Development of Platform for Total Energy Management - Proposal for Total Energy Solution -

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In response to the need for liberalization and the stable supply of energy, energy supply systems have been diversified and many options are now available. On the other hand, the prompt proposal and evaluation of large-scale energy supply systems consisting of various pieces of energy equipment and related operating procedures has become difficult. Mitsubishi Heavy Industries, Ltd. (MHI) is working on the development of a platform for offering a total energy solution that realizes efficient energy utilization under normal circumstances and ensures business continuity in times of emergency such as power outages or equipment failure. This paper describes an overview, applications, and the future development of the planning system, which is a part of the platform.

1. Introduction

Distributed power supply systems are attracting attention as a means of the stable supply of energy to deal with risks caused by large-scale natural disasters and changes in social conditions. As energy liberalization moves forward, various energy utilization options have become available.

Actions for energy leveling and the reduction of supply amount based on this background are spreading widely from households to factories and cities, and therefore increases in number and the diversification of the types of energy equipment have been progressing. As a result, the combination and operating procedures of the equipment became complicated and branched out, and it is now hard to examine them with existing manual calculation.

In addition, advances in sensing technology and information and communications technology in recent years have enabled the understanding and visualization of energy flow at a low cost, and as a result, energy management systems utilizing ICT have become increasingly widespread.

MHI is proceeding with the offering of total energy solutions that satisfy both efficient energy utilization under normal circumstances and business continuity in times of emergency through working on 1S5R (Store, Reduce (reduction of demand), React (reaction to demand according to supply), Reuse, Recovery, and Recycle) as shown in **Figure 1**. In that process, MHI has developed a planning system for a large-scale energy supply system consisting of various energy equipment, that enables the prompt proposal and evaluation of more optimum combinations of energy equipment and operating procedures, utilizing knowledge accumulated from the company's position as a comprehensive machinery manufacturer. The following chapters describe an overview and applications of the developed planning system.

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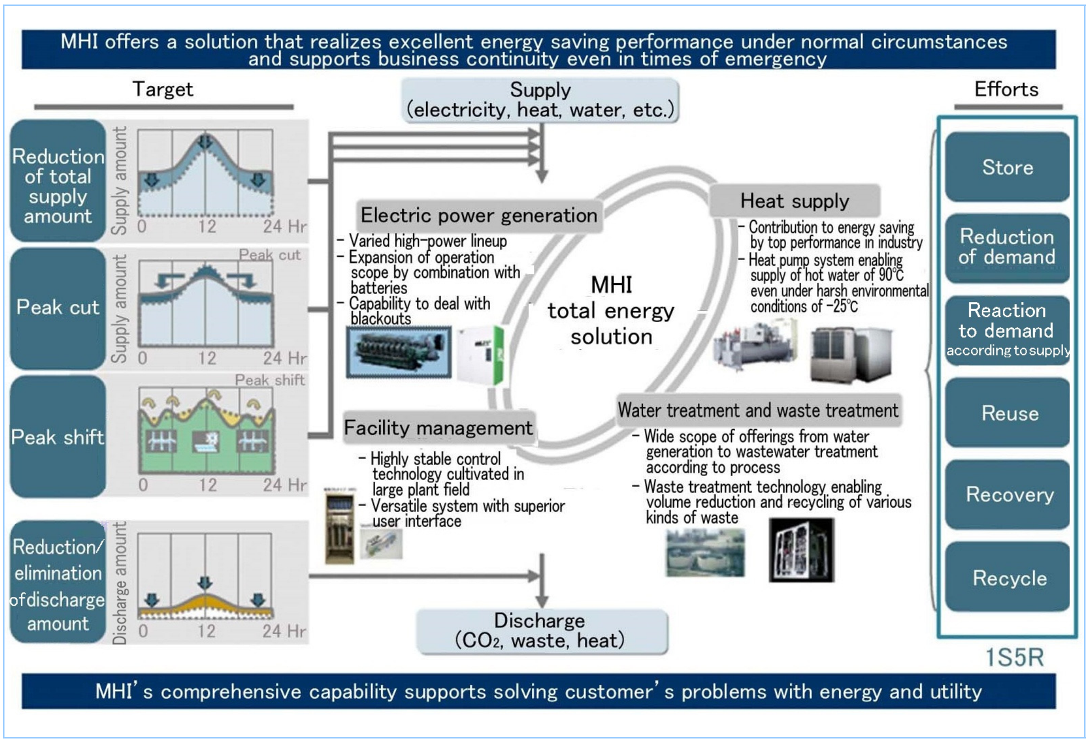

Figure 1 Total energy solution

2. Features of the developed planning system

An energy solution consists of measures to minimize or level the energy demand for electricity and heat (steam, chilled water, hot water, etc.) and to supply the necessary amount of energy efficiently. Energy solutions also need to consider the stability of energy for business continuity in times of emergency, including start-up time and the transient behavior of the equipment.

