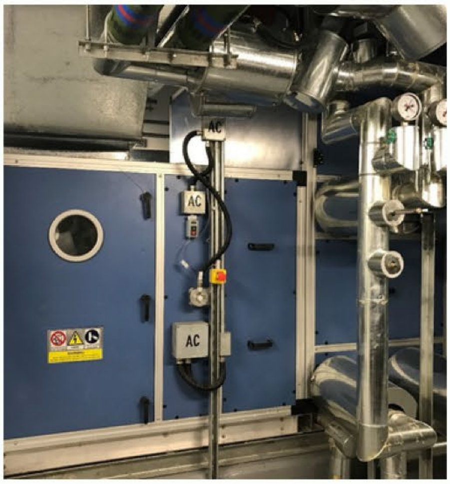
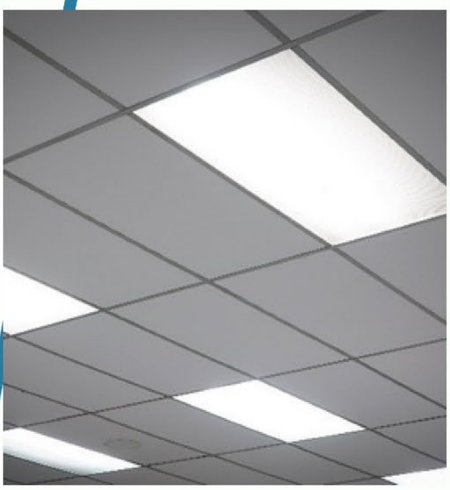
EMSD

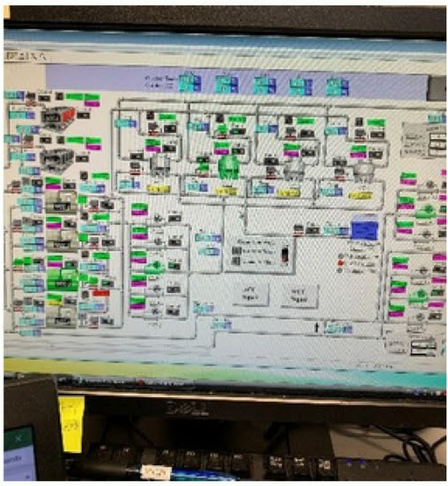
TECHNICAL GUIDELINES ON RETRO-COMMISSIONING

SUPPLEMENTARY INFORMATION

2023







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Annex A

Information Checklist for Engagement of RCx service Provider

Annex A – Information Checklist for Engagement of RCx Service Provider

The aim of this Appendix is to provide an information checklist for the building owner. This allows information preparation to be performed in advance for the RCx service provider engagement. As a result, the building owner can have a clearer understanding of the deliverables to expect throughout the RCx exercise.

Information required from building owner

Drawings
Architecture layout drawings
M&E layout drawings*
M&E schematics drawings*
Documentation
Project requirement*
Construction record documents
M&E specification*
Operations and maintenance manuals*
HVAC equipment control sequence and setpoint*
Energy audit report
Past record of energy saving opportunity implementation
CCMS data point list
CCMS data point trend logged data
Past utility bills

All information provided should be the most up to date version. The building owner should keep record of any amendments to the building systems and operation requirement.

**To facilitate the process of RCx service provider engagement, the building owner should provide sufficient information. As a minimum, a description of the building (e.g. total floor area, building height, number of storeys, type of building, usage of building) and building systems (e.g. provisions for central air conditioning system, operation hours, electrical schematics from these documents) should be provided in the RCx service provider engagement tender agreement. This will allow the RCx service provider to make sensible estimations on the pricing and enable the provider to make estimations on the potential energy saving opportunities. Further details may be requested by the RCx service provider for more in-depth understanding of the system operation. A site walk through with the O&M staff should also be considered to collect the necessary information that may be missing in the documentation.*

As the RCx exercise is mainly related to building systems operation, any amendments done on the systems from the initial design should be mentioned during the procurement procedure. This *will allow RCx service provider to take into considerations the adjustment on energy saving opportunities exploration.*

Deliverables from RCx service provider

Deliverables
Review current building information and data
Develop RCx plan
Facilitates staff interviews, walkthrough and visual inspection
Carry out analysis on building performance and identify potential ESOs
Develop M&V plan
Prepare Investigation report
Prepare Implemantion report
Witness M&V
Develop RCx final report
Provide training to operation staff for on-going commissioning
Develop On-going commissioning report
Update building manual

Annex B

Technical Guidance Notes

Annex B – Technical Guidance Notes

Guidance notes in this section are not intended to be definitive or exhaustive. The RCx team is mainly responsible for finding energy saving opportunities to suit the building operation and requirement.

B1. Chilled water system (chiller, chilled water pump and condenser water pump)

B1.1 Understanding the system

B1.1.1 System description

A chilled water system distributes cooled water around the building. It consists of a series of components including chillers, pumps, heat rejection systems, coils and valves that provide chilled water throughout the refrigeration cycle.

The main characteristic of a chilled water system is its capacity, a value that describes how much cooling load the chiller can be provided at various weather conditions, this value is also known as the capacity output of the chiller. Another important value is the coefficient of performance (COP), a ratio of the amount cooling generated per unit of electricity input, which is an indicator of efficiency.

B1.1.2 Data reporting period

Ideally, whole-year operating data would allow to determine ESOs effectively. However, if data collection during a whole year is not feasible, short-term measurements during maximum, minimum load and transition seasons are required. Generally, 1-2 weeks measurement is enough to understand the operational characteristics of the chiller. Considering a similar data collection period after the implementation of any ESO to assess its effectiveness, the preferable sample period of the data is up to 15 minutes as per ASHARE guideline 14-2014.

B1.1.3 System schematics

Fig. B.1.1.3 is a schematic representation of a chilled water system. It contains chillers, pumps, valves, and loads. Additionally, flow meters (F) and temperature sensors (T) are included.

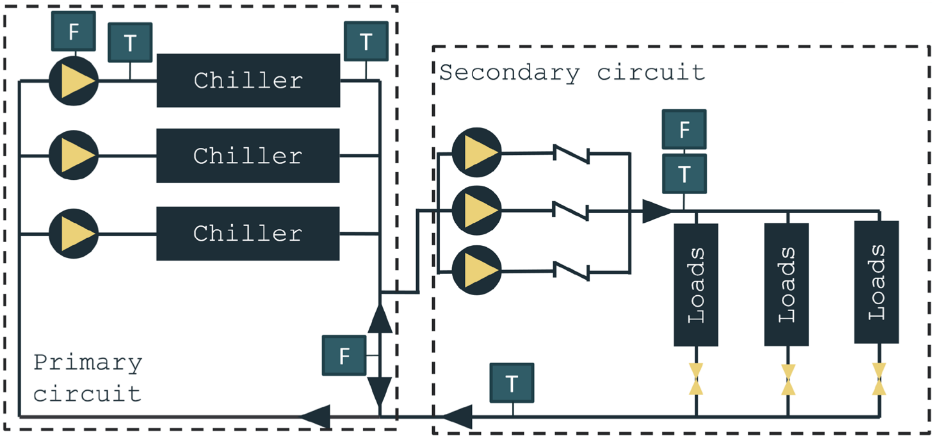

Fig. B.1.1.3 Chilled water plant block diagram

B1.1.4 Key measurements points

1. Chilled water flow, leaving and entering water temperatures of primary circuit;
2. Chillers and pump electricity consumption (excluding chilled water pumps for COP calculations);
3. Chilled water flow passing through bypass pipe (Decoupler flow);
4. Secondary circuit flow, leaving and entering water temperatures; and
5. Water differential pressure across evaporator / condenser tube of chiller (only for VFDs).

