METHODOLOGIES OF ON-GOING COMMISSIONING FOR AN EXISTING BUILDING WITH VRV ICE THERMAL STORAGE SYSTEMS

Ken Sekiyama
Motoi Yamaha
Chubu University
JAPAN
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   What are VRV ice thermal storage systems?

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Variable refrigerant volume (VRV) systems are commonly used in Japan.

The indoor units of each room can be operated independently.

Moreover, some VRV systems have ice thermal storage tanks for sub-cooling of the refrigerant to increase the cooling capacity of the systems.

They achieve peak shaving of power consumption.
Commissioning of VRV systems is hardly completed.

Difficult to measure the actual cooling capacities in operation.

The objective of this study

To establish methodologies for the on-going commissioning of VRV ice thermal storage systems in existing buildings by evaluating measurement results.
Methods of this study

Analysis of measured data

- By using a visualization tool
- By calculating the ratio of shifted power consumption
- By using the primary power consumption per total floor area
The detail of the measured building

<table>
<thead>
<tr>
<th>Building name</th>
<th>Chubu University Building No. 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total floor area</td>
<td>6,964 m²</td>
</tr>
<tr>
<td>Building structure</td>
<td>SRC structure</td>
</tr>
<tr>
<td>Building scale</td>
<td>6 floors above the ground, 1 floor underground</td>
</tr>
<tr>
<td>Uses of this building</td>
<td>Lectures, seminars</td>
</tr>
<tr>
<td>Air conditioning facilities</td>
<td>VRV ice thermal storage systems</td>
</tr>
</tbody>
</table>
The detail of the measured rooms

The lecture rooms on the second floor

The seminar rooms on the fourth floor

<table>
<thead>
<tr>
<th>PAC3</th>
<th>PAC7</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The cooling capacity</strong></td>
<td><strong>78kW</strong></td>
</tr>
<tr>
<td>120kW</td>
<td></td>
</tr>
<tr>
<td><strong>The operations of the indoor units</strong></td>
<td><strong>Manually</strong></td>
</tr>
<tr>
<td>Occupancy sensors</td>
<td></td>
</tr>
</tbody>
</table>
The detail of the measurements

<table>
<thead>
<tr>
<th>Measured quantities</th>
<th>Measuring devices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor temperature and humidity</td>
<td>Hand-held temperature and humidity recorders</td>
</tr>
<tr>
<td>Outdoor temperature and humidity</td>
<td>Wattmeters</td>
</tr>
<tr>
<td>Power consumption of each system</td>
<td>Solar radiation meter</td>
</tr>
<tr>
<td>Amount of direct solar radiation</td>
<td>Power meters</td>
</tr>
<tr>
<td>Power consumption in the entire building</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>The measurement periods</th>
<th>The spring semester</th>
<th>The summer vacation</th>
<th>The fall semester</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From May 25th to</td>
<td>From Jul. 15th to</td>
<td>From Sept. 21st</td>
</tr>
<tr>
<td></td>
<td>Jul. 14th</td>
<td>Sept. 20th</td>
<td>to Dec. 22nd</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Air-conditioning periods</th>
<th>Cooling operation period</th>
<th>Heating operation period</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>From May 25th to Nov. 10th</td>
<td>After Nov. 11th</td>
</tr>
</tbody>
</table>

This building was totally closed from 10th to 15th of August over the summer holidays.
Results and Analysis
A visualized chart of temperature in a lecture room during the spring semester displays the data by a color scale.

The indoor temperature decreased at around 9:00, and it was steady between 24C and 26C until 17:00.

The indoor temperature was about 20C during Tuesday afternoons every week.

This reason is thought to be due to the occupants of the room lowering the target temperature of the room.
Indoor humidity in a lecture room during the fall semester

In heating period, the humidity went down below 40% RH.

This value is lower limit in Japanese building code.

This reason was that the VRV system didn’t humidify the room in heating operation.
Power consumption of PAC3 during the spring semester

- The electric power was consumed constantly during lecture time.
- The electric power was used for ice thermal storage at night. This power consumption was much greater than that during the day.

The thermal storage operation continued only for three hours.

Storage operation appeared longer on only few days, when stored ice was completely melted.

It was considered that ice was left for other days.
Power consumption of PAC7 during the spring semester

The power consumption for PAC7 during day was less than that for PAC3.

For some days, the electric power around 3kW was consumed even in nighttime.

This reason is to not turn off the indoor units since these were controlled manually.
Power consumption of both systems during summer vacation

- The power consumption in daytime decreased.
- No electric power was consumed during the day from 10th to 15th of August when the building was completely closed.
- Nevertheless, the thermal storage was done every night as if it was ordinary day.
Power consumption of both systems during the fall semester

- The cooling operation continued until the beginning of November.
- In heating period, the electric power was consumed sporadically, because the heating load became lower than minimum capacity of heating operation.
- Inappropriate operation due to not turning off the indoor units in the heating operation period happened more frequently.
- Thermal storage for heating was also operated during the heating operation period.
The ratio of shifted power consumption during the spring semester

\[ \eta_n = \frac{E_n}{E_D} \times 100 \]

- \( \eta_n \) : The ratio of shifted power consumption [%]
- \( E_n \) : The power consumption during a night (22:00~8:00) [kW]
- \( E_D \) : The power consumption during a day [kWh]

The average of the ratio of PAC3 was about 34%.

Because the ratio of the manufacturer’s specification was 30%, it is considered that the ice thermal storage operation was appropriate.

The average of the ratio of PAC7 was about 42%.

This value was more than the manufacturer’s specification value.

This reason was that the time of air-conditioning at daytime was short.
The estimation of heat loss from ice tank

The maximum power consumption at night occurred on May 25th.

No power consumption in the day during summer vacation

The ratio of heat loss was calculated by dividing power consumption with maximum

The thermal storage operation in this period had replenished the ice that had melted without being used for air-conditioning during the day.
The estimated heat loss from ice tank

The result was about 7%.

These thermal storage tanks melted about 7% ice in the height of summer.

\[ \delta_{nh} = \frac{E_{nh}}{E_{nf}} \times 100 \]

\( \delta_{nf} \): The ratio of the power consumption at nighttime [%]  
\( E_{nh} \): The power consumption at nighttime [kWh]  
\( E_{nf} \): The maximum power consumption at nighttime [kWh]
Summary

The VRV ice thermal storage systems installed in the lecture building of Chubu University had been measured, and the methods of evaluating the measurement data had been examined.

By using our methods, we have detected the problems in use and the performance of systems.

<table>
<thead>
<tr>
<th>Problems in use</th>
<th>Performance of systems</th>
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<tbody>
<tr>
<td>•Occupants sometimes set target temperature inadequately low in cooling operation period.</td>
<td></td>
</tr>
<tr>
<td>•These systems were operated for ice thermal storage without cooling during the day in summer vacation.</td>
<td></td>
</tr>
<tr>
<td>•The indoor units were sometimes left operated.</td>
<td>•The ratio of sifted power consumption satisfied with the manufactures specification.</td>
</tr>
<tr>
<td></td>
<td>•Heat loss from ice tank was estimated as 7 %.</td>
</tr>
<tr>
<td></td>
<td>•Estimation of baseline of energy consumption will be future study.</td>
</tr>
</tbody>
</table>
Thank you for your attention.