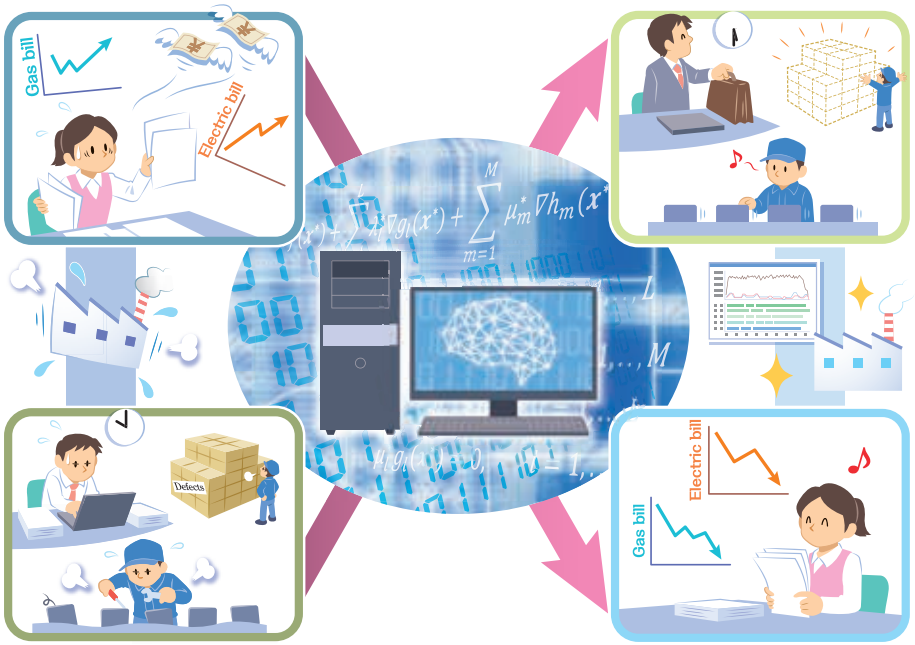
Energy Optimization Ventures into the Realm of Production

Power peak shifting at plants — Realized by IHI's technology for automatic scheduling of production facilities

IHI Group is developing energy management technologies that contribute to the reduction of energy costs at plants. This is accomplished by coordinating production systems with energy systems to realize energy saving and cost reductions while maintaining or even increasing production volume.



Energy management technology pursued by IHI in which production systems and energy systems work together

Energy management technology pursued by IHI

For manufacturers, the reduction of energy costs for their plants is a major issue. IHI Group, providing products such as energy storage systems, gas turbines for emergency use, compressors, and heat and surface treatment facilities, has a big influence on the demand and supply of electricity at customers' plants. Keeping this in mind, IHI engages in various fields of research and development that aim to contribute to resolving the challenge mentioned at the beginning of this article.

Recently, Energy Management Systems (EMS) have been drawing attention because they serve as a means of realizing the reduction of energy costs. An EMS is intended to help to manage energy such as electricity, gas, and heat in an optimal manner to save energy and reduce costs, for example, in visualizing how energy is being used, proposing the optimal management of energy-related facilities, and controlling such facilities.

The important thing in the energy management of plants is the compatibility of the keeping or increase of production volume with energy saving and cost reduction. Generally, energy consumption at a plant is mostly attributed to production facilities. However, if the facilities are shut down or left idle for energy-saving without proper consideration, it could cause the decrease of the production volume. In response to this issue, IHI promotes research and development with advantage of abundant know-how on characteristics of various production facilities as well as plant operation, to establish energy management technologies that achieve compatibility and coordination between production systems

and energy systems.

This article describes our technology for automatic scheduling of production facilities that enables electric power peak shifting, which is one of IHI's energy management technologies for plants that can have a major cost-saving effect on production systems. In addition, this article also describes IHI's research and development in mathematical optimization that is the fundamental technology of the automatic scheduling.

