Driving Ultimate Building Performance Through Smart E&M Systems for Sustainable Built Environment

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ABSTRACT

Buildings are major components in a city and they account for more than 40 percent of global energy usage. Together with the long life-cycle of buildings, their performance has significant impact to the sustainable built environment. The building performance relies heavily on electrical and mechanical (E&M) systems and services. The E&M systems in modern high rise buildings have become more comprehensive and sophisticated. This paper will discuss the technological changes for building performance indicators, including availability, maintainability and reliability (AMR), and energy efficiency. Emerging data and information and communications technologies (ICT) bring in new concept and development of smart E&M system and services for driving ultimate building performance and sustainable building environment.

Keywords: *sustainability, built environment, energy efficiency, availability, maintainability, reliability, data, information and communications technologies, driver, E&M systems*

1. INTRODUCTION

The built environment refers to everything manmade to modify the spaces in which we live and work, including buildings of all types, roads, parks, and landscaping, etc. It has a broad spectrum of impacts on our lives. For a built environment to be sustainable, it shall meet the needs of present without compromising the ability of future generations to meet their own needs ("Our Common Future", 1987). It must also be flexible and adaptable to future uses, has low carbon emission and be resilient to cope with imminent threats of climate change. With the continuous world population growth, the rate of urbanization is increased and the built environment in cities is affected, e.g. constructing roads, utility and transportation facilities, as well as commercial and residential buildings. Buildings are major components in a city. They account for more than 40 percent of global energy usage and as much as one third of global greenhouse gas emissions which is the major cause of global climate change. In Hong Kong, the residential and commercial buildings consume around 51 percent of total energy use in which around 90% are used in electrical and mechanical (E&M) systems, e.g. air-conditioning, lift and escalator, fire services, lighting, etc. Performance of building depends largely on the E&M system design and service performance, and it is an essential element for sustainable built environment. Buildings' expected life span can reach 50 years or more while the lifecycle of typical E&M systems is about 15-25 years. How the E&M systems and services performance can sustain within the expected lifecycle and what will be the optimal time to replace them will affect the building performance. Conventionally, managing the availability, maintainability and reliability (AMR) and energy efficiency of E&M systems and services is crucial to building performance. With the advancement of data and information and communication technologies (ICT), E&M system performance will have substantial changes. This paper will discuss the challenge on some performance indicators of E&M systems from such technological change. The data and ICT will bring in the smart building concept and development which drive ultimate building performance and sustainable built environment. Sustainable built environment for buildings will include smart data technology on top of energy efficient, green and low carbon.

2. SMARTER E&M SYSTEMS DRIVING BETTER BUILDING PERFORMANCE

In large scale and high rise buildings, the demand of E&M systems and services for meeting the needs of users are increased and the requirements for managing them are complicated. Interruption of the E&M systems will cause inconvenience or even disastrous consequences, resulting in unacceptable building performance. Therefore, enhancing AMR on E&M systems is important for preventing service interruption. Apart from this, as E&M systems consume 90% of energy used in buildings, inefficient use of energy in them will decrease the energy

performance and also lead to high electricity bill. As energy performance of E&M systems will affect building performance, managing their use is very important. Therefore, AMR and energy efficiency are considered as the major performance indicators for building performance.

With the fast advancement of data and ICT, it brings in the new concept of smart building and development on smart E&M systems and services. It enables more automatic, intelligent, remote monitoring and control features to be built in E&M systems. This will drastically change the mode of operation and maintenance of E&M systems with increase in intelligence but less manpower resources. This will become the key driver in raising the capability of E&M systems for enhancing the AMR, energy efficiency and ultimately the smart building performance. AMR, energy efficiency, and data and ICT will be further discussed in the following sections.

2.1 Availability, maintainability and reliability

2.1.1 Availability

Availability of E&M systems is an important indicator to measure the operational effectiveness of the building. It is the probability of a system to operate and perform its intended function over its expected life-cycle. In modern financial cities and densely populated areas, the operation of both commercial and residential buildings, in particular the high rise ones, relies heavily on the availability of various E&M systems. Inability to access to service of an E&M system, e.g. lift, fire services installations, etc., will cause inconvenience or even safety impact to the building performance. Availability is inter-related with maintainability and reliability.