Measures for energy supply are roughly classified into (1) operation planning and (2) system planning. (1) Operation planning evaluates the operation of the equipment, which bases the running cost including the cost of maintaining the energy supply system and CO_2 emission amount as indexes, in terms of daily electric and heat demand. (2) System planning evaluates, in consideration of annual demand fluctuation and future changes in demand, the initial cost of the introduced equipment and changes of running cost between before and after the introduction of the equipment.

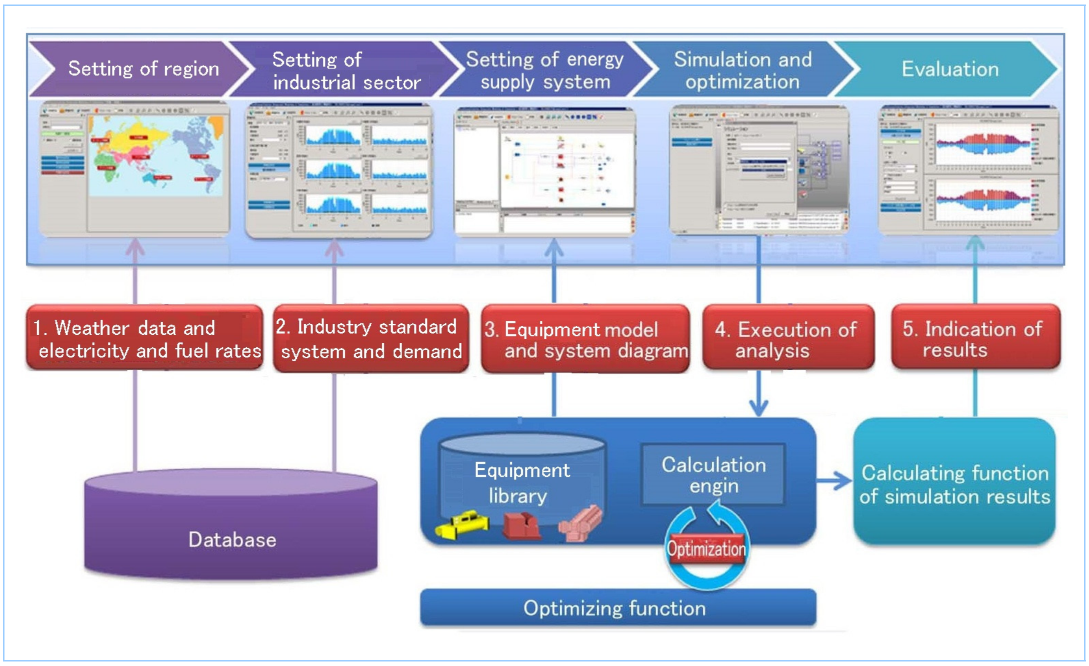

Figure 2 Structure of developed system

Furthermore, system planning is broadly classified into cases where some of the equipment is replaced and cases where a new energy supply system is introduced. Partial replacement of equipment requires consideration for compatibility with existing equipment and long-term system planning.

For these measures, various conditions that vary depending on the object items of the examination or the targets, such as the rate system of electricity or fuel, the electric and heat demand, etc., must be considered in addition to various characteristics of the equipment. This is one of the causes complicating the examination process. In order to make these measure examination processes simple and efficient, MHI has developed a planning system with the following features.

Figure 2 presents the structure of the developed planning system.

2.1 Simple evaluation process

In the developed planning system, the processes necessary for the energy solution evaluation are arranged and defined as the five steps shown in Figure 2: (1) setting of the region, (2) setting of the industrial sector, (3) setting of the energy supply system, (4) execution of calculation and (5) evaluation. The setting of the region, the setting of the industrial sector and the setting of the energy supply system are entered by the user. The user follows the steps to enter the input values required for the examination.

