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ICC Hong Kong: Exemplary Performance

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The International Commerce Centre (ICC) is a landmark skyscraper located in Hong Kong. It is the tallest building in Hong Kong, with office spaces, fine dining restaurants, an observation deck and a world class hotel. ICC has firmly established itself as a world class businesses address that offers the highest quality in property and facilities management, providing quick and responsive services while maintaining an environmentally friendly and sustainable operation. To manage this supertall high-rise commercial building, a life-cycle commissioning and optimization approach is adopted and ISO 50001:2011 energy management systems are implemented. By continuously exploring various innovative technologies and the application of many energy savings strategies, environmental impacts of the building are reduced while delivering benefits in terms of energy efficiency, indoor air quality and cost savings to landlord and occupants.

Introduction

Standing at the south-western tip of the Kowloon Peninsula, the International Commerce Centre (ICC) is an iconic building in Hong Kong. The 484-meter-tall building, with 108 stories, is currently the 6th-tallest building in the world and the tallest in Hong Kong. Apart from providing Grade A office premises, ICC also contains one of the first observation decks in Hong Kong – Sky100 – as well as a premium class hotel, the Ritz Carlton Hong Kong. ICC is showcasing the prosperity of the city. The 3-million-square-foot development is also a 21st-century engineering wonder in the eyes of Hong Kong people.

With an aim to reduce the environmental impacts to the surrounding environment, ICC was designed and built based on an earlier version (04/04) of the Hong Kong Building Environment Assessment Method (BEAM) (International Commerce Centre, n.d.).[1] With its almost full occupancy, the energy consumption of the building must be further controlled even though it was built based

1: BEAM is a green building standard promoted by the Hong Kong BEAM Society Limited in Hong Kong, an authoritative but non-profit making organization.

Left: External overall view of ICC. Source: Sun Hung Kai Properties

Top: Overall view of ICC from the northwest. Source: Sun Hung Kai Properties

on a set of stringent energy conservation designs and measures. This paper discusses the various energy conservation measures of ICC during the operation and maintenance stage striving to reduce its carbon footprint as well as benchmarking with other supertall buildings in the world.

Building Design / Provision

With respect to the business nature of its tenants, ICC is equipped with various types of provisions to support occupant's needs and optimize building operations. The major elements are summarized in the following paragraphs.

Redundant Backup Systems for the Electrical Power Supply

Since more than 90% of tenants in ICC are international banks that conduct 24/7 operations, addressing the power consumption of the building has been and will be the ICC management team's top priority. With most of the tenants primarily engaged in international finance, the reliability of electricity supply and air conditioning are of topmost importance under all conditions. The service level agreement between ICC and tenants includes non-stop air-conditioning in certain areas and guaranteed availability of some passenger elevators at all times, providing more than 8 hours of emergency power backup, a backup system for the backup power supply as well as 2N (completely redundant power supply system configuration, i.e. redundant transformers, main switch boards and rising cables) power supply systems. To ensure the reliability and sustainability of power, 68 sets of 1.5-2.0 MVA dry type transformers are used to meet an overall power demand of more than 70 MVA. Substations spreading over 8 mechanical floors of the building and Dual Risers for Low Voltage and Extra Low Voltage devices and telecommunication systems were installed. Additionally, there were 39 emergency generators installed for backing up all the significant services in ICC like fire services, essential plants and high voltage chillers in case of emergency. The building has an auto fuel supply system to maintain the diesel fuel supply to the backup generators. On top of that, the ICC management team has developed a special, manual transport system to deliver fuel to all required generators.

Mega Cooling Loading Demand

In order to fulfill the cooling demand requirement, high voltage (11 kV) water-cooled chillers, double deck indoor cooling towers and numerous heat exchangers are installed. ICC's air conditioning system is equipped with a centralized intelligent control system that collects and analyses operational data day-and-night and evaluates seasonal variations. This provides data for the adjustment of various control parameters of the air conditioning system for energy efficiency control. With this system, energy consumption can be 15% lower compared to general office buildings without such an application.

