THE HONG KONG
INSTITUTION OF ENGINEERS
ELECTRICAL DIVISION

The 28th Annual Symposium

Tuesday

26th October 2010

MODERN PROJECTS - CHALLENGES AND SOLUTIONS

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 Registration and Coffee

09.00 Welcome Address

- Ir Geoffrey L. Chan
  Chairman, Electrical Division, The HKIE

09.05 Opening Address

- Ir Prof. Reuben P.K. Chu, JP
  President, The HKIE

09.10 Keynote Speech

- Ir Prof. C.C. Chan
  President
  World Electric Vehicle Association

1. Power Plant and Network

09.40 A Utility Scale Thin-Film Photovoltaic System at Lamma Power Station

- Ir C.K. Lau
  Chief Electrical Engineer
  Projects Division
  The Hongkong Electric Co., Ltd.

10.00 Smart Grid – The Way for Renewable Energy Integration to Power Grid

- Dr Jin Zhong, Associate Professor
- Ir W.K. Lee, Senior Teaching Consultant
  Department of Electrical and Electronic Engineering
  University of Hong Kong

10.20 Discussion

10.40 Coffee Break

2. *Railway Projeets*

11.10 Beijing Line 4 – Steep Climb to Opening

– Ir T.M. Lee
Project Manager – SCL/KTE E&M
MTR Corporation Ltd.

11.30 E&M Design for Express Rail Link

– Ir Alvin W.K. Luk
Project Manager – XRL E&M
MTR Corporation Ltd.

11.50 Railways for Metropolitan City

– Ir Raymond W.F. Ho, Government Engineer
– Ir Jimmy W.W. Hui, Senior E&M Engineer
– Ir Dennis K.H. Wan, Senior Engineer
Railway Development Office
Highways Department
The Government of the HKSAR

12.10 Discussion

12.30 Luneh

3. *Power System Planning*

14.00 Preparedness against Super Typhoon

– Ir Steven K.H. Chan, Asset Utilization Engineer
Asset Management Department
– Ir Paul C.F. Chan, Project Manager
Engineering Projects Department
CLP Power Hong Kong Ltd.

14.20 Challenges and Opportunities in Delivering Energy Infrastrueture Projeets to Aehieve a Low-Carbon Eeonomy for Hong Kong

– Ir S.H. Chan
Corporate Development Director
CLP Power Hong Kong Ltd.

14.40 **Utilization and Integration of Condition Monitoring Techniques in Modern Power System Asset Management**

- Ir Tony K.T. Yeung, Senior Area Engineer (Eastern)
- Ir Andrew K.W. Yan, Area Engineer (Central)
  Transmission and Distribution Division
  Construction & Maintenance Department
  The Hongkong Electric Co., Ltd.

15.00 **Discussion**

15.20 **Coffee Break**

4. Tall Buildings

15.50 **Tall Buildings in South China – Cases of Challenges**

- Ir Simon F.W. Chung, Director
- Ir Y.L. Cheng, Director
- Ir Tom W.K. Cheung, Associate
  Ove Arup & Partners Hong Kong Ltd.

16.10 **Vertical Transportation Challenges for Super High Rise Buildings**

- Mr Jeremy Youker, Senior Manager
- Mr King H. Chau, Senior Sales Manager
  Otis Elevator Company (H.K.) Limited

16.30 **Discnssion**

16.45 **Snmming Up**

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

Closing Address

- Ir Stephen H.C. Chan, JP
  Director
  Electrical & Mechanical Serviees Department
  The Government of the HKSAR

Acknowlcdgcmcnt

The Electrical Division of The Hong Kong Institution of Engineers would like to express its sincere appreciation and gratitude to the following persons and organizations for their contributions to the Symposium :

Speakers / Authors

Ir Professor C.C. Chan
Ir Stephen H.C. Chan, JP
Ir Professor Reuben P.K. Chu, JP
Ir C.K. Lau
Dr Jin Zhong
Ir W.K. Lee
Ir T.M. Lee
Ir Alvin W.K. Luk
Ir Raymond W.F. Ho
Ir Jimmy W.W. Hui
Ir Dennis K.H. Wan
Ir Steven K.H. Chan
Ir Paul C.F. Chan
Ir S.H. Chan
Ir Tony K.T. Yeung
Ir Andrew K.W. Yan
Ir Simon F.W. Chung
Ir Y.L. Cheng
Ir Tom W.K. Cheung
Mr Jeremy Youker
Mr King H. Chau

Sponsors

Siemens Ltd.
CLP Power Hong Kong Ltd.
The Hongkong Electric Co., Ltd.
Junefair Engineering Co. Ltd.
Kum Shing Group
The Jardine Engineering Corporation Ltd.
Greenland Engineering Co., Ltd.
Schneider Electric (Hong Kong) Limited
Keystone Electric Wire & Cable Co. Ltd.
MTR Corporation Ltd.
Mitsubishi Electric (Hong Kong) Ltd.
Tyco Electronics Hong Kong Ltd.
Wenden Engineering Service Co., Ltd.
Metrix Engiueering Co., Ltd
Chat Horn Eugineering Ltd.
NWS Engineering Group Ltd.
Beghelli Asia Pacific Ltd.
Gammon E&M Ltd.
The Hong Kong & Kowloon Electric Trade Association
Hong Kong Eleetrieal Contraetors' Assoeiation Ltd.

Cover Design of this Booklet by Ir Dr F.C. Chan

28TH ANNUAL SYMPOSIUM ORGANIZING COMMITTEE

Symposium Chairman	**:**	**Ir Simon F.W. Chung**
Members	**:**	**Ir Geoffrey L. Chan**
		Ir Dr K.M. Leung
		Ir S.K. Ho
		Ir Gary C.W. Ko
		Ir Albert W.K. To
		Ir Gordon M.S. Woo
		Ir C.L. Leung
		Ir P.K. Chan
		Ir Mandy M.Y. Leung
		Ir C.L. Wong
		Ir Y.H. Chan
Hon. Secretary and Treasurer	**:**	**Ir Y.K. Chu**

Paper No. 1

A UTILITY SCALE THIN-FILM PHOTOVOLTAIC SYSTEM AT LAMMA POWER STATION

Speaker : Ir C.K. Lau
Chief Eleetrical Engineer
Projeets Division
The Hongkong Eleetrie Co., Ltd.

A UTILITY SCALE THIN-FILM PHOTOVOLTAIC SYSTEM AT LAMMA POWER STATION

Ir C.K. Lau
Chief Electrical Engineer
Projects Division
The Hongkong Electric Co., Ltd.

ABSTRACT

To support the Government's Blue Sky Campaign for improving local air quality while recognizing the growing demand for wider use of renewable energy, HK Electric has decided to build a utility scale solar Photovoltaic (PV) system comprising 5,500 Amorphous Thin Film Photovoltaic (TFPV) modules, each rated at 100W peak. The system will generate green electricity of about 620,000kWh a year, offsetting 520 tonnes of carbon dioxide emission. This paper presents the development of the project and shares experience in operation and performance evaluation of the TFPV system.

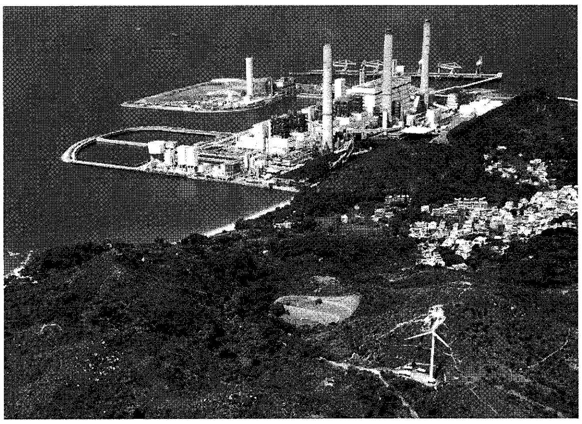
1. INTRODUCTION

At present, HK Electric has a total installed capacity of 3,736MW, serving more than 550,000 customers with a consistently high supply reliability rating of over 99.999% since 1997. All the electricity is generated primarily from Lamma Power Station and Lamma Power Station Extension of Po Lo Tsui at Lamma Island.

HK Electric has been actively pursuing the use of renewable energy (RE) in recent years aiming at achieving better environment in Hong Kong and supporting government policy. In the recent years, small wind turbines, small scale PV systems, solar water heating systems have been retrofitted in various premises of HK Electric.

Following the success of commissioning the first commercial scale wind turbine in 2006, HK Electric continues to explore the introduction of utility scale solar energy project and the feasibility of building a 100MW offshore wind farm in the southern waters of Hong Kong. The Wind Turbine and Lamma Power Station of HK Electric are shown in Figure 1.

Figure 1 Lamma Power Statiou and Wind Turbiue



2. FEASIBILITY STUDY AND SITE SELECTION

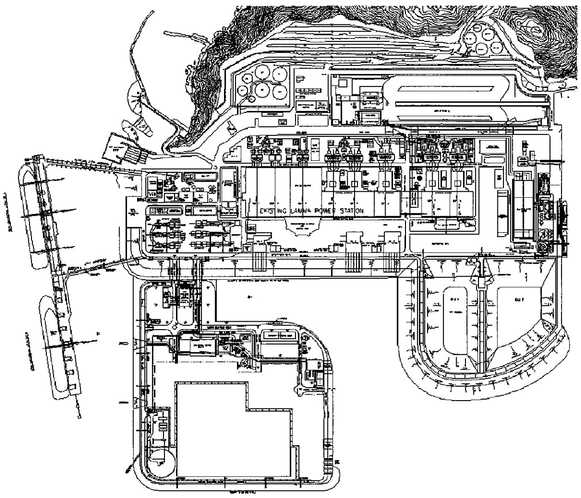
Hong Kong is a densely populated area. Finding large flat areas at commercial and residential areas suitable for large scale solar system without shading from surrounding high rise buildings and visual intrusion to the residents nearby is impossible. Moreover, the country side of Hong Kong Island is checked and no suitable site can be located.

A variety of study and investigation on existing solar PV systems including the two most largest systems in Hong Kong, i) 350kW system at Headquarters of the Electrical and Mechanical Services Department (EMSD) and ii) 198kW system at Hong Kong Science Park, was conducted from April to September 2009 and key factors for site selection of a utility scale solar power system are identified as follows:-

i. Large flat area
ii. Floor loading on roof of buildings
iii. Orientation of PV modules
iv. Shading
v. Visual impact
vi. Ease of grid connection
vii. Access for operation and maintenance

Finally, Lamma Power Station is considered as a site generally meeting the selection criteria. Site plan of Lamma Power Station is shown in Figure 2.

