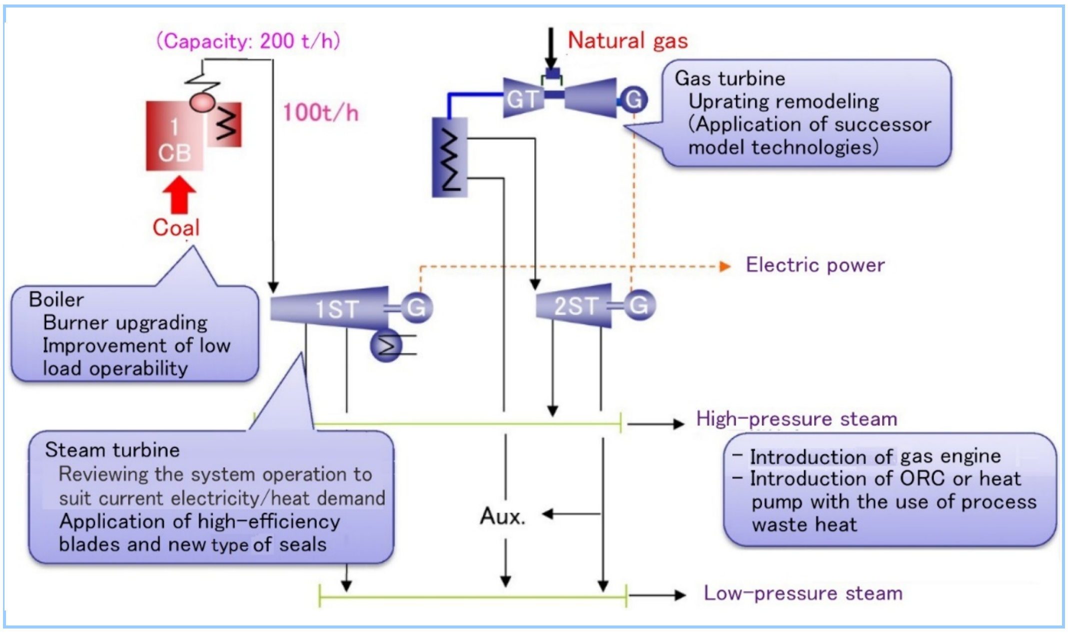

Figure 3 Example of adjusting the energy balance

2.2 Rearrange the energy balance

In order for large-scale effects (such as efficiency improvement and CO_2 reduction) to continue over a medium and long period of time (say, until 2040 or 2050) in the process of the independent power generation facility achieving carbon neutrality, the options to consider are converting the fuel type for use in the units, or addition/replacing of the main unit. For example, in the case of boilers, a coal or heavy oil-fired unit can convert its fuel to other types such as natural gas and town gas. If it is a coal-fired unit, biomass can in part or fully replace coal. If the independent power generation facility is mainly comprised of boiler units, replacing some of them by gas turbine cogeneration units is also effective. In this case, however, it is worthy of note that the resulting thermoelectric ratio of the gas turbine unit may differ considerably from the previous unit consisting of boiler and steam turbine. As the independent power generation system is basically operated to meet the heat demand (steam demand is given priority), the introduction of a gas turbine often allows more electricity to be generated than the pre-introduction level. Although the surplus can be sold, this sometimes works unfavorably from the viewpoint of system constraint or economic effect. Therefore, it is important to optimize the combination of units by considering the overall energy balance. **Figure 4** shows a successful example in terms of the following two outcomes: the CO_2 reducing effect by converting the fuel type in use for the boiler and introducing a gas turbine cogeneration unit, and the thermoelectric ratio remaining the same at a low cost by remodeling the condensing steam turbine into the back-pressure type (old foundation structures and casing are used as they are). Furthermore, the reduction in the heat loss due to condensation enhances the overall efficiency, thereby improving the economy as well as realizing further CO_2 reduction.