Efficient & Reliable Vertical Transportation

Due to the sheer size of building population, multiplicity of user-groups and complexity in ICC, it is essential to ensure that its building population will be transported within the supertall building efficiently. It was estimated that over 20,000 people require vertical transportation daily in the ICC. A holistic approach combining new elevator technologies and an intuitive strategy for circulation and wayfinding was put into place. In the design of the elevators or

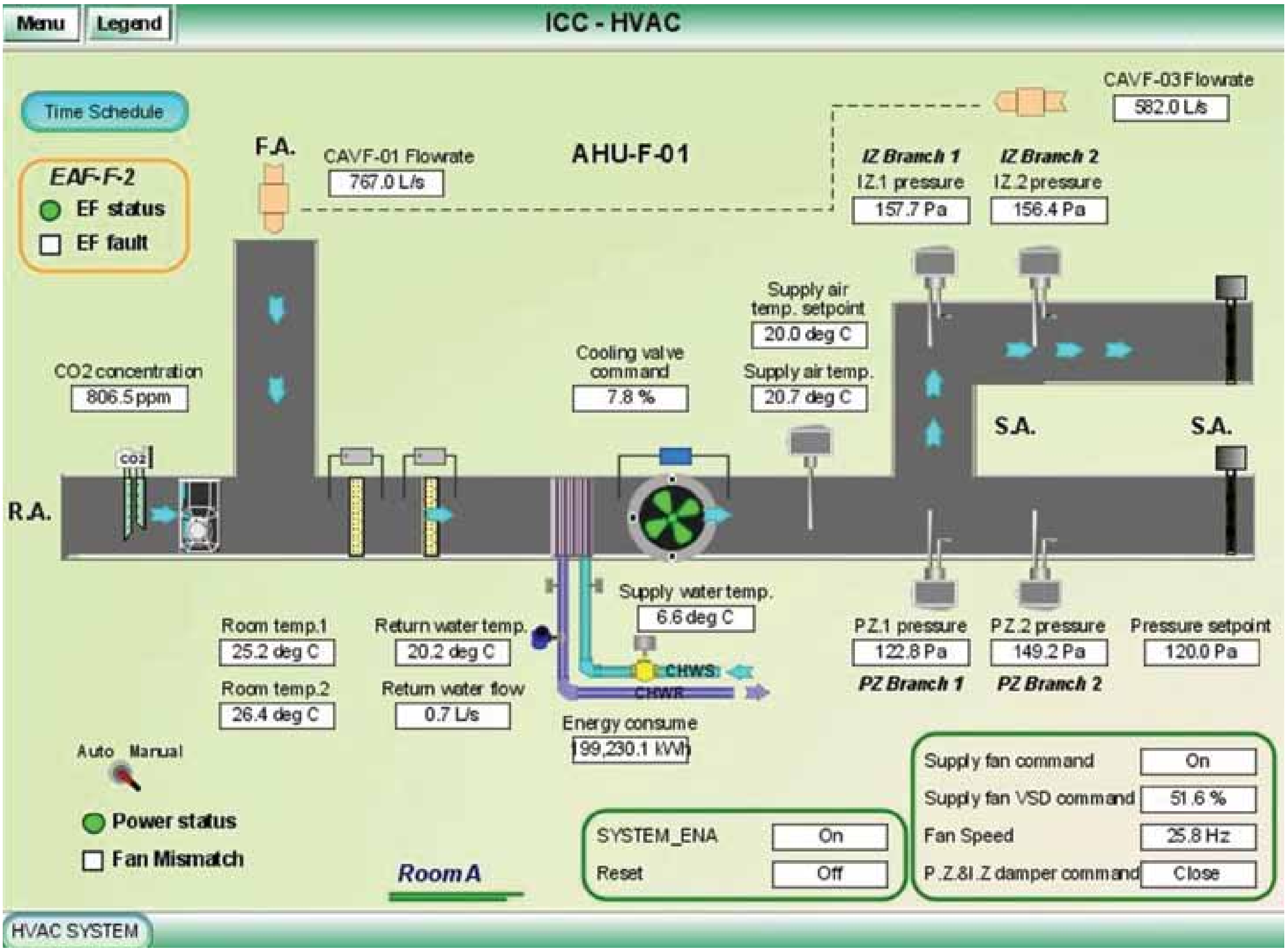
Opposite: Lobby interior (Facing Dragon Tail). Source: Sun Hung Kai Properties

Bottom: Chiller plant room. Source: Sun Hung Kai Properties

"Since more than 90% of tenants in ICC are international banks that conduct 24/7 operations, addressing the power consumption of the building has been and will be the ICC management team's top priority."

