Retro-commissioning Practice and In-depth Analysis: Case Study on A Retail Mall in China

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Speaker: Jean Qin, Swire Properties Ltd.
Background
Challenge: Multi-discipline

Owner

Designer

Manufacturer

T&C Executors

Contractor

Operator

Government departments
Challenge: Limited Budget and Tight Schedule

Stringent Regulations vs. “Loose” Implementation

No separate budget for T&C

Tight Schedule

- Owner: Schedule for Opening
- Contractors/Consultants: Eager to leave
Common Problems

T&C requirements were not fully understood during the design stage
T&C facilities were not installed
No space reserved for T&C
Technical data / catalogues outstanding
Retro-commissioning Process

**Level 1**
- Equipment performance commissioning
  1. Testing on the performance of major equipment (chiller, pump, cooling tower, boiler, air-side equipment, etc.)
  2. Commissioning under part-load conditions

**Level 2**
- System performance commissioning
  1. Commissioning for system balance
  2. Commissioning for terminal devices
  3. Pressure distribution measurement of water systems
  4. Commissioning for system control performance

**Level 3**
- Annual operation commissioning
  1. Whole year heating & cooling system control and BMS performance
  2. Whole year energy pattern analysis and saving opportunities identification

Retro-commissioning process
Commissioning process

Organisers: CONSTRUCTION INDUSTRY COUNCIL, HKGBC, SBE SERIES, iiSBE
International Co-owners: Global Alliance for Buildings and Construction
A Retail Mall: Sino-ocean Taikoo Li Chengdu
Historical Buildings
Energy Study During Design

- Whole year heating/cooling load simulation
- Heating/Cooling source: life cycle analysis – central plant/de-central plant/ice storage/tri-gen system
- Jet-fan and CO level control for car-park ventilation
- Primary variable flow chilled water system
- Cooling tower free cooling
- Fresh air free cooling and demand control
- Energy recovery wheel life cycle analysis
- Microclimate analysis
HVAC Systems

- Cooling

- Heating
Level 1: Equipment Performance Commissioning
<table>
<thead>
<tr>
<th>Equipment performance commissioning</th>
<th>Testing object</th>
<th>Testing Parameters and evaluation index</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>COP of chiller, capacity and efficiency of boiler, efficiency of cooling tower</td>
<td>Measure the COP of the chiller at the rated flow, rated supply/return water temperature. Measure boiler gas consumption, water flow, supply/return water temperature. Evaluate the output and efficiency of the boiler. Measure the supply/return water temperature, flow of water and air, operation power of the cooling tower, etc. Evaluate the efficiency of the cooling Tower.</td>
</tr>
<tr>
<td></td>
<td>Performance of pump (CHW pump, condensing water pump, hot water pump)</td>
<td>Measure the pump head, power under different flow rate, calculate the efficiency of the pump, make the flow-efficiency, flow-pressure, flow-power curve of the pump.</td>
</tr>
<tr>
<td></td>
<td>Efficiency of plate heat exchanger (hot water and free-cooling)</td>
<td>Measure flow rate and supply/return water temperature of plate heat exchanger, evaluate the efficiency of plate heat exchanger.</td>
</tr>
<tr>
<td></td>
<td>Performance of air-side equipment (primary air unit, air handling unit, fan)</td>
<td>Measure air flow, air pressure, operation power, supply air temperature, evaluate the performance of air-side equipment.</td>
</tr>
</tbody>
</table>
Pumps

<table>
<thead>
<tr>
<th>Pump</th>
<th>Flow (m³/h)</th>
<th>Head (mH₂O)</th>
<th>Power (kW)</th>
<th>Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1100</td>
<td>41</td>
<td>160</td>
<td>88.8</td>
</tr>
</tbody>
</table>

Graphs showing measured and specified performance characteristics.
Chillers

Chiller No. 3

Chiller No. 4

Chiller No. 6
Cooling Towers

Before

After
Level 2: System Performance
Commissioning
System performance commissioning

Testing object

- Hydraulic balance testing for main equipment of the heating & cooling system
- Pump commissioning under operating conditions
- Water system pressure measurement
- Balancing valve commissioning
- Air balance

Testing Parameters and evaluation index

- Measure the flow rate of each equipment and adjust the pumps to the reasonable flow.
- Adjust the group of pumps in parallel to the operating conditions by the valve adjustment or the control of VSD.
- Measure the pressure of the critical points of the system, discover unreasonable resistance.
- Balancing all water loops by operating the balance valve.
- Balancing the branches by adjusting the dampers provided. Each air diffuser needs to be measured to obtain the required air flow.
Unreasonable Resistance
# Free Cooling

