Retro-commissioning (RCx)
Sample Technical Approaches from Pilot Projects
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<td>Adjust the chiller load factor in order to improve chiller efficiency</td>
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Retro-commissioning (RCx)

Example 1 - Chiller Sequencing Optimization

- ESO: Improving COP – More chillers operated at partial load

Facility / Equipment

Observation

- 4 sets of VSD air-cooled chillers (3 duty & 1 standby) with 4 sets of chilled water pumps (3 duty & 1 standby)
Example 1 - Chiller Sequencing Optimization

- ESO: Improving COP – More chillers operated at partial load

**Facility / Equipment**

**Principle**

- VSD air-cooled chiller has higher COP in part load condition

VSD Air-cool chiller’s performance curves under different condensate water temp.
Example 1 - Chiller Sequencing Optimization

- ESO: Improving COP – More chillers operated at partial load

Observation

- Two chiller combinations (2 chillers and 3 chillers) have been used between an overall loading of 30%-50% loading.
Retro-commissioning (RCx)

Example 1 - Chiller Sequencing Optimization

- ESO: Improving COP – More chillers operated at partial load

Facility / Equipment

**Recommendation**

- Three chillers are now used between an overall loading of 30%-50% loading.
Example 1 - Chiller Sequencing Optimization

- ESO: Improving COP – More chillers operated at partial load

Remarks:

100% of COP = Baseline COP (before RCx) = 3.39

108.2% of COP = Improved COP (after RCx) = 3.67
Retro-commissioning (RCx)

Example 2 - Chiller Sequencing Optimization

ESO: Prevent the activating of low-cut function of the oil-free chiller at light load operation

Facility / Equipment

Observation

- The building is served by 2 sets of air-cooled chiller (1 duty & 1 standby). One of the chillers is an oil-free centrifugal chiller (the duty chiller - new) with 2 compressors and the other one is an air-cooled screw chiller (the standby chiller - old) with 4 compressors.
Example 2 - Chiller Sequencing Optimization

ESO: Prevent the activating of low-cut function of the oil-free chiller at light load operation

Facility / Equipment

Observation

- During peak seasons, the oil-free chiller were only running at about 50-60%.
- Because it is a constant pump speed differential pressure bypass system, the chilled water temperature difference is only about 3 deg C or below resulting from the large among of chilled water needed to be bypassed back to the chiller.
Example 2 - Chiller Sequencing Optimization

ESO: Prevent the activating of low-cut function of the oil-free chiller at light load operation

Facility / Equipment

Recommendation

- Modify the low temperature cut control so that the chiller will be switched to standby mode (with the compressor stopped) instead of tripping the chiller when the chiller water is lower than the cut-off temperature.
- Maintain the chilled water temperature difference across the chiller not less than 5 deg.C by converting the system to primary variable flow.
Retro-commissioning (RCx)

Example 3 - Air-conditioning (Central Chiller plant)

- ESO: Adjust the chiller’s load factor by CHWST setpoint reset in order to improve chiller efficiency

<table>
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<tr>
<th>Facility / Equipment</th>
<th>Observation</th>
<th>Existing chiller load distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller 1</td>
<td>Chiller 2</td>
<td>Chiller 1</td>
</tr>
<tr>
<td>Type of Chiller</td>
<td>CSD</td>
<td>VSD</td>
</tr>
<tr>
<td>Existing CHWST Setpoint</td>
<td>7 deg C</td>
<td>7 deg C</td>
</tr>
<tr>
<td>Existing Distribution of Chiller Average Load Factor</td>
<td>60%</td>
<td>60%</td>
</tr>
</tbody>
</table>
Retro-commissioning (RCx)

Example 3 - Air-conditioning (Central Chiller Plant)

- ESO: Adjust the chiller’s load factor by CHWST setpoint reset in order to improve chiller efficiency

---

**Facility / Equipment**

**Observation**

**Existing monthly COP of chillers**

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller 1 (CSD) COP</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>4.04</td>
<td>3.97</td>
<td>3.56</td>
<td>3.56</td>
<td>3.56</td>
<td>3.56</td>
<td>3.56</td>
<td>3.85</td>
<td>NA</td>
</tr>
<tr>
<td>Chiller 2 (VSD) COP</td>
<td>5.36</td>
<td>5.36</td>
<td>4.8</td>
<td>4.19</td>
<td>4.38</td>
<td>3.81</td>
<td>3.68</td>
<td>3.68</td>
<td>3.68</td>
<td>4.38</td>
<td>4.64</td>
<td>6.22</td>
</tr>
</tbody>
</table>
Retro-commissioning (RCx)

Example 3 - Air-conditioning (Central Chiller Plant)

- ESO: Adjust the chiller’s load factor by CHWST setpoint reset in order to improve chiller efficiency

Recommendation

COP Curve of CSD chiller

From the sample CSD Chiller graph, COP is the highest at 70 to 80%.