Bottom: Building Management System (BMS) – AHU control.
Source: Sun Hung Kai Properties

Opposite: Elevator lobby. Source: Sun Hung Kai Properties



vertical transportation system, the building was zoned with overlapping elevator shafts and several elevator lobbies (i.e., sky lobbies) on different high-level floors. Further, the use of high-speed double-decker elevators can cut down the number of elevator shafts needed while a specially designed, coordinated elevator destination control system with crowd control sensors can ensure smooth vertical passenger movements even in rush hours.

Intelligent Building Management System (BMS)

A state-of-the-art computerized system manages and controls the ventilation and energy usage in the building. Air conditioning usage and airflow are being adjusted remotely while lighting and various electrical consumption levels are being monitored by a Building Management System (BMS). The BMS helps ICC to be more environmentally friendly with the smart building system control function. The system consists of four main servers with over 1,000 outstations and a network hub connecting all the control and monitoring devices. The system interfaces with major building systems like MVAC, electrical, lighting, fire services, plumbing and drainage.

Passive Design

Built environment studies were carried out at the early design stage to explore opportunities to integrate the design with natural systems, striking a balance between daylight provisions and solar heat transmittance, resulting in improved visibility without affecting thermal and acoustic comfort. For instance, CO_2 sensors are installed in offices for user comfort. Vibration isolators in all water pumps can mitigate noise and vibration transmission and an air conditioning system is designed to meet the internal noise criteria of NC40 levels. For lighting systems, daylight analysis is conducted to enhance daylight design and reduce the demand for electrical lighting through daylight control. High-frequency electronic ballasts and energy efficient T5 florescent lights with low mercury content are used for the office and observation deck lighting at the ICC for better energy efficiency.

Building Operation & Maintenance

Since ICC is a supertall high-rise equipped with a wide range of advanced facilities,

a comprehensive routine and preventive maintenance program is required.
This is done by following a 5-year plan supplemented by a yearly plan. Under the yearly plan, the routine inspection and preventive maintenance schedule would be further broken down into monthly schedules for strict adherence. Any unforeseen maintenance requirements will either be quickly scheduled or inserted into the monthly schedule, depending on the urgency of the case. Below lists some of the major maintenance responsibilities and how they are handled with precision, absolute devotion and a customer-oriented and safety-conscious mindset. Moreover, the facility maintenance strategy of ICC is supported by a computerized BMS that oversees the MVAC, elevator and escalator system, fire services system, plumbing and drainage, and lighting system, since all of them are state-of-the-art equipment employed at a large scale.

Specialized and Tenant-Friendly Facilities Maintenance

Under the Technical In-charge, the ICC technical team has seven professionally qualified technical managers. With assistance from staff and qualified contractors, each technical manager accounts for one special aspect of the building's facilities. All facilities maintenance works are carried out during non-business hours to keep disturbance to tenants minimal.

The maintenance of the elevator system is used as an example. Weekly and overnight maintenance are conducted for the majority of the elevators to maintain system reliability. An in-house elevator expert from the elevator manufacturer was deployed to monitor and review the elevator and escalator operations regularly. Under our Check, Check and Check program, every day the elevators are checked by the on-site elevator technicians, double-checked by the on-site elevator service manager and then checked by the in-house elevator expert. Furthermore, the building sway system provides three levels of safety operation to allow the elevators to run during adverse weather such as a heavy storm. This is an advance safety mechanism. Also, the database of the elevator access card system is backed up on a daily basis. This is done to maintain proper records of building occupants for security and other reasons.