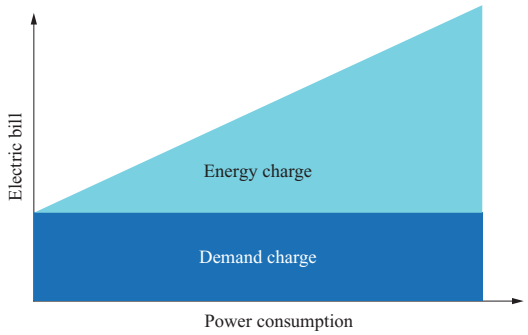
The importance of electric power peak shifting at plants

One of the main energy costs at plants is the electric bill. An electric bill consists of a demand charge and an energy charge. The demand charge is proportionate to the maximum demand (peak power) and the energy charge is proportionate to the actual power consumption (kW·h). Of the two, demand charge can be reduced by lowering peak power without making any changes to the production facilities or production volume. Depending on the types of production facilities owned by a plant and their style of operation, the demand charge generally accounts for as much as 30% of the bill. Given this, it can be said that reducing the peak power will lead to a considerable reduction in the electric bill. In this connection, the demand charge is determined based on the contract demand, which is generally determined based on the peak power over the past year at the plant. Therefore, a continuous and smart approach to reducing peak power is needed to reduce the contract demand.

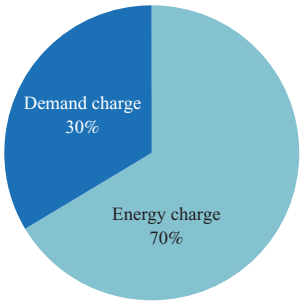
Several methods of reducing peak power have been proposed. One example is the introduction of a photovoltaic power generation system and a battery for the operation of production facilities. In addition, an operation method called peak shifting is often implemented. This method is practicable without the need for such equipment investments. It adjusts the operating schedules of production facilities that consume a larger amount of power in a plant, thereby reducing the peaks in the power demand. However, the implementation of peak shifting requires scheduling that takes into account both production systems and energy systems, and it has not been easy to reduce peak power without changing production volume. Therefore, IHI has developed a technology for automatically creating a facility operation schedule that is capable of reducing the peaks in electric power demand without changing production volume.

Automatic scheduling of production facilities

The technology we developed is an algorithm for automatically creating a schedule that specifies what facilities are to be used to perform processes for products, and when the processes are to be started. Specifically, this technology forces all predetermined processes to be performed on products to be completed within a given period (one week), as well as derives a schedule in which the maximum total wattage of all production facilities is minimized taking various factors into consideration, including the sequence of the processes, time to delivery of the products, work shifts, maintenance schedules for the production facilities, and the possibility of responding to a request for expedited production. This technology is not intended to minimize energy consumption and therefore does not directly lead to a smaller energy charge. It is expected, however, that reducing peak power with this technology will result in lower contract demand, which will then lead to a reduction in a demand charge.