COP Curve of VSD chiller

From the sample VSD Chiller graph, COP keep increasing in part load condition.
Example 3 - Air-conditioning (Central Chiller Plant)

- ESO: Adjust the chiller’s load factor by CHWST setpoint reset in order to improve chiller efficiency

### Proposed chiller load distribution

<table>
<thead>
<tr>
<th></th>
<th>Chiller 1</th>
<th>Chiller 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Chiller</strong></td>
<td>CSD</td>
<td>VSD</td>
</tr>
<tr>
<td><strong>Proposed CHWST Setpoint</strong></td>
<td>6.5 deg C</td>
<td>7.5 deg C</td>
</tr>
<tr>
<td><strong>Proposed Distribution of Chiller Average Load Factor</strong></td>
<td>70%</td>
<td>50%</td>
</tr>
</tbody>
</table>

### Proposed COP of chillers

<table>
<thead>
<tr>
<th></th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chiller 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(CSD) COP</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>4.07</td>
<td>4.07</td>
<td>3.61</td>
<td>3.61</td>
<td>3.61</td>
<td>3.61</td>
<td>4.07</td>
<td>3.97</td>
<td>NA</td>
</tr>
<tr>
<td><strong>Chiller 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(VSD) COP</td>
<td>5.36</td>
<td>5.36</td>
<td>4.8</td>
<td>4.56</td>
<td>4.64</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4.64</td>
<td>4.72</td>
<td>6.22</td>
</tr>
</tbody>
</table>

Retro-commissioning (RCx)
Example 3 - Air-conditioning (Central Chiller Plant)

- ESO: Adjust the chiller’s load factor by CHWST setpoint reset in order to improve chiller efficiency

**Energy saving**

- Annual electricity consumption before RCx: 353,370kWh
- Annual electricity consumption after RCx: 343,450kWh
- Savings 9,920kWh (~3% of annual chiller electricity consumption)
Retro-commissioning (RCx)

Example 4 - Air-conditioning (Central Chiller Plant)

- ESO: Evaluating existing chiller plant performance with retrofitting consideration

**Facility / Equipment**

**Observation**

- 4 sets of chillers in operation
- Some compressors are out of order
- The chillers are operating at 85% of full load current
Example 4 - Air-conditioning (Central Chiller Plant)

- ESO: Evaluating existing chiller plant performance with retrofiting consideration

**Facility / Equipment**

**Observation**

- Chilled water supply temp. unable to meet the set point 8.5 deg.C
- Differential bypass pipes cannot manually closed leading to 3.5 deg.C temp. difference of CHWS and CHWR
- The constant flow chilled water pumps were connected directly to individual chillers without a common header (less flexibility in controlling the flow through chillers)
Retro-commissioning (RCx)

Example 4 - Air-conditioning (Central Chiller Plant)

- ESO: Evaluating existing chiller plant performance with retrofitting consideration

Findings

- Figure 3a: more chillers than required to cater for the loading

Figure 3a Full load Ampere Vs cooling load
**Retro-commissioning (RCx)**

**Example 4 - Air-conditioning (Central Chiller Plant)**

- ESO: Evaluating existing chiller plant performance with retrofitting consideration

**Findings**

- Figure 3b: a very low chilled water temperature difference (< 3 deg C) across chillers

**Figure 3b Temp difference between CHWR and CHWS**
Example 4 - Air-conditioning (Central Chiller Plant)

- ESO: Evaluating existing chiller plant performance with retrofitting consideration

**Recommendation**

- To replace chillers
- To convert the chilled water system with a variable flow system

<table>
<thead>
<tr>
<th></th>
<th>Original</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chiller</td>
<td>4 x 400 TR Air-cooled (VSD)</td>
<td>3 x 400 TR Air-cooled (VSD)</td>
<td>2 x 400 TR Air-cooled (VSD)</td>
<td>2 x 450 TR Air-cooled (VSD)</td>
</tr>
<tr>
<td>Estimated Payback</td>
<td>9-10 years</td>
<td>8 years</td>
<td>6 years</td>
<td>5.5-6 years</td>
</tr>
<tr>
<td>Annual Saving (kWh)</td>
<td>1,365,000</td>
<td>1,365,000</td>
<td>1,210,000</td>
<td>1,490,000</td>
</tr>
</tbody>
</table>
### Retro-commissioning (RCx)

#### Example 5 - Air-conditioning (Central Chiller Plant)

- **ESO:** To upgrade chiller plant control system in order to improve energy efficiency operation.

#### Background Information

- 1 set of 1000 kW air-cooled screw type chiller and 2 sets of 1000 kW heat recovery screw type chillers for day-mode or high-demand operation time.
- 4 nos. of 9.0kW primary pumps and 3 nos. of 34.0kW secondary chilled water pumps.
- In night mode operation, 2 sets of air-cooled packaged screw heat pumps (300 kW) are operated with 3 nos. of 9.0 kW primary chilled water pumps.
## Retro-commissioning (RCx)

### Example 5 - Air-conditioning (Central Chiller Plant)

- **ESO:** To upgrade chiller plant control system in order to improve energy efficiency operation

### Facility / Equipment

<table>
<thead>
<tr>
<th>Loads</th>
<th>Bypass</th>
<th>Chillers</th>
</tr>
</thead>
</table>

### Observation

- The flow meters could not provide accurate readings
- The control logic of chiller plant could not be identified
- On site measurement on chilled water flow rate and not tally with CCMS

*Simplified schematic (For indicative only)*
Retro-commissioning (RCx)

Example 5 - Air-conditioning (Central Chiller Plant)

- ESO: To upgrade chiller plant control system in order to improve energy efficiency operation

Facility / Equipment

Recommendation

- To repair/ replace the water flow sensors
- To develop a proper control sequencing of chillers to meet the actual cooling load and improve the chiller performance
Retro-commissioning (RCx)

Example 5 - Air-conditioning (Central Chiller Plant)

- ESO: To upgrade chiller plant control system in order to improve energy efficiency operation

Principle

- To reset chiller water supply temperature at a higher value under partial load condition can reduce energy consumption of chiller
By operating the chillers at the designated chilled water supply and return temperature, excessive pump energy required for surplus chilled water flowrate can be avoided.