These measurement points provide critical information to determine potential energy savings opportunities. In general, temperature sensors shall be located at or near the chillers outlets in order to measure the actual temperature. A flow meter is recommended to be installed on each of the chillers, secondary circuit and in the bypass pipe. Water flow meters can be an orifice plate, ultrasonic, etc. A water flow switch is also a reliable status indicator of flow through chillers.

B1.2 Potential Energy Saving Opportunities

The following list of energy saving opportunities is not exhaustive but is intended to provide guidance on how to identify commonly found ESOs in chiller systems.

B1.2.1 Chiller sequencing optimisation

Consist of adjusting the sequence of operation of the chillers to achieve a higher system efficiency. A duty chiller is the first that activates when there is a demand for cooling, or cooling load. Standby chillers activate when the duty chiller reaches a certain demand or when the chiller is unable to start due to a fault. Duty / standby designations interchange regularly to achieve a similar number of operating hours during the year or according to the efficiency of each chiller.

B1.2.1.1 Symptom

a. Adding or subtraction of individual chiller with part load ratio fall out of the high COP zone among operating chillers.

B1.2.1.2 Results

a. Chillers are operated at part load ratio fall out of the high COP zone or fall into a low COP zone; and
b. The COP of the entire chiller plant system is low.

B1.2.1.3 Analysis

a. Check flow entering and supply temperature of the chilled water to determine the load;
b. Check manufacturer's performance curves to estimate the range of loads with highest COP;
c. If whole year data is not available, verify chillers' loads in several seasons;
d. Check load profiles or the variation of cooling demand during a 24 hour period during similar days across the year;
e. Check the actual chiller sequencing; and
f. After computing cooling load of the building with the available data, create a load range breakdown table. See example 20 in Main Content Appendix A.

B1.2.1.4 Recommendations

a. Prepare a chiller operation table based on the building cooling load range. This consists of sequencing the chillers to maximise part-load operations by keeping them in the range of highest efficiency. This can be created by combining the building cooling load range breakdown with the chiller manufacturer's performance curves. See example 20 in Main Content Appendix A;
b. Generally, chillers should be operated at part load ratio with high COP value. The part load ratio of chillers can be adjusted by adjusting the number of chillers with appropriate capacity put in operation; and
c. See Main Content Appendix A, example 1 and 2.

B1.2.2 Set-point optimisation

Adjusting the chilled water supply temperature set point of the chillers or main return chilled water temperature of chiller plant to achieve a higher system efficiency.

B1.2.2.1 Symptom

a. Cooling load is not fulfilled and chilled water temperature cannot achieve its set-point;
b. Continuous chilled water flow through the by-pass pipe;
c. Numbers of chillers in operation do not match with the demand in loads; and
d. Control valves of airside terminals often fully opened or closed.

B1.2.2.2 Results

a. Low/high temperature difference (delta T) across the chillers / cooling coil of the airside terminals;
b. Low chilled water return temperatures caused by additional use of the pumps with excessive water recirculation through the bypass pipe in the primary circuit; and
c. Low chilled water supply temperature required a high compression lift of chiller even when cooling demand is low.

B1.2.2.3 Analysis

a. Check chiller supply and return temperatures against the set point;
b. Check delta T and bypass flow rate during high, low and transition season; and
c. Compare building actual peak loads with design loads to determine whether the system is under / oversized.

B1.2.2.4 Recommendations

a. Typical chilled water supply and return temperatures are 7°C and 12°C respectively with a temperature differential of 5°C. Temperature reset should be considered based on external weather condition, temperature differential and/or building load;
b. Optimise water temperature to achieve maximum heat transfer efficiency, consider pumps trade-off; and
c. See Main Content Appendix A, example 3.

B1.2.3 Review variable speed driven pump pressure setting

When VSD pumps are installed in existing site with differential pressure as the control parameter, the differential pressure control setting can be reduced at part-load when the cooling demand reduced to help reduce pump energy consumption.

B1.2.3.1 Symptom

a. Pump differential setting is constant during part load operation.

B1.2.3.2 Results

a. Speed of pumps may not be further reduced for energy saving at low load condition.

B1.2.3.3 Analysis

a. Compare the differential pressure set point against the pressure head of VSD pump at part load condition;
b. Check the opening of control valves of downstream airside equipment at critical path during part load condition; and
c. Check the air temperature of the downstream airside equipment at critical path.

B1.2.3.4 Recommendations

a. Before actual implementation, the user can make trials to reduce the differential pressure step by step to ensure the air temperature of downstream airside equipment at critical path still satisfy the set point and the opening of corresponding control valves are significantly re-opened again.

B1.2.4 Chiller plant inspection

Chillers are typically the largest single energy-consuming item in commercial buildings. Hence, inspection the operating environment and conditions of the oil and refrigerant systems and the moving parts of chiller is a key O&M practice for determining potential ESOs such as change of lubrication oil or the right time to schedule chiller replacement in the near future. It is worth to evaluate the performance of chillers that have exceeded their expected operational life span, are not able to fulfil the cooling design requirements or are no longer reliable; involvement of cost-effective ESO such as chiller optimisation strategies for having more potential energy savings can be considered when chiller replacement is scheduled.

B1.2.4.1 Symptom

a. Chiller cannot meet and work on the design condition or factory setting;
b. Excessive noise and vibrations; and
c. Corrosion and other visible deterioration signs.

B1.2.4.2 Results

a. Chillers always operated at low COP in the system even under favour operating conditions;
b. Slow reaction for cooling demand, especially in high demand season;
c. Electricity use of the chiller is higher as compared to previous years without apparent explanation; and
d. Electricity use of the chiller system does not drop as expected in low demand seasons.

B1.2.4.3 Analysis

a. Visually inspect for severe corrosion, wear and tear of components;
b. Verify with O&M staff whether there has been any abnormal noise / vibration generated from chillers;
c. Check maintenance logs to determine whether chiller has been properly maintained over a long period of time;
d. Check the operating environment and condition of the oil system, including the oil temperature, oil level of sump pump chamber, tracing for any metal residual accumulated in the oil that would indicate any wear and tear of metallic components.
e. Check whether the supply temperature can achieve it set point at different operating conditions; and
f. Check any abnormal temperature differential across chillers.