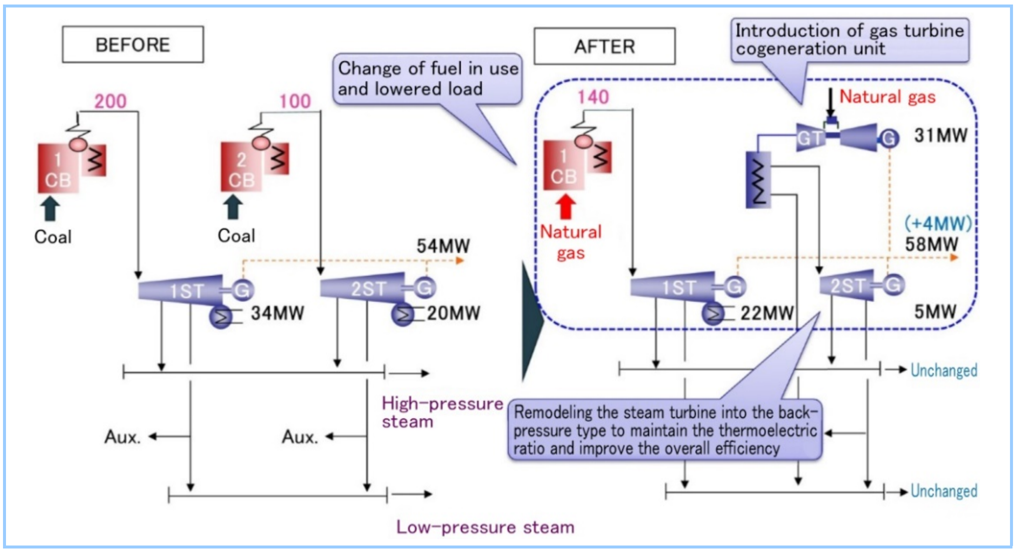

Figure 4 Example of rearranging the energy balance

2.3 Toward achievement of carbon neutrality in 2050

Toward realizing achievement of carbon neutrality, MHI is diligently developing technologies that enable achievement of carbon neutrality of the equipment such as the boiler, gas turbine and gas engine (which means to make it possible to switch to carbon neutral fuel in the future). Although there are some issues in terms of the availability of carbon neutral fuel such as hydrogen and ammonia (procurable quantity, security, price, etc.), our proposals are tailored to each of the independent power generation facilities of our customers based on their medium- and long-term goals, future fuel procurement preference (affinity with their main businesses) and such (**Figure 5**).

Given the uncertainty regarding future trends in the development of carbon neutral fuel infrastructure and energy policies among others, it is necessary to make facility investment while keeping the options open. We are therefore developing a gas turbine that will be adaptable to firing of either hydrogen or ammonia. Another possibility is the addition of MHI Group's CO_2 capture equipment to the independent power generation facility, with the expectation that CO_2 capture and storage and its application technologies will become more common. In addition to achieving carbon neutral fuel for independent power generation facility, the CO_2 capture equipment is added, the facility itself becomes carbon negative. This can be an effective measure toward achieving carbon neutrality by 2050, extensively including the customer's process side (main business). (For the development status of each piece of equipment, see the relevant reports in this energy system special edition(1)).

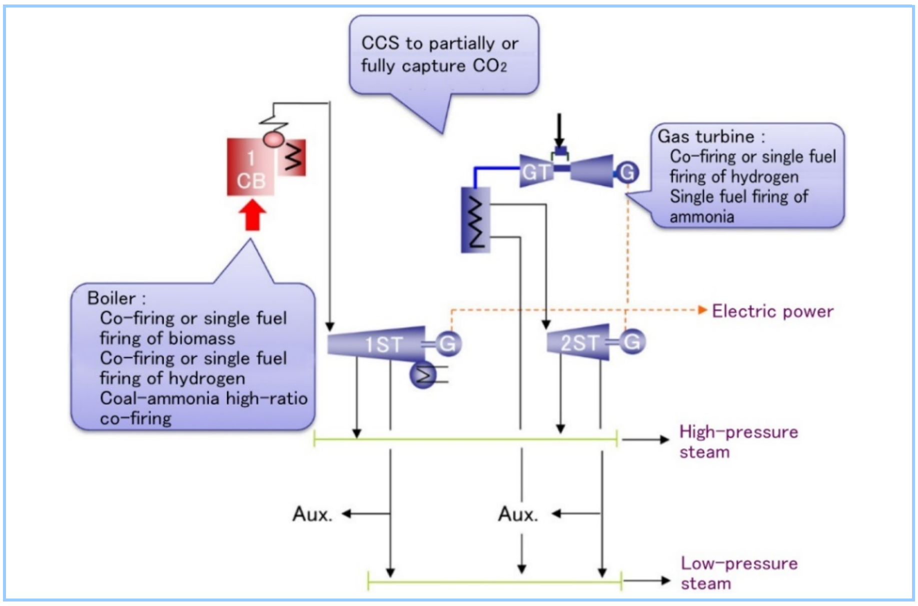

Figure 5 Example measures to achieve carbon neutrality

3. Solution for the needs (pain points) pertaining to independent power generation facilities

In achieving the optimization or carbon neutrality of independent power generation facilities, there are also various challenges in addition to the aforementioned facility improvement.