Figure 2 Site Plan of Lamma Power Station



There are about 20 power station buildings/ plants in Lamma Power Station. Considering the layout and orientation of the power station buildings and various technical constraints such as required flat roof area/loading, accessibility, obstruction, connection to system grid, as a whole, PV modules were planned to be installed on the following roofs of Units 1-8 Main Station Buildings:-

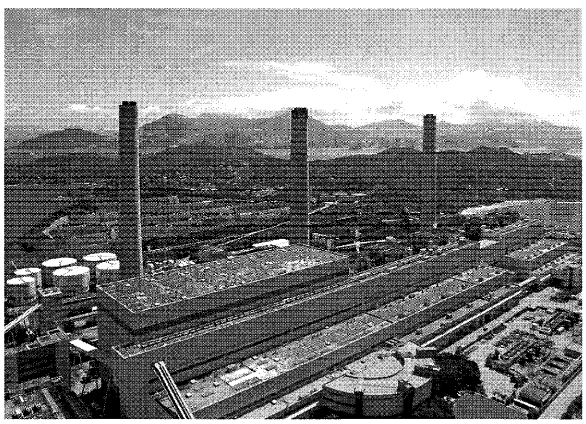
i. Units 1-3 Boiler House at EL+80.15
ii. Units 1-6 Bunker Floor at EL+62.00
iii. Units 1-6 Turbine Hall at EL+37.00
iv. Units 7&8 Bunker Floor at EL+62.00
v. Units 7&8 Turbine Hall at EL+37.00
vi. No. 2 Circulating Water Intake Area

The total area of roof areas where PV modules are installed is about 35,000m^2. Taking into consideration the space occupied by existing equipment and spaces required for emergency access, operation & maintenance of the PV System and existing plant equipment as well as avoiding shadow from existing equipment on rooftops, it was concluded that installation of 5,500PV modules with dimension of 1,410mm (L) x 1,110mm (W) x 35mm (D) is technically feasible.

According to geographic location of Hong Kong, PV modules should be installed facing south and tilted at about 22° in order to capture solar irradiance as much as possible. As PV modules to be installed at Lamma Power Station are faced toward seaside, visual impact to residents nearby is not envisaged. Based on the estimated maximum power of 100W can be generated by each PV module, the total estimated installed capacity of the solar PV system is 550kW approximately.

An aerial view of the solar power system on the rooftops of Units 1-8 Main Station Buildings is shown in Figure 3.

Figure 3 Aerial View of Units 1-8 Main Station Buildings and PV System



3. SELECTION OF PV MODULE

From the market search, solar cells are grossly divided into two types, namely, i) crystalline and ii) thin-film.

The thickness of silicon material for thin film PV is only about 1/200 of that for crystalline

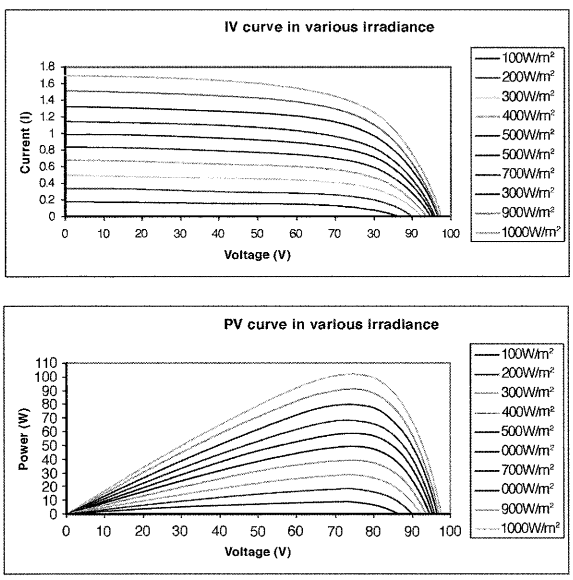
PV. The more silicon is used for production of PV panels, the more energy is required. Energy payback time for a-Si Thin Film PV is about 1.5 year vs. about 2.5 years for c-Si module. Therefore, thin film PV is more environmentally friendly in production.

Temperature coefficient for maximum power output Pm of a-Si Thin Film PV and c-Si PV module are about -0.25% and -0.4% per °C rise on module temperature respectively. The temperature in standard test conditions (STC) is 25°C. The ability to maintain power output level at high temperature of thin film PV module is better than crystalline PV module and is more suitable for tropical environment like Hong Kong.

Rate of decrease in conversion efficiency at weak light for a-Si thin film PV module is less significant than c-Si PV module. Hence, thin film PV modules are able to effectively produce power at low irradiance conditions.

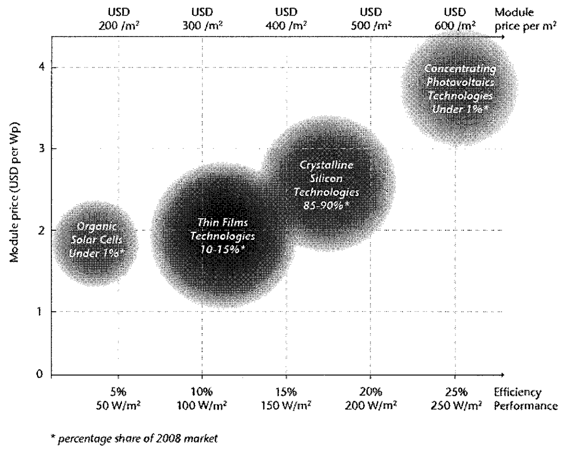
The electrical characteristics of TFPV module are shown in Figure 4.

Figure 4 Characteristics of TFPV Module



Available information shows that the cost of crystalline PV modules is in some degree higher than thin film PV modules. Their comparison together with other PV teehnologies is shown in Figure 5.

Figure 5 Cost of Different PV Module Technologies



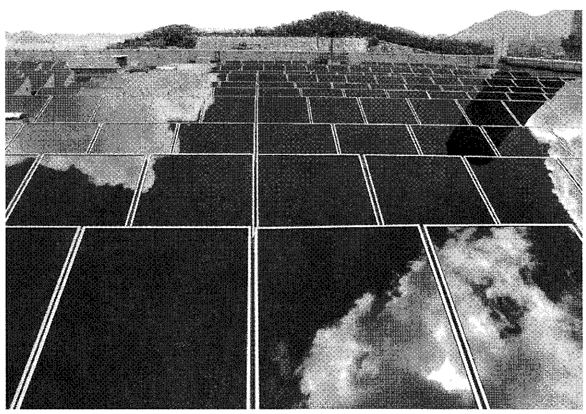
* percentage share of 2008 market

It is anticipated that thin film PV will continue to increase their market share due to the advantages mentioned above and foreseeable continued improvement of module performance.

After careful consideration, thin film PV modules are adopted as they are considered more environmentally friendly in production and are the more cost competitive for application especially in tropical areas similar to the harsh environment in Lamma Power Station.

A close view of the PV module installed at the roof of Units 1-3 Boiler House is shown in Figure 6.

Figure 6 PV System at roof of Units 1-3 Boiler House



4. PROJECT IMPLEMENTATION

After tendering, the supply contract was awarded to Du Pont Apollo Limited (Du Pont). Du Pont was established in May 2008 under "Shenzhen/Hong Kong Innovative Circle" co-operation agreement signed between Shenzhen Municipal Government and HKSAR Government to promote technology collaboration.

Detailed system design was started immediately and was completed in end March 2010. Approximately 11,000 concrete blocks, 22,000 fixing brackets, 119 sets of electrical equipment, 100,000 metres cables and cables supports were required.

Installation of PV module supporting concrete blocks and erection of PV modules onto the concrete blocks at various rooftops were commenced in end March 2010.

Individual PV system testing and commissioning was started in early May 2010 and completed in end June 2010. The overall project schedule is shown in Figure 7.

Figure 7 Project Schedule

Activities	Date														
	04/09	05/09	06/09	07/09	08/09	09/09	10/09	11/09	12/09	01/10	02/10	03/10	04/10	05/10	06/10
Feasibility Study and Site Investigation	■	■	■	■	■	■									
Supply Tender							■	■							
Detailed Design									■	■	■	■			
Erection Tender										■	■	■			
Construction												■	■	■	
Testing and Commissioning														■	■

From initial study, the project takes 15 months to complete.

5. SYSTEM CONFIGURATION

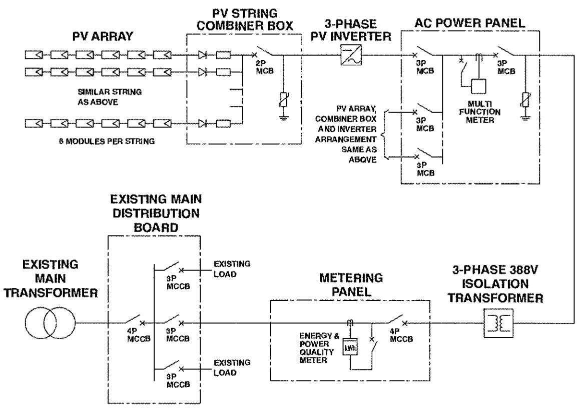
As the solar power system is a grid connected system, the "Teehnical Guidelines on Grid Connection of Renewable Energy Power Systems" published by the Electrical and Mechanical Services Department (EMSD) and relevant information of renewable energy and solar system in the "HK RE Net" (http://re.emsd.gov.hk/) launched by the Energy Efficiency Office (EEO) of the EMSD, have been scrutinized and used as reference in design of the Lamma PV system. The home page of "HK RE Net" is shown in Figure 8.

Figure 8 Home Page of HK RE Net"

a. Basic system design

Amorphous silicon thin film PV modules are connected in series and grouped in form of PV strings through combiner boxes, which are further connected to PV inverters for converting to AC 380V 3-phase power supply for grid connection to the electrical system. Associated electrical components such as AC power panels, isolation transformers, metering panels and cables have been installed to form as a completely workable system. The simplified single line diagram of the PV System is shown in Figure 9.

Figure 9 Simplified Siugle Line Diagram of PV System

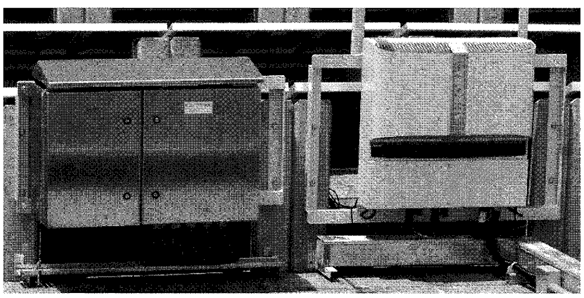


lnstead of using large capacity PV inverters, 10kW and 12.5kW 3-phase PV inverters are adopted to inerease the overall system availability and flexibility in operation and maintenance. Having considered open circuit voltage at 99.29Vdc of each PV module, nominal DC input voltage of 580Vdc and maximum power point tracking (MPPT) operating range at 200 - 850Vdc of PV inverters, six (6) PV modules is connected in series to form a PV string.

There are two (2) MPPT channels available in each selected 3-phase inverters, which are used for individual output control of two PV arrays with different configuration, different characteristics or under different environmental conditions. However, considering respective PV array for each PV inverter is installed in the same location and will be exposed to the same environmental conditions, separation of original PV array into two (2) smaller PV arrays will not contribute to significant improvement in PV module output but leading to additional cabling work. Two MPPT channels are connected in parallel for accepting power generated from one (1) PV array.