B1.2.4.4 Recommendations

a. If cooling load output or temperature differential across chiller at full load condition is low as compared to the design value, or the % of full load current is much higher than that of the part load ratio, inspecting the operation environment, condition and components of chiller and if equipment is old (+20 years) even with proper maintenance, schedule the replacement of chiller is recommended. For further detail on recommended HVAC equipment lifespan, please refer to ASHRAE equipment life expectancy chart;
b. If maintenance problems such as metal wear and tear, abnormal oil temperature, low level of lubrication oil, fouling of condenser tubes, etc. are detected from the analysis, prepare a plan for addressing the issue;
c. For M&V requirements, install meters before and after the chiller ESO implementation to estimate changes in efficiencies; and
d. See Main Content Appendix A, example 4.

B1.3 Improving energy efficiency by other means

Besides the potential energy saving opportunities mentioned in above sections, there are other technique(s) which can be considered to apply for improving the energy efficiency in the system.

B1.3.1 Install Variable Speed Drive to Control Water Pump/Fan Speed

For the pumps or fans in HVAC system, the functionality of the motor drive that allows motors to operate at varying speeds could be applied, to minimize the energy for the desired function, and therefore reducing the energy wasted by motorized devices. As the speed of the fans or pump is reduced, the flow will reduce proportionally, and the power of the fans or the pumps will reduce with the cube of the speed.

B2. Water balancing

B2.1 Understanding the system

B2.1.1 System description

A chilled plant system circulates chilled water from chillers to the conditioned areas in the building. In one side, the chiller water loop is connected to the evaporator in the chiller and on the other side, the water loop feeds air handling or fan coil units throughout the building. The function of a chilled water loop is to fulfil the cooling load needs of the building, and it is typically measured in kilowatts (kW). In ideal conditions, the supply and demand of cooling load are in equilibrium.

B2.1.2 Data reporting period

It is recommended to collect relevant cooling load data for the whole year in order to determine ESOs effectively. However, if data collection during a whole year is not feasible, short-term measurements during maximum, minimum load and transition seasons is required. The preferable sample period of the data is up to 15 minutes as per ASHARE guideline 14-2014.

B2.1.3 System schematics

Refer to Fig. B.1.1.3 in the previous section.

B2.1.4 Key measurements points

a. Primary circuit chilled water flow, leaving and entering chilled water temperatures;
b. Secondary circuit chilled water flow, leaving and return chilled water temperature;
c. Primary and secondary chilled water pumps' speed;
d. Chilled water differential pressure of primary and secondary circuit loops (only for VFD pumps); and
e. Surplus or deficit flow rate.

B2.2 Potential energy saving opportunities

The following list of energy saving opportunities is not exhaustive but is intended to provide guidance on how to identify commonly found ESOs in chiller systems.

B2.2.1 Control upgrade

Primary and secondary circuits circulate chilled water using pumps. A control upgrade would improve energy efficiency operation by eliminating excess in the use of pumps providing a similar cooling to the demanded by the building.

B2.2.1.1 Symptom

a. Numbers of chiller running do not correspond to the demand in load of the building.

B2.2.1.2 Results

a. Oversizing or Excessive use of primary pumps; and
b. Potential rapid temperature fluctuation causing early wear on equipment.

B2.2.1.3 Analysis

a. Determine the current sequencing by doing an operational check;
b. Determine cooling load using flow, supply and return water temperature recorded on-site and compare it with the cooling load calculated by the control system, report any inconsistencies; and
c. Use 15 minutes supply water temperature readings to detect the hunting of control mechanism.

B2.2.1.4 Recommendations

a. Make sure that sensors are properly calibrated with data used for calculating the cooling loads in the control system;
b. Verify that the existing control strategy can be provided with adequate throttling range, count time and dead band, and the controller with proper PID gain values in order to avoid rapid fluctuation of temperature control; and
c. See Main Content Appendix A, example 5.

B3. Heat rejection system

B3.1 Understanding the system

B3.1.1 System description

In water-cooled systems, the cooling tower is responsible for rejecting heat contained in the refrigerant into the atmosphere. Water absorbing heat from the condenser is sent to the cooling tower where the heat is then removed.

Towers can be either wet or dry, both using fan to circulate air through the tower. It is common that more than one cooling tower is installed in the building (known as cells), and they are usually located on the roof.

On the other hand, air-cooled systems reject heat contained in the refrigerant directly to the air. Air-cooled systems are typically found in small to medium size buildings, as they tend to take less space, however they are also less efficient as compared to water-cooled systems.

Treatment of sea water for condenser cooling should be also carried out to maintain water in proper "balance" condition (to kill or inhibit marine growth and to inhibit the formation of scale, slime and foam in the pumps, pipework and condensers).

B3.1.2 Data reporting period

Ideally, collection of whole year operation data would allow to determine ESOs effectively. However, if data collection during a whole year is not feasible, short-term measurements during maximum, minimum load and transition seasons are required.

The preferable sample period of data is up to 15 minutes as per ASHARE guideline 14-2014 or at a minimum of one hour for air-cooled system. Outdoor air temperatures, supply and return chilled water temperatures and fan power (or speed) should be recorded.

For the case of cooling towers, it is recommended a minimum of half hour per reading for entering wet bulb and entering dry bulb temperature and water flow rate and fan power input.

B3.1.3 System schematics

Fig. B.3.1.3 represents a wet cooling tower. Main elements are fan, water nozzles, screens, basins, and pump. Valves for controlling the quantity and quality of the water are represented as well as make-up water and bleed-off lines.

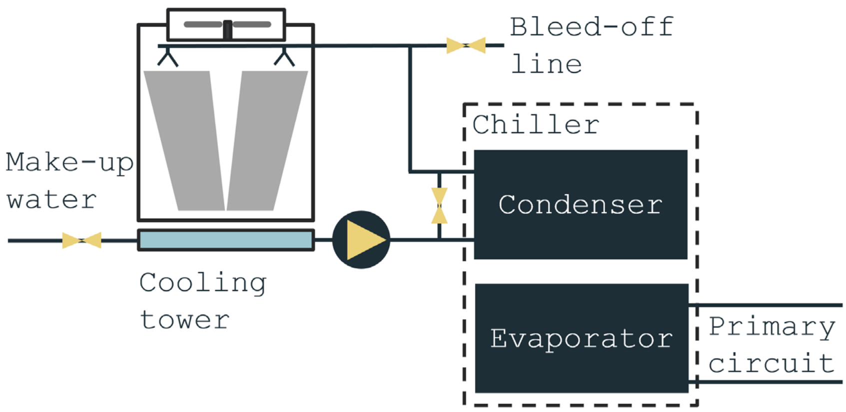

Fig. B.3.1.3 Heat rejection block diagram for water-cooled systems

B3.1.4 Key measurements points

a. VSD fan speed (water and air cooled);
b. condensing water leaving and entering temperature (water and air cooled);
c. cooling tower power meter (water cooled);
d. water sampling for biological and chemical tests (water cooled); and
e. Outdoor air wet bulb temperature (water and air cooled).

In addition to the listed points, noise inspection and visual inspections are critical for determining ESOs.

B3.2 Potential Energy Saving Opportunities

The following list of energy saving opportunities is not exhaustive but is intended to provide guidance on how to identify commonly found ESOs in chiller systems.

