Development of Prediction Method of Characteristics of Stratified Thermal Storage by Machine Learning

Research Background and Purpose
In recent years, the use of artificial neural network (ANN) has attracted attention as the optimal operation of building facilities. However, ANN model has a concern that prediction errors may occur depending on the training data and the training method. Therefore, in this study, the thermal stratified heat storage tank was modelized and the feasibility of ANN was clarified through case study.

Methodology
In modeling of ANN, the training data is necessary to be prepared, and in this study, training data set was prepared in different ways and the results from those different training data set was compared.

Training Data for ANN

1) Utilization of calculation results through physical model
   • The number of stratification in storage tank: 20 layer
   • Initial temperature: 14 ℃
   • Overall heat transfer coefficient: 0.5 W/(m² K)
   • Water temperature from heat source during charging($T_C$): 4 ℃
   • Return temperature from secondary side during discharging($T_R$): 14 ℃
   • Total rated output in heat source: assumed to be 20,500 kW
   • Operation plan for charged heat amount
     2000 patterns of operation plan was randomly written in reference to the average cooling load data in August by CASCADEIII

2) Utilization of measured data
   • Actual building’s measured data located in Tokyo
   • Duration of measurement: 2016/1/1～12/31 (Measuring intervals 10min)
   • The number of stratification in storage tank: 20 layer
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Case study
- $Q^{t-1}$: Remaining heat amount at previous time
- $Q^t$: Predicted remaining heat amount at current time
- $T_{20}^{t-1}$: Temperature of 20th layer at previous time
- $T_{20}^t$: Predicted temperature of 20th layer at current time
- $T_{1}^{t-1}, \ldots, T_{20}^{t-1}$: Temperature of all layers at previous time
- $T_{1}^{t}, \ldots, T_{20}^{t}$: Predicted temperature of all layers at current time

<table>
<thead>
<tr>
<th>Data source</th>
<th>Input data</th>
<th>Output data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Physical model</td>
<td>$Q^{t-1}, Q^t, T_{20}^{t-1}$</td>
</tr>
<tr>
<td>Case 2-1</td>
<td>Measured data</td>
<td>$Q^{t-1}, Q^t, T_{20}^{t-1}$</td>
</tr>
<tr>
<td>Case 2-2</td>
<td>Measured data</td>
<td>$Q^{t-1}, T_{1}^{t-1}, \ldots, T_{20}^{t-1}$</td>
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</tbody>
</table>

Training Condition
- Used Tool: MATLAB R2017a Neural network toolbox
- Algorithm: Levenberg-Marquardt

<table>
<thead>
<tr>
<th>Structure of ANN</th>
<th>Number of hidden nodes</th>
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<tbody>
<tr>
<td>Case 1 4 layer (input – hidden – hidden – output)</td>
<td>10 nodes</td>
</tr>
<tr>
<td>Case 2-1 4 layer (input – hidden – hidden – output)</td>
<td>10 nodes</td>
</tr>
<tr>
<td>Case 2-2 4 layer (input – hidden – hidden – output)</td>
<td>20 nodes</td>
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As a result, all of 3 cases showed high prediction accuracy. Therefore, it turned out that it is important to select an appropriate ANN structure, input/output data considering the difficulty of training data preparation.