ICC Standard: Complying & Surpassing the Legal Requirements

In order to improve the maintenance quality of ICC's facilities, some maintenance services not only comply with the statutory requirements but exceed the general standards and code of practices. For instance, ICC will conduct inspections and testing for fixed electrical installation at least every 2.5 years, much more frequent than the requirement of Electricity (Wiring) Regulations – Periodic Test, which calls for inspections at least once every five years. Furthermore, weekly maintenance services for elevators are conducted in ICC, which is more frequent than the local statutory requirement for monthly maintenance.

ISO 50001:2011 Energy Management System (EnMS)

In light of the huge energy demand for the building's daily operation, maintaining the optimal energy performance of ICC is crucial. The ICC maintenance team has set up a task force team to optimize the energy use in ICC as well as supporting the company's policy on environmental protection and sustainable development. On September 20, 2011, ICC was the first Hong Kong commercial

Bottom: Plan-Do-Check-Act (PDCA) Model. Source: Sun Hung Kai Properties

Opposite: Routine maintenance. Source: Sun Hung Kai Properties

property awarded the ISO 50001:2011 Energy Management System Certification by the Hong Kong Quality Assurance Agency (HKQAA).[2]

The ICC management team is governed by ISO 50001 Energy Management System (EnMS), i.e., a model based on the Plan-Do-Check-Act (PDCA) cycle to monitor and continually improve the building's energy performance.

Plan

ICC establishes an energy policy and energy objective for its commitment to continual energy improvement and compliance of legal and other requirements in relation to its energy uses, consumption and efficiency. Based on the data from the Power Monitoring System (PMS), studies are conducted to identify areas of significant energy use and set up the baseline as well as energy performance indicators (EnPI). Mechanical ventilation and air conditioning (MVAC), electrical lighting as well as elevator and escalator system are the three significant energy uses which occupy approximately 65%, 22% and 13% of total energy consumption of ICC. The baseline and EnPI are important factors for ICC to assess its energy performance. In 2014, a 5% energy reduction was targeted over a baseline year (2012), and a series of action plans in relation to energy saving opportunities were made.

Do

ICC implements various energy saving action plans in order to achieve the annual target. The action plans include shortening the operating hours of AHU & exhaust air fans, the ICC Celsius 26 campaign that raises indoor temperature settings in common areas from 24°C to 26°C, switching off normal lighting for common areas during non-office hours, replacement of MR16 with LED in bathrooms, turning off normal lighting for corridors at 8 mechanical floors as well as reduction of one 18W lamp from two. In order to enhance energy performance of the MVAC system and reduce the energy consumption, ICC has worked with the Hong Kong Polytechnic University to implement various energy optimization strategies for the chiller plant system of ICC.

Check

ICC performs regular checking and internal audits to monitor the energy performance of ICC effectively. In the regular review meeting, several items are reviewed and monitored, including all significant energy uses and their performance, relevant variables related to significant energy uses, EnPIs, energy record

2: This is the result of a comprehensive energy audit of the building and its subsequent adoptions of the audited findings; over 70 advanced and efficient energy saving measures were set up as a result.

and analysis as well as the effectiveness of the action plans. Internal audits are carried out by third parties so as to ensure effective implementation of EnMS in ICC and identify the nonconformities and opportunities for improvement of EnMS. With regular reviews of the facilities' operations and close monitoring of their energy usages via routine checking and energy performance review, the efficiency of the action plans can be verified.

Act

In addition to regular review meetings, ICC holds meeting with top management to review the whole EnMS annually. It is the opportunity for top management to ensure the suitability, adequacy and effectiveness of the EnMS in ICC. Through evaluation of the energy performance of EnMS against energy policy, objectives and targets, unsatisfactory or further improvement areas can be spotted. Improvement plans would be developed and followed up to ensure the sustainable enhancement of the energy management system.