B3.2.1 Control optimization (water cooled)

Adjust control strategy including sequencing and VSD in fans to maximise efficiency.

B3.2.1.1 Symptom

a. High approach temperature, or temperature difference between the water to the condenser and the wet-bulb temperature.

B3.2.1.2 Results

a. Water temperature to the condenser is not being cooled down as expected, leading to a reduction of the efficiency of the chiller as it receives warmer water.

B3.2.1.3 Analysis

a. Check water leaving and wet bulb temperature to calculate approach temperature in various seasons of the year.

B3.2.1.4 Recommendations

a. Typical water entering temperatures to the cooling towers are about 37°C and leaving temperatures about 32°C in summer but it will vary on each case;
b. Optimise the operation of the cells in the cooling tower to achieve an approach temperature between 2°C to 8°C, depending on weather conditions and the configuration of tower. The optimal approach temperature is when it is close to the design values as listed in the manufacturer's specification. It can be achieved by adjusting the numbers of cooling tower per condensing water pump, and/or adjusting the fan speed on each of the cells to achieve this target. It will increase efficiency of the chiller specially during periods with low wet-bulb temperature;
c. Consider modulating condenser water pump speed to maintain condensing water temperature difference according to the building loads and outdoor conditions; and
d. See Main Content Appendix A, example 6.

B3.2.2 Maintenance plan (water and air cooled)

Whereas air cooled systems are generally more resilient to outdoor conditions; cooling towers, especially wet ones, are vulnerable to external conditions and must be maintained regularly. Also due to the constant water losses, it is important to monitor the accumulation of minerals in the screen and debris in the water basin.

For a detailed water-cooled description, refer to EMSD Code of Practice for Fresh Water Cooling Towers.

B3.2.2.1 Symptom

a. The cooling tower failing to provide cooled water to the condenser or (water-cooled systems); and
b. Water entering to the condenser as hot as compared to previous years even with similar water leaving and wet bulb temperatures (water and air-cooled systems).

B3.2.2.2 Results

a. Lack of maintenance on a cooling tower leads to a decline of the overall capacity of the heat rejection system, which causes a rise on the cooling water temperature. Hence the air-conditioning chiller will decline in efficiency and capacity.

B3.2.2.3 Analysis

a. Check the current maintenance plan, if any (water and air-cooled systems);
b. Inspect the cooling towers to detect excess noise, vibration, signs of corrosion and other types of deterioration (water-cooled systems);
c. Check the status of the nozzles and report the ones that are clogged (water-cooled systems);
d. Check the status of the screens, including potential accumulation of minerals or debris (water-cooled systems);
e. Check the status of the water basin, including potential accumulation of debris (water-cooled systems);
f. Obtain samples of water to determine if its composition is acceptable (water-cooled systems);
g. Use infrared cameras to detect high temperatures in fans (water and air-cooled systems);
h. Check the status of the condenser including the tube, fins, and fans, look for debris blocking airflow (air-cooled systems); and
i. Make sure the outdoor temperature conditions are within the design capabilities of the heat rejection system (water and air-cooled systems).

B3.2.2.4 Recommendations

a. Clean surfaces in the condenser, including tube and fins (air-cooled systems);
b. Remove debris that can block airflow. Check that all fans are working. (water and air-cooled systems); and
c. Compute approach temperature and compare it to the design approach temperature (water-cooled systems).

B3.3 Improving energy efficiency by other means

Besides the potential energy saving opportunities mentioned in above sections, there are other technique(s) which can be considered to apply for improving the energy efficiency in the system.

B3.3.1 Install Side Stream Filtration at Cooling Tower

A side stream filtration system for cooling tower can be applied to filter the circulating water for the condenser loop in the HVAC system, effectively removing dust and particles which may degrade the system performance. Furthermore, the side stream filtration system can remove the chemically treated biomass, which may also cause problems, including temperature control or greater maintenance issues.

B4. Airside system

B4.1 Understanding the system

B4.1.1 System description

The airside system is responsible for collecting the heat from the building space and transferring it to the chilled water system through cooling coils. Air is circulated through the cooling coils to the conditioned spaces.

B4.1.2 Data reporting period

If data collection during a whole year is not feasible, short-term measurements in weekdays/weekends are required, especially during peak cooling load seasons. For VAV system, short-term measurements are also required during minimum load and transition seasons.

B4.1.3 System schematics

A wide number of air system configurations exist. Fig. B.4.1.3 shows an example of a variable air volume system.

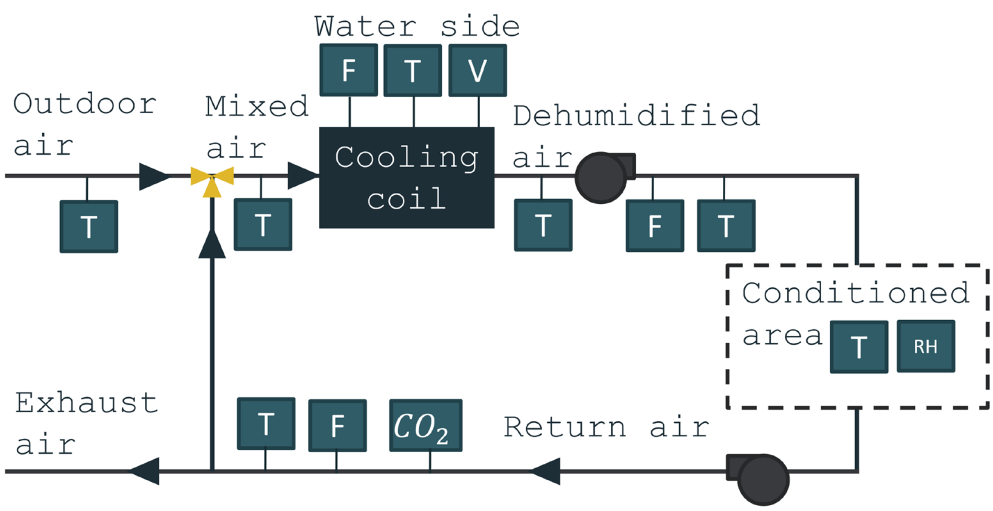

Fig. B.4.1.3 Air side system block diagram

B4.1.4 Relevant areas

a. Airflow;
b. Air temperature in various points including supply and return;
c. CO_2 concentration from conditioned areas;
d. Cooling coils water temperature, flow and valve position; and
e. In some VAVs, air pressure in ducts is relevant.

B4.2 Potential Energy Saving Opportunities

The following list of energy saving opportunities is not exhaustive but is intended to provide guidance on how to identify commonly found ESOs in chiller systems.

B4.2.1 Review indoor air temperature setpoint

Temperature set point in conditioned areas is a major driver of cooling energy consumption in a building. A thermostat is the first point of interaction between a building user and an air conditioning system; however, a set point that may seem adequate for one person or facility manager could have a negative impact on a number of users and the energy consumption of the system. Careful analysis is required when defining a set point especially in large conditioned areas.

B4.2.1.1 Symptom

a. Space is too cold or too hot and the temperature set-point is not responding to air temperature re-sets; and
b. Air ventilation excess in some areas (air drafts).