The user can examine the optimum solution by changing the input values of the setting of the region, the setting of the industrial sector and the setting of the energy supply system according to the item to be examined, and then confirming the quantitative figures of the evaluation. For example, for customers to be able to examine the contents of a contract that minimizes the running cost in response to widely fluctuating electricity and gas rates, a quantitative evaluation can be made by changing the rates in the setting of electricity and fuel rates and then comparing the results. Moreover, if the customer wants to examine the cost benefit resulting from the operation of a gas engine, examination including exhaust heat utilization for a boiler and absorption type chiller is possible by changing the operating pattern of the gas engine in the setting of the energy supply system.

2.2 Comprehensive evaluation

The planning system uses Modelica language and therefore can deal with the combined area of the heat transfer system, the electric system, the mechanical system, etc., in common(1). In addition, the planning system has a wide range of energy equipment models such as electric power generation equipment including a renewable energy equipment, chillers, cogeneration systems and heat storage tanks in the equipment library, enabling the consideration of various equipment configurations. Each equipment model contains the equipment properties including partial load and cost models such as the initial cost and maintenance cost. For this reason, the developed planning system can make comprehensive evaluations including cost evaluation.

2.3 Standard database

Typically, understanding and obtaining all the information necessary for examination is difficult and simple primary evaluation is hindered in many cases. The developed planning system has a standard database with registered data for weather information and electricity/fuel rate systems linked with the respective region, seasonal electricity/heat demand and equipment configurations standardized for each industrial sector, as well as typical equipment specifications. Even when sufficient data are not available in an early examination phase, the user can promptly execute a simple primary evaluation by using data selected from the standard database, editing the values set from the standard data according to the object items of the examination, or setting the values based on actual measured data if available.

2.4 Optimization

The developed planning system has an optimization feature that searches optimum equipment operating procedures. With this feature, the user sets the convergence conditions and evaluation function that uses the running cost, CO_2 emission amount and other parameters. This feature enables the user to obtain, through calculation based on the standards set by the user, optimum operating procedures that take into account the efficiency of various pieces of equipment, the effective utilization of exhaust heat and other factors.

3. Process of evaluation using the developed planning system

The developed planning system displays screens that follow the process shown in Figure 2. The user can evaluate an energy solution quickly by carrying out an evaluation process consisting of five steps in accordance with the screen flow. Each step is described below.

3.1 Setting the region

The weather conditions and electricity and fuel rates are set in this step. When the user selects a region from the map, the standard data associated with the region can be set. The user can directly enter values instead.

3.2 Setting the industrial sector

Electricity demand and heat demand such as chilled water, hot water, and steam are set in this step. Similarly to 3.1, when the user selects an industrial sector, the standard data can be set, and the user can also directly enter values instead.

3.3 Setting the energy supply system

The energy supply system is set in this step. The energy supply system must be able to be set flexibly by simple operation because it varies for each object evaluation item. The developed planning system utilizes a graphical schematic diagram that is easily understood visually. In addition, each equipment system can be set flexibly and easily on the screen with the mouse by dragging and dropping an equipment model from the equipment library and by connecting equipment with lines in a color exclusive for each classification such as electricity, hot water, chilled water, etc.

Similarly to 3.1 and 3.2, representative equipment system data are available in the standard database and the user can select a schematic diagram similar to the object evaluation item from the database to set the energy supply system efficiently. In addition, the operation pattern, specifications and performance of the equipment can be set by using the standard data or entering parameters arbitrarily instead.

3.4 Simulation and optimization

The running cost and CO_2 emission amount are calculated based on the data entered by the user in the steps above.

When the optimization of equipment operation procedures is to be executed, an evaluation function that uses the convergence condition, the running cost, CO_2 emission amount, etc., and the convergence condition are set in this step.

3.5 Evaluation

The results calculated in 3.4 and represented in the graph are evaluated in this step. The developed planning system displays the equipment operating pattern and the electricity-heat balance diagram in addition to the graphs of the running cost and the CO_2 emission amount, which are indexes of the evaluation of efficient energy supply. These can be displayed for multiple cases simultaneously and therefore the user can easily understand the quantitative values for multiple cases.

4. Applications

This chapter presents energy solution examination cases to which the developed planning system described above has been applied.

4.1 Examination of introduction of gas engine cogeneration

For an energy supply system that uses a boiler and a centrifugal chiller mainly based on electricity purchase as shown in **Figure 3**, we examined the changes of the running cost due to the introduction of a gas engine and a cogeneration system consisting of a boiler and an absorption type chiller that are capable of utilizing the exhaust heat.

