BSOMES
Building Services Operation and Maintenance Executives Society
屋宇設備運行及維修行政人員學會

Strengthening the Technical Capability and Regional Collaboration in Implementing Retro-commissioning (RCx) in Buildings

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Message from BSOMES

Dear Members and Friends,

It is my honour and pleasure to be the Retro-commissioning (RCx) Chamber Chairman of BSOMES Professional Services Advancement Support Scheme (PASS) Project called "Strengthening the Technical Capability and Regional Collaboration in Implementing Retro-commissioning (RCx) in Buildings" for the year of 2019 to 2021. Since I am the Technical Committee Vice Chairman of the BSOMES, I am very happy to work with our organization committee members during these 2 years. Our RCx Chamber of BSOMES PASS project has organized 2 Half days' seminars on RCx for building energy efficiency and RCx 10 showcases' casebooks with 10 video clips and e-copy to be uploaded on BSOMES website. Therefore we help and support the Electrical and Mechanical Services Department (EMSD) & Hong Kong Green Building Council (HKGBC) to enhance the promotion of professional knowledge about improvement on energy efficiency of existed buildings into a higher level. Meanwhile, we provide different technical seminars and casebooks & videos with case studies including Hong Kong and China Overseas.

Our Chamber held the professional seminar to enhance our engineers' knowledge of RCx Era such as "New Era of RCx for Building Energy Efficiency "and 10 showcases such as "Key Achievement of RCx and Introduction of RCx Casebooks", "Casebook Sharing – RCx for chiller water system & Condenser Water System, Carpark Ventilation System, AHU and Secondary Chilled Water Pump Strategy, Fresh Air System & BMS System." We are not only inviting our engineers, the HKGBC are also joined us. Our speakers are contributed from their key management staff of each topic of the RCx Casebook. We are well to prepare our future engineers / O&M / FM Engineers.

We also have the 1 day BSOMES RCx International Conference at end of Sep 2021 with different countries including USA, Australia, China and Local Hong Kong / Government Engineers to exchange the ideas in RCx Engineering & Technology Development. Meanwhile, our RCx Chamber of BSOMES were introduced during this conference. Our BSOMES members are active, smart and enthusiastic. They always support a lot in different activities of our BSOMES Chapter. Meanwhile, our BSOMES would like to take opportunity to deliver my sincerely grateful to the council members, sponsors and supporting organization.

CHAN Nai-Kin, Steven
Retro-commissioning (RCx) Chamber Chairman (2019-2021)
BSOMES 2021/2022

Terms & Definitions

Term	Definition
Air-Conditioning	The process of cooling, heating, dehumidification, humidification, air distribution or air purification.
Air Handling Unit (AHU)	An equipment that includes a fan or blower, cooling and/or heating coils, and provisions for air filtering and condensate drain etc.
Building Management System (BMS)	A computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. A BMS consists of software and hardware; the software program, usually configured in a hierarchical manner, can be proprietary, using such protocols as C-Bus, Profibus, and so on.
Chilled/Heated Water Plant	A system of chillers/heat pumps, with associated chilled/heated water pumps and if applicable associated condenser water pumps, cooling towers and/or radiators.
Chiller	An air conditioning equipment that includes evaporator, compressor, condenser, and regulator controls, which serves to supply chilled water.
Condenser Water System	While the chilled water systems are used to absorb heat energy from within a building or process, condenser water systems are used to remove that heat energy from the building and reject it to the atmosphere. Air is drawn through porous media using a fan, causing the water to cool.
Coefficient of Performance (COP) – cooling	The ratio of the rate of heat removal to the rate of energy input, in consistent units, for an air-conditioning equipment.
Coefficient of Performance (COP), heat pump - heating	The ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a heat pump type air conditioning equipment.
De-lamping	De-lamping means removing lamps from fittings where the light output exceeds what is required. It can result in significant energy savings at very low costs and also reduce air conditioner cooling loads, reduce lamp replacement costs, and decrease circuit loading due to lower electricity demand. There are good de-lamping opportunities in toilets, kitchens, offices, corridors, stairwells, meeting rooms (often over-specified for lighting), and near windows in buildings not used at night.

Demand Control Ventilation (DCV)	Demand controlled ventilation (DCV) is a feedback control method to maintain indoor air quality that automatically adjusts the ventilation rate provided to a space in response to changes in conditions such as occupant number or indoor pollutant concentration. The control strategy is mainly intended to reduce the energy use by heating, cooling, and ventilation systems compared to buildings that use open-loop controls with constant ventilation rates.
Electrical Installation	Fixed equipment, distribution network or accessories for electricity distribution or utilization in the building.
Energy Saving Opportunity (ESO)	The saving opportunity that can be found after the investigation stage of RCx.
Equipment	Any item for such purposes as conversion, distribution, measurement or utilization of electrical energy, such as luminaires, air conditioning equipment, motors, motor drives, machines, transformers, apparatus, meters, protective devices, wiring materials, accessories and appliances.
Fresh Air System	Fresh Air System (FAS) features a Fresh Air Damper (FAD) that works automatically with the Fresh Air Ventilation Control (FAVC) to efficiently and effectively distribute air throughout the building. FAVC utilizes the central fan to supply outdoor air from a known source through a controlled duct for fresh air intake, while the Fresh Air Damper prevents infiltration during off periods. When there is a call for fresh air intake, the control opens the damper allowing fresh air to enter the HVAC return. When the control is satisfied, the damper is closed.
Implementation Stage	A stage that carries out the selected energy saving opportunities (ESOs). A verification process will also be carried out so as to see if the ESO contributes to any energy savings. After the whole implementation and verification, a final RCx report should be carried out which summarizes the progress of above stages.
Internet of Things (IoT)	The Internet of Things (IoT) describes the network of physical objects—“things”—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. These devices range from ordinary household objects to sophisticated industrial tools.
Investigation Stage	A stage that includes an in-depth system analysis so as to find out the possible energy gaps. A detailed list of recommended energy saving opportunities (ESOs) should be provided showing estimated energy savings and payback period. The methodology of energy saving verification should be presented clearly. A list of selected energy saving opportunities (ESOs) should be confirmed at the end of this stage and agreed by the building owner(s)/ facility manager.

Meter	A measuring instrument to measure, register or indicate the value of voltage, current, power factor, electrical consumption or demand, water flow, energy input/output etc.
On-going Commissioning Stage	A stage that aims at ensuring building systems remain optimized continuously. Thus, data will be continuously gathered and compared.
Operation and Maintenance (O&M)	Facilities operations and maintenance encompasses a broad spectrum of services, competencies, processes, and tools required to assure the built environment will perform the functions for which a facility was designed and constructed. Operations and maintenance typically includes the day-to-day activities necessary for the building/built structure, its systems and equipment, and occupants/users to perform their intended function.
Planning Stage	A stage that includes the collection of building documentation such as schematic drawings, layout plans, electricity bills, etc. For the understanding of building system operations, an initial site walk-through should be carried out. After having a walk-through and reading the trend log data, a RCx plan should be written which covers system analysis and upcoming site measurement plan.
Retro-Commissioning (RCx)	A knowledge based systematic process to periodically check an existing building’s performance to identify operational improvements than can save energy and thus lower energy bills and improve indoor environment.
Sensor	Sensor is a device that is used to record that something is present or that there are changes in something.
Variable Air Volume (VAV) air distribution system	A system that controls the dry-bulb temperature within a space by varying the volume of supply air to the space automatically as a function of the air-conditioning load.
Variable Speed Drive (VSD) of a motor	A motor drive that controls the motor speed over a continuous range.
Water Transfer Factor (WTF)	The water transfer factor is defined as the net water flux across the MEA membrane divided by the water production flux and is defined as positive for water transfer process.

Part I – Knowledge on Implementing Retro-Commissioning

1.1 Why Implement RCx?

Retro-commissioning (RCx) is a systematic process to periodically check an existing building's performance to identify operational improvements that can save energy and thus lower energy bills and improve indoor environment.

There are many benefits brought by RCx and some are shown as the following:

- provide the building energy cost savings with no or low investment with short payback period;
- reduce the operation and maintenance (O&M) cost;
- reduce the chance of energy consuming equipment/ systems failure and extend the equipment life;
- ensure the energy consuming equipment/ systems operate at the most efficient level; provide a healthy and comfortable indoor environment for the occupants;
- increase the asset value of the building and
- build up the knowledge and skills within the building management team for development of O&M industry.

RCx focused on checking whether the energy consuming equipment / systems operate properly as design or users' requirements and to identify some area of improvements (e.g. shifting of system control settings, inaccuracy of sensors, improper operational schedules and improper air & water balancing, etc.). Besides, RCx has an implementation of ESOs and ongoing commissioning plan for the building owners to implement and maintain the building operating in high energy efficiency level.

1.2 Systematic Way in Implementing RCx

"Retro-commissioning" covers the scope of "existing building commissioning", "re-commissioning" and "continuous commissioning". There are four stages in RCx:

The RCx commences from collection of operational data of energy consuming equipment/systems, followed with site measurement testing and data analysis and then come up with proposed Energy Saving Opportunities (ESOs). Through the implementation of the ESOs, the operational performance of building systems improve which in turn enhances the building energy efficiency.

1.3 Major Energy Saving Areas

To check where the greatest improvement and energy saving opportunities in existing building, it can be determined by reviewing which energy consuming equipment/systems consume the most energy.

If there is sub-metering installed in different types of energy consuming equipment/systems in the building, we could know the breakdown of annual building energy consumption for each equipment/ system.

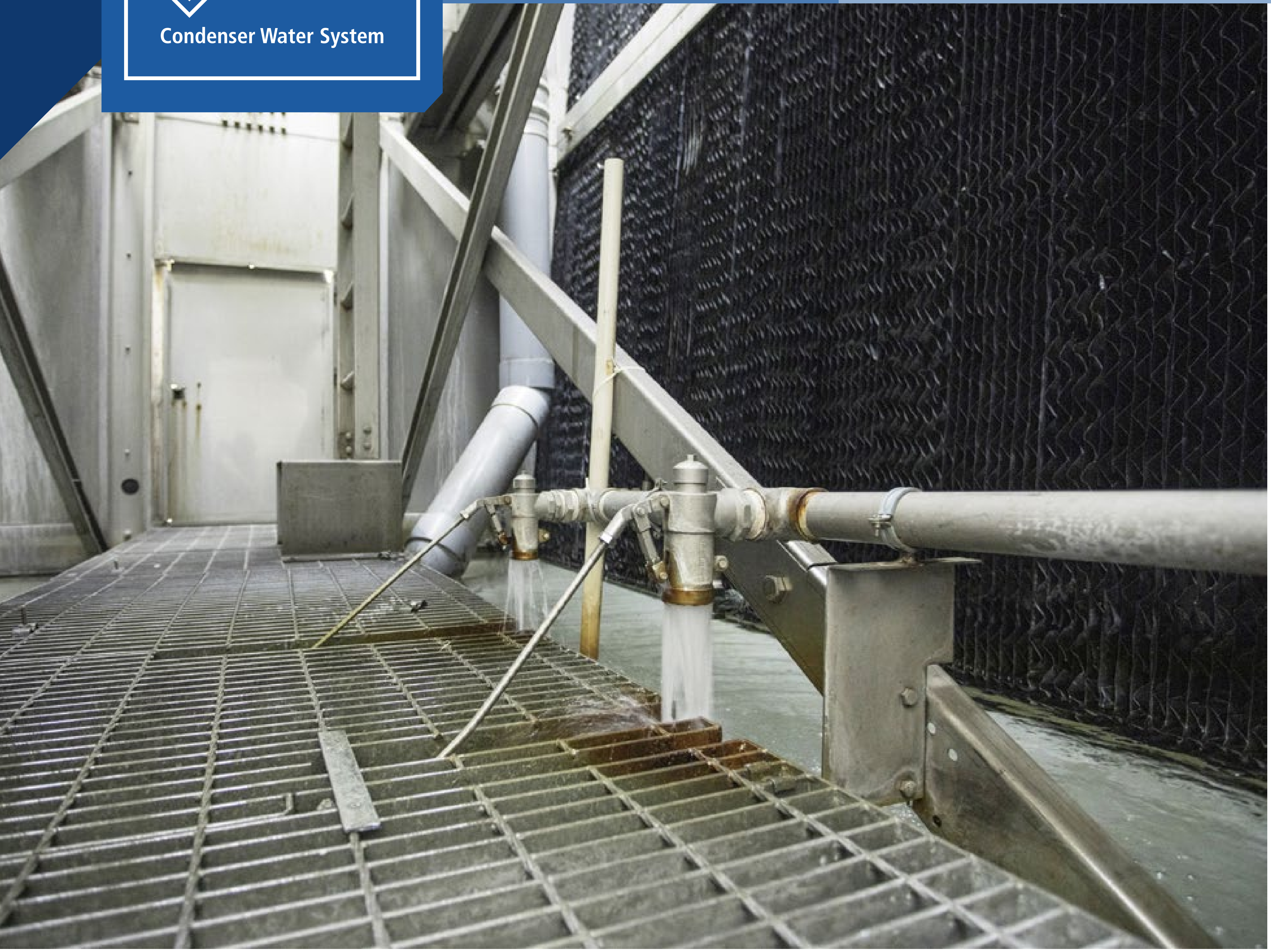
However, many of the existing buildings in Hong Kong do not have such sub-metering provisions. In such case, the computerized energy simulation tools in the market can be used to simulate an energy models based on the existing system information, operation schedule and electricity bills.