B4.2.1.2 Results

a. Complaints from users due to internal drafts and uneven cooling.

B4.2.1.3 Analysis

a. Check air temperature on conditioned areas and compare it against the thermostat set point;
b. Verify the activity of the cooling coils to detect cases of simultaneous heating/cooling;
c. Verify the status of air diffusers and air dampers in the VAV; and
d. Check the status of the valves in the cooling coils.

B4.2.1.4 Recommendations

a. Verify room temperatures achieve set-points by plotting trended data;
b. Analyse the status of the valves focused on cases where valves are always on/off;
c. Adjust set points in the building to minimise simultaneous heating/cooling; and
d. See Appendix A, example 7.

B4.2.2 Demand Controlled ventilation

During summer period, the hot and humid fresh air will increase the overall cooling load. Therefore, by controlling the amount of fresh air to suit the system requirement will help reduce the system cooling load and fan power.

B4.2.2.1 Symptom

a. The carbon dioxide concentration in return air duct is well below the threshold value; and
b. Fresh air amount to each AHU is constant.

B4.2.2.2 Results

a. Constant supply of fresh air exceeding demand need;
b. Energy wastage in fresh air fan power; and
c. Increase cooling load demand on air handling units.

B4.2.2.3 Analysis

a. Check the carbon dioxide concentration level in return air duct and compare with threshold value.

B4.2.2.4 Recommendations

a. If the average carbon dioxide concentration is well below the threshold, the building operator can consider reducing the fresh air amount by reducing the fresh air fan speed or using variable speed control.

B4.2.3 Air Handling Unit fan static pressure reset

In situation where variable speed driven AHU fan is installed, the duct static pressure is used as control parameter. The fan speed is modulated to maintain constant static pressure in the ductwork.

During low cooling demand periods, the static pressure setting for the fan speed modulation can considered to lower further in order to achieve some savings in distribution fan energy.

B4.2.3.1 Symptom

a. The air flow rate is still high at low cooling demand condition; and
b. Duct static pressure set point is constant even during low load condition.

B4.2.3.2 Results

a. Oversupply of air flow during low cooling demand period;
b. Room is too cold during low demand period; and
c. Energy wastage in AHU fan power.

B4.2.3.3 Recommendations

a. Before actual implementation, users can make trials to reduce the static pressure set point step by step to ensure the downstream air temperature still satisfies the set point and the damper opening of VAV-boxes, if any, at critical path would not significantly re-open to maximum flow position; and
b. See Main Content Appendix A, example 9.

B4.2.4 Consider preconditioning periods

Controlling the Preconditioning periods is a strategy that consist of cooling the building before working hours especially after continuous days without cooling. This is a common situation in buildings where the system is off during the weekend or holiday periods.

B4.2.4.1 Symptom

a. Temperature in conditioned areas fail to meet the set-point temperature during the first hours on Monday.

B4.2.4.2 Results

a. The system works at full capacity to meet the demand.

B4.2.4.3 Analysis

a. Use a time series plot to detect the time required for the system to meet the demand; and
b. Check air supply temperatures and flow in primary air handling units.

B4.2.4.4 Recommendations

a. Calculate a preconditioning period of primary air handling units; and
b. See Main Content Appendix A, example 8.

B4.2.5 Test and balance equipment

Ensure that airflow sensors are calibrated, and that air flow is balanced. Refer to ASHRAE standard 111-2008 – Measurement, Testing, Adjusting and Balancing of Building HVAC Systems for further reference.

B4.2.5.1 Symptom

a. Building users constantly?? complain about air drafts;
b. Other comfort complaints in other areas of the buildings;
c. Temperature range across chillers / chilled water rises with same capacities will be different; and
d. Pressure differential across pumps / AHUs with same capacities will be different.

B4.2.5.2 Results

a. A system with an unbalanced air distribution will fail to regulate internal air temperatures in the whole building.

B4.2.5.3 Analysis

a. Use anemometers to verify the airflow in ducts. Refer to ASHRAE standard 111-2008 – Measurement, Testing, Adjusting and Balancing of Building HVAC Systems for further guidance on types and calibration requirements;
b. Review air pressure set-point; and
c. Review the critical path of airflow.

B4.2.5.4 Recommendations

a. Compare measurements with the values recorded by the control system. Report excess or shortfall of air, which should not be beyond +/-10%;
b. Repair/replace fault sensors; and
c. See Main Content Appendix A, example 9.

B4.3 Improving energy efficiency by other means

Besides the potential energy saving opportunities mentioned in above sections, there are other technique(s) which can be considered to apply for improving the energy efficiency in the system.

B4.3.1 Use of electronically commutated (EC) plug fan

EC plug fan or electronically commutated plug fan can be applied in PAU/AHU which does not use a brush to control the electrical motor and an electronic circuitry controls the rotation of the motor instead. The motor plugs into alternating current (AC) and converts it to direct current (DC). By using DC instead of AC, the fan does not need to create the additional electromagnetic fields that a normal fan does and instead uses a permanent magnet for the second field saving significant portion of the energy used by a typical AC fan. With the wheel design, EC plug fans are inherently more efficient than centrifugal fans. In addition, besides the benefit of improving the energy efficiency, the installation space of the EC plug fan is generally much less than the same rating of centrifugal fans, which are commonly used in PAU/AHU.

B4.3.2 Install Heat Recovery Ventilation

Heat recovery ventilation system allows the heat exchange between the fresh air into building and exhausted air leaving building. The indoor air is discharged to the outside through the heat recovery ventilation system while the filtered fresh air enters the same high-efficiency heat recovery device for heat exchange. As a result, the temperature of fresh air can be adjusted to room temperature approximately and the extra energy is greatly reduced for the cooling or heating of the fresh air.

B4.3.3 Off-hour Control

Each air-conditioning system, except for the cooling or heating capacity no more than 10 kW (BEC 2021), could be equipped with automatic controls capable of accomplishing a reduction of energy use in the corresponding cooling or heating mode of operation through control setback or equipment shutdown during periods of non-use of the spaces served by the system. Similar energy saving opportunities can be applied to thermostat on/off, speed control of exhaust fans and automatically switching off ventilation fan or air conditioning in the spaces concerned.

B5. Lighting system and automatic control

B5.1 Understanding the system

B5.1.1 System description

Lighting systems consist of two main categories of lights: normal and emergency. They are also known as tradable and non-tradable lighting. Normal lighting includes task and general lighting. Emergency lighting covers evacuation sings, ATM lighting, main entrances, lighting in emergency rooms, etc.

B5.1.2 Data reporting period

If variability is low, short-term electricity metering is enough to determine actual lighting demands during weekdays and weekend. Consider at least two weeks using half-hourly resolution. Typically, low variability profiles across different weeks are found in office buildings.

If lighting use profiles varies considerably, longer metering periods will be required.

B5.1.3 System schematics

N/A

B5.2 Potential Energy Saving Opportunities

The following list of energy saving opportunities is not exhaustive but is intended to provide guidance on how to detect commonly found ESOs in lighting systems.

