Simulated annealing based simulation method for minimizing electricity cost considering production line scheduling including injection molding machines

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Abstract
While the price of electricity in Japan is increasing continuously, the plastic industry consumes considerable electric power for injection molding. The cost of electricity must be reduced to maintain product prices. Some strategies have been proposed to reduce the cost of electricity at the production stage, one of which is to reduce the contract electric energy amount with an electric company while increasing the facility operation rate and reducing excess power. This study proposes a method to minimize the electricity cost of injection molding lines by using the simulation for injection molding lines with an approximation solution. The simulated annealing method was used as the approximation solution. Based on the proposed method, numerous case studies were performed, and the results were analyzed.

Keywords: Production lines scheduling, Injection molding machine, Electricity cost optimization, Simulated annealing, Simulation method

1. Introduction

Since the Great East Japan Earthquake, the price of electric power has increased and is expected to continue increasing in the future. Under such circumstances, it is necessary to reduce the cost of electricity and raw materials to maintain international competitiveness.

A variety of industries operate in Japan; among these, the plastics industry in particular has grown rapidly every year and is predicted to continue to expand in the future (World Economic Forum, 2017). The major processing methods in the plastics industry include extrusion molding, blow molding, and injection molding. The processing method called injection molding requires high temperatures and pressures; therefore, it consumes a significant amount of electric power, and its electricity cost is high. It is important to reduce its electric power consumption and electricity cost while maintaining international competitiveness.

In previous research on the energy consumption evaluation of injection molding machines, there are three types of studies. The first type developed formulations considering relationships between processing conditions and energy consumption in injection molding processes (Chein and Dornfeld, 2013; RiBeiro et al., 2012; Wessman et al., 2010; Mattis et al., 1996). The second type evaluated energy saving amounts in one cycle of injection molding processes (Madan et al., 2015; Spiering et al., 2015). The third type evaluated life cycle assessments of injection molding processes (Thiriez and Gutowski; 2006; Elduque et al., 2015). These studies mainly focused on the energy evaluation of physical phenomena that occur in injection molding machines. Therefore, an energy evaluation of the entire production line including the injection molding machine was excluded. Recently, simulation-based methods have been proposed to evaluate the productivity and energy consumption of production lines including injection molding machines (Takasaki et al., 2017; Kaifuku et al., 2019). As a result, it is becoming possible to evaluate in advance the productivity and energy consumption of production lines including injection molding machines at a design stage. On the other hand, at the operation stage of production lines including injection molding machines, the contract electric power changes according to the production schedule. The contract electric power is defined as the maximum average value of cumulative electric power used every 30 min in each month. The electric power cost in a factory is calculated by the sum of the basic cost proportional to the
contract electric power and the electric power cost proportional to the electric power consumption (Tokyo Electric Power Company, 2019). When reducing the contract electric power, the peak cut of electric power is important. Production scheduling that takes the peak cut of electric power into consideration can potentially reduce basic costs. However, the optimization using production schedules that take the peak cut of electric power into consideration becomes a large-scale combinatorial optimization problem. It is difficult to obtain an exact solution efficiently.

This study proposes a method to minimize the electricity cost of injection molding lines by using a simulation for injection molding lines with an approximate solution. The simulated annealing method was used as the approximate solution. Based on the proposed method, numerous case studies were performed, and the results were analyzed.

2. Electricity cost and production schedule of an injection molding line

2.1 What is an injection molding line?

An injection molding line is a series of operations that supply raw materials and processes them through injection molding to produce molded products. Figure 1 shows the machinery and movement of raw materials that form an injection molding line, which consists of a material loader, material dryer, injection molding machine, and take-out machine. A material loader supplies materials to the injection molding line. Next, the material is transferred to the material dryer and dried. When the material is completely dried, it is transferred into the injection molding machine to be melted and injected into a mold. This processed product is then cooled and subsequently transported out of the injection molding line by a take-out machine. This series of tasks is performed on an injection molding line. In this research, our target machines in the injection molding lines are from the material loaders to the take-out machines.

![Material flow diagram](image)

Fig. 1 Injection molding line.

