Retro-Commissioning – Effective Energy Conservation Initiatives in Existing Buildings

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Abstract. Hong Kong is a densely populated metropolitan city crowded with more than 7 million people. of the 42,000 buildings in Hong Kong, more than half (55%) of Hong Kong’s total annual energy end-use is in the form of electricity consumption and buildings take up about 90% of our total electricity consumption. Thus, energy saving in buildings is a key factor of addressing climate change and associated environmental issues of Hong Kong. In January 2017, the Environment Bureau of Hong Kong Special Administration Region Government (HKSARG) published “Hong Kong’s Climate Action Plan 2030+” which set target to reduce our carbon intensity by 65-70% by 2030 compared with the 2005 level. With this ambitious vision, the whole community have to further endeavour to achieve energy conservation with concrete supporting measures. Electrical and Mechanical Services Department (EMSD) of HKSARG is actively pursuing the cost-effective program of “Retro-commissioning (RCx)”, new energy saving initiative, to further encourage energy conservation works in existing buildings. RCx is a cost-effective and systematic process to periodically check the energy efficiency performance of existing building. EMSD has carried out numbers of pilot projects on both government and private buildings with Hong Kong Green Building Council (HKGBC); launched the “Technical Guidelines on Retro-commissioning [TG(RCx)]”; led and co-organized with different stakeholders on showcasing the government-industry collaboration and promoting effort of RCx training for the industry. The paper will introduce the framework and technical approach of TG(RCx), share the latest development and implementation programme of RCx in Hong Kong.

1. Introduction
Under the high population density in Hong Kong, high rise buildings are designed to fulfil the living purpose and business operation, whereas low demand on industrial production. From Figure 1, the energy used in commercial purpose is gradually increasing. It is therefore not surprised that buildings take up about 90% of total electricity consumption in Hong Kong. Asia-Pacific Economic Cooperation (APEC) is on target to meet its green growth goals to reduce aggregate energy intensity by 45% by 2035 using 2005 as the base year. Hong Kong as a member economy of APEC, Hong Kong has published the Energy Saving Plan for (ESP) in 2015. It set a target of reducing energy intensity by 40% reduction target by 2025 using 2005 as base. In 2005, the energy intensity of Hong Kong was 161 TJ per billion Hong Kong Dollar, where energy intensity is the ratio of energy end-use to Gross Domestic product.
(GDP), therefore the amount of energy end-use consumed in producing a unit of GDP. It represents the foundation from which we plan our energy saving work.

2. Application of Building Energy Efficiency

HKSAR Government has been pursuing various energy efficiency policies and initiatives to reduce energy use in buildings. In 2009, Mandatory Energy Efficiency Labelling Scheme (MEELS) has been fully implemented under the Energy Efficiency (Labelling of Products) Ordinance, Cap 598 for monitoring the energy performance of domestic electrical appliances. Meanwhile, in 2012, the Buildings Energy Efficiency Ordinance, Cap 610 (BEEO) came into full operation. It requires new buildings as well as existing buildings undergoing major retrofitting to comply with the energy efficiency standards and requirements specified in the Building Energy Code (BEC). Besides, the Government built a large scale centralised air-conditioning system – District Cooling System (DCS) in Hong Kong at Kai Tak Development, which in operation in 2013. It can save electricity compared to conventional air-cooled air-conditioning system. With implementation of energy efficiency policies, in 2016, the energy intensity reduction is 28% using 2005 as base year.

To maintain the momentum of energy intensity reduction to the target by 2025, EMSD will regularly review on BEC for more stringent requirement, review of MEELS to cover more products and explore the feasibility of proposed DCS in other areas will be applied. However, current energy efficiency policies mainly focused on new installation and new development. According to the statistic shown in Table 1, more than 85% of building stocks in Hong Kong are aged more than 10 years. Existing buildings in Hong Kong frequently undergo operational and occupancy changes that hinder optimal performance. Systems are highly interactive with sophisticated control systems that can create a trickle-down effect on building operations with impact on energy performance. No matter how well building operators and service contractors maintains equipment, if the equipment operates inefficiently, it can still lead to energy wastage and reliability problems. Retro-commissioning (RCx) implement on existing buildings, with cost-effective process on review and tuning aged services to improve their performance, provides significant energy saving potential to maintain energy intensity reduction.