B5.2.1 Adjust lighting to meet allowance and lighting levels

Whereas energy saving opportunities in emergency lighting are limited, normal lighting almost always features opportunities for performance improvement by comparing actual lighting levels and power to recommended values in guidelines.

B5.2.1.1 Symptom

a. Lighting levels are above recommended levels;
b. Levels of lighting are adequate but above the lighting power density allowance; and
c. Passenger / occupants usage pattern is not related with the lighting level and its usage pattern.

B5.2.1.2 Results

a. Energy wasted by excess of installed lighting; and
b. Reduction of the operative life of the lights.

B5.2.1.3 Analysis

a. Calculate maximum interior lighting power installed determining tradable and non-tradable areas;
b. Calculate exterior lighting power installed determining tradable and non-tradable areas;
c. Measure interior lighting levels in large occupied areas using a lux meter; and
d. Check interior daylight zone controls.

B5.2.1.4 Recommendations

a. Compare interior lighting power installed to maximum lighting power allowance as per EMSD Code of Practice for Energy Efficiency of Building Services Installation. Alternatively, use the CIBSE, CIE or IES reference. If installed lighting power is higher than allowed, consider replacement for more efficient fixtures;
b. Compare lighting levels to recommended values. If installed lighting levels are higher than recommended, consider a de-lamping plan;
c. For the case of office buildings, using task lighting can reduce energy use while preserving adequate levels of lighting; and
d. If M&V is carried out, measurements pre and post ESO implementation are required;
e. See Main Content Appendix A, example 16.

B5.2.2 Occupancy sensors

In large buildings, occupancy sensors can reduce the energy used for lighting.

B5.2.2.1 Symptom

a. Normal lighting is left on during the night, weekends and holidays.

B5.2.2.2 Results

a. Energy wasted by lighting when not needed; and
b. Reduction of the operative life of the lights.

B5.2.2.3 Analysis

a. Locate interior lighting controls; and
b. Install electricity sub-metering to lighting circuits in the main areas of the building during a recommended period.

B5.2.2.4 Recommendations

a. Install occupancy sensors in tradable areas for automatic on/off;
b. For the case of office buildings, using task light can reduce energy use while preserving adequate levels of lighting; and
c. If M&V is carried out, measurements pre and post ESO implementation are required.

B5.2.3 Daylight zone controls

Lighting control in exterior areas as well as in occupied areas in large buildings can reduce energy use for artificial lighting by taking advantage of the natural light. When installed indoors, photocells can also integrate occupancy sensors for improved lighting efficiency.

B5.2.3.1 Symptom

a. Areas in the building next to large vertical windows or skylights keep lighting on during daytime with the aim of preventing building-user complaints during early morning or afternoon periods.

B5.2.3.2 Results

a. Energy wasted by operating lighting when is not needed;
b. Increased cooling loads from lighting; and
c. Reduction of the operative life of the lights.

B5.2.3.3 Analysis

a. Determine if the building has areas with daylighting potential, use 2015 International Energy Conservation Code (IECC) or ASHARE Standard 90.1 2016 as reference;
b. Determine minimum lighting requirements of the areas, adhere to the referenced standard in the previous step;
c. Estimate potential savings from installing these sensors; and
d. If daily use patterns vary considerably, install electricity sub-metering to lighting circuits in the main areas of the building during a recommended period.

B5.2.3.4 Recommendations

a. Install daylighting sensors in areas with daylighting potentials;
b. Ensure to collect user feedback and adjust the sensibility of the sensors as required;
c. For the case of office buildings, using task light can reduce energy use while preserving adequate levels of lighting; and
d. If M&V is carried out, measurements pre and post ESO implementation are required.

B6. Lift and escalator

B6.1 Understanding the system

B6.1.1 System description

Means of vertical transportation installed in buildings vary widely, hence each system must be assessed individually.

B6.1.2 Data reporting period

If variability is low, short-term electricity metering is enough to determine actual vertical transport equipment demands during weekdays and weekends. Consider at least two weeks using half-hourly resolution during peak and off-peak seasons.

B6.1.3 System schematics

N/A

B6.2 Potential Energy Saving Opportunities

The following list of energy saving opportunities is not exhaustive but is intended to provide guidance on how to detect commonly found ESOs in vertical transport systems.

B6.2.1 Install metering devices

The installation of metering devices beyond energy codes can provide a better picture of how energy is used in lifts allowing a more accurate ESO estimation.

B6.2.1.1 Symptom

a. Energy used in lifts is unknown;
b. Energy usage pattern is not related with the travelling capacity pattern; and
c. High residual power of lifts at standby mode.

B6.2.1.2 Results

a. It is difficult to propose ESOs due to the lack of data.

B6.2.1.3 Analysis

a. Check testing and commissioning records of the actual lift or similar ones;
b. Check access to circuits for installation of meters; and
c. Check the passenger flow against the numbers of lift required per lift zone.

B6.2.1.4 Recommendations

a. Collect voltage, current, total power factor, energy consumption, power and maximum demand readings for each bank of lift;
b. Reduce the residual power of standby lifts
c. See EMSD – Code of Practice for Energy Efficiency of Building Services Installation, section 8 – Energy Efficiency Requirement for Lift and Escalator Installation.

B6.2.2 Optimise lift operation

Especially during off-peak period, minimising the number of available lifts beyond codes as well as reducing lighting and cooling in active lifts will help to reduce energy use.

B6.2.2.1 Symptom

a. Lifts are switched on during low-peak period.

B6.2.2.2 Results

a. Energy wasted by running several unused lifts.

B6.2.2.3 Analysis

a. Collect voltage, current, total power factor, energy consumption, power and maximum demand readings for each lift bank.

B6.2.2.4 Recommendations

a. Switch off light and ventilation during stand-by mode;
b. Switch off lift units beyond code requirements;
c. Use smart technologies to reduce the travel of lifts.

d. Optimise the counter balancing weight of lift when upward and downward travelling weight is significantly different.
e. Fitted in regenerative power of lifts into the power supply systems.
f. See EMSD – Code of Practice for Energy Efficiency of Building Services Installation, section 8 – Energy Efficiency Requirement for Lift and Escalator Installation.

B6.3 Improving energy efficiency by other means

Besides the potential energy saving opportunities mentioned in above sections, there are other technique(s) which can be considered to apply for improving the energy efficiency in the system.

B6.3.1 Lift Destination Control

In elevators banks with more than one shaft, a destination control system could be installed. The passengers select their destination before entering the elevator car and the elevator control systems are then able to calculate the most efficient servicing schedule based on the destination entries. This allows the elevator systems to optimize the flow of passengers, minimize the number of stops needed, and increase the operational efficiency for the elevator system.

B6.3.2 Service on Demand Escalator

Service on demand escalator will operate only when the passengers are detected by occupancy sensors, and the escalator will keep running at low speeds (with variable speed driven motor) or stop completely to conserve energy when there is no passenger. The amount of energy saving of a service-on-demand escalator will vary with different building types.