2.2 Relationship of production schedule and electricity cost for one injection molding line

Previous research proposed state transition models for four kinds of machines (Takasaki et al., 2017; Kaifuku et al., 2019). By relating the proposed state transition models to the electric consumption of each machine, it is possible to simultaneously evaluate the productivity and energy consumption of the entire production line. Multiple production lines, including injection molding lines, are often implemented in parallel in response to production demands. By comprehensively calculating the electricity consumption using the state transition models of each production line, it becomes possible to evaluate the productivity and energy consumption in the entire production system.
Figure 2 shows the relationships between the production schedule, injection molding machine states, and electric power in a line. In one cycle of the injection molding process, molds are first closed in the injection machine, and melted plastic is injected into the molds. When the melted plastic has completely spread into the cavity of the molds, the melted plastic is cooled and solidified. The necessary amount of plastic to produce the next products is continuously melted. When the plastic solidifies after the default cooling time, the molds are opened, and the products are removed. The processes of melting and cooling the plastic generally consume the highest amount of power. A cycle time for the injection molding process varies depending on the types of products. In particular, the process time for melting and cooling the plastic is different. Therefore, the energy consumption per injection molding cycle varies depending on the types of products.

When one production lot is finished, a setting up operation occurs for the next production lot. There are mainly two kinds of setting ups: mold and material (color, etc.). It is possible to operate mold and material setting ups simultaneously. Therefore, there are three types of setting ups: the mold only, material only, and both mold and material setting ups. These types of setting ups are determined by the relationships between the current and the next production lots. The amount of energy consumption differs for each of the three types of setting ups. The setting up process time also varies.

The electricity cost in this study is defined as the sum of the basic and electric power usage costs (Eq. (1)).

\[
\text{Electricity cost [JPY]} = \text{basic cost [JPY]} + \text{electric power usage cost [JPY]}
\] (1)

The basic cost is calculated based on the contract electric power, i.e., the maximum value obtained during the past 12 months by recording the maximum average value of electric power used every 30 min in each month. The electric power usage cost is proportional to the electric power consumption in a certain single month. The basic cost calculation equation is shown below (Eq. (2)) (Tokyo Electric Power Company, 2019).

\[
\text{Basic cost [JPY]} = \text{basic cost unit price [JPY/kW]} \times \left(185 - \text{power factor}\right) \times \text{contract electric power [kW]}
\] (2)

The basic cost unit price is the constant of proportionality to the contract electric power. The power factor is a value...
that represents the degree to which electric power purchased from an electric power company is used without loss, and the part, (185-power factor) represents that if electric power is used at an efficiency of 85% or higher, the basic cost will be reduced. The power factor is a value impacted by the equipment and is unrelated to the production order.

To reduce the basic cost, it is necessary to reduce the contract electric power. When reducing the contract electric power, the peak cut of the electric power is important as it reduces the cumulative electric power during 30-min periods that include the electric power peak time; therefore, the contract electric power, which is the average value of the 30-min cumulative electric power is reduced as well.

For example, there are two typical ways to reduce the contract electric power by changing production schedules.

In the first example, Fig. 3 shows that by changing a production schedule that assigns production lot $\gamma$ instead of lot $\beta$, the setting up time is longer, and the contract electric power during the period from $X$ to $X+1,800$ s is reduced. In this example, by changing the schedule, the setting up time associated with switching production lots is longer. Therefore, it might be possible to reduce the machine operating time for 30 min and reduce the electric power consumption. This may reduce the contract electric power for the last 30 min. On the other hand, productivity might be reduced, and the operating time might be longer, which would then increase the total power consumption.

In the second example, Fig. 4 shows a case in which the contract electric power is reduced by changing the production schedule from A to C. By changing a production schedule that assigns the production lot $\gamma$ instead of lot $\beta$, the electric consumption in one cycle is reduced; then, the contract electric power during the period from $X$ to $X+1,800$ s is also reduced. In this example, by changing a schedule, the setting up time associated with switching production lots is the same. A lot with tasks that consume less energy in the injection molding process is allocated. This may reduce the contract electric power for the last 30 min. On the other hand, a task that consumes a lot of energy in the injection molding process might be assigned for another 30 min, and the setting up time might be longer.
The electric power usage cost calculation formula is shown in Eq. (3).

Electric power usage cost [JPY]  

\[ \text{Electric power usage cost} = \text{electric power usage cost unit price} \times \text{electric power consumption} \]  

(3)

The electricity cost unit price is a constant of proportionality to the electric power consumption. The electric power consumption refers to the total electric power used during a month. To reduce the electric power consumption cost, it is necessary to reduce the electric power consumption.

