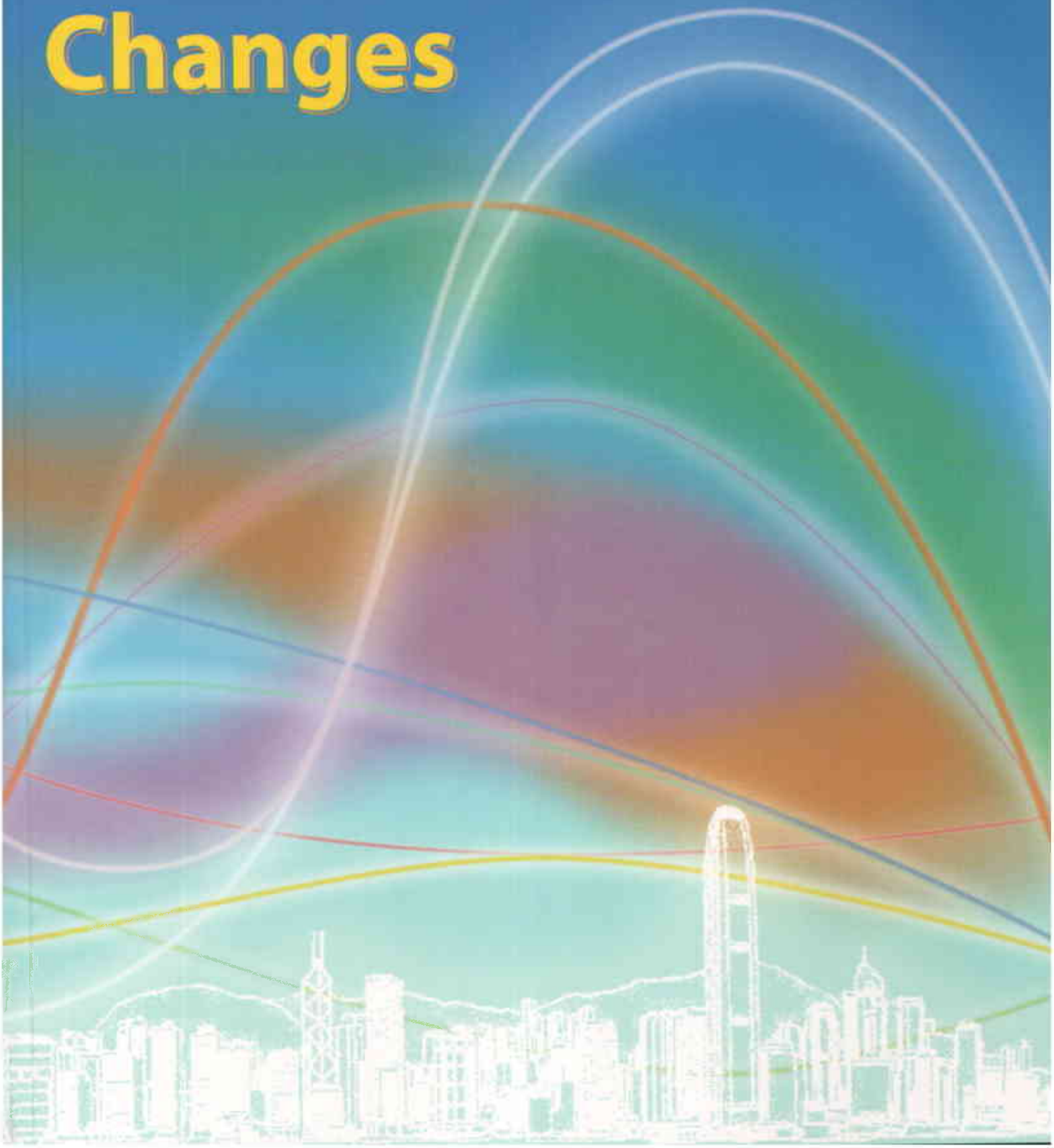
The Hong Kong Institution of Engineers - Electrical Division
The 27th Annual Symposium
22nd October 2009

Engineering the Changes



THE HONG KONG INSTITUTION OF ENGINEERS ELECTRICAL DIVISION

The 27th Annual Symposium

Thursday

22nd October 2009

ENGINEERING THE CHANGES

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 Registration and Coffee

09.00 Welcome Address

- Ir Simon F.W. Chung
  Chairman, Electrical Division, The HKIE

09.05 Opening Address

- Ir Dr F.C. Chan
  Vice President, The HKIE

09.10 Keynote Speech

- Professor Andrew McCusker
  Operations Director
  MTR Corporation Limited

1. Carbon Reduction

09.40 A Techonlogy Roadmap Towards a Low Carbon Electric System – A Utility's Experience Sharing

- Ms Priscilla P.S. Lee, Energy Technologist
- Ir Dr John W.M. Cheng, Program Development Manager
- Mr C.C. Ngan, Innovation Architect
  CLP Research Institute Ltd.
- Mr Andrew Kinross, Director/Energy
  Navigant Consulting, Inc.

10.00 Green Technology Applications to Combat Climate Change - An Electrical Engineering Perspective

- Ir Dr F.C. Chan
  General Manager
  CLP Engineering Ltd.

10.20 Discussion

10.40 Coffee Break

2. Emerging Technologies

11.10 State-of-the-art Batteries for Electric Vehicle and Industrial Applications

- Mr Kevin K.M. Yiu
  Business Development Director
  EVB Technology (HK) Limited

11.30 Enhanced System Reliability – Perspective from Distribution Cable/Materials

- Dr Peter K. Pang
  End-Use Marketing Manager
  Dow Wire & Cable
  Dow Chemical (China) Investment Co. Ltd.

11.50 Contemporary Design of Electrical and Vertical Transportation Systems for Super High-rise Buildings in Mainland China and Hong Kong

- Ir H.K. Yung, Director
  Ir Tony C.F. Lau, Associate Director
  Ir Tony C.W. Leung, Associate
  J. Roger Preston Ltd., Hong Kong

12.10 Discussion

12.30 Lunch

3. Asset Management

14.15 Smart Use of System Control Statistical Data to Enhance Power System Operations

- Mr Dennis K. Wong
  Vice President, Business Development
  ASAT Solutions Inc., Canada

14.35 Fibre Bragg Grating Sensor Networks for Condition-Monitoring of Railway System

– Professor H.Y. Tam
Director
Photonics Research Centre
The Hong Kong Polytechnic University

14.55 Discussion

15.15 Coffee Break

4. Migrating to New Era

15.45 Evolution in Electrical Engineering Curriculum

– Ir W.K. Lee, Senior Teaching Consultant
– Ir Dr Wilton W.T. Fok, Senior Teaching Consultant
– Ir Professor K.T. Chau, EE Programme Director
– Ir Professor Felix F. Wu, Chair Professor
Department of Electrical and Electronic Engineering
The University of Hong Kong

16.05 2009 Edition of Code of Practice for the Electricity (Wiring) Regulations

– Ir Y.H. Leung, Senior E&M Engineer
– Ir Y.T. Wong, E&M Engineer
Electrical and Mechanical Services Department
The Government of the HKSAR

16.25 Discussion

16.45 Summing Up

– Ir S.K. Ho
Symposium Chairman
Electrical Division, The HKIE

Closing Address

– Mr Ricky W.K. Wong
Chairman
Hong Kong Broadband Network Limited

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Speakers / Authors

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Ir Tony C.F. Lau
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Professor H.Y. Tam
Ir W.K. Lee
Ir Dr Wilton W.T. Fok
Ir Professor K.T. Chau
Ir Professor Felix F. Wu
Ir Y.H. Leung
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Paper No. 1

A TECHNOLOGY ROADMAP TOWARDS A LOW CARBON ELECTRIC SYSTEM – A UTILITY'S EXPERIENCE SHARING

Speakers : **Ms Priscilla P.S. Lee, Energy Technologist**
Ir Dr John W.M. Cheng, Program Development Manager
Mr C.C. Ngan, Innovation Architect
CLP Research Institute Ltd.
Mr Andrew Kinross, Director/Energy
Navigant Consulting, Inc.

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Paper No. 1

ABSTRACT

The power industry is confronted with the urgency of climate change, environmental concerns and regulatory pressure to move towards a low carbon environment. In the face of these emerging issues, utilities are turning to clean energy and technological innovations to lower carbon emissions. This paper presents a power utility's experience in developing a technology roadmap for the transition to a low carbon electric system. As the issue of climate change does not have a silver bullet solution, a portfolio approach was used to identify a range of key technologies to achieve low carbon energy. The spectrum of technologies includes renewable energy resources, carbon capture and storage, as well as green and innovative energy services.

1. INTRODUCTION

The environmental challenges faced by today's power industry are quite daunting. The issue of climate change in particular requires that the industry respond quickly to avoid irreversible impact. There are few existing solutions but a range of new technological solutions are emerging in the horizon. In order to deploy the technologies effectively to address climate change, technology planning is critical. One tool for technology planning is a technology roadmap [1]. This paper offers a look at how one utility develops a technology roadmap to strategize its approach for addressing climate change.

2. WHAT IS A TECHNOLOGY ROADMAP?

A technology roadmap is a tool used to identify the critical technologies necessary for meeting specific objectives. Such a roadmap can have different applications under various settings. An industry may use a technology roadmap to identify and address technology challenges for the future development of the sector. A company may use a technology roadmap to establish the framework for developing a particular new product.

Some examples of technology roadmaps used in the energy sector include those developed by Electricite de France (EDF) and Continental Automated Buildings Association (CABA). EDF R&D through its Demand Response Technology Roadmap identified the controls, internet standards, and tariff structures that will help the development of demand response and smart homes [2]. The CABA technology roadmap describes the current and evolving intelligent building technologies, such as intelligent lighting, voice and data communications, and energy management systems. CABA also uses its technology roadmap to recommend actions for the building industry to promote the application of intelligent building technologies [3].

Although there is no standard structure for the technology roadmap process, the development of a roadmap typically begins with a vision of a future scenario, challenge, or issue that can not

be addressed with existing technologies. Then the technologies that are essential to closing the gap between now and the future are identified and prioritised. In other words, a technology roadmap is a strategic approach towards a future objective.

3. EXPERIENCE OF DEVELOPING A UTILITY's TECHNOLOGY ROADMAP

3.1 OBJECTIVE

Power utilities worldwide are facing the issue of climate change. One approach to addressing this issue is by developing a technology roadmap that identifies the technologies needed for transforming a largely conventional fuel portfolio to one that uses low-carbon technologies.

As a major power utility operating throughout the Asia-Pacific region, CLP has set aggressive carbon emissions intensity reductions target through its Climate Vision 2050 initiative [4]. Through the initiative, the company committed to a 75% reduction in carbon intensity relative to year 2007 emissions. The company developed a technology roadmap that outlines the key technologies that will be important for transforming to a low-carbon portfolio. This paper shares the experience of developing such a roadmap.

3.2. METHODOLOGY

The development process began with the identification of a broad range of technologies that can potentially impact the power industry. These identified technologies became the basis of the Technology Atlas; that is all those innovations which should be monitored for developments.

While a spectrum of potential challenges facing the power industry was considered, climate change was one of the significant issues that called for a targeted low-carbon technology roadmap. Selective innovations from the Technology Atlas that can significantly mitigate the climate change challenge from a utility standpoint were integrated into the low-carbon technology roadmap.

As a first step to identifying and prioritizing the technologies and innovations that could potentially impact the power industry, we took the "universe" of technologies and put it through a screen to identify which ones would be best suited to meet the company's needs. Key criteria that were considered included the following:

- Time to commercialization
- Potential for market transformation
- Potential for strategic value to the company

We scored 80 technologies in all, based on a scoring system that defined how each technology would be scored and ranked with the goal being to identify the key technologies that most likely contribute to solving the challenges set out by the company.

Thirty-six technologies were short-listed from an original list of 80. We developed profiles of each of these technologies. After gaining insights and a deeper understanding of the potential of the different technologies from this exercise, we then conducted another screen to find out the technologies that were really going to be the critical ones in the roadmap. Following that selection we developed reports one level of detail greater than the prior reports.

While the *mechanics* of the scoring and ranking ended up being a relatively straightforward exercise, the *insights* gained from the research on the potential impact of the different technologies was considerable. The scope of the researched topics is described in the subsequent section.

3.3 SCOPE

Extensive research was conducted for each technology and innovation identified as having significant potential impact on the power industry. To help us better understand the development of the technologies, we analyzed factors ranging from market drivers to

development enablers and barriers. The scope of analysis for each technology and innovation are described below.

3.3.1 DRIVERS

These are the main drivers of developing and utilizing such a technology. For example, the drivers of *smart grids* would include preventing blackout, accommodating widespread deployment of intermittent distributed energy resources, growing needs to engage and accommodate customer-side interactions, requiring high efficiency, reliability and power quality for the digital age, climate-change and long-term business competitiveness considerations [5,6].

3.3.2 POTENTIAL FOR MARKET TRANSFORMATION

Each technology included in the Atlas must have a certain level of potential to transform the industry. By means of transformation, we mean the new technology could do at least one or more of the following: 1) Add new value(s) to the customers/service provider; 2) Enable the conducting conventional business in a substantially more effective and efficient way; 3) Reduce the cost of the product/service significantly; and 4) Reduce the impact to the environment at an affordable cost. In fact, we realize different technologies could offer different types of transformation with different level of impact. Therefore, this section is to highlight the condition and reasons how a technology could transform the industry. We also assigned a High/Medium/Low to gauge the impact. For instance, *hydrogen-based applications* are still being developed currently. When hydrogen is produced by electrolysis, the low energy conversion efficiency is an obstacle. When hydrogen is used in stationary fuel cells for electricity generation, the high cost of fuel cells also remains a challenge. As such, the hydrogen technology is considered as Low at the moment [7].

3.3.3 ECONOMICS

This is the economic overview/assessment of a technology. We examine the cost and benefit of how the new technology can either replace or add to the existing market. It includes the cost trends and some projection if available. It is understood that all technologies we examine are not in a wide-spread deployment phase hence the detailed economic analysis are not necessary complete. However, we would try to use the most reliable and credible authorities such as International Energy Association (IEA), government reports and forecasts to estimate the likely trends and future paths. For example, *New Building Commissioning* is an approach which can make a new building to function efficiently and hence that could reduce a lot of wasteful consumption/emission. It was shown that in 2004, Lawrence Berkeley National Laboratory in the US released an analysis based on 20 years of data, that median commissioning costs for new buildings was US $1 per square foot (0.6 percent of total construction costs), yielding a median payback period of 4.8 years if the technology is used [8].

3.3.4 ADVANTAGES AND DISADVANTAGES

We use simple bullet form to highlight the pros and cons of implementing such a technology/ innovation. For example, *synchronous condensers* can provide dynamic voltage support to uphold the system voltage and help improve reliability and vulnerability. However, its advantages and disadvantages could include:

- Able to cushion the effect of abrupt changes in grid system conditions
- Does not produce harmonic current that disturbs system performance
- Long lifespan, given proper maintenance
- Restrictions on deployment site locations
- Bulky, noisy and heavy hardware
- Sensitive to moisture, chemical contamination and dirt

3.3.5 ENABLERS AND BARRIERS

Wide-spread adaptation of a technology in any industry or the rejection of it does not merely

depend on cost alone. The enablers and barriers here provide some other technical and non-technical considerations which can make or break the taking-off of a technology. Quite often, the regulatory environment and market competition will play a key role in this. For example, for *geothermal generation,* these are the enables and barriers:

- Policies promoting use of renewable energy
- Government grants of exploration licenses and development rights
- Advancement in rock drilling technology
- Permitting, legal, and environmental issues of enhanced geothermal systems (EGS) development
- High capital cost for EGS relative to natural gas plant
- Mismatch between geothermal sources and load centres

3.3.6 ALTERNATIVE/COMPETING TECHNOLOGIES

For considering a technology, we would also look at the alternatives and competing products. This is a different dimension from the cost as some technologies may offer multiple values to the customers/service providers and subsequently beating out the lower cost option.

For example, for *flue gas desulphurization,* the alternatives include burning low-sulfur coal and using multi-pollutant controls in power plants.

3.3.7 HOW IT WORKS

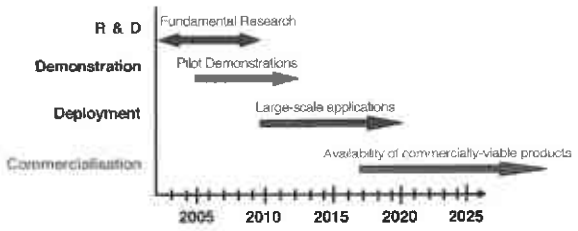
We consider it very important to establish an accurate and comprehensive understanding of the technology. Due to the rapidly changing technological development and proprietary issues, the description of each technology will give a snapshot of the key components or support needed to make the technology function and integrate with the rest. Here we provide an example description for *heat pump water heater* (HPWH):

- HPWH transfer heat from the surroundings into the water tank. HPWH use electrically driven compressors to drive a vapour compression cycle using conventional refrigerant as the working fluid. Newer HPWH use CO_2 as the working fluid to achieve higher water temperatures. In indoor applications HPWH have a cooling effect that may be beneficial in warm climates.

3.3.8 TECHNOLOGY STATUS

We use a graphical depiction similar to Figure 1 to summarize the current stage of the technology. Typically, there are four stages: 1) R&D phase - meaning the technology is in early stage of development which focus on basic and application research; 2) Demonstration phase - the technology is deployed for first commercial-scale applications; 3) Deployment phase - the technology is being wide-spread deployed and/or in large-scale application; and 4) Commercialization phase - the technology is available on the market but may be still expensive in comparison to conventional or alternative technologies.

Figure 1 Example Technology Status Timeline



3.3.9 R&D OBJECTIVES

We propose or highlight some of the R&D needs and trends within the industry as well as in the academics. It also serves to illustrate where some of the weak links are in the new technology. For instance, the followings are the R&D objective for *smart appliances:*

- Incorporate price signal reception capabilities into the system design
- Develop inexpensive technological solutions for retrofitting existing homes
- Integrate with other aspects of home automation systems (e.g., communications, entertainment, and security)

3.3.10 KEY DEVELOPMENTS/ DEMONSTRATIONS

In this section, we collect and summarize the key demonstration projects and/or product developments for the specific technology. As these demos and projects/programs have a wide variety, it may be best to illustrate with an example like in the *solid-state lighting* technology:

- In August 2008, the Summer Olympics in Beijing adopted LED lighting technology with the budget of about RMB¥ 0.5 billion and the estimated electricity savings of some 750MWh per year. The "Bird's Nest" featured LED-lit signage and energy efficient lighting from various vendors. The "Water Cube" featured approximately 440,000 AAA XLamp LEDs embedded in the facade and structure of the building. BBB provided CFL, LED and solar-powered LED streetlamps for use on Olympic Buildings and around venues [10].

3.3.11 KEY DEVELOPERS/RESEARCH ORGANISATIONS

This section includes the information of prominent/major entities who are either the technology provider, utility off-taker and/or developer; the location and commission date, capacity and application type.

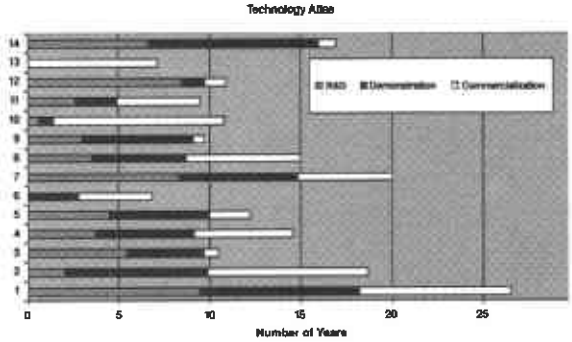
3.3.12 POTENTIAL STRATEGIC VALUE TO THE COMPANY

Finally, but not least, we conclude whether each of the technologies will be strategically important to the business, mainly from the perspectives of the maturity of the technology and its applicability.

3.4 TECHNOLOGY ATLAS

Given the above mentioned scope and criteria, we collect, review and analyze a broad range of technologies covering generation, delivery, emission control, operation and maintenance, environmental, storage, power electronics, energy efficiency, end-use, transportation and others. For each of the technology, we classify them into Research & Development, Demonstration or Commercialization stage and then project the time duration for the development of each of these stages for the specified technology. At the end, a technology atlas similar to Figure 2 is obtained.

Figure 2 Technology Atlas of Different Technologies



From the Atlas, we can have a global view on which technology is closer in range to become commercially available and likely be competitive. In addition, we may also observe the likely relationships among the technologies (whether they are complementary or competitive to each other).

3.5 TECHNOLOGY ROADMAP

Based on the analysis conducted for the Technology Atlas, we examined the technologies and innovations that can significantly reduce carbon emissions and integrated these into the low-carbon technology roadmap. The low-carbon technology roadmap includes technology categories such as renewable energy and green energy and services.

The technology roadmap we have developed so far is high level and in broad terms. More efforts and works are necessary for detailed maps of those identified technology groups. Moreover, the technology roadmap itself and the preparation process have laid down a platform to facilitate on-going communication, engagement and consideration of technological matters at corporate levels.

In general, when developing a technology roadmap for individual organisations, each entity will need to consider its own relevant

factors for evaluating the applicability of different technologies. Each organisation will also need to determine the suitable approach for managing technologies at different development stages. As technology development is rapid with many uncertainties, the roadmap will have to be updated and modified periodicially based on the latest regulatory, market and technology environment.

4. CLOSING REMARKS

A technology roadmap is a useful tool for addressing large-scale challenges, such as climate change, that do not have a silver bullet solution. The approach presented in this paper is one example of the technology roadmap development process. Each organization will need to determine the technology types that are most applicable to it, such as the maturity of technology and the associated risks. Lastly, developing a technology roadmap is not a one-time process but rather a process that should be revisited periodically.

5. ACKNOWLEDGEMENT

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Paper No. 2

GREEN TECHNOLOGY APPLICATIONS TO COMBAT CLIMATE CHANGE - AN ELECTRICAL ENGINEERING PERSPECTIVE

Speaker : Ir Dr F.C. Chan
General Manager
CLP Engineering Ltd.

GREEN TECHNOLOGY APPLICATIONS TO COMBAT CLIMATE CHANGE - AN ELECTRICAL ENGINEERING PERSPECTIVE

Ir Dr F.C. Chan
General Manager
CLP Engineering Ltd.

Paper No. 2

ABSTRACT

This paper examines various green technologies that we can adopt to combat with the climate change. By enhancing energy efficiency and 'do more with less' a better utilization of energy can be achieved. In this paper, the focus on green technology is mainly related to the equipment in the electrical engineering areas for end-user applications. These technologies include lighting, heat pumps, control system, induction cooking, motoring and small scale renewable. Their anticipated energy saving potential is also reviewed. To have a systematic approach, energy and carbon audits is the first step to identify improvement areas. Once these improvement areas can be identified, implementation considerations can then be followed. Finally, the effectiveness of each of these technologies can be further reviewed.

1. INTRODUCTION

Green technology is the applied science and engineering to conserve the natural environment and resources to enable a sustainable future. In applying green technology as a solution, it should be economically viable and environmentally sound. For the preservation of the environment, there are two approaches:

(a) in the energy saving journey, there are two ways: 'don't waste when not in use' and 'do more with less'. In both of these cases, energy efficiency and energy utilization effectiveness can be achieved.

(b) in the renewable energy aspect, 'free energy' could be obtained. However, this normally involves capital investment which may not have a short payback period.

Before considering any green technologies, it is essential to carry out energy and carbon audits so that we know where we are. By establishing a baseline, we can then identify improvement opportunities and hence the required applications for better energy utilization.

2. ENERGY AND CARBON AUDITS

2.1 ENERGY AUDIT

Energy audit is an examination of an energy consuming equipment/system to ensure that energy is being used efficiently. It looks for Energy Management Opportunities (EMOs) for improvement. There are two types of energy audit: Walkthrough Energy Audit and Detailed Energy Audit, varying by the breath and depth of the examination[1]. Walkthrough Energy Audit is like a general health check to review the general conditions of the energy equipment/system, operation and maintenance practices, identify and prioritise these EMO and make coarse estimate of the benefit and cost of its implementation. Detailed Energy Audit is carried out on specific equipment or system focusing on its energy efficiency performance. The more complex and high-benefit-high-cost EMOs identified from walkthrough energy audit can be further examined and assessed in the detailed energy audit. This detailed energy audit is to understand the uniqueness and characteristics of the building and its system usages. Detailed analysis of historical system operating data and comprehensive field measurement on related energy efficiency performance are required. As the term 'Energy Audit' has been vaguely

used, a more specific term 'Energy Efficiency Assessment' is proposed to give a more specific focus.

2.2 CARBON AUDIT

Carbon audit is a means of measuring and recording the organization's emissions of greenhouse gases (GHG) - notably the carbon dioxide CO_2 (or the greenhouse gas's CO_2 equivalents). It is essential that if we want to reduce CO_2, we must establish a baseline to measure and hence control. The procedure to carry out carbon audit can follow the guidelines issued by the EMSD of the HKSAR Government to account for and report on GHG Emission and Removals for Buildings (Commercial, Residential or Institutional Purpose) [2].

Carbon audit starts by determining the physical boundaries of the concerned building where the organization is situated. Following that, the operational boundaries are also determined based on the organization's operational activities. These boundaries defined the area where relevant data can be collected, for example, lighting, air-conditioning, machinery, office equipment, industrial processes, fuel used, waster disposal etc. Under the guidelines, GHG emissions are categorized under three different scopes.