Table 1. Age Profile of Buildings (as at 31 December 2009)

| Age  | No. of Buildings |
|------|-----------------|
| <10  | 5814 (14%)      |
| 10-19| 8569 (20.6%)    |
| 20-29| 11148 (26.7%)   |
| 30-39| 6688 (16.1%)    |
| 40-49| 5712 (13.7%)    |
| >50  | 3690 (8.9%)     |

Figure 1. Energy End-use in Hong Kong Sector (1984–2016)

3. Retro-commissioning (RCx)

RCx is a systematic and cost-effective process to periodically check an existing building’s energy and other performances, such as equipment conditions, systems function, shift from the designed conditions, the effectiveness of operation and maintenance (O&M) strategies, etc. The process identifies operational improvements that can save energy which can be performed alone or with a retrofit project, such as replacement of inefficient appliance.
4. **Technical Guidelines on Retro-commissioning [TG(RCx)]**

The experience gained from both EMSD’s pilot projects and HKGBC’s “ACT-Shop” programme is used to develop TG(RCx) 2018 edition.

![Figure 2. Technical Guideline on Retro-commissioning](image1)

![Figure 3. The major steps in each work stages](image2)

**4.1. Framework of TG(RCx)**

In the TG(RCx), retro-commissioning consists of four work stages which include: (1) Planning, (2) Investigation, (3) Implementation, and (4) Ongoing commissioning stages.

**4.2. Stage 1 – Planning**

4.2.1. **Collect Building Documentation.** When a building is going to conduct RCx, the first step is to collect building information such as buildings services (BS) schematics diagrams and layout plans, BS design document, O&M manual, operating logs, electricity bills and energy audit report, etc. A “Building Design Information Checklist” has been formulated in the TG(RCx) to facilitate the RCx Team to collect relevant building documentation.

4.2.2. **Interview and Meeting with O&M Staff and Building Occupants.** RCx team will conduct interview and meeting with O&M staff together with building occupants to find out the building operational pattern, operational deficiencies and unsatisfactory indoor environment etc. Relevant Interview Forms have been also developed to facilitate the RCx team to carry out this interview.

4.2.3. **Carry out Initial Building Walk-through.** RCx team together with O&M staff will conduct an initial building walk-through to observe the actual operational conditions and discover any operational problems.

4.2.4. **Conduct Initial Equipment and System Checking.** RCx team compares actual operational and design condition or general engineering practices. Such comparison can identify the areas of potential problems if design condition is drifted-off.

4.2.5. **Develop a RCx Plan.** RCx Team formulates a RCx plan by summarizing observation and findings in planning stage including actual building operational condition, energy consumption, operational problem, prioritizing improvements etc. RCx plan would highlight the areas for further study. A sample of RCx plan has been developed in the TG(RCx).

**4.3. Stage 2 – Investigation**

4.3.1. **Conduct Site Survey and Measurement.** A site survey and measurement had been carried out to determine how BS systems are operate, and a prioritized list of operating deficiencies is prepared.
Common scope at this stage is to take logs on the operation patterns and get adequate operation data at different seasons for carrying out diagnostics. “Data Collection Form” has been developed in the TG(RCx) to facilitate the users to carry out the site survey and measurement.

4.3.2. Analysis of Data Collected. RCx team analyses the collected information against design data, O&M logs and/or general engineering practices and identify any operational parameter deviated from what would be anticipated or required.

4.3.3. Identification of Potential Improvement and Energy Saving Opportunities. When energy saving opportunities (ESO) are identified, summary of potential improvement, estimated energy savings, cost and benefits analysis and estimated payback period could be formulated. The benefits of RCx should be fully demonstrated to building owner if resource is required.

4.4. Stage 3 – Implementation

4.4.1. Implementation of Selected Energy Saving Opportunities. An implementation plan should be developed to carry out those selected improvements and optimization opportunities. The building owner may propose a staged implementation plan to suit their budget or to minimize the disturbance to the current operation and occupants inside the building.

4.4.2. Performing Verification. After carrying out the implementation, measurement and verification should be conducted to verify the effectiveness of the implemented items. The measurement and verification method should be agreed with the building owner and stated in the implementation plan.

4.4.3. Develop a RCx Final Report. A RCx final report is prepared to record all activities conducted in the RCx implementation plan. The report should include recommended interval of RCx works on specific system or equipment, RCx training materials for building operator and a list of improvement items and optimization opportunities for building owner’s further investigation.

4.5. Stage 4 – On-going Commissioning

4.5.1. Develop an Ongoing Commissioning Plan. In order to ensure that the benefits of RCx can be maintained and building services systems are operated in high energy efficiency condition, the RCx team should include an ongoing commissioning plan: (1) Tracking on energy performance of building services systems, (2) Maintain the energy performance.