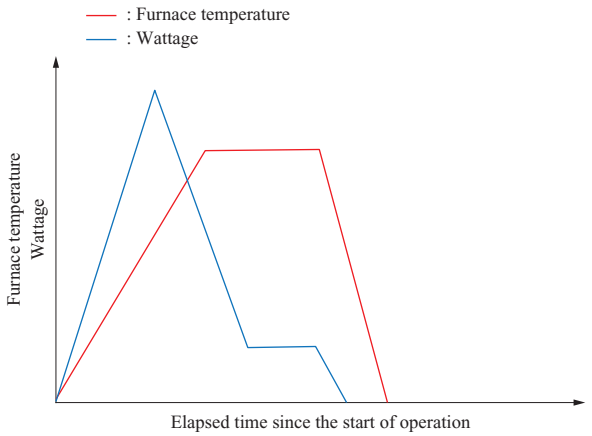


Relationship between power consumption and electric bill

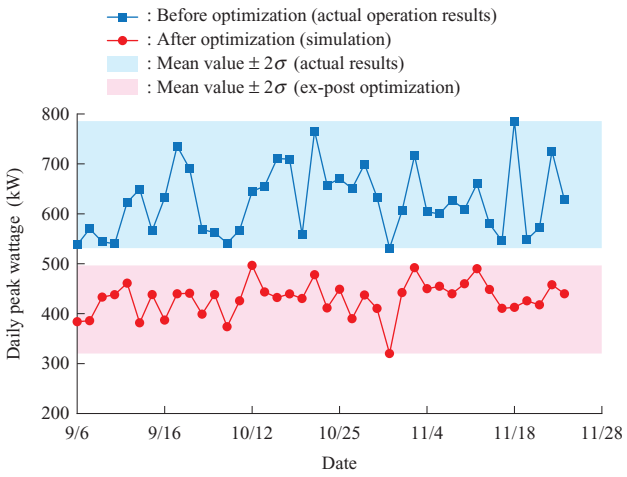


Breakdown of energy and demand charges to an electric bill

This technology is particularly effective in plants with multiple high wattage production facilities such as batch-type vacuum heat treatment furnaces. A vacuum heat treatment furnace is a facility that heats and processes steel parts or the like at high temperatures (ranging from approximately 500 to 1 000°C or more). From the time it starts operating, a high peak in the wattage demand is formed while the temperature in the furnace is increased to the set temperature. In a batch-type furnace, once treatment is started, it is impossible to load it with additional parts or to take parts out of it until treatment is completed. This means that the operating schedule of this type of furnace cannot be changed after starting, and the schedule therefore occupies an extremely important place in both production systems and energy systems. In order to reduce peak power at a plant or production line having multiple batch-type vacuum heat treatment furnaces, it is necessary to formulate an operating schedule that prevents the peak of one furnace from overlapping with that of another furnace. It is not easy to



Outline drawing of furnace temperature and wattage during the operation of a vacuum heat treatment furnace



Simulation-based verification of effects of peak shifting

manually formulate such a schedule without changing production volume, as already mentioned, but with this technology, such a schedule can be obtained quickly and automatically.

Based on the developed algorithm, we are currently carrying out simulations and furnace operation tests on actual production facilities including the eight heat treatment furnaces at IHI Soma No. 2 Aero-Engine Works in Fukushima Prefecture, as well as verifying the effects of peak shifting and identifying issues to be addressed for the practical use of this technology. Our ultimate goal is to provide this technology as a system coordinating, for example, with factory ERP (Enterprise Resource Planning), i.e., a production control system, MES (Manufacturing Execution System), sensors, and ILIPS, i.e., the remote maintenance shared platform that IHI Group has already made available.

Contribution to energy optimization at customers' plants

We believe that we will be able to take advantage of this technology to contribute to energy optimization at customers' plants where a number of high wattage production facilities, such as vacuum heat treatment furnaces, are used. As already mentioned, the realization of peak shifting requires scheduling that takes into account both production systems and energy systems. Up until now, an attempt to reduce peak power would adversely affect production systems. If this technology is introduced, however, peak power can be reduced without changing production volume, and it can be expected that contract demand will be reduced and lead to a reduction in demand charge. Or, the technology could expand the scale of production without increasing the contract demand.

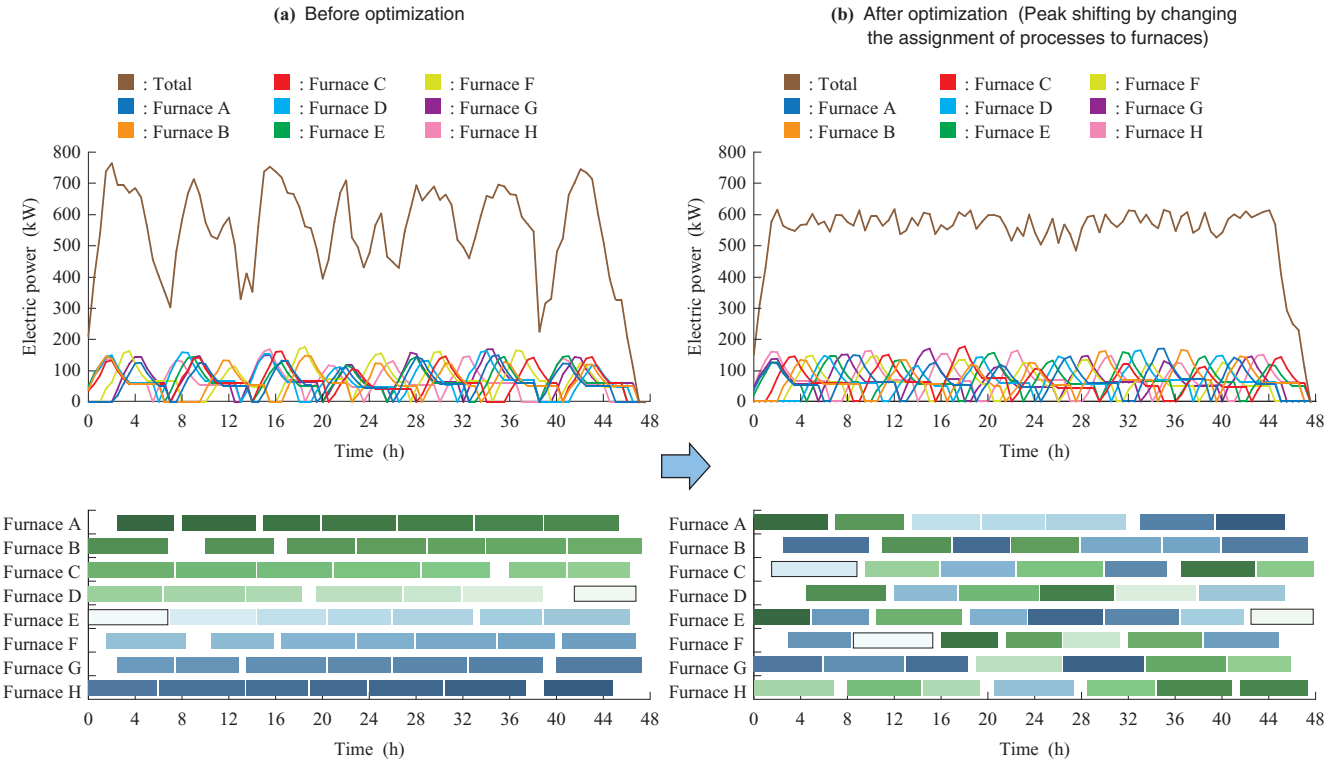
Automatic scheduling based on mathematical optimization