Scope 1 is to deal with the direct emission from sources and the removals by sinks. These include: Combustion of fuels in stationary sources, Combustion of fuels in mobile sources, Fugitive emissions and Removals of greenhouse gas. Scope 2 covers indirect emissions when using energy sources from electricity or gas. Scope 3 covers indirect emissions for those activities the organization required to conduct their business. Scope 3 activities may be implicit in nature and some quantification tables are required in order to calculate its emission equivalent. Other common activities under Scope 3 include: Transportation of purchased goods and materials, Employee travels, and Outsourcing.

After collecting all relevant data based on the defined scope 1 to 3 elements, the GHG emission quantity can be calculated with relevant to some published conversion factors. As data collection process might be carried out by a number of parties, it is essential to validate such data and hence their meanings so derived. After calculating the emission quantity, the qualified engineer is to prepare the report which also includes an appropriate carbon reduction plan to improve and reduce the organization existing carbon emission. It is a great challenge for conducting the first carbon audit and setting out the associated reduction plan.

After carrying out energy and carbon audits, a list of potential improvement areas can be identified. Based on the audit results, we can prioritize the items for enhancement. These improvement areas normally include the following system and equipment: lighting, mechanical ventilation and air conditioning, lifts and escalators, water and space heating, cooking, control and energy management systems, building design and finally, renewable energy installation.

3. GREEN TECHNOLOGY APPLICATIONS

Green technology is the application of the environmental science to conserve the natural environment and resources, and to curb the negative impacts of human involvement. In 2008 Chief Executive Policy Address, Clause 95 stated that "We will make early preparations to meet the challenge of climate change. In Particular, we will enhance energy efficiency, use clean fuels, rely less on fossil fuel and promote a low carbon economy - an economy based on low energy consumption and low pollution." It is therefore essential that we need to look for product and technology with better efficiency and lower carbon emission. The following is a brief review of various green technologies focusing on the technology trend and energy saving potential.

3.1 LIGHTING

Lighting contributes quite a major portion of

energy usage and is one of the areas where easy energy reduction can be achieved. With the advancement of LED technology in recent years, the use of LED lamp becomes more widespread and popular due to its long service life (50,000 hours), versatile colour changing ability and low power consumption (recently up to 100 to 120 lumen per Watt). LED has no filament or breakable glass bulb with very little heat generated. Owing to the very core technology of the semiconductor chip is still under 3 or 4 global companies' control, the price of LED is still high at the moment. Nevertheless, with increasing popularity of general lighting purpose application, more players will enter into the manufacturing market and eventually drive down the LED price.

Lantern replacement by higher light output ratio lighting fittings can be a straight forward approach, particularly where incandescent lamps replacement by high efficient lamp sources in some countries are mandatory. With the development LED technology which is the future of lighting, complete replacement of conventional lighting is not far away. Of course, re-design the lighting provision based on the LED characteristics may be required. Care must be taken in the LED provision because of its colour changing capabilities as additional lighting might be provided to demonstrate the vivid of a metropolitan city.

Yet, if replacement and maintenance cost is included and disturbance to users is considered, it is not difficult to get a payback period of less than 2 years for some difficult access areas like high ceiling. Besides, lighting control technology has been growing rigorously these few years with digital and addressable control, wireless communication and built-in occupancy sensor and controls. The role of lighting control is getting more and more important. The use of photo sensors and programmable logic controllers can further enhance the energy saving performance of lighting system.

The potential energy savings under this category include:

- Compact Fluorescent Lamps to replace incandescent lamps (save ~80%)
- Energy efficient fluorescent tubes (electronic ballasts, T5 tubes) to replace electromagnetic ballasts & T8 tubes (~30%)
- LED exit signs to replace conventional exit signs that use fluorescent tubes (~80%)
- Coated reflector - achieving comparable lighting level using specially coated reflector but with less lamps (~30%, depending on the number of lamps removed.)

Paper No. 2

3.2 MECHANICAL VENTILATION & AIR CONDITIONING (MVAC)

Oil-free chillers with magnetic drive compressor which could eliminate oil contamination and minimize friction could improve the Coefficient of Performance (COP) from traditional figures of 5 ~ 6 to 10 ~ 12 under a partial load condition[3]. Besides, variable speed chillers, predictive system curve control for secondary pumps could also raise the system COP significantly. Other new technology on low pressure and temperature cooling towers and thermal storage are now available in the MVAC market. Besides, chiller controls are now mature and can effectively communicate with the Building Management System to enable suitable amount of cooling capacity is being generated and flown to the required with minimum energy loss.

Energy evaluation by different energy models also shows that the central seawater scheme (seawater cooled) and cooling tower scheme (fresh water cooled) are more energy efficient than the conventional air-cooled air-conditioning scheme. Of course, such increase in the energy efficiency depends on the building type, air-conditioning plant configuration and piping layout. Water cooled chillers can provide better efficiency than the air-cooled ones. Fresh water cooling towers can provide a more effective solution as using copper tubes in the condenser can achieve a higher efficiency. The use of variable speed

drives in fans and pumps also enhance the system efficiency.

The potential savings under this category are:

- Water-cooled chillers to replace air-cooled chillers (save ~30%)
- Automatic tube cleaning system that keep heat exchange surface in chiller efficient heat transfer (10~15%)
- Variable speed fans and pumps (e.g. Variable speed drive (VSD) for secondary chilled water pumps, VSD for regulating supply & exhaust air fans through detecting CO_2 or CO concentration) (10~30%)
- Heat wheel to recapture energy from cooled exhaust air stream to supply air stream (Recover ~40% energy)
- Proper air-balancing (ratio between exhaust & make-up air) in kitchen to reduce cooled air escape through kitchen exhaust (case varies, depending on level of shortfall in makeup air)

3.3 LIFTS AND ESCALATORS

The advancement in energy efficiency for lifts and escalators is largely attributable to the improvements in electric motor technology, power electronics and intelligent control system. The most commonly used induction motors are now coupled with variable-voltage-variable-frequency (VVVF) drives, allowing the motors to operate at optimal efficiency at different load and speed. Some newer designs feature permanent magnet motors and regeneration devices to reduce power transmission losses and re-feed braking energy into the electrical distribution network rather than dissipated as heat.

Some forms of intelligent lift management system would pool and analyze service requests, then coordinate the lift movements so that the requests could be met responsively while minimizing energy consumption[4]. The application of double-deck lifts is one example to optimize traffic flow. Other intelligent control system commonly found in escalator applies proximity detectors at the entrance and exit points. It runs the unit only when it "sees" there are passengers to be served.

The potential savings under this category are:

- Variable voltage variable frequency drive for regulating escalator's motor torque and speed at light load (save ~10%)
- Intelligent detection system for escalator (case varies, depending on utilization pattern)

3.4 WATER AND SPACE HEATING

Heat pump technology has a very long history of more than 100 years. In fact, the heat pump cycle is exactly the same as the refrigeration cycle except that the useful heat energy lies on the condenser side. With the adoption of better refrigerants, high efficiency heat pumps (COP around 8) and high temperature heat pumps (output water temperature up to 90°C)[5] are being developed for various applications.

Many commercial and industrial processes demand hot water. Different kinds of energy efficient water heating system exist. Apart from the more common air-to-water heat pumps and water-to-water heat pumps, it is not unusual to find many newer designs are bundled with solar water heaters[6] or designed to extract heat from free energy sources like waste heat of industrial processes or condensing water of chillers. For the latter case, it may even improve the chiller COP because of the lowering of condensing water temperature after heat extraction.

The potential savings under this category are:

- Heat pump water heaters to replace direct heating electric or gas-fired boilers (save ~70%)
- Fuel-fired boiler air-fuel optimization controller to ensure complete combustion and minimizing heat loss caused by over supply of air (~5%)
- Heat recovery device (optimizer) at flue gas exhaust of fuel-fired boiler for process water / process air pre-heating (~5%)

3.5 INDUCTION COOKING

Electric induction heating technology is a mature technology that has been around for decades. But it was not until its broad appearance in the domestic and commercial cooking applications that its supreme energy efficiency (>3 times) than fuel-fired technology is being publicly recognized.

Induction cooking equipment was first seen with unit rating seldom exceeded 5kW and all were having flat ceramic glass cook-top. With the advancement in material, power electronics and manufacturing technologies, much higher power rating (>35kW), stronger and curved cook-top equipment appeared. The latter is a particularly important development as using curved wok is key to many traditional Chinese cooking methods. Its presence removes a barrier of switching electric induction cooking amongst Chinese chefs and thus, has led to a significant amount of energy saving in the food catering sector.

In terms of energy saving, electric induction cooking is more efficient than the gas-fired cooking. Electric induction cook-tops, woks and stoves to replace equivalent gas-fired equipment can save energy of some 60 to 80%. In addition, a healthier, less hot and quieter kitchen environment can be provided.

3.6 BUILDING ENERGY MANAGEMENT

Being a tool to achieve building energy saving, the success of a Building Energy Management System (BEMS) would rest on the availability, adequacy and accuracy of the building operating data and the intelligence of the BEMS processing core.

On the data acquisition side, wireless technologies have made it easier and more cost-effective to establish two-way communication between the BEMS core and the services facilities. Wireless BEMS are actually built on-top of well-established wireless computer networking and telecommunication protocols. These networks have the intelligence to dynamically alter their logical topology to assure reliable data communications.

At the processing core, some advanced BEMS will have self-learning and predictive capabilities. It will analyze historical facility operating data, predict changes in operating conditions, formulate the optimal responses under various scenarios, and then issue control commands to end facilities to meet various control objectives such as minimizing overall energy consumption over a period of time or limiting the peak electricity demand at any shorter interval.

A simple form of BEMS may have only distributed hardware like timer switches, occupancy sensors, photo sensors that keep air-conditioning or lighting active only when needed; and with hardware & software for monitoring and controlling of only the major equipment. This simple BEMS is already ready to deliver energy saving but the potential would vary from case to case.

In the building design aspect, application of solar film on windows or double glaze windows to shield against incident heat from incident sunlight but allow light to pass through can save energy on air-conditioning. It is estimated that some 70% of the heat can be blocked. Green roof and green wall is another approach where culturing plants at roof top to reduce heat transmitted from roof[7]. The effectiveness depends on building locality, geometry and orientation

3.7 RENEWABLE ENERGY

Renewable energy is normally sustainable and energy efficient. Its viability depends on the availability of the resources. In the case of Hong Kong, solar and wind power are the two most popular renewable energy applications.

For solar energy, photovoltaic (PV) panels can be installed on roof to transform solar energy into electrical energy. The energy can be grid-connected for other application usage. In distributed renewable energy applications for buildings, solar thermal technology is customarily used for space and water heating whereas solar PV for electricity generation.

Instead of relying on solely solar energy for water heating, hybrid system using heat pumps and solar water heaters would be more appropriate for typical buildings in HK. Like serviced-apartments and hotels, where roof space is limited but hot water demand is high, running a solar thermal system as an assisting unit to the main heat pump-based system could be one of the most practical approach of applying renewable energy in HK.

For the PV technology, the power density and its conversion efficiency remain limited and may take some years of development before it can substitute purchased electricity to any appreciable extent. Nonetheless, progresses in crystalline silicon cell and wafer production technologies have boosted the technical and economical viability of Building Integrated PV (BIPV) system.

Small scale wind turbines are also suitable for building roof-type applications. Wind turbines turns wind energy into electrical energy and again connected back to the system for other electrical appliances. Normally, the power output is low and is suitable for light load application such as lighting. A combination of wind turbine and solar panels are common for some outdoor lighting poles applications.

3.8 ELECTRIC VEHICLES

In a modern city, high rise building equipped with high energy efficiency building and transportation is essential for sustainable development. Although the acceptance of full battery powered electric vehicles (BEV) is limited by the available battery energy density, the development of the Hybrid Electric Vehicle (HEV) taking the merits of the conventional propulsion system with an electric propulsion system are essential. It allows a longer driving range and offers better fuel economy, e.g. energy can be saved by regeneration during braking and down slope driving. In battery development, new energy storages using Ni-MH, Li-ion batteries and ultra-capacitor are being actively developed. Performance can be further enhanced with the combination of Li-ion and ultra-capacitor with the ultra-capacitor delivering an extra short time power for acceleration[8]. The deployment of electric vehicles has to be supported by good charging infrastructure and services. Charging can be carried out by the following types: domestic charging, commuter charging and public charging. Electric vehicles are definitely an area where low carbon economy will base upon.

4. ENERGY SAVING STRATEGY-BASE LOAD APPROACH

For new buildings, there will be less technical constraints on the choice of energy equipment and therefore energy efficiency could be more easily achieved. But for old buildings, adopting new technology could be more costly as there would be more system integration and implementation issues to be resolved.

If both financially and physical site conditions allows for a complete system replacement, it is always recommended to capture every energy saving opportunities. However, if a full replacement cannot be carried out, one could go for partial implementation to achieve the best saving out of the available capital. This approach is also known as "base load" approach.

From energy audit, one should try to identify the load pattern for heating, cooling and even lighting systems. From the load pattern, "base load" can be identified: for example, some chiller plants still need to operate during night time; some water heating equipment still need to inject energy to maintain the water temperature; some emergency lighting are needed to operate on a 24-hour basis etc. These "must use" loadings can be focused and hence tailor-made energy saving solutions can be developed for these equipments. As this 'base load' is constant and predictable, it is therefore possible to apply small scales energy efficient techniques for the equipment to operate at the most efficient settings for saving maximization. By adopting this approach, although the capital investment may be small, the achieved saving could be significant.

One other important consideration in

carrying out energy efficiency project is its expandability or extendibility. The need for future expansion must be taken into account during the design phase. After the first small scale applications of the energy saving equipment, it is important to allow for possible future extension. For example, one can choose some control system with open protocol for easy modifications. Additional new control points must be capable of being added later with simple programming works to expand the control network. Wireless technologies such as WiFi, Zigbee could be good solutions to reduce the cabling costs during network extension or retrofit to existing equipment where cabling cannot be effectively carried out.

The HKSAR Government has launched the 'Energy Conservation Funding' scheme this April to promote energy saving. Building owners can make good use of this Fund to facilitate their energy saving projects.

5. CONCLUSION

With the help of the Government and the different learning societies (like HKIE) in promoting energy and carbon audits, the general public now knows more and more where their energy and money goes. People start to realize that there are many means to help to reduce energy and hence their operating expenses. Many companies are also aware of the carbon emission and develop plans to reduce their carbon emission. The green technologies that described in this paper can help to reduce carbon emission and it is not far from our dream to significantly reduce carbon emission. The 'base load' approach can address some of the issue with insufficient investment to replace old equipment. On the other hand, these green technologies can help to trigger behaviour change and form the green culture to sustain our future.

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Paper No. 3

STATE-OF-THE-ART BATTERIES FOR ELECTRIC VEHICLE AND INDUSTRIAL APPLICATIONS

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EVB Technology (HK) Limited

STATE-OF-THE-ART BATTERIES FOR ELECTRIC VEHICLE AND INDUSTRIAL APPLICATIONS

Mr Kevin K.M. Yiu
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ABSTRACT

Electric vehicles have been around since the introduction of automobile. For many years, lead-acid batteries had been the choice due to availability, technology and cost. Since 1990 the industry began seeking advanced battery solutions to satisfy the market needs for a compact, reliable, powerful and light-weight alternative to traditional flooded lead-acid batteries. During this time, Gold Peak began investigating various battery technologies, and decided to develop heavy-duty prismatic batteries for electric vehicle and industrial applications. In 1993, with a NiMH licensing agreement from Ovonic/ECD, we began manufacturing our first Nickel Metal Hydride (NiMH) batteries for electric vehicles.

Gold Peak (GP Batteries) manufactures a wide range of battery cells and battery systems for many consumer and industrial applications. Our product range includes small consumer type batteries in various chemistries and sizes; from small primary silver-oxide button cells to primary lithium, alkaline and carbon zinc cylindrical and 9V cells. Our rechargeable battery cells include button, cylindrical, polymer and prismatic formats in the following chemistries: NiMH, Lithium Cobalt, Lithium Manganese, and Lithium Iron Phosphate. We have significant experience in manufacturing many popular chemistries, and EVB Technology (a member of the Gold Peak Group) chose to design and manufacture prismatic format NiMH and Lithium Iron Phosphate chemistries for the electric vehicle industry. Based on our extensive experience and data in manufacturing large quantities of smaller cells, we are here to present our findings and reasons for selecting Ni-MH and Lithium Iron Phosphate as our preferred choice for electric vehicle and industrial applications, and a comparison of different chemistries.

Paper No. 3

1. NICKEL METAL HYDRIDE BATTERIES (NiMH)

It is the most popular choice of chemistry for almost every mass-produced vehicle from major automobile manufacturers. Although the NiMH license required for manufacturing limits the technology rights to an exclusive group of reputable battery manufacturers, the performance, reliability, robustness, safety and power of this chemistry make it the most common chemistry used in hybrid and electric vehicles today.

The advantages of NiMH for electric vehicle and industrial applications include:

1. Long cycle life and calendar life, long storage life, wide range of operating temperatures.
2. Ability to have high regeneration charge acceptance.
3. Proven safety and reliability record on over 2 million HEVs worldwide *
4. Low cost, simple monitoring and cell balancing.
5. Recyclable and life of car performance.
6. Robust enough for more than 10 years service life.

Please reference the following performance curves for our Ni-MH batteries used in electric vehicle and industrial applications:

Figure 1 Constant Current Charging Characteristic of 10/MQ90EVH at Positive and Negative Temperature Cut-off by -dV of (0.1/Module)

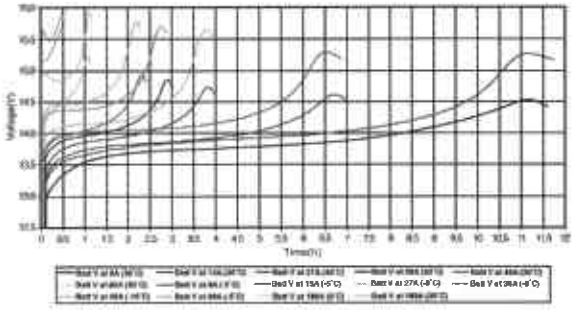

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Figure 2 Constant Current Discharge Characteristic of 10/MQ90EVH at Positive and Negative Temperature Cut-off by Vdco of (10V/Module)

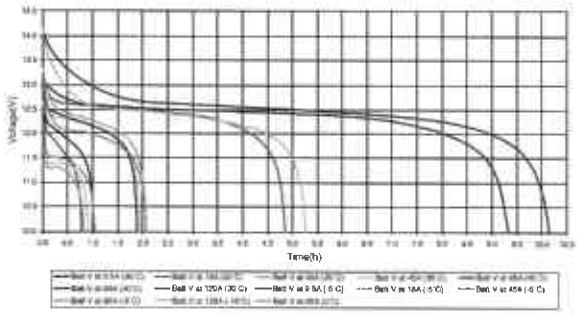


Figure 3 Storage Characteristics

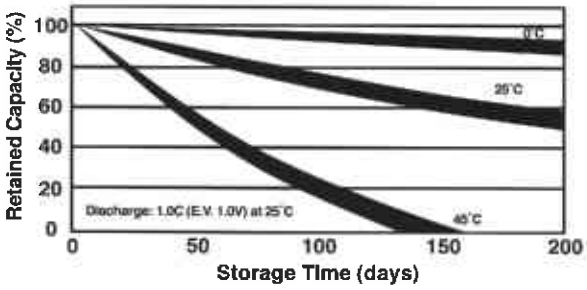
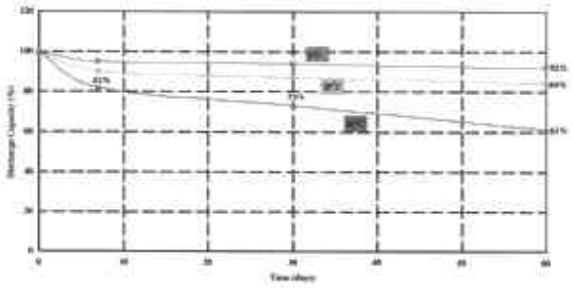


Figure 4 Charge Retention Test



2. LITHIUM IRON PHOSPHATE ($LIFEPO_4$)

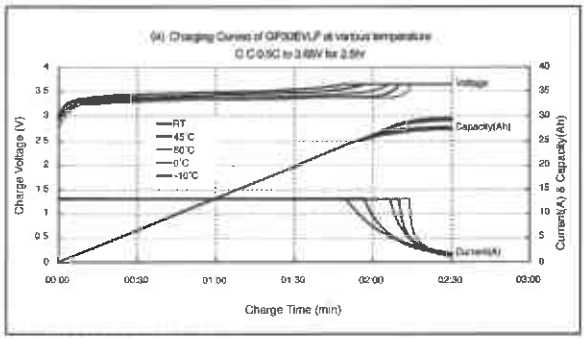
Lithium Iron Phosphate is one of the most sensible choices among Lithium based chemistries. As the pursuit of higher energy density batteries for the electric vehicle market continued, EVB Technology responded by introducing our prismatic Lithium Ion type Lithium Iron Phosphate batteries in 2008. It is very likely that Lithium Iron Phosphate will be the choice of tomorrow and the results of our in-house testing indicate excellent performance characteristics. However, Lithium Iron Phosphate still lacks the track record in real applications necessary to prove its road worthiness.

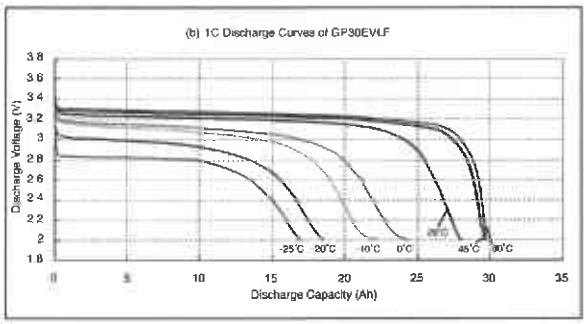
The advantages of Lithium Iron Phosphate for electric vehicle and industrial applications include:

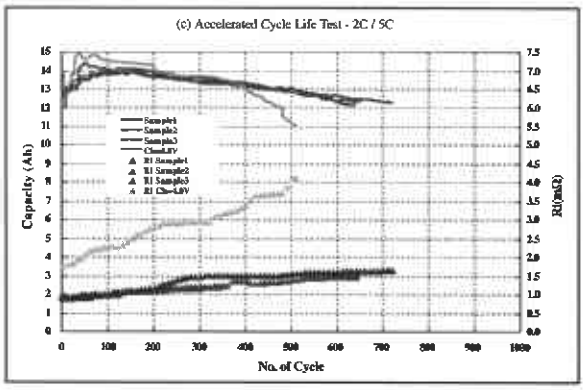
1. High cycle life and calendar life (accelerated test)
2. High C-rate charge and discharge capability
3. Charge and discharge abuse tolerance (compared to other Lithium based chemistries)
4. Wide operating temperature range.
5. Stable raw material cost

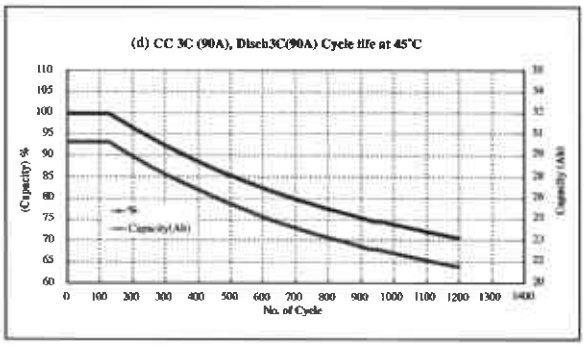
Please see the following performance curves of our $LiFePO_4$ Batteries:

Figure 5 Performance Curves of $LiFePO_4$ Batteries









3. CONCLUSION

In Summary, EVB Technology's position on the practical choice of batteries for electric vehicle and industrial applications:

NiMH is the most practical choice for batteries in electric vehicle and industrial applications today, and Lithium Iron Phosphate will be our focus for future development and applications.

Paper No. 4

ENHANCED SYSTEM RELIABILITY – PERSPECTIVE FROM DISTRIBUTION CABLE/MATERIALS

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ENHANCED SYSTEM RELIABILITY – PERSPECTIVE FROM DISTRIBUTION CABLE/MATERIALS

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ABSTRACT

With ever increasing demand for improving transmission and distribution system reliability and rising cost for infrastructure needed to ensure uninterrupted electricity supply to critical customers, increasing expectations are being put on performance of cable materials that can provide significantly longer life. Such materials with increasing life expectancy can provide positive returns based on life cycle cost analysis. The key variables affecting cable life are described and the 25-plus years of field performance on cables provided by tree-retardant crosslinkable polyethylene insulation materials are illustrated with actual field performance data. In addition to continuously improve the quality of cable materials to ensure their integrity in positively impacting cable life, some ideas about future development for next generation materials to meet the continuous demand from electrical utilities for lower system cost with good reliability are discussed.

1. INTRODUCTION

Electrical utility companies are striving to reduce the life cycle cost of their transmission and distribution systems in response to economic and environmental drives. The use of tree retardant crosslinked polyethylene (TR-XLPE) insulation for medium voltage (MV) and very clean insulation for high (HV) and extra-high voltage (EHV) cables has allowed utilities to achieve long service life under severe operating conditions. This has led to improved life cycle economics and minimized social and environmental issues resulting from cable replacement activities.

In this paper an overview of the current state-of-the-art material technology for MV and HV cables will be presented, then followed by discussion on the possibility of future material technology development that can either provide better performance-cost ratio or further enhance cable connectivity.