Example 5 - Air-conditioning (Central Chiller Plant)

- ESO: To upgrade chiller plant control system in order to improve energy efficiency operation

Principle

- By operating the chillers at the designated chilled water supply and return temperature, excessive pump energy required for surplus chilled water flowrate can be avoided.
Example 5 - Air-conditioning (Central Chiller Plant)

- ESO: To upgrade chiller plant control system in order to improve energy efficiency operation

Energy Saving Estimation *(Estimated Annual Energy Saving: 93,300 kWh)*

- Chilled water temperature reset (1.5°C) for day mode operation (Dec to Apr) => 10,000 kWh
- Reduction of operation for extra secondary chilled water pump (3 hrs saving on weekday from Jun to Nov) => 7,300 kWh
- Adjusted operation of night mode chiller & pump for equipment cooling (Dec to Apr) => 68,000 kWh
- Prevent extra pump operation of night mode chiller (May to Nov) => 8,000 kWh
Example 6 – Cooling Tower & Chillers Optimization

ESO: Reduce the condensing water entering temperature of chillers

Facility / Equipment

Observation

• 4 sets of centrifugal chiller (2 duty & 2 standby) with associated fresh water cooling towers and condensing water pumps connected in a one-to-one basis.

• The cooling towers, condensing water pumps and chillers are connected in series to common headers. Variable speed drives are installed for speed control of cooling tower fans.
Example 6 – Cooling Tower & Chillers Optimization

ESO: Reduce the condensing water entering temperature of chillers

Facility / Equipment

- The approach temperature of cooling towers ranges from 6 deg C to 12 deg C.
- While the condensing water entering temperature has not dropped to below 26 deg C even when the wet-bulb temperature falls to below 20 deg C.

Principle
Example 6 – Cooling Tower & Chillers Optimization

ESO: Reduce the condensing water entering temperature of chillers

Observation
Retro-commissioning (RCx)

Example 6 – Cooling Tower & Chillers Optimization

ESO: Reduce the condensing water entering temperature of chillers

Facility / Equipment

Recommendation

- to decrease the approach temperature during periods with lower wet-bulb.
- When the average approach temperature is higher than the recommended value, one more cooling tower will be called on and the cooling tower fan speed will start from 30 Hz and will be increased when the approach temperature still cannot meet.
Example 7 – Air-conditioning (Air-side System)

- ESO: To adjust indoor room air temperature thermostat

**Facility / Equipment**

**Observation**

- In an office, VAV system is adopted to serve the floor. The AHU supply air temperature is set to be 15 deg C in summer.
- Indoor room temp continues to drop due to the low set pt.
- Measure average indoor room temp is 23 deg C
Example 7 – Air-conditioning (Air-side System)

- ESO: To adjust indoor room air temperature thermostat

**Findings**

- AHU supply air temperature: 15 deg C
- Measured average return air temperature: 23 deg C
- Daily Operation Hours: 8am to 6pm
- \( DT_1 = 23 - 15 = 8 \) deg C

**Recommendation**

- Indoor room thermostat sets back to from 15 to 24 deg C
- Targeted average return air temperature: 24 deg C
Example 7 – Air-conditioning (Air-side System)

- ESO: To adjust indoor room air temperature thermostat

**Recommendations**

**ASHRAE Standard 90.1-2013 Table G3.1.3.15**

<table>
<thead>
<tr>
<th>Fan Part-Load Ratio</th>
<th>Fraction of Full-Load Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>0.10</td>
<td>0.03</td>
</tr>
<tr>
<td>0.20</td>
<td>0.07</td>
</tr>
<tr>
<td>0.30</td>
<td>0.13</td>
</tr>
<tr>
<td>0.40</td>
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<tr>
<td>0.50</td>
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<td>0.83</td>
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<td>1.00</td>
<td>1.00</td>
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</tbody>
</table>

**Site Measurement Findings**

<table>
<thead>
<tr>
<th></th>
<th>Before RCx</th>
<th>After RCx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measured Air Flow (L/s)</td>
<td>4450</td>
<td>3600</td>
</tr>
<tr>
<td>Fan Rated Flow (L/s)</td>
<td>4600</td>
<td>4600</td>
</tr>
<tr>
<td>Fan Part-Load Ratio</td>
<td>0.97</td>
<td>0.78</td>
</tr>
<tr>
<td>Fraction of Full Load Power</td>
<td>~0.95</td>
<td>~0.65</td>
</tr>
</tbody>
</table>
Example 7 – Air-conditioning (Air-side System)

- ESO: To adjust indoor room air temperature thermostat

**Energy Saving**

Measured electricity consumption of all AHUs in that measurement hour (before RCx)
= 590kW

Hourly Electricity Consumption after adjusting indoor air temperature set point hence reduces the AHU flowrate :
= 404 kWh

Assume the AHU operation from Monday to Friday, 8:00 to 18:00.
Numbers of hour that can adopt with similar cooling load in annual: 662 hours

Calculated annual electricity saving of all AHUs after RCx = 123,132 kWh – (A)

Measured annual electricity consumption saving of all AHUs before RCx = 1,348,950 kWh – (B)

Annual AHU electricity consumption saving is around 9%.
Example 8 - Air-conditioning (Air-side System)

- ESO: To adjust operation hours of Primary Air Handling Units

Background Information

- 4 nos. of Primary Air Handling Units (PAU) ranging from 5.8 m³/s to 9.2 m³/s
- Air Handling Units (AHU) serving conditioned spaces start operating from 8:00 a.m. on Tuesday to Friday whereas from 7:30 a.m. on Monday for morning start pre-cooling after weekend.
Facility / Equipment

