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Development of load scheduling application for peak shaving of electricity demand in an industrial customer having a distributed generator

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Introduction

Electricity shortages in the last summer were caused by The Great East Japan Earthquake.

- ✓ The national power-saving edict was issued for the first time in 37 years.
- ✓ Large-lot users served by Tokyo Electric Power Company and Tohoku Electric Power Company were required to reduce their electricity consumption by 15 percent from the previous year during peak weekday hours on mandatory basis.
- ✓ Most of industrial large-lot users reduced use of lights and air conditioning systems
- ✓ They tried to reduce their electricity consumption by thoroughgoing improvement of energy efficiency.
- ✓ In order to achieve the reduction target, some users excessively reduced their use of lights and air conditioning systems in their offices, and some users shifted their operation time.
- ✓ As a result, 96% of large-lot users accomplished their reduction target in 2011 summer.

Objectives

We developed the load scheduling tool (OPTLOAD) for an industrial customer, which has several facilities consuming electricity such as more than 100kW, and each facilities being operated independently.

The objectives of this tool are;

- ✓ To reduce peak electric demand
- ✓ To reduce facility operation shift often involving workers' overtime working
- ✓ To optimize operation planning of facilities and distributed generation in a customer by minimizing energy cost and labor cost

OPTLOAD can search the optimal weekly operations of facilities by minimizing the sum of energy cost and labor cost under the constraints fulfilling the number of utilization and operation period of each facility in each day. In this study, we improved OPTLOAD to apply to an industrial customer having distributed generators. (Figure 1)