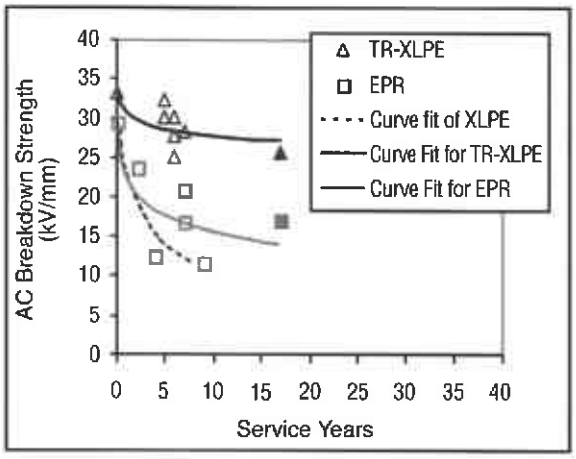
2. CURRENT STATE-OF-THE-ART TECHNOLOGY

2.1 GLOBAL EXPERIENCE WITH TR-XLPE INSULATION

In addition to significantly retard the growth of water trees, TR-XLPE was designed to maintain the high dielectric strength and low electrical loss of XLPE materials. It was introduced in 1983 and in the following 26 years, TR-XLPE has become the predominant insulation used for MV underground distribution cables in North America.

Recent studies from field aged cables have clearly demonstrated that TR-XLPE shows the highest level of dielectric strength after 17 years of field aging[1], as shown in Figure 1. Over the past 24 years, the demonstrated performance of TR-XLPE insulated cables has met the initial design expectations such that projections are being made for TR-XLPE cables to have useful life in excess of 40 years[2].

Figure 1 Dielectric Strength of Field Aged 35kV Cables



In Europe, an approach being different than that in North America is used to prolong cable life. Researchers found that blends of polyethylene resin used in XLPE with copolymers, based on alkyl acrylate copolymers, resulted in improved resistance to electrical breakdown after aging in water under electrical stress. This technology has also had excellent field service performance for MV cables.

Historically in Asia, there was little emphasis on the long term performance of MV cables such that there were no performance specifications to ensure long life cables. As the performance results of TR-XLPE insulations being used in North America and Europe have been consistently demonstrated, several Asian countries began adopting performance specifications for their cables. For example, in the Philippines, South Korea, Australia, and New Zealand, TR-XLPE cables have been used since 1990's.

In China, electric utilities are beginning to focus on improving the life and reliability of MV cables. In order to access the performance improvement with TR-XLPE insulation for the PRC utilities, a major cable compound manufacturer and Wuhan High Voltage Research Institute jointly developed a cable testing programme, using accelerated water tree test (AWTT) as stipulated in ICEA S-94-649-2004 specifications. Results from this cable aging test programme clearly demonstrated the performance superiority of TR-XLPE cables and this had led to the establishment of industrial specifications DL/T 1070-2007 (Qualification test methods and requirements for tree retardant performance of medium voltage XLPE power cables). The latter stipulates the qualification test method and performance requirements for TR-XLPE power cables, in terms of retained AC breakdown (ACBD) strength after aging. The requirements of retained ACBD are summarized in Table 1 for DL/T 1070-2007 and ICEA S-94-649-2004 specifications. Apparently, DL/T 1070-2007 specification has demanded a higher retention of ACBD than ICEA S-94-649 after 360 days of aging.

Table 1 RETAINED ACBD for TR-XLPE INSULATION

(kV/mm)	14d Cyclic	After 120d	After 180d	After 360d
DL/T 1070-2007	26.0	26.0	22.8	20.0
ICEAS-94-649-2004	26.0	26.0	22.8	15.0

In Latin America, TR-XLPE has been used in Brazil, Chile, Columbia, and Mexico. In Mexico, TR-XLPE is also specified as one of the materials of choice for HV cables up to 132kV. As typical HV cables have built-in moisture barriers, apparently TR-XLPE is being considered as an additional insurance for potential water treeing due to water ingress that could be resulted from damaged moisture barriers.

In India and the Middle East regions, several utilities have incorporated TR-XLPE into their performance specifications for MV cables. In India, TR-XLPE is also specified for 66kV HV cables.

2.2 HIGH VOLTAGE INSULATION

HV and EHV cable usage is growing around the world, especially in urban areas. With the advent of ultra high voltage transmission from east to west in China, more HV cables of 220kV and above are being used to upgrade the transmission grids.

HV and EHV cables are produced with constructions that are intended to keep them dry radially and longitudinally. Hence, electrical aging of and tree formation within the insulation are the most important properties for determining the life of cables. Two key factors in the electrical tree retardance of insulation are the insulation cleanliness and the smoothness of the insulation-conductor semi-conductive shield interface[3].

Two of the key requirements for high voltage and extra- high voltage XLPE insulation under IEC 60840 and IEC 62067 norms respectively are summarized in Table 2.

Critical to the performance of XLPE insulation operating under high electrical stresses is the cleanliness of the insulation and the need for very low dissipation factor values. Cleanliness of the insulation is ensured by precise control and monitoring of the manufacturing process and subsequent compounding, packaging and logistic operations. XLPE insulation compounds should be free of metal contamination and particles greater than 100µm.

Customer specifications are even more stringent for EHV insulation materials. To ensure that the insulation compound cleanliness is maintained from compound manufacturing centre to cable production, one of the major cable compound manufacturers has developed a multi-liner bulk carton system which helps to preserve material cleanliness. Using this system, the cable manufacturer can remove the outer cardboard packaging before the material enters the cable production area. The inner liner design ensures that the insulation material remains in a closed system from initial production through to cable extrusion, thus minimizing the possibility of external contamination.

TABLE 2 KEY REQUIREMENTS for HV/ EHV INSULATION

	High Voltage	Extra High Voltage
Key Standards	IEC 60840	IEC 62067 AEIC CS9 TEPCO
Cleanliness	100µm Clean	70µm Clean
Dissipation F. (Uo,100°C)	< 0.1%	< 0.05% customer requirements

As the operating voltage increases, the dielectric power loss also increases. Tan delta is a measure of the degree of power dissipation in a dielectric and therefore a measure of its losses. For power cables, the tan delta value of the insulation should be as low as possible to minimize the power loss. This is particularly true for HV transmission cables in which the dielectric loss component becomes a significant portion of the overall losses in the cable.

In fact the dissipation factor or tan δ is highly sensitive to polar impurities in the XLPE insulation material and minute quantities of contamination can have a drastic effect on tan delta. As shown in Table 2, IEC 60840 requires that the cable dissipation factor be less than 0.001 or 0.1%.

Paper No. 4

Figure 2 Dissipation Factor Improvement with Super Clean Compound

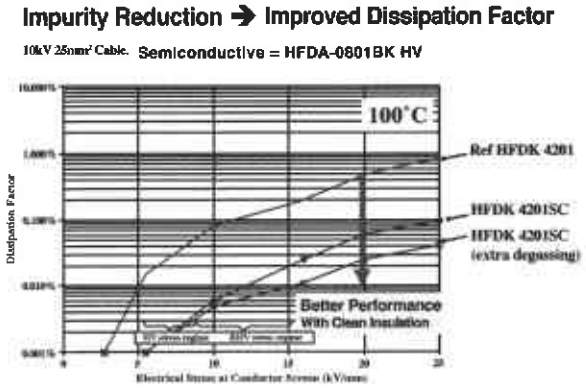


Figure 2 shows the dissipation factor measurements on model medium voltage cables using conventional and super clean insulation compounds at 100°C as a function of electrical stress level. The conventional compound is an insulation compound designed for MV cables. The super clean compound is an insulation compound designed for HV and EHV cables. The data in Figure 2 clearly illustrates the importance of insulation cleanliness on its dissipation factor value.

The presence of polar residues from peroxide decomposition can have a negative impact on tan delta values and therefore cable performance.

Illustrated in Figure 2 is the effect of an

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improved degassing regime on cable tan delta performance.

Of course insulation cleanliness and dissipation factor are not the only requirements for high performance insulation materials. Additives used to ensure long term heat ageing performance must not migrate out of the polymer pellets during transportation or storage at the customer. Some HV cable polymers incorporate a migration resistant additive package allowing long term storage even at high temperatures. The correct balance of stabilizers and peroxide curatives must also be determined to help ensure, not only long term ageing performance, but also scorch resistance and minimization of amber or gel formation during long production runs.

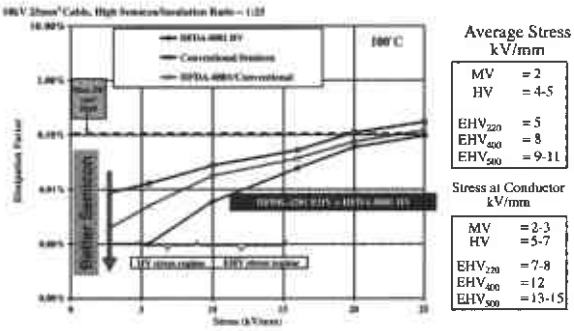
2.3 SEMI-CONDUCTOR SHIELDS

A very important development in raising cable quality and performance levels has been the improvement in the semi-conductor shield properties[3]. In MV and HV power cables an inner (conductor) and outer (insulation) semi-conductive layers are needed to smooth and equalize the strong electrical field in the cable. This semi-conductive compound is typically a carbon black filled polymer having between a 30-40% carbon black addition levels. The inner semi-conductor layer is always cross-linked and "fully bonded" to the insulation. It must also have low impurity levels and yield both a very smooth interface with the insulation layer. The smoothness at the interface between the insulation layer and semi-conductive shields is very important to the long term electrical performance of power cables. Micro-protrusions from the semi-conductive shields can result in localized electrical stresses and induce undesired treeing or electrical degradation. Typical sources of the protrusions are grit from carbon black, poor dispersion of carbon black, polymer gels, or external contamination.

For HV cables, semi-conductive materials based on acetylene carbon blacks, referred to as "supersmooth", are generally used.

Figure 3 shows the reduction in cable dissipation factor achieved by replacing conventional semi-conductive materials as both inner and outer semi-con in a model medium voltage cable.

Figure 3 Dissipation Factor Reduction when Replacing a Conventional Semi-Con by Super Smooth Semi-Con in a Medium Voltage Model Cable



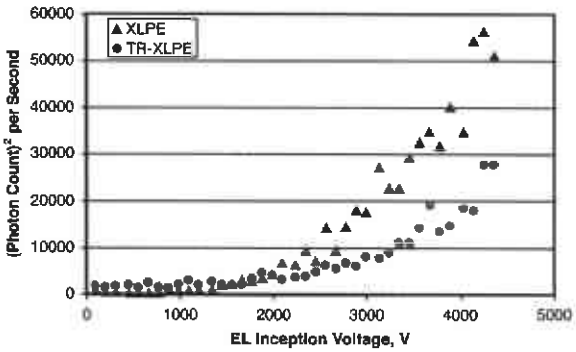
3. FUTURE TECHNOLOGY TRENDS

3.1 IMPROVE WATER TREE RESISTANCE OF HV CABLES

For HV cables, moisture barriers, like water swellable tapes and metallic sheaths, are present to prevent the ingress of moisture during cable installation and subsequent operation. Although, such moisture barriers can be damaged during cable installation and can subsequently lead to water ingress and cable failures. TR-XLPE insulation can be considered as an additional means of insurance against water treeing in HV cables.

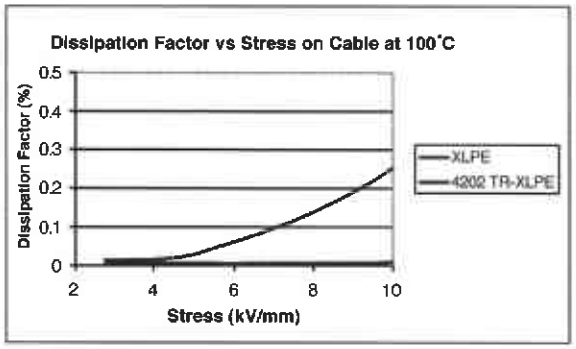
Due to higher operating stress in HV cables, the resistance of electrical treeing of an insulation material should be considered. As shown in Figure 4[4], the electroluminescence of TR-XLPE material shows comparable performance to that of XLPE as a function of inception voltage.

Figure 4 Electroluminescence of XLPE and TR-XLPE materials



Due to the chemical nature of TR-XLPE compounds, their dissipation factor is usually slightly higher than that of XLPE compounds at operating temperatures. Thus, it is imperative to understand the dissipation factor of TR-XLPE material at higher operating electrical stresses, to ensure there will not be any adverse effect at operating voltages of HV cables. A model cable made with a 24mm² aluminium conductor and 3mm insulation was tested for dissipation at different operating stresses[5]. As shown in Figure 5, the dissipation factor of TR-XLPE at 100°C increases with increasing stress. In order to meet the dissipation factor requirement of less than 0.1%, as specified in AEIC CS9-06, ICEA S-108-720-2004, and IEC 60840 specifications, TR-XLPE material can be used up to a stress level of 7kV/mm. Typical maximum stress for a 138kV cable is 7 - 8 kV/mm.

Figure 5 Dissipation Factor at 100°C for a Model Cable Comparing XLPE and TR-XLPE Materials Operating at Increasing Stress Levels



The retained ACBD strength of cables made with TR-XLPE was also evaluated at higher electrical stress during wet aging (AWTT) study by varying the insulation thickness. Model cables made with 53mm² aluminium conductor and insulation thicknesses of 2.7 and 4.4mm were tested under AWTT condition. As shown in Table 3[5], TR-XLPE demonstrates excellent dielectric strength after wet aging at high stress vs. XLPE materials.

TABLE 3 RETAINED ACBD FOR TR-XLPE INSULATION AT HIGH STRESS

Insulation Thickness (mm)	Average Electrical Stress During Aging (kV/mm)	Maximum Electrical Stress During Aging (kV/mm)	AC Breakdown Stress (kV/mm)		
			TR-XLPE		XLPE
			Unaged	Aged-120d	Aged-120d
4.4	5.6	8.1	58 56 59	38 34 33	19– 25
2.7	9.8	12.1	54 41 54	37 34 34	

Today, only a 115kV HV cable made with TR-XLPE has been in use in Mexico. Given the very limited usage of TR-XLPE materials for HV cables, more full-size cable data should be generated and evaluated before adopting the technology for wider commercial use.

3.2 INCREASE DIELECTRIC STRENGTH OF XLPE MATERIALS

The perceived benefits of increasing the dielectric strength of XLPE are mainly in reducing insulation thickness and overall cable diameter. This would allow installation of smaller diameter cables through existing constrained underground conduits.

Another way to take advantage of increased dielectric strength is to achieve lower distribution loss by operating cables at higher voltages. For example, the State Grid in China has decided to increase operating voltage from 10kV to 20kV in some local cities, to reduce investment cost[6]. Using cables that were originally designed for 10kV and operate them at 20kV will subject insulation materials to a higher electrical stress and decrease their expected life. Thus, insulation materials with better dielectric strength will be needed for such an application.

Power loss can also be reduced by using cables with a larger conductor, while retaining the same overall cable diameter. However, this will require additional capital investment, as cost of conductor accounts for the majority material cost of cables.

Nanocomposite dielectrics is being evaluated to increase the dielectric strength of XLPE, in which nano filler materials are incorporated into regular dielectrics like XLPE. In the laboratory, XLPE materials containing vinylsilane-treated silica have exhibited longer time-to-failure and higher breakdown strength [7]. Nanocomposite dielectrics made of MgO and low density polyethylene have also been shown to have superior thermal breakdown performance in HVDC application[8].

Despite some of these successes demonstrated in the laboratory, nanocomposite dielectrics are not yet available commercially. One of the key reasons is that the incorporation and dispersion of nano fillers into XLPE is not easily attained in commercial scale mixing equipment. Without proper dispersion of these nano fillers, large aggregates of these particulates can actually cause localized dielectric failures[9]. In addition, the long-term stability of these nanocomposite dielectrics under field aging has not been evaluated and needs to be understood before field application can be proliferated.

3.3 INCREASE ELECTRICAL TREE RESISTANCE OF XLPE MATERIALS

Similar to increasing the dielectric strength of XLPE, the key benefits of improving the resistance to electrical treeing of XLPE insulation are increasing the longetivity and economical value of HV and EHV cables, where the insulation materials are subjected to higher electrical stresses.

Electrical treeing processes are divided into three stages: inception, growth, and breakdown of insulation materials[10]. Given the importance of the inception phase of electrical treeing, studies have been conducted to find additives that could inhibit tree inception. As shown in Table 4[11], using ASTM D3756 double-needle test, polymers with aromatic structures on their backbone, such as polysulfone, polyethylene terephthalate, and polycarbonate, have much higher characteristic voltage (or resistance to electrical treeing) than polyethylene.

TABLE 4 DOUBLE-NEEDLE TEST CHARACTERISTIC VOLTAGE for POLYMERIC INSULATION MATERIALS[12]

Material	Characteristic Voltage (kV)
Polysulfone	27
Polyethylene terephthalate	25
Polycarbonate	19
XLPE	18
Polystyrene	12.5

This led to the idea of incorporating additives called voltage stabilizers into XLPE materials that were considered to be capable of absorbing energetic electrons and thereby preventing the occurrence of electron avalanches that lead to dielectric failure of polyethylene insulation[12]. Voltage stabilizers are additives that have: (1) at least one electron acceptor group, an unsaturated radical containing a π bond such as $-NO_2$, -CN, =CO, benzyl group, or a polycyclic aromatic; (2) an electron donor group , such as amino and lower alkyl radicals which contain a transferable proton such as $-N(CH_3)_2$, $-NH_2$, and $-CH_3$; (3) potential hydrogen bonding between the acceptor and donor group by a transferable proton, as when they are ortho on a benzene ring; (4) reversibility of the proton transfer between groups; (5) an aromatic ring structure to facilitate transfer of charge between substituent groups; (6) adequate size and complexity of the aromatic rings system to provide for electron capture and subsequent energy dissipation without producing bond rupture; (7) adequate solubility of the additive in polyethylene.

Recent study[13] using quantum mechanics has identified electron affinities and ionisation potentials as fundamental properties of voltage stabilizers to inhibit electrical tree inception. This study concluded that voltage stabilizers are molecules that have high adiabatic electron

affinity and low ionization potential. Molecules with high electron affinity will easily accept space charge electrons. And molecules with low ionization potential will form ions more easily with injected space charge.

Numerous additives have been demonstrated in the laboratory to increase the breakdown voltage of XLPE materials[14]. However, due to the limited solubility of these types of additives in polyethylene and their long-term stability under actual field aging conditions, commercial use of voltage stabilizers have not been prevalent.

3.4 SELF-HEALING CABLE MATERIALS.

Many of the damages to direct-burial cables occur during installation as a result of accidental dig-in. These kinds of damages often lead to moisture ingress that can subsequently cause cable failures. The concept of self-healing cables which discusses cables with self-healing capability to mitigate damages caused by accidental dig-in has been in the patent literatures. Many of these have discussed the use of water swellable agents either in the jacket or insulation materials[15],[16] that react with ingressed moisture to form a sealant for the damaged areas.

Another concept that has surfaced recently is the use of compressible/expandable foam that can seal the damaged cable once breach of the jacket has occured[15].

Although self-healing concept has been promoted for many years, but it has not been practiced commercially for many reasons. Among which are: (1) Compatibility of self-healing agents with cable materials, as many of which being proposed were incompatible with polyolefinic materials. (2) Effectiveness of self-healing agents, as the chemical reaction between the agents and ingressed water may not be fast enough to capture all the ingressed water. (3) Long-term effectiveness of self-healing agents. Some of the proposed methods of incorporating self-healing agents include use of micro-encapsulated agents in the insulation materials. Potency of these agents may be reduced over time as diffusion out of the encapsulant may occur.

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Paper No. 5

CONTEMPORARY DESIGN OF ELECTRICAL AND VERTICAL TRANSPORTATION SYSTEMS FOR SUPER HIGH-RISE BUILDINGS IN MAINLAND CHINA AND HONG KONG

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Ir Tony C.F. Lau, Associate Director
Ir Tony C.W. Leung, Associate
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ABSTRACT

In the recent decade, the developments of skyscrapers have been growing significantly in the metropolitan cities of Mainland China such as Tianjin, Shanghai and Shenzhen. The heights of the skyscrapers hit new record all over the world.

As a special region of Mainland China, Hong Kong is a pioneer in the development of super high-rise buildings. The recent representatives are 2IFC and ICC which are skyscrapers of more than 400m in height. Engineers of Hong Kong are fully conversant with the design of electrical and vertical transportation systems which best suit the needs of super high-rise buildings. However, the rules, regulations and practices in Mainland China and Hong Kong are mostly different though the design concepts have a lot in common. This paper outlines the design of electrical and vertical transportation systems for projects in Mainland China and Hong Kong, along with special considerations on system design from perspectives on supply voltage level selection, equipment rating determination, delivery strategy etc.

1. INTRODUCTION

With the economic boom in Mainland China, modern skyscrapers have changed the urban landscape of the metropolitan cities in the last decade. Most of the leading consulting firms in Hong Kong nowadays are taking part in the MEP design of super high-rise building projects in Mainland China which demand designs with cutting-edge technologies and compliance with rules and regulations in Mainland China. These all-embracing designs pose formidable challenge to all engineers in Hong Kong.

2. MAIN ELECTRICAL SYSTEM

2.1 ELECTRICITY SUPPLY

Technical and financial considerations are important factors in determining the supply voltage level and the configuration of substations in the development for projects in Mainland China.

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While the supply voltage levels in Hong Kong range from 380V to 11kV and the substations are designed according to the requirements of HEC/CLP, the supply voltage levels in Mainland China range from 380V to 220kV. 380V is classified as low voltage, 10kV and 35kV are classified as middle voltage and 110kV and 220kV as high voltage. The supply voltages vary from provinces to provinces. 10kV and 35kV are popular in cities of northern provinces, e.g. Shanghai and Tianjin whereas 10kV and 110kV are popular in cities of southern provinces, e.g. Shenzhen.

Besides, power bureaus in various cities/ provinces may have their own rules to determine the level of supply voltage and the requirements of substations in the development. In general, 10kV power supply substations is required for transformer load not exceeding 8MVA and 35kV/110kV power supply substations are required for transformer load not exceeding 30~40MVA. The incoming power supplies usually come from underground power cable networks which are the mainstream of electricity distribution in metropolitan cities.

2.2 POWER TRANSFORMATION

Oil-filled, SF_6 and cast resin power

transformers are commonly used in Mainland China. According to GB, oil-filled and SF_6 power transformers must be installed at either ground level or underground level whereas there is less constraint for cast resin power transformer application since cast resin power transformer is 'dry type' transformer which poses no leakage hazard and therefore, is commonly used in super high rise building. The drawbacks of cast resin transformers are, however, heavy weight and bulky size.

Unlike the practice of Hong Kong whereby the power transformers are usually provided by the power companies and the ratings of the transformers are usually 1000kVA, 1500kVA and 2000kVA, the power transformers of PRC projects are usually owned by the property developer, supplied and installed by power bureau recognized contractors and with ratings of 800kVA, 1000kVA, 1250kVA, 1600kVA, 2000kVA and 2500kVA which are readily available in commercial market of Mainland China.

When the transformers are installed at upper floors, equipment delivery is a concern. In Hong Kong, the common practice is to provide a dedicated 'Transformer' Lift to carry the heavy transformers or high voltage equipment according to CLP/HEC requirements. However, in Mainland China, lift shaft of service lift, as an alternative to transformer lift, is commonly adopted as a delivery route for transportation of transformers or heavy equipment. Therefore, the dimensions of the lift shaft of the service lift shall be large enough and installations inside the lift shaft shall be well coordinated to allow for free passage for transformer delivery.

2.3 POWER DISTRIBUTION

In super high-rise building, the length of power distribution risers will be very long which leads to voltage drop problems. Locating the power transformers as closely to the load centers as possible is the best way to contain voltage drop.

Super-high rise buildings in Hong Kong and Mainland China usually site the transformer rooms in above ground mechanical floors, which are usually 25 storeys apart in Hong Kong and 15 storeys apart in Mainland China. Besides, transformer rooms can also be located in refuge floors for projects in Mainland China. This arrangement can limit the 'supply distance' of outgoing circuits within 150~200m such that the voltage drop across busducts/cable risers can be limited to reasonable values.

According to GB codes, an intelligent Electric Leakage Protective (ELP) system is required for Grade 1 buildings i.e. high-rise non-domestic buildings. It is realized by installing earth leakage current detection device for main circuits. For super high-rise buildings, the devices are usually addressable and installed at the outgoing circuits of the main electrical distribution risers. Whenever the measured earth leakage currents exceed the preset limit, the device will be activated and issue audio-visual alarms and/or initiates signals to trip the faulty circuitries.

2.4 CLASSIFICATION OF LOADS

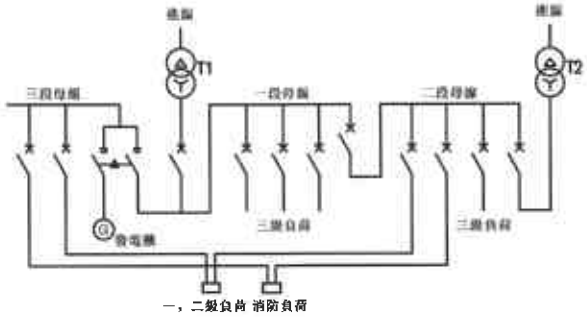
The electrical loads of Hong Kong buildings are classified as non-essential loads, non-FSI essential loads and FSI essential loads, whereas the electrical loads of PRC buildings are classified as four types, namely most-important loads, Class 1 loads, Class 2 loads and Class 3 loads according to GB codes.