To provide sufficient power to PV inverters, PV strings are connected in parallel to form a PV array. Two types of PV combiner boxes capable of accepting maximum connection of 20 PV strings and 24 PV strings are used for interface with 10kW and 12.5kW PV inverters respectively. Blocking diodes for current flow control and fuses for overcurrent protection are provided for each PV string. PV inverter and combiner box installed at the roof of Units 1-3 Boiler House are shown in Figure 10.

Figure 10 PV Invertcr and Combiner Box



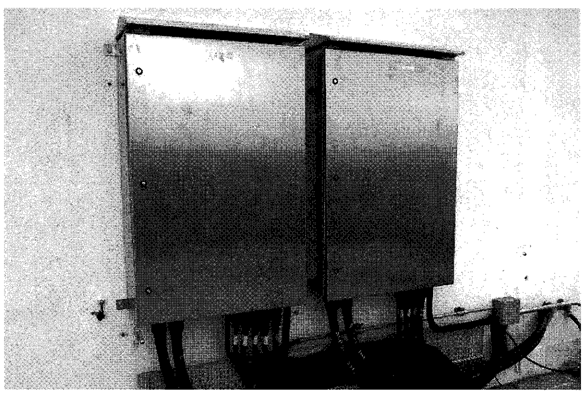
PV inverters are designed for automatic grid connection applications. When PV Array output voltage reaches 200Vdc, PV inverters will be started up automatically. PV inverters starts grid connection check once the output voltage of PV array is at 360Vdc after higher solar irradiance is captured by the PV array. PV inverters connect to the grid automatically when the grid voltage and frequency are within operating range.

To comply with safety requirements on the electrical system which is dual fed from a normal supply and from the PV system, all PV inverters are equipped with anti-islanding protection so that PV inverters will be shut down automatically when the normal supply of the electrical system is isolated.

AC power panels are installed at each location for linking up PV inverters and for transmitting AC power supply from PV inverters to the grid connection points in Switchgear Bay at 1/F Main Station Buildings. To prevent injection of direct current into the electrical systems, isolation transformers have been provided near the grid connection points. Metering panels complete with 4-pole MCCB and power quality analyzer are installed in vicinity of the grid connection point for completion isolation of the PV system and measurement of instantaneous voltage, current, power, harmonics as well as accumulative electricity supplied from the PV system respectively.

All equipment to be installed at outdoor location is weatherproof type with minimum degree of ingress protection at IP 55. Sunshade is provided for those PV inverters and electrical panels which will be exposed directly to sun light. Surge arrestors are fitted to electrical equipment and instruments for lightning and overvoltage protection. Weatherproof type electrical panels with sunshade are shown in Figure 11.

Figurc 11 Watcrproof Typc Electrical Pancls



For verification of PV system performance, solar irradiance meters, ambient and module temperature scnsors are installed at each roof areas for acquiring environmental data. All the instruments together with PV inverters and power quality analyzers are connected to the Remote Monitoring Computer at Central Control Room of Lamma Power Station via RS485 communication links.

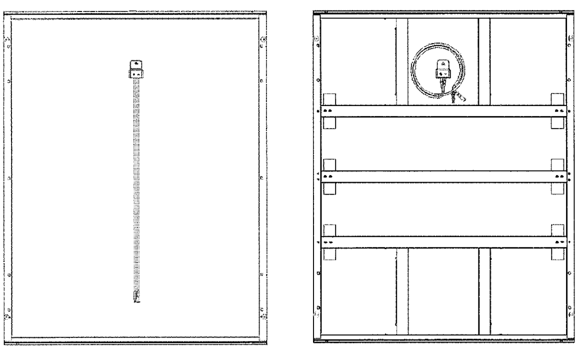
The Remote Monitoring Computer is industrial grade PC designed for 24 hours continuous operation. The Computer is further connected to Centralized Historical Information System (CHIS) in Lamma Power Station by high speed communication link for long term historical data storage and remote access by PCs in the offices via Corporate LAN.

Present solar irradiance, present electricity output, cumulative electricity production and aerial view of the PV system are repeated to the 42" LCD display at Visitor Centre for introduction of the large scale solar system to visitors.

b. Particular design to suit site conditions

The TFPV modules proposed by Du Pont are manufactured and tested according to IEC standards. The maximum mechanical load of the standard module is 2,400Pa/m^2. However, to comply with the Wind Code of HKSAR and to meet the prevailing strong wind conditions at roof areas especially for Units 1-3 Boiler House which is about 80 metres above ground, additional stiffeners have been installed at the back of PV module. The maximum mechanical load of the final TFPV module after strengthening is 5,600Pa/m^2. The construction of PV module before and after strengthening is shown in Figure 12.

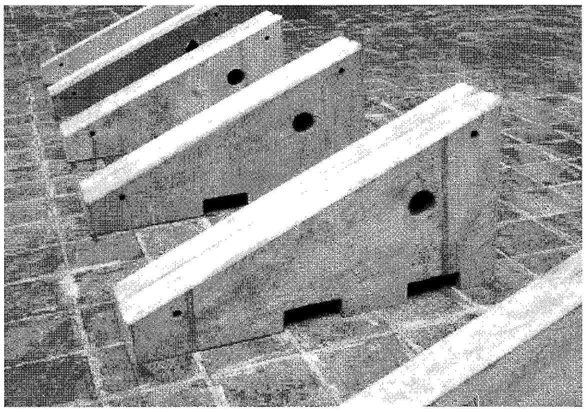
Figure 12 Stiffeuers of PV Modules



Before strengthening **After Strengthening**

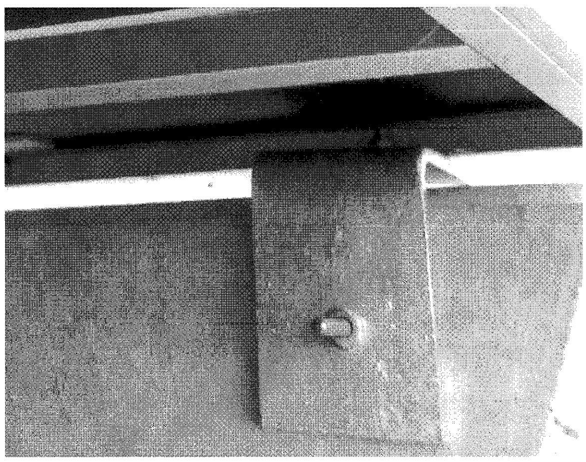
In order not to damage the waterproofing layers of roof floors, typical installation method of PV modules using metallic structure fixed by anchor bolts should be avoided. Instead, pre-fabricated concrete blocks had been specially designed to ensure that PV module will be sitting at 22° after installation and will be freely stood on the roof floor combating with the wind load by its own weight. Layout of the concrete blocks is shown in Figure 13.

Figure 13 Coucrete Block for PV Modules Support



PV modules are fixed onto concrete blocks by four (4) angle steel brackets together with bolts and nuts. Insulated washers are inserted between the contact surfaces of aluminum frame of PV module and angle steel brackets to inhibit galvanic corrosion. The angle steel bracket for fixing PV module is shown in Figure 14.

Figure 14 Augle Steel Bracket for PV Module Fixiug



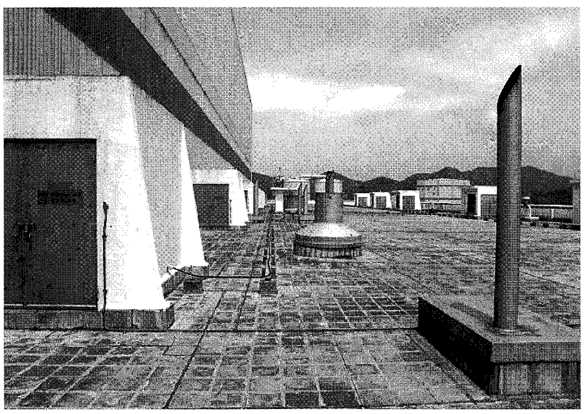
All PV modules in the same row are tied together by bolts and nuts for better PV array alignment and increasing the overall dead weight of the whole assembly. The completed PV installation at the roof of Units 1-3 Boiler House is shown in Figure 15.

Figure 15 Completed PV System

6. CHALLENGES

Existing services, such as silencers, vent pipes, ventilation fan enclosures, water tanks, antenna poles, horizontal air termination conductors, etc. are distributed over the rooftops. Repeatedly detailed site measurements and computer simulations had been conducted to find a suitable location on the roof for retrofitting large scale solar power system without any shade to set up PV modules while not affecting plant operations. The layout of roof area is shown in Figure 16.

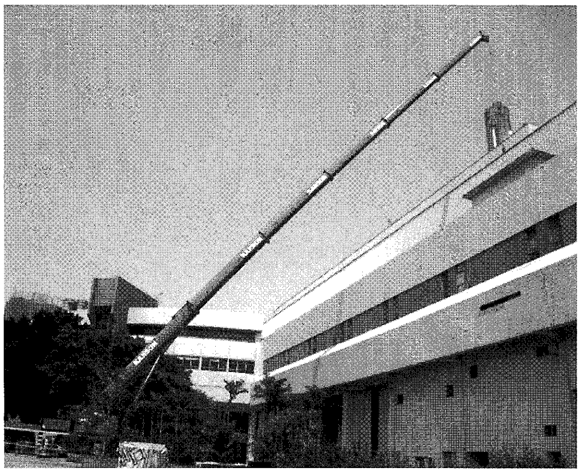
Figure 16 Layout of Roof Area



As aforementioned, a large quantity of PV modules, concrete blocks, PV module fixing accessories, electrical equipment, cables and cable supports were required to be transported to roof areas for installation.

Due to no proper route is available for delivery of material using fort lift and trolleys, a 250 tonne crane had been deployed for transportation of materials from ground level to roof areas. To ensure safe and efficient operation of the 250 tonne crane, method statement and risk assessment report on the lifting work had been submitted and approved well before work commencement. Lifting of material using the 250 tonne crane is shown in Figure 17.

Figure 17 Lifting of Materials by 250 Tonne Crane



Most of the equipment is located outdoors. To minimize outdoor erection work to be carried out in hot and high humid weather conditions during the summer time, rainy and typhoon season in Hong Kong, the site work has to be executed on fast track basis. In particular extremely hot environment of Boiler House further increases the degree of difficulty in installation work. Close site supervision and well planning on erection, testing and commissioning work are thus required.

Paper No. 1

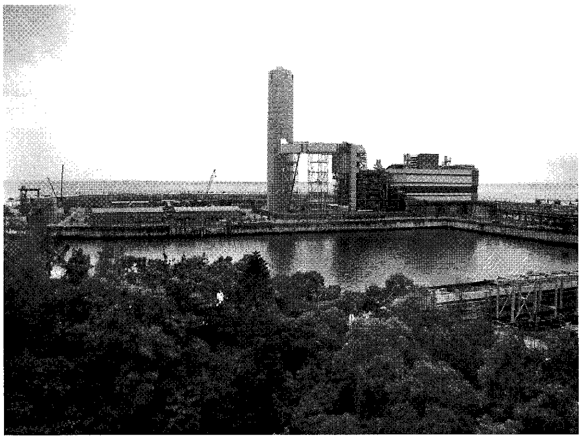
SIEMENS

7. ENVIRONMENTAL BENEFITS

The anticipated annual output of the PV System after computer simulation using solar irradiance and climatic data from NASA and Hong Kong Observatory is 620,000kWh. The capacity factor is 12.9%.