2.1.2 Maintainability and reliability

Maintainability refers to the ease and rapidity of restoring a system back to operational status. Conventional maintenance approaches on E&M systems are basically to carry out regular preventive maintenance to prevent failure and corrective maintenance after failure occurrence. Regular preventive maintenance is carried out through inspection, scheduled servicing or even overhaul so as to maintain the performance and prevent the occurrence of failure. Since this approach does not consider asset condition, excessive maintenance and provision of extra manpower resources. For corrective maintenance, it is essential to respond to unpredictable service interruption. However, neither of these approaches is desirable for sustainable built environment as they involve excessive resources and unpredicted failure, i.e. system not available.

The rapid advancement of technology on sensors and IoT, condition monitoring and data analytic has permeated into E&M industry and leading to a paradigm shift in maintenance approach. The techniques and manpower resources for maintaining E&M systems will become smarter. Through connecting sensors, controlling and monitoring equipment and software, E&M system data can be collected for analysis to enhance the maintainability. For example, various remote monitoring and self-diagnosis systems for lift installations have been put into operation. The operating data of lift, including travelling speed, lift car vibration spectrum, door opening and closing speeds, hoisting rope condition, etc. can be collected remotely for central monitoring and trend analysis. Through continuous condition monitoring and automatic self-diagnosis functions, the frequency of on-site inspection, the maintenance costs and manpower can be reduced. The pre-mature fault can also be detected for early rectification before a real fault occurrence. In case of failure, the fault attendance time can also be shortened since maintenance staff will be alerted instantly. Trouble-shooting and system downtime will also be reduced because maintenance staff can realize the cause of failure before arriving the site. This has changed the traditional work process in maintenance, repair and service, and enhanced their maintainability as well as availability.

In addition, advanced technology also brings in new challenges to maintainability of E&M systems. Nowadays, electronic or software control are widely used in E&M systems as more advanced and sophisticated functions are built in. Since electronic control is an integral part of the E&M systems and the core component of controlling their operation, its failure can cause complete malfunction of the system. Comparing with conventional E&M components, electronic parts are more vulnerable and have a shorter lifecycle as they are tightly coupled with the fast pace of technology advancement. These bring challenges to the maintenance of this kind of E&M systems because of replacement or repair of the electronic control or software will have obsolete or incompatibility issues after several years of service. Stocking more spare parts may alleviate the situation but the challenge to the maintainability as well as lifecycle asset management of these E&M systems still exist.

Reliability is the chance of a failure occurring over a specified time interval. In practice, components faults or aging issue will affect the reliability of the E&M systems. Typical approach to increase the reliability of E&M systems is to set up redundancy in the design which will automatically cut in to provide service in case of failure of the duty unit.

In order to reduce unpredicted interruption to E&M systems, innovative condition monitoring technology and smart sensors will come into play. These technologies can be used for keeping consistent system performance by monitoring deviation of various operating parameters such as vibration of compressor, component temperature and current, etc., so that building managers can timely examine and make necessary adjustment to the system. By integration of various E&M systems and deployment of an integrated Building Management System (iBMS) – aggregating and analyzing E&M systems and services information in a building or cluster of buildings, building managers can use remote monitor system and be fully aware of the condition of each system under a single platform. This system can facilitate building managers to take early action on potential problem in a well-planned manner and minimize the interruption to achieve a better reliability of the E&M systems and services.

2.2 Energy efficiency

Apart from AMR, effective use of energy in building is another key indicator for building performance. Buildings can be considered as energy-intensive system through their whole life-cycle. Knowing the current energy performance of a building is important to building managers. The commonly used metrics of building energy performance is Energy Use Intensity (EUI), which is presented as annual building energy use per building area. This unit is adopted for designing E&M systems in new green buildings and assessing the energy use in the existing buildings. Building managers can use the EUI to benchmark their buildings' energy performance and look for improvement on energy efficiency.

Energy audit is widely used to examine E&M systems' energy performance of a building. Through the process of energy consumption checks, energy management opportunities (EMOs) are identified for energy saving. The EMOs will then be realized through developing new operation and maintenance strategy, retrofitting of existing systems and thus bringing in higher energy efficiency system to improve building energy performance. The Hong Kong government led by example had carried out energy audits in 120 existing government buildings and achieved around 16% of reduction in electricity consumption in 9 years since 2003through the implementation of energy efficiency measures. In 2015, another round of energy audits for around 340 existing government buildings has been rolled out targeting for further 5% electricity saving in the coming 5 years with 2014 as the baseline.