- Most important loads such as central control of security system, central clock system and building data storage system etc, require high reliability than the Class 1 loads as described in item 2 and shall be supplied with dual-feed circuits in different power sources as well as ready to be fed from standalone standby alternative power generation source, e.g. diesel generator set.
- Class 1 loads such as fire pumps, fireman's lift and emergency lighting etc shall be supplied with dual-feed circuits in different power source, e.g. two different substations.
- Class 2 loads such as air conditioning system and escalator etc shall be supplied with dual-feed from different circuits/

transformers, e.g. two different transformers in same substation.

- Class 3 loads such as general lighting and small power etc shall be supplied with single-feed circuit in single power source.

Figure 1 LV Schematic Diagram



The following are options of secondary power supply which fulfill the different power source requirements as stipulated for the most important loads and the Class 1 loads: -

- One of dual-feed power supply from city power substation of Power Bureau;
- Diesel/gas generator set or cogen set.
- Solid-state power sustain unit. It can be interruptible or uninterruptible type. The former is named 'Emergency Power Supply (EPS)' e.g. self-contained rechargeable battery power pack for emergency lighting and the latter is named 'Uninterruptible Power Supply (UPS)' e.g. battery type UPS or fly-wheel type UPS for data equipment or production lines.

Figure 2 Self-contained Rechargeable Battery Power Pack

2.5 DIESEL GENSET SYSTEM

There are single-feed supply and dual-feed 'high reliability' power supply available from Power Grid in Mainland China. If the dual-feed power supply is not available in the vicinity of the development or not reliable enough to support the important loads, diesel genset will be an alternative. While Hong Kong regulations allow installation of gensets at high-level mechanical floors, GB codes however only allow installation of diesel gensets at ground floor or basement one.

For super high-rise buildings of height exceeding 300m, the length of the essential power cables will be very long when all the gensets are located at ground floor or basement one floor. Overcoming the heavy voltage drop will be the first challenge.

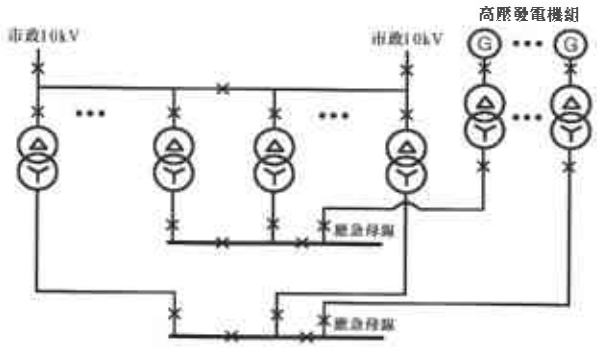
The second challenge will be the ventilation problem. Air is an essential element for proper operation of diesel gensets which need huge amount of air for engine combustion and heat removal. Sufficient louvers at the building facade and numerous air ducts are required to enable sufficient air entering and leaving the genset rooms at G/F or B1 floor.

The following strategies are usually adopted for skyscrapers in Mainland China to overcome the problems:-

i. Voltage Drop

As there is no way to re-site the gensets close to the loads, the possible solution is to apply a higher voltage to transmit essential power to loads at high levels. It can be realized by using high voltage (10kV) gensets and step down transformers. However, high voltage gensets are more expensive and will incur a higher maintenance cost. As an alternative, low voltage gensets complete with step up and step down transformers are usually adopted. The secondary of the step up transformer and the primary of the setup down transformer are usually connected in delta configuration in order to avoid the need of neutral conductors in the cable risers and to isolate the third order harmonics.

Figure 3 HV Schematic Diagram



ii. Ventilation

Since the available space on ground floor or basement is usually limited and the size and location of intake and exhaust air ducts/duct shafts are often constrained by the site conditions, remote air-cooling or remote water-cooling in lieu of set mount cooling is often adopted to reduce the intake and exhaust ducts sizes and minimize the footprint required for the gensets room.

Figure 4 Remote Water-cooling

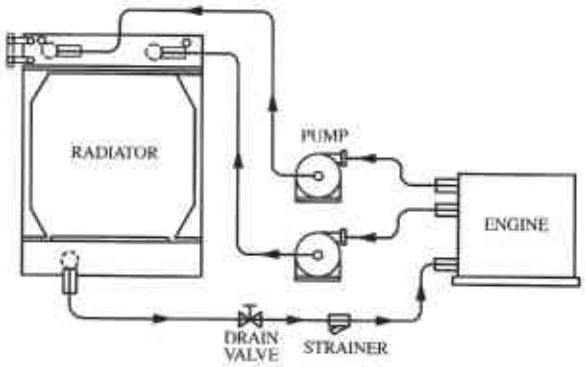
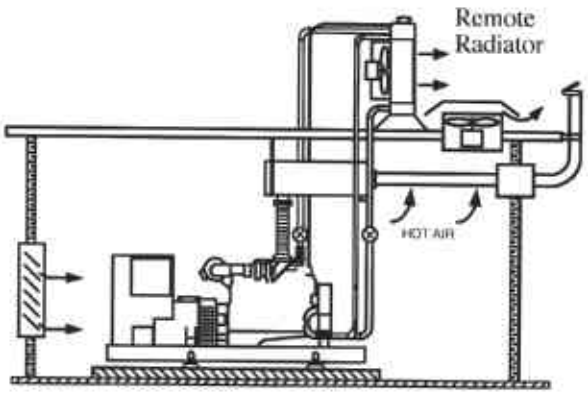


Figure 5 Remote Air-cooling



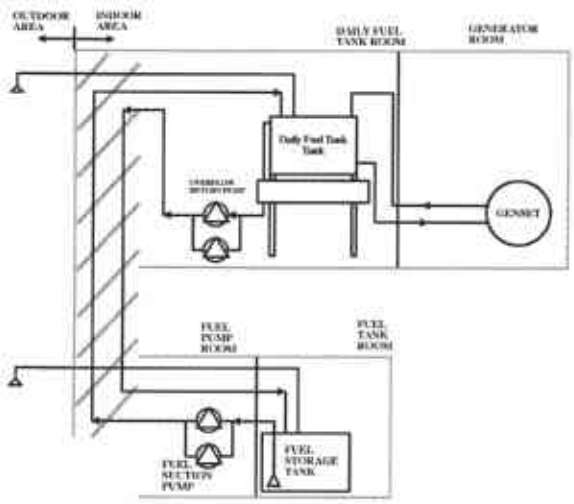
Remote water-cooling e.g. cooling tower can further minimize the plant room space since specific heat capacity of water is much higher than air. However, remote air-cooling e.g. remote radiator offers a more reliable way of ventilation and cooling as the risk of failure of pumps set and pipework for cooling tower is eliminated.

2.6 FUEL STORAGE AND FUEL RISERS

As gensets can be located on above ground mechanical floors in Hong Kong, daily tanks are also located on the mechanical floors to back up the gensets on the same mechanical floors. Bulk fuel tanks will be provided on ground floor for manual replenish of the daily tanks whenever required. Fuel pipe risers are also acceptable to the authorities when the installation can meet the stringent requirements as stipulated by FSD(DG).

In Mainland China, all the gensets can only be installed on ground floor or the first basement, no fuel pipe riser is needed and the daily tanks and the bulk fuel tanks are located on these two levels.

Figure 6 Fuel System Schematic Diagram



2.7 LIGHTNING PROTECTION

No doubt skyscrapers, whether located in Hong Kong or Mainland China, are prime targets for lightning strikes. On the roof of the skyscrapers, early streamer type lightning

arrestors are often adopted to offer lightning protection to the entire buildings. The arrestors will usually be connected to a number of dedicated re-bar down conductors embedded in structural columns evenly spread around the building perimeter and finally connected to the lightning earth pits/grids at the basement.

Along with the lightning protection by the early streamer arrestors, the curtain wall system will also be designed as an electrical continuous envelope and bonded to the re-bar to form a Faraday cage to protect the building from attack of side-flashing.

3. VERTICAL TRANSPORTATION SYSTEM

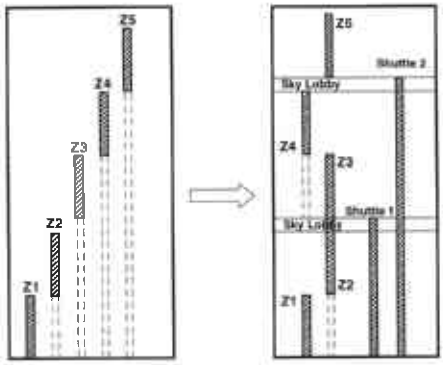
With a height of several hundred meters accommodating population of tens of thousand combined, flexible and expedient lift services play an important role in sustaining the operation of super-high rise buildings in good conditions. The following are the design approach to bring these about.

3.1 DESIGN APPROACH

SkyLobby Approach

Direct transportation between the main lift lobbies and all the local lift zones will be penalized for wasting a lot of lift shaft spaces and reducing the efficiency of the building core drastically. Sky-lobby approach, whereby low zone lifts and high zone lifts can share with each other the lift shaft spaces, is the best way to overcome such inefficiency.

Figure 7 Skylobby Approach



Double Deck Lift

When designing super high-rise buildings, double deck lift system combined with skylobby approach is often applied in order to further reduce floor space occupied by lift shafts. Also, double deck lifts are able to load/ unload passengers on two consecutive floors simultaneously thus significantly increase the handling capacity of the lift services.

Destination Control

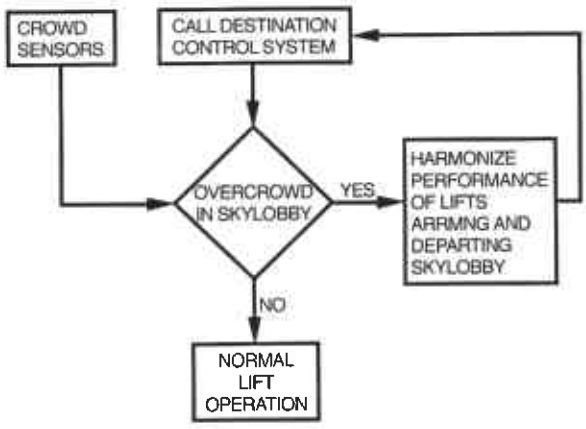
In order to achieve a smoother and more efficient way of handling passengers during peak and off-peak hours, destination control system is often adopted in super high-rise buildings.

Before getting in a lift car, passengers will register a call to the destination floors by either keying in the destination floor at the keypad or presenting a smartcard. Once a call is registered on the system, the control system will assign the most appropriate lift cars for the passengers. Combined with the function of grouping passengers destined for the same floors in the same lift cars, the handling capacity can be increased and the lifting performance will be optimized.

Crowd Control

Crowd sensor control function, which prevents passengers from crowding into lobby areas that have lifts of different capacities arriving and departing, is essential to lift installations incorporated with sky-lobby approach.

Figure 8 Crowd Sensor Control Schematic



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SIEMENS

Under the crowd sensor control, passengers arriving and leaving the sky-lobbies can be closely monitored by the call destination control system and crowd detectors in lobbies. If there are more people arriving than people leaving, the departure trips will be prioritized compared to trips which bring people to sky-lobbies. Thus the transportation of passengers to the sky-lobbies will be reduced until the lobbies are no longer overcrowded.

Conquering Building Sway

Super high-rise buildings in tropical and subtropical areas e.g. Hong Kong and Southern regions of Mainland China will be subject to strong wind effects during typhoon seasons which create a complex oscillation and torsional movement of the building i.e. building sway. The sway might be barely perceptible to occupants but the roping systems inside lift shafts could be excited to oscillate under the influence of building sway, and in extreme circumstances come to resonance with the sway resulting in severe damages to the installations inside lift shafts.

Figure 9 Sway Control Algorithm

Inputs from high wind Sensor	Control function	Functionality	Duration
Level 0 : No Building sway	No sway	Normal operation	Min 5 minutes with <300 displacement
Level 1 : Building displacement >=350mm	Low sway Max speed 5m/s (Speed adjustable)	Speed reduction about 50%, critical zones will not be served anymore	>=3 minutes
Level 2: Building displacement >=450mm	Medium sway Max speed 2.5m/s (Speed adjustable)	Further Speed reduction about 25%. Critical zones will not be served anymore	>=3 minutes
Level 3: Building displacement >=600mm	High sway	Elevator evaculates people to main floor and parks at a predefined floor (non-resonant floor)	>=3 minutes

Lifts with long roping systems are more susceptible to building sway effects. High wind operation sensors shall be equipped to safeguard the lift installations by means of sway control algorithm.

3.2 DESIGN STANDARD

Despite comprehensive codes and rules available in Mainland China and Hong Kong, those codes and rules are written for single deck conventional lifts with capacities and speeds not exceeding 1600kg and 3.5m/s.

Ultra-high speed and high capacity double-deck lift system, however, is dominant in super-high rise buildings. The current set of codes and rules fall short of design information of modern lift systems. It is important that engineers shall keep abreast of the new technologies/products launched by lift manufacturers and wisely apply them to super high-rise building projects

3.3 EVACUATION UNDER EMERGENCY

After the 11 September 2001 incident in the United State, it is of great concern to building managers of super high-rise building when time is of the essence in trying to quickly evacuate the occupants in case of bomb scare, terrorist attack or other emergency situations.

Traditionally during fire outbreak, fireman's lifts will be dedicated for firemen only and pressurized exit stairs will be the only escape routes for occupants. Although refuge floors are designed in every 15 to 25 floors for super high-rise buildings, the tenants have to congregate at refuge floors and wait passively for rescue. While this still holds true for projects in Hong Kong, projects in Mainland China have been using assigned shuttle lifts for evacuation of occupants at high level floors under emergency. When the lifts are switched to evacuation mode, the lifts will serve expressly only between the designated rescue floors and the designated exit floor and all other calls will be inoperative.

3.4 EMERGENCY RESCUE DOORS

Emergency rescue doors, which can provide a safe way to rescue passengers in event of lift failure, are compulsory for lift installations.

In accordance with COP in Hong Kong and GB in Mainland China, if the distance between any two adjacent lift landing doors exceeds 11m, a dedicated emergency rescue door is required on the lift shaft. The emergency rescue door shall be spaced with intermediate interval not exceeding 11m as well.

Besides, GB also allows cab-by-cab rescue as a supplement to the rescue doors. The cab-by-cab rescue method is suitable for multiple lift cabs in common lift shafts which enable rescue of trapped passengers from faulty lift to healthy lift via side rescue doors of size 1.8m high and 0.35m wide at least, subject to the distance between two lift cabs must be not more than 750mm.

3.5 FIREMAN'S LIFT

According to GB, fireman's lift shall be provided for the following buildings:

- Category 1 public building such as hotel, hospital or, office with height more than 50m etc.
- Residential Building with 12 or more storey
- Category 2 building such as hotel, apartment or office etc with height exceeding 32m.

For tall buildings, the minimum number of fireman's lift is determined as follows: -

- 1 unit for serving floor area not exceeding 1500m^2 GFA;
- 2 units for serving floor area exceeding 1500m^2 GFA but not exceeding 4500m^2 GFA;
- 3 units for serving floor area exceeding 4500m^2 GFA.

As compared with the Hong Kong practice, fireman's lift is required for buildings having 2 or more storeys and with height exceeding 30m and the fireman's lift has to be located at appropriate locations where the distance from the fireman's lift to any part of a floor will not be exceeding 60m.

Figure 10 Fireman's Lift Direction Sign

Regulations of Hong Kong and Mainland China both require the fireman's lift shall be fast enough to reach the topmost discharge point of the building within 60 seconds. Under special circumstances, authority of Mainland China may accept transfer of fireman's lifts at high levels.

Furthermore, in Mainland China, a dedicated sump pit must be provided for each fireman's lift. The holding capacity of sump pit shall not be less than 2m^3 as stipulated in GB while there is no such provision required in Hong Kong

3.6 BARRIER FREE ACCESS

Figure 11 Barrier Free Access

Paper No. 5

While regulations of Hong Kong and Mainland China both require assigned lifts be provided with facilities for disabled, there are differences in the provisions:-

Figure 12 Barrier Free Access Requirements Comparison Table Between Hong Kong and Mainland China

	Barrier Free Access 2008 Hong Kong	JGJ 50 – Codes for design on accessibility of urban roads and buildings
Minimum internal dimension of lift cab floor	1200mm x 1100mm	1400mm x 1100mm
Minimum clear entrance width	850mm	800mm
Fixing height of handrail	850mm-950mm	800mm-850mm
Position of control button for disabled use	900mm-1200mm	900mm-1100mm

In Mainland China, in order to facilitate disabled passenger's awareness on the running status of moving lift car, a mirror should be installed above the handrail of the internal wall which is opposite to the car door.

4. CONCLUSION

With Hong Kong reunion with Mainland China since July 1997 and the continual economic boom in Mainland China over the last decade,

engineers of Hong Kong, who are gifted with experience of projects world-wide since the 1980's, get more chances to participate in mega projects in Mainland China.

Of these mega projects, super high-rise buildings supported by highly secure and reliable power supply and state-of-the-art vertical transportation systems are the mainstream developments in Mainland China in the recent decade. Keeping abreast of the regulations and practices of engineering in Mainland China is essential to all engineers of Hong Kong to face the challenges of the 21st century for years to come.

Paper No. 6

SMART USE OF SYSTEM CONTROL STATISTICAL DATA TO ENHANCE POWER SYSTEM OPERATIONS

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SMART USE OF SYSTEM CONTROL STATISTICAL DATA TO ENHANCE POWER SYSTEM OPERATIONS

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ABSTRACT

Many utilities implement substation intelligent electronic device (IED) integration and automation projects. In most cases, the focus is on acquiring real-time operational data for supervisory control and data acquisition (SCADA), automation, protection and control applications. However, non-operational data such as fault records, waveform captures, breaker contact wearing, and transformer conditions is also invaluable data for power system operators and utility engineers. Access to the non-operational data is generally not available from the SCADA system. It usually requires access through IED maintenance ports using native IED vendor software. This paper examines the benefits of using non-operational data in the operation, maintenance and management of substation equipment. It also explores the approaches of integrating non-operational data into substation automation projects. By combining real-time operational data and more productive use of non-operational data, utilities can maximize return on investment in substation automation projects and capital assets.

1. INTRODUCTION

Driven by dynamic market environments, utility management and engineering professionals are constantly looking for improvements in power system operation. The Smart Grid initiative is driven by industry regulators, utilities and suppliers in the electric power industry in an enterprise-wide coordinated approach to modernize the aging electric power infrastructure using communication and information technologies for greater reliability and efficiency in electricity supply. In addition to effective operation of power grids, the maintenance and management of critical substation equipment is equally important in meeting business metrics. Proper use of non-operational data from substation automation systems can produce significant value and benefits in managing these high-value assets.

2. SUBSTATION ASSET MANAGEMENT

Paper No. 6

Of all industries, the electric power industry has the highest asset value in its infrastructure. Much of the equipment is classified as critical assets to power system operation. According to the North American Electric Reliability Corporation (NERC), critical assets are defined as: facilities, systems, and equipment which, if destroyed, degraded, or otherwise rendered unavailable, would affect the reliability or operability of the bulk electric system. Thus, asset management is vital in today's utilities operation.

Utilities asset management is a broad subject and the asset management paradigm includes:

- maximizing business performance
- using rigorous and data-driven process
- having strategic business goals, to drive engineering and operation decisions
- having multiple considerations:
  - profitability
  - performance
  - reliability
  - risk
  - safety
  - tolerance
  - cash flow

- regulatory relations
- environmental
- customer satisfaction
- employee satisfaction

In brief, asset management involves spending decisions made with the explicit objectives of maximizing business performance while proactively managing risk, budgets, resources and key performance indicators. (Source: R.E. Brown and L. Willis).

In vertically integrated utilities, assets include power system operation-related equipment in generation, transmission and distribution systems, as well as other business operation-related assets. For the purpose of this paper, the focus of discussion is the management of substation assets, including:

1. Apparatus or equipment:

- transformers
- capacitors
- circuit breakers and switches
- other equipment

2. Intelligent Electronic Device (IED):

- protection relays
- remote terminal units (RTU)
- meters
- monitoring sensors
- fault recorders
- programmable logic controller
- other electronics

The maintenance, planning and management of these high value and critical substation assets have a significant impact on the managing utility business. In recent years, utility businesses have shifted from standard-driven to condition-based management of assets.

2.1 STANDARD-DRIVEN MANAGEMENT OF ASSETS

In standard-driven management, equipment standards, as well as operations and maintenance (O&M) guidelines govern the way we work with equipment. Typical work processes starts from defined standards from which budget and resources are planned accordingly, and then are approved for implementation. Typical practices of equipment maintenance, planning and management include: scheduled inspections, review and work orders, manual data logging or retrieval, planning based on standards and estimates, as well as managing based on experience. While this has been the best practice in the past in order to ensure safety and reliability, it has also presented numerous challenges including:

- intensive resource requirement
- unnecessary maintenance work
- high O&M expenditures
- no visibility between maintenances

2.2 CONDITION-DRIVEN MANAGEMENT OF ASSETS

In condition-based management, assets are monitored on a continuous basis and conditions are assessed through data analysis. Typical work processes include equipment condition monitoring and assessment, prediction of possible scenarios and recommendation of action. Budget and resources are then planned accordingly, and approved for implementation.

This approach needs to use data collected from equipment, and this data is typically non-operational data.

3. OPERATIONAL DATA VS NON-OPERATIONAL DATA

In general, operational data refers to real-time data typically required for the operation of power systems. Operational data attributes focus on what and when, and status and measurements are typically in real time. This data includes circuit breaker open and close statuses, alarms, events with time tags, line currents and bus voltages. The corresponding

action of operational data is protection, control and SCADA. The main users are power system operators.

On other hand, non-operational data is usually historical data, files and records that focus on what and why, and typically include counts, accumulation and trends. This data includes fault and waveform records, circuit breaker operation counts and contact wear, as well as transformer dissolved gas, moisture and temperature. The primary objectives of non-operational data are equipment maintenance, system planning and asset management. The corresponding action of non-operational data is analysis, prediction and planning. The main users are equipment maintenance, asset management, system planning and system operation.

A collection of non-operational data or historical data can be processed, trended, analyzed or fed into modeling algorithms for identifying equipment deterioration or problems. Condition monitoring of equipment empowers decisions about maintenance work, repair or replacement, work order issuance and resource deployment. It facilitates the planning of work, resources, schedules and budgets. Results from non-operational data analysis are also valuable and powerful in supporting and justifying budgets for proper capital expenditure (CAPEX) or operating expenditure (OPEX).

The following are examples of non-operational data that are valuable to utilities managers and engineers in power system operation, maintenance and planning. This data can be made available from substation IEDs and sensors.

1. Transformer monitoring:

- Dissolved gas in the oil as an incipient of faults:
  - electrical faults from partial discharge and arcing
  - thermal faults from overheating
- On-line dissolved gas analysis (DGA):
  - acetylene (C_2H_2)
  - carbon monoxide (CO)
  - ethylene (C_2H_4)
  - hydrogen (H_2)
- Moisture in the oil:
  - degradation of paper
  - aging insulation
- Transformer monitoring modeling:
  - cooling system efficiency
  - winding apparent power
  - winding hotpot temperature
  - dynamic rating and efficiency

2. Switchgear Monitoring

- Partial discharge monitoring:
  - various sensor technologies are available
  - useful in gas and air-insulated switchgear
  - detects, logs and analyzes partial discharges

Table 1 Comparing Operational Data to Non-operational Data

Characteristics	Operational Data	Non-operational Data
Data format	Individual time-sequenced data	Data file, collection of related data
Time dependence	Real-time or near real-time	Historical, trends over time
Data integration	Standard or de facto standard	Proprietary and vendor specific
SCADA as carrier	Easily transportable	Difficult to transport
Accessibility	Accessible and retrievable	Difficult to access, manual retrieve

J.D. McDonald, Substation Integration and Automation

  - avoids progressive deterioration of equipment, which ultimately leads to equipment failure
- Gas Monitoring:
  - Pressure, temperature, density, alarm
  - Insulation deterioration
  - Detect early leakage
  - Prevent partial discharge and flashover

3. Circuit breaker monitoring:

- operational count and history
- time to break or close
- operation current
- contact wearing percentage

4. Load Tap Changer Monitoring:

- identify motor and mechanical problems
- verify proper operation
- identify contact wear

5. Bushing Monitoring:

- temperature
- leakage current

6. Substation battery:

- alarm
- charging current

7. IED monitoring and remote maintenance:

- operational history and data
- events, fault and waveform records
- device setting changes
- communication error logs
- setting history and update

4. THE BENEFITS OF USING NON-OPERATIONAL DATA FOR CONDITION MONITORING

The benefits of using non-operational data, in combination with operational data, can be significant to utilities engineers and managers. With the ability to access data and information related to equipment conditions in real-time, performing remote troubleshooting and diagnostics without unnecessary travel to remote sites, as well as analyzing and archiving historical data, utilities can achieve many of the following:

- avoiding catastrophic equipment failure
- reducing unplanned outages
- reducing outage frequency, durations and revenue losses
- implementing condition-based and predictive maintenance
- improving the effectiveness of maintenance planning and work order issuances
- reducing spare parts inventory
- reducing cost and lead time of spare parts purchase
- taking corrective action instead of reactive action
- implementing post-mortem analyses for root cause identifications
- empowering decision making, which is faster and more accurate
- improving human resource utilization and deployment
- optimizing asset and equipment life cycles, hence better return on investment (ROI)
- right-sizing operation and maintenance budgets
- facilitating business planning
- using data and fact-based justifications for CAPEX, OPEX and resource planning
- improving safety, health and environmental measures
- improving relationships with customers, government regulatory organizations and the general public
- reducing insurance premiums

5. ACQUIRING NON-OPERATIONAL DATA

Many modern IEDs are capable of providing both operational and non-operational data. However, making this data available and

accessible is often challenging. While most operational data is available through SCADA communication, non-operational data is typically available only through a physical connection to the IED maintenance port using of vendor proprietary software to extract the data. Such data access is time-consuming, labour intensive, inconvenient, and therefore often not used. Even if the data is available and accessible, it is often not usable due to the proprietary nature of vendor-specific devices and software. Since most of this valuable data exists in substation IEDs and sensors, extracting and utilizing the hidden treasures in the substation, will reap many valuable benefits.