Comparing with conventional coal fire generating units in Lamma Power Station, the PV system will reduce emission of about 520 tonnes of carbon dioxide a year which is equivalent to planting 22,000 trees. The amount of sulphur dioxide and nitrogen oxides emissions is also reduced, thus further improving Hong Kong's air quality. A beautiful landscape in Lamma Power Station is shown in Figure 18.

Fignre 18 Beautiful Landseape in Lamma Power Station

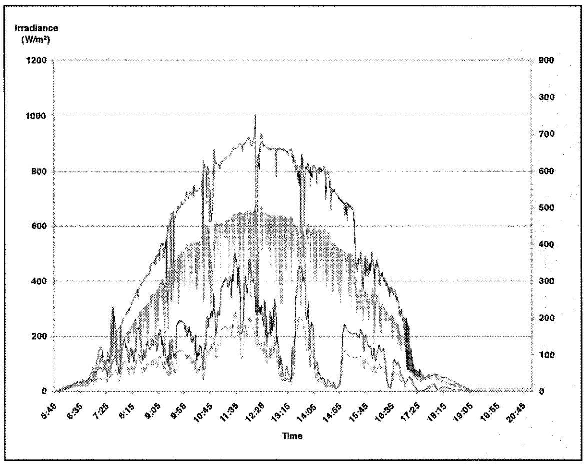


8. INITIAL SYSTEM PERFORMANCE

Since commissioned in end June 2010, total electricity output from the PV system for one month is about 88,000kWh. The capacity factor is 21.5% which is well above the design capacity factor of 12.9%.

Typical solar irradiance data and associated system output for sunny and cloudy/rainy are shown in Figure 19.

Figure 19 Solar Irradianee and System Output under Sunny, Cloudy & Rainy Conditions



Legend

- Solar irradiance (Sunny)
- Output (Sunny) - total 3,582kWh
- Solar irradiance (Cloudy & rainy)
- Output (Cloudy & rainy) - total 1,258kWh

Electricity output varies with solar irradiance conditions. The result shows that electricity generated from the PV system under cloudy and rainy conditions is about 1/3 of total electricity generated from the system under sunny day with strong solar irradiance, which is very impressive.

To review the performance of PV module output under high PV module temperature and various weather and seasonal conditions, solar irradiance, ambient temperature and PV module temperature sensors have been installed at each location for data collection.

The solar irradiance, ambient and PV module temperature and PV array output current in

SIEMENS

sunny, cloudy and rainy days during initial operation phase, which were captured by the sensors, are tabulated in Figures 20 & 21.

Figure 20 Environmental Data and PV Array Current for Sunny Day

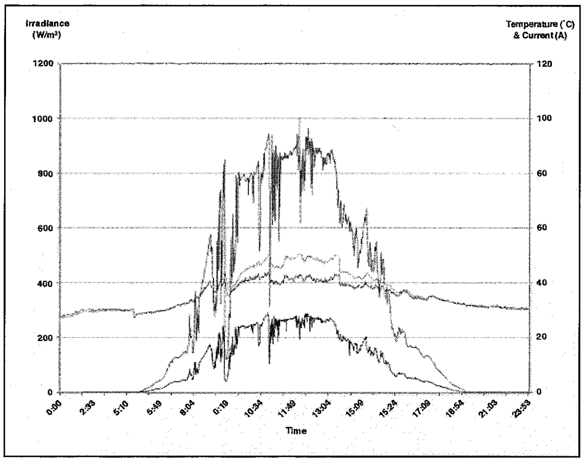
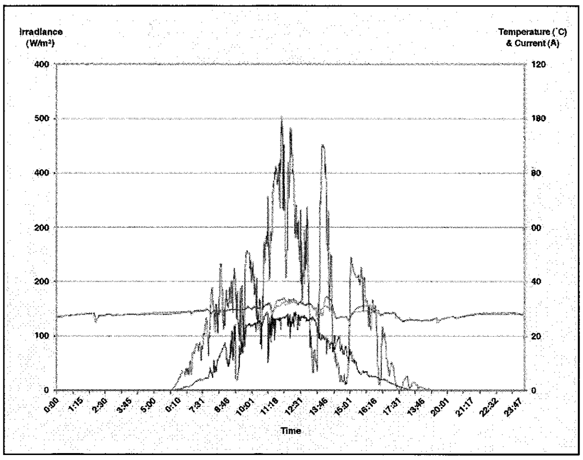


Figure 21 Euvironmental Data and PV Array Outpnt Current for Clondy and Rainy Day



Legend

——— Solar irradiance

——— PV module temperature

——— Ambient temperature

——— PV array current

Despite not significant, there is some sign that the power output of PV modules somewhat decreases with increase in module temperature.

9. CONCLUDING REMARKS

The successful completion of the solar power project marks another milestone for HK Electric in harnessing renewable energy (RE) for power generation in Hong Kong for better air quality since introduction of wind energy to the city by building and operating the only commercial scale wind power station on Lamma Island in 2006.

The completed 550kW solar power system is now the largest solar power system in Hong Kong and is also the first large scale project applying amorphous silicon thin-film technology.

Based on initial results, amorphous silicon PV module is considered suitable for use in the site conditions of Lamma Power Station.

HK Electric will continuously evaluate the system performance of the 550kW PV system and conduct further study for the possibility to expand the solar power system to achieve a total capacity of 1MW.

REFERENCES

[1] "HK RE Net" web site

[2] Technical Guidelines on Grid Connection of Renewable Energy Power Systems 2007 Edition.

[3] "What is the energy payback for PV?", U.S. Department of Energy.

[4] "Weak Light Performance and Spectral Response of Different Solar Cell Types", N.H. Reich - Dept. of Science, Utrecht University.

[5] Web site of Solarbuzz, LLC.

[6] Technology Roadmap Solar photovoltaic energy, International Energy Agency.

SIEMENS

- Notes and Questions -

Paper No. 2

SMART GRID – THE WAY FOR RENEWABLE ENERGY INTEGRATION TO POWER GRID

Speakers : Dr Jin Zhong, Associate Professor
Ir W.K. Lee, Senior Teaehing Consnltant
Department of Electrical and Electronic Engineering
University of Hong Kong

SMART GRID – THE WAY FOR RENEWABLE ENERGY INTEGRATION TO POWER GRID

Dr Jin Zhong, Associate Professor
Ir W.K. Lee, Senior Teaching Consultant
Department of Electrical and Electronic Engineering
University of Hong Kong

Paper No. 2

ABSTRACT

Electrical energy has become the most important secondary energy in the modern society. Traditional fossil-fuel power plants are the major emitters of pollutants and green house gases. The environmental and energy depletion issues are the incentives to develop renewable energy generation and integrate the generators to power grid. Smart grid technologies provide the platform for renewable energy integration to power grid.

Energy efficiency can be improved by renewable energy generation and clean energy based distributed generation, whereas mitigate the environmental problem. The other method to improve energy efficiency is two-way demand side management (DSM). For example, electrical vehicle (EV) is well accepted as an environmentally friendly way of demand response. The intermittent renewable energy increases generation uncertainties in power grid. Energy storage is necessary to a grid with a high penetration of wind and solar generation. The real time control on distributed generation and demand side response requires fast, two-way modern information and communication technologies (ICTs). The international trend in smart grid development is to start from distribution network and demand side by installing advanced metering infrastructure (AMI), ICT, distributed renewable generation, and distributed storages. In this paper, we will discuss these issues and the application of smart grid technologies in power systems.

1. INTRODUCTION

Power industry has been developed for more than one century. Nowadays, electricity is a necessity of daily life. Power system automation technologies have been developed and applied in power grid operation and control since 1960s. The existing power system automation techniques support automatic generation control, automatic fault clearance, automatic voltage regulation, large system inter-connection, etc. The reliability of power supply has been improved significantly due to the application of automation and control techniques in the past decades. Since the beginning of the 20th century, large-scale electric power plants have been developed as the major generation techniques due to the economy of scale of power industry. Thermal power plants that burn fossil fuels, mainly coals, have been used as the major generation sources. In 2009, around 66% of electricity allover the world is generated by fossil fuel power plants. The efficiency of traditional fossil-fuel thermal power plants for converting energy of fuels to electrical energy is usually around 1/3, which is not high. The CO_2 and sulfur emissions from fossil-fuel power plants exert pressures on environment.

Nowadays, power industry is facing many challenges from various aspects. With the development of economy, there is an increasing demand for electricity. However, we are facing energy issues caused by energy crisis and environmental problem. The modern society has higher requirement on reliability, security and quality of power supply, but many transmission and distribution facilities currently on operation were built decades ago. Infrastructures for power generation and delivery need to be upgraded.

Smart power grid has been raised recent years as a solution of energy and environmental issues. In traditional power systems, power flows from generation units to transmission and distribution (T&D) grid then to consumers. With the installation of distributed generation (DG) at customer sides, power could also flow from customer side to T&D grid. Generators, grid companies and customers all have information exchange with control center through communication networks. Smart grid technologies apply to all sections of power system, generation, T&D grid and consumer, as well as control center. Customers' role in smart grid is mainly demand response. Smart meters and advanced metering infrastructure (AMI) provide hardware support of demand response. The role of generation section in smart grid is renewable energy integration. For transmission and distribution systems, smart substations and installations of phasor measurement units (PMS) and wide area management system (WMU) provide the possibility of forecasting fault events in advance. As the brain of the power system, control center play an important role in smart grid. A smart control center requires integrated communication, advanced control and improved interfaces for decision making support. On the other hand, a mature electricity market as well as regulations and policies are needed to facilitate the functions of smart grids.

2. CUSTOMER DEMAND RESPONSE IN SMART GRID

In the U.S. and some European countries, the implementation of smart grid starts from customer sides. Electricity consumers, in the past, are passive users. By installing smart meters and AMI, a customer could adjust his energy consumption pattern according to real-time electricity price. If the customer has his own distributed renewable energy generation, e.g. solar panels and small wind turbines, he can sell surplus electricity to the grid during the peak-load hours. In this case, smart meters will be the smart agent with optimization functions as well as two way communication functions. The AMI system installed over a distribution system will enable consumers to participate in demand response programs. With a well designed economic incentive mechanism, electricity users' energy consumption patterns could be adjusted to an optimum way. For example, some appliances are scheduled to run during the hours of low electricity prices, which are usually non-peaking periods. The surplus electricity generated by customer owned distributed generators are storage in batteries for selling to the grid during the peaking load hours at higher electricity prices. Customer demand response can help shaving peak load, hence reduce the capacity reserve requirement of increasing demand. The implementation of demand response requires 1) AMI and smart meters to measure electricity consumption and response to the electricity prices and commands sent by the system operators; 2) real-time (RT) or time of use (TOU) pricing mechanisms to encourage consumers to participate in the program.