Through the successful implementation of ISO 50001 Energy Management, over 10 million kWh of energy were conserved from 2012 to 2014, and an energy savings of over 6 million kWh in 2013 and another 3.8 million kWh in 2014 was achieved. During this time, there was no significant change in the occupancy rate, operating hours of systems and average outdoor temperature for each year. This represents a CO_2 emission reduction by 4.2 million kg in 2013 and another 2.66 million kg was achieved in 2014 (Hong Kong Polytechnic University, 2014).

PolyU Optimization Saving Strategies

Regarding the optimal operation of the MVAC system, the ICC management team has maintained the collaborative relationship with the Hong Kong Polytechnic University (PolyU) since 2010 (Department of Building Services Engineering, n.d.). The two core objectives of this relationship deal with the building life cycle testing and commissioning, as well as the identification and implementation of a series of energy saving strategies for the MVAC system operations (i.e., including the main HV chiller plant, water and air side installations, etc.). Meanwhile, some other studies are also conducted in parallel, such as the building's energy consumption analysis

Left: The base of ICC, looking up. Source: Sun Hung Kai Properties

as well as devising the building's energy performance optimization strategies, which are the joint effort between PolyU and the ICC management team.

Simplification of the Secondary Water Loop Systems for Middle and High Zones

The original design of the primary-secondary pumping paradigm in the upper part of the building (Zones 3 and 4) is replaced by the alternative design which eliminates the primary pumps. The original speed control of the pumps is used to distribute chilled water to the HX. In this strategy, the pump speed is controlled to maintain a fixed pressure difference between the supply pipe and the return pipe. The opening degree of the modulating valve is controlled to maintain the temperature of the HX outlet water at its set-point. An alternative control strategy is proposed in which the modulating valve is always kept fully opened. In this cascade control, the temperature monitored by the temperature sensor is used to determine the required water flow rate with respect to the temperature set-point. The required water flow rate is then compared with the measured water flow rate in the primary side of heat exchangers to carry out the pump speed control. Energy savings can be achieved since the pipe resistance is minimized in the alternative control.

Cooling Tower System Selection and Operation

The objective function in this strategy is to minimize the instantaneous total power consumption of the chillers and both types of cooling towers. All the cooling tower fans were revised from two-speed (two-stage) to variable speed using Variable Frequency Drive (VFD) for energy savings. Furthermore, a reduction in minimum operating frequency from 37 Hz to 20 Hz was confirmed and implemented. Based on the commissioning test results, such lower operating frequency and the use of VFD can provide an annual energy savings up to 2.36 million kWh. The payback period for those added VFD is less than 1 year.

"Through the successful implementation of ISO 50001 Energy Management, over 10 million kWh of energy were conserved from 2012 to 2014, and an energy savings of over 6 million kWh in 2013 and another 3.8 million kWh in 2014 was achieved."

Robust Chiller Sequencing Control

An innovative data fusion scheme is used to improve the reliability of building cooling load measurements (while providing a degree of confidence in the fused load measurement for robust control and fault detection). The advantages of direct measurement and indirect measurement are merged in the final fused cooling load measurement. A chiller's online calculation scheme for the maximum cooling capacity is used to improve the reliability of chiller sequencing control together with the data fusion scheme. The test results show about half of the unnecessary chiller switch operations were avoided and over 1% of the chiller plant energy consumption can be saved.

Optimal Control of the Secondary Water Pumps

A cascade controller is used to control the operating speeds of pumps distributing water to heat exchangers (fully open control valves) instead of using the modulating valves while keeping a fixed differential pressure. The fully opened valve in the cascade control minimizes the water loop resistance and therefore saves the energy of pumps. The test results showed good control reliability of the strategy and contributes to annual energy savings up to 250,000 kWh.

DCV and Model-Based Outdoor Air Ventilation Control

To solve the over-ventilation or under-ventilation problem in the conventional ventilation controls, a robust DCV control strategy based on ASHRAE standard 62.1 was developed and used. Additionally, a model-based free cooling outdoor air control strategy was combined with the DCV strategy. The test results in commissioning and operation confirmed that the energy consumption of the primary air-handling unit (PAU) can be saved up to 50% under a partial load compared with the original two stage control and the energy consumption for cooling outdoor air can be reduced by 65% at most. With the CO_2 concentration being maintained below 800 ppm in each zone, the excellent indoor air quality is ensured.