Modelling can also benefit to RCx while data is available, this allows the operational data to be used for a number of energy modelling strategies that will further enhance the RCx process and should therefore be included in more detail;

1. Utilise operational data to refine energy model predictions and therefore refine more accurately cost reductions as a result of analysing various energy saving proposals.
2. Provide an energy model that once updated with recent operational data, will provide an accurate benchmark that will provide the means for comparison when completing continuous commissioning.
3. Perform measurement and verification studies to identify accurately the savings that can been generated as a result of an energy saving proposal.
4. Provide a high value asset to the client with respect to the energy model, and results of the M&V process that can be adopted on future project for the purpose of design, or RCx.

In general, applications of energy modelling in RCx including:

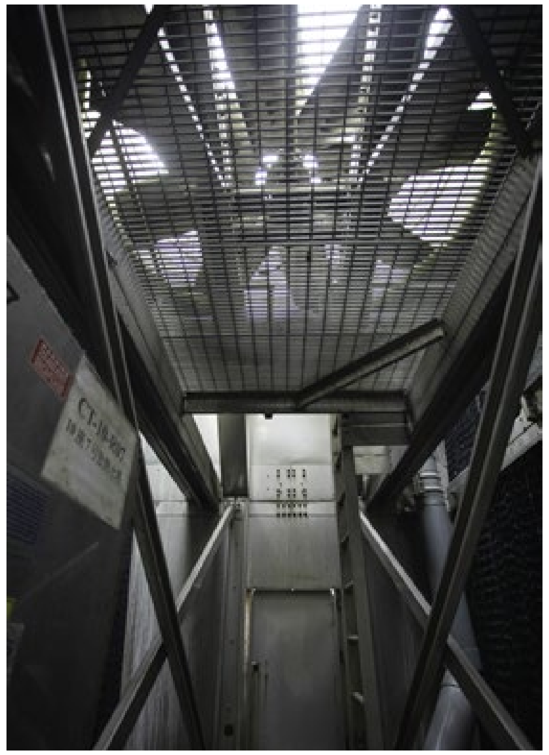
1. Evaluate the breakdown of energy use for the existing building accurately;
2. Identify the gap between the simulated results and the energy bill; and
3. Estimate the amount of energy cost saving for selection of the identified opportunities.



1. Brief Introduction of the Building and System

Hong Kong Science Park is designed according to the key design principles of reduction, efficiency and generation. As a green hub focusing on cost-effective energy-saving measures, buildings incorporate the latest green technologies and sustainable building design. One of the green technology incorporated in the buildings in Hong Kong Science Park is "Condensing water temperature setting" applied on Chiller Plants including the following case.

The Chiller Plant serves one of single block of Buildings in Hong Kong Science Park. 4 sets of Water-Cooled Chiller unit each with cooling capacity 879kW were installed with 4 sets of Fresh Water Cooling Tower that match with the chiller unit.



2. Energy Saving Opportunities

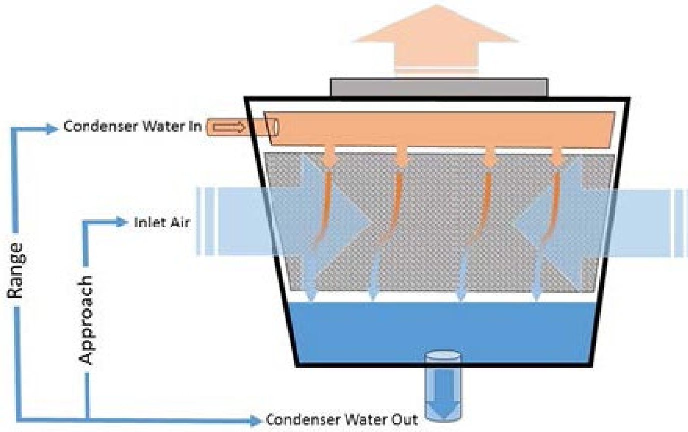
A cooling tower is an important heat rejection device to lower the temperature of condenser water by process of evaporative cooling in which the ambient air is drawn in to contact with the falling water to absorb heat before discharged into the atmosphere. It was operated in accordance with chiller operation, i.e. one cooling tower operated with one chiller unit, in a fixed speed of fan motors and was operated to maintain fixed condenser water temperature throughout the year.

After cooled down in cooling tower, condenser water enters into the chiller to absorb the heat from the refrigerant circuit. Thus, condenser water temperature affects the refrigerant pressure of the chiller unit and the coefficient of performance (COP) of the chiller unit (ratio of the amount of cooling capacity generated by the chiller to the electricity power provided). Especially in hot summer, high condenser temperature will induce high refrigerant pressure and lower the COP of the chiller units.

However, in order to lower the condenser water temperature as possible, excess energy may be used for the cooling tower fan motor.

Thus, the operation of cooling tower could be controlled such that the condenser water temperature is optimized for better the chiller system performance as a whole.

3. Technical Guidelines



The cooling tower relies on evaporating condensed water to dissipate heat. Outdoor wet bulb temperature, packing area and condensed water surface area are factors that determine the amount of evaporation. When the dry bulb temperature decreases, the wet bulb temperature will also decrease. The lower the air humidity is, the better the evaporation can achieve.

Thus, the condenser water temperature should be set in accordance with the wet bulb temperature of ambient air. The below Figure 1 showed the operating parameters for chiller system with cooling tower. In general, the approach temperature of a cooling tower (difference between condenser water supply temperature and outdoor air wet build temperature) in summer is around 2°C to 4°C, while around 7°C to 10°C in winter.

In order to maintain a favorable condenser water temperature, especially in hot weather, an extra cooling tower can be operated, without increasing the condenser water pump, to increase the effective area of heat exchange. It can effectively lower the approach temperature and improve the COP of the chiller unit and thus improve the total energy consumption of the whole chiller system.

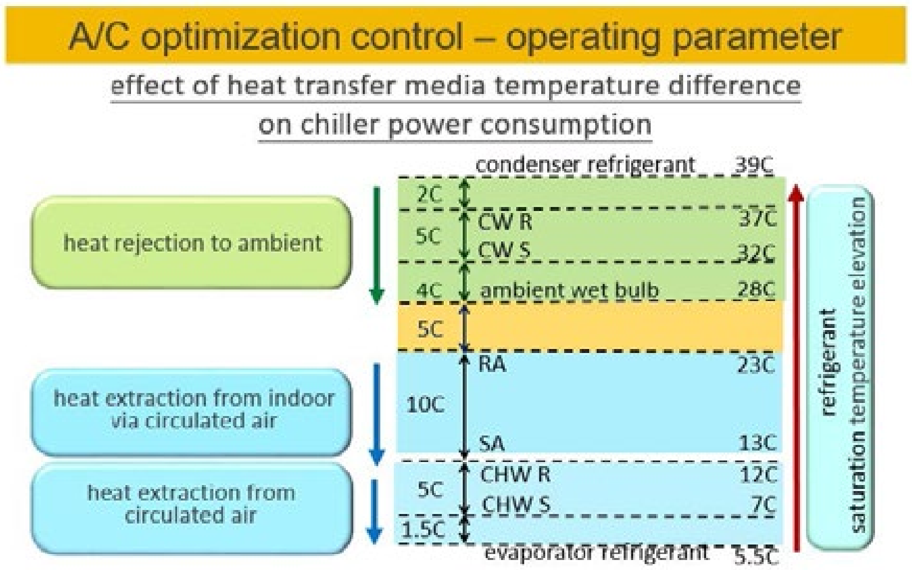


Figure 1 – *A/C optimization control – Operating Parameter*

4. Performance Analysis

In general, the wet bulb temperature or outdoor air in Hong Kong is around 3℃ lower than dry bulb temperature. Since wet bulb temperature sensor has not been installed, it is estimated by reduce 3℃ of dry bulb temperature. For instance:

In Summer		In Winter
33°C to 31°C	**Dry Bulb Temperature**	16°C to 13°C
30°C to 28°C	**Wet Bulb Temperature**	13°C to 10°C
2°C to 4°C	**Approach Temperature of a Cooling Tower**	7°C to 10°C
33°C-3°C+2°C to 31°C-3°C+4°C = 32°C	**Condenser Water Entering Temperature**	16°C-3°C+7°C to 13°C-3°C+10°C = 20°C

The below Figure 2 indicates the condenser water setpoint in relate to the outdoor dry bulb temperatures.

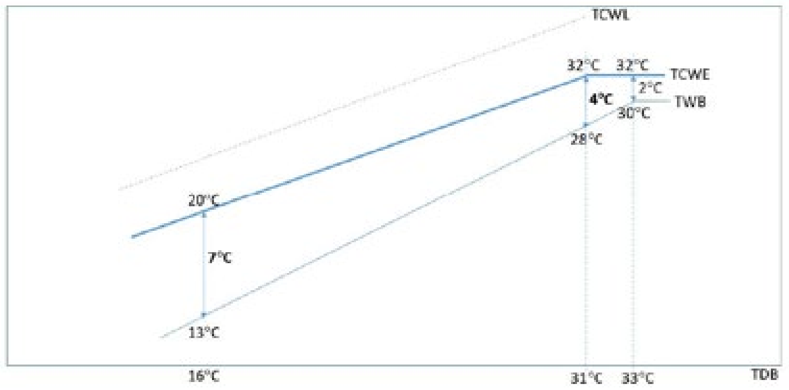


Figure 2

If the condenser water temperature cannot achieve the above condenser water supply temperature setpoint, an extra cooling tower will be operated without increasing the number of condenser water pump. This could help to increase the packing area and condensate surface area of the condenser water, and result in lower the condensing water entering temperature.

COP of the chiller can be improved by 1-3% for every 1 ℃ reducing Condenser Entering Water Temperature.

5. Sharing by Implementation Parties

With the application of condenser water system, Hong Kong Science Park could take the advantage of maximizing heat transfer efficiency of the cooling tower, additional cooling tower can be considered to optimise the positive outcome. It is also important to ensure the cleanliness of cooling towers, as well as the condenser tubes to achieve higher energy efficiency and better hygienic conditions of the system.

It is a cost-effective energy saving measure, as it involves only operating resilience cooling tower which contribute to better overall COP of the system. Variable speed drive can be considered to control the cooling tower fan speed in order to achieve the condenser water temperature at the appropriate approach temperature with minimum fan power energy consumption.

1. Brief Introduction of the Building and System

Hong Kong Science Park not only has adapted condenser water system but also adapted chilled water system in buildings to save energy. There are District Cooling Plants to serve various office towers.

Due to the key design principles of reduction, efficiency and generation and incorporates the latest green technologies and sustainable building design, Hong Kong Science Park Phase 3a and 3b has won the Grand Award in Green Building Award ("GBA") 2012 – New Building Category – Building Project as well as the Grand Award in GBA 2014 – New Buildings Category – Completed Buildings.

2. Energy Saving Opportunities

An air conditioning plant is generally designed for a specific indoor and outdoor condition. Chilled water is main source for cooling down the buildings that absorb heat from the building's space. The design chilled water supply temperature is generally 7°C. All air handling equipment are also designed base on this chilled water supply temperature to provide cooling and dehumidification for the space. In order to meet this chilled water supply temperature requirement especially at far end of the chilled water system, the chilled water supply temperature setpoint sometimes was set at a little bit lower to 6.5°C.

However, the actual outdoor temperature always lower than the design outdoor temperature that general specified at 35°C. As the outdoor temperature is lower than the design value, the indoor heat load and dehumidification requirement also lower. Thus, there is opportunity to raise the chilled water temperature and maintaining the indoor comfortability for better energy efficiency.

3. Technical Guidelines

The chilled water supply temperature is usually control at 7°C to cope with design and the dehumidification effect of fan coil units and air-handling units. However, the decrease of outdoor temperature would lead to reduction of indoor active human body evaporation, and thus reduce the demand of dehumidification requirements.

When outdoor temperature decreases, the indoor cooling requirement also decreases. As the cooling coil area is fixed in the air handling equipment, the chilled water flow through the cooling coil will be reduced by the modulating water valve to maintain the indoor temperature.

However, it is possible to raise the chilled water supply temperature such that the water valve opens larger to allow more water flow to maintain the indoor temperature. In general, the COP of chiller unit as well as the energy consumption can be improved by 2% to 5% for 1°C rise in chilled water supply temperature.