The electric power consumed by a series of processes is not affected by the production order. Therefore, to reduce the electric power consumption, it is important to reduce the electric power consumption by non-processing steps. In this study, the frequency of setting ups corresponds to non-processing steps. Figure 4 shows that the total electric power consumption is reduced by changing from production order A to production order C that requires few setting ups.

Substituting Eqs. (2) and (3) into Eq. (1) yields Eq. (4).

Electricity cost [JPY]  

\[ \text{Electricity cost} = \text{basic cost unit price} \times \text{contract electric power} \times \left( \frac{185 - \text{power factor}}{100} \right) + \text{electric power usage cost unit price} \times \text{electric power consumption} \]  

(4)

As shown in Eq. (4), to optimize the electricity cost, it is necessary to balance the basic and electric power usage costs. As shown in the two examples, when priority is given to lowering the contract electric power, the electric power usage cost tends to increase. There is a trade-off between the basic and electric power usage costs. Therefore, it is necessary to optimize the schedule considering the balance between the basic and electric power usage costs. However, in previous studies, schedule optimization considering the balance between the basic and electric power usage costs has not progressed.
2.3 Relationship of production schedule and electricity cost for multiple injection molding lines

Section 2.2 explained the relationship of the production order and electricity cost in a single injection molding line. This section explains the relationships of production orders and the electricity cost in multiple injection molding lines. In multiple injection molding lines, the basic and electric power usage costs are considered as the sum of the electric power of each line. For example, as shown in Figure 5, if there are two selectable schedules for each line, the contract electric power may change depending on the combination of those schedules. In addition, the cost of energy consumption changes depending on the combination. Therefore, for multiple injection molding lines, it is necessary to balance the basic and electric power usage costs to optimize the electricity cost as shown in Eq. (4). If priority is given to lowering the contract electric power, the electric power usage cost tends to increase. Because the relationships between the basic cost and the electric power usage cost are unknown, an optimization method is necessary.

3. Electricity cost minimization method based on a simulation of an injection molding line and the simulated annealing method

3.1 Simulation of an injection molding line and simulated annealing method

The electricity cost calculation includes two equations: one with basic cost as the value that is minimized and the other with the electric power usage cost as the value that is minimized. However, the production schedule that minimizes the basic cost and the production schedule that minimizes the electric power usage cost do not always conform; therefore, it is difficult to calculate a production schedule that minimizes the electricity cost. According to the production line scale, the number of combinations of production schedules expands; therefore, it is difficult to discover a production schedule that minimizes the electricity cost. Hence, a neighborhood solution is used to obtain the production schedule that minimizes the electricity cost. This study considers the combinatorial optimization problem. As the number of injection molding lines increases, the combination of production schedules to be considered increases explosively. Therefore, we apply the simulated annealing method, which is an efficient approximation method, to large-scale combinatorial optimization problems.
Figure 6 shows the relationship between the injection molding simulation and simulated annealing method. First, a production schedule is generated in the simulated annealing method. Next, the power cost of the production schedule is calculated using the injection molding simulation. In the simulated annealing method, the calculated power cost is compared with the current solution (production schedule), the current solution is updated based on the comparison result, and a new production schedule is generated. Then, these steps are repeated.

In the minimization problem in this study, the explanatory variable is the production order, and the objective function is the electricity cost.

### 3.2 Simulated annealing method

This study uses the simulated annealing method (Scott et al., 1983) (Cerny, 1985). The simulated annealing method is metaheuristic and is an evaluation method that uses the difference between the value calculated by the present solution (in this study, electricity cost of the present solution) and that calculated by the neighborhood solution for the present solution (in this study, electricity cost of the neighborhood solution). If the electricity cost of the neighborhood solution is lower than that of the present solution, the neighborhood solution becomes the new present solution. In other cases, the stochastic function is used to decide whether the neighborhood solution is the new present solution. The higher the value of the stochastic function, the higher is the probability that the neighborhood solution becomes the new present solution. In other cases, the stochastic function is used to decide whether the neighborhood solution is the new present solution. The higher the value of the stochastic function, the higher is the probability that the neighborhood solution becomes the new present solution. The following two controls of the stochastic function are used. The first control is the difference between the electricity cost of the present solution and that of the neighborhood solution. The smaller the difference, the larger is the stochastic function, and the greater is the probability that the neighborhood solution will be selected as the new present solution. The second control involves parameters assigned to the stochastic function. The parameters that control the stochastic function are the temperature (in this study, “T”), cooling multiplier parameter (in this study, “F”), and cooling frequency parameter (in this study, “N”). As the number of search steps increase, these parameters reduce the stochastic function, thus reducing the likelihood that the neighborhood solution will be selected as the new present solution. Furthermore, as the number of search steps increase, it becomes less likely that the neighborhood solution with a poor evaluation value will be selected; therefore, it can be stated that parameters T, F, and N control the search space.
3.3 Injection molding line simulation