The AMI mentioned in smart grid is different from the automatic metering reading that has been applied in some utilities. AMI has more two-way communication functions. For an AMI system, all smart meters at a home (electricity, gas, heat and water meters) communicate with the data concentrator through local area network (LAN). Through the wide area network (WAN), the concentrator exchange data with AMI host server, which is managed by the meter data management system (MDMS). Installing smart meter is the first step of implementing smart grid. In some countries, electricity utilities have started to install smart meters to their customers. In Italy, smart meters have been installed in over 30 million homes, which lead to 5% energy saving per year. In the U.S. 13 million smart meters have been installed by 2010, more will be installed later. Tokyo Electric Power plans to install smart meters to their 27 million customers free of charge. Some other countries are also planning to start smart meter and AMI projects.

3. RENEWABLE ENERGY INTEGRATION TO GRID AND ENERGY STORAGE

Renewable energy generation is an effective solution to environmental and energy crisis issues. Howcver, there are some technical concerns of connecting renewable energy generation. Smart grid provides a technical platform for renewable energy grid integration.

Renewable energy generation could be installed either at the generation side, such as large wind farms and solar farms, or at the customer side as distributed generation (DG). Distributed generations refer to those small-scaled generators installed close to customers. DGs are usually clean energy or renewable energy based generators, such as, combined head and power (CHP), micro turbine, fuel cell, wind turbine and photovoltaic panel, etc. To a traditional power grid, the concern of connecting DGs to the distribution network is the reverse power flow from DGs to the grid when a local microgrid generates more power than it consumes. Traditional protection schemes need to be re-designed to accommodate bi-directional power flow.

Large-scale renewable energy generation connecting to power grid is constrained by the security and reliability operation requirements of power systems. Renewable energy, e.g. wind and solar, has intermittent characteristics. The generations of wind farm and solar farm are unstable and uncontrollable. Although power system automatic generation control (AGC) and spinning reserve capacity can compensate some load deviations in short term, the sudden changes of power outputs due to intermittent wind power and solar energy require a much higher amount of compensation in a short time. The traditional AGC and reserve criteria may not be enough. More ancillary services and fast generation compensations are needed. Large capacity of wind turbines will also cause voltage problems and harmonic issues. Until these technical issues are solved, the total capacity of wind farm connecting to a power grid will be limited under certain penetration levels.

Energy storage is the solution to compensate intermittent renewable energy generation once practical and inexpensive energy storage methods are developed maturely. Electric energy could be stored mechanically through pump storage, compressed air, and fly wheel; or stored electro-magnetically through superconducting magnetic storage, and super-capacitor; or stored electron-chemically through lead-acid battery, flow battery and other advanced battery technologies.

Large-scale energy storage system could be installed at the generation side coordinating with wind and solar generation. For example, a combined renewable energy system with wind farms, solar panels and storage system (e.g. pump storage station) will provide a stable output profile of renewable energy to the power grid. A well-developed storage system could also be used to provide ancillary services to power grid. The optimization and coordination of renewable energy generation and storage charging and discharging is a key issue of improving energy efficiency of the combined renewable energy system. The other challenge is developing mature storage techniques that are practical and inexpensive for large-scale storage usage.

Distributed energy storage as well as distributed renewable energy generation are the key components in customer demand response in additional to consumption pattern adjustments using smart meters. Battery is a popular storage method for distributed energy storage. The combination of small renewable energy generators and batteries could be used as stand-alone system or used for grid-connected micro-grid system.

Electric Vehicle (EV), especially EV to Grid (V2G) technique, is a very important issue in smart grid. EV could perform as generation as well as storage with a V2G control system. EV could be used for leveling peak load, and as a backup for power failure. EV is an effective means of street CO_2 reduction. V2G is a promising technique for the future. However, to use EV in a wide range, some issues need to be considered 1) A high penetration of EVs may affect the existing power system operation, a smart power grid will have the capability of accommodating high penetration of EVs; 2) Standards need to be set to solve the problem of reverse power from EVs; 3) More charging spots and replacing stations are needed for drained batteries, so it is convenient for customers to use EVs.

Renewable energy and storage integration to power grid will provide a solution to energy and environmental issues. The coordination of renewable, storage and EV will significantly reduce the fluctuation of renewable energy generation. However, there are some barriers of accommodating all generation and storage options in power grid. The cost of owning these generation sources and storages are high. Consumers and investors are not motivated to invest. The techniques of grid-connection with high penetrations are not mature. To break the barriers, the smart grid needs to have 1) applications and standards that support Plug and Play functionality; 2) operational and planning tools; 3) smart sensors and smart controllers; 4) real-time pricing mechanisms.

5. FUTURE CONTROL CENTER AND ICT APPLICATIONS

Information and communication technologies (ICT) are the fundamental of power system automation. The existing automation consists of: supervisory control and data acquisition (SCADA), energy management system (EMS), distribution management system (DMS), distribution automation (DA), substation automation (SA), and feeder automation (FA), etc. Most utility companies started to construct their automation systems since 1980s. The automation techniques significantly improved system reliability and service of power supply.

In the past decade, the information revolution has changed human's living style. Applying the latest ICT to power system automation will significantly improve efficiency of energy usage, improve power quality and reduce total cost. According to DOE, the capabilities of smart grid include: self healing, consumer participation, high quality of power, resist attack, accommodate diversified generation options, enable power market, optimize asset, and enable high penetration of intermittent generation sources [1]. ICT will be the fundamental and necessary techniques to implement these functions of smart grids.

Substations are important nodes in a power grid that assemble all monitoring, protection and control devices. Substation also plays a role as collecting data from feeders and consumers, and communicating information with upper level control centers. Smart substations widely dispersed in the grid are key elements of a smart grid. A smart substation should be equipped with accurate data measurement units and data analysis tools for online network analysis. The standard communication and processes inside the station and among stations are also important for information exchange. Phasor measurement unit (PMU) will increase the accuracy of data measurement in power grid. The data measured by traditional remote terminal unit (RTU) is not synchronized. PMU data is synchronized by a global positioning system (GPS). A phasor data concentrator (PDC) collects data from PMUs and sends data to SCADA and wide area management system (WAMS). Using data from PMUs and applying wide area control, power system operating conditions can be accurately monitored and simulated; hence it is possible to forecast fault events before events occur. That will significantly increase the system security and reliability.

The future control center, by applying smart grid technologies, will be able to monitor operation conditions of primary devices, diagnose fault events, clear faults before they occur, support demand response, support intermittent renewable generations using real-time on-line data analysis and system control.

6. CONCLUSION

Renewable energy and customer demand responses are the major solutions of energy and environmental issues. Smart grid provides the platform for renewable energy integration to grid and customer participation. Latest information and communication technologies will improve power system operation though online data analysis and real-time control, hence improve power system security and reliability, and the quality of power supply. Various smart grid technologies applied in power generation, transmission, distribution and consumption will change customers' life styles, improve energy consumption pattern and the environment of the earth.

REFERENCES

[1] "A system view of the modern grid", reported by the NETL Modern Grid Initiative, 2007. Available at: http://www.netl.doe.gov/smartgrid/referenceshelf/whitepapers/ASystemsViewoftheModern Grid_Final_v2_0.pdf

- Notes and Questions -

Paper No. 3

BEIJING LINE 4 - STEEP CLIMB TO OPENING

Speaker : Ir T.M. Lee
Project Manager – SCL/KTE E&M
MTR Corporation Ltd.

BEIJING LINE 4 - STEEP CLIMB TO OPENING

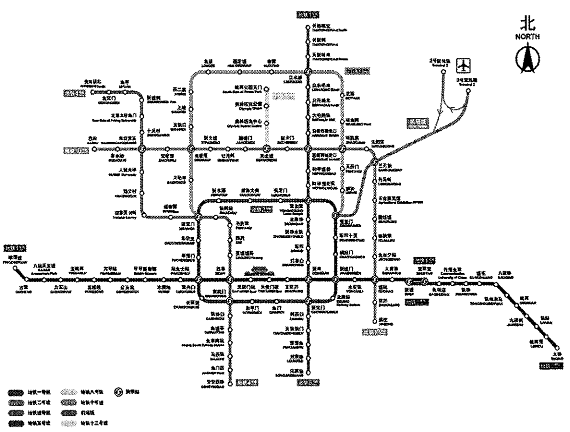
Ir T.M. Lee
Project Manager – SCL/KTE E&M
MTR Corporation Ltd.

Paper No. 3

ABSTRACT

Beijing Line 4 (BJL4), being the first PPP (Public Private Partnership) urban railway investment project in Mainland China, set many records when it was opened for revenue service on 28 September 2009, the 60th National Anniversary of PRC. It was the first time in Mainland China that a metro line of 28km and 24 stations was opened with ATO (Automatic Train Operation) system in full operation, achieving a headway of 3-minute. This paper gives an account of how the project team overcame the technical and political challenges, unfavorable circumstances and unexpected events that occurred during the testing and commissioning stages of the project and delivered a high performance Signalling System for revenue service. Currently, the Beijing metro network carries a daily average of 5.4 millions passengers with BJL4 contributing 0.75 millions or 14% of the total.

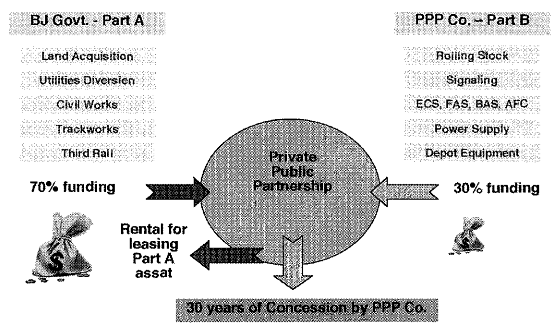
Figure 1 Beijing Metro Network



1. INTRODUCTION

Beijing MTR Corporation (BJMTR) is the first foreign invested cooperation company in urban railway transportation sector in Mainland China. BJMTR being a subsidiary of MTR was established in 16 January 2006. It is jointly invested by Beijing Infrastructure Investment Co. Ltd (BIIC, 2%), Beijing Capital Group (BCG, 49%) and MTR Corporation (MTR, 49%). The company is responsible for the investment and construction of the part B (Rolling Stock, Signal and E&M Systems), and will rent part A of the BJL4 project (Tunnels, Structures, etc). The company is granted under a Concession Agreement (CA) to operate BJL4 for 30 years upon the completion of construction.

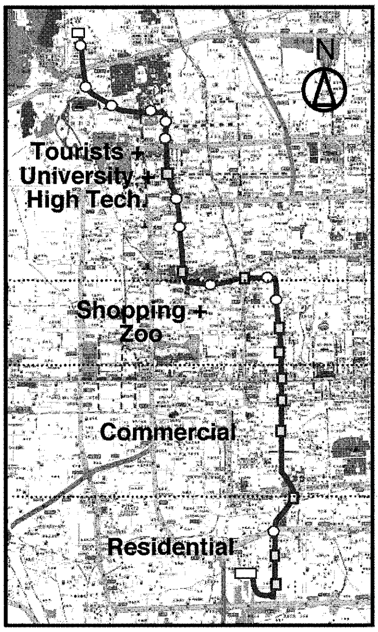
Figure 2 BJL4 PPP Overview



BJL4 is the major North-to-South traffic artery in the western part of Beijing. It is approximately 28.2 kilometers long with 24 stations, 23 stations are underground. There are 10 interchange stations (including 6 future lines) connecting BJL4 with other metro lines.