• PAUs are interlocked with AHUs and operating with the same time schedule

• Delay in start-up of the PAUs can reduce cooling energy

• To modify the control logic PAUs

• PAUs will start only 15 minutes before the normal operating hours of the building

Observation & Recommendation

Example 8 - Air-conditioning (Air-side System)

- ESO: To adjust operation hours of Primary Air Handling Units
Retro-commissioning (RCx)

Example 8 - Air-conditioning (Air-side System)

- ESO: To adjust operation hours of Primary Air Handling Units

Energy Saving Estimation

- Potential saving of PAU fan power consumption (25kW)
- Potential saving from the chiller plant due to the reduction of cooling load from fresh air (120kW)
- Saving from operation of: delay start (1.25 hrs for Mon, 0.75 hrs for Tue to Fri) early stop (0.5 hrs for Mon to Fri)

Estimated Annual Energy Saving => 49,000 kWh
(~ 2.6 % of chiller plant annual energy consumption)
Facility / Equipment

Observation

- No reading on the air flow of some VAV boxes
- The position of air damper in such VAV box was fully opened
- The pressure sensors may be clogged or failed or deviated from design pressure/flow rate

Example 9 - Air-conditioning (Air-side System)

ESO: To review and adjust pressure setting for VAV systems
Retro-commissioning (RCx)

Example 9 - Air-conditioning (Air-side System)

- ESO: To review and adjust pressure setting for VAV systems

Recommendation:
- Repair/ replace faulty pressure sensors
- Review and adjust setting of VAV boxes
- Amount of air supplied by AHUs of VAV system could be reduced and lower the fan power consumption
The damper position of VAV box shall vary according to the dynamics of cooling demand in the conditioned space.

- If less cooling demand is required, the damper opening will reduce and the static pressure in the air duct will increase accordingly.

**Example 9 - Air-conditioning (Air-side System)**

- ESO: To review and adjust pressure setting for VAV systems

**Principle**

- The damper position of VAV box shall vary according to the dynamics of cooling demand in the conditioned space.
- If less cooling demand is required, the damper opening will reduce and the static pressure in the air duct will increase accordingly.
Retro-commissioning (RCx)

Example 9 - Air-conditioning (Air-side System)

- ESO: To review and adjust pressure setting for VAV systems

### Principle

- Under static pressure reset control, the volume of air delivered by VAV supply fan with variable speed drive will be reduced based on the pressure feedback signal.

- The power consumption of VAV supply fan is thus reduced due to lower supply air flowrate.
Retro-commissioning (RCx)

Example 9 - Air-conditioning (Air-side System)
- ESO: To review and adjust pressure setting for VAV systems

Energy Saving Estimation
- Estimated fan power saving from air side equipment: 18KW
- Saving from operation of 8 hours per day from Mon to Fri

Estimated Annual Energy Saving => 36,000 kWh
(~ 2% of chiller plant annual energy consumption)
Example 10 - Air-conditioning (Water-side System)

- ESO: To setback chilled water supply temperature during non-office hour operation

Background Information

- 2 sets of air-cooled packaged screw type chillers (1 duty & 1 standby each with 300 kW cooling capacity) for the non-office hour operation
- Chilled water supply temperature of these chillers is designed and operated at 7°C.
- Operation schedule of chiller is listed below:

Mon to Fri - 00:00 to 07:00 & 21:00 to 24:00
Sat - 00:00 to 07:00 & 17:00 to 24:00
Sun - 00:00 to 24:00
Retro-commissioning (RCx)

Example 10 - Air-conditioning (Water-side System)

- ESO: To setback chilled water supply temperature during non-office hour operation

Facility / Equipment

Observation

- The chilled water supply temperature is designed at 7°C in Summer
- Chilled water supply temperature can be higher during non-office hours for low cooling load
Retro-commissioning (RCx)

Example 10 - Air-conditioning (Water-side System)

- ESO: To setback chilled water supply temperature during non-office hour operation

**Facility / Equipment**

- **Loads**
- **Bypass**
- **Chiller**

**Simplified schematic**
(For indicative only)

**Recommendation**

- Setting higher (2°C) chilled water supply temperature during non-peak hours
Retro-commissioning (RCx)

Example 10 - Air-conditioning (Water-side System)

- ESO: To setback chilled water supply temperature during non-office hour operation

Energy Saving Estimation

- Assume 6% saving on average chiller plant power consumption (~ 30kW)
- Annual operation hours: (5 days x 10 hrs + 14 hrs + 24 hrs) x 52 weeks = 4,576 hours

Estimated Annual Energy Saving => 8,000 kWh
(~ 0.5 % of chiller plant annual energy consumption)
Retro-commissioning (RCx)

Example 11 - Air-conditioning (Water-side System)

- ESO: To adjust the chilled water flowrate during non-office hours

<table>
<thead>
<tr>
<th>Facility / Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small temp. difference</td>
</tr>
<tr>
<td>Loads</td>
</tr>
<tr>
<td>By pass</td>
</tr>
<tr>
<td>Chillers</td>
</tr>
</tbody>
</table>

Simplified schematic (For indicative only)

Observation

- Small temp. difference (2.7°C) between chilled water supply and return temperature at night mode
- Measured volume flow rate of chilled water supply is 20.7 l/s
- By keeping 5°C temperature difference, the required flow rate is 11.5 l/s only. The actual flow rate is almost doubled.
Example 11 - Air-conditioning (Water-side System)