To calculate the electricity cost, data for the contract electric power and electric power consumption are needed. Additionally, to calculate the contract electric power and electric power consumption, data concerning the state of use of electric power are necessary. Therefore, we use a model of an injection molding line and a simulation in which the model is installed, as have been proposed by the previous research (Takasaki et al., 2017; Kaifuku et al., 2019).

This simulation can calculate the energy consumption rate by clarifying the state of each machine on the injection molding line and the electric power in this state in every second. The simulation also permits changes in the production schedule that, in turn, permits assessments of the energy consumption rate due to the changes in the production schedule. From the electric power data produced by this simulation, the contract electric power and electric power consumption are calculated, and the electricity cost is calculated by substituting these values into Eq. (4).

Figure 7 shows a flow chart of the injection molding line simulation. The data entered to calculate the electricity cost of the injection molding line is the production schedule. The output data is the electricity cost by month. If the production schedule, which is the input data, is revised, the resulting electric power that differs from that before the revision of the production schedule is obtained. Furthermore, because the contract electric power and electric power consumption are the changed, the electricity cost changes. In this study, all production objects arrive at the initial time, and the production line is never idle.

STEP 1-1: calculate the contract electric energy and electric power consumption of the initial solution using the method proposed (Takasaki et al., 2017; Kaifuku et al., 2019).
STEP 1-2: using the value calculated in STEP 1-1, calculate the electricity cost of the initial solution. Subsequently, the initial solution is considered as the present solution.
STEP 1-3: using the method proposed (Takasaki et al., 2017; Kaifuku et al., 2019), calculate the contract electric power and electric power consumption of the neighborhood solution.
STEP 1-4: using the value calculated in STEP 1-3, calculate the electricity cost of the neighborhood solution.
STEP 1-5: return the electricity cost of the present solution and the electricity cost of the neighborhood solution to the simulated annealing method.
STEP 1-6: receive the new present solution and its neighborhood solution from the simulated annealing method.
STEP 1-7: return to STEP 1-3; subsequently, repeat STEP 1-3 to STEP 1-6.
The initial solution creation flow is shown in Fig. 7. Fig. 8 corresponds to STEP 0 of Fig. 7. The initial solution is created by randomly ordering the production lots.

![Diagram](image-url)
3.4 Procedure for minimizing electricity cost by injection molding line simulation, and simulated annealing method

The method—minimizing the electricity cost by the injection molding line simulation and simulated annealing method—determines the production schedule that minimizes the electricity cost by incorporating the simulated annealing method into the method of calculating the injection molding line electricity cost. Two values are minimized in the calculation of the electricity cost: the basic cost and electric power usage cost. However, in this case, the electricity cost that is the total of the two is considered as one objective function. The injection molding line simulation is installed in WITNESS, and the simulated annealing method is installed in Visual Basic for Applications.

3.5 Application of the simulated annealing method

The electricity cost of the present solution and the electricity cost of the neighborhood solution are input, and the solution that provides the lowest evaluated electricity cost is output as the new present solution.

To perform the evaluation based on the simulated annealing method in this study, the electricity cost of the present solution and that of the neighborhood solution are necessary.

Figure 9 shows the creation flow of the neighborhood solution of the present solution.