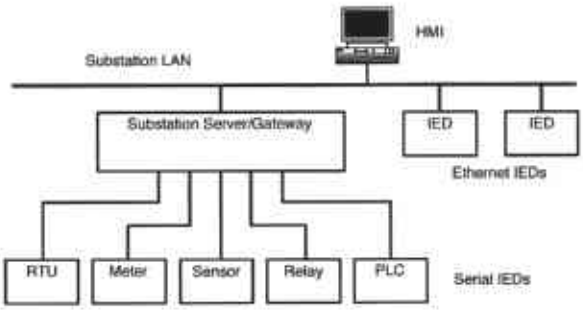
6. IED INTEGRATION

Acquiring operational and non-operational data can be accomplished through IED integration in the substation. According to Newton-Evans Research Company, Inc.'s report, more than 50% of substations are equipped with IEDs. However, fewer than 50% of these substation IEDs are integrated to make the data accessible and usable. IEDs that have valuable data for maintenance and asset management include: RTUs, protection relays, meters, fault recorders, event recorders, as well as monitoring sensors of various types. Data from IEDs should be integrated onto a common platform in the substation to be further processed, utilized and managed.

The following steps can be considered in the integration process:

- define and rank data that has a high impact on the business metrics
- assess existing IEDs and sensors regarding data availability
- review the need for additional IEDs and sensors
- examine IED communication capability
- identify communication protocols used and their compatibility

Figure 1 Integrated Substation Automation System



6.1 IED COMMUNICATION INTERFACE

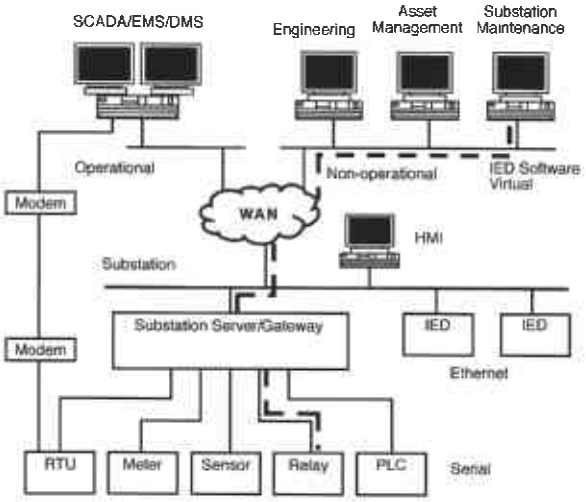
Most substation IEDs are equipped with serial or network communication capability. Typical legacy IEDs have serial communication ports in the form of RS-232 or RS-485. Many IEDs have more than one serial communication channel. One can consider using one channel as the real-time communication channel for operational data and using the second channel as a maintenance channel for non-operational data. If an IED has only one communication channel, then an IED with "inter-leave" capability can be easily integrated. New IEDs with Ethernet interfaces that make integration much easier. High speed Ethernet local area networks (LAN) in substations should be considered in IED integration for handling large amounts of data. Serial IEDs should be consolidated and converted to network communication "capable" devices via data concentrator, communication gateway, terminal sever.

6.2 PROTOCOL SELECTION

Most IEDs communicate using protocol of some form. For real-time operational data, protocols are commonly used, and are a mixture of vendor proprietary and open protocols. In recent years, most IEDs support open protocols such as DNP3.0 or IEC-60870-5-101, 103 and 104. Industry standard de facto protocol such as Modbus is also commonly used. Attention should be given to ensure the compatibility of protocols, or to consider using data concentrators for protocol conversion. For non-operational data, the data is made available

in many ways, such as ASCII-based protocols, datalink or file transfers. "Virtual connection" or "pass through" techniques can be used to establish communication with IEDs using manufacturer software to retrieve data and files from the IEDs.

Figure 2 Non-operational Data via Virtual Connection of Pass Through



6.3 MULTIPLE DATA PATHS

It is necessary to use multiple data paths to separate real-time operational data and non-operational data. Operational data is real-time, deterministic, mission-critical data, has the highest priority and should not be interrupted by non-operational data. In serial communication, bandwidth is limited for such high volume non-operational data transfers. Also, using a SCADA control center to forward or relay non-operational data unnecessarily burdens the SCADA system and dispatch operators. For network communication, the same philosophy should apply to separate the data into two LANs where there can be two or more physical or virtual LANs in a substation.

Other reasons for separate communication paths include: reducing nuisance alarms to the SCADA control center, accessing security, as well as other operational reasons. In general, data paths for non-operational data is best be separated from the SCADA system and protection communication paths.

6.4 SUBSTATION SERVER PLATFORM

It is important to design a substation system with a hierarchical architecture where data paths, applications and equipment are clearly defined. A substation server that incorporating, data concentrator, communication gateway features for IED integration is necessary in an integrated substation system. In some cases, multiple servers are used for different applications such as condition monitoring and maintenance, protection and control, as well as SCADA and automation.

For condition monitoring and maintenance applications, it is desirable to have a dedicated integrated condition monitoring (ICM) server platform. The substation ICM server is the central platform for integrating all sensors and centralizing all non-operational data within the substations. In reviewing the use of a substation server, the following should be considered:

- the substation hardened server, designed for embedded application with no moving part
- is a true open system with cross-platform capability (i.e. it runs on multiple hardware platforms)
- functions as a substation server, data concentrator, as well as communication gateway
- is equipped with cyber security capability
- supports redundant failover system architecture
- supports open and proprietary protocols
- integrates multiple vendor IEDs
- supports both serial and network communication
- has data collection and consolidation capability
- has data-to-information conversion capability
- has multiple user data distribution capability
- supports virtual connection/pass through to multi-vendor IEDs

- supports data logging, data files and records retrieval
- supports scheduled and event trigger file retrieval
- has temporary data storage
- supports a GPS interface for synchronization
- uses an application programming interface (API) for third-party expert applications

6.5 INFORMATION PRESENTATION AND VISUALIZATION

It is also important that the substation server is equipped with an intuitive and user-friendly graphical user interface (GUI) or human-machine interface (HMI). No matter how comprehensive the system data is, only a system with a good HMI application will be extensively used. Some of the HMI elements to be considered are:

- embedded HMI integrated with the substation server
- local graphical display in the substation
- remote graphical display and access
- web browser based
- user configurable and maintainable
- object library and device templates
- configurable user/group privilege
- cyber security
- ease of use

7. SYSTEM SECURITY

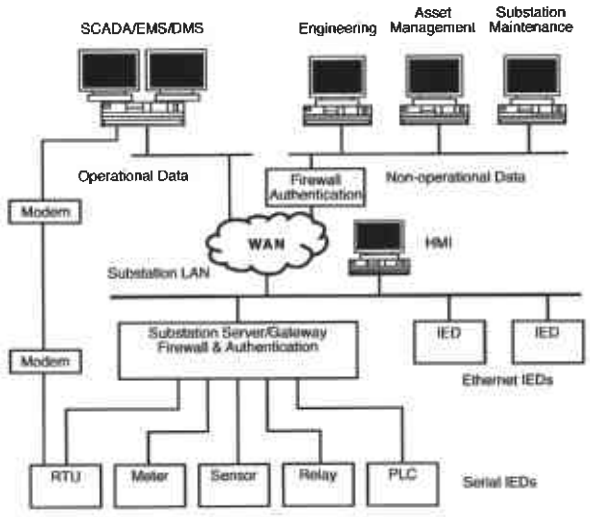
As the number of users accessing the system increases, it is necessary to implement security measures to restrict and manage user access. User activities logging and reporting should also be included. Access security features can be integrated in the substation server. It can also be implemented at the enterprise level. Each approach has its advantages and disadvantages. Access authentication should be implemented to secure all user access portals including but not limited to access through SCADA, HMI, direct or virtual connection to IED maintenance port, as well as operating system level access.

Cyber security features that should be considered including:

- Definition for individual and group users and privileges
- Unique user names and passwords
- User authentication
- Access authorization
- Activity log and report
- Data encryption and secured file transfer
- Secured web browser
- Interface to enterprise security servers
- Capable of disable unused communication ports and services
- User administration and management tools

Paper No. 6

Figure 3 Securing the Integrated Substation Automation System



Regardless of security implementation at the substation or enterprise level, centralized user administrative tools and utilities software should be considered for effective system management.

Network security features such as firewall as well as procedural implementation are also necessary securing the substation system.

Other techniques can also be considered. For

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instance, substation server can be used to automatically acquire data or files from IEDs in a scheduled or event driven manner. The data and files are temporarily stored in the substation server. The substation server can then notify users and made data and files available for retrieval through HMI and web browser interface. This approach reduce direct access to IEDs by users and therefore reduces security risk.

Many utilities in North America is adopting the NERC CIP (North America Electricity Reliability Corporation, Critical Infrastructure Protection) Standards in improving cyber security in the utilities infrastructure. Utilities in other regions and countries can also reference the standards for bench marking.

8. CONCLUSION

In conclusion, by leveraging substation automation projects and systems, IED integration and non-operational data, utility managers and engineers can greatly benefit from many aspects of the utility business, including:

- leveraging priceless data and information
- faster respond time
- empowering decision making
- reducing unnecessary trips to sites
- right-sizing resources, CAPEX and OPEX
- optimizing resource utilization
- optimizing asset utilization
- optimizing equipment operation efficiency
- optimizing system efficiency, reduces energy losses and fuel costs
- maximizing return on assets (ROA) and ROI
- reducing unplanned outages
- reducing revenue losses
- facilitate operation and capital planning
- supporting and justifying budgets
- increasing earnings and profitability
- migrating to a Smart Grid

Since most substation IEDs in operation - such as protection relays, RTUs, meters, sensors, PLCs, event and fault recorders - already have large amounts of non-operational data stored in the IED, one can further leverage substation integration projects to realize greater value of the existing equipment in operation. Additional sensors for plant equipment monitoring and diagnostics can also be introduced and integrated into the same system for even greater benefits.

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Paper No. 7

FIBRE BRAGG GRATING SENSOR NETWORKS FOR CONDITION-MONITORING OF RAILWAY SYSTEM

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FIBRE BRAGG GRATING SENSOR NETWORKS FOR CONDITION-MONITORING OF RAILWAY SYSTEM

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ABSTRACT

The concept of distributed or quasi-distributed sensing is mainly promoted by optical fibres. In these sensing systems, a single fibre can be used as the sensing element to substitute for thousand of conventional point sensors. In this technical talk, the principle and applications of fibre-optics distributed sensing techniques based on fibre Bragg grating sensors and their applications in railway industry will be introduced. Fibre Bragg gratings are essentially small lengths (typically less than 1cm) of singlemode fibre with periodic refractive-index variation in the cores of the fibre. Depending on the period, fibre Bragg gratings can be created to reflect narrow band of spectrum at virtually any wavelength. The reflection wavelength is sensitive to temperature and strain and thus could be used as sensors. The unique multi-functionality feature of FBG-based sensors to measure temperature, strain, inclination, acceleration, etc. will be highlighted in this talk. The engineering issues and applications of fibre Bragg grating sensors on several industrial projects such as vibration monitoring of MTR trains and rail tracks will be described.

1. INTRODUCTION

The rail industry is enjoying its biggest building boom worldwide in recent years. Fuelled by growing trade and rising environmental concerns on road transportation, the United States invested nearly US$ 10 billion in 2008 and allocated US$ 8 billion for high-speed trains in 2009. Indian Railways will invest about US$ 50 billion under the 11th Five Year Plan to modernize its railway system. As part and parcel of China's rapid economic rise to become a modern nation, the scale of railway investment in China is gargantuan. In 2009, China spent US$ 50 billion on its high-speed rail system with a top speed of up to 350km/hr. By 2020, China will have added more than 25,000km of high-speed tracks and spend up to US$ 300 billion.

Undoubtedly, the improvement of safety, reliability and productivity will continue to be the most important topics of the railway industry. This could be achieved through advances in on-board computers, on-board train condition monitoring systems, and wireless data transmission from wayside monitoring systems. There is also an increasing demand for better system reliability, availability, maintainability and safety from the communities. A smart condition monitoring system would allow real-time and continuous monitoring of the structural and operational conditions of trains [8, 9], overhead contact lines [1-7] as well as monitoring of the structural health of rail tracks and the location, speed and weight of passing trains of the entire rail systems. Ultimately, the inclusion of train location, speed restrictions, and train, track and overhead contact line conditions to the 'intelligent systems' will herald a safer railway industry with reduced maintenance cost, optimized performance and capacity. Therefore, the need of a smart condition monitoring system is imminent as indicated by the increase in railway/underground accidents/ incidences around the world. Smart condition monitoring systems for the railway industry would require extensive sensor networks with large number (1,000s') of multifunctional sensors for the measurements of temperature, strain/stress, vibration, acceleration, etc.

Fiber Bragg grating sensors, in comparison to electrical sensors and other types of fiber-optic

sensors, offer many advantages that are particularly well suited to railway transportation systems. These include immunity to EMI/RFI, long life-time (>20 years), and massive multiplexing capability - hundreds of sensing points along a single strand of optical fiber with length up to 230km [10], fast measurement speed, self-referencing and inherent redundancy feature.

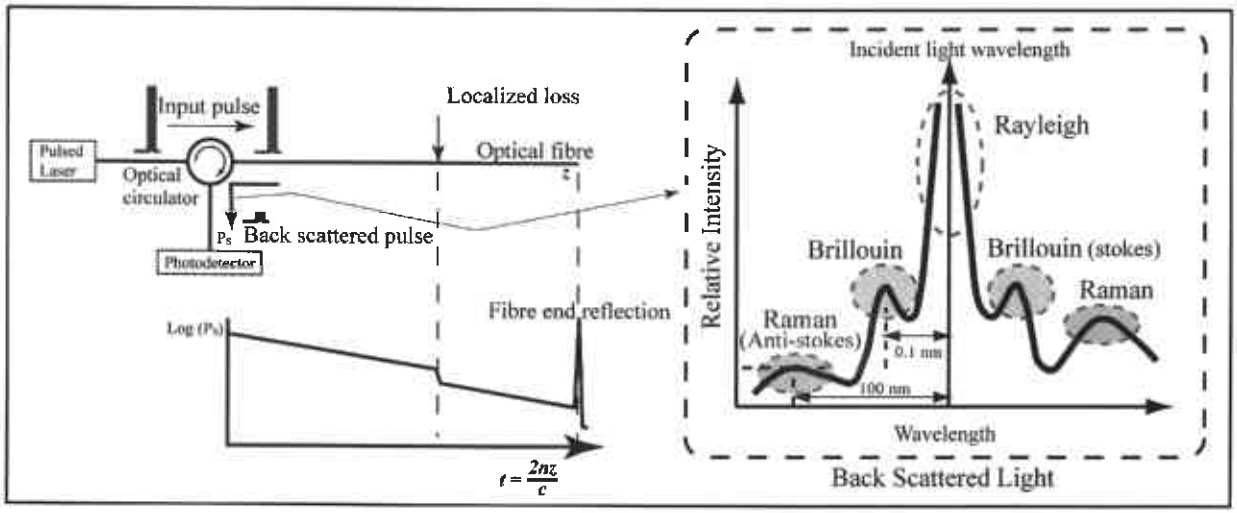
Quasi-distributed fiber-optic sensor based on Fiber Bragg gratings (FBGs) is an excellent candidate for the realization of smart condition monitoring systems for the railway industry. There are more established distributed fiber-optic sensors based on Raman or Brillouin optical time-domain reflectometry but they are less suitable for condition and structural monitoring of railways which demand fast measurement time and high spatial resolution. In this paper, the important characteristics of distributed photonic sensors, potential applications for the railway industry and some field trials will be described. Some of the FBG sensor-based monitoring systems are fully operational and in present service use - are providing valuable information about stresses experienced during service, both static and dynamic, under different operational conditions. The sensors also provide information on the loading and traffic status of the passenger cars; temperature-induced stresses and deformations on rails and carriages; temperatures in and around axles and wheel brakes; dynamic axle vibrations due to corrosion and bearing wear; and many other parameters relevant to railroad health monitoring and integrity.

2. DISTRIBUTED FIBER-OPTIC SENSOR TECHNOLOGIES

In distributed photonic sensor systems, a single fiber can be used as the sensing element to substitute for thousands of conventional point sensors. The concept of distributed sensing was initially promoted in the late 70's by optical fibers based on Rayleigh backscattering mechanism and through the technique of optical time-domain reflectometry (OTDR) [11-17] for locating faults in optical fibers, up to 250km with a resolution of ~3 meters.

Figure 1 shows the basic configuration of an OTDR in which a short pulse (~10ns) of light is launched into a test fiber. The back-scattered spectrum due to Rayleigh, Brillouin and Raman is also shown. The position of the measured quantity is computed via the time of flight of the backscattered light pulse propagating in the fiber. In the late 80's, a number of sensor configurations were proposed, mostly originated from the Raman and Brillouin scatterings in optical fibers.

Figure 1 Principle of Optical Time-domain Reflectometer for Distributed Measurement along an Optical Fiber



Raman distributed sensing is based on the spontaneous scattering process that is generated by thermally-activated acoustic waves. Information about temperature is retrieved from the comparison between the intensities backscattered into the Stokes and the Anti-Stokes waves. Raman distributed sensor is very mature and commercial units have typical performance of 1K temperature accuracy with 1m spatial resolution for fiber lengths up to 10km. The measurement time varies from 1 minute to 10 minutes, depending on the required accuracy and spatial resolution. On the other hand, Brillouin OTDR does not based on intensity measurement, but on the frequency shift of the Brillouin scattered wave. The Brillouin frequency shift depends on both temperature and strain, and the backscattered power depends solely on temperature. Brillouin OTDR can thus be used to measure temperature and strain simultaneously.

Commercial Brillouin OTDR has the capability to measure distributed strain and temperature with a resolution of 20με and 1K respectively, with 1m spatial resolution over a distance of 30km in 1 minute. Distributed photonic sensors based on Raman and Brillouin OTDRs offer many advantages over conventional sensors in applications where a large number of sensing points is required and the environment is hazardous. In addition, optical fibers are non-conductive, non-corrosive, unaffected by EMI and RFI, low loss and small size. A common application of Raman OTDR is in the measurement of hot spots in power transmission lines. Brillouin OTDRs are being employed in locating leaks in oil-pipe lines. However, the Raman and Brillouin distributed sensing systems require long measurement time and generally exhibit spatial resolution of the order of meter. Consequently, they are not suitable for applications where fast response time is needed or the required sensing regions are small.

On the contrary, fiber Bragg grating sensors [18,19] can be interrogated at very high-speed of up to 2.5 Msamples/sec [13]. FBGs are very small - short length of single-mode fiber (down to 0.1mm) with periodic refractive-index variation in its 9-micron core, as shown in Figure 2 (a). FBGs can be created to reflect narrow-bands of spectrum (typically <0.2nm) at virtually any wavelengths. Consequently, many gratings with different reflection wavelengths can be fabricated in a single strand of optical fiber. The fabrication of long-period gratings (LPGs) with period of several hundreds of microns is shown in Figure 2(b). LPGs operate in transmission mode and could be employed as low-cost optical filters or sensors. They are, however, very sensitive to environmental perturbation and are therefore not as popular as FBGs.

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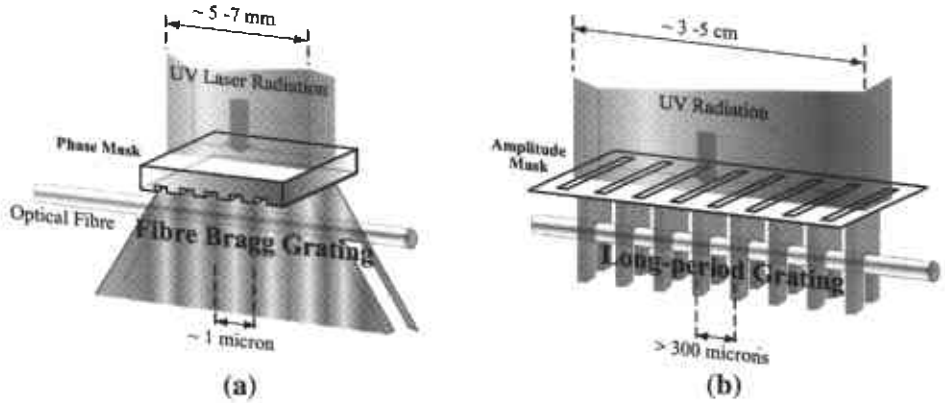
3. FIBER BRAGG GRATING SENSOR TECHNOLOGY

Fiber Bragg grating sensors are normally fabricated in standard telecommunication optical fibers using either an interferometric

Figure 2 Schematic Diagrams of the Common Techniques employed for the Fabrication of (a) Fiber Bragg Grating using Phase Mask and (b) LPG using Metal Amplitude Mask



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technique or phase mask technique to create an interference patterns in the fiber core with an UV laser beam. The latter technique is easier and thus more popular. More information on the fabrication and interrogation of FBGs are given in other chapters of this book. Typical price of standard fiber is about US$ 10/km and therefore the material cost of an FBG is very inexpensive. The majority of the cost of an FBG sensor system comes from the sensor packaging and the interrogator. The reflection/ Bragg wavelength of FBGs created in standard optical fibers exhibit wavelength-shift of 10pm/K and 1pm/microstrain around 1550nm. Consequently, FBGs can be employed to measure temperature and strain by determining the reflection wavelength of an FBG. Many schemes to discriminate strain and temperature or to measure both parameters simultaneously using FBG sensors were derived [21-26]. So far, the simplest and practical scheme is to use two FBGs with one of them not attaching to the structure where strain is to be measured. Therefore, one of the FBGs is only sensitive to temperature.

In additional to the intrinsic advantages of optical sensors over electrical sensors, such as EMI/RFI immunity, non-electrical conductive, FBG sensor technology exhibits many advantages that are particularly suitable for railway applications. The important features of FBG sensor technology for railway transportation systems are:

- Entirely passive sensors

  Unlike most electrical sensors, FBG sensors do not require any power to operate and therefore no active electronic circuit is required within the measuring objects. Consequently, trackside equipment susceptible to EMI/RFI is not needed in FBG sensor networks. This is important because it reduces the downtime of the sensor systems.

- Multiplexing capability

  Unlike truly distributed sensors such as Raman- and Brillouin- OTDR where the entire optical fiber is used to measure temperature or strain, only sections of an optical fiber where FBGs are inscribed are sensitive to strain/temperature. This is important because in railway applications truly distributed sensing is rarely required and FBG sensor systems allow the critical points of a railway system to be measured. The multiplexing capability of large number of FBGs on a single optical fiber simplify sensor installation and also make the sensor system cost-effective in railways where large number of sensing points are needed.

- Multi-functionality sensing

  FBGs are very small and function like strain gauges but operate optically. FBG-based transducers for measuring parameters other than temperature and strain can be realized, allowing one FBG-interrogator to measure many parameters such as acceleration [27], E-field, B-field [28], and tilt angles [29,30]. Therefore, a single FBG sensor network could replace a multitude of conventional electrical sensor systems employed in railway industry.

- Ultra-long reach sensing

  The exceptionally low-loss of standard telecommunication fibers permits light around 1550nm wavelength travel to and from FBG sensors over 100km. The distance between the FBGs and the interrogator is limited by Rayleigh scattering noise to about 25km and can be extended to 50km by introducing distributed Raman amplification to the connecting fibers [31,32]. The distance can be further extended to 230km by switching on and off the interrogating wavelength-tunable laser to reduce the Rayleigh scattering noise [33]. Other schemes for improving the signal-to-noise ratio and dynamic range of ultra-long reach FBG sensor systems were also demonstrated [34,35]. A single FBG-interrogator therefore has the capability to monitor rail tracks up to 460km long without the need of any trackside equipment.

- Redundancy

  Redundancy is essential in railway industry

to provide safety, reliability and quality of service. Redundancy in FBG sensor systems is relatively inexpensive and easy to implement because of the reflective native of the FBGs and the fact that a single FBG-interrogator can handle many FBGs for measuring many difference parameters over ultra-long distances. The reflection wavelength of an FBG can be measured from either end. Furthermore, a single FBG interrogator with the unique capability of handling many FBGs to measure various kinds of parameters makes redundancy implementation easy and relatively inexpensive.

- Uniquely identifiable sensors

  Wavelength-division multiplexing (WDM) technique is commonly used to demultiplex FBG sensors along a single optical fiber. In WDM sensor system, each FBG along a single optical fiber is uniquely identifiable by its reflection wavelength as no two FBGs occupy the same wavelength slot at any time. This feature greatly reduce the risk of mistaken the mesaurands obtained from the FBG sensors along an optical fiber and reduce the sensor system downtime. The uniquely identifiable FBGs along a fiber do not require any re-calibration nor re-initialization, therefore would significantly reduces system downtime.