## Design Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design</th>
<th>Trial Free Cooling Operation</th>
<th>Trial Chiller Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outlet Temperature ( °C )</td>
<td>11.0</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>Inlet Temperature ( °C )</td>
<td>8.0</td>
<td>9.2</td>
<td></td>
</tr>
<tr>
<td>Flow rate ( m³/h )</td>
<td>1432.0</td>
<td>1393.0</td>
<td></td>
</tr>
<tr>
<td>Cooling Load ( kW )</td>
<td>4996.2</td>
<td>1021.1</td>
<td>1021.1</td>
</tr>
<tr>
<td>Chiller ( kW )</td>
<td>0</td>
<td>0</td>
<td>145.9</td>
</tr>
<tr>
<td>Cooling Tower ( kW )</td>
<td>88.6</td>
<td>88.6</td>
<td>45.0</td>
</tr>
<tr>
<td>Pump ( kW )</td>
<td>229.9</td>
<td>229.9</td>
<td>15.0</td>
</tr>
<tr>
<td>System COP</td>
<td>15.7</td>
<td>3.2</td>
<td>5.0</td>
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</tbody>
</table>
Level 3: Dynamic Operation Commissioning
Annual system operation commissioning and reconstruction

T&C Stage Object Testing Parameters and evaluation index

Heating & cooling system control
- Check the strategy, interface, functionality, accuracy of sensor.

BMS system
- Check the completeness of the user control strategy, interface and control function. Check the accuracy of sensors and the realization of control function.

Efficiency operation strategy for heating & cooling system
- Research on outlet chilled water temperature setting, operation strategy of cooling tower, pressure differential of chilled water setting, collocation of large & small chillers, etc.

Efficiency operation strategy for air-side System
- Research on operating strategy of primary air unit, air handling unit and fine-tune the set-points.

Energy-saving reconstruction
- Executing energy-saving reconstruction of equipments and systems by In-depth operation data mining.

Energy-saving reconstruction

Annual system operation commissioning and reconstruction

combination
Chiller Sequencing Control

<table>
<thead>
<tr>
<th>CT Operating Hz</th>
<th>Chillers ON</th>
<th>Cooling Towers ON</th>
<th>CT Operating Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>1</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>2</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>25</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>25</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>25</td>
<td>2</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>31</td>
<td>3</td>
<td>1</td>
<td>6</td>
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<tr>
<td>31</td>
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<tr>
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<td>6</td>
</tr>
<tr>
<td>31</td>
<td>2</td>
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<td>31</td>
<td>0</td>
<td>3</td>
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</table>
BMS Function of Control Valves

- northeast loop
- northwest loop
- southwest loop
- cinema loop
- central loop 1
- central loop 2

- 10:00-22:00
- 22:00-1:00
- 6:30-10:00

Shop

Riser

FCU

FCU

FCU
Conclusion
Energy Saving

![Energy Saving Chart]

- Fresh air demand control: 337 MWh/Year
  - Year 2016 Saving: 169 MWh/Year
  - Year 2017 Saving: 178 MWh/Year
- CT control improvement: 281 MWh/Year
  - Year 2016 Saving: 121 MWh/Year
  - Year 2017 Saving: 160 MWh/Year
- Condensing pumps VSD retrofitting: 130 MWh/Year
  - Year 2016 Saving: 89 MWh/Year
  - Year 2017 Saving: 41 MWh/Year
- Check valve replacement: 89 MWh/Year
  - Year 2016 Saving: 54 MWh/Year
  - Year 2017 Saving: 35 MWh/Year
- Better control of zone valves: 39 MWh/Year
  - Year 2016 Saving: 29 MWh/Year
  - Year 2017 Saving: 10 MWh/Year
Big Data Analysis

2. Total Electricity Consumption Breakdown
   (a) Total
   Yr. 2015
   4.2% 11.5% 41.1%
   30.9% 24.3% 48.2%
   Yr. 2016
   4.0% 11.0% 48.2%
   30.9% 24.3% 48.2%

   (b) Mall
   Yr. 2015
   4.5% 12.2% 43.6%
   28.0% 22.2% 10.3%
   Yr. 2016
   4.3% 11.8% 51.5%
   28.0% 22.2% 10.3%

4. Electricity Consumption Breakdown for Each Portfolio
   - AC Package Unit (Compressor Unit + Water Pump + Cooling Tower)
   - AC Air-Side
   - Lighting and Small Power (Mall + Carpark + Event Show + Exterior)
   - Lift and Escalator
   - Others

   Notes:
   (a) Negative value implies reduction/saving.
   (b) AC Air-Side includes air distribution and mechanical vents.
   (c) Lighting and Small Power includes lighting and small power.
   (d) Others includes plumbing and drainage system and fire system.

   - AC Water Side
   - AC Air-Side
   - Lighting and Small Power (Mall + Carpark + Event Show + Exterior)
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Life Cycle Management

Adopt a holistic standard process in managing the life cycle of the building

- Seamless Takeover
  - T&C, QA/QC & Documentation
- New Project
- Handover
- Operating Buildings
- Integrated Design Approach
- Continuous Improvement
  (Knowledge-based energy management)
- Design feedback / Operating experience input
Thank you