- ESO: To adjust the chilled water flowrate during non-office hours

Recommendation

- Pump flow rate can be reduced at non-office hour
- Power consumption of the chilled water pump will be saved.
Retro-commissioning (RCx)

Example 11 - Air-conditioning (Water-side System)

- ESO: To adjust the chilled water flowrate during non-office hours

Energy Saving Estimation

- Pump Power reduced from 13.5kW to 8.0kW
- Annual operation hours: (5 days x 10 hrs + 14 hrs + 24 hrs) x 52 weeks = 4,576 hours

Estimated Annual Energy Saving => 25,000 kWh
(≈ 1.5% of chiller plant annual energy consumption)
Example 12 – Electrical Installation

- ESO: To review power quality of electrical distribution network

**Facility / Equipment**

**Observation**

**Baseline case:**
1. The building has 2 transformers (1 Tx for AC, 1 Tx for Ltg & power)
2. Measured PF below 0.92 and 0.9 respectively

**Optimization opportunities:**
1. Check Capacitor Banks, carry out necessary repair / upgrade work to improve PF
Retro-commissioning (RCx)

Example 12 – Electrical Installation

- ESO: To review power quality of electrical distribution network

Excessive distribution loss and poor power quality reduce efficiency of the electrical distribution network, cause unwanted energy losses, as well as overheating of conductors and apparatus that may impose additional cooling load for air-conditioning system.
Example 12 – Electrical Installation

- ESO: To review power quality of electrical distribution network

Power Factor & Copper Loss

- copper loss = I^2R
- The loss fraction reduction through improving power factor is expressed by:
  \[1-(PF/PF'\)^2\] x 100%
- When PF improves from 0.85 to 0.95, the loss fraction reduction is:
  \[1-(0.85/0.95)^2\] x 100% = 20%
- Assume the original copper loss of the circuit without correction device is 2%, the reduced copper loss is 0.4% (=2% x 20%) (assume correction devices install at load side)
- i.e. max. 0.4% energy saving
Example 12 – Electrical Installation

- ESO: To review power quality of electrical distribution network

**Power Factor & Demand Charge**

- Improving TPF of the building can directly reduce the demand charge by reducing the peak demand value.
- Reduction in peak demand can be calculated by:
  \((1 - \text{TPF} / \text{TPF'}) \times 100\%\)
- When TPF improves from 0.85 to 0.95
- Reduction in peak demand (kVA)
  \(= (1 - 0.85/0.95) \times 100\% = 10.5\%\)
Example 12 – Electrical Installation

- ESO: To review power quality of electrical distribution network

Example

- Annual electricity charge: $4,000,000 (85% energy charge, 15% demand charge)
- TPF from 0.85 to 0.95
- Energy charge saving = $4,000,000 x 0.85 x 0.4% = $13,600
- Demand charge saving = $4,000,000 x 15% x 10.5% = $63,000
- Total saving = $76,600
# HKE Tariff table (for reference)

## Max Demand Tariff (min. 100 kVA of chargeable demand) (1 Jan 2017)

<table>
<thead>
<tr>
<th>(a) Demand Charge</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>For each of the first 400kVA</td>
<td>$48.3</td>
</tr>
<tr>
<td>For each of the next additional kVA</td>
<td>$47.3</td>
</tr>
</tbody>
</table>

## (b) Energy Charge (basic without fuel adjustment)

### On-Peak Period

| For each of the first 200 units supplied per month per kVA of maximum demand | 101.0 cents |
| For each additional unit supplied in the month                              | 96.4 cents  |
# CLP Tariff table (for reference)

<table>
<thead>
<tr>
<th>Bulk Tariff (expected monthly consumption min. 20,000 units) (1 Jan 2017)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(a) Demand Charge</strong></td>
</tr>
<tr>
<td><strong>On-Peak Period</strong></td>
</tr>
<tr>
<td>Each of the first 650 kVA</td>
</tr>
<tr>
<td>Each kVA above 650</td>
</tr>
<tr>
<td><strong>Off-Peak Period</strong></td>
</tr>
<tr>
<td>Each off-peak kVA up to the on-peak billing demand</td>
</tr>
<tr>
<td>Each off-peak kVA in excess of the on-peak billing demand</td>
</tr>
<tr>
<td><strong>(b) Energy Charge (basic without fuel adjustment)</strong></td>
</tr>
<tr>
<td><strong>On-Peak Period</strong></td>
</tr>
<tr>
<td>Each of the first 200,000 units</td>
</tr>
<tr>
<td>Each unit over 200,000</td>
</tr>
<tr>
<td><strong>On-Peak Period</strong></td>
</tr>
<tr>
<td>Each unit</td>
</tr>
</tbody>
</table>
### CLP Tariff table (for reference)

#### Large Power Tariff (expected monthly consumption min. 3,000 kVA) (1 Jan 2017)

**(a) Demand Charge**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On-Peak Period</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Each of the first 5,000 kVA</td>
<td></td>
<td>$120.3</td>
</tr>
<tr>
<td>Each kVA over 5,000</td>
<td></td>
<td>$115.3</td>
</tr>
<tr>
<td><strong>Off-Peak Period</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Each off-peak kVA up to the on-peak billing demand</td>
<td></td>
<td>$0.0</td>
</tr>
<tr>
<td>Each off-peak kVA in excess of the on-peak billing demand</td>
<td></td>
<td>$33.9</td>
</tr>
</tbody>
</table>