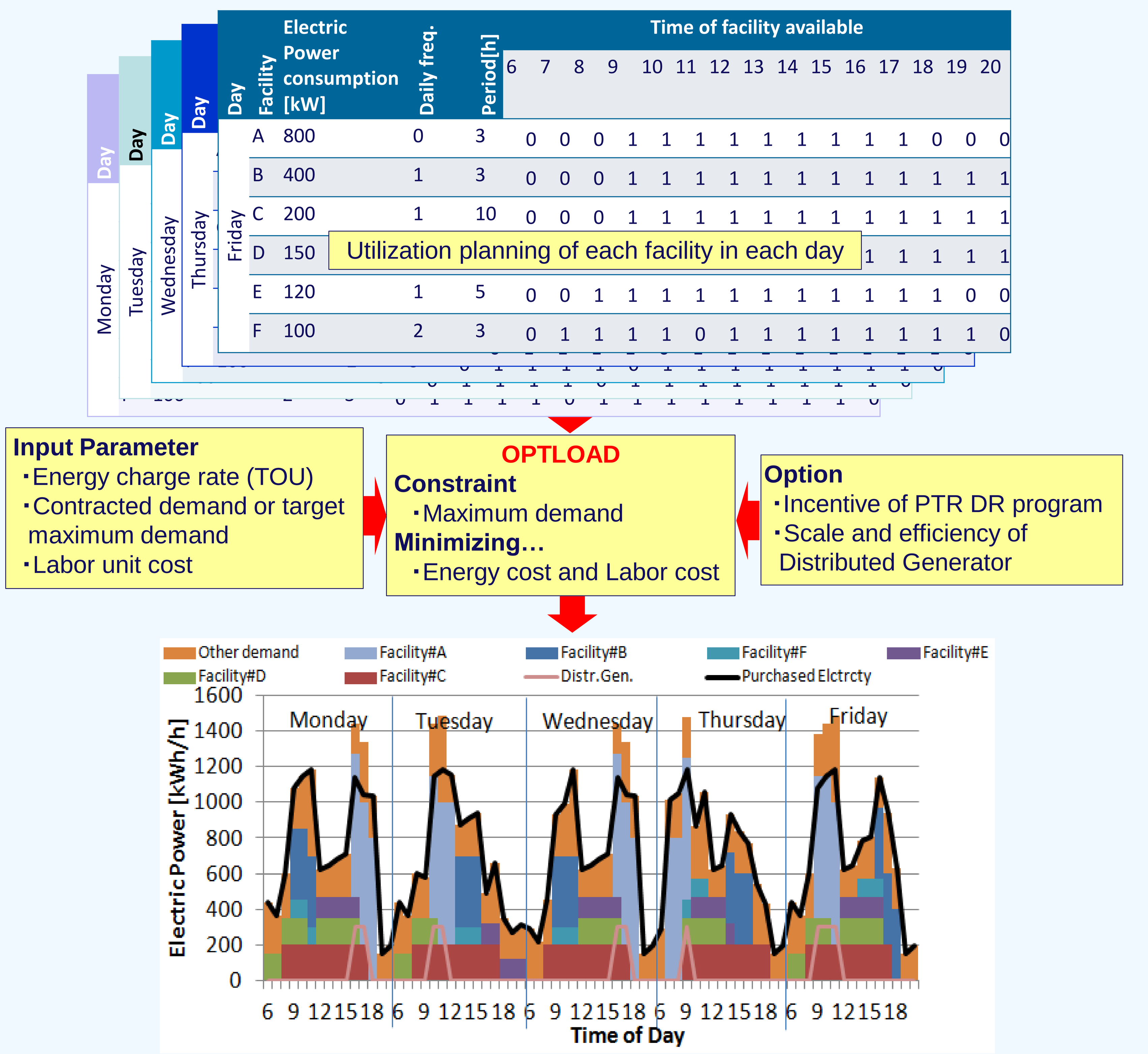

Figure 1 Calculation flow of OPTLOAD

A Case Study

In this study, we simulated optimal operation planning of five facilities and a distributed generator in Institute of Technology in Shimizu Corporation. They have six experimental facilities consuming electricity such as more than 100kW, and each facilities being operated independently. (Table 1)

Table 1 Facilities in Technology Research Center of Shimizu corporation

Facility's name	Peak demand	Average operation time	Average number of workers
Shaking Table (A)	800 kW	3 ~ 5 h	5 persons/hr
Small Shaking Table (B)	400 kW	3 ~ 5 h	5 persons/hr
Wind tunnel Lab (C)	200 kW	7 ~ 10 h	0.2 persons/hr
Meas. Instrument of rock hardness (D)	100 kW	5 ~ 8 h	0.1 persons /hr
Clean room Lab (E)	120 kW	8 ~ 10 h	2 persons/hr
Heat Pump (F)	100 kW	5 ~ 8 h	2 persons/hr
Distributed Generator	350 kW	---	---

Formulation

◆ Objective Function

Objective function is the sum of energy charge of electricity from utility, energy charge of gas, and labor cost.

$$Z = \sum_{j,k} U_{el}(j)\cdot P_{buy}(j,k) + \sum_{j,k} U_{gas}\cdot F(j,k) + \sum_{i,j,k} \delta_i(j,k)\cdot \lambda_i \cdot C \cdot w(j) \quad \text{(Eq.1)}$$

U: unit energy charge, P_{buy}: purchased electric power, F: volume of purchased gas, δ: Binary variable representing On-Off of facility, λ: average number of workers, C: average hourly wage per person, w: ratio representing overtime money, i: facility's name, j: time of day, k: day

◆ Constraints

α: 1.0(Off-peak time), β(peak-time)<1.0

$$P_{buy}(j,k) \le \alpha(j)\cdot P_m$$ purchased electric power <= contracted demand (Eq.2)

$$P_{buy}(j,k) = \sum_i P(i,j,k) + P_{load}(j,k) - P_{DG}(j,k)$$ demand and supply balance (Eq.3)

$$P(i,j,k) = \delta(i,j,k)\cdot P_{max}(i)$$ relationship between facility's electric demand and its on-off variable (Eq.4)

$$P_{DG}(j,k) = S_{DG}\cdot x(j,k)$$ relationship between output and load factor (Eq.5)

$$F(j,k)\cdot Q = \frac{S_{DG}\cdot x(j,k)}{a\cdot x(j,k)+b}$$

- relationship between consumed gas vol. and load factor of DG
- coeffs a and b are determined from given generating efficiency

(Eq.6)

$$0.5\cdot\delta_{DG}(j,k) \le x(j,k) \le 1.0\cdot\delta_{DG}(j,k)$$ Load factor is between from 50% to 100% when it is operated (Eq.9)

Algorithm

1. Picking up all the operation pattern of each facility in each day fulfilling the given condition (the number of utilization and expected operation period of the facility in the day)

