Development of planning optimization method for distributed energy system using GA

Objectives

Genetic algorithm (GA)

This algorithm mimics animals behaviors and evolution to find a better solution

First generation

Second generation

\( n \) th generation

- This method is the best for finding a better solution when there are many combinations.
- Nonlinear configuration is one of the suitable condition when using GA.

Conceptual diagram of optimization method

Many combinations of machines
Complex heat balances

Many combinations of operating schedules
Hard to plan an optimal system
Evaluation of a suggested plan is not easy

Nonlinear characteristics
Key factor is an optimization method

Central energy system
Heat-sharing system

Distributed energy system

Objectives

Although this concept could improve the efficiency and resilience of the city, it is not easy to decide an optimal solution. Thus, an optimization method is significant.

Ex) Hachinohe city, Kita-kyushu city and so on.

This concept promote to introduce renewable energy in districts.

• This method is the best for finding a better solution when there are many combinations.
• Nonlinear configuration is one of the suitable condition when using GA.
Development of planning optimization method for distributed energy system using GA

Multi-objective optimization of energy consumption and saving costs

We developed an optimization method (objective function is primary energy consumption)

Initial costs
Machine prices
- Catalogue
- Questionnaire
- Making regression models

Introducing costs
- Catalogue
- Making regression models

Running and maintenance costs
\[ \text{Cost}_{\text{run}} = \text{Cost}_{\text{gas}} + \text{Cost}_{\text{electricity}} \times 30_{\text{days/mo}} \times 4_{\text{mo/yr}} \times 15_{\text{yr}} \]

Case study: Hospital with 6,000m² of total floor space
Objective function:
1) primary energy consumption
2) Initial and running costs

Multi-objective optimization

Energy usage vs. costs

Results: capacity combination (pareto solutions)

<table>
<thead>
<tr>
<th>System Candidate</th>
<th>Cooling TR1</th>
<th>Cooling/Heating TR2</th>
<th>Heating GB1</th>
<th>Hot Water HP1</th>
<th>Electricity AR1</th>
<th>Objectives</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 200 10 10</td>
<td>120 120 87 25 25 186 10 10</td>
<td>380 300 500</td>
<td>64,754 149,254</td>
<td>Energy minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0 150 20 0</td>
<td>50 120 87 32 25 186 10 10</td>
<td>380 300 50</td>
<td>65,843 130,736</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0 150 0 10</td>
<td>100 120 87 0 25 186 10 10</td>
<td>380 300 0</td>
<td>68,117 108,434</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>125 150 20 0</td>
<td>50 120 87 32 25 186 10 10</td>
<td>380 230 500</td>
<td>68,548 94,516</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0 215 0 0</td>
<td>100 100 186 25 25 186 10 10</td>
<td>380 350 0</td>
<td>72,891 88,216</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0 200 0 10</td>
<td>100 120 87 25 0 232 10 10</td>
<td>380 350 0</td>
<td>75,279 81,231</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0 0 10 0</td>
<td>100 120 58 10 0 186 10 10</td>
<td>380 300 0</td>
<td>80,447 68,465</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>0 0 16 0</td>
<td>100 120 87 20 10 186 10 10</td>
<td>380 350 0</td>
<td>86,552 52,554</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>0 0 0 0</td>
<td>100 120 58 0 10 186 10 10</td>
<td>380 350 0</td>
<td>92,526 44,164</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>0 0 0 0</td>
<td>100 120 87 0 10 186 10 10</td>
<td>350 350 0</td>
<td>109,168 42,270</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results: capacity combination (pareto solutions)

<table>
<thead>
<tr>
<th>System Candidate</th>
<th>Cooling TR1</th>
<th>Cooling/Heating TR2</th>
<th>Heating GB1</th>
<th>Hot Water HP1</th>
<th>Electricity AR1</th>
<th>Objectives</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 200 10 10</td>
<td>120 120 87 25 25 186 10 10</td>
<td>380 300 500</td>
<td>64,754 149,254</td>
<td>Energy minimum</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>0 150 20 0</td>
<td>50 120 87 32 25 186 10 10</td>
<td>380 300 50</td>
<td>65,843 130,736</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>0 150 0 10</td>
<td>100 120 87 0 25 186 10 10</td>
<td>380 300 0</td>
<td>68,117 108,434</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>125 150 20 0</td>
<td>50 120 87 32 25 186 10 10</td>
<td>380 230 500</td>
<td>68,548 94,516</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>0 215 0 0</td>
<td>100 100 186 25 25 186 10 10</td>
<td>380 350 0</td>
<td>72,891 88,216</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>0 200 0 10</td>
<td>100 120 87 25 0 232 10 10</td>
<td>380 350 0</td>
<td>75,279 81,231</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>0 0 10 0</td>
<td>100 120 58 10 0 186 10 10</td>
<td>380 300 0</td>
<td>80,447 68,465</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>0 0 16 0</td>
<td>100 120 87 20 10 186 10 10</td>
<td>380 350 0</td>
<td>86,552 52,554</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>0 0 0 0</td>
<td>100 120 58 0 10 186 10 10</td>
<td>380 350 0</td>
<td>92,526 44,164</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>0 0 0 0</td>
<td>100 120 87 0 10 186 10 10</td>
<td>350 350 0</td>
<td>109,168 42,270</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Development of planning optimization method for distributed energy system using GA

**Optimal planning of heat sharing between two buildings**

The building and machine models were improved to deal with a heat-sharing network between two buildings.

The new model considered detail functions of pipes and heat losses.

**Heat losses through the pipes**
- Regression model was developed
- Amount of heat loss depended on thermal output of machine.
- Heat loss: $Q_{loss} = \frac{1}{d_i\alpha_i} + \frac{1}{d_o\alpha_o} \left( \ln \frac{d_i}{d_o} + \frac{1}{\alpha_o} \ln \frac{d_o}{d_i} \right) \left( 1 - e^{-\frac{\Delta T}{T}} \right)$

**Connected pipe with two buildings**

<table>
<thead>
<tr>
<th>Diameter: $d_1$:200~400A</th>
<th>Thickness: $d_2$:25mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation material: $d_2$:32mm</td>
<td>Temperature difference: $\Delta T$</td>
</tr>
<tr>
<td>$\Delta T$:7°C (cooling)</td>
<td>$\Delta T$:12°C (heating)</td>
</tr>
</tbody>
</table>

**Case studies: office and residential building**

- Case1a: Without heat-sharing
- Case2a: Connected buildings
- Case1b: Heat-sharing
- Case2b: Heat-sharing

**Results: primary energy consumption**

- Case1a: Office building
- Case1b: Residential building

**Optimal operation in Summer**

**Optimal operation in intermediate season**

- APT: 27.2%
- CGS: 32.3%
- TR: 30.5%

**Video:**

1. Video of optimal planning methodology
2. Video of heat loss calculation
3. Video of connected pipe design