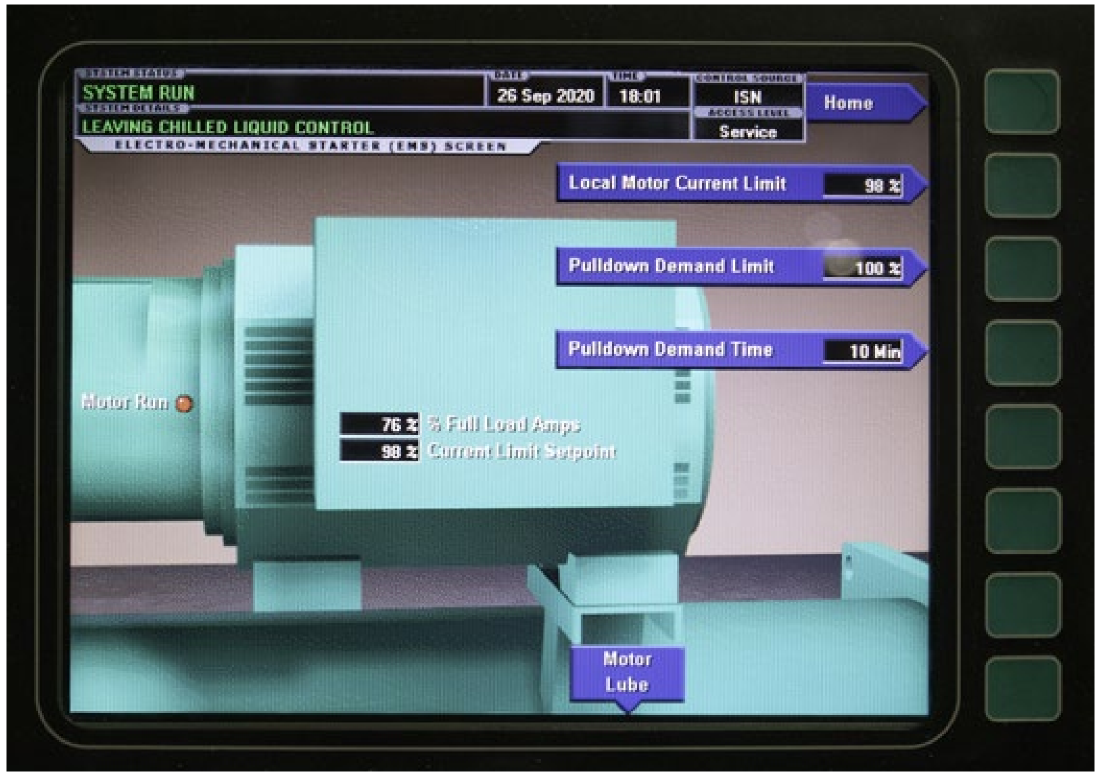
Table 1 indicates example of the Operating schedule for efficient air conditioning system.

Description		Summer	Spring & Autumn	Winter
Indoor Temperature (°C)		23	23	20
Chilled Water Supply Temperature (subject to lease condition) (°C)		7	7-10	10
Condensing Water S / R ΔT (°C)			5	
Cooling Tower Approach Temperature (°C)		4	4-7	7
Chilled Water Mains S / R ΔP (kPa)		150	80-150	80
Chilled Water Index S / R ΔP (kPa)		100	60-100	60
AHU Supply Air	Temperature (°C)	13	13-18	18
	Quantity (%)	100%	70-100%	70%

Table 1 – *A/C Efficient Operating Annual Schedule*

4. Performance Analysis

The chilled water supply temperature is set from 7°C to 10°C according to the outdoor temperature. Raising of the chilled water supply temperature in winter has not affected the indoor environment with average energy saving of 8% over the year.



5. Sharing by Implementation Parties

It is a very practical energy saving opportunity as there is no cost implication on this RCx application. We can implement easily by re-set the chilled water supply temperature of the chillers. The application of RCx for chilled water system can ensure the indoor cooling load demand are within the design limit and keep monitoring the AHU Return Air Relative Humidity values to ensure it is varying in a normal range.

The chilled water supply temperature re-set can be automatically done by building management system based on pre-set formula that relates to the ambient temperature.

CASE 03

Chillers Control

1. Brief Introduction of the Building and System

Chong Hing Bank Centre is a 26-storey Grade A office building located at Central, Hong Kong since 2006. The gross floor area is around 10,000 m2 with 2 sets of 280RT air-cooled chiller unit for normal office use, and 2 sets of 55RT air-cooled chiller unit for 24-hour operation for partial floors with server rooms.

2. Energy Saving Opportunities

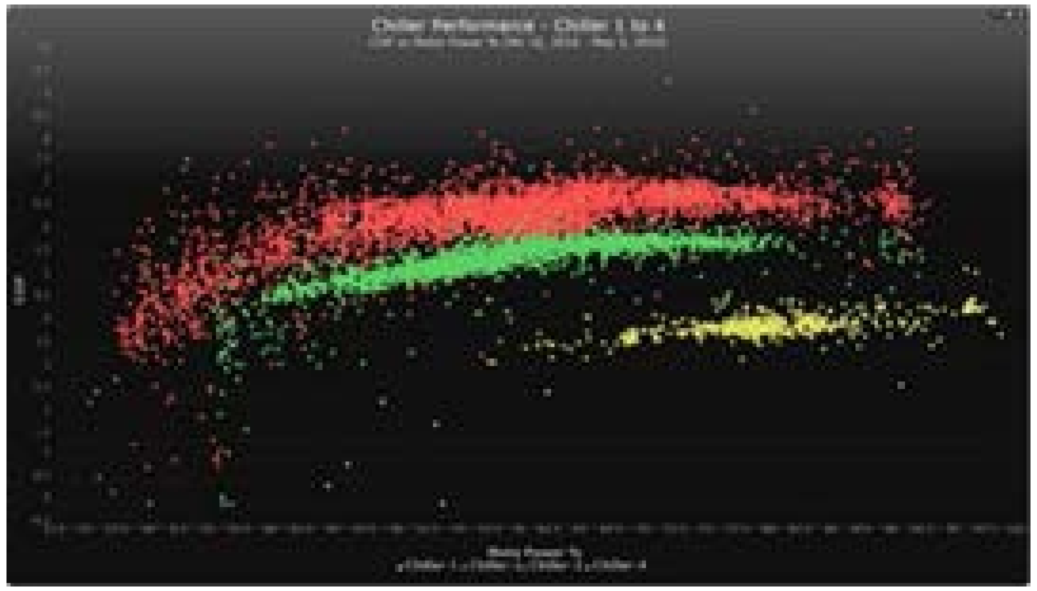
Chiller unit is the major air conditioning equipment and the most energy consumable equipment in a commercial building. Generally, multiple chillers are installed in a building to maintain sufficient cooling capacity in various seasons and cooling load requirement.

The energy efficiency of chiller unit is indicated by Coefficient of Performance (COP) of the chiller unit (cooling capacity in kW vs power input). However, COP of the chiller unit is not a constant, but subjects to the part load operating condition, cleanliness of the condenser coil, refrigerant charge of the chiller etc. Thus, different chiller units with the same model may have a different COP characteristics after operating for years.

In general, the COP of a chiller is higher in between 60% to 90% part load operating condition. If the chillers are being operated in this high COP region, the energy effectiveness can be maintained as high as possible.

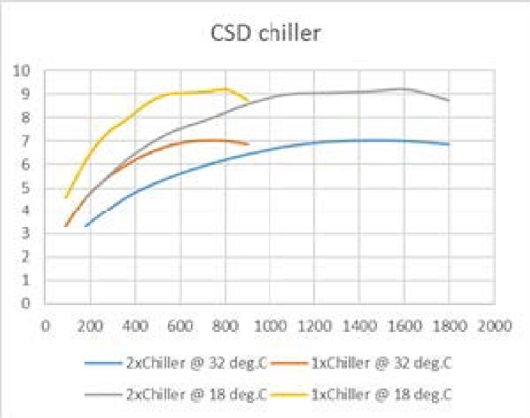
3. Technical Guidelines

In order to effective operate the chiller units at the most energy efficient way, it is necessary to record the operating parameters of the chiller unit under different operation condition. The operational characteristics of each chiller can then be created as the below figure.

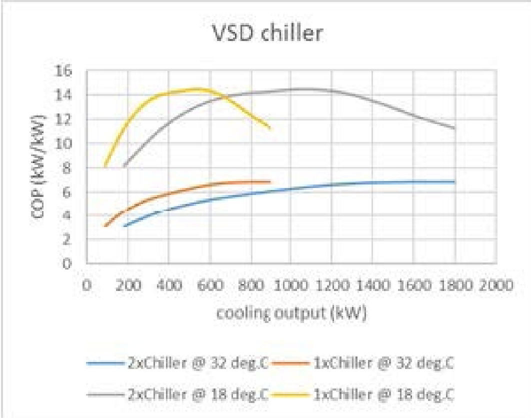


Example of a Chiller's Operational Characteristics

With the above figure, the highest COP range of each chiller can be identified and a combined COP chart for against cooling capacity can be created as below.



Comparison of CSD Chillers



Comparison of VSD Chillers

If the chiller system can always be operated at the highest COP area in accordance to the cooling load as in the combined COP chart, the energy consumption can be minimized. In general, there is 15% to 20% different in COP between high energy performance zone and normal performance zone. If the operation time for chiller system in high energy performance zone can be raised from 40% to 60%, 3% of energy saving can be achieved.

Since there would be deviation of the chiller's operational characteristics when the chiller has been operated for a period of time, it is necessary to implement RCx to re-create the COP characteristic chart for further operational review.

4. Performance Analysis

According to the analysis of the COP of the chiller units, it was identified that the chillers were operated at the high performance zone at 50% to 100% part load ratio. The chiller operation sequence was then adjusted to make sure that the chillers are operated within this part load range.

The control sequence logic was set as below

- If the chiller operates at part load ratio over 95% with chilled supply temperature 1°C above the chilled water setpoint for 15 minutes, additional chiller will be added;
- If two chillers operate at part load ratio lower than 50%, one set chiller will be switched off;
- Small chillers are operated beyond office hours when cooling load requirement is low.

All chillers are being operated in the high performance zone

5. Sharing by Implementation Parties

An implementation plan is developed to carry out those selected improvements and optimization opportunities which minimize the disturbance to current operation and occupants inside the building.

By recording the operating parameters of the chiller units through building management system, the chiller performance can be fully monitored and the COP characteristic can be easily created.

The chiller operation should be carefully adjusted at the time when normal office hour start and end to avoid sudden increase or drop of chilled water temperature that leads chillers to be operated at the low performance zone. Residue cooling can be best used before end of office hours for energy saving.

The chilled water supply temperature can be raised by 1 to 2 ℃ in winter for further improving of energy efficiency.

1. Brief Introduction of the Building and System

Since 2017, Pacific Place operated with a monitoring-based RCx programme to enhance energy efficiency. Energy saving opportunities (ESOs) with a total energy saving potential of 3.2 million kWh/year, equivalent to 10% reduction of landlord energy consumption have been identified. There are two Grade A Office towers and a shopping mall operated with two central sea water-cooled chiller plant with a total capacity of 14,200RT. Plant 1 of 5,200RT serves One Pacific Place office tower and part of the shopping mall while Plant 2 of 9,000RT serves Two Pacific Place office tower, part of the shopping mall, and other attached buildings. Constant primary and variable secondary system are applied for chilled water distribution.

2. Energy Saving Opportunities

An accurate control on the supply of cooling water could help to save energy and maintain adequate indoor environment. The water pressure control in the chilled water system requires operating chilled water pump(s) to maintain the water pressure at the point of the differential pressure sensor, which affects the pump energy consumption. An energy saving opportunity can be achieved by eliminating excess pump operation under a similar water flow demand.

Excessive pressure drop in terminals (air handling unit) was found in chilled water system, which was caused by a higher differential pressure setpoint in the chilled water system. Most of the AHU modulating valves were operating at 40-60% opening. The high differential pressure setpoint required larger pumping power.

It is suggested to lower the differential pressure setpoint and reduce secondary pump operating speed by adding an additional one if necessary. The system resistance will be reduced by the increased openness of modulating valves with the same chilled water flow rate demand. The operating efficiency of chilled water pumps would be improved as well.

3. Technical Guidelines

In general, a thermostat is used to control the motorized valve of the terminal unit. (see Figure 3). In response to the temperature change, the motorized valve will open or close to allow more or less chilled water to pass through the terminal. This action affects the water pressure across the terminal and the system differential pressure. While, the speed of secondary chilled water pump should be adjusted to maintain the system differential pressure in the appropriate range.