BJL4 is unique in that it goes through 4 major districts of the Capital, namely, Fengtai, Xuanwu, Xicheng and Haidian Districts. Along the line, there are dense residential areas, high-tech parks, university campus, hustle and bustle business areas and famous scenic tourist areas. The forecast patronage on Day One is about 600,000 per day.

Figure 3 BJL4 Alignment



Key Data

Route Length (km)	28.7
Stations (total/underground)	24/23
Depots	2
Interchange Stations - Initial	4
Ultimate	14
Journey Time (mins.)	48
Capital Cost (RMB)	15.3B
Opening Date	Sept 2009
Operating Concession (from date of opening)	30yrs

The BJL4 Signalling system was procured from a Consortium comprising Alcatel Shanghai Bell (ASB), Thales Rail Signalling Solutions (TRSS), China Academy of Railway Sciences (CARS) and China Railway Telecommunication Signalling Construction Company (CRSC). ASB is the leading partly of the Consortium with TRSS the technical solution provider, CARS the provider of the Depot/Stabling Yard Interlocking System and CRSC responsible for installation. The formation of a Consortium for the Signalling Contract was needed to fulfill the 60% local content requirement as stipulated by NDRC (National Development Reform Committee).

The BJL4 Signalling System is a Communication Based Train Control (CBTC) System developed by Thales. It is a radio based CBTC system with continuous Train-Track communication. To satisfy the CA requirements and to meet the 28 September 2009 BJL4 Opening target, a 2-Stage implementation approach was adopted for the Signalling System.

Stage 1 of the Signalling System was required to deliver a 3-min headway CBTC system on 28 September 2009 and Stage 2 a 2-min headway CBTC system by 28 December 2010. To aehieve these targets, the Stage 1 system was designed to be a CBTC fixed block system and Stage 2 a CBTC moving block system. Only software upgrade would be required to migrate from Stage 1 to Stage 2.

Figure 4 Signalliug System Stage 1 Architecture

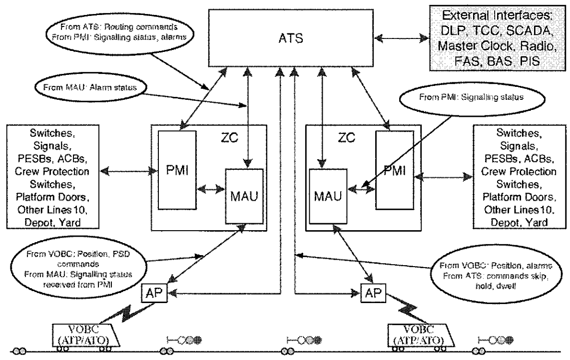
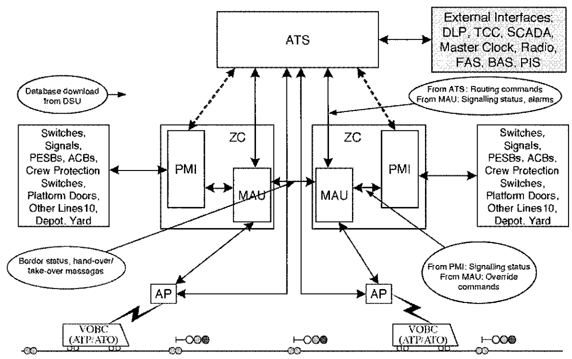


Figure 5 Signalling System Stage 2 Architecture



2. CHALLENGES

Signalling system is one the most critical systems to the reliable operation of a high performance metro line. Due to the very nature of metro construction projects, Signalling is always at the back end of activities and one that suffers the most from delays in civil and track-laying works. Without exception, Signalling is handed with the last baton and has to race under tremendous pressure to the finish line within the set time limit to succeed. This was also epitomized in the Beijing Line 4 project.

BJL4 is special not only because it was the first PPP railway investment projeet in the

Mainland but more importantly it was one of the major projects in the Capital to celebrate for the 60th National Anniversary of PRC. However, because of the 2008 Beijing Summer Olympics, the Government's focus in Beijing prior to August 2008 was on the Games preparation works and the accompanied infrastructure projects such as the Airport Railway and Metro Lines 8 & 10. The focus only shifted to the BJL4 project after the Olympics.

2.1 COMPRESSED PROGRAMME DUE TO LAND ACQUISITION ISSUE

The major obstacle to the BJL4 project and civil work progress was the land acquisition issue which was a problem throughout the construction of the project. Major land issues were only resolved in early 2009.

Land acquisition problem was not only confined to a small area but scattered in pockets over the entire 28km alignment. The biggest problem areas were the Depot/Stabling Yard lands at the Southern and Northern ends of the line and a military gas station located on top of the TBM tunnel near Yunmingyuan where a shaft has to be built to allow the TBM to exit and turn around. The land issue at Stabling Yard and the military gas station site were resolved in October 2008 and December 2008 respectively. The Depot land issue was more complicated and about 80% of the land was resolved by early 2009. The remaining 20% of the land which occupied section of the Heavy Maintenance Shed was only resolved three months after Opening.

The land acquisition issue severely affected the civil and track-laying programme to the effect that completion of track-laying was 11 months behind the original programme. Despite all the delays, the 28 September Opening date remained. To achieve the Opening target, the back end E&M works and in particular Signalling T&C had to absorb all the delays.

2.2 UNFORESEEN EVENTS

Other than the land acquisition issue, a number of unexpected events resulting in significant disruptions occurred at different stages of the BJL4 project.

i) Wenchuan (汶川) earthquake in May 2008

The earthquake occurred on 12 May 2008 in Wenchuan, affected the rail manufacturing at Panzhihua(攀枝花). The rail factory suffered only slight damage but the access road and railway from the factory to the outside world were severely damaged. Rail supply to BJL4 project was significantly affected and exacerbated the track-laying delay.

ii) Flooding of six Stations on 20 April and 13 June 2008

Heavy downpour flooded six stations in the southern end of the line twice within 2 months in 2008. Although signalling equipment was not affected, the HV and DC traction power supply equipment were severely damaged. All the damaged equipment had to be dismantled and new equipment had to be ordered, and re-installed, taking up to eight months to complete. Mitigation measures such as renting temporary power generator and re-sequencing the HV power on schedule contained the knock on impact to the T&C works of signalling and other E&M Systems.

iii) Olympics stop work period from mid July - end August 2008

Staging a successful and incident free Olympic Games was the number one priority to the Beijing Government and all construction works in Beijing were stopped before and during the Games. Over a seven weeks period, no construction activity is allowed in any of the BJL4 work sites.

2.3 TRAINING OF 350 DRIVERS ON THE MAINLAND

To properly train 350 train drivers is a challenge to any newly established metro operator in a new environment. For BJL4, the issue was made more difficult because of the civil delays and that most of the 350 drivers did not have any experience in train operation. To get around these problems, arrangements were made with the Beijing and Tianjin metro companies to train the BJL4 drivers in their Depot test track and later on at their operating lines after passing a driving test. In addition, some of the drivers were sent to Hong Kong to learn and practice their driving skills. With these measures in place, when the BJL4 Depot test track and the Mainline became available, all the drivers have acquired the necessary driving skills to take part in dynamic testing and the Trial Run.

2.4 OPERATIONS DRILLS DURING TRIAL RUN

Over 120 operations drills and exercises were required to be completed before BJL4 is allowed to put into revenue service. This posed a tremendous challenge to the management team as well as the operation staff given the time pressure they were under. The concurrent T&C works being carried out by Contractors certainly did not help. The management team utilized their Hong Kong experience and adjusted the drills and exercises based on the local environment and around the various project constraints. Some drills and exercises that are of similar nature were optimized or combined. Exercises that do not require train movements were scheduled during NTH. Flexible and pragmatic measures like these were instrumental in completing successfully all the required drills and exercises prior to the final stage of the Trial Run.

3. T&C INNOVATIVE STRATEGIES

To overcome the various delays and problems encountered in the project, particularly during the compressed T&C stage, pragmatic approach and innovative strategies that are unconventional in conventional metro construction projects were adopted.

3.1 UTILIZATION OF ROLLING STOCK FACTORY TEST TRACK

The 12-month delay in handing over the Depot Test Track to the Signalling contractor would have significant impact on the Rolling Stock testing as well as Signalling-RS interface test if decisive mitigation measure was not taken. As soon as the civil delay started to surface, the management team immediately looked for alternative test tracks in both Beijing and Qingdao, hometown of the Rolling Stock supplier Sifang (南車四方). After extensive site investigation and liaison with the owners of the various test track facilities, it was decided that utilization of the test track in the Sifang's factory at Qingdao was the most effective solution. Another set of Signalling Test Track equipment was purchased and fast track software development, installation and T&C enabled the Sifang test track to become functional in May 2008. RS-Signalling Static and Dynamic interface test of the first train started at the Sifang test track in June 2008 and continued until the last train was delivered in August 2009. Without the Sifang test track, Opening on 28 September 2009 with all 40 trains operating in high performance conditions under a 3-min headway timetable would not be possible.

3.2 CUSTOM MADE RADIO SURVEY METHODS

Signalling system, along with Rolling Stock is most affected by any delay in track-laying. This is not specific to BJL4 but prevalent to all metro construction projects. A radio based CBTC system relies heavily on adequate radio coverage for it to work properly. Site radio survey is an important exercise to verify the radio design before installation of radio Access Points (AP) on site. Under normal practice, radio survey is done with test equipment such as antenna and spectrum analyzer mounted on a wagon in such a way that mimic the actual configuration on a train. The wagon is pulled along the track area under test by a locomotive and radio signal strength measurements are collected.

This could not be used at BJL4 as time pressure did not allow the Signalling contractor the luxury of waiting for track-laying to be eompleted before doing the measurements. Instead, as soon as the short rails were laid, a specially built hand push trolley mounted with relevant equipment was used to take the required measurements. This method of work saved up to 4 weeks of time in the Signalling T&C programme.

3.3 CASCADED MAIN LINE TESTING

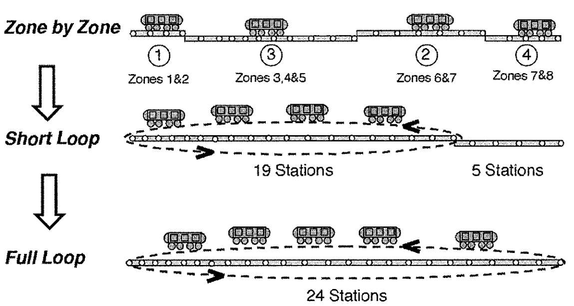
Due to land acquisition issue, the track-laying works was completed in batches and not in the original sequence. The entire mainline had to be split into 4 sections with each section having a different track-laying completion date. Signalling dynamic tests conducted over the entire mainline end to end continuously was not possible. An alternative plan was devised whereby mainline Signalling dynamic test was split into 4 sections and cascaded in such a way that aligned with the track-laying works.