Other Optimal Control Strategies

Other optimal control strategies used for the energy efficiency of the MVAC system include deficit flow control for eliminating deficit flow and saving pump energy, chilled water supply temperature optimization, AHU supply air temperature optimization and differential pressure set-point optimization in the secondary pumps.

The significant energy reduction of 3.80 million kWh was achieved in 2014 as compared with 2013, the total energy savings from the MVAC system in 2014 was about 3.35 million kWh, which resulted from the reduced building cooling load (about 1.77 million kWh) and the improvement of the system efficiency (1.58 million kWh). The cooling load reduction is due to the fresh air control, such as using the DCV control and closing the unnecessary PAUs manually. For system efficiency, the average value of COP increases from 5.1 in 2013 to 5.2 in 2014.

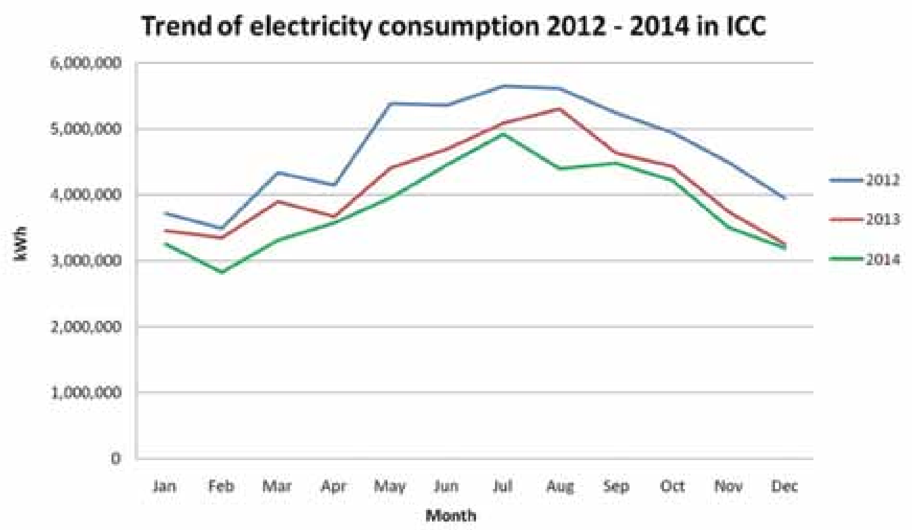
Energy Audit

Energy audits are an effective way to examine the energy use and performance of a building. In ICC, an energy audit is conducted annually so as to understand and update the building energy use clearly for internal reference and external benchmarking. In addition, recommendations in the energy audit report can also be referred and adopted to further enhance the building energy performance to achieve environmental and economic benefits. See Table 1 for a summary of the results from 2013 and 2014.

The current energy audit conducted in ICC is based on the Building Energy Efficiency Ordinance (BEEO) of Hong Kong Legislation Chapter 610 (Cap.610) which was enacted by the Hong Kong Special Administrative Region Government in November 2010 and fully implemented on September 21

End-uses	2013 Energy Consumption (kWh)	2014 Energy Consumption (kWh)	Energy Saving (kWh)
HVAC	32.06M	28.7M	3.35M
Lighting & Equipment	11.07M	10.75M	0.32M
Lifts	6.78M	6.65M	0.12M
Whole building	49.90M	46.10M	3.80M

Table 1: Energy Consumption Summary of 2013 and 2014. Source: Sun Hung Kai Properties



Graph 1: Trends of electricity consumption from 2012–2014. Source: Sun Hung Kai Properties

2012 and aims to enhance the building's energy efficiency, extend equipment/system service lives, achieve energy conservation and environmental protection (HKSAR, n.d.). The ordinance requires energy audits to be carried out in accordance with the "Code of Practice for Building Energy Audit" (referred to as "Energy Audit Code" or "EAC") and building services installations in prescribed buildings should comply with the "Code of Practice for Building Services Installation" (referred to as "Building Energy Code" or "BEC") (EMSD, n.d.). For instance, the maximum allowable lighting power density shall be 15 W/m^2 for office use and a minimum coefficient of performance (COP) for centrifugal water-cooled chiller is 5.6 for a capacity range within 50 to 1,000 kW.