**(b) Energy Charge (basic without fuel adjustment)**

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>On-Peak Period</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Each of the first 200 units per kVA of on-peak billing demand</td>
<td></td>
<td>56.7 cents</td>
</tr>
<tr>
<td>Each unit in excess of above</td>
<td></td>
<td>54.7 cents</td>
</tr>
<tr>
<td><strong>On-Peak Period</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Each unit</td>
<td></td>
<td>46.9 cents</td>
</tr>
</tbody>
</table>
### Energy Charge & Demand Charge in Electricity Bill

<table>
<thead>
<tr>
<th>Service</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Table:

<table>
<thead>
<tr>
<th>Meter Number</th>
<th>Meter Reading</th>
<th>Maximum Demand / Consumption</th>
<th>Amount HK$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present次</td>
<td>Previous上次</td>
<td>同電量 (kVA)</td>
<td>805.50</td>
</tr>
<tr>
<td>5413059</td>
<td>2641259</td>
<td>1495680</td>
<td>1319310</td>
</tr>
<tr>
<td>Basic Charge</td>
<td>消耗費</td>
<td>65,256.50</td>
<td></td>
</tr>
<tr>
<td>Fuel Adjustment</td>
<td>燃料調整</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Previous Balance</td>
<td>上次結算金額</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balance Carried Forward</td>
<td>前期餘額</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Peak demand**

**Total consumption**

**Demand charge**

**Energy charge**
Example 13 – Lighting System

- ESO: To adjust lighting level

**Facility / Equipment**

**Observation**

- In an office, the lighting level at different functional areas have been reviewed.
- Check the measurement results against current facility requirement and some international standard
- T5 1500 fluorescent tubes installed (each with 35W)
Example 13 – Lighting System

ESO: To adjust lighting level

Findings

Recommendation

• About 5 nos. of 1500 T5 fluorescent can be delamped along the corridor as highlighted

• Annual electricity consumption saving

  = 275 no. of fluorescent tubes x 35w x 8hr x

  x 240 days

  = 18,480kWh
Example 14 - Adjust Equipment Operation Hour

- ESO: Optimize operational hour of plant and equipment with timer control.
Example 14 - Adjust Equipment Operation Hour

- ESO: Optimize operational hour of plant and equipment with timer control.

- Use power meter / amp meter with logger to measure the daily operation of facility or equipment continuous for a period.

- Measurement period cover working day, weekly holiday and public holiday.

- Check the measurement result against the working hour.
Saving Estimation
Saving = Equipment power rating x saved operation hour

An 5-days working office with AHU, which is schedule to operate from 8:00 to 19:00. The AHU fan power is 15kW. It was found that the timer is malfunction and the fan is operation 24 hours non-stop.
Retro-commissioning (RCx)

Example 14 - Adjust Equipment Operation Hour

Case Study

Saved Operation hour on working day
= 24 – 11 = 13 hours

Total saved operation hour per year
= 13 x 5 x 52 + 24 x 2 x 52 = 5,876 hours

Saving = 15 x 5,876 = 88,140 kWh
Example 15 - Improve Gas Boiler Combustion Efficiency

ESO: Adjust Gas / air ratio in order to achieve optimal combustion efficiency.

Facility/ Equipment

Recommendation

- Adjust gas / air ratio in order to achieve optimal combustion
Example 15 - Improve Gas Boiler Combustion Efficiency

- ESO: Adjust gas / air ratio in order to achieve better combustion efficiency.

- Measure CO content of flue gas at boiler exhaust and trace amount of CO
- high CO content in the flue gas
- incomplete combustion occurred
- Boiler Combustion efficiency affected
Example 15 - Improve Gas Boiler Combustion Efficiency

- ESO: Adjust gas / air ratio in order to achieve better combustion efficiency.

\[
\text{% of CO (Produced from combustion)} = \left( \frac{\text{Measured CO in ppm}}{\text{CO density in kg/m}^3} \right) / 1000 - \text{% of CO (from Gas)}
\]

\[
\text{% excess fuel gas in combustion} = \text{% of CO (Produced from combustion)}
\]

Annual Fuel gas saving
\[
= \text{(Annual consumption of fuel gas)} \times (\text{% excess fuel gas in combustion})
\]
The Boiler’s annual gas consumption is about 18,195 unit and spending about $221,311 for the bill per annual.

According to the site measurement, the measured concentration of CO is 78 ppm.

% of CO \(_\text{(Produced from combustion)}\) = \(\frac{78}{1.4\#} \times \frac{1}{1000} - 2.1\%\)

= 5.3% – 2.1%

= 3.2%

% excess fuel gas \(_\text{in combustion}\) = 3.2%
Retro-commissioning (RCx)

Example 15 - Improve Gas Boiler Combustion Efficiency

Case Study

Remark:-

@In the study, the concentration of CO in fuel gas is ranged from 1% to 3.1%. The average value of CO concentration is 2.1%.