Table 1 Sigualling Dynamic Test Sequeuce

Test Sequence	Coutrol Zone	Dyuamic Test Start Date
1	1 & 2	28 March 2009
2	6 & 7	18 April 2009
3	3, 4 & 5	10 May 2009
4	7 & 8	21 June 2009

This innovative method of dynamic test was needed under this special circumstance. All parties supported that this was the only way to meet the Opening deadline. With the full support and cooperation by the Contractor, Signalling dynamic test started in the sample section of Zones 1&2 on 28 March 2009. The other mainline sections were merged progressively and Signalling dynamic test gradually expanded to cover the entire mainline by 21 June 2009.

Figure 6 Signalling Dynamic Test Sequeuce



3.4 TRIAL RUN INTERLEAVES WITH T&C

To meet the statutory requirement of 3-month Trial Run before a metro line can be certified for revenue service, Trial Run covering the small loop of 19 stations from Gonyixiqiao to Zhongguancun started on 20 June 2009. Although all the safety related tests have been passed and certified by the contractor's independent safety team, a lot of non-safety related ATS functions were incomplete when Trial Run started. In addition, a large amount of civil, trackwork and E&M systems remedial works requiring track access needed to be completed before Opening.

After intensive coordination with all the stakeholders, a timesharing arrangement was agreed and implemented. This entailed splitting a working day into 3 sessions. The Trial Run occupied the 5am to 2pm timeslot, Signalling T&C took the 2pm to 11pm timeslot and the remaining time was shared by civil, trackwork and E&M Contractors. Time was invaluable and all parties worked as a team to get the work done in a collaborative manner. Everybody helped each other and not an hour was wasted. This really epitomised the teamwork spirit in the BJL4 project.

4. SIGNALLING SYSTEM T&C PROBLEMS

It was not surprising that most of the critical and operation related problems found during dynamic test and Trial Run were associated with the Signalling System which is common in any metro construction project. In BJL4, owing to the extensive testing done in factory and at the Sifang test track, the number of Signalling problems found on site was not excessive and very much under control. The exception is the Train-Track communication loss problem which only surfaced during Trial Run and under full load conditions.

Other Signalling problems such as black out of Train Operator Display (TOD), Vehicle On Board Computer (VOBC) going passive and

ATO stopping accuracy were largely resolved before official assessment of Trial Run started.

4.1 TRAIN-TRACK COMMUNICATION LOSS

The Train-Track communication loss problem surfaced only 2 months before Opening. The problem was first observed during the second stage of the Trial Run around mid August 2009 that Train-Track communication loss suddenly appeared with over 100 occurrences per hour. Of these communication losses, about one third triggered the VOBC to apply Emergency Brake (EB) to stop the train when communication loss lasted over 3 seconds. This problem caused the Punctuality of train service to drop below the Government target of 80% as EB trains have to run in Restricted manual (RM) mode of only 25km/hr until Train-Track communication is re-established.

Series of tests narrowed down the problem be caused by unauthorized ATS data blocking the transmission of data from trackside to train via the AP, but the root cause was still unknown.

An interim solution called "Slow and Go" was developed to allow the trial run to continue. This function forces a communication loss train to slow down in accordance with the re-calculated speed profile and allows the affected train a longer time to re-establish communication and regain ATP/ATO operation. With this function activated, the number of EB trains was effectively reduced and helped to keep the Punctuality figure above the Government Trial Run assessment target. This also allowed the DCS team the valuable time they required to find the ultimate solution to resolvc the communication loss problem.

After a week's intensive testing the team found the solution and the communication loss problem was successfully resolved in the first week of September.

5. TRIAL RUN PERFORMANCE

The BJL4 Opening criteria set out by the Beijing Government included the following:

i) 3-Month Successful Trial Run

ii) 3-min Headway with ATP/ATO

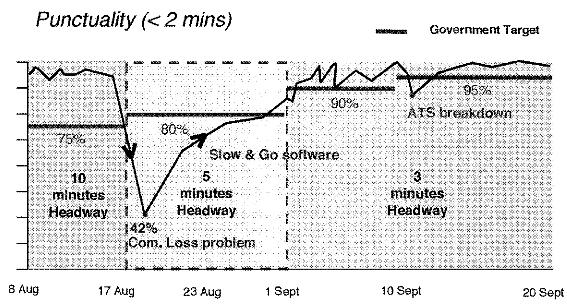
iii) Train Services Performance - 95% for Availability & Punctuality

iv) Statutory & Safety Inspections Validated by Expert Panel

Trial Run officially started on 20 June 2009 on section by section basis, and the Beijing Government's formal assessment of Trial Run was conducted over 4 stages from 8 August to 20 September 2009 with performance requirements increasing progressively over each stage.

Over the entire assessment period, the only occasion where the Government target was not met was the failure to achieve the Punctuality requirement of 80% during Stage 2 of the Trial Run. This occurred during the Train-Track communication loss period where trains frequently went into Restricted Manual (RM) mode with speed limit of 25km/hr. Once the Train-Track communication loss problem was mitigated and finally resolved, the more stringent Stages 3&4 Trial Run acceptance criteria set by Government were all achieved and paved the way towards Government approval of Opening on 28 September.

Figure 7 Trial Ruu Assessmeut Graph



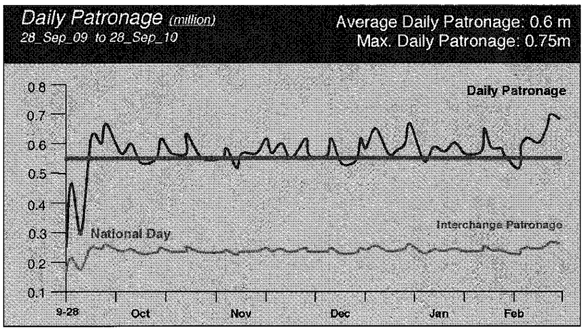
6. BJL4 ANNIVERSARY AND NEXT CHALLENGE

6.1 BJL4 ANNIVERSARY

On 28 September 2010, BJL4 successfully

completed its first year of Revenue Service. All the key service performance indicators achieved and exceeded by a good margin the Concession Agreement (CA) requirements. The Train Service Availability and Punctuality were consistently maintained over 99.5% during the first year of revenue service. The average monthly patronage was on a steady increasing trend. In fact, during peak hours, the maximum carrying capacity was reached since July 2010.

Figure 8 BJL4 Patronage September 2009 to September 2010



7. CONCLUSION

Whichever way we look at it, Beijing Metro Line 4 (BJL4) has been a phenomenal success in the eyes of all the stakeholders, including MTR, our JV partners, the Beijing Government, the Beijing community and all the parties involved in the construction. The line was opened to the public on time with 3-minute headway operation on 28 September 2009 after 5 years of construction.

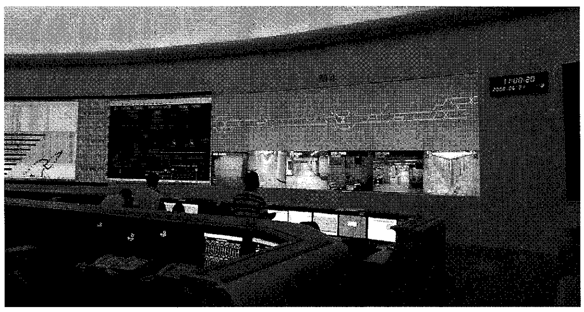
Figure 9 Lining Up for Eutry

Since opening, all the railway systems have been performing reliably and met all our KPIs, not to mention the Beijing Government's targets. Train service availability and punctuality have reached 99.94% and 99.7% respectively. Daily patronage has been steadily rising with a daily average of over 650,000 passengers and a daily peak of 996,000 passengers on the Labour Day Holiday.

Just six months after opening, the line has carried over 100 million passengers, which is probably a record for any newly-opened line. With all the unique design features transferred from MTR HK during the construction stage, it is safe to say that BJL4 is now the best metro line in Beijing. Also, the success of BJL4 has attracted countless visitors from the Central Government, including the Chairman of China, metro operators in various Mainland cities, HKIE Delegation, and SMRT of Singapore etc.

What is remarkable about BJL4 is that it was a project full of huge challenges and risks and yet it was delivered on the due date, well within budget and meeting all the expectations of the stakeholders. The challenges came firstly from the huge scale of the project, i.e. for MTR to invest, construct and operate a 28km line with 24 stations in the Capital. Secondly, it is the first Public-Private Partnership (PPP) railway project in China which means it was a new endeavour for all the involved parties. Thirdly, it had to operate reliably right from Day One with 3-minute headway because of the anticipated patronage demand.

Figure 10 OCC During Commissioning



The success in overcoming the project challenges has set many records in the metro industry and raised the bar for other metro project teams, both in China and abroad.

Amongst all the records set by BJL4, probably the most significant one is the Day One delivery of full functionalities of the signalling system, operating at 3-minute headway with Automatic Train Operation (ATO). And yet through innovative planning of the commissioning activities, it only took six months, instead of the conventional nine to twelve months, to fully complete the commissioning and trial running of 40 trains and a modern wireless Computer Based Train Control (CBTC) Signalling system.

The success is the result of the hard work and team spirit of all the involved parties in achieving the common goal of opening the line before the 60th Anniversary of New China. It is safe to say that rarely has any signalling system been delivered before with full functionalities and operating at 3-minute headway on Day One with such a short testing duration. The success of BJL4 therefore warrants reflection on how we could improve delivery of future signalling system, which is always the final piece of the jigsaw puzzle for successful opening of a new railway line.

In December 2010, BJL4 will be coupled with Daxing Line when it is completed by the Beijing Government and will be operated by Beijing MTR as a single line which will then set the reeord for the longest metro line (50km) with 35 stations running in China.

Paper No. 4

E&M DESIGN FOR EXPRESS RAIL LINK

Speaker : Ir Alvin W.K. Luk
Project Manager – XRL E&M
MTR Corporation Ltd.

E&M DESIGN FOR EXPRESS RAIL LINK

Ir Alvin W.K. Luk
Project Manager – XRL E&M
MTR Corporation Ltd.

1. INTRODUCTION

The Guangzhou-Shenzhen-Hong Kong Express Rail Link (XRL) is part of the strategic national express rail network that connects Hong Kong to major cities in the Mainland, via stations at Futian in Shenzhen, Longhua (New Shenzhen), Humen in Dongguan and Shibi (New Guangzhou). It aims at providing a rapid and convenient high speed rail service.

Under the current plan the total distance will be 142 kilometres, and the expected travel time from West Kowloon Terminus to Guangzhou South Railway Station (Shibi Station) will be 48 minutes. It will be connected with the Wuguang High-Speed Railway at Guangzhou South Station; to reach Wuhan in 5 hours, and the Xiashen Railway at Shenzhen North Station (Longhua Station).

The proposed project scheme in Hong Kong comprises the underground West Kowloon Terminus (WKT), and a 26km-dedicated tunnel running from WKT to the Hong Kong / Shenzhen Boundary. There will be no intermediate station in the Hong Kong Section.