STEP A: the present solution is prepared.
STEP B: one production lot is selected randomly from the production schedules of the present solution. Denoting the number of production lines as $num_{line}$, the number of production lots as $num_{lot}$, the selected production line as $line_{select}$, and the selected production lot as $lot_{select}$, it is calculated by Eq. (5) and Eq. (6). The variables $\alpha_{line_{select}}$ and $\beta_{line_{select}}$ in Eq. (6) represent production lots to be changed in the production line selected by Eq. (5).

\[
line_{select} = \begin{cases} 
M1 & \text{if } 0 \leq random < \frac{1}{num_{line}} \\
M2 & \text{if } \frac{1}{num_{line}} \leq random < \frac{2}{num_{line}} \\
& \vdots \\
Mnum_{line} & \text{if } \frac{num_{line}-1}{num_{line}} \leq random < \frac{num_{line}}{num_{line}} 
\end{cases}
\]  (5)

\[
lot_{select} = \begin{cases} 
\alpha_{line_{select}} & \text{if } 0 \leq random < \frac{1}{num_{lot}} \\
\beta_{line_{select}} & \text{if } \frac{1}{num_{lot}} \leq random < \frac{2}{num_{lot}} \\
& \vdots 
\end{cases}
\]  (6)

STEP C: the production order of the selected production lot and the next lot produced are switched. When the production lot that is finally produced has been selected, the production order is switched with the production lot that is created initially.
The simulated annealing method evaluates the present solution and its neighborhood solution and selects the solution that is best evaluated as the new present solution. At this time, if the electricity cost of the neighborhood solution is higher than that of the present solution, the stochastic function $P(T)$ is used to perform the evaluation. The stochastic function $P(T)$ in this case study is shown in Eq. (7). The $\Delta\text{cost}$ is the value obtained by subtracting the electricity cost of the present solution from the electricity cost of the neighborhood solution.

$$P(T) = e^{-\frac{\Delta\text{cost}}{T}}$$

(7)

The probability that the neighborhood solution will be selected as the new present solution in the case in which the electricity cost of the neighborhood solution is higher than that of the present solution is $P(T)$. To control Eq. (7), three parameters are set: the temperature ($T$), cooling multiplier ($F$), and cooling frequency ($N$). According to Eq. (7), the larger the $\Delta\text{cost}$ or the smaller the $T$, the lower is $P(T)$, and the lower is the probability that the neighborhood solution will be selected as the new present solution. $T$ decreases as in Eq. (8), each time the number of search steps is a natural number multiple of $N$.

$$T = T \times F$$

(8)

4. Case study

4.1 Setting the injection molding line

The electric power in the case study herein is calculated based on Eq. (9).
Electricity cost [JPY]

\[
= 1684.8 \left( \frac{\text{JPY}}{\text{kW}} \right) \times \text{contract electric power [kW]} \times \frac{(185 - 85)}{100} + 16.08 \left( \frac{\text{JPY}}{\text{kWs}} \right) \times \text{electric power consumption [kWs]}
\] (9)

This case study addressed a production system consisting of two injection molding lines installed in parallel (Kaifuku et al., 2019). The injection molding lines are denoted M1 and M2. Six products are produced on each production line. Table 1 shows product information for production line No. 1, in which there are six types of products including two colors and four molds. Table 2 shows product information for production line No. 2, in which there are six types of products including five colors and four molds. The characteristics of each product are color and shape, and when the color or the shape of the product being produced differs from that of the next product to be produced, a setting up occurs. Regarding the setting time in production line No. 1, the setting up time for a color change is 180 s, and the setting up time for a mold change is 420 s. In production line No. 2, the setting up time for a color change is 900 s, and the setting up time for a mold change is 1200 s. In production line No. 1, the production time varies depending on the product and is 37, 38, 42, or 52 s. In production line No. 2, the production time varies depending on the product and is 56 or 58 s. The material loader cycle time is 10 s. The material dryer cycle time is 8 s. The take-out machine cycle time is 10 s.

The daily production in the factory continues until all planned products have been produced completely, and the simulation time is 20 d.

The case study involves three restrictive conditions. The first is that switching the production order is performed in product lot units. The second is that the production order is not switched between production lines. The third is that the production time/day does not exceed 24 h.

To obtain the minimum value of electricity cost in the case study and the production schedule at that time, an exhaustive search was performed. The result was the minimum electricity cost of 1,141,473 (JPY/20 d). When the exhaustive search was performed, six PCs were used; however, it was predicted that if one PC was used, the search would require 2 months. All six PCs had the same specifications, which are listed in Table 3.