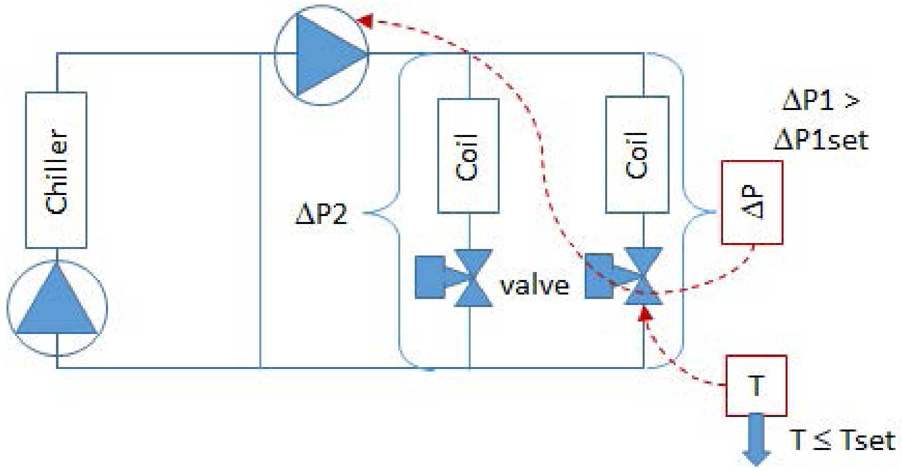


Figure 3

Testing had been carried out with Tsinghua University and showed that reducing secondary pump operating speed by adding an additional one, the system resistance will be reduced by the increased openness of modulating valves with the same chilled water flow rate demand. (See Figure 4) The operating efficiency of the chilled water pump would be improved. (See Figure 5) The water transport factor (WTF) [Cooling Energy / Energy Consumption of Chilled Water Pumps] would be improved and the energy consumption would also be reduced.

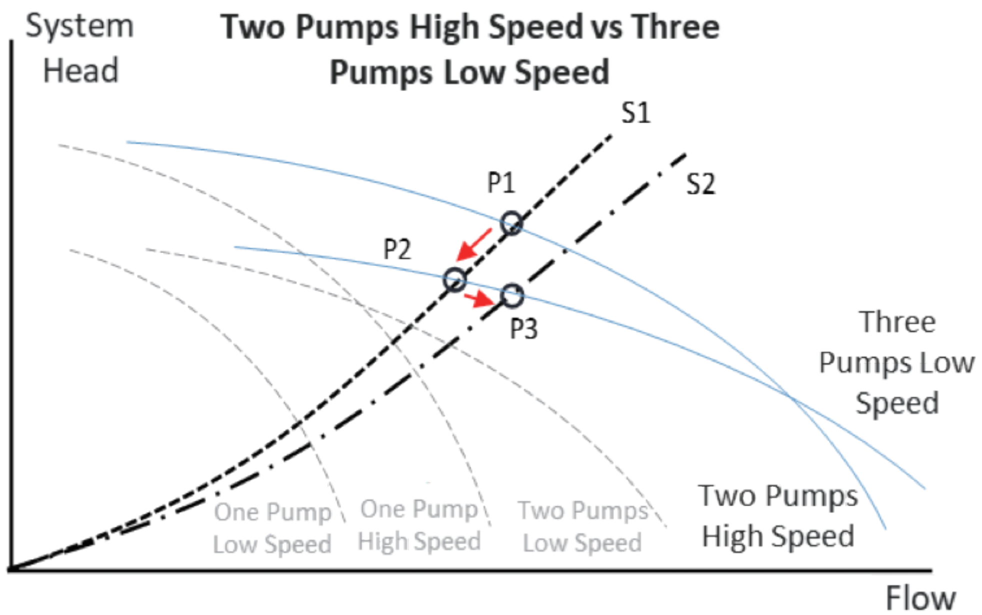


Figure 4

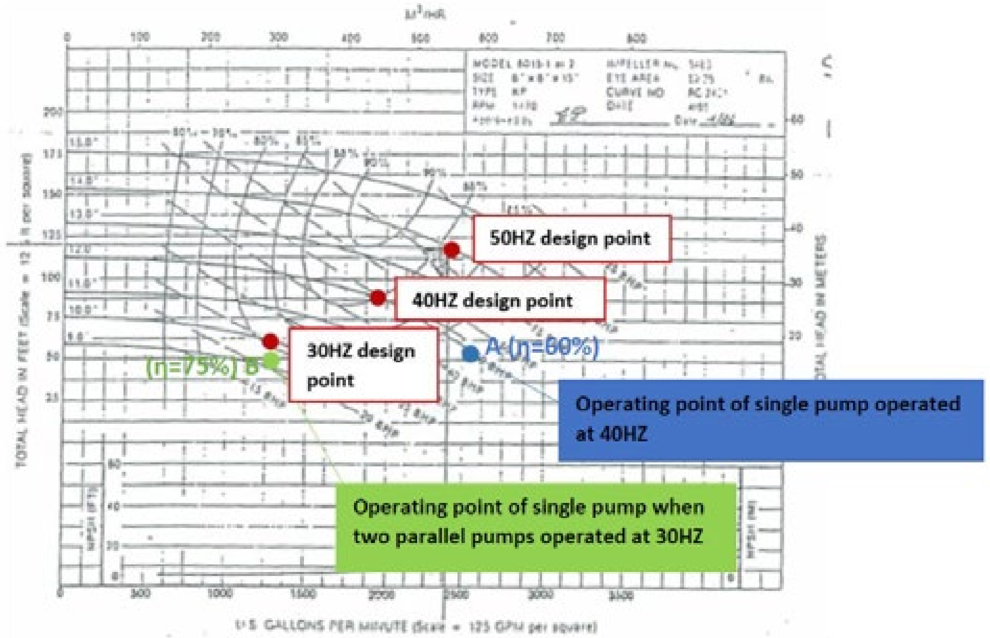
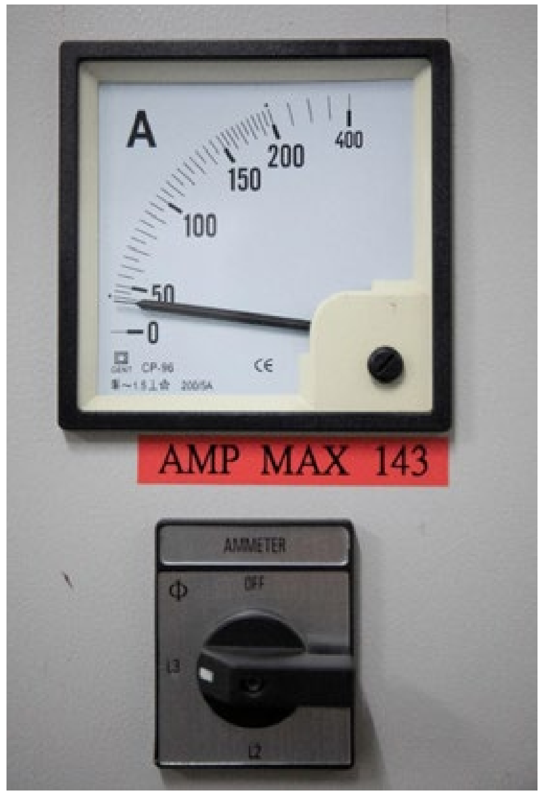


Figure 5

4. Performance Analysis

By implementing the secondary chilled water pump strategy optimization, i.e. operate an additional pump and reduce operating speed, the differential pressure setpoint was reset from 130kPa to 100kPa. Originally the secondary chilled water pumps were operating at 40Hz and above, after strategy implementation the secondary chilled water pumps are operated between 30Hz to 38Hz. As a result, 10.9% chilled water pump energy saving was achieved.

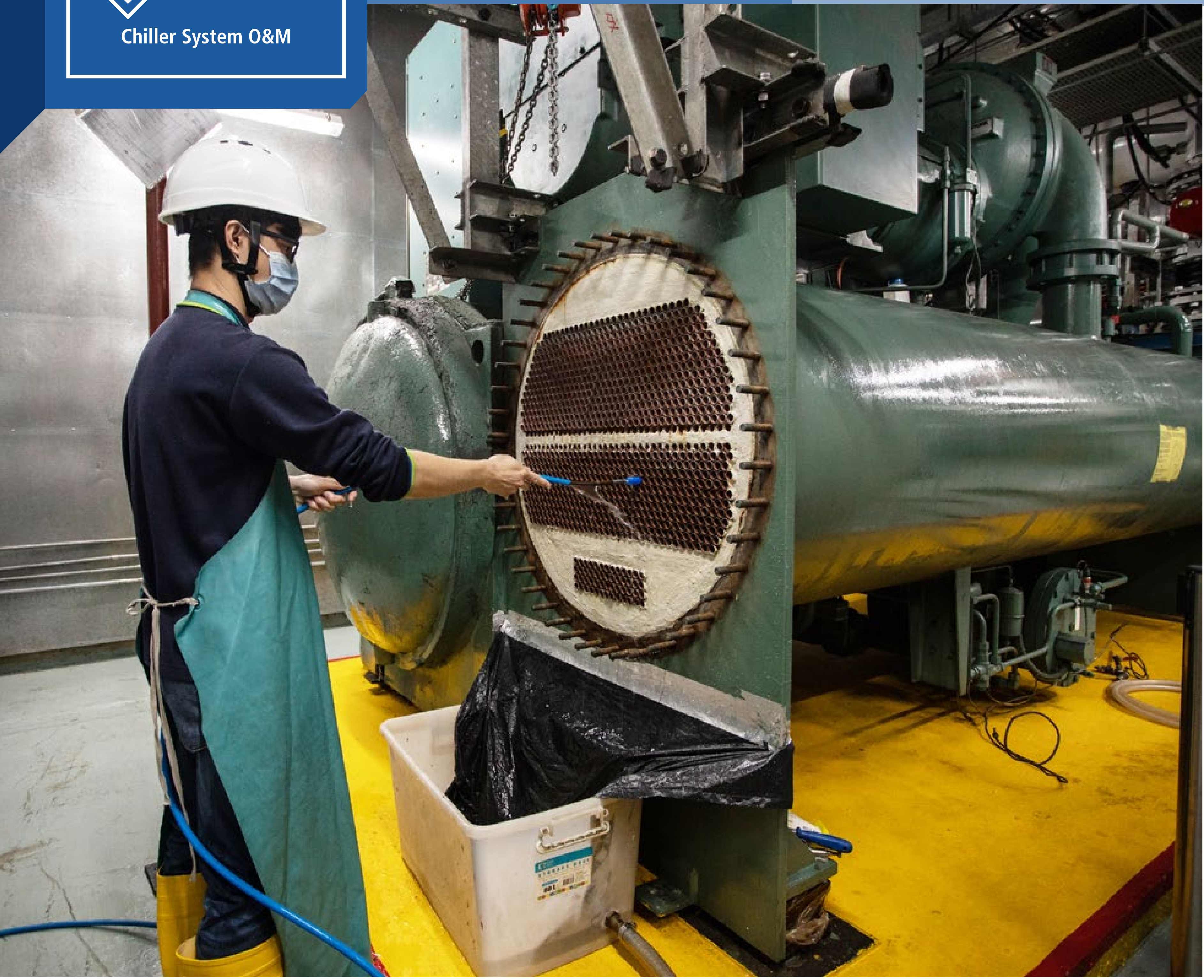


5. Sharing by Implementation Parties

Water Transfer Factor (WTF) is applied to monitor chilled water pump efficiency throughout the year. On-field testing would be required to understand the actual operating conditions of the pumps under different frequency, including its head, flow rate, and energy consumption. This information can determine the correct frequency range for the pumps.

Different differential pressure setpoint under different load conditions and seasons can be implemented to extract further savings.

Implementation of RCx is preferable in mild seasons / part-load operation mode as the critical terminal is operated at part load condition.



1. Brief Introduction of the Building and System

The Langham Place composite an office Tower and a shopping mall, which attained the highest rating - Final Platinum under BEAM Plus EB V2.0 Comprehensive Scheme, a prestigious green building certification. An excellent result of 100% credits was achieved in the aspect of Energy Use. There are 6 sets of water-cooled chiller unit with 6 sets of water cooling towers for shopping mall and 5 sets of water-cooled chiller unit with 5 sets of water cooling tower for Office Tower.

2. Energy Saving Opportunities

Chiller system is the main energy consuming item in a building. It composes of various equipment and components. Such components may become dirty, inaccurate, wear and tear during the daily operation. These can cause poor operating performance with extra energy consumption. RCx is in favour of figuring out the cause of deficiency by analysis and inspection.

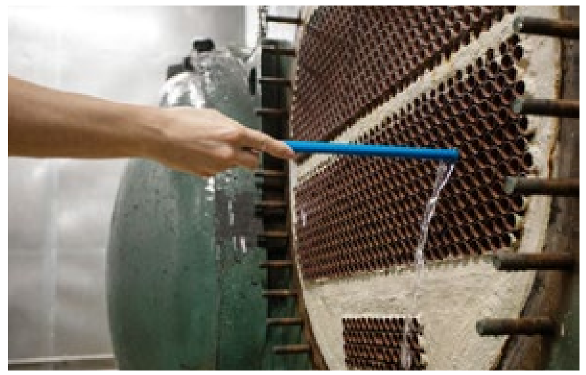
Operating log or record provides the details of various operating parameters. In certain extend, such parameters can be interpreted and analysed to determine the operating situation. In general, if the operating parameters indicate a gap with the design operating range, it indicates certain of deficiency. By comparing the parameters with the design range, the deficiency can be identified in the earliest stage and corrective measures can be arranged to restore the energy efficiency of the equipment.