For example, some customers need to start with the “visualization” of current operation status, because the balance between supply and demand for energy (electricity or heat/steam) as a utility is not clear. In others, the project has been brought to a standstill because of the shortage of project personnel and financial resources, despite the need to examine and find a solution to the problem. To solve these pain points, we believe that the key lies in our ability to find a fine-tuned solution for customers by putting ourselves in their shoes. Presented below are the examples of such solutions including independent power generation facility asset management, digital tools and utilization of surplus electricity through the capacity market.

3.1 Asset management for independent power generation facility (an ESCO approach)

The term ESCO originally stands for Energy Service Company. It is a business operator that helps customers to reduce energy consumption or lighting/heating/water utility expenses, and shares the benefits with customers. Specifically, the services are a combination of the following (according to the website of the Japan Association of Energy Service Companies):

(1) Energy-saving proposals based on the energy-saving diagnosis
(2) Energy-saving design and construction for the implementation of proposals
(3) Operation and maintenance management of energy-saving equipment
(4) Energy supply-related services
(5) Arrangement of business funds
(6) Guarantee for energy-saving effect
(7) Measurement and verification of energy-saving effects
(8) Proposals for improvement based on measurement and verification

While these services are mainly directed at commercial or industrial equipment, it is very difficult and takes time to provide these services for the entire independent power generation facility for industrial purposes whose system configuration is large-scale and complicated. However, we believe that an ESCO approach is vital in terms of setting out a proposal from a standpoint much closer to customers, instead of following the protocol as a system supplier. That is to say, we must stand by customers and, together with them, create a solution proposal and offer services for it.

As an example, our asset management service is described below.

In the above list of services, this service of ours is primarily related to some part of (3) Operation and maintenance management of energy-saving equipment. Until now, when something went wrong in the facilities of customers, they consulted us after they became aware of the problem. This is just like our visiting a primary care doctor every time we feel sick or come down with a disease. Depending on the conditions, immediate hospitalization or emergency surgery may be required. This means that the customers’ facilities may also be subjected to long-term suspension of operation for large-scale repair. On the other hand, our new service aims to realize the stable execution of production processes by monitoring the system conditions of the independent power generation facility together with customers and proposing necessary measures in a timely manner to avoid the occurrence of failure or address a problem when it is still minor. As shown in **Figure 6**, instead of being a “primary care doctor,” we want to be and will be a “escort runner” who accompanies the runner (that is, the customer) all the way toward their goal.

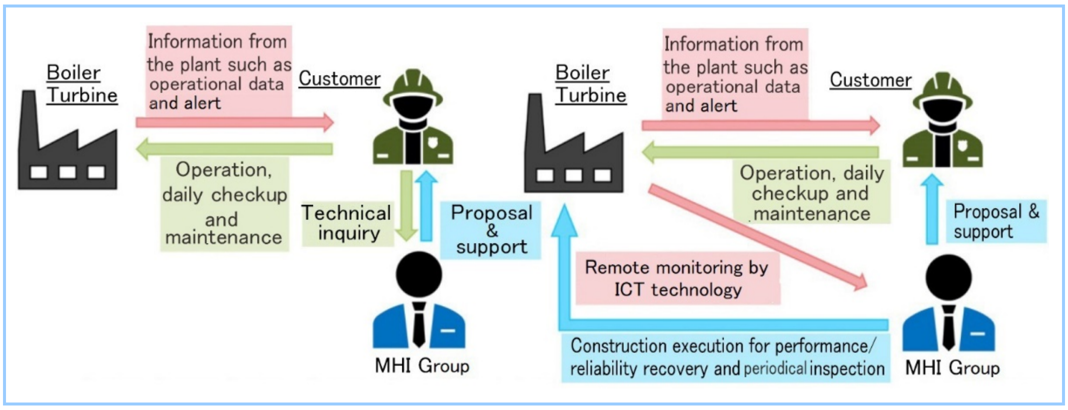

Figure 6 From primary care doctor to escort runner

3.2 Digital tools: Basic Package (TOMONI facility maintenance support)

In order to address the challenges in business management facing the on-site workers who perform system maintenance, such as labor shortages, aging facilities and declining on-site capabilities, many sites are exploring how DX (Digital Transformation) or smartification can be promoted. The Japanese Ministry of Economy, Trade and Industry is strongly backing up their efforts to overcome these challenges by introducing new digital technologies such as IoT (Internet of Things), AI (Artificial Intelligence) and drones, and the adoption of “smart industrial safety” for the simultaneous realization of maintenance/improvement of industrial safety and productivity in the future. Furthermore, toward achieving carbon neutrality, digital capabilities will become more indispensable than ever for coping with the shift to carbon neutral fuel such as hydrogen and ammonia, introducing new equipment and enabling a control system to manage such new equipment in a complex and organic manner.