When a cogeneration system is used as in this case, the operation of the gas engine needs to be examined based on not only a comparison between the electricity purchase expense and the fuel expense, but also demand for steam and chilled water. In addition, there are two options for the utilization of exhaust heat from the gas engine: utilization as steam and utilization as chilled water. Whichever is more efficient should be selected.

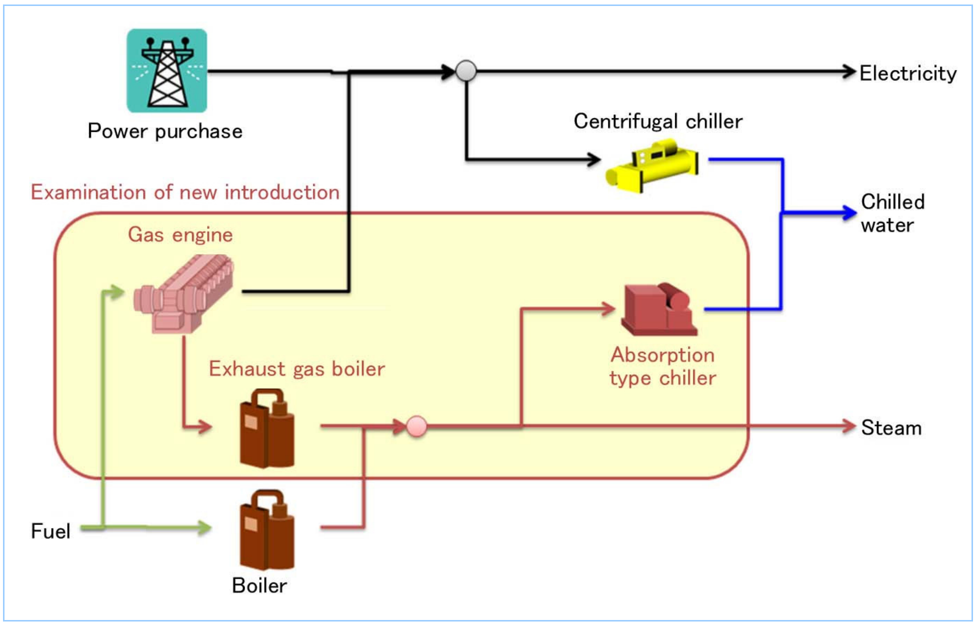

Figure 3 Examination of introduction of gas engine cogeneration

Figure 4 gives the optimization results based on the electricity and heat demand, the electricity rate and the fuel rate set in this case, using the evaluation functions of the running cost. In this case, as represented in this figure, the running cost is minimized by an operation that uses steam from the exhaust gas boiler for the steam supply and supplies chilled water by the centrifugal chiller during the daytime when steam demand exists, and uses steam from the exhaust gas boiler for the generation of chilled water at the steam charging type absorption type chiller during night time when no steam demand exists. In addition, the running cost, which can be reduced by the introduction of the gas engine, and the number of years for investment recovery, which takes into account the initial investment and the running cost, can be quantitatively indicated as shown in **Figure 5**.

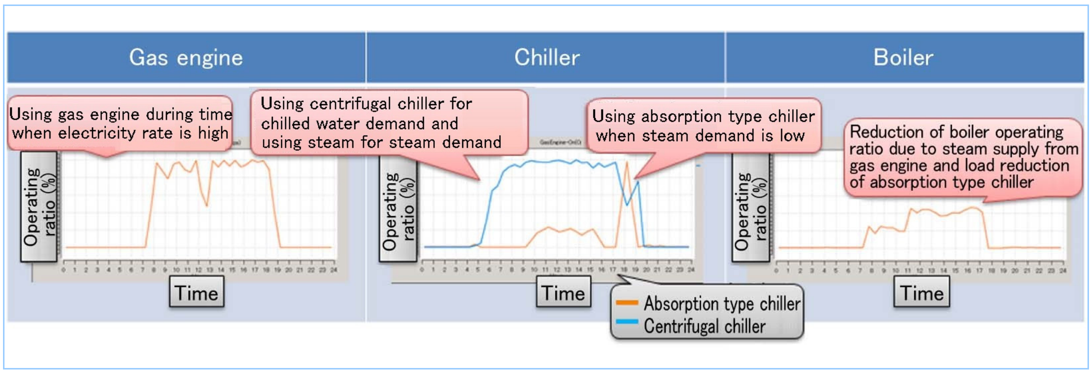

Figure 4 Operation of equipment in case of introduction of gas engine cogeneration