B6.3.3 Re-generative lift

Lifts with regenerative braking systems are able to recover some of the energy that would otherwise be lost from braking. The system’s motor could act as a generator for the energy when a lift car is traveling up with light loading, or down with a heavy loading, which allows the lift to lower its net energy usage.

B6.3.4 Variable Voltage Variable Frequency (VVVF) drives of lift motor

The Variable Voltage Variable Frequency Drive (VVVF) could change the input voltage and frequency of the lift motor with some frequency inverter technology. The system could achieve the desired motion with optimum frequency. There are some advantages to lifts with VVVF drives, including low starting current, high power factor and efficiency, and good ride experience.

B7. Power quality

B7.1 Understanding the system

B7.1.1 System description

Electricity distribution losses cause overheating of conductors and devices, which affects the energy consumption of the building. Power quality is critical to minimise electricity distribution loss.

Reactive loads in the circuit, the ones originated by induction motors, consist of an additional current in the circuit that does not do productive work. The ration between the true and the apparent power is called power factor. For instance, a power factor (Pf) equal to 1 suggests that only resistive loads such incandescent lighting and electric heating is present. Power therefore includes a correction factor called "total power factor".

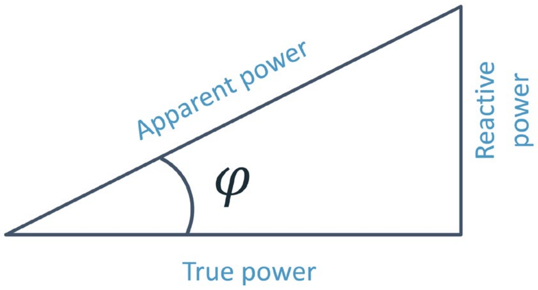

Fig. B.7.1.1 Power triangle

Total Power factor (cos phi) = phase angle between amps and volts. This angle can negatively affect true consumption and shall be minimised. True RMS meters measure voltage, amperage and phase angle.

B7.1.2 Data reporting period

Short-term electricity metering is generally enough to determine Total Power Factor (TPF) and Total Harmonic Distortion (THD).

B7.1.3 System schematics

N/A

B7.2 Potential Energy Saving Opportunities

The following list of energy saving opportunities is not exhaustive but is intended to provide guidance on how to detect commonly found ESOs in chiller systems.

B7.2.1 Measure TPF and THD

Harmonics are waveform distortions in current or voltages that exist in an ideally sinusoidal signal. Harmonics are caused by any non-linear loads in the network and have a negative impact on the quality of the electricity (current and voltage). Examples of non-linear loads include computers, copying machines, battery chargers, etc. On the other hand, linear load examples include incandescent lighting and electric heating. Total Harmonic Distortion THD is a measure in percentage that represents the ratio between the true voltage of the harmonic frequencies and the fundamental frequency of the signal. THD provides an estimation of how much of the variation in voltage or current can be attributed to harmonics. The lower the THD the better the quality of the signal. For further reference on the maximum limit of THD, please refer to EMSD Code of Practice for Energy Efficiency of Building Services Installation. Section 7.6

In practice, THD is considered through the calculation of the TPF, which is defined as the ratio between true and apparent power. TPF is close to one when only linear loads are connected to the circuit and this value reduces as non-linear loads are added. The recommended lower limit for TPF is 0.85, further reference can be found in EMSD Code of Practice for Energy Efficiency of Building Services Installation Section 7.6.

B7.2.1.1 Symptom

a. Excess of inductive loads create additional demand of electricity due to the additional resistance of the circuit.

B7.2.1.2 Results

a. Energy wasted due to cables and component overheating.

B7.2.1.3 Analysis

a. Calculate apparent and real power

B7.2.1.4 Recommendations

a. When metering electricity, the best practice is to always measure true RMS Watts, to be sure of including all possible power factor and harmonic influences. A simple wattmeter can only be used in circumstances where the technician is sure that loads are only resistive;
b. If TPF is less than minimum requirements, implement a correction plan;
c. If the percentage of THD is above the specified limits, implement a correction plan; and
d. See Main Content Appendix A, example 15.

Annex C

Central Control & Monitoring System (CCMS) Data Sample

Annex C – Central Control & Monitoring System (CCMS) Data Sample

The following examples show different data format samples that can be exported from CCMS. In this example, two data points, AHU off coil temperature and air supply flow rate (l/s) for illustration. Some CCMS are able to configure different data format based on user specification. User should consult the CCMS service provider for further reference.

<u>Sample 1</u>

Date and time stamp

Data point variable value
- AHU off coil temp
- AHU airflow supply rate

Date and time	AHU 1 off coil temp (degC)	AHU 1 flow rate(l/s)
30/11/2016 00:00	15	987
30/11/2016 00:15	17	1244
30/11/2016 00:30	17	1806
30/11/2016 00:45	14	1760
30/11/2016 01:00	15	592
30/11/2016 01:15	14	1945
30/11/2016 01:30	16	1004
30/11/2016 01:45	14	1005
30/11/2016 02:00	17	1937
30/11/2016 02:15	17	1607
30/11/2016 02:30	15	835
30/11/2016 02:45	16	1372
30/11/2016 03:00	15	1937

In this data format, each row represents one data logging time interval, with the columns representing different data points recorded value.

<u>Sample 2</u>

Date and time stamp

Data point variable value
- AHU off coil temp
- AHU airflow supply rate

Date and time	Reference	Value
30/11/2016 00:00	AHU 1 off coil temp (degC)	16
30/11/2016 00:00	AHU 1 flow rate(l/s)	590
30/11/2016 00:15	AHU 1 off coil temp (degC)	15
30/11/2016 00:15	AHU 1 flow rate(l/s)	1023
30/11/2016 00:30	AHU 1 off coil temp (degC)	15
30/11/2016 00:30	AHU 1 flow rate(l/s)	801
30/11/2016 00:45	AHU 1 off coil temp (degC)	15
30/11/2016 00:45	AHU 1 flow rate(l/s)	1103
30/11/2016 01:00	AHU 1 off coil temp (degC)	14
30/11/2016 01:00	AHU 1 flow rate(l/s)	1964
30/11/2016 01:15	AHU 1 off coil temp (degC)	17
30/11/2016 01:15	AHU 1 flow rate(l/s)	1195
30/11/2016 01:30	AHU 1 off coil temp (degC)	14
30/11/2016 01:30	AHU 1 flow rate(l/s)	1070
30/11/2016 01:45	AHU 1 off coil temp (degC)	14
30/11/2016 01:45	AHU 1 flow rate(l/s)	1303
30/11/2016 02:00	AHU 1 off coil temp (degC)	14
30/11/2016 02:00	AHU 1 flow rate(l/s)	781

In this data format, the data points value are listed together in rows (red line separation) for every data logging time interval. This type of data format is less common compared to sample 1 and 3.