Therefore, the building services installations of ICC should comply with the BEC 2012 Edition and the energy audit should be carried out in accordance with the EAC 2012 Edition under the ordinance. Under the ordinance, a Registered Energy Assessor (REA) is the authorized personnel to conduct energy audits and issue an Energy Audit Form for the premises. ICC appointed an REA to provide an analysis and assessment of the ICC system/equipment's energy performance covering the central building services installation (CBSI), which includes lighting installation, air-conditioning installation, electrical installation as well as the elevator and escalator system. In the initial stage of energy audit, the REA collects ICC's building information (focus on CBSI) so as to determine the technical and operational characteristics of ICC; the information collected includes equipment inventories, floor area, energy bills and O&M manual. After reviewing the collected information, site inspections with measurements were conducted by the REA to calculate and identify the energy consumption of CBSI in ICC. Supplementary records were also provided for REA to review and formulae of audit report.

Opposite: The central monitoring and control system.
Source: Sun Hung Kai Properties

After that, the energy performance of CBSI is analyzed by comparing their original design with corresponding operation conditions in accordance with the BEC 2012 Edition. Therefore, the REA identifies the potential energy saving estimate's so-called "Energy Management Opportunities (EMOs). The EMOs can be further divided into three categories (i) Category I – involving housekeeping measures which are improvements with practically no cost investment and no disruption to building operation; (ii) Category II – involving changes in operation measures with relatively low cost investment and (iii) Category III – involving relatively higher capital cost investment to attain efficient use of energy. Finally, the REA submits the energy audit report to ICC which consist of an executive summary, objective and scope, equipment/ system operating characteristics, potential EMO with energy saving and cost benefit analysis as well as recommendations for EMO implementation and follow-up actions.

By continuously optimizing the energy consumption facilities, the annual audit of ICC showed that the Energy Utilization Index (EUI) of ICC in 2014 reduced from 157 kWH/ m^2/year to 141 kWH/m^2/year compared to that in 2013, as seen in Graph 1.

Results and Achievements

Based on the above mentioned energy management action plans, like the implementation of ISO 50001:2011 EnMS, the ICC management team can monitor and improve the energy performance of the building by launching a wide range of energy saving measures for different building services installations. Meanwhile, the continuous collaboration with PolyU allows for substantial energy reductions by optimizing the operation strategies of the MVAC system. Moreover, the annual energy audit of the ICC enables the management team to understand the standpoint of ICC in terms of energy performance compared with the other properties. The actual energy performance of ICC has been improving significantly over the past two years. The overall energy savings between January 2013 and December 2014 is over 10 million kWh, reduced 18%, and equivalent to a 7 million kg CO_2 reduction. The effort of ICC in conserving the environment is well-recognized for acquiring various awards and recognitions, like the 2015 International Building Performance Awards - Facilities Management Operation Award bestowed by CIBSE, Gold Award of Hong Kong Awards for Environmental Excellence 2013 (Property Management Sector), 2014 ASHRAE Technology Award – Honorable Mention, Gold Award of Low-carbon Office Operation Program (LOOP) by WWF Hong Kong, Best Practice Awards 2013 (Green Development) presented by Best Practice Group, China Light Power (Hong Kong) Limited (CLP) GREENPLUS Recognition Award - Gold Award (Commercial and Industrial Section) in 2013 and Prestige Honour Award in 2014, and the 2014 CTBUH Performance Award; all these achievements illustrate the good energy performance of ICC.

Last but not least, the ICC management team intends to constantly improve, as opposed to stopping at the current stage of performance. The team will seek any feasible opportunities and make all endeavors on various aspects to contribute to the sustainable improvement of ICC, which is a triple-win situation for the environment, tenants and the landlord.

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