3. Technical Guidelines

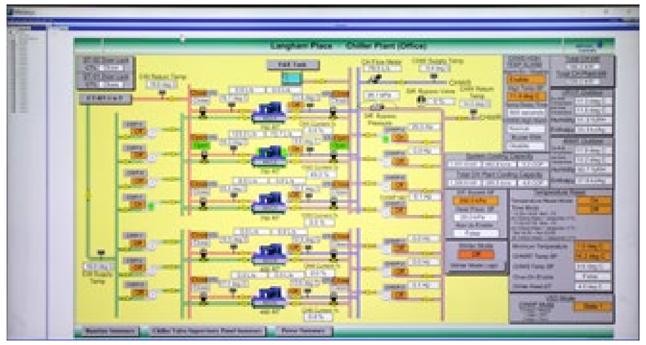
Heat exchanger is one of the key components in a chiller system and the heat transfer efficiency would directly affect the cooling function and efficiency. Approach temperature is the indicator of the heat transfer efficiency of the heat exchanger.

Approach Temperature = Refrigerant Saturated Temperature – Water Leaving Temperature

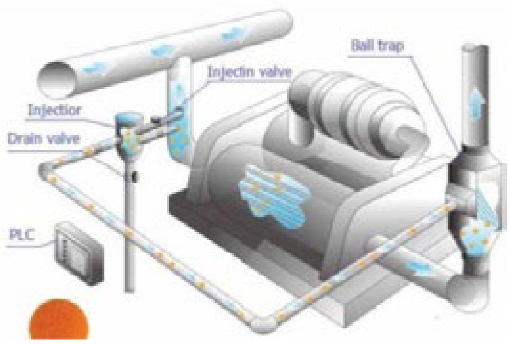
Normal approach temperature is in the range of 2°C to 4°C. High approach temperature indicates there are fouling accumulated in the tube surface and lead to low heat transfer efficiency of the heat exchanger. 1°C higher in approach temperature, 3% to 5% lower in energy efficiency of the chiller unit. Thus, when the operation record shows that the approach temperature reach the designated value, cleaning of the heat exchanger is necessary.

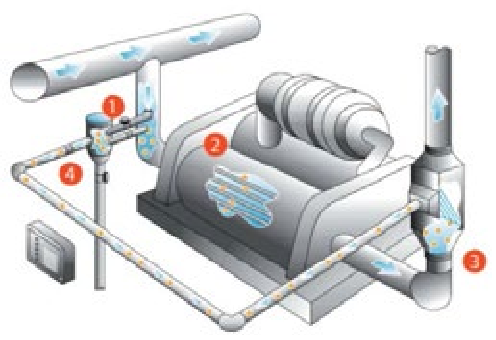


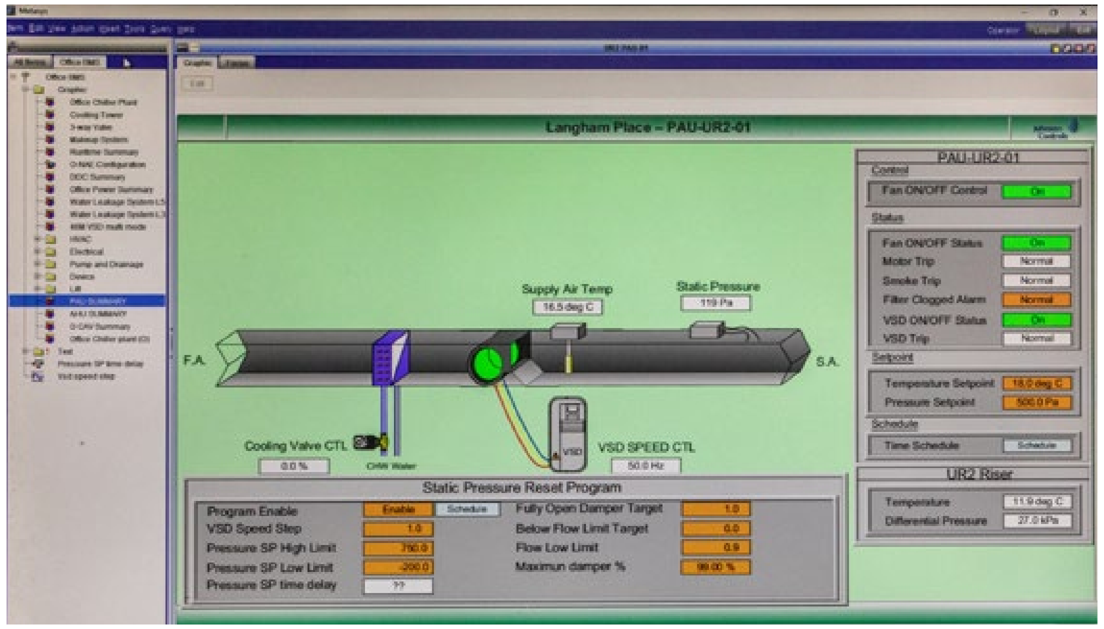
Regular cleaning of heat exchanger is the general practice in the industry. However, it may lead to higher maintenance cost if the exchanger is still within the effective operating range. Or energy wastage as the heat exchanger need earlier cleaning.



Automatic tube cleaning system can be installed to prevent the accumulation of the fouling effectively by circulating a number of soft sponge balls through the condenser tubes at pre-set time interval. The condenser tube are kept cleaning and the heat transfer efficiency of the heat exchanger can be maintained at the best level.







4. Performance Analysis

Recently, the condenser tube cleaning was carried out regularly at twice a year. They are generally carried out before summer and after summer. By applying the condenser tube cleaning in accordance to the approach temperature, the frequency of cleaning was around 8 months in average and the heat transfer efficiency of the condenser is maintained with energy saving of 5% to 10%.

5. Sharing by Implementation Parties

Considering the effectiveness of the tube cleaning services, done as needed is much better than regular cleaning. Besides, the cooling capacity of the chiller can be maintained that eliminated excess operation of chiller unit.

Building management system can also be used to monitor the level of approach temperature. Formula can be set in the building management system to provide alert when the approach temperature is higher than the standard operating range,

1. Brief Introduction of the Building and System

Apart from water pumping system, the monitoring-based RCx programme operated by Pacific Place also included air handling units (AHUs) in Three Pacific Place, a Grade A Office Tower in Hong Kong. In 628,000 square feet gross floor area, there are 34 office floors and 110 car park spaces with a total capacity of 3,600 RT chiller plant. The air side system consists of variable air volume (VAV) air handling units and primary air handling units.

2. Energy Saving Opportunities

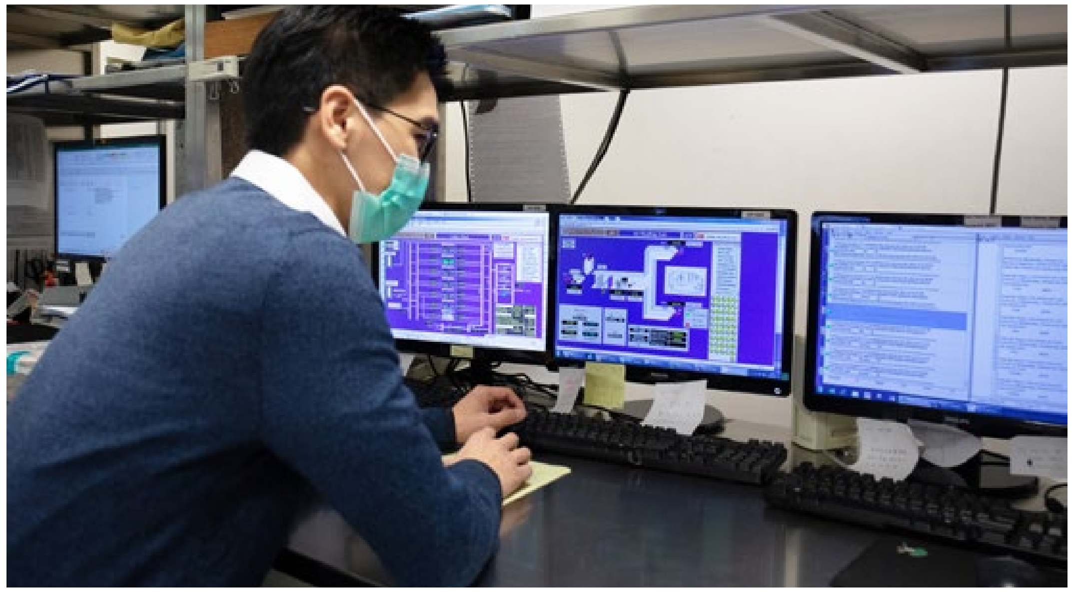
A lot of shopping malls and office towers like Three Pacific Place control the room temperature by variable air volume (VAV) system. The air handling unit delivers supply cold air at a constant temperature while the VAV box control the amount of airflow delivered to different spaces according to the temperature at that particular area. When the room temperature reaches the temperature set point, the volume control damper of VAV box will automatically close to lower the cooling air flow, the static pressure in the ductwork would be increased and vice versa. Thus, the duct static pressure and the VAV box opening are interactive.

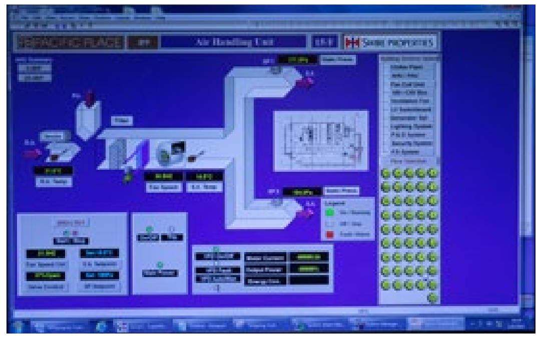
The static pressure of supply air duct is used as the indicator of air flow requirement of the space. Thus, the fan speed of the air handling unit is varied according to the static pressure of the supply air duct. However, the static pressure setpoint is usually higher than the demand level so as to ensure sufficient cooling air is delivered to the spaces.

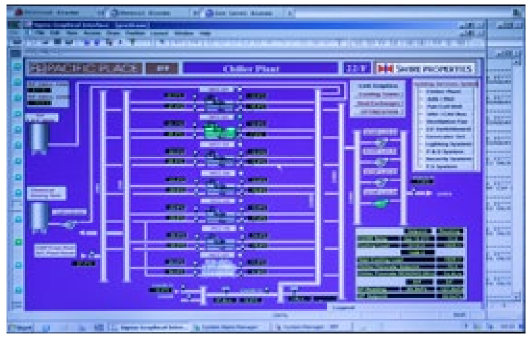
Careful analysis found that the average damper positions of the VAV boxes in Three Pacific Place was only 53% during office hours, while 58% of the VAV boxes had less than 50% opening. This indicates that there is a potential to decrease pressure setpoint to reduce fan power consumption.

3. Technical Guidelines

The static pressure of supply air duct, normally at 2/3 of the critical path, is used as the control parameter of the fan speed of the air handling unit. If the static pressure setpoint is too low, the air handling unit may not deliver sufficient cold air to the required space. However, if the static pressure setpoint is too high, excess pressure will be induced in the air duct when the space cooling demand is low. Excess fan power to introduce the static pressure is wasted.







By verifying the cooling demand of each space area, re-position of the temperature sensor if necessary, identify the openness of the VAV boxes especially the farthest end of the supply air duct etc., the static pressure set point can be lowered for better AHU performance and higher energy efficiency.

4. Performance Analysis

To find the optimal pressure setpoint, the static pressure setpoint of AHU was reduced gradually, 10Pa every time. The VAV damper position, AHU return temperature, indoor temperature were monitored and to be maintained. The setpoint was identified to be appropriate where over 60% VAV box damper openness is more than 60% and less than 10% VAV boxes damper openness is more than 90%.

A trial case was conducted with result of 13.5% energy saving by reduce the static pressure setpoint from 240pa to 180pa. The static pressure setpoint of all AHUs was reset floor by floor. 12% of energy saving was achieved after the adjustment process.

5. Sharing by Implementation Parties

It is important to check VAV boxes' operation to ensure that the dampers are working as designed, many times stuck dampers or malfunctioning VAV boxes would limit the operational adjustments that the AHU can make, thus limiting potential energy saving. Temperature sensor locations of VAV boxes, zoning of the VAV boxes, and zone temperature setpoint will also impact the ability of the AHU to reduce static pressure due to artificial demand for cooling by certain VAV boxes.

A different static pressure setpoint for different seasons can be implemented to extract further savings. Dynamic static pressure setpoint reset according to room cooling demand through analysing VAV box required flow versus demand flow or VAV damper openness can be implemented for a better control of AHU fan operation.

The supply air temperature setpoint of the AHU and the chilled water supply temperature can also be increased to uncover further savings in the water-side.

Implementation of RCx for the VAV system is preferable in mild seasons or under part-load operation condition when the openness of the critical VAV box is in half-way.

CASE 07

Fresh Air System

1. Brief Introduction of the Building and System

Ngau Tau Kok Engineering Center is an office building with 10-storey. There is a chilled water plant with 3 sets of air-cooled chiller unit serving the whole building.A new fresh air system was installed to solve the insufficient cooling and improve the indoor air quality.