- Large usable wavelength range

  FBGs are normally inscribed in standard singlemode telecommunication optical fibers which has a cut-off wavelength around 1250nm and thus can operates in singlemode for wavelength range from ~1250nm to ~1650nm, spanning the entire O-, E-, S-, C- and L-band defined in optical communication WDM systems. A single fiber has a large usable wavelength range to support many FBG sensors. Time-division multiplexing technique (TDM) permits the use of FBGs with identical wavelength. The combination of TDM and WDM techniques would allow a single optical fiber to measure several hundreds of locations [36]. The main disadvantage of the TDM approach is the small signal-to-noise ratio compare to that of WDM technique and consequently TDM is not common.

- Wavelength-encoded measurands

  Temperature, strain and vibration measured with FBGs are encoded in the wavelength-shift of the reflection spectrum. Wavelength is an absolute parameter, the measured signals is therefore not loss-affected. Unlike most conventional sensors, loss fluctuations in FBG sensor systems do not affect the measurement result so long as sufficient power reaches the FBG-interrogator. This feature minimizes noise and significantly enhances signal integrity of the FBG sensors.

An FBG sensor network configuration with redundancy to anticipate sensor fiber breaks

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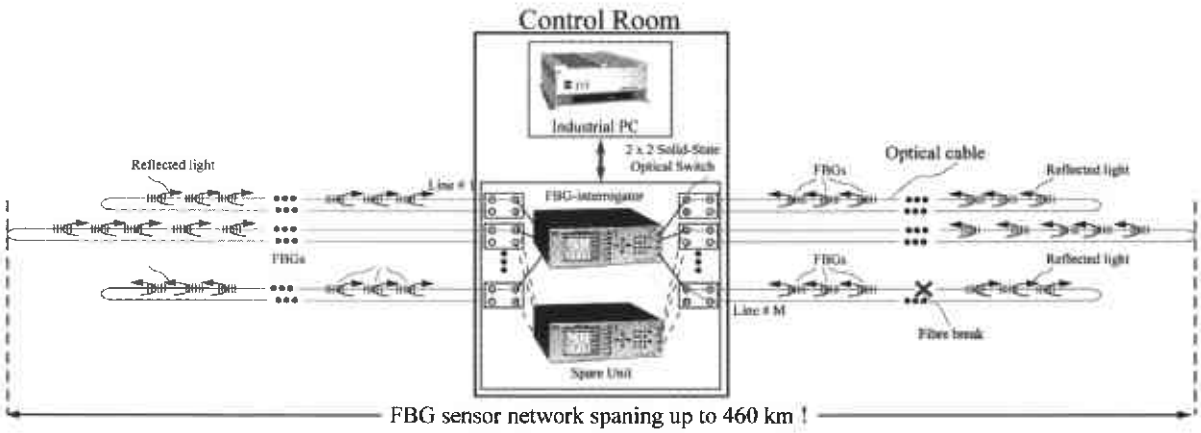
Figure 3 An FBG Sensor Network covering up to 460km of Rail Tracks with Hundreds of Sensing Points with Redundancy in Fiber Links and FBG-interrogator



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and interrogator failure can be easily implemented compare to conventional sensors because of the many unique features of FBGs aforementioned.

Figure 3 shows an FBG sensor configuration in which the far ends of all the FBG sensor fibers are connected back to the FBG-interrogator via 2x2 solid-state optical switches which exhibit much higher reliability and longer lifetime than mechanical switches. In normal operation only one output of the optical switches is connected. In case there is a break in the sensing fiber, as shown in Line # M of Figure 3, all the FBG sensors in Line # M can still be interrogated by switching the input of the optical switch to its two outputs, alternatively. The second inputs of all the optical switches are connected to a spare FBG-interrogator incase the first FBG-interrogator break down.

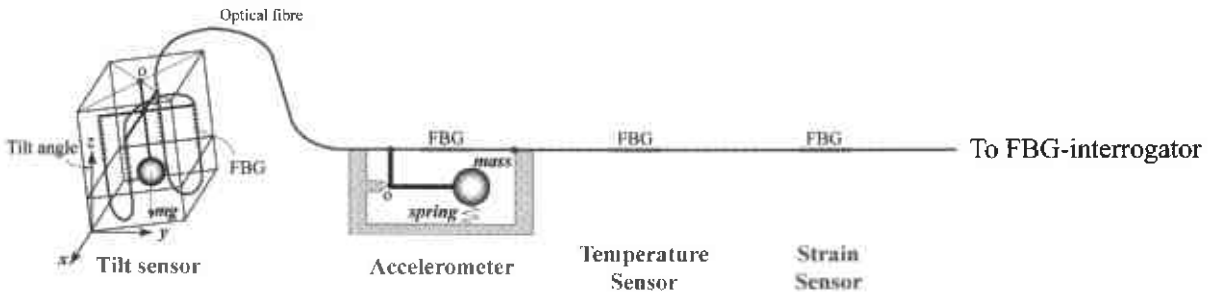
Figure 4 (a) shows the use of 7 FBGs, along a single optical fiber, to measure strain, temperature, acceleration, and tilt angle. Therefore, many FBGs for measuring different parameters of a train can be integrated in a single sensor system with one FBG interrogator - greatly simplify installation, renders the sensing system cost effective and provides a unified sensing solution to railway industry.

Figure 4 (b) shows the user interface of an FBG sensor array for displaying the results of acceleration, tile angle, strain, temperature and vibration. The photographs show an FBG-based inclinometer and FBG-based accelerometer developed at the The Hong Kong Polytechnic University.

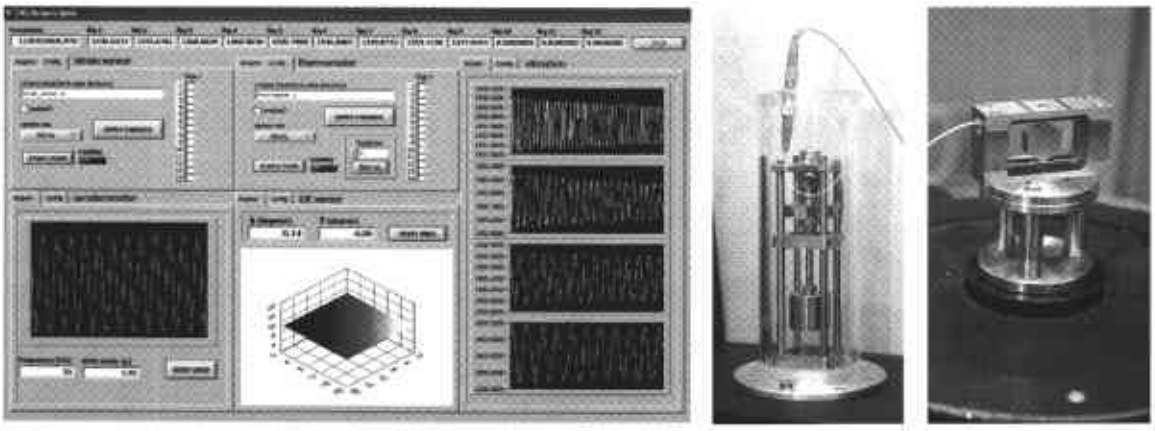
4. APPLICATIONS OF FBG SENSOR ARRAYS IN RAILWAYS

In railway systems, the smooth operation of trains necessitates proper designs and

Figure 4 Multi-functionality of FBG Sensors for the Measurement of Temperature, Strain, Tilt Angle, and Acceleration of Train Wagons using one FBG Interrogator



(a)



FBG sensor interface Inclinometer Accelerometer

(b)

integration of trains and tracks. Since a train-on-track system is a highly complex integration of various engineering entities while operational and environmental factors may vary significantly from one system to another, railway engineers do not rely on fundamental engineering knowledge alone but also their experience and on-site data in order to achieve high quality train services. In short, the quality of train service includes general safety of the rolling stock, reliability and availability of services, payload stability and passenger comfort. There are numerous factors among trains and tracks affecting the overall quality of train service.

For trains, the wheels are the frontline components in contact with the track and the condition of wheels is determinative to train operation safety and ride comfort. Out-of-round wheels, wheel flats, spalling, pitting and distorted wheel profiles are common problems that can be found on train wheels. Impaired wheels can lead to excessive vibration and low adhesion to track or even flange-climb which in turn may result in derailment. Powering the next generation of trains will be more demanding because of the higher speed and more power will be needed to support the increased number of electrical amenities inside trains. It is therefore crucial to monitor the temperature and contact force [R.8, R.9] of the overhead line to ensure reliable electrical supply. Other moving parts on bogies, such as axle bearings, motor and gearbox bearings, brake mechanisms, primary and secondary suspension systems, are prone to malfunctions due to tear-and-wear, over-stress, under-maintenance or even improper installation. Overheat at axle bearings may arise when they are run dry or operated under excessive vibration of the wheels. Moreover, brake and suspension jams are not uncommon and they may lead to catastrophic derailment and train collision. Apart from the moving parts, structural components of a train may have problem from time to time. Train structures, such as sole bar, body shell, equipment brackets and the corresponding weld joints, are the most susceptible components to have problems. When a train is running on track, the train structures are subjected to multi-dimensional forces which can lead to train structure deformation and fatigue. For example, shearing and torsion stress are the two main forces experienced by the train body which can result in torsion distortion of the body shell, door jam and window shatter. When a train roll, pitch, or yaw as it runs on track, underframe equipments which are essentially swing masses hanging beneath the train body are imposing dynamic stresses accumulatively to the equipment brackets and build up metal fatigue at high stress points such as weld joints. Although the life time of these structural components are comparatively long and some of them are even lifetime guaranteed, damages could still been observed occasionally. Any deformation or breakage of these structural parts can do the same harm to the railway as a broken moving part.

A real-time monitoring system capable of monitoring train-to-track interaction is indeed an effective means to avoid derailment and accidents. For example, the Eschede high speed train disaster [37] which occurred on 1998 near the village of Eschede in the Celle district of Lower Saxony, Germany, could have probably been avoided if a real-time monitoring system were installed and the train operator were being warned in time.

In future, railway systems will certainly incorporate more high-speed lines with increasing traffic demands, problems in trains and tracks will occur more frequently and they need to be attended to and rectified as soon as possible. Obviously, the conventional practice for flaw detection and maintenance is inadequate and there is an urgent need of a practical online monitoring system to report and record the status of trains and tracks. Being versatile, small in size and immune to EMI/RFI, FBG sensors have found their niches particularly in railway applications.

Recently, substantial amount of researches and field tests have been conducted using FBG sensors in railway applications. It has been demonstrated using FBG sensors for train and track condition monitoring, train tracking [38], identification, train speed and weight measurement and axle counting [39]. For

Figure 5 Many Railway Applications currently monitored using Various Conventional Electrical Sensor Systems as shown in the Figure could be replaced with FBG Sensor Technology

instance, FBG sensors have been used for temperature and strain measurements on train wagons, bogies and rail tracks so as to develop a "Smart Railway Sensor Network" by incorporating optical sensory nerves at various parts of the railway networks. The "optical nerves" can be extended to monitor other railway installations or equipment, such as transformers and overhead power lines.

The studies demonstrated that the application of FBG sensors in the railway system have the potential to revolutionize the railway industry and to upgrade the conventional systems into 'Smart Railways', thereby providing safe, reliable and vital information to rail operators. The FBG sensors can be used to build up many important railway sub-systems, such as axle counters, derailment monitors, train load

detectors as well as continuous rail crack detectors to permit real-time monitoring of the entire rail network, allowing maximization of network capacity, optimisation of electricity utilisation and effective detection of potential operational hazards to enhance overall service safety and quality.

4.1 FBG TRACK-BASED WHEEL-RAIL INTERACTION SENSING SYSTEMS– (AXLE COUNTING, SPEED AND WEIGHT MEASUREMENT)

The safety, operating performance, and ride quality of railway system rely on the interactions between the wheels and the rail tracks. Measurements on the wheel-rail interaction provide critical information on the condition of the rails and the trains running on them. When an axle passing on a rail track, the forces at the wheel-rail interface can be monitored with FBGs attached to the rail foot.

In order to ensure the most sensitive measurement of strain change on the rail, it is necessary to analyze the momentary deformation of the rail due to a passing wheel. The Ansys Multiphysics™ software has been employed to simulate the levels of rail deformation when a train is standing by the rail. The rail model UIC54 is adopted in the simulation. It is made of steel, with a Young's modulus of 207 GPa and a Poisson ratio 0.29. Under the weight of a static train car of 48 tones, supported by 8 wheels, the maximum deformation of the track is found at its head of the rail where the train wheel stands, and the second highest deformation is at the rail foot, as shown in Figure 6. In the longitudinal direction, the deformation is reduced as one moves farther away from the contact point. In the vertical direction, the rail web suffers from the least deformation, and both the rail head and foot are experiencing high deformation.

Figure 6 Simulation of Stress Distribution on a Rail Track due to the Passing of a Train

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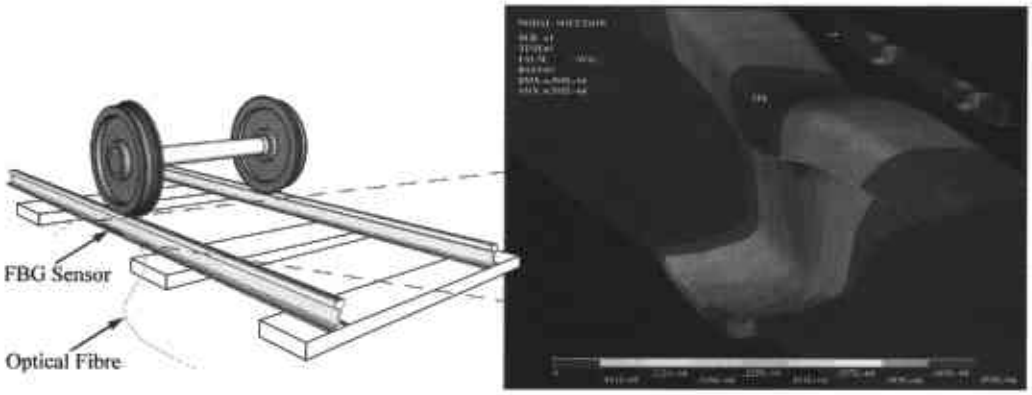
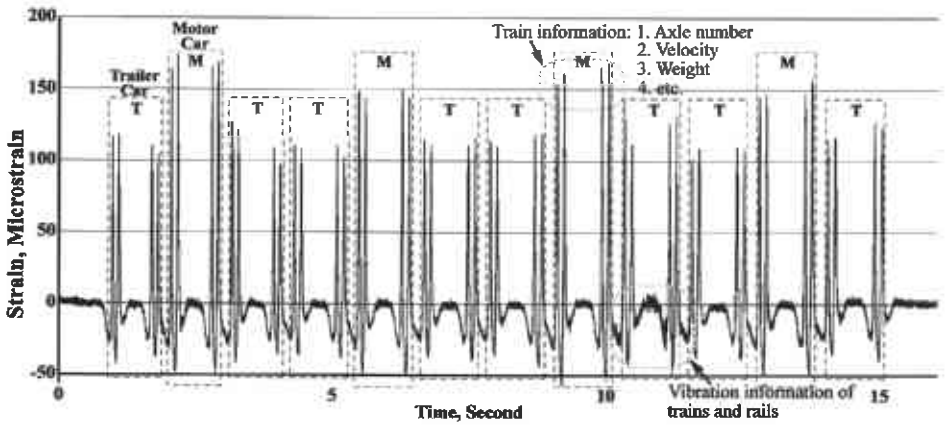


Figure 7 Measured Induced Strain due to a 12-Wagon Passenger Train Passed Over a Rail



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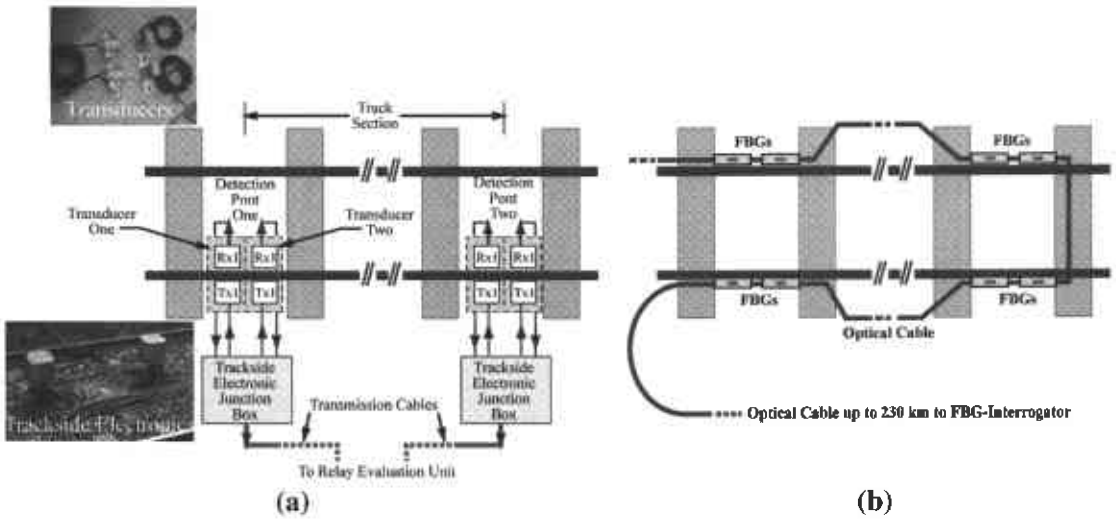
The simulated stress distribution result indicates that there is region of sufficiently large area of relatively uniform stress region on the rail foot where FBG could be attached without suffering significant chirping that would broaden the reflection spectrum of the FBG. Figure 7 shows a typical strain measurement result obtained from an FBG attached on a rail track when a train consisting of 12 cars in the "T-M-T=T-M-T=T-M-T=T-M-T" configuration was passing over it, where T and M represent the trailer and motor cars, respectively.

The results shown in Figure 7 give important and vital information related to the structural and operating conditions of the trains and rails. It is quite amazing that a single 6-mm long FBG sensor attached onto a rail could provide such a multitude of important information with very good signal-to-noise ratio. The occurrence of a peak strain represents an axle, the actual strain conveys the wagon's weight, and the vibration of the train/rail can be extracted from the high-frequency components. The motor car is generally heavy than a trailer car because it also carry two motors and therefore the measured strain of motor cars is higher than that of trailer cars.

Figure 8 (a) and (b) show conventional axle counters and a fibre-optics version of axle counter realized by FBG sensors, respectively. The attractiveness of the FBG-based axle counter over the conventional approach is quite obvious from the figure. The main disadvantages of conventional electrical train detection methods are the need of expensive substantial trackside equipment, and reliability and maintainability concerns, susceptibility to EMI, and traction return current interferences.

Figure 9 shows the typical measured result of an FBG installed on a rail track. Each individual wheel passing through the FBG sensor is clearly identifiable. The minimum induced strain due to a wheel passes on the track is more than 120 micronstrain and the noise is less than 5 microstrain, giving a SNR of better than 17dB. For comparison, a typical received signal from a conventional magnetic axle counter is also shown in the inset of Figure 9. It is evident that the FBG system is substantially cleaner than the conventional axle counter system which is very much susceptible to EMI. Since the distances between the wheels are known, train speed can be easily computed by using just one FBG sensors. Alternatively, two FBG sensors installed on rail track, separated by a known distance can also be used to measure train speed. The wavelength shift, i.e. the amplitude of the peaks shown in the figure is related to the force applied to the sensor by the wheel passing over it. FBG sensors on rail tracks are thus be used as axle counters and at the same time they provide important information for speed and weight measurements.

Figure 8 (a) Conventional Axle Counters and (b) Fibre-optic FBG-based 'Axle Counter'



(a) (b)

Figure 9 Measurement Results of FBG Sensors for Counting Train Axle. Inset shows the Received Signal from a Conventional Magnetic Axle Counter after Transmitted Through a Copper Cable

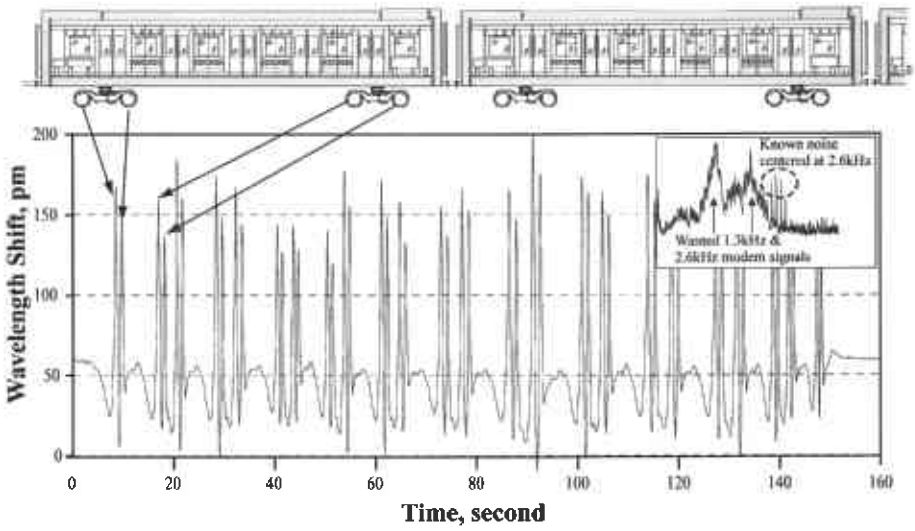


Figure 10 shows the track based FBG sensing system identifying a train with excessive vibration due to damaged wheels. Damaged wheel produces abnormal vibration patterns which are observed in between the axle signals Figure 10 (a). In order to quantify the vibration strength and make it more indicative to train operators, an algorithm was developed to convert the vibration signal to numeric indices. In this demonstration, the 4th and 10th cars of the train are vibration prone and were producing high vibration indices as shown in Figure 10 (b).

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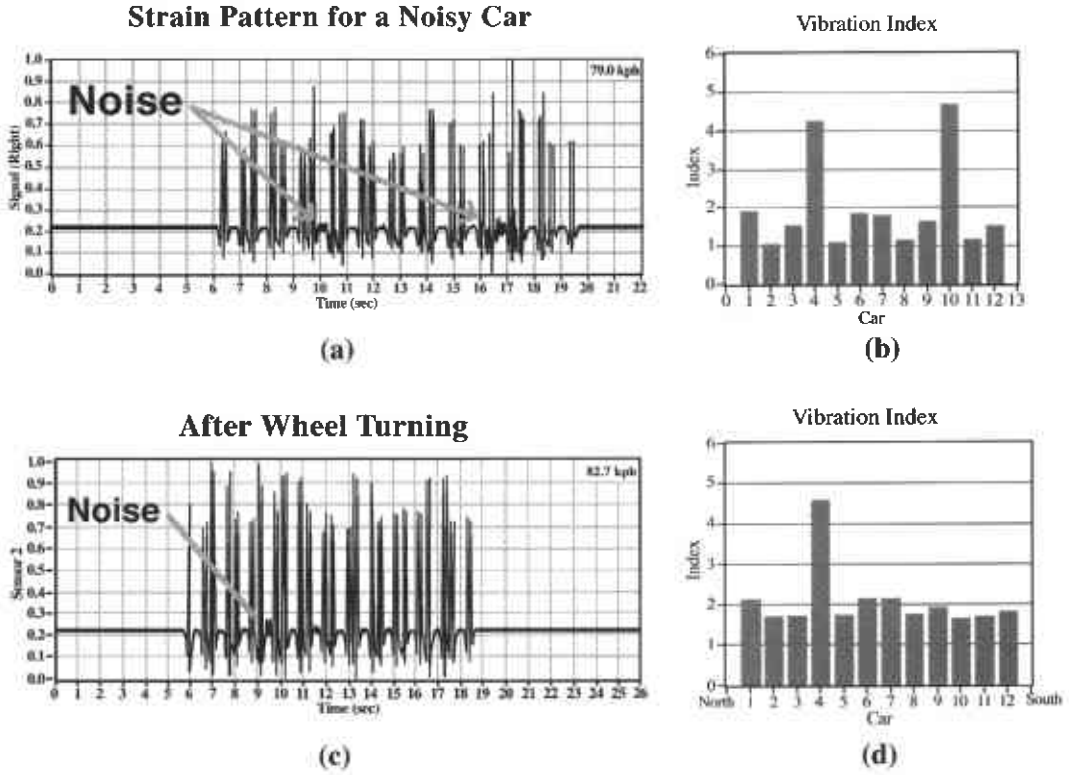
Figure 10 Identification of Train with Excessive Vibration



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The performance of the system is evaluated by turning the wheels of the 10th car while the wheels of the 4th car were not repaired as control. From Figure 10 (c), it can be observed that the vibration pattern and index of the 10th car returned to normal as shown in Figure 10 (d) after wheel turning but the 4th car was still experienced large vibration. The system measures and records the vibration patterns of all trains and produce databases for each individual train. Based on these records, the system keeps tracks of the wearing rates of wheels which help the operator to identify abnormality among the trains.

FBG sensors can also be installed on two sides of a rail to detect imbalances of strain on the two sides of a rail. If there is significant difference between the left and right hand side loading of an axle, the danger of derailment rises. Thus, freight trains are required to go through a wheel weighing system. Conventional systems use electrical strain gauge sensors to detect the train loading, train speed and to assess the possibility of derailment. The working principle of the strain gauge sensors is that when a train is residing on top of the rail at which the strain gauge is installed, its resistance changed and the bridge circuit, which consists of the stain gauge, becomes imbalanced. The degree of imbalances in the bridge circuit can be calibrated to give an indication of the train loading. However, the system is expensive, bulky and can be adversely affected by electromagnetic interferences. On the other hand, FBG sensors can be readily installed on both rails (for the two wheels of the same axle) at low cost and such information are of paramount importance if the railway engineer is to monitor the derailment ratio of the trains.