#CO density \(_{\text{in kg/m}^3} = 1.14\text{kg/m}^3\)
Annual Fuel gas saving  = (Annual gas consumption) x (% excess fuel gas in combustion)

Annual Fuel gas saving  = 18,195 x 3.2%
= 582 unit
= 27,936MJ*1
~ $ 7,000

Remark:-
*1 Each unit of fuel gas represents a heat value of 48MJ
Example 16 – Lightings Optimization

ESO: To adopt the use of daylighting (by computer simulation)

Facility / Equipment

Observation

- No daylighting sensors are installed in the building except for the main entrance lobby. As a consequence, lighting fixtures keep on operating even when a space is well illuminated due to transmission of visible light during daytime.
Retro-commissioning (RCx)

Example 16 – Lightings Optimization

ESO: To adopt the use of daylighting (by computer simulation)

<table>
<thead>
<tr>
<th>Space Type</th>
<th>Typical illuminance level (lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking</td>
<td>50**</td>
</tr>
</tbody>
</table>

1F carpark daylight distribution

2F carpark daylight distribution

5F carpark daylight distribution

19% area exceed 300lux

10% area exceed 300lux

36% area exceed 300lux
Retro-commissioning (RCx)

Example 16 – Lightings Optimization

ESO: To adopt the use of daylighting (by computer simulation)
Example 17 – Chillers Plant Optimization

ESO: Improving Cooling Tower and Chiller sequencing (by computer simulation)

Facility / Equipment

- 2 heat recovery VSD centrifugal chillers and 2 VSD centrifugal chillers all with ~1900kW
- 1 small screw chiller (~800kW) and 1 small air cooled chiller (~500kW)
- Operation control of the chillers is based on the building load demand (ranged from 300kW to 3500kW) and the operating hours of the chillers
- Consist
Retro-commissioning (RCx)

Example 17 – Chillers Plant Optimization

ESO: Improving Cooling Tower and Chiller sequencing (by computer simulation)
Example 17 – Chillers Plant Optimization

ESO: Improving Cooling Tower and Chiller sequencing (by computer simulation)
**Example 17 – Chillers Plant Optimization**

ESO: Improving Cooling Tower and Chiller sequencing (by computer simulation)

- 1 chiller with 1 Cooling tower
- 1 chiller with 2 Cooling towers

<table>
<thead>
<tr>
<th>Cooling Tower Fan + Condensate water pump</th>
<th>Power consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load percentage</td>
<td>10% load</td>
</tr>
<tr>
<td></td>
<td>20% load</td>
</tr>
<tr>
<td></td>
<td>30% load</td>
</tr>
<tr>
<td></td>
<td>40% load</td>
</tr>
<tr>
<td></td>
<td>50% load</td>
</tr>
<tr>
<td></td>
<td>60% load</td>
</tr>
<tr>
<td></td>
<td>70% load</td>
</tr>
<tr>
<td></td>
<td>80% load</td>
</tr>
<tr>
<td></td>
<td>90% load</td>
</tr>
<tr>
<td></td>
<td>100% load</td>
</tr>
</tbody>
</table>

![Graph showing Cooling load vs heat rejection power consumption comparison]

Load percentage
Example 17 – Chillers Plant Optimization

ESO: Improving Cooling Tower and Chiller sequencing (by computer simulation)
Example 17 – Chillers Plant Optimization

ESO: Improving Cooling Tower and Chiller sequencing (by computer simulation)

Chiller COP vs time

Low COP during winter

Fluctuation in COP

Higher COP during winter

Retro-commissioning (RCx)
Retro-commissioning (RCx)

Example 17 – Chillers Plant Optimization

ESO: Improving Cooling Tower and Chiller sequencing (by computer simulation)

High ration of chilled water by-passed

By-pass flow rate l/s

Facility / Equipment

Observation

Chiller COP vs Time

with CWST reset

January
February
March
April
May
June
July
August
September
October
November
December

0 5 10 15 20 25 30 35

## Retro-commissioning (RCx)

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Supply water flow (l/s)</th>
<th>Bypass pipe water flow (l/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thu, 15/Jan</td>
<td>0:30</td>
<td>8.84</td>
<td>31.43</td>
</tr>
<tr>
<td></td>
<td>1:30</td>
<td>8.58</td>
<td>31.69</td>
</tr>
<tr>
<td></td>
<td>2:30</td>
<td>8.25</td>
<td>32.01</td>
</tr>
<tr>
<td></td>
<td>3:30</td>
<td>7.99</td>
<td>32.28</td>
</tr>
<tr>
<td></td>
<td>4:30</td>
<td>7.7</td>
<td>32.57</td>
</tr>
<tr>
<td></td>
<td>5:30</td>
<td>7.49</td>
<td>32.78</td>
</tr>
<tr>
<td></td>
<td>6:30</td>
<td>9.73</td>
<td>30.54</td>
</tr>
<tr>
<td></td>
<td>7:30</td>
<td>13.09</td>
<td>27.18</td>
</tr>
<tr>
<td></td>
<td>8:30</td>
<td>13.06</td>
<td>27.21</td>
</tr>
<tr>
<td></td>
<td>9:30</td>
<td>17.56</td>
<td>22.7</td>
</tr>
<tr>
<td></td>
<td>10:30</td>
<td>20.2</td>
<td>20.07</td>
</tr>
<tr>
<td></td>
<td>11:30</td>
<td>20.97</td>
<td>19.3</td>
</tr>
<tr>
<td></td>
<td>12:30</td>
<td>21.61</td>
<td>18.66</td>
</tr>
<tr>
<td></td>
<td>13:30</td>
<td>22.18</td>
<td>18.09</td>
</tr>
<tr>
<td></td>
<td>14:30</td>
<td>23.24</td>
<td>17.03</td>
</tr>
<tr>
<td></td>
<td>15:30</td>
<td>24.33</td>
<td>15.94</td>
</tr>
<tr>
<td></td>
<td>16:30</td>
<td>22.11</td>
<td>18.15</td>
</tr>
<tr>
<td></td>
<td>17:30</td>
<td>17.43</td>
<td>22.84</td>
</tr>
<tr>
<td></td>
<td>18:30</td>
<td>12.43</td>
<td>27.84</td>
</tr>
<tr>
<td></td>
<td>19:30</td>
<td>11.71</td>
<td>28.56</td>
</tr>
<tr>
<td></td>
<td>20:30</td>
<td>10.74</td>
<td>29.52</td>
</tr>
<tr>
<td></td>
<td>21:30</td>
<td>10.84</td>
<td>29.43</td>
</tr>
<tr>
<td></td>
<td>22:30</td>
<td>10.17</td>
<td>30.1</td>
</tr>
<tr>
<td></td>
<td>23:30</td>
<td>10.24</td>
<td>30.02</td>
</tr>
</tbody>
</table>
Example 17 – Chillers Plant Optimization