4.5.2. Conduct Training for O&M Staff. In post-handover stage, one of the major goals is to ensure the building services system after the RCx would be maintained at “good” energy performance. As such, an ongoing commissioning plan including key energy performance indicators should be developed for the operators to keep track on “good” energy performance.

5. Pilot study in Government Buildings

Retro-commissioning is new energy saving initiatives in Hong Kong. To investigate effectiveness of RCx applied to existing buildings, EMSD commenced a pilot study covering both Government and private buildings in 2016. For Government buildings, six existing government buildings, aged from 10 to 30 years are selected to undergo RCx.

5.1. Case Study of RCx implementation

The pilot study for each buildings applied the four phases mentioned in TG(RCx). To verify the effectiveness of the RCx, one of the pilot project, Kowloon Tong Education Services Centre, is given as an example. The gross floor area of Kowloon Tong Education Services Centre has around 22,000 m². It is commenced operation in early 2006. The building includes public transportation facilities, office area for educational departments and provides communal facilities for holding conferences, seminars, training courses and meetings. The RCx was commenced in mid of 2016. The annual electricity consumption of last 3 years are summarized in following Table:
Table 2. Annual Total Electricity Consumption in Kowloon Tong Education Services Centre

| Time period          | Annual Total Electricity Consumption (,000 kWh) |
|----------------------|-------------------------------------------------|
| Sep 2015 – Aug 2016  | 3,750                                           |
| Sep 2014 – Aug 2015  | 3,694                                           |
| Sep 2013 – Aug 2014  | 3,505                                           |

After investigation stage, several ESOs were suggested to be implemented include (1) Adjust the chilled water flow of Chilled Water Pumps across the night mode Chiller, (2) Offset the Supply Chilled Water Temperature Set-point for the night mode Chiller, (3) Review the set-point of room temperature of VAV in office area, (4) Review the set-point of AHU static pressure serving for VAV system and (5) Shut off Harmonic filters with low harmonic load to reduce cooling load demand.

During investigation stage, two active harmonic filters were selected to measure the inlet and discharge temperature, it was found that the temperature difference of discharge and inlet of each filter are around 8°C and 10°C respectively. The temperature difference maintain same for night mode and day mode. During the site inspection, harmonic currents are measured in office and non-office hour. It is observed that current harmonic are at low level or zero level at both duration of measurement. It can be conclude that harmonic currents shall not be a major factor to affecting the electrical system power quality even if switch off all those harmonic filters. Therefore, it is suggested to switch off all active harmonic filters to reduce cooling load demand and without reduction of power quality.

5.2. Data Analysis

After the RCx implementation stage, a review on electricity bills for the years before and after RCx action was performed. In order to make a valid comparison, consideration on Cooling Degree Days (CDD) is important. The CDD is a measure of how much (in degrees) and for how long (in days) that outside air temperature was higher than a specific base temperature (assumed 18.5°C in this calculation) start to use air conditioning for cooling. Hence, the higher value of CDD, it represent the higher ambient condition and require higher cooling demand over the period. The CDD of the year 2017 is larger than 2016. It is meaning that the cooling requirement of the building in 2017 shall require higher cooling load as well as energy consumption of MVAC system. However, the energy consumption of the building was reduced in 2017.

The following chart showing the monthly energy consumption and CDD of years 2017 and 2016:

![Figure 4. Monthly Energy Consumption & CDD of 2017 vs 2016](image)

From the latest energy consumption data of Education Services Centre, comparing the energy consumption between 2015 & 2016, the variation is not significant. After implementation of ESOs applied in 2017, the annual energy consumption the annual energy of the building was reduced 352,000kWh (i.e. 9.4%) compare with 2016.
### Table 3. Annual Energy Consumption Summary of past three years

| Year | Annual CDD | % Change of CDD from last year | Annual Electricity Consumption (,000 kWh) | % Change of Electricity Consumption from last year |
|------|------------|--------------------------------|------------------------------------------|--------------------------------------------------|
| 2017 | 2,272      | +12.1%                          | 3,399                                    | -9.4%                                             |
| 2016 | 2,027      | -5.6%                           | 3,751                                    | +0.5%                                            |
| 2015 | 2,147      | N/A                             | 3,734                                    | N/A                                              |

In view of the case study, low cost or no cost process identifies operational improvements that can optimize energy efficiency performance of the buildings and thus lower electrical consumption. With considering the low initial cost in RCx, the payback period of those ESOs from RCx is usually ranges from several months to a few years, about 3 years in average, which is more cost-effective comparing to replacement of equipment. A summary of the six pilot projects are shown below:

### Table 4. Electricity Saving in six pilot projects of Government Buildings

| Building Name                                      | Total Internal Floor Area, \((m^2)\) | Anticipated Annual Electricity Saving, \(000\ kWh\) | Change of Electricity Consumption from last year, \(\%\) | Payback Period, \(\text{year}\) |
|---------------------------------------------------|--------------------------------------|-----------------------------------------------------|----------------------------------------------------------|-------------------------------|
| Kowloon Tong Education Services Centre            | 22,000                               | 350                                                 | 9.4%                                                     | 2–3                           |
| New Territories South Regional Police Headquarter | 38,000                               | 490                                                 | 7.0%                                                     | 3–4                           |
| North Point Government Offices                     | 49,000                               | 430                                                 | 3.3%                                                     | 2–3                           |
| Queensway Government Offices                       | 81,000                               | 450                                                 | 3.0%                                                     | 3–4                           |
| Smithfield Municipal Services Building             | 19,000                               | 320                                                 | 5.0%                                                     | 3–4                           |
| Hung Hom Municipal Services Building               | 24,000                               | 280                                                 | 5.0%                                                     | 5–6                           |

The energy saving which arising from these ESOs is estimated at 2,300,000 kWh per year, which is equivalent to about 5% of the total annual building energy consumption. The payback period of these ESOs aside from demonstrating the benefits of RCx, the pilot study also helped the formulation of the TG(RCx) with real life examples. To further develop the popularity of RCx, all government buildings will be applied with RCx to enhance the energy efficiency.

### 6. Collaboration with HKGBC and 4Ts Partner

#### 6.1. A Leading Action on RCx for Private Building Sector

The Environmental Bureau further developed a “4Ts framework”, namely Target, Timeline, Transparency and Together, to engage the industry stakeholder in joining hands and achieving the energy saving target.

#### 6.2. Hong Kong Green Building Council (HKGBC)

Hong Kong Green Building Council (HKGBC), being a professional body and partner of the Government, launched the RCx Pilot Projects Practicing Scheme – “ACT-Shop” programme in 2016. The programme adopts the 4Ts approach to assist building owners to enhance the energy performance of existing buildings, by implementing RCx practices in buildings. By participating in the programme, building owners could identify the potential improvements on energy saving and make decisions based on data analytic and diagnostic. In the programme, RCx pilot projects were being conducted on a batch-by-batch basis with 5–7 numbers of participating buildings per batch in order to optimise the resources and time, and make the sharing process more effective.
6.3. Role and Responsibility between various parties in the “ACT-Shop” programme

The HKGBC is the programme administrator as well as the facilitator to operate the sharing platform in which procedures, methodologies, practices, issues and solutions adopted are shared among groups of participants. The HKGBC facilitates participants to go through a step-by-step approach on collecting and analysing of operating data to identify ESOs, estimate saving and implement improvement measures, and measure and verify the improvements. Likewise, the participants would be one of the key stakeholders to make the programme successful through active participation in the on-site practices and discussion process by sharing their experience and practical knowledge, providing necessary operating data and information, implementing suggested improvement measures and following up by measurement and verification. The Government shares the best practices into the TG(RCx) and works closely with the HKGBC and various institutions from the industry to provide professional training and continuous professional development talks to industry practitioners.

6.4. Details in “ACT-Shop” programme

The programme has already conducted to 4th batch of pilot projects and a total of 24 private buildings are participating in this programme, including office, retail, composite (office and retail), hotel and single tenant buildings. The multidisciplinary participants including facility / property management, contractors, manufacturers, operators, professionals and the Government make use of existing buildings as living laboratories for demonstrating the practices of RCx.

An alignment meeting for programme participants will be held before any RCx process taken place to ensure the understanding of their roles and responsibilities between each other as well as the works and scopes of RCx. Followed by site evaluation exercises in which participants can understand the document, information and operating data, meters and other instrumentation that are required to be provided on-site. Also, they can comprehend the best practices for operating building facilities, maintaining instrument, keeping records, and reviewing the settings and control performance of equipment. As a result, participants can realise the importance of determining the RCx scopes and approaches in the planning stage.

When implementing RCx process, some difficulties are encountered such as insufficient building information including services drawings, equipment schedules, O&M manuals, equipment control logic and operating schedules), inadequate and unreliable trend log data due to insufficient provision and poor condition of sensors, inappropriate control accessories as some control devices and actuators are out of order and mismatching of control logic and operation practices. There are ESOs proposed to be implemented for AC system include but not limit to optimizing operating quantity, optimizing operation, off-coil set point of AC equipment according to weather condition such as summer to winter, day to night, replacement of malfunction sensing element in order to execute energy efficiency control logic, VSD and differential pressure sensors installation for chilled water pumps part load speed control.