This automatic scheduling is based on mathematical optimization, or more specifically, by a technology called combinatorial optimization. Mathematical optimization refers to algorithm techniques for obtaining an optimal solution (an optimal combination specifically in combinatorial optimization) while meeting various constraints. The usage of these techniques is not only to scheduling, but also to various purposes everywhere in a plant, including the optimization of production plans, equipment layout, and the assignment of tasks to workers.

However, mathematical optimization is not silver bullet. It serves as a practical technique only if the thing that is to be optimized is clearly defined and the algorithm is designed using the structure and attributes of the problem. For example, the problem of obtaining an operating schedule for production facilities that minimizes peak power is a considerable challenge in terms of algorithm design. If an attempt is made to obtain an exact optimal solution, calculation will be tremendously time-consuming. In practical terms, an exact optimal schedule is not necessarily needed, and it is more important to be able to quickly obtain a reasonably good schedule. Since the type and number of constraints that should be considered for scheduling vary from site to site, high scalability is required. In addition, an algorithm that outputs multiple reasonably good scheduling proposals is more helpful in terms of ability to provide grounds for decision-making than one that outputs one scheduling proposal.

The algorithm developed by IHI is based on these studies and in several seconds to several minutes can propose multiple schedules that drastically reduce peak power even in cases of large-scale scheduling (e.g., one-week scheduling of production facilities with more than 20 pieces of equipment). In addition, the algorithm can respond to the addition of complicated constraints and is designed to easily customize scheduling in accordance with individual sites. In a series of studies, IHI's insights into production, such as constraints attributed to on-site operating rules, have been widely utilized.

As mentioned above, IHI is actively carrying out research



Conceptual diagram of power peak shifting by automatic scheduling of a group of production facilities

and development of mathematical optimization techniques for implementing optimal operation and control of products as well and will further develop these techniques so that they will serve as a key to improving the added value of products and services.

Pursuit of the realization of a smart factory where both production systems and energy systems are optimized

With a focus on the production sector, that is to say, the source of power demand, we have developed an energy management technology for use in plants that enables power peak shifting using only automatic scheduling. This technology brings about a substantial effect on its own, but if a facility such as a battery or a photovoltaic generation system is introduced alongside it to ensure optimal control, it is expected that additional peak shifting effects will be produced. We are currently conducting the relevant research.

Recently, not only energy management, but also improvements in production efficiency at factories taking advantage of ICT (Information Communication Technology) have been drawing attention. We will accelerate our research and development as well as demonstration of various technologies, not limited to power peak shifting described in this article, from now on toward the realization of a smart factory where the operation of both energy systems and production systems is optimized.

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