The new fresh air system is a typical variable speed primary air handling unit that withdraw and cool down the fresh air from roof floor and delivery to air handling units at each floor. Demand control ventilation and free cooling control are applied to control the fresh air quantity to achieve energy saving.

2. Energy Saving Opportunities

With the original design, fixed fresh air quantity was provided from the fresh air unit at the roof floor, and distributed to the air conditioning plant room at each floor. The fresh air was then mixed with return air and cooled down by the air handling unit at each floor.

In some office floors with high staff population, the fresh air supply quantity is insufficient and the carbon dioxide concentration level was high. The space temperature was also high in summer due to insufficient cooling capacity of the air handling unit for the large population.

For the office floors with less staff population, the fresh air supply is more than sufficient, exceed energy was used to cool down the fresh air especially in summer.

3. Technical Guidelines

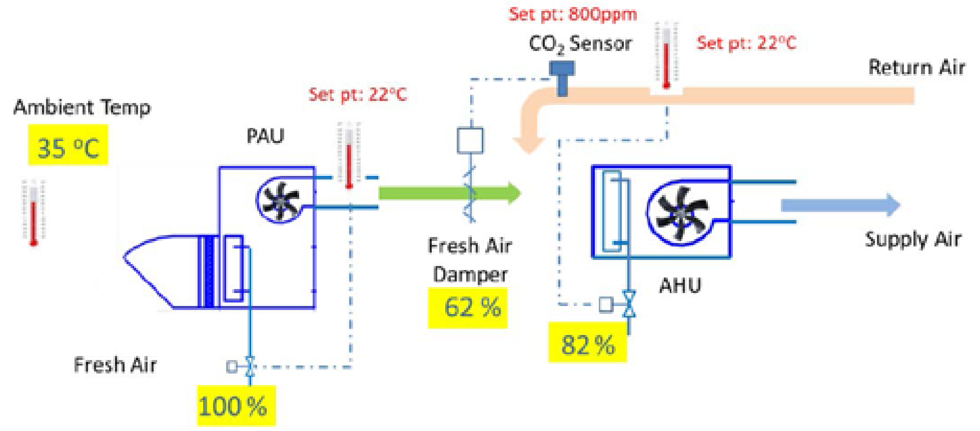
To reduce the cooling load requirement of air handling units in each floor, the fixed speed fresh air unit was replaced by a variable speed primary air handling unit that pre-treat fresh air to normal room temperature (22oC).

Demand control ventilation is adopted for the fresh air supply in each floor to maintain the indoor air quality at a comfortable level (i.e. the indoor carbon dioxide concentration below 800ppm). It could optimise the cooling demand for fresh air, especially in summer. In order to provide the ventilation control, a carbon dioxide sensor has been installed and the manual operated fresh air dampers were replaced by a motorized dampers.

A "free-cooling mode" control strategy has been added on the building management system (BMS), to withdraw relative cold fresh air to lower the cooling load of the air conditioning system when the outdoor temperature is lower than the indoor temperature setpoint.

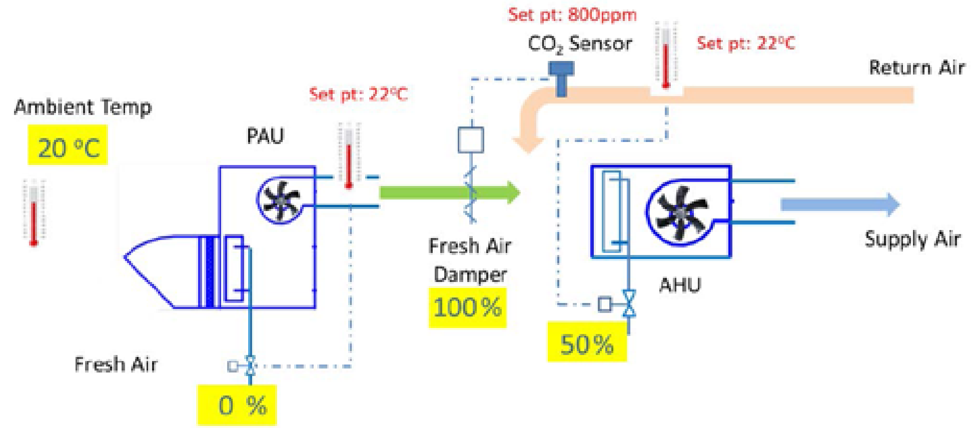
The overall control logic is as indicated below,

A) Normal operating mode: For outdoor temperature above 22°C (indoor temperature setpoint), the fresh air supply quantity is controlled to maintain indoor carbon dioxide concentration at 800ppm as illustrate in the below figure:

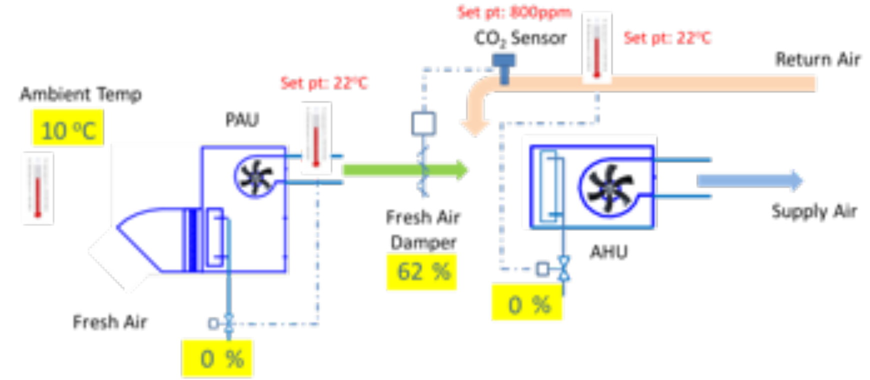


B) Free cooling mode: For outdoor temperature below 20°C (2°C below indoor temperature setpoint), the fresh air supply quantity will be maximized according to the room temperature.

At 20°C outdoor temperature, the fresh air damper will be fully opened to withdrawn as much fresh air as possible (100% opening for fresh air dampers) to lower the cooling load of the air handling unit.



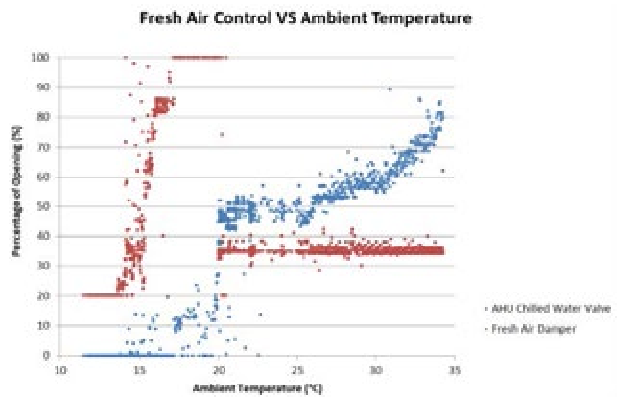
At outdoor temperature that cooling effect from air handling unit is not necessary, the fresh air supply quantity is then limited to maintain the indoor temperature,



4. Performance Analysis

With the installation of sensor and automatic damper, and the demand basis of fresh air supply control, an adequate level of carbon dioxide concentration in the indoor environment could be maintained below 800ppm. Complaints on insufficient or over cooling are also eliminated.

5% of energy in air conditioning power in winter has been saved, given that the "free-cooling mode" has applied, and the cold fresh air has been used to circulate around the building and created a comfort environment.



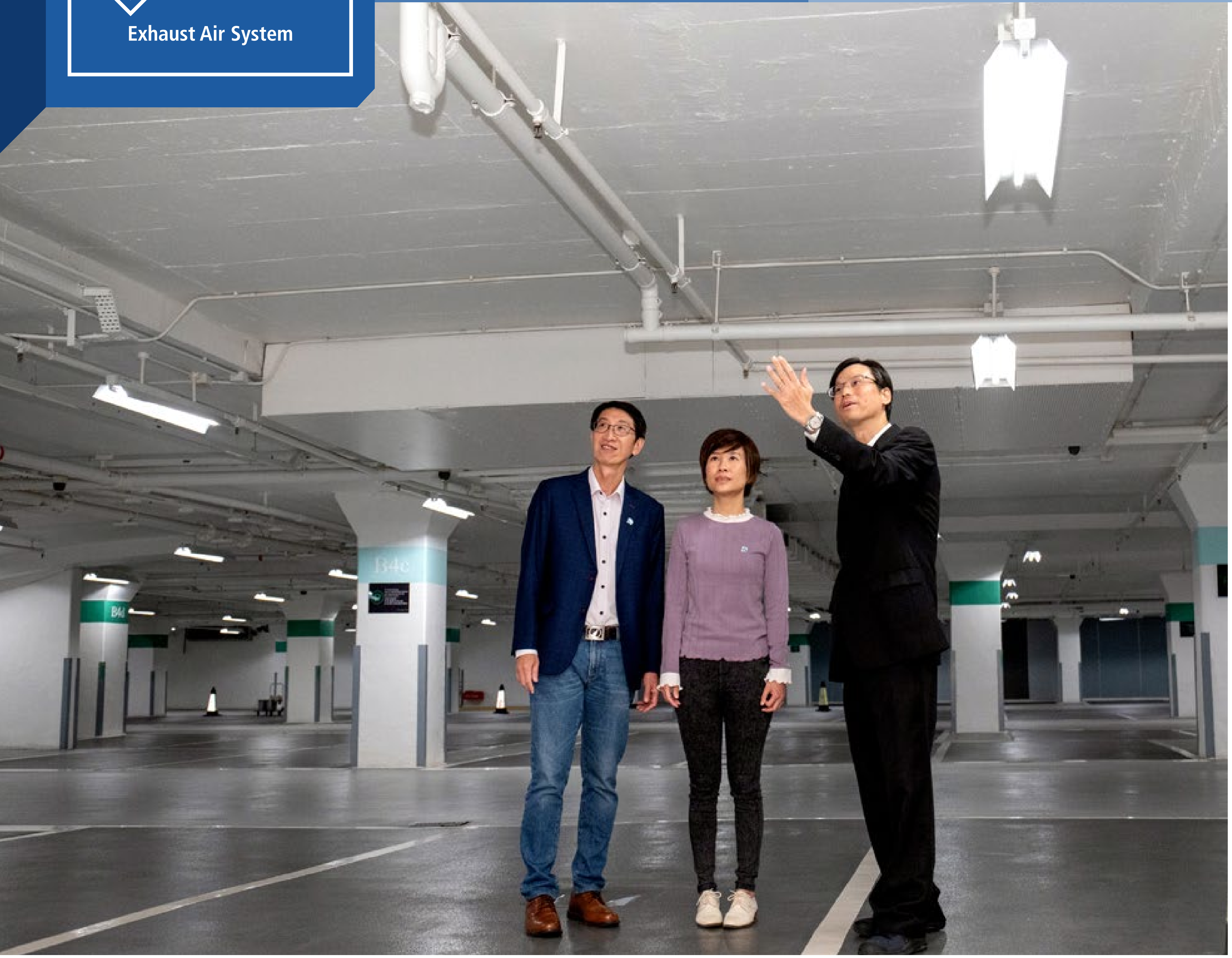
5. Sharing by Implementation Parties

It is a good practice to use relative cool fresh air to reduce the cooling load requirement, especially the air conditioning system is the prime energy use in a building.

"On-demand" control of fresh air provides adequate and comfort indoor environment. In summer, it could optimize the cooling load demand for fresh air so as to achieve the target of energy saving and efficiency.

The quality of fresh air plays key role on maintaining a good indoor environment. Therefore, the location of the fresh air intake point is critical and important.

In order to obtain the optimal control logic for the fresh air system, it is necessary to carry out various trial and adjustment. The control strategy should be adjusted according to the specific operating condition of the building.



1. Brief Introduction of the Building and System

Three Garden Road is an office complex located at No. 3 Garden Road, Central. The office complex comprises two office towers and 20,000 sq. meter carpark area. A ventilation system with 18 nos. of exhaust air unit and 9 nos. of fresh air unit have been installed and serving for the carpark area.