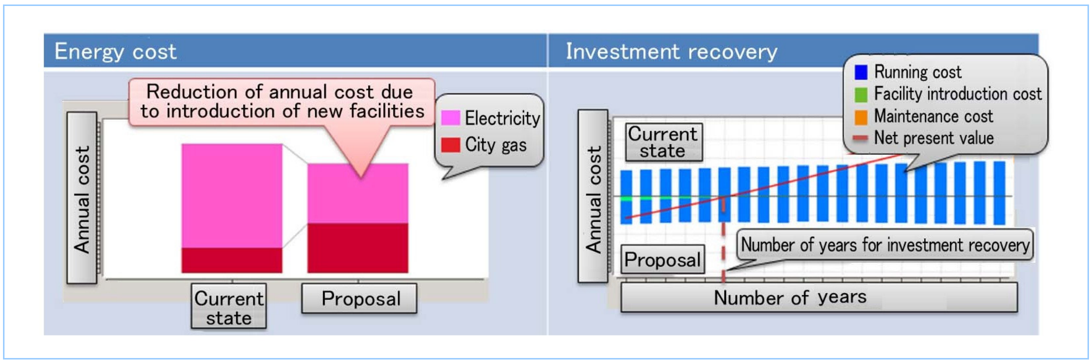

Figure 5 Cost benefit due to introduction of gas engine cogeneration

4.2 Examination of rate system

In addition to section 4.1, **Figure 6** shows the examination results of the contract power and the power rate system in consideration of changes in the electricity purchase amount caused by the operation of the gas engine. From these results, it is found that the running cost may be reduced if the contract power is changed from the current one.

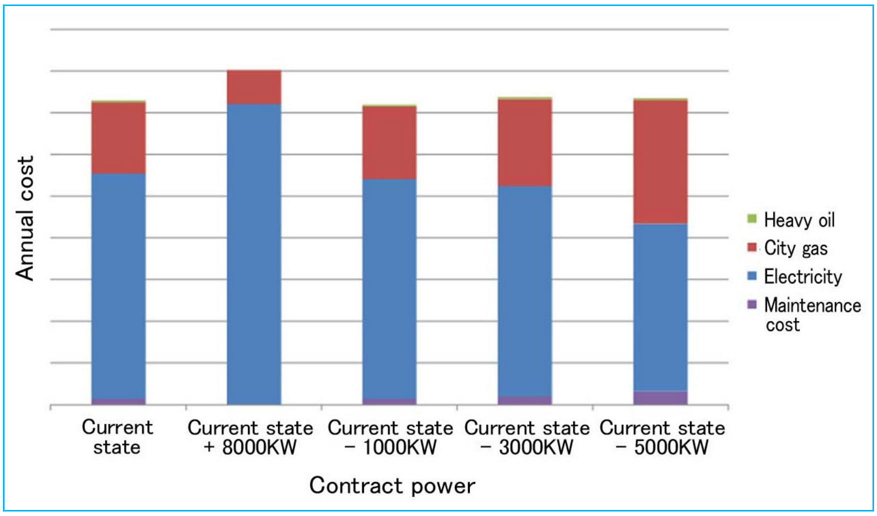

Figure 6 Contract power and annual cost

5. Conclusion

As described above, the present report presented a planning system for a large-scale energy supply system consisting of various pieces of equipment, that enables prompt quantitative evaluation of benefits in running cost resulting from changes of the operating procedures of existing equipment systems and return on investment in the introduction of a new energy supply system and the partial replacement of existing equipment including the initial cost. The developed planning system enables the evaluation of the optimum combination of equipment that realizes efficient energy supply and related operation procedures.

MHI is planning future expansion of the developed planning system to include the ability to consider the frequency fluctuation of the electric power system and dynamic delay of the equipment such as start-up time, etc. The development of the expanded model is aimed at evaluating an energy supply system capable of stably supplying energy with an eye toward energy liberalization. MHI also plans to add a function to predict energy demand changing in response to the production plan of plants and the flow of people and products in a city, commercial facility, building, etc. Through this effort, we will establish an energy management system that responds quickly to a momentarily changing environment and offers an optimum solution online. These enhancements of the developed planning system will contribute to the improvement of the energy management platform.

Reference

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