4.3 REAL-TIME CONDITION MONITORING OF TRAIN BOGIE USING FBG SENSORS

Failure of critical moving components on a bogie can be very dangerous. For example, the hotbox problem is a classical issue which has led to numerous accidents. The term "hotbox" refers to the overheating of the axle box of a rail rolling stock which is resulting from a problematic axle bearing. If a hotbox is left unattended, the heat developed at the axle box will lead to axle fracturing and causing major derailment. In addition, the hotbox can be an ignition source of inflammable goods, dust grains and even the rail track with combustible materials such as electrical cables and wood. The traditional method to detect hotbox is by installing hotbox detectors or infrared cameras along the railway line at intermitted distance. The shortcoming of this method is that the hotbox detector or IR camera has no temperature record of the axle boxes and it is difficult to determine how bad the temperature of the each individual axle box is. Besides, it is also difficult to identify the problematic axle box even a hotbox alarm is being received, especially when the train is running on high speed because there is not means to identify the axle boxes. In additional to hotbox, malfunctioning brakes or brakes jam can also lead to serious accidents too, such as fire problem, train collision and derailment.

FBG sensors are also used to measure the temperature of critical components on a train, such as the moving parts on a bogie. By making use of the temperature measurements, early problems of critical moving parts can be detected before developing into total failure. The principle of early problem detection for moving parts is based on the fact that a deteriorating moving part would heat up abnormally due to excessive dragging friction and in the case when the moving part is jammed, tremendous amount of heat will build up. Failure of a critical moving part on a bogie can lead to suspension of train service and damages to other components. For example, an unattended problematic motor bearing may cause a lot of damages to the motor which is more costly to repair than fixing or replacing the motor bearing in advance.

Figure 11 shows an FBG sensor network consisting of 20 FBGs were employed to investigate the practicality of using FBG sensors to measure continuously the temperature at the critical parts of a train bogie in real-time. The main objective of this work is to detect early signs of problems associated with the moving parts of bogies, such as

traction motors, bearings and brakes by ensuring that the daily operating temperature at these various parts does not exceed their acceptable limits. The system is installed with a display console at the driving cab showing the real-time temperature of which component and in the case when the temperature of a component exceeded the pre-set high alarm level for that component, a warning signal will be displayed. As a secondary objective, the temperature change of these parts during daily operation will also be logged during revenue services and analyzed to give important information for the development of an intelligent condition monitoring system for bogies.

Hitherto, thermal sensitive stickers are being used to measure the temperature of different mechanical and electrical parts of train bogies. The thermal paper stickers, which have to be replaced every 10 days, give very crude readings and only record the maximum temperature experienced at the point of measurement. Thermocouples are sometimes employed when long-term temperature measurement is needed. However, thermocouples are susceptible to electromagnetic interference (EMI). Besides, the lead wires are limited to several meters, making them not suitable for measurement at locations that are far away from the drive cab. Complex cabling and connections also create additional problem when large number of sensing points are involved. The small size, EMI immunity and multiplexing capability of FBG sensors provide a highly potential solution overcoming the aforementioned issues.

The test bogie is installed on the first car of a train that operates at the Airport Express Line (AEL) which links between Hong Kong International Airport at Chek Lap Kok and the Central District of Hong Kong Island. The airport railways cover a rail length of 35.3km, having two intermediate stations with an average traveling time of 24 minutes.

Practically, the FBG sensors system has demonstrated its capability in identifying abnormal incidence on the bogie. On one

Paper No. 7

Figure 11 Locations and Arrangement of FBG Temperature Sensors on Train Bogie

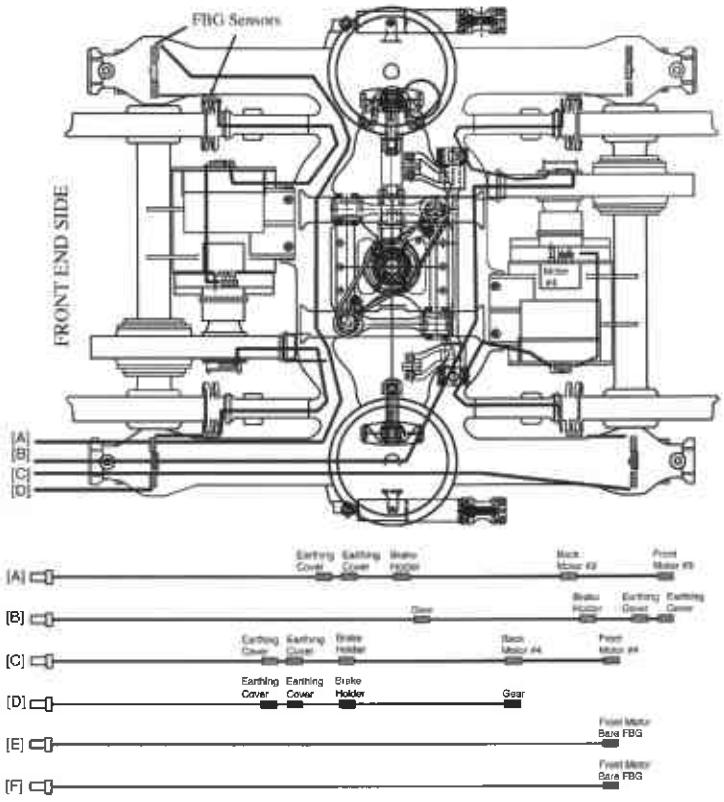

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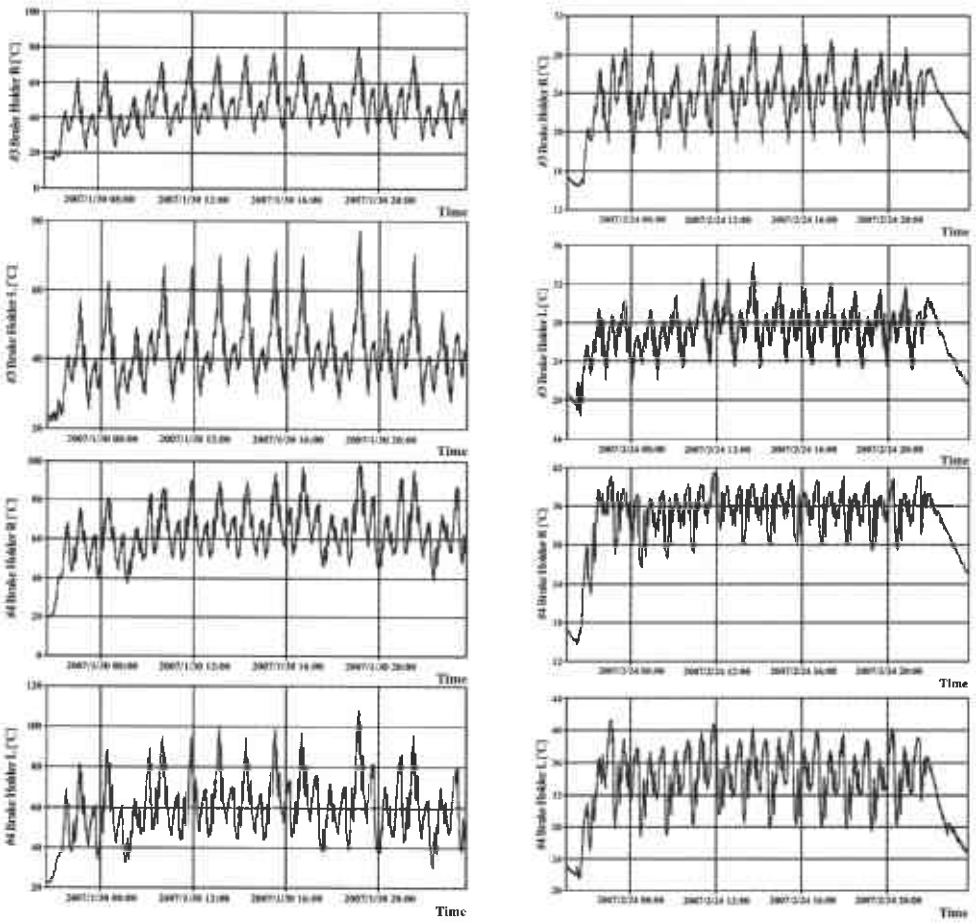
Figure12 FBG Sensor Packages and Installation Details

Axle Bearings | Brake Calipers | Gearbox bearing

Motor Bearing (Rear) | Motor Bearing (Front) | Motor Bearing holder (Front)

Figure 13 Temperatures of the Four Brake Calipers on the Test Bogie during (a) Normal Operation with Regenerative Braking (Average Temperature 40˚C-50˚C), (b) Abnormal Operation without Regenerative Braking (Average Temperature 80˚C-100˚C)



occasion, it was observed by the FBG sensor system that the temperature around the braking pads became as high as 100°C throughout a normal service day, and this was exceptionally high as the normal temperature around the braking pads should be around 40°C to 50°C. Upon further checking, it was found that the cause of such high temperature in the vicinity of the braking pads was because the train had suffered from a non-resettable power fault in power regeneration and hence the brakes had to stop the train mechanically from high speed without regenerative braking. Figure 13 shows the temperature records of brake calipers for normal and abnormal brake operations. This information was not the intended objective of the trial but such example serves to illustrate that a wealth of information can be derived from the sensors if the data are interpreted intelligently.

5. CONCLUSION

In this paper, we outlined the advantages of using fiber Bragg grating sensor arrays for railway applications. Some results obtained from field measurement over the past few years are also presented. The field measurement results together with the experiences gained from these projects demonstrated that distributed photonic sensor based on fiber Bragg gratings (FBGs) is an excellent candidate for the realization of smart condition monitoring systems for the railway industry. Two FBG sensor systems, one installed on rail tracks (for the detection of wheel/rail interface response) and one installed on board of trains, have been developed.

The FBG sensors inherently offer a practical solution for railway condition monitoring application. They allow easy and flexible installation, remote sensing and low-distortion data collection over long distance, multiple parameter measurements, and complete electromagnetic compatibility with electrified traction and signaling systems. The advantages and potentials of FBG sensing system are obvious in the early projects and the attained results so far are encouraging while the experiences are valuable for further development. The ultimate goal is to develop a "Smart Railway Monitoring System' based on FBG sensor network that conform to the high requirements on safety and system integrity stipulated by the railway industry.

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Paper No. 8

EVOLUTION IN ELECTRICAL ENGINEERING CURRICULUM

Speakers : Ir W.K. Lee, Senior Teaching Consultant
Ir Dr Wilton W.T. Fok, Senior Teaching Consultant
Ir Professor K.T. Chau, EE Programme Director
Ir Professor Felix F. Wu, Chair Professor
Department of Electrical and Electronic Engineering
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ABSTRACT

The University of Hong Kong (HKU) has close to a hundred years of education experience in Engineering programmes. Professor F Wu joined the University of Hong Kong as the Chair of Electrical Engineering in the year 1996 to plan the centennial evolution for the undergraduate curriculum of Electrical Engineering (EE). Continuing with massive changes that started in late 1980s, there have been additional framework upgrades under Professor Wu's leadership, and further changes will take place in the coming three years. The changes include value enhancement; program brand; assessment scoreboard; admission condition; and later on, the 3 to 4-year curriculum extension. The changes impinge on a wide continuum of potential students wishing to develop professional skill in the EE discipline. Evolution is a necessary process for these changes. The proposed evolution is also in line with the Government educational reform and the regular consultation offered by HKIE. New technology and societal concerns, especially in the area of sustainable energy and system operation, are receiving additional attention. Some transitional forces are turbulent, but smooth transition to the next level of robustness is expected. Prof. Wu and colleagues also establish research centers to enhance research values which the undergraduate EE program may also take part. A mission of upgrading nationalization and inter-nationalization is being implemented. This paper shares the vision.

1. OUR MISSION AND OBLIGATION

For over a century, the electrical industry makes contribution to developing Hong Kong to a first-class city. Electricity walks into every aspect of our life and every spot of the society. Our days will be inconvenient, if not miserable, when our electrical systems are not as reliable as they are now. The University of Hong Kong (HKU) feels the obligation to maintain the Electrical Engineering programme to sustain this development momentum. Engineering programme is one of the founding programmes of the University between 1911 and 1912, and we formally established electrical engineering(s) discipline at 1958. [1] Since then, we never dwarfs down our mission. Incessantly we appoint prominent leaders to direct the programme to ensure its professional quality and academic standard. Along the time line, we have Professor S Y King; Professor W S Leung; Professor C C Chan; and Professor F Wu. [2] Each of them is scholarly distinctive in the electrical engineering field. Their superb guidance is important to propel the curriculum to move to this 21st Century. We oblige to continue our mission, and are pleased to believe that famous professorial scholars will continue to express their intent to join our team for sustaining our development of new heights in the coming decades. This paper acknowledges the support and the philosophy that build the confidence to meet the future.

Paper No. 8

2. SUPPORT FROM THE INDUSTRY AND HKIE

2.1 SCHOLARSHIP

The success of an undergraduate programme is highly dependent on how much the industry appreciates the programme. The Electrical Engineering curriculum of HKU is receiving high regards from the electrical industry since its establishment, and the support is consistent, even when the economy is under depression.

We are pleased that the Electrical Engineering programme has the highest number of scholarship among all the engineering curricula in the Faculty; [7] despite in terms of student numbers; we are not the largest programme. The scholarship comes from a spectrum of entities: engineering institutions; power utilities; engineering consultants; trading firms and manufacturers; etc. [7] The scholarship-amounts for our programme are substantial. The encouragement does help to attract elites from the high school, and also upsurge learning spirit in the curriculum. Some scholarship donors also provide in-house internship to respective scholarship incumbents for bonus professional development before their graduation. We appreciate the arrangement, and note that these incumbents of maturity are always among the first batch of classmates stepping into the industry at their graduation.

We are delighted to understand that the same industrial support is received by the Hong Kong Polytechnic University. The scholarship support has been a great momentum to persuade youngsters to look at the EE professional programmes in the two universities.

2.2 EMPLOYMENT AND INTERNSHIP

Relative to vulnerability of counterpart engineering fields in economic downturns, electrical engineering is a highly stable industry. It requires professionals for design, construction, operation, training, education, maintenance, sales, service and many other sectors consistently in recent decades. The wide-span of engineering needs in this stable industry establishes a stable demand for new-blood. In the past 12 years, Hong Kong experienced economic downturn in the years 1997, 2003, and 2008. Despite crisis might affect certain societal needs, yet in none of these years, did our graduates face difficulties in seeking jobs of their profession. "Full employment" was the achieved norm in any recent year, except in the year 2004, one graduate still being unemployed at the end of the year. [8] We expect the same statistic this year, despite a complete survey would only be done in December 2009. The vast graduate internship opportunities and the zero unemployment rates are definitely the result of vision and support from the industry.

2.3 AMBASSADOR PROGRAMME AND HKIE ACCREDITATION

Understanding that most of the graduates have received multiple job offers, we comprehend that we may have under-supplied graduates to meet the real need of the industry. The present common-intake policy of the HKU Faculty of Engineering enables the curriculum to enroll a flexible number of undergraduates. We pledge to expand our undergraduate curriculum when there are able students expressing their interest, and we are pleased to note that the HKIE has been conducting an "Ambassador Programme" in secondary schools to encourage students to consider the profession. By this face-to-face sharing opportunity, teenagers of this age may increase tendency of choosing engineering. Nowadays the universities have provided ample undergraduate places to cope with the new blood projection of the society.

We always ensure that our EE curriculum is in a rigorous, robust and challenging manner. The professional accreditation conducted by HKIE is one key assurance step in this quality management process. The professional organization has been accrediting our programme every five-years since they have joined the Washington Accord in 1995. The Accord empowers HKIE. The degrees that have been accredited by HKIE shall receive the same recognition rights in the Accord participating countries around the globe. [1]

We understand that receiving Scheme-A training is the first step of professional career for most of our graduates. The HKIE accreditation and support on the training are highly regarded by the undergraduates, albeit the average entry salaries are generally less than graduates from counterpart faculties. Supported by a sense of mission of serving the society by a profession, 90+% of our recent graduates maintain electrical engineering as their life-long occupation. [6]

3. EVOLUTION IN THE PROGRAMME: COURSE STRUCTURE

The importance of electrical industry never fades. The industry is responsible to revitalize the revolution that it triggers for the World. We are contented that the industry always keeps in pace with the modernization, and in most cases, moves ahead of the advancement. To commensurate with the expectation of the industry, we make the curriculum dynamic and responsive to arising needs of the society. We highlight following curriculum features to explain our strategic development.

3.1 APPLIED TECHNOLOGY COURSES

In the past, the engineering programmes of HKU are highly focused to scientific study and basic engineering research methodology. We expected students to develop analytical skill and innovative skill through theoretical challenges. The degree conferred to graduates was Bachelor of Science in Engineering, or B.Sc.(Eng). Following the complexity that the engineering pioneers had built, and the tall intelligent buildings that were emerging from the earth, thus in 1989, we renamed the degree as Bachelor of Engineering, or B.Eng. [1] The Programme provides a balanced, broad-based and well-structured three-year Honours degree curriculum in the field of Electrical Engineering. The new degree decoration acknowledged that our graduates were approvingly valued to novelty and assembling engineering resources into highly valuable assets for the society. Basic engineering principles alone might not be adequate even in their career path. From that point onward, we introduced applied technology courses, for example: building services, electric vehicle technology, etc., as optional courses to the curriculum. The courses were well received by students who wished to prepare themselves diligently for the profession. Indeed since those years, there has been a high demand of fresh graduates by the building services consultants and the railway companies. [2] We are also pleased to note that there are also new graduates picking contracting business as their first job.

3.2 CREDIT-UNIT SYSTEM

Following the sovereignty return of Hong Kong to China, the Faculty of Engineering changed the programmes from a rigidly structured triple-level learning hierarchy into an appropriately flexible learning platform. The reform brought the internationally accepted credit-unit system to the Faculty in 1998. Nonetheless we still treasure the merit of 循序漸進 progressive learning embedded in the old system. [1] Hence we structured the EE programme and recommend students how they should take the courses in sequentially for a progressive learning that suits most of the average classmates. By that norm, students take more fundamental core course in their first year; more breadth courses in their second year; and more depth courses in their final year. [2] Time tabling of core electrical engineering courses is conscientious to ensure no time-clash such that the students of the year may take the desirable courses in their learning path. By this assimilation, the new credit-unit system provides sufficient flexibility in the selection of courses and broadens the existing curriculum without sacrificing foundation, depth and quality.

3.3 ENGINEERING MANAGEMENT AND COMMUNICATION

The Faculty of Engineering has long emphasized a balance among all aspects of the education we provide - technical and non-technical subjects, theoretical foundation and practical design and applications, engineering principles and skills, the education of the mind as well as the complete person. [1]

Alongside the introduction of B.Eng. programmes in late 1980s, we recognized the need of management, decision-making and problem-solving skill in our students. Hence besides the subject of "Engineers in Society" which later transformed to "Engineering and Society", we also introduced topics of engineering organization, leadership, economics, business plan, crisis management and finance to form new and compulsory management subjects. Ethics, integrity, safety, and sustainability are some of the key issues

critically and constantly addressed. [2]

To better prepare our students to meet the challenges of the knowledge-based economy, the Faculty has devised a number of measures to enhance their competitiveness. In addition to technical subjects and compulsory management classes, all students are required to take courses in professional communication. In HKU, language skill is considered a very important area of training. All students are required to take English enhancement courses and Chinese enhancement courses. They are also encouraged to participate in the English Club of the Society, organized under the auspices of the Faculty, in which teachers and alumni interact with students in English. [1] In recent years, attention has also been drawn to include Putonghua in the communication enlargement, and local students are encouraged to practice the national language with the increasing number of university-mates from the Mainland.

HKU believes in complete-person education. In the new credit-based flexible learning system, students are required to take broadening courses or complementary studies outside their own disciplines. We set about 20-percent of the credits be from the complementary studies so that the students can receive a wider-range of knowledge with integration of technology to contribute to the society. Since HKU recognizes that broadening knowledge is fundamental, hence expects students to finish most of the complementary studies, but never all, within the first two years of their curricula. [1][2][3]

3.4 SUSTAINABILITY AND CLEAN ENERGY ENVIRONMENT

We emphasize that the EE undergraduate is an energy related course. At one time, we named this programme "Electrical Energy System Engineering" which later converted back to "Electrical Engineering". The concerns for energy related issues have always been high in our research. As a principle, all teachers embed the concern in our EE technology courses.

Under the leadership of Professor Felix Wu, HKU established the "Initiative for Clean Energy and Environment (ICEE)' in 2008. [10] The new Research Center calls for collaboration among Faculties for collaboration and concerted effort on renewable energy study with a strategic goal to effect cleaner environments. Whilst the center is new, a good network has already been established at inter-faculty and international levels.

With the initiatives, and more funding commissioned to related research, we are able to allocate a substantial portion of undergraduate students taking this area as final year projects.

3.5 RECURRENT QUALITY CONTROL

Besides the five-yearly accreditation visit of HKIE, [6] our EE programme is subject to review by an external examiner annually to ensure that our academic standard of the programme is comparable to the international standard, and our graduates are able to meet the global needs. The concept of external examiner has long been established, and is still viewed as a crucial model which vitalizes our thoughts from year to year. [2]

Examination is a major assessment in EE programme. In respect of the importance, we maintain to give a second-examiner to each examination subject to ensure that all the examination papers receive second-opinion and all the answer scripts are double-checked. On top of it, there are examiners' meetings to ensure the normality and fairness of marks before the final endorsement.

3.6 OBJECTIVE & OUTCOME-BASED STUDY

All students in the Faculty are required to do objective-based projects during their course of study. These projects involve design and/or experiment and analytical investigation which stimulate lateral thinking and creativity. Many of them are indeed outcome-based. The new Innovation and Technology Internship Scheme exposes students to interesting ongoing research projects in innovation and technology

and the vigorous process of discovering and creating knowledge. [2]

The concept extends to courses by which objectives are well stated, and where feasible, outcomes are measurable.

3.7 OUTREACH DEVELOPMENT

A complete-person professional development is also an outcome of the EE programme. Nowadays engineering is no longer a discipline learnt in classrooms, workshops and laboratories alone. Societal technical observation and Community commitment are additional tactics to shape up the youngsters. Many schemes have been installed to response to these objectives, and they have received much blessing from the Department and from the University. For example, HKU has set up a team to build "A Solar-powered Multimedia e-learning System for a Reconstructed School in Sichuan". Volunteers from the EE programme formed a major core of its members. The systems required integration of multiple engineering sub-systems: a solar energy power grid; a multi-media classroom; a satellite educational TV system and server; an e-learning system; and a computer laboratory.

It is a blessing that the EE programme is in the Department of Electrical & Electronic Engineering which also carries the undergraduate programmes of Information Engineering; Computer Engineering; and Electronic & Communication Engineering. The short yet wide organization structure enabled us working effectively for this community project that required participation of all the four undergraduate programmes. Under the leadership of Dr. Wilton Fok, the project was finished at the site within three days in recent August. It was tested; commissioned and linked the Sichuan school with Hong Kong (HK) on 5 August 2009. In HK, Mr. Joshua Law, Secretary for Constitutional and Mainland Affairs; Ir Dr. Hon Raymond HO Chung-tai, Member of the Legislative Council and Hong Kong Delegate to the National People's Congress; Professor Chow, Shew-Ping, HKU Pro-Vice-Chancellor had addressed the participants in the launching ceremony. Mr. Li Ning, Deputy Secretary, Education, Science and Technology Department, Liaison Office of the Central People's Government in the HKSAR was in-attendance to congratulate the success. In Sichuan, Mr. Luchi Chew, Secretary of Education Bureau of the Deyang City and Dr. Wilton Fok, the project leader, also greeted the guests in HK via the on-line interactive e-learning system. [11] The project offered a great learning opportunity to EE students in terms of community philanthropy; project planning; resource organizing; team building, leadership and control. As part of global vision development, we encouraged the team members to share their philanthropy and environment-protection experience with teenaged Asian students under a "Young Power Programme" sponsored by the industry.

We supported EE students to utilize green-concept for an international young entrepreneurship competition and also the National Challenge Cup in 2007 and 2008 respectively. Each of the competitions accommodated hundreds of competitors. Besides technical and business skill, our EE students earned valuable presentation experience at the competitions. And of course, their silver award in each case also stimulated their future mission in the profession. [12]

Besides the Sichuan project, EE colleagues organize local and Mainland technical visits from time to time so that students may explore beyond the laboratory horizon on how the real industry is operating. The technical visits go as far as to Shanghai.

HKU EE programme still maintain internship as an indispensable part of the curriculum. This is another outreach component. Internship aims at inserting students to work environment where their practical engineering knowledge can be reinforced in applied situations. Whilst most of the students opt for summer internship, EE students are still encouraged to take a full-year study-work internship before their final year of study. We are pleased that their Employers' provide feedback during and after the internship as an important step of our assessment. [2][5]

3.8 UNIVERSITY COMPANIONSHIP

Each student is assigned with a non-academic tutor who is a teacher of the Department that can offer directional guidance and support to the student during the years of Electrical Engineering study. The guardian scheme has been in effect for many years.

A peer tutoring scheme was also introduced in 1999 to provide additional tutorship support to freshmen by senior students. Most of the peer-tutors are one year senior than the freshmen. The idea of peer tutoring was first raised by Professor Eric Mazur, Professor of Applied Physics, Harvard University. We shared his view that sometimes the second-year students understand and echo the problems of the freshmen better than teachers. [2] The senior students may have experienced similar hurdles. Those who achieved outstanding academic results are believed to be good tutors and they are invited to contribute to this scheme.