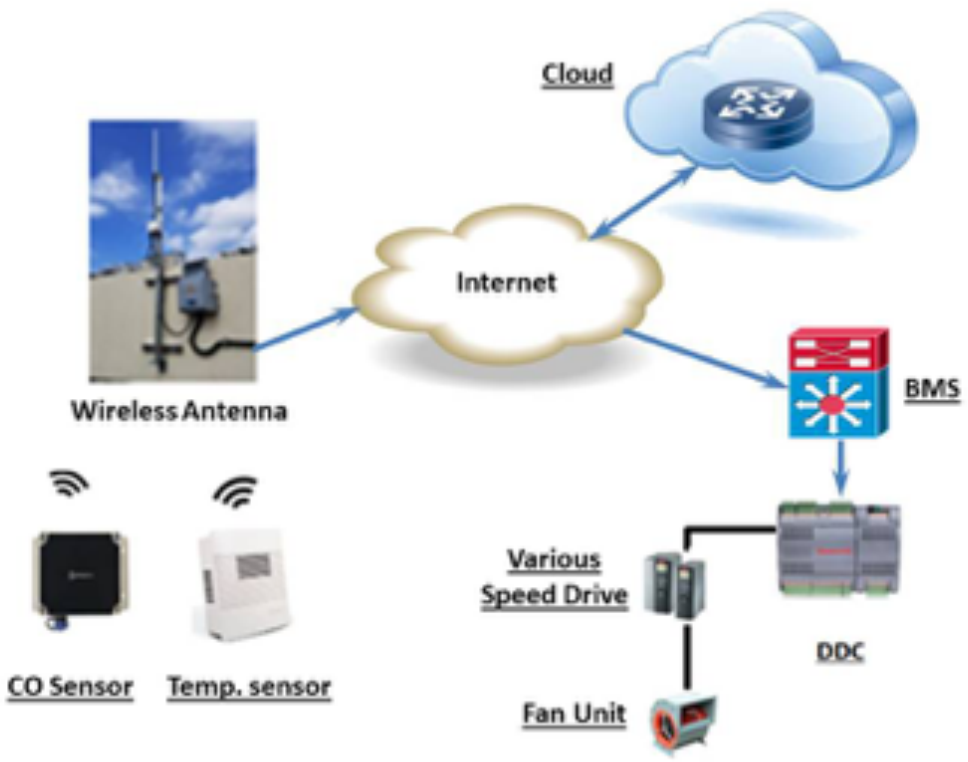
2. Energy Saving Opportunities

All ventilation fans serving carpark areas are operated at fixed time schedule and provided constant ventilation regardless actual demand. No sensors are installed for monitoring air quality. However, a site survey has found CO level is always lower than EPD guideline.

“Demand Control Ventilation” for controlling volume of ventilation which continuously matches indoor environment can improve energy efficiency and lower the energy consumption.

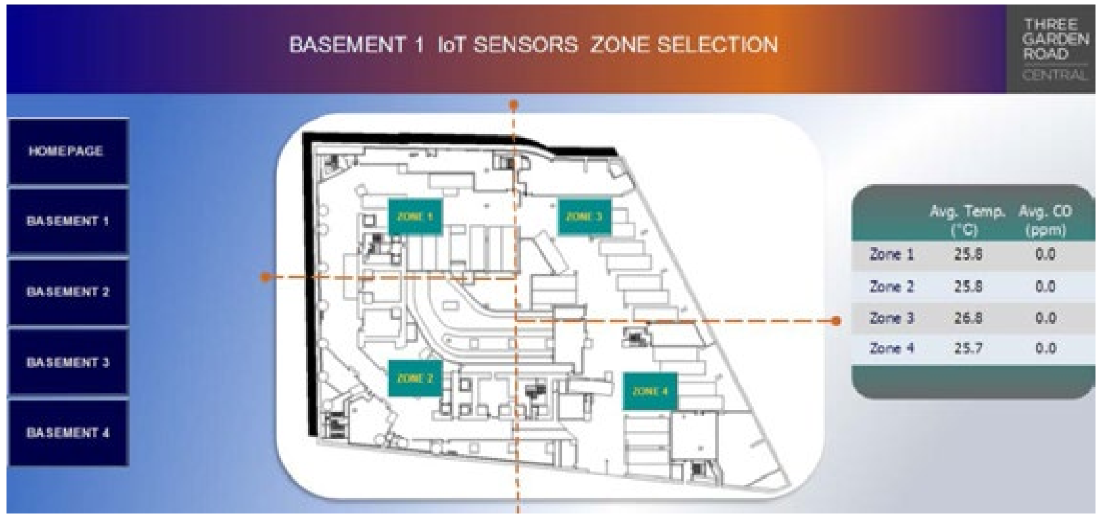
3. Technical Guidelines

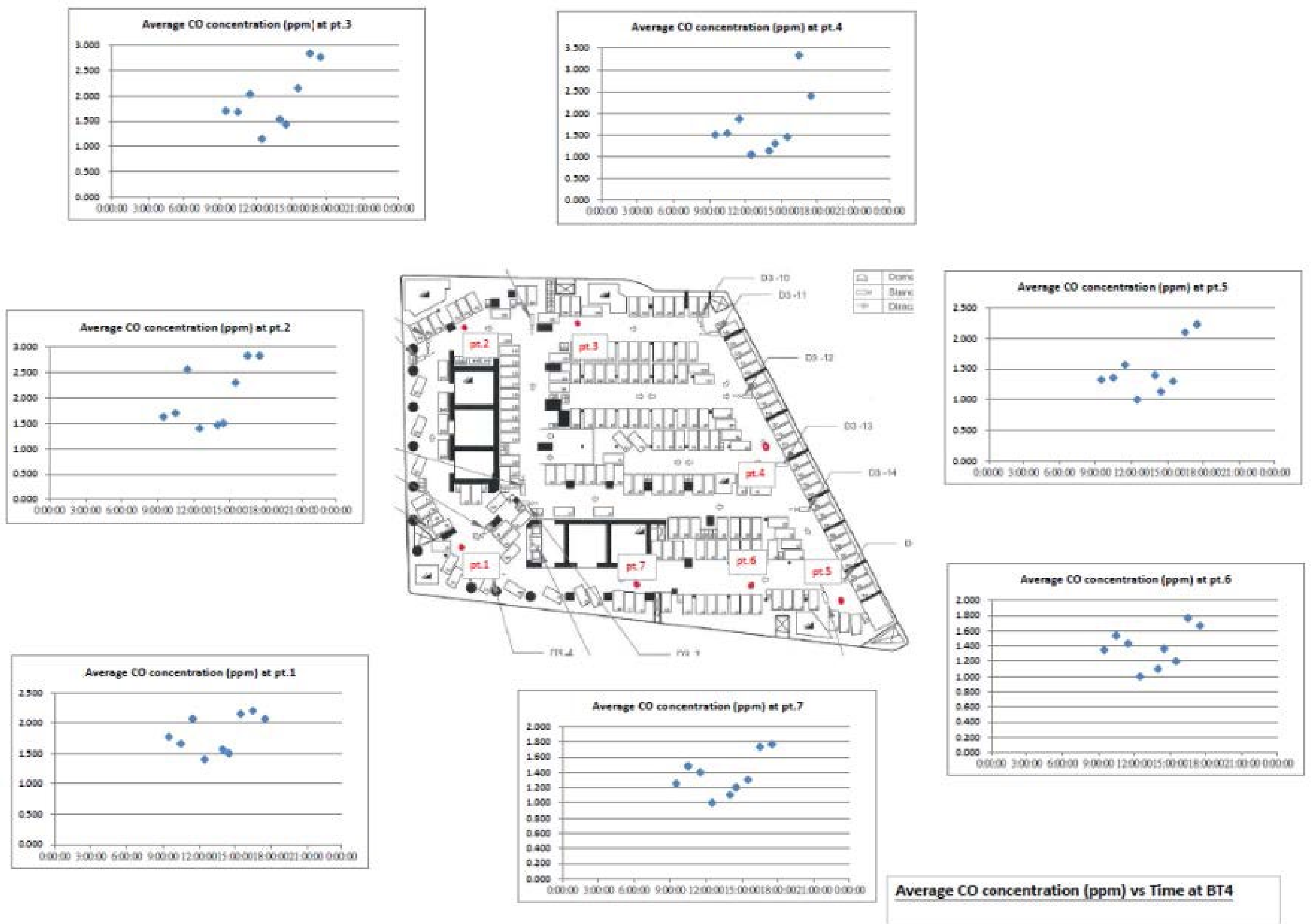
When undergoing the process of retro-commissioning (RCx), Three Garden Road achieved energy saving with aid of smart technology in addition to typical measures. A Demand Control Ventilation in carpark with IoT sensors is applied to measure indoor air quality and ensure sufficient ventilation within the area. Real-time data can then be transmitted to the BMS system. With the carpark ventilation fans upgraded with variable speed drive (VSD), the speed can be adjusted automatically according to the actual exhaust loading inside the carpark. Hence, a healthy indoor air quality can be maintained while a significant amount of electricity is conserved.



By applying wireless CO sensors and temperature sensors, the investment costs can be lowered as wiring works are eliminated.

Sigfox (IoT services provider) auto record 5min/data and upload to Honeywell cloud, fan motor speed automatically controlled by carpark indoor CO level and temperature which should keep less than 10ppm and within 1°C difference of outdoor temperature respectively.





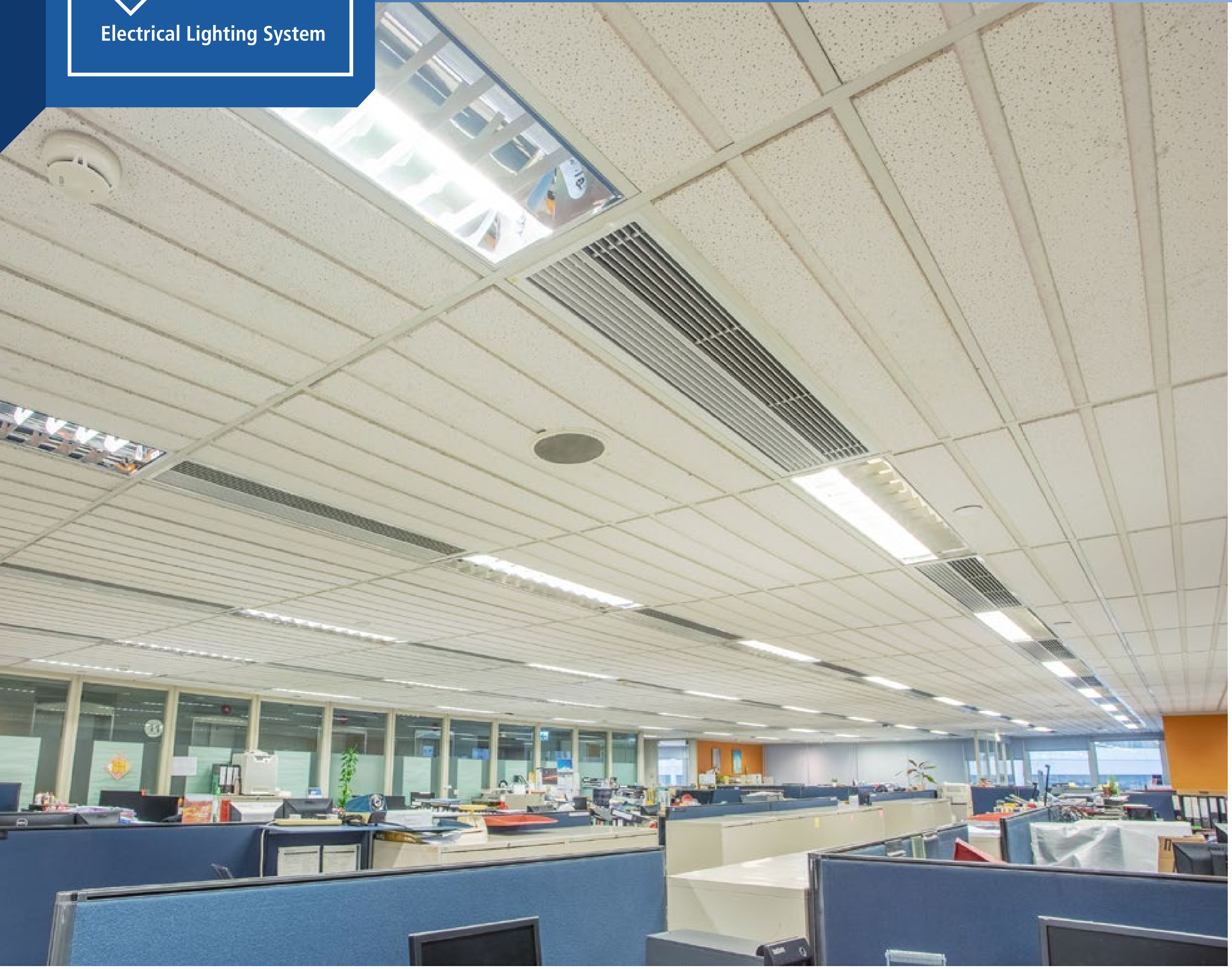
4. Performance Analysis

After the implementation of RCx, CO level in the indoor area keeps below 10ppm, and the difference between carpark indoor and outdoor temperature maintains within 1°C. The energy saving is significant, with 605,193kWh electricity has been saved and around 57.6% of power consumption of previous year.

5. Sharing by Implementation Parties

After completion of project, carpark air quality not only is continuously monitored and maintained at excellent level, but also fan power is reduced.

The frequency of data logging should be carefully decided to avoid shorten of battery life that increases the operating costs in battery replacement. Besides poor connectivity between the IoT sensors and gateway may also shorten the life time of sensor battery. Thus, careful selection of the sensor location is also important.



1. Brief Introduction of the Building and System

East Exchange Tower is a 26-story high rise building located in 38 Leighton Road, Causeway Bay since 1989. The gross floor area is around 112,300 sq. ft., with a composition of telecom exchange and commercial office.