MHI has launched the “Smart Maintenance” initiative, which aims to bring about a revolution in maintenance by digitalization. Specifically, our goal is to improve the efficiency and quality of maintenance by means of digitizing, accumulating and visualizing useful maintenance data and performing advanced analysis. The tasks to be made smart include daily maintenance routines, regular inspection procedures, facility maintenance (i.e., detection of abnormal signs and performance monitoring) and digital support tools for individual sites. As one of the digital tools to provide such smart maintenance, we offer the following “TOMONI Basic Package” (**Figure 7**).

<TOMONI Basic Package>

(1) Maintenance planner: to support a wide range of maintenance processes including management of maintenance history and work planning
(2) Smart search: to easily search technical materials and documents
(3) TOMONI bulletin board: a communication tool with the manufacturer’s engineers
(4) TOMONI blog: brief explanations about technical term, technical information, industry news, etc.

This package was designed under the concept of “hassle-free and ready-to-use”. When customers receive this system product, the necessary data related to the documents that we have provided (e.g., drawings and technological correspondence) and the maintenance/technical information have already been input in the system (i.e., provided as built-in system data). Therefore, customers can start using the product on the very day of the receipt without requiring the work and time for data entry. We have received favorable comments from TOMONI user customers, especially from the viewpoint of training, labor saving and communication. Given the issue of labor shortages in recent years, we also offer maintenance tools that cover a wider range of services by combining the digital solutions with the asset management service described in Section 3.1.

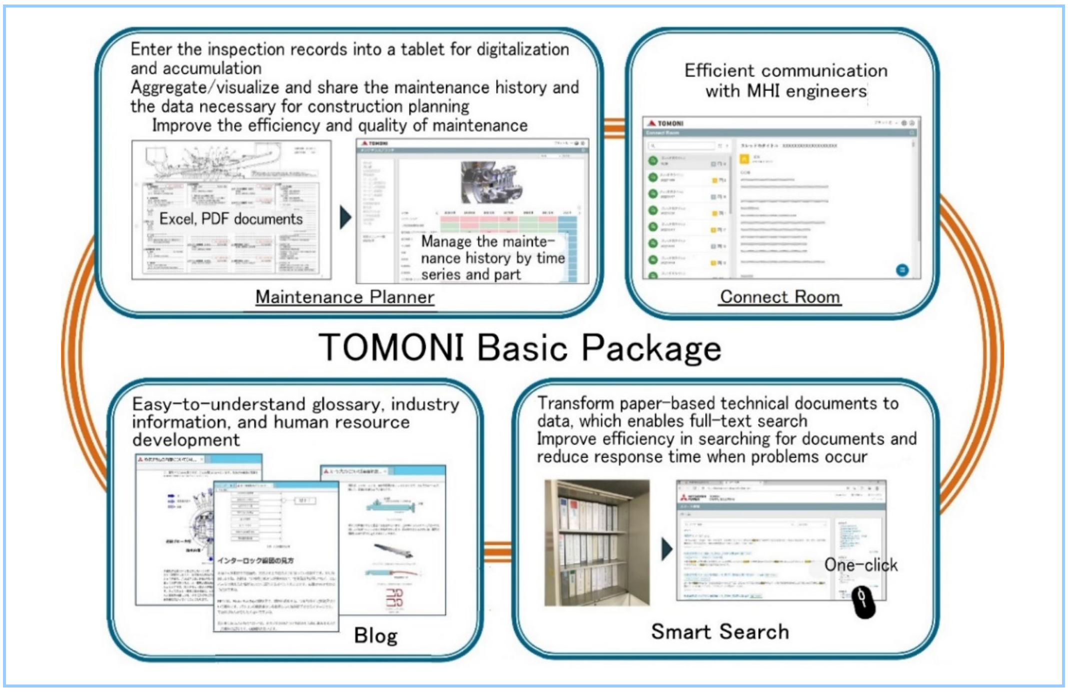

Figure 7 Maintenance revolution with digitization: Smart Maintenance

3.3 Utilization of surplus electricity through the capacity market

As described so far, we have strived to contribute to customers' businesses through provision of safe and high-efficiency power generation facilities and their maintenance, placing importance on (1) stability, (2) economy and (3) environmental performance. On the other hand, the challenges in electric power business are changing considerably because of the electricity system reform. Especially the capacity market, which has been created to secure the electricity supply capacity, is closely related to independent power generation facilities. This market requires to utilize surplus electricity from independent power generation systems and unused facilities.