Sample 3

Time

Date stamp

AHU 1 off coil temp (degC)									
Date	00:00	00:15	00:30	00:45	01:00	01:15	01:30	01:45	02:00
30/11/2016	16	15	15	15	14	17	14	14	14
01/12/2016	17	16	14	17	15	17	17	15	15
02/12/2016	15	14	16	15	17	17	16	15	16
03/12/2016	15	15	16	15	15	14	14	15	15
04/12/2016	14	17	16	17	14	15	15	14	16
05/12/2016	17	16	16	15	15	16	15	16	15
06/12/2016	15	15	14	16	14	14	17	17	15
07/12/2016	14	16	14	14	14	14	16	15	16
08/12/2016	15	14	16	16	15	15	14	14	17
09/12/2016	16	15	14	15	17	15	15	17	17

Time

Date stamp

AHU 1 airflow rate (l/s)									
Date	00:00	00:15	00:30	00:45	01:00	01:15	01:30	01:45	02:00
30/11/2016	590	1023	801	1103	1964	1195	1070	1303	781
01/12/2016	1477	1425	1436	1626	1689	1198	1144	1595	1992
02/12/2016	1417	908	1038	984	1997	1896	1313	1545	1773
03/12/2016	1604	1386	979	728	1269	1563	1042	1380	1472
04/12/2016	1002	1972	1350	1457	736	1312	1607	553	1674
05/12/2016	1661	627	1556	1299	1231	1760	893	1779	1918
06/12/2016	2000	1935	1379	855	1232	982	659	1806	724
07/12/2016	707	1946	744	841	707	657	1076	1652	795
08/12/2016	1880	1913	1291	1570	1000	1393	761	1970	861
09/12/2016	1439	1596	769	1310	1799	1438	644	1506	1334

In this data format, each row represent one day, where each column represent one data logging time interval recorded value. The column should read from left to right for the whole day trend.

The above examples are some data samples commonly encountered, there are other data formats available from different CCMS service providers. Users should consult the CCMS service provider for further explanation should there be any enquiries to understand the logged data.

Annex D

Innovative Sensor (IoT Sensor)

Annex D – Innovative Sensor (IoT Sensor)

D1. Background and application in buildings

With the development of wireless technologies, it is now more convenient than ever to obtain sensor readings at a relatively low cost for various components in HVAC systems. Furthermore, the huge technical progress in data storage and cloud computing provides building operators with convenient access to the full range of HVAC data points, including temperature, pressure, flow rate, and so on.

IoT refers to “the internet of things”, it can be defined as a network of physical objects or people designated as "things” and allows collection and exchange of data gathered from connected sensors.

IoT sensors consist of three parts: the sensing component, the data acquisition processor and the communicator. Different sensors, different data acquisition processors, and different communication methods results in a range of distinct performances, prices, and application scenarios. The data from the IoT sensor is delivered and presented to the user in various communication standards, such as Wi-Fi, Bluetooth, ZigBee, LoRa, Sigfox, or Narrow-band.

In terms of communication standard, LPWAN, including Lora, Sigfox and Narrow-Band is commonly used by IoT devices. The reason is that this technology is focused on Machine-to-Machine (M2M) communication. Its low power consumption and wide range transmission is ideal for metering, smart building, smart city, smart agriculture, track and trace.

Due to the development of LPWAN technology, the installation of the IoT sensor has become less complex. The city-wide unified communications infrastructure for LPWAN technology is becoming omnipresent in urban cities, which greatly benefit the network infrastructure.

IoT sensor, combined with the IoT switches and gateways can be innovative solutions with various properties. These IoT devices can be directly applied in buildings which don’t have building management systems (BMS). Furthermore, apps with friendly interfaces enable non-specialized personnel to monitor and manage building performance. As a result, IoT sensors become increasingly important in retro-commissioning, especially for buildings without BMS.

D2. Pros and Cons

The advantages and disadvantages for IoT sensors are listed as below:

Advantages

- Allows to schedule logging time and to directly send information to the cloud for storage or further processing
- Allows for automation of tasks that are performed daily
- Reduced installation complexity for building systems due to wireless communication
- Real time alerts on sensor malfunction. This ensures consistent data quality.

Disadvantages

- Privacy/Security: Risk of data loss due to increased reliance on wireless communication.
- Compatibility: Currently, there is no international compatibility standard for IoT sensors.
- Complexity: The design of the IOT system, as well as the system deployment and maintenance are quite complicated.

Annex E

The Differential Pressure Setting for VSD Chilled Water Pump and Chilled Water Bypass Valve

Annex E – The Differential Pressure Setting for VSD Chilled Water Pump and Chilled Water Bypass Valve

A chilled water system with VSD pump is typically used in building chiller plant, which means chilled water flows varies in proportion to the cooling load to reduce the part load energy consumption. Differential pressure control for VSD chilled water pumps to adjust the flow to match the cooling demand is usually applied, including the fixed differential pressure control and differential pressure resetting control.

E1. Fixed Differential Pressure Control

For the fixed differential pressure control, the setting value should be obtained through the system commissioning. The setting procedures can be referred as below.

a. Keep the chilled water flow regulating valve for each branch pipe fully open;
b. Keep the VSD chilled water pumps running at design flow condition;
c. Adjust the differential pressure value setting of the VSD pumps, until the design flow condition is achieved on the critical path; and
d. Use this differential pressure setting as the setting value for the fixed differential pressure of the VSD pumps.

E2. Differential Pressure Resetting Control

For the differential pressure resetting control, the opening status of flow regulating value will be monitored for the chilled water flow control to match the cooling load. The basic industrial practice can be referred as below.

a. Keep the chilled water flow regulating valve fully open for each branch pipe loading fully open;
b. Keep the VSD chilled water pumps running at design flow condition;
c. Adjust the differential pressure value setting of the VSD pump, until the design flow condition is achieved on the critical path; and
d. Use this differential pressure setting as the initial input value for the differential pressure resetting control of the VSD pumps.

The opening status of flow regulating valve on the critical path, e.g. furthest end loading, will be feedbacked to the controller.

- If the degree of opening is lower than lower limit for some time (e.g., less than 90% for 10 minutes), the pressure lose will rise accordingly which results in the energy loss. The differential pressure setting will be decreased by some value (e.g. 5 kPa) gradually and control system will decrease the operating frequency of the pump to lower the chilled water flow gradually until the regulating valve's degree of opening can keep within the range.
- Conversely, if the degree of opening is greater than the upper limit for some time, (e.g., larger than 95% for 10 minutes), the differential pressure setting will be increased by some value (e.g. 5 kPa) gradually and the control system will increase the pump operating frequency to increases the chilled water flow gradually until the regulating valve's degree of opening can keep within the range.
- With such differential pressure resetting control, the regulating valve's degree of opening can be kept within the optimized operational range to match with the variable loading, to achieve optimized energy saving as well.

E3. Differential Pressure Setting for Chilled Water Bypass Valve

There is bypass pipeline in the chilled water circuit, which will bypass the extra supplied chilled water to return side when the cooling load demand is less than the minimum flow of the chiller for the operation safety. For the secondary pump system, there are usually no bypass valve or only one-way valve on the chilled water bypass pipeline to prevent the inverse flow from the chilled water return side to the supply side. For the variable primary flow system, the differential pressure for the bypass valve will be set as the pressure difference for the chiller evaporator under the minimum flow condition and the bypass valve will be opened when such differential pressure value reaches.