- Different CWST gives different Chiller performance curve
- Try to lower the CWST hence to improve COP

Help the chiller lift and hence improve COP
Retro-commissioning (RCx)

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Cooling load (kW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thu, 15/Jan</td>
<td>0:30</td>
<td>208.216</td>
</tr>
<tr>
<td></td>
<td>1:30</td>
<td>201.867</td>
</tr>
<tr>
<td></td>
<td>2:30</td>
<td>194.728</td>
</tr>
<tr>
<td></td>
<td>3:30</td>
<td>188.3</td>
</tr>
<tr>
<td></td>
<td>4:30</td>
<td>182.116</td>
</tr>
<tr>
<td></td>
<td>5:30</td>
<td>176.673</td>
</tr>
<tr>
<td></td>
<td>6:30</td>
<td>229.057</td>
</tr>
<tr>
<td></td>
<td>7:30</td>
<td>305.556</td>
</tr>
<tr>
<td></td>
<td>8:30</td>
<td>305.103</td>
</tr>
<tr>
<td></td>
<td>9:30</td>
<td>408.651</td>
</tr>
<tr>
<td></td>
<td>10:30</td>
<td>469.693</td>
</tr>
<tr>
<td></td>
<td>11:30</td>
<td>487.285</td>
</tr>
<tr>
<td></td>
<td>12:30</td>
<td>502.139</td>
</tr>
<tr>
<td></td>
<td>13:30</td>
<td>512.658</td>
</tr>
<tr>
<td></td>
<td>14:30</td>
<td>542.107</td>
</tr>
<tr>
<td></td>
<td>15:30</td>
<td>562.703</td>
</tr>
<tr>
<td></td>
<td>16:30</td>
<td>515.626</td>
</tr>
<tr>
<td></td>
<td>17:30</td>
<td>405.232</td>
</tr>
<tr>
<td></td>
<td>18:30</td>
<td>289.249</td>
</tr>
<tr>
<td></td>
<td>19:30</td>
<td>273.944</td>
</tr>
<tr>
<td></td>
<td>20:30</td>
<td>251.902</td>
</tr>
<tr>
<td></td>
<td>21:30</td>
<td>254.797</td>
</tr>
<tr>
<td></td>
<td>22:30</td>
<td>238.44</td>
</tr>
<tr>
<td></td>
<td>23:30</td>
<td>240.323</td>
</tr>
</tbody>
</table>

(540TR, 1900kW ) | ~10%  | (225TR, 790kW )  
(540TR, 1900kW ) | ~25%  | Or              
(225TR, 790kW )  | ~60%  |                
(540TR, 1900kW ) | ~13%  | (225TR, 790kW )  
(540TR, 1900kW ) | ~30%  |                

WCC

~25%

~60%

~30%
Retro-commissioning (RCx)

Chiller load distribution

- <= 500.00
- >500.00 to <=875.00
- >875.00 to <=1250.00
- >1250.00 to <=1625.00
- >1625.00 to <=2000.00
- >2000.00 to <=2375.00
- >2375.00 to <=2750.00
- >2750.00 to <=3125.00
- >3125.00 to <=3500.00
- >3500.00
<table>
<thead>
<tr>
<th>Operation Mode</th>
<th>Building load</th>
<th>No. of chiller required</th>
<th>Chiller to operate</th>
<th>No of cooling tower to operate</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>&lt; 500kW</td>
<td>1</td>
<td>WCC1</td>
<td>2</td>
</tr>
<tr>
<td>B</td>
<td>500kW &lt; and &lt; 1700kW</td>
<td>1</td>
<td>HRC1/HRC2/WCC2/WCC3</td>
<td>2</td>
</tr>
<tr>
<td>C</td>
<td>1700kW &lt; and &lt; 3000kW</td>
<td>2</td>
<td>HRC1/HRC2/WCC2/WCC3 and HRC1/HRC2/WCC2/WCC3</td>
<td>3</td>
</tr>
<tr>
<td>D</td>
<td>&gt; 3000kW</td>
<td>3</td>
<td>HRC1/HRC2/WCC2/WCC3 and HRC1/HRC2/WCC2/WCC3</td>
<td>4</td>
</tr>
</tbody>
</table>

**Loading range**

<table>
<thead>
<tr>
<th>Loading range</th>
<th>Suggested operation mode</th>
<th>Loading range</th>
<th>Suggested operation mode</th>
<th>Loading range</th>
<th>Suggested operation mode</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
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**Notes**

1. If loading more than 1 chiller capacity, extra chiller to be kick in
Example 17 – Chillers Plant Optimization

ESO: Improving Cooling Tower and Chiller sequencing (by computer simulation)

COP improvement (estimated by simulation)

Approx. 5 -10%
Example 17 – Chillers Plant Optimization
ESO: Improving Cooling Tower and Chiller sequencing (by computer simulation)
END