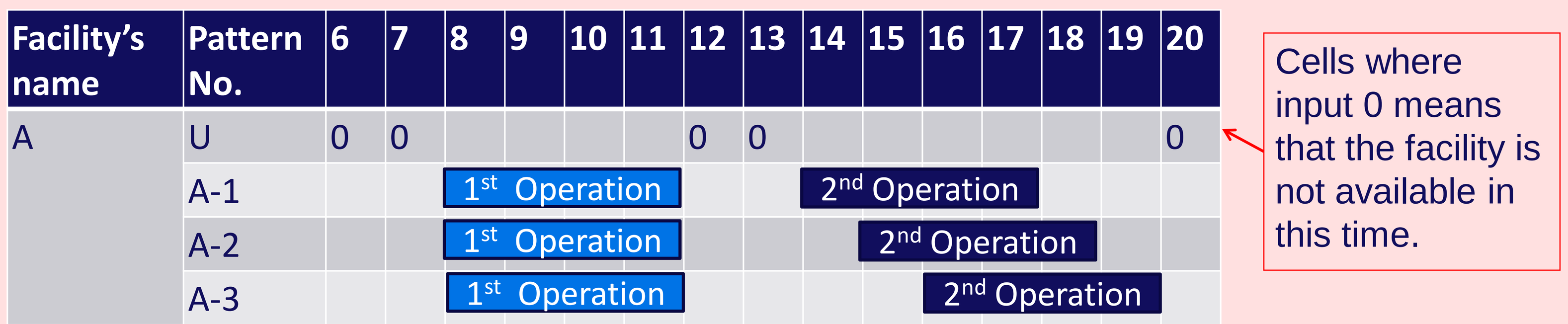

Figure 2 Example of enumerating operation pattern of facility #A in a day
(Operation period: 4 hours, the number of utilization : 2 times)

2. Picking up combinations of operation patterns of facilities in each day fulfilling Eq.2 and 3 (In Eq.3 , Scale of DG, S_{DG} is substituted for output of DG, P_{DG})

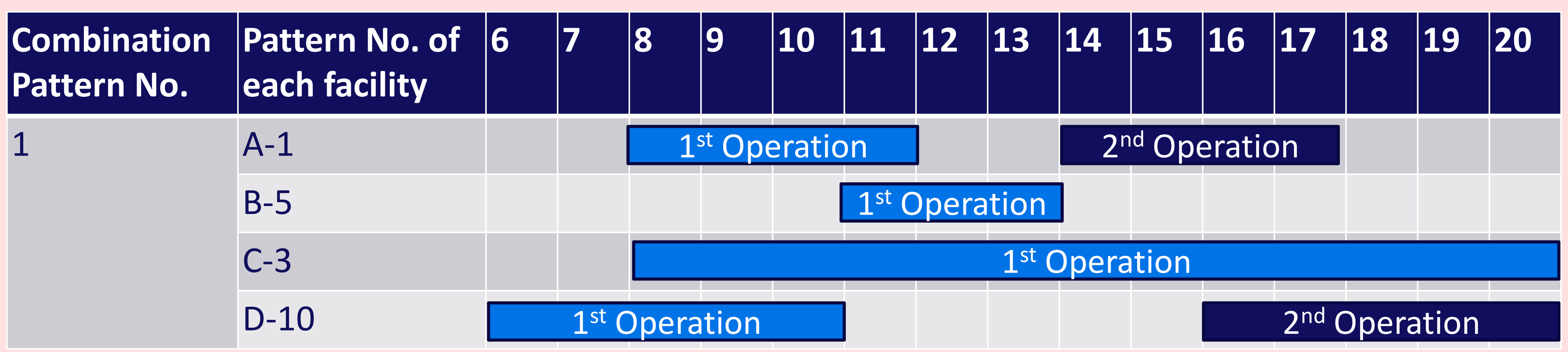

Figure 3 Example of enumerating combinations of operation patterns of facilities

3. Identifying the time slot in which DG must be operated in order to fulfilling Eq.2
4. Determining δ_{DG} in order to fulfill the daily-start-and-stop constraint
5. Searching optimal load factor of a distributed generator in each combination (Eq.6, Eq.9)
6. Calculation of values of objective function in each combination pattern,
7. Comparing of the values of objective function and choosing the best one
8. If the customer contracts a peak-time-rebate-type demand response program, start this algorithm flow again at next beta-value in Eq. 2.. Search optimal beta-value.

Result & Discussion

◆ Calculation Result

Bottom graph of Fig.1 shows the example result of OPTLOAD applied in Institute of Technology in Shimizu Corporation.

◆ Calculation spec of OPTLOAD

Enumeration method reaches the optimal solution , but on the other hand , calculation time tends to be long. OPTLOAD applies the enumeration method for optimizing calculation, but it excludes operation patterns not fulfilling constraints, especially, "Algorithm 1", so calculation time is very short. (Table 2)

Table 2 Spec of Scheduling software "OPTLOAD"

		Note
The number of days	5 days	Monday to Friday
Time slot in a day	15 hours	from 6 o'clock to 21 o'clock
The number of facilities including DG	7	
The number of binary variables	355	Summation of "1" of "Time-of-facilities –available" in Tables in Fig.1
Calculation time	20 seconds	Machine spec CPU: Intel(R)Core(TM)i7 800 3.07GHz × 2 Memory: 4.00GB

◆ Future Work

- ✓ Taking into account thermal demand in OPTLOAD
- ✓ Heuristic approach is necessary when OPTLOAD is applied in a customer having large number of facilities.