With implementation of ESOs in 4 batches of buildings, Measurement & Verification had been performed and summarized in Table 5. The results show the short payback period for each batch and also the effect of electricity saving comparing with the year before RCx implementation.

| Batch | Total No. of Building involved | Total Internal Floor Area (m²) | Anticipated Annual Electricity Saving (,000 kWh) | Change of Electricity Consumption from last year (%) | Payback Period (year) |
|-------|--------------------------------|-------------------------------|-----------------------------------------------|-----------------------------------------------|----------------------|
| 1     | 5                              | 308,000                       | 6,400                                         | 9.5%                                          | 2–3                  |
| 2     | 6                              | 1,063,000                     | 4,300                                         | 1.8%                                          | 1–2                  |
| 3     | 7                              | 418,000                       | 2,200                                         | 2.6%                                          | 1–2                  |
| 4     | 6                              | 544,000                       | 1,800                                         | 3.0%                                          | 1–2                  |
| Total | 24                             | 2,333,000                     | 1,500                                         | 3.2%                                          | 1–2                  |

Table 5. Electricity Saving in 4 batches of 24 Private Buildings
7. Way forward
Having considered the above energy saving potential and the positive results of the aforesaid RCx projects, EMSD would adopt the following strategy measures to further promote the concept of RCx, connect trades and facilitate the stakeholders to conduct RCx in private and public sectors.

7.1. Review and updated Technical Guidelines
Since EMSD published the TG(RCx) in June 2017, the responses received on the TG(RCx) are positive and encouraging. With feedback from local RCx projects in progress, the current TG(RCx) will be further enriched with more common technical approaches for reference in different premises and to provide step-by-step technical tips for industry players to follow. The updated version of TG(RCx) is completed in 2018. More ESOs are supplemented for companies and customers referral.

7.2. Setting up RCx Online Resources Centre
In order to promote RCx, EMSD is developing an online resources centre for providing common RCx technical tips, a directory of RCx services providers and successful RCx cases, training and seminar for promoting and developing RCx. This website will become a repository platform for providing latest information about RCx for trades and stakeholders. A directory to facilitate the building owners to select the RCx service provider will also be included in this platform. Besides, HKGBC developed a webpage for advocating the efforts of the industry leaders and followers from the industry on promoting RCx to be the best practices in building O&M. It becomes an online RCx academy for providing sources and paths of practices training and knowledge sharing from various institutions and colleges. It also serves as an on-line information centre for the activities related to RCx such as recent news from the industry and the Government, funding supports, the latest technologies and list of practitioners, etc.

7.3. Active Training – A Way forward of “ACT-Shop” Programme
The HKGBC has been collaborated with the Government to develop strategic plans to build up capacity of industry with an objective to make RCx becoming the mainstream practices in O&M. To this end, the HKGBC launched the “ACT-Shop” programme in 2016. Industrial sharing and trainings for professionals through “Active Training” courses emphasise on investigation and implementation process of RCx, identifying ESOs from the evaluation results and conducting measurement to verify actual saving. By participating in the Active Training, industry practitioners could identify potential improvements and ways for implementing the ESOs, and adopt data analysis for energy saving decision-making, and provide specify requirements to contractors, suppliers / service providers when contracting out partial specific process. The mode of training includes lectures on basic knowledge and an “ACT-Shop” model for practices training where the target participants will go through the essential RCx process in existing buildings.

8. Upcoming trend for Retro-commissioning
With developing RCx implementation plan, final reports, and on-going commissioning plan, more data connected from public sectors and private sectors, big data base for set-points, conditions troubleshooting strategy can be a valuable reference. Smart centre can be provided for new building to access the clouded computing strategy to achieve economies of scale, deliver BS systems that are flexible and responsive to demand, take advantage of new technologies in order to support various activities, meet environmental and sustainability targets, provide an open platform to allow client to hook new emerging future BS applications

9. Conclusion
To be an initiator of RCx for effective energy conservation, EMSD will continue to promote RCx to stakeholders in private sector, liaising with professional institutions and trade associations for training on RCx and development of RCx technologies database, enhancing the energy efficiency and reducing
greenhouse gases emission under a low or no cost adjustment. We hope that both public and private sectors can work hand-in hand to promote the RCx and meet the energy saving target.

Acknowledgements
Sincere thanks are extended to Hong Kong Green Building Council in offering their expertise advice, information of their RCx projects and support in the preparation of this paper.

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