The Department of Electrical and Electronic Engineering has instituted the Electrical and Electronic Engineering Association (EEEA) in recent years. [2] We note that in these two years, many voluntary executives are from the EE programme. The association establishes a closer link between the Department and its students, especially the undergraduates. It also provides prompt assistance and advice to new students who are still tuning to adapt to the credit-unit system and university life. And of course, we receive a great publicity supported from the association on the aforementioned Sichuan project, and also on the HKIE.

4. THE NEW FOUR-YEAR PROGRAMME

4.1 THE REFORM

After a heated debate of several years, the Hong Kong Government decides to change the study period of university first-degree programmes from the current 3-year to following the international learning norm of 4-year. It is also an implementation response to the knowledge-based economy of Hong Kong. The Education Commission acknowledged that the universities would be the better places to nuture teenagers for the specialised knowledge. Whilst most of the people consider the four-year degree as a new change, yet to the University of Hong Kong, the 4-year is just a reversal. HKU had been running her basic first degree programmes by 4-year only since her establishment until the year 1957, from which year we had a 3-year transition educating both 3-year intake and 4-year intake. [1] The reason for the change was to follow an education reform in United Kingdom that moved some 1st year university subjects to the upper forms of high school. The programmes of engineering followed the change, but unfortunately became the only professional programmes in the whole university that required less than 4 years of study to graduate students for professional careers. [1] However, engineering technology has been expanding rapidly since that curriculum condensation reform. Complexity of new engineering systems demands a more in-depth education for engineering undergraduates that obviously require additonal study in the university. The Faculty brought up the issue of 4-year programmes in late 1980s, but unfortunately was forced to abandon because of lacking funding support from the Government. The University also saw by herself that introducing a 4th year M.Eng. study for able students was not viable. [1]

4.2 MESSAGE FROM PROFESSOR AMY TSUI [3]

Hence the implementation of a four-year programme for Electrical Engineering is a long want of the Department. We welcome the reversal change. At corporate level, Professor Amy Tsui, HKU Pro-Vice-Chancellor and Vice-President (Teaching & Learning), is appointed to lead the mission. She commented: [3]

"The 4-year undergraduate curriculum is a once-in-a-life time opportunity for us to critically reflect on the total learning experience afforded to our students, to deliberate on how we can not only help students to develop intellectual capabilities and

professional skills, but also nurture the core values of responsible global citizens, and to accomplish this within a new and innovative teaching and learning campus.

Our goals for the next four years are ambitious, encompassing:

- Introduction of, and transition to, the new 4-year undergraduate curriculum in 2012
- Building and deepening institutional knowledge of student learning
- Enhancement and assurance of teaching and learning quality
- Promotion of innovation in curriculum design and pedagogy
- Recognition of excellence in teaching and learning

These goals are also an expression of confidence in our teachers, students, and the future of HKU as a vibrant teaching and learning community."

4.3 COMMON CORE CURRICULUM [4]

The HKU Common Core Curriculum is the centerpiece of the new undergraduate curriculum which each undergraduate admitted at or after 2012 must esteem. That is, regardless which disciplinary curriculum an undergraduate would eventually enrol, he or she must go through the new Common Core Curriculum in the 4-year of study.

The Common Core Curriculum provides the key common learning experience for all HKU students. The word "common" delimits the scope of the curriculum and the word "core" defines its essence. There are common attributes that all HKU graduates could be expected to have acquired. It involves "dis-orientating" and "re-orientating" students to learning at a higher intellectual level that entails different learning approaches, learning styles, and modes of thinking and enquiry. It is conceptualized on the basis of the HKU motto, 明德格物 *mingde gewu* - illustrious virtue and investigation of things. In addition to the exploration of common human expereinces, there should be also be a link between the Common Core Curriculum and the disciplinary studies. [4]

On top of two English and one Chinese Language courses, four "Areas of Inquiry" (AoI) are formulated to serve as a means of organizing the curriculum. The four areas are considered inter-related rather than mutually exclusive:

1. Scientific and Technological Literacy
2. Humanities
3. Global Issues
4. China: Culture, State and Society

Each AoI has several themes to provide student adequate choices to build up their mingde gewu. Take Scientific and Technological Literacy as an example, tentatively, the following themes will be addressed: [5]

I. The Nature and Methods of Science

II. Science, Technology and Society

III. Science, Technology and Global Issues

IV. Science and Technology in Everyday Life

V. Frontiers of Science and Technology

Similarly, the other AoI also provides a wide-spectrum of themes to induce interest and learning in students. Each undergraduate will be required to choose a minimum of one course, and a maximum of two courses, from each AoI. There is no theme restriction in the course selection, but curriculum director shall ensure that courses chosen do not have much overlap in the content.

4.4 FOUR-YEAR CURRICULUM STRUCTURE

In the four-year undergraduate programmes, each student is required to take a minimum of 240 credits instead of the 180 credits for the current three-year programmes. [4][5] In view of the additional courses, it is envisaged that there is a room for students asking for one additional major discipline (two majors) and/or one minor discipline. The second major may be an intra-faculty programme. Task forces have been working on the principles which the EE

programme shall follow. We expect that through the four-year B.Eng. programme in EE, our graduates are better equipped, to depth and to breadth, to serve the industry.

The first double degrees were offered in HKU from 1998. In the new curriculum, the policy will continue to enable capable talent to finish two degrees in dual (double degrees). The two degrees are generally offered by two Faculties jointly with an aim to interact two valuable knowledge-bases in the same talents. Inter-faculties may have different courses to be pursued. Hence the study period as well as disciplinary courses requirement among the double-degrees programmes can be different. The complexity of detail may not be appropriately presented by his paper.

As far as EE programme is concerned, no double-degrees programme is being implemented. Yet definitely, we shall encourage and guide our students to select major and minor to the best benefits of the industrial stakeholders.

4.5 NATIONALIZATION AND INTERNATIONALIZATION

Most of the universities in the globe offer four-year programmes. Hence the new curriculum in HKU, and of course in the whole HK, connects more readily to the curriculum of the counterparts.

There has been increasing nationalization and inter-nationalization in the HKU undergraduate programmes since the start of this century. This phenomeon is most obvious in the School of Business and in the Faculty of Engineering. We consider that it is a response to the fact that Hong Kong is a developed city with a competitive strategic enviornment. The number of applications from the Mainland is reassuring. [9] Each year we are able to admit first-class competent students of Mailand to HKU, despite we still obliged to offer most of the places to the local students. Admissions to inter-national students has not been to that effect yet, nonetheless we have substantial exchange students from various European and North American countries coming to HKU to provide useful cultural and global-view interaction. Through the establishment of the four-year curriculum which facilitates credit-transfer more efficiently, we envision and welcome the trend of internationalization in HKU.

As aforementioned under the paragraphs on "Evolution of the Programme", We outreach for nationalization and internationalization of our education [11][12] By the four-year curriculum, and by continuing the outreach opportunities that we have, HKU will implement a wider and more superior nationalized and global vision in engineering education. Our students are strongly encouraged and duly prepared to take up challenges beyond Hong Kong. This year on top of his current duties, Professor Felix Wu has been appointed as the HKU-Shenzhen Coordinator, for strategic plans and implementation of campus and research faciltities requirement in Shenzhen. The national connection is not a new issue, and many academic collaboration channels have already been established with renown universities in the Mainland. For example, EEE collaborated with Tsinghua University for a Power System Research Institute in 1999. The objective of that collaboration was primarily on research. [1][2] Yet this time, the strategic move by Professor Wu will anticipatingly benefit the interflow undergraduate education in the Mainland, with a HKU brand.

5. CONCLUSION

Hong Kong as a first-class international city. HKU is receiving blessing. Continuing the evolution of the EE programme, and making the programme world-class are HKU commitments to the city. HKU walks hand in hand, and foot by foot with the Government and with the HKIE along this line. The EE programme has been upgrading nationalization and inter-nationalization by means of research, and by means of facilities. Adopting a Common-Core Curriculum in a credit-unit system, we shall prepare our graduates more

responsive to the modern world, and especially to China, with management concepts, with integrity and with sustainability.

6. ACKNOWLEDGEMENT AND REMARKS

This paper outlines a brief history of the curriculum development of the EE programme in HKU. Many steps of it was an evolution that gracefully has been receiving momentum to move further ahead. Substantial of the new evolution, including the new four-year programme and the Common-Core Curriculum, is a HKU-wise evolution. To show respect to the original meanings and expressions, a cut-and-paste of relevant descriptions was adopted for building part of this paper. The authors also wish to thank the various faculty members for contributing valuable information that supplements this paper to its present completeness.

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Paper No. 9

2009 EDITION OF CODE OF PRACTICE FOR THE ELECTRICITY (WIRING) REGULATIONS

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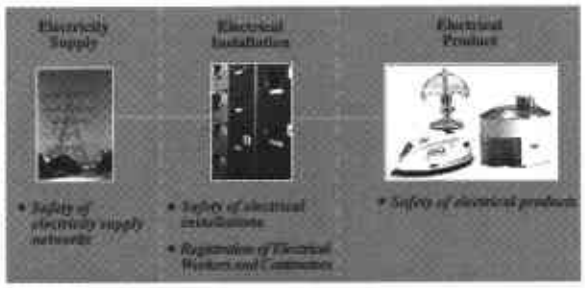
ABSTRACT

The Code of Practice for the Electricity (Wiring) Regulations (CoP) is published by the Electrical and Mechanical Services Department to elaborate on how the statutory safety requirements stipulated in the Electricity (Wiring) Regulations for fixed electrical installations can be met. The CoP provides technical guidelines for the trade to follow and has been widely adopted as local electrical standards. The CoP is periodically reviewed with the inputs from various trade organizations to enhance electrical safety not only for the electrical workers but also the general public. This paper highlights the major revisions in the latest 2009 Edition of the CoP such as safety for live work, reduced automatic disconnection time under fault conditions, enhanced safety requirements for bathroom electrical equipment, fault protection for temporary electrical installations, etc.

1. INTRODUCTION

The Electricity Ordinance (Cap. 406) establishes an embracing and systematic regulatory framework to ensure electrical safety in Hong Kong. It is supported by a number of subsidiary regulations including the Electricity (Wiring) Regulations, Electricity (Registration) Regulations, Electrical Products (Safety) Regulation, Electricity Supply Lines (Protection) Regulation, and others to govern the transmission, distribution and utilization of electricity. The Electrical and Mechanical Services Department (EMSD) is the authority in Hong Kong responsible for the enforcement of the Electricity Ordinance and its subsidiary regulations.

Figure 1 Regulatory Framework on Electrical Safety



2. CODE OF PRACTICE FOR THE ELECTRICITY (WIRING) REGULATIONS

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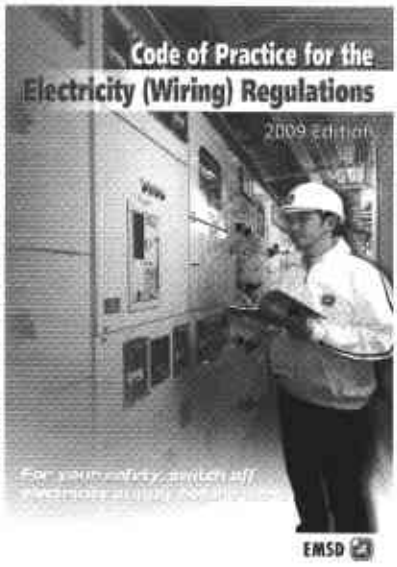
The Electricity Ordinance and the Electricity (Wiring) Regulations, enacted respectively in 1990 and 1992, stipulate the general safety requirements for fixed electrical installations. The CoP was first published by EMSD in 1992 to elaborate on how the statutory safety requirements stipulated in the Electricity (Wiring) Regulations can be met. The CoP is periodically reviewed with the inputs from various trade organizations (including the Hong Kong Institution of Engineers) to cater for on-going development of international electrical safety standards, technological advancement in the electrical trade and industry as well as current local trade practices. Two previous revisions to the CoP were completed in 1997 and 2003 respectively, and the latest revision was completed in early 2009.

Figure 2 2009 Edition of the CoP



The current revision to the CoP makes reference to the latest international standards promulgated by the International Electrotechnical Commission (IEC standards), BS EN standards, and also national standards such as British Standard BS 7671:2008 (the IEE Wiring Regulations 17th Edition), Australia/New Zealand Standard AS/NZS 3000:2007 (the Australian/New Zealand Wiring Rules), etc.

3. COLLABORATION WITH THE TRADE

The latest round of CoP revision was kicked off in mid 2007. Similar to past practices, revision to the CoP involved extensive participation from the trade. A Working Group for Revision of the CoP was established to collect feedback from different sectors of the electrical industry, comprising 5 trade associations, 3 professional institutions, 3 academic institutes, 2 power companies and 7 government departments.

Trade consultation was conducted through the Working Group members. After many rounds of full discussions and consultations, the revision items were agreed by the members. It is worthwhile to note that over half of the agreed revision items were put forward by trade members to suit the local conditions.

4. MAJOR REVISIONS IN THE NEW EDITION

4.1 GENERAL

Electrical installations or parts of installation which are completed and connected to electricity supplies on or after 31 March 2011 should comply with the 2009 edition of the CoP. In line with the established practice for the past revisions, there is about 2-year "grace period" to ensure smooth transition by allowing sufficient time for the design, tendering, installation, testing and commissioning.

The key revisions of the CoP would enhance electrical safety not only for electrical workers but also the general public. Some major revisions are described below.

4.2 RESTRICTIONS ON LIVE WORK (CODE 4 & APPENDIX 15)

According to our records, live work is a major factor contributing to electrical accidents, especially fatal cases. Live work means electrical work on or near any live conductor. This is anywhere a worker is exposed to energised conductors, terminals, busbars or contacts. The new CoP includes a new Appendix 15 on safety for live work, which specifies strict restrictions on live work. Under the new requirements, live work should not be performed unless:

(i) it is necessary in the interests of safety, whether or not electrical safety, for the work to be performed while the electrical equipment is energised; or

(ii) a supply of electricity is essential for the proper performance of the electrical measurement; or

(iii) there is no reasonable alternative to perform the electrical work by live work; or

(iv) it is justified and approved by the registered electrical worker, registered electrical contractor and owner of the installation.

Where live work is unavoidable, adequate precautions should be taken to avoid danger for work involving the handling of energised parts or working within touchable distance, direct or indirect, of energised parts. The following safety measures are to be taken:

(i) work on energised low voltage electrical equipment should be done only by registered electrical workers who are by virtue of knowledge and training competent to be allowed to carry out live work;

(ii) prior risk assessment should be carried out by the registered electrical contractor, registered electrical worker or a registered safety officer on the performance of the live work;

(iii) personal protective equipment (including insulating gloves, safety shoes and insulating mat) and testing equipment appropriate to the performance of the live work should be properly used by the person performing the electrical work;

(iv) screen or other means to avoid danger from inadvertent contact with energised conductors should be provided;

(v) fixing of warning notices for repair, barriers and screens;

(vi) the duration and the extent of the live work should be minimized as far as practicable; and

(vii) the isolation point of the electricity supply for the subject electrical equipment has been clearly identified.

4.3 REDUCED AUTOMATIC DISCONNECTION TIME (CODE 11B)

The new CoP has introduced more stringent requirements on automatic disconnection time in case of electrical fault. The objective of automatic disconnection of supply is that during an earth fault, the voltages on any exposed conductive parts occurring anywhere in the installation should be of such magnitude and duration as not to cause danger. For final circuits supplying fixed electrical equipment within the equipotential zone, the earth fault loop impedance at every point of utilisation should be such that disconnection occurs within 0.4 second (instead of 5 seconds in the past). For circuits supplying fixed electrical equipment outside the equipotential zone, the earth fault loop impedance should be such that disconnection occurs within 0.2 second (instead of 0.4 second in the past). With reference to IEC 60479, which studied the effects of current on human beings, 0.4 second is a relatively safe disconnection time for a touch voltage of 220V.

Some circuits are exempted and they can follow the original disconnection time requirement. These include circuits exceeding 32A, Category 3 circuits, circuits supplying essential equipment which are not readily accessible to the general public, or circuits supplying life-support systems.

4.4 SUPPLEMENTARY BONDING (CODE 11F & APPENDIX 12C)

In each installation, main equipotential bonding conductors should be connected to the main earthing terminal for all extraneous conductive parts to create an equipotential zone. An extraneous conductive part means a conductive part, that does not form part of an electrical installation, liable to introduce a potential. Within the zone formed by the main equipotential bonding, local supplementary bonding connections should be made to metal parts. Metalwork which may be required to be bonded includes mains water pipe, gas pipe, etc. which are at a distance not exceeding 2m from exposed conductive parts.

To determine whether conductive parts such as metallic bathroom accessories, metallic windows or metallic door handles are extraneous conductive part, Appendix 12C of the CoP suggests that the insulation resistance between the conductive part and the main earthing terminal should be measured. For a typical single-phase supply system with a nominal supply voltage of 220V, if the measured resistance could be maintained at not

less than a certain value even under the worst conditions (e.g. high moisture), the metallic part could be considered as a non-extraneous conductive part and supplementary bonding is not be required. This value is 45,000 ohm in the new CoP (based on IEC 60479:2005), compared with 21,000 ohm in the previous CoP (based on the old edition of IEC 60479).

4.5 NEW CABLE COLOUR CODE (CODES 13, 17, 18 & APPENDIX 18)

The new cable colour code (CCC) has been fully implemented in Hong Kong since 1 July 2009 after a two-year grace period for new installations as well as extensions, alterations and repair to existing installations. An addendum to the 2003 Edition of the CoP was published in 2007 to incorporate a set of installation guidelines for ensuring safety of electrical workers when they are working on installations containing both old and new cable colours. Such requirements are all integrated into the new CoP.

The new CoP specifies that every cable core of a non-flexible cable or bare conductors in a fixed wiring installation should be identifiable at its terminations and preferably throughout its length by appropriate labels, colours or coding. Label and coding identification should be clearly legible and durable and should be in contrast to the colours of the insulations. The application of tapes, sleeves or discs of the appropriate colours at terminations is acceptable.

Table 1 Cable colour code

Function	Colour		
	Old Colour	New Colour	Coding
Phase of single phase circuit	Red (or Yellow or White or Blue)	Brown	L
Phase 1 of 3-phase circuit	Red	Brown	L1
Phase 2 of 3-phase circuit	Yellow (or White)	Black	L2
Phase 3 of 3-phase circuit	Blue	Grey	L3
Neutral	Black	Blue	N
Protective conductor	Green-and-yellow	Green-and-yellow	–

Regarding the safety precautions, provision of a warning notice and proper cable identification are required where there is interfacing between old and new colour cables.

Before carrying out wiring work, test should be conducted to check whether the cables are live and all conductors should be correctly identified, i.e. whether they are phase or neutral conductor (for single-phase installation), or they belong to which phase (for three-phase installation). As a general guideline, to ensure personal safety, live work should be avoided.

4.6 INCREASED MINIMUM INSULATION RESISTANCE (CODE 21B)

When testing low voltage installations, the previous requirement is that the insulation resistance between conductors should not be less than 0.5 megohm when applying a 500V d.c. test voltage. This minimum insulation resistance requirement is now raised to 1 megohm. A higher insulation resistance value would provide better electrical insulation and reduce the risk of electricity leakage. The requirements of insulation resistance test are shown in Table 2.

Table 2 Minimum values of insulation resistance

Circuit Nominal Voltage (Volts)	Test Voltage d.c. (Volts)	Minimum Insulation Resistance (megohms)
Extra-low voltage circuits when the circuit is supplied from a safety isolating transformer/SELV	250	0.5
Up to and including 500V with the exception of the above cases	500	1.0
Above 500V	1000	1.0

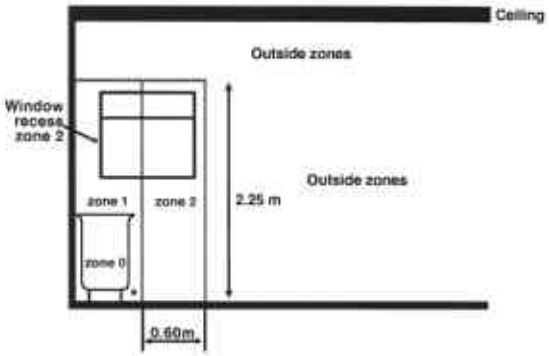
4.7 BATHROOM ELECTRICAL EQUIPMENT (CODE 26A)

People in bathrooms have an increased risk of electric shock due to their wet and naked bodies with reduced body resistance. In a room containing a fixed bath or shower, according to 2003 edition of the CoP, socket outlets should be installed beyond 0.6m away from shower basin or bath tub and the socket outlets should be protected by a residual current device (RCD) with a residual operating current not exceeding 30mA.

To further enhance electrical safety in bathrooms, the new CoP requires that RCD should be provided for other electrical circuits

in addition to socket outlets. All circuits supplying electrical equipment with exposed conductive parts installed within 2.25m above finished floor level should be protected by RCD with a residual operating current not exceeding 30mA.

Figure 3 Zoning of Bathroom (Source: BS 7671:2008)



4.8 TEMPORARY SUPPLY INSTALLATION FOR CONSTRUCTION SITE (CODE 26K)

Temporary generator set is commonly used at construction sites. The old CoP did not have any specific requirement on the earthing arrangement of the generator set while the new CoP specifies that the TN-S earthing system should be used.

4.9 HOT AIR SAUNAS INSTALLATION (CODE 26L)

For better protection against electric shock, the new CoP requires that additional protection should be provided for all circuits of the sauna by the use of one or more RCDs. RCD protection need not be provided for the sauna heater unless such protection is recommended by the manufacturer.

4.10 RENEWABLE ENERGY POWER SYSTEMS (CODE 26P)

Renewable energy power systems (REPS) are becoming more common and some of them are connected to the grid of the electricity supply company. A new Code is added to the latest edition of the CoP to provide general guidelines on design, operational and maintenance requirements with reference to the "Technical Guidelines on Grid Connection of Renewable Energy Power Systems" published by Energy Efficiency Office of EMSD. The objectives are to ensure safe working and reliable supply to the electricity consumer. Special attention should be paid to ensure that the renewable energy power system is automatically disconnected from the mains supply when tripping occurs. Moreover, the power generation side of REPS should be isolated to prevent electric shock to electrical workers during maintenance.

4.11 TEMPORARY ELECTRICAL INSTALLATION FOR EXHIBITIONS, SHOWS, STANDS AND FESTIVE LIGHTING (CODE 26Q)

A new Code is added to enhance electrical safety of temporary electrical installation. The new Code specifies that each socket outlet circuit and all final circuits other than emergency lighting for the temporary electrical installations should be protected by RCD. Every separate temporary structure, such as a stand or unit, intended to be occupied by one specific user, and each distribution circuit supplying outdoor installations should be provided with its own readily accessible and properly identifiable means of isolation. Furthermore, all equipment and cables exposed to weather conditions should be of the weather proof type or contained in suitable weather proof enclosures.

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4.12 OTHER REVISIONS

Other than the above-mentioned major revisions, there are many other minor changes or updates. Some examples include:

(i) Code 2 - Some new definitions are added, including "basic protection", "fault protection", "powertrack system", "busbar trunking system", etc.;

(ii) Code 8 - The new CoP has provided more guidelines on when isolation and emergency switching devices should be provided;

(iii) Code 26M - 220V luminaires are now allowed near swimming pools provided that there is RCD protection, the height is at least 2m above the floor, and they have an enclosure providing Class II or equivalent insulation and with suitable mechanical protection;

(iv) Appendix 13 - The checklists for inspection and testing are updated to incorporate the relevant changes in other parts of the CoP;

(v) Appendix 14 - The list of reference standards is updated. For instance, as the previous lightning protection reference standards IEC 61024 and BS 6651 are already obsolete, the new CoP requires in Code 26I that lightning protection installations are installed according to the new lightning protection standards such as IEC 62305, BS EN 62305, AS/NZS 1768 (an Australia/New Zealand standard) or NFPA 780 (an American standard). A list of standards for common personal protective equipment and tools for electrical work is also added.

5. PUBLICITY FOR THE TRADE AND PUBLIC

Currently, there are about 70,000 registered electrical workers in Hong Kong. Publicity work on the new CoP is a big challenge.

In collaboration with various government departments and trade organizations, training in the form of technical talks and seminars has been conducted to elaborate the changes in this new edition. Such organizations include the Hong Kong Institution of Engineers, Institution of Engineering and Technology, Workers' Union, Electrical Contractors' Association, Occupational Safety and Health Council, etc. The target audiences of the talks and seminars include all trade members including frontline electrical workers and professional engineers.

Apart from promotion talks and seminars, feature articles on the technical revisions have been included in the "Electricity News" (which is distributed free of charge to all registered electrical workers/contractors on a half-yearly basis by EMSD) as well as trade publications.

Furthermore, EMSD website provides a convenient platform to disseminate relevant news to the trade and public. A video on "Safe Electrical Work" has also been produced for promoting electrical wiring good practices.

Figure 4 Video Promoting Safe Electrical Work

6. CONCLUSION

The major revisions of the CoP have been introduced in this paper. In summary, the revisions will bring about positive effects on electrical design or electrical work practices in the long run without creating substantial impact to the trade. The revisions basically refine the safety requirements to enhance electrical safety for both the trade workers and the general public.

Electrical safety is a common responsibility of the regulator, designers, contractors and workers. To make a better and safer environment, support and cooperation of the trade to enhance electrical safety are of paramount importance.