### Table 1 Product information for production line No. 1

| Lot size [products] | Product 1-1 | Product 1-2 | Product 1-3 | Product 1-4 | Product 1-5 | Product 1-6 |
|---------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Color type          | A           | A           | B           | B           | B           | A           |
| Mold type           | a           | b           | c           | c           | d           | d           |

### Table 2 Product information for production line No. 2

| Lot size [products] | Product 2-1 | Product 2-2 | Product 2-3 | Product 2-4 | Product 2-5 | Product 2-6 |
|---------------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Color type          | C           | C           | D           | E           | F           | G           |
| Mold type           | e           | f           | g           | f           | f           | i           |

### Table 3 Specifications of personal computer used in case study.

| Item name       | specification       |
|-----------------|---------------------|
| OS              | Windows 10 Pro      |
| Processor       | Intel® Core™ i7-6700 CPU @ 3.40 GHz, 3.41 GHz |
| Memory          | 32.0[GB]            |
| Type of system  | 64-bit operating system |

4.2 Setting the simulated annealing method
The condition for terminating the simulated annealing method is that comparing the minimal electricity cost after 1,000 steps with that before the 1,000 steps yields an improvement of less than 50 JPY/20 d.

A preliminary experiment is performed to determine the parameters for this case study. The candidates for the parameters for the primary experiment are summarized in Table 4. All combinations of the initial values of \( T \), \( F \), and \( N \) that can be prepared from Table 4 are sought. Ten searches for the combinations of the parameters are performed, and the average value of the electricity cost of the termination solution is calculated. The primary experiment uses the combination of parameters that minimizes the average electricity cost of the termination solutions.

| Initial value of \( T \) | \( F \) | \( N \) |
|------------------------|-------|-------|
| 1,000                  | 0.95  | 50    |
| 3,000                  | 0.98  | 100   |
| 5,000                  | 0.99  | 150   |

According to the preliminary experiment, the parameters for the primary experiment are \( T = 5,000 \), \( F = 0.98 \), and \( N = 150 \). The primary experiment was performed 100 times using the parameters obtained in the preliminary experiment.

### 4.3 Results

Table 5 and Fig. 10 show the distribution of electricity costs in the 100 primary experiments. The minimum electricity cost, 1,141,473 JPY/20 d was calculated four times. The electricity cost value calculated in the experiment that yielded the worst results from the 100 primary experiments was 1,143,478 JPY/20 d. However, even in the worst case, the difference from the minimum electricity cost value was reduced to 0.176%.

| Electric power cost obtained in the preliminary experiment | Electric power cost [JPY/20days] | The difference from the minimum electric power cost [%] |
|----------------------------------------------------------|---------------------------------|-------------------------------------------------------|
| The minimum value                                        | 1,141,473                       | 0.000                                                 |
| The maximum value                                        | 1,143,478                       | 0.176                                                 |

![Fig. 10 Distribution of termination values of electricity cost in the case study.](image-url)
Figure 11 shows the transition of the average electricity cost for each search step. The average electricity cost was calculated by performing an experiment 100 times under the condition that the parameters of the simulated annealing method are $T = 5,000$, $F = 0.98$, $N = 150$ and calculating the average value of the power cost in each search step. The number of search steps until each experiment was complete is not the same number, because random numbers are used in STEP 2-3 and STEP 2-5-2. Therefore, the minimum number of search steps in 100 experiments was used as an upper bound. The average electricity cost in each step up to the upper bound was plotted. The upper bound in this case study is 1050 steps.

Under these settings, an average of 3.957 h was required to execute the proposed method and determine the solution.

5. Conclusions

The plastic industry is predicted to continue growing. Injection molding machines, which are crucial in the processing of plastics, consume large quantities of electric power. However, no studies have investigated methods to reduce their electricity cost. Therefore, a method of combining the simulation of an injection molding line with an approximation method was proposed herein. In this study, the simulated annealing method, which reduced the search time, was selected from various approximation methods. For the case study, the optimum combination of parameters selected from Table 4 was used to perform 100 searches. Consequently, it was possible to obtain a production schedule that obtained a differential with the minimum value of the electricity cost of less than 0.176%, in a search time that was 3/1,000 that of an exhaustive research. These findings confirmed the practicability of the proposed method. In the future, the proposed method with added personnel and other costs will be explored.

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