Recognizing the importance of the solicitation of balancing capacity (Generator I'), which is the precursor of the capacity market, MHI took part as an aggregator and, at the same time, as a consumer for our factories. Thus, utilizing this experience of a dual role as an aggregator and a consumer, we have also participated in the capacity market (demand resource) as an aggregate-cum-consumer.

Figure 8 shows the scheme of the capacity market and the flow chart of requesting the demand response. The Demand Response Aggregation System (DRAS) is a system to communicate with electric power companies (electricity transmission and distribution). When balancing power is called for, DRAS receives the request from the Organization for Cross-regional Coordination of Transmission Operators, Japan (OCCTO) through the power grid, thereby connecting directly to customers (consumers). This enables the response to be made in a timely manner.

In the case of participating in the capacity market, it is important to set the optimal power supply capacity. The more electricity you can supply on request for balancing power, the more reward you will receive and the more you can contribute to easing the power crunch. However, if you fail to supply as much electricity as you have set, the reward may be reduced. Based on the know-how and experience as a facility manufacturer, we can assess and propose the optimal power supply capacity by analyzing the data such as the operating conditions of the independent power generation facility and the factory's electricity/heat (steam) demand and estimating the probability of success/failure. In the process of achieving carbon neutrality, the environment surrounding independent power generation facilities is also expected to change considerably. We will cope with such change in a timely manner and contribute to the businesses of our customers, power supply/demand stabilization and resilience.

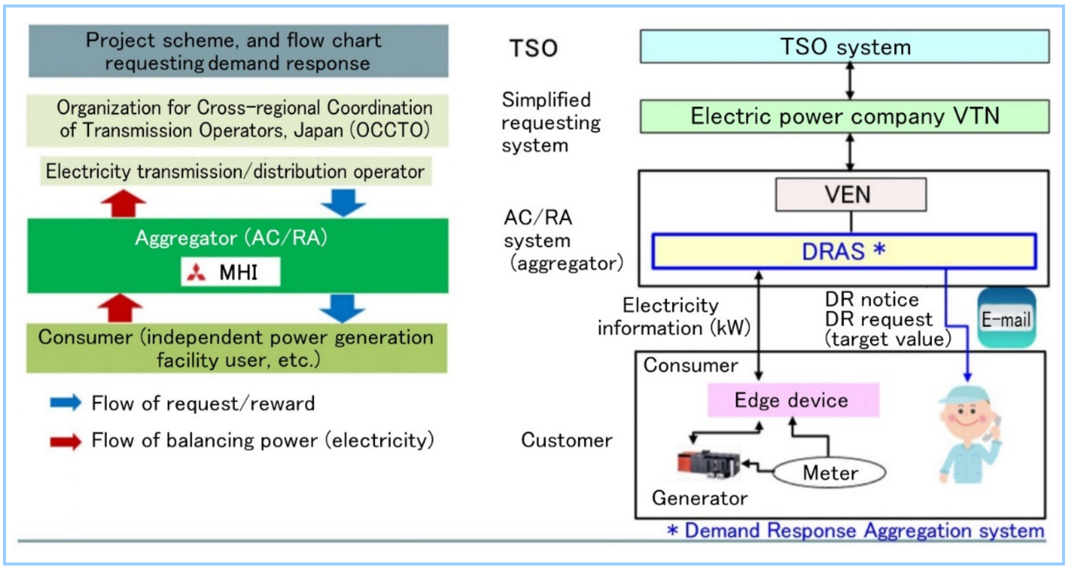

Figure 8　Capacity market scheme and flow chart requesting balancing power

4. Conclusion

This report presents our carbon neutral solutions from two approaches: “energy balance diagnosis and improvement” and “finding a solution to the needs (pain points) pertaining to independent power generation facilities”. Based on the medium- and long-term business goals and needs of our customers, we will continue to propose a customized and valuable carbon neutral solution tailored to each independent power generation facility by putting ourselves in their shoes, consequently looking to succeed in making these facilities operable over a long period of time in a sustainable manner.

TOMONI® is a registered trademark of Mitsubishi Heavy Industries, Ltd. in Japan and other countries.

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