2. Energy Saving Opportunities

In general commercial building, lighting system is the second largest electricity consumption, accounting for around 20 % of consumption of the building. Meanwhile, concerning the installation fee of new lighting device, fluorescent light are still widely used in most of the building. However, by using lighting device of latest technologies, like LED, over 50% of energy consumption can be saved.

Lighting design commonly adopts the conventional general lighting system to provide uniform design illuminance over the whole space. However, the lighting intensity at the less critical task areas or the non-task area always higher than requirement. By removing unnecessary and maintain adequate illumination, de-lamping is one fairly simple way to resolve the energy waste issues.

In many circumstances, normal lighting is left on during the night, weekends and holidays, which resulted in the energy wasted and reduction of the operative life of the lights. Motion sensor and occupancy sensor can be used to switch or dim the lighting equipment for energy saving, especially in the area with low occupancy in the buildings.

According to the EMSD's guidelines, lighting system consist on 2 main categories of lights: normal and emergency. Normal lighting includes task and general lighting. Emergency lighting cover evacuation signs, lighting along the escape route, etc. Whereas energy saving opportunities in emergency lighting are limited, normal lighting almost always have areas for performance improvement with the principle of "spend where necessary and save where possible".

3. Technical Guidelines

Comparing with the fluorescent light, LED light only requires 50% of power consumption with the same lighting intensity. Although the initial cost of LED light is higher than the typical lighting, the gap is narrowing in recent years by the mass production and improvement of technologies. Meanwhile, the lifetime of LED light is around 35,000 to 50,000 hours, which 10 times longer than the fluorescent light (around 5,000 to 10,000 hours). If the maintenance cost is included, LED light will be more cost effective in the long run.

The general lighting or task lighting should be suitably provided in accordance with the nature of work and the visual demand. In general, the optimum lighting for normal desk work is between 300 to 500 lux. It should not be less than 200 lux under any condition. It is possible to re-position the lighting sources or workstation or remove exceed lighting to achieve comfortable illumination.

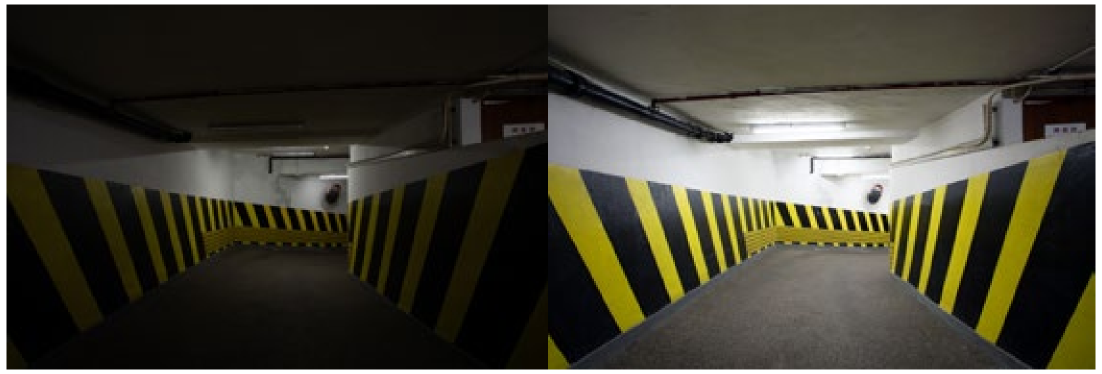
When the workstation is not occupied, the illumination can be reduced for energy saving. It can be achieved by installing occupancy sensor or motion sensor that dims the illumination for that particular workstation or area.

Sensor

Apart from the work space, the illuminance can be switched to minimum when there is no occupancy in the area for energy saving, like staircase, car park and toilets. According to the Code of Practice for Fire Safety in Buildings, the illuminance of every part of the exit route should be maintained at a level not less than 30 lux.

4. Performance Analysis

Carpark is the area that normally with little people flow, the electricity consumption could be reduced by replacing of LED light tube with motion sensor. In the typical lighting system, T8 fluorescent light tube will be used for 24 hours non-stop operation with 40W power consumption. LED light tube could provide same luminosity level with 16W power consumption. Equipped with the motion sensor to detect the people movement and provide minimum lighting, the new lighting system could save 80% of electricity consumption.



Although there is an ordinance requirement on the minimum illumination provided at the staircase (not less than 30 lux), the electricity consumption of staircase lighting could also be saved by the installation of LED lighting and motion sensor. With the occupancy sensor, 50% of normal illumination level near fire rated door could be maintained, and the rest lighting would be switch off if there is no people movement. Over 85% electricity consumption on staircase lighting has been saved. This application also applied on the toilet area with over 50% power save.

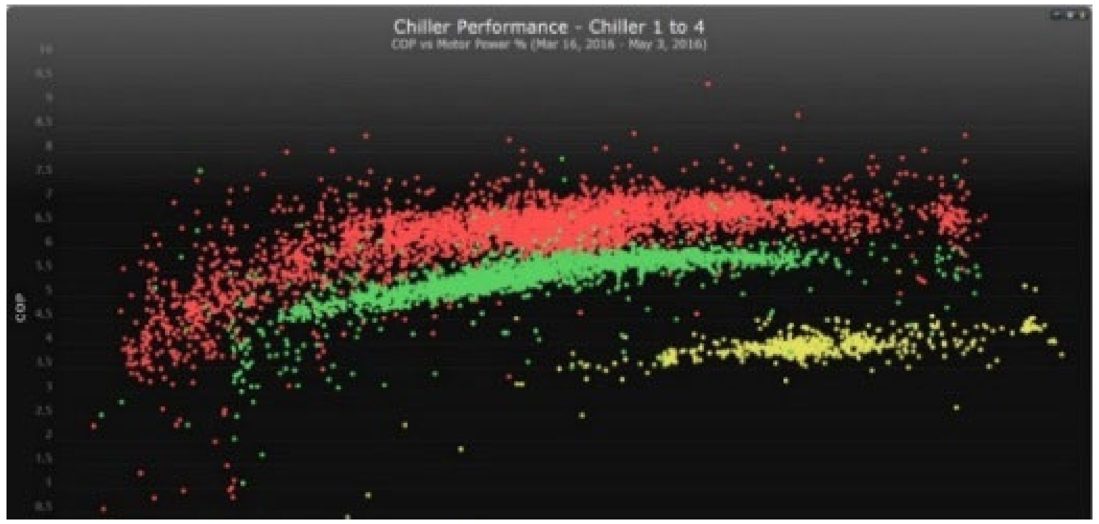
For the office area, except the installation of LED lighting and motion sensor, de-lamping is another way to reduce the energy consumption. By assessing and evaluating the minimum illumination requirement of task area, and removing unnecessary light tube in area that producing greater-than-needed illumination, over 70% electricity consumption saving could be achieved.

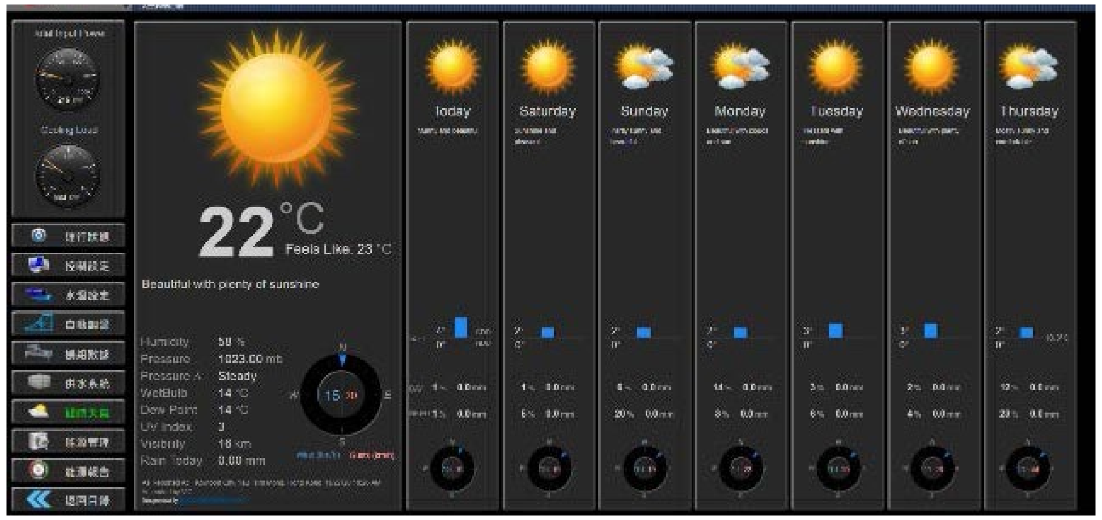
5. Sharing by Implementation Parties

Although the initial cost is higher than typical fluorescent tube, LED lighting enjoy much longer lifetime, which implicate the cost saving on the workman of replacement and daily maintenance on the lighting system in the long run.

Measurement is necessary to ensure adequate lighting intensity is provided. A well-arranged assessment and plan are important before de-lamping.

All lighting electricity saving plan must be fully comply with the regulation. Minimum lighting intensity according to the Ordinance requirement should be maintained. If occupancy sensor or motion sensor is applied to any emergency lighting, the sensor control should be by-passed to allow full illuminance of the emergency lighting during normal power interruption.





1. Brief Introduction of the Building and System

With the development of digital technology, the functions of building management system (BMS) has been greatly enhanced. For example, in East Exchange Tower, a 24 hours BMS control centre has been established to closely monitor and control both onsite and offsite equipment (over 50 remote sites). BMS also plays key role on the energy saving. For example, BMS could automatically adjust the operating status of air conditioning system, in accordance to the onsite environment, chillers, pumps and other equipment operation data, which faster and more accurate than manual adjustment. Some advanced BMS could even base on historical data and weather forecast to control each equipment in a state with the lowest total power consumption, and maximize the efficiency of whole system.

When an abnormal situation occurs, for example unusual operation of equipment and power usage, BMS could send email or SMS alert to specific staff to counter the issues as soon as possible.

2. Energy Saving Opportunities

The operation of BMS relies on the data collected by sensors (e.g. temperature, pressure, motion sensors). However, given a certain period of running time, the error of sensors will increase and input inaccurate data to BMS. Operation control based on inaccurate sensors and feedback status could cause an inappropriate operation of equipment and energy waste.

Moreover, climate change, or other environmental factors change could cause the pre-set control logic or parameters being not suit with the current environment and situation. RCx may need to deal with the above issues.

3. Technical Guidelines

Re-calibration on sensors, especially those under the control logic, is an important process to ensure the BMS and equipment are operating in an efficient and effective way. It should be carried out at least once per year and will be perfect for quarterly (every 3 months) re-calibration.

For the control logic, it should be reviewed annually in accordance to the change of the environment, usage equipment efficiency, etc. If the changes of environmental factors are dramatic and significant, the review of control logic should be done as soon as possible to ensure the BMS and equipment always in appropriate operating condition.

4. Performance Analysis

After the re-calibration, it found that the deviation of sensors was around 10%-25%. For example, the data collected by the return chilled water temperature sensor which higher than the actual temperature, may mislead the BMS to increase the cooling capacity. Additional air conditioning equipment may be operated in order to lower the chilled water temperature. These error could cause 5%-10% energy waste (estimated).

By reviewing the operating log and identify the deficiency operation, the operation strategy can be adjusted to meet the actual environment. An operating log of frequent chiller unit start/stop has indicated un-match of chiller capacity and cooling requirement. By adjusting the operating control logic, the MVAC equipment was operated smoothly and the residue cooling is best used for a saving of 1.2% energy.

5. Sharing by Implementation Parties

It is very important for the control logic of the BMS to match with the requirement to ensure energy effectiveness. Environmental factors, operating mode, system requirements or customers' needs may be vary among different buildings or sites, a single system or control logic may not applicable on every situations. The system should be custom-made or modified according to the actual situations and experience of operating staffs.

Regular review on operating parameter and performance is also important to identify any deficiency. If the deviation of sensor occurs frequently, it should be replaced accordingly.

Acknowledge

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Business Environment Council

Hong Kong Association of Energy Engineers

The Energy Institute Hong Kong (Branch)

Hong Kong Air Conditioning and Refrigeration Association

Hong Kong Institute of Qualified Environmental Professional

Supporting Organisations

Asian Institute of Intelligent Buildings

Chartered Institute of Housing Asian Pacific Branch

Chartered Institution of Building Services Engineers

Electrical and Mechanical Services Department, HKSAR

Hong Kong Institute of Certified Property Managers

Hong Kong Institute of Real Estate Administrators

Royal Institution of Chartered Surveyors

The American Society of Heating, Refrigerating and Air-Conditioning Engineers Hong Kong Chapter

The Hong Kong Association of Property Management Companies

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The Hong Kong Institute of Housing

The Hong Kong Institute of Surveyors

The Hong Kong Institution of Engineers- Building Services Division

The Hong Kong Institution of Engineers- Control, Automation & Instrumentation Division

The Hong Kong Institution of Engineers- Gas & Energy Division

The Society of Operations Engineers Hong Kong Region

Corporations

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Hong Kong Science Park

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Building Services Operation and Maintenance Executives Society

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