The traditional energy management approach by monitoring annual building energy use and auditing energy used is time-consuming, labor intensive and costly. Recent technology advances of sensors, meters, and Building Energy Management System (BEMS) allow the building manager to visualize real-time energy consumption of E&M systems. With energy usage data in real time, building energy profile and energy consumption in different zones of the building will be automatically available for monitoring and managing E&M systems. Having online BEMS, the building manager can monitor the energy usage and engage occupants on energy efficiency. The building managers can use those data analysis tools to set energy saving targets and to control the E&M systems to optimize energy performance of the building.

Throughout the long life span of a building, changes to the existing building due to alternation and addition works, different occupants, different landlords or usage are not uncommon. The original settings in various E&M systems during commissioning, in particular air-conditioning system, may not optimize energy efficiency in the changed building environment. Retro-commissioning has been introduced recently which enables the E&M systems to adapt to changes and demand for services. It applies smart sensors, uses data mining and implements control algorithms such that the E&M system can respond to changes in building dynamically and to determine the optimal operation mode. In a research study, it is revealed that 15% of saving on energy use can be achieved by retro-commissioning.

2.3 Data and Information and Communications Technologies

Over the past decades, technological progress, building deployment, and falling prices have brought data and ICT, such as IoT, big data, cloud computing, analytic tool, smart senor, etc. to be widely used in E&M systems and services. The smart E&M systems described above have substantially improved the AMR and energy efficiency to result in enhancing building performance. In the context of smart cities, E&M systems and services in buildings are no longer standalone. E&M systems are connected in the building and interacting with people, environment, and city activities to deliver a better built environment. Modern data and ICT therefore become the key driver for ultimate building performance for sustainable built environment.

Buildings are full of data, information and assets from design, construction to operation phase. The inability to centralize building information and manage E&M assets are the challenges to sustainable built environment. Recently, Building Information Modelling (BIM) has made a revolutionary change in the construction industry which enables building and E&M system design and construction works to be more efficient. The information of building and E&M systems in BIM can be easily searched, accessed and updated. However, such 3D application has not reached the building operation phase yet. Being the largest E&M maintenance agency for the public sector in Hong Kong, the Electrical and Mechanical Services Department (EMSD) has developed a novel architecture for exploiting BIM in asset management (AM) and realised the concept in an integrated BIM-AM system featuring multiple operation and maintenance systems and tools in a single platform. Results of the pilot project demonstrated that BIM-AM is a highly visual operation and maintenance system and asset management tool can enhance the maintainability and availability of E&M systems, especially in fault location and service restoration. The integrated platform has proved effective in streamlining workflow, facilitating incident response, and AM. It is envisaged that the emerging BIM-AM system can improve the building performance and leading building industry to attune to smart E&M systems.

3. OTHER AREAS FOR BUILDING PERFORMANCE

There are other areas that should be considered for building performance. Safety is an issue affecting the building performance in built environment. Fire services and security systems are the E&M systems for protecting the safety of a building. In high rise and commercial buildings, the fire services and security systems are becoming sophisticated and they are no exemption in the trend of smarter technology and data driven system. Building management and security guards shall better utilize these systems to increase the building performance in safety aspect.

Resilience of E&M systems in building is another issue that should be considered when designing a sustainable built environment. Design for resilient E&M system to cope with impacts of extreme weather conditions arising from global climate change and minimizing the damages to buildings is a new challenge.

4. CONCLUSIONS

The aim of enhancement of building performance is to create a better and a more sustainable living and business environment for the purpose of meeting needs of the built environment. The building performance depends heavily on the design, operation and maintenance of E&M systems and services. The smart and data technology has brought smart concept in E&M system in driving ultimate building performance.

While the advancement of E&M systems is to enhance the building performance, designers, building managers, engineers and technicians are facing challenges of maintenance strategies for buildings. Smart and data technology has brought drastic change of AMR from traditional preventive maintenance and post-fault rectification to predictive maintenance and pre-fault rectification. The iBMS enables the building managers to monitor and control the availability of the E&M systems and services. To ride on the smart meters and big data analytics, building energy performance can be visualized in real-time, energy used data can be audited automatically, and energy usage can be optimized continuously. To implement the smart E&M technology in buildings, the emerging technology BIM-AM provides a single platform to centralize building information and to manage E&M assets effectively.

With the collaboration of all building stakeholders, including designers, the construction industry, operation and maintenance and facility management personnel who are acquainted with smart data technology and capability, delivery of smart E&M solutions will be the trend to make sustainable built environment a success. Let us stay connected, join hands and make every possible effort to drive ultimate building performance for sustainable built environment.

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