With a footprint of approximately 12Ha, WKT is an underground railway terminus located immediately north of the proposed West Kowloon Culture District, and between Kowloon and Austin Station. The XRL tunnel configuration will vary depending upon the geological conditions and method of construction. The tunnels between WKT and Futian Station will be designed to cater for train operating speeds of up to 200kph.

WKT will be one of the largest underground station in the world (consists of 15 platform tracks). The building services design within the station is phenomenally challenging. Another special aspect of this project is the interface with Mainland counterparts on railway systems such as signaling, ticketing system, overhead line system, main control system etc.

2. SYSTEM CHALLENGES AND CONSTRAINTS

There are a lot of technical challenges and constraints arisen from the project on Building Services and Railway Systems issues. In this section, the method of overcoming these difficulties by adopting various engineering solutions in planning, design and construction aspects will be discussed.

Paper No. 4

2.1 BUILDING SERVICES IN WKT

The difficulties encountered in designing the building services systems for XRL mainly rest on the shear size of the West Kowloon Terminus (WKT). Its total floor area is approximately 450,000m^2. This is further complicated by the existence of the Boundary Control Facilities (BCF).

2.1.1 ELECTRICAL SYSTEMS

The estimated electrical loads (WKT total) for the different modes of operation are as follows:

Table 1 Estimated Eleetrieal Loads

Normal Mode	Emcrgency Mode (one of the dual supply sources fails)	Fire Mode (Fire fighting and smoke control eqnipment in operation)
32MVA (including approx. 5MVA on HV supply for chillers)	19MVA	18MVA

Dual independent CLP incoming low voltage supplies will be provided to each LV switchboard with two sets of busbar for non-essential and essential loads. The system will be designed such that upon failure of one of the incoming power supply sources or one of the paired transformers, non-essential loads will be shed automatically and the healthy power source will be able to take over the power supply of all essential loads.

Based on the estimated electrical load summarized above and for effective distribution of power to different load centres, 20 nos. of 1,500kVA transformer & 8 nos. of 2,000kVA transformers are required to support the loads in WKT.

For a Terminus of this project scale that spans 300m from station head to end, it is not uncommon to see that the voltage drop will predominantly be the main factor, in many occasions, contributing inevitably to a larger cable size than normal. However, with a flexible approach in the allowable voltage drop for percentages over sub-main and final circuit, e.g. 2.5% + 1.5% or 2.0% + 2.0%, a reasonable balance of sub-main and final circuit cable sizes can be achieved.

2.1.2 FIRE SERVICES AND PLUMBING AND DRAINAGE SYSTEM

The extent of fire service installations is being designed according to statutory requirements issued by HK Fire Services Department / MTR Standards / CLP Standards, including the following:

- Fire Detection and Alarm System
- Fire Hydrant and Hose Reel System
- Automatic Sprinkler System
- Recycling Sprinkler System
- Total Flooding Extinguishing System
- Water Spray System
- Street Fire Hydrant System
- Drencher System
- Portable Fire Extinguishing Equipment
- Interface with Fire Shutters and Mechanical Ventilation System

A special feature of the WKT is the 45m high atrium. Within this area, conventional sprinklers head cannot be employed to fulfill the statutory requirements. Two systems, namely the "Long Throw Sprinklers" and the "Large Space Intelligent Active Control Sprinkler System" were considered for the installation within the atrium.

It was concluded that Large Space Intelligent Active Control Sprinkler System will not be used as it is not a FSD approved system and there is no precedence use in Hong Kong. Long Throw Sprinklers will be used covering 8m x 2.5m by each sprinkler.

2.1.3 AIR CONDITIONING AND MECHANICAL VENTILATION SYSTEM

As WKT and the Topside Development will be operated independently by MTR and the future property owners, every component of the central refrigeration plant of either side has to be independent, and each should be equipped with its own dedicated access. This aims to allow higher flexibility in facility management, so as to provide better segregation on equity ownership and maintenance responsibility.

Among different combinations of chiller plant system schemes, there are three potentially feasible options for WKT, including:

- Water-Cooled Chillers with Seawater Cooling System
- Water-Cooled Chillers with Fresh Water Cooling Tower System
- Air-cooled Chiller System

  It is considered that water-chiller with seawater cooling system is still the most favourable option to be adopted in WKT because of the following reasons:

- The large heat rejection capacity of WKT will require a lot of areas aboveground for accommodating and ventilating the air cooled chillers which will reduce the flexibility to top-side development.
- Fresh water evaporative cooling requires plenty of unobstructed open area to avoid short circuit of hot and misty discharge air and achieve efficient heat rejection from the

cooling towers. The cooling towers will inevitably occupy substantial floor space on WKT podium roof and consequently impairs the flexibility in station / development space planning for this iconic gateway.

- The seawater cooling option, on the contrary, provides higher flexibility in plant disposition as it does not require open space. Although the seawater pumping station allocation is still an issue to be further reviewed, it is nevertheless more favorable than allocating space for bulky cooling towers.
- The life cycle analysis shows that the payback period for adopting sea-water cooled system will be less than 5 years.

The cooling load demand is estimated to be 29,800kW (8,480TR) including 10% allowance for future expansion.

2.1.4 BUILDING MANAGEMENT SYSTEM

The configuration of the Station Based Control System comprises three main subsystems which are the Station ECS Control System, Tunnel ECS control system and the Station BS Control System. The three main subsystems shall interface with the Main Control System (MCS). The MCS will provide Man Machine Interface (MMI) in the OCC and in the Station Control Room for the operators to monitor and control station and tunnel ECS and BS equipment via the Station ECS Control System, Tunnel ECS Control System and the Station BS Control System respectively. Due to the large quantity of equipment for WKT, the expected number of I/O points for the Building Management System is approximately 30,000 (one typical metro station has around 4,000 I/O points).

2.2 RAILWAY SYSTEMS

The difficulties encountered in this project are not only just engineering problems, but very often interface issues as some of the systems require extensive interface with the Mainland counterparts. These systems being :

- Ticketing system
- Overhead Line system
- Tunnel Environmental Control System
- Fixed Communications System
- Radio Communications System
- Main Control System
- Rolling Stocks
- Signalling and Control System

2.2.1 TICKETING SYSTEM

The ticketing system for the XRL will be a closed system i.e. the station will be divided into paid and unpaid areas, and valid tickets will have to be presented at the gates for entry into and exit from the paid areas. Although this is similar to systems that are in use in the HK MTR system, the concept of the arrangement of gates is different. To align with the Mainland practice, there will be 2 tiers of ticket gates. The 1st tier of gates will be used to permit entry for travelers with valid tickets only. This tier of gate will also be the gateway to control the passenger flow through Custom, Immigration and Quarantine (CIQ) and paid area. The 2nd tier of gates will be used to ensure passengers to board on the correct train.

An important aspect for XRL with Mainland is the coordination of ticket sales. Mainland has developed a backbone system for ticket sales and seats reservation - "Ticket Business System (TBS)". The TBS has recently been put on trial on the Shanghai to Nanjing line since July 2010. Upon successful trial operation of the system, TBS will be introduced to all dedicated passenger lines in Mainland progressively. This TBS will eventually be responsible for the ticket sales for the whole nationwide dedicated passenger high speed network. If this real-time ticket sales function is compromised, a fallback scenario has to be designed for :- it is proposed to continue the ticket sales of XRL trains departing from WKT based on a pre-agreed quota; then sales could still be achieved even though the communication has been de-linked.

2.2.2 OVERHEAD LINE SYSTEM

Simple catenary type OHL system suitable for a line speed of 200km/h will be used throughout the XRL tunnels while trolley wire system will be used at Shek Kong Stabling Siding. The adoption of overhead rigid conductor rail (ORCR) will not be considered in this project as there are only a few railway lines using ORCR which are operating at running speed of 200km/h.

Electrical sectioning by means of insulated overlaps, neutral sections and section insulators will be provided at strategy locations for fault protection, fault limitation, isolation and earthing for maintenance purposes as well as to support single line working and to effectively isolate a fault on the OHL, such that disruption to train serviee is minimized.

Neutral section will be in the form of 6 span 2 overlap arrangement and will be installed at the border to separate the Traction Power System from the Mainland. Two more neutral sections will be installed near the Shek Kong. As 25kV single-phase a.c. direct feed Traction Power System will be adopted at either side of the border, the demarcation between Mainland and Hong Kong Section will be separated by neutral sections on both tracks.

2.2.3 TUNNEL ENVIRONMENTAL CONTROL SYSTEM

The tunnel ventilation system (TECS) consists of provisions required to maintain an acceptable environment in the tunnels during normal and congestion scenarios; and to provide smoke control and safe evacuation for passengers during emergency situations. The design criteria (temperature to be maintained within the tunnels) will be in line with the Mainland, setting at 40°C for normal operation and 45°C for congestion operation. For emergency operation, this will follow the Hong Kong practice of achieving an annular velocity greater than the critical velocity.

The system design is similar to many of the existing railway lines in tunnels design, such as West Rail, Lok Ma Chau Spur Line. A push-pull system with only one train within one ventilation section will be adopted for tunnel sections. Upon the occurrence of a fire scenario, the TECS will be operated to control the movement of smoke to provide a smoke free path for passenger evacuation. An enhancement has been proposed in the XRL TECS design - a local pull system will be provided for cross-over areas to prevent smoke from entering into the non-incident tunnel.

Specific attention is required for the design of the ventilation section which cross over the boundary. This ventilation section will cover from Mai Po in Hong Kong to Huangang Park in Shenzhen. Although TECS has no physical interface with the mainland counter part, control interface through MCS is required to achieve the necessary push-pull effect for this section.

In addition, the fire strategy within this section requires specific consideration and approval by fire services department from both Hong Kong and Mainland. The aim is to achieve an unified approach for evacuation strategy supported by fire fighting / evacuation equipment such as fire hydrants, radio communications, lighting etc.

2.2.4 FIXED COMMUNICATIONS SYSTEM

On the contrary to TECS, this system has only a physical interface with the Mainland as it provides the transmission network for XRL Hong Kong Section.

2.2.5 RADIO COMMUNICATIONS SYSTEM

In Hong Kong section, radio system is required for 3 main areas :

1. Train-track radio communication
2. Operation radio communication
3. Radio communication for Hong Kong Police and FSD

For Train-Track radio communication, the Global System for Mobile Communications - Railway (GSM-R) radio technology will be adopted to support signalling data communication according to the requirements of the Chinese Train Control System (CTCS). In the event of a failure of connection to MSC, CTCS-3 will fallback to CTCS-2.

For operation radio communication, it is required to provide voice communication between the Train Operator in the driving cab and the Traffic Controller in the Guangzhou OCC, as well as the Station Control Room in WKT. Communication between the Controller in Shek Kong Stabling Sidings (SSS) and the Train Operator will also be provided to support train shunting operation.

Besides radio communication for railway operations, radio coverage will also be provided for the Hong Kong Police Force (HKPF) and the Hong Kong Fire Services Department (FSD) to support policing patrol, fire fighting and emergency rescue operations. Radio coverage will also be required for various working parties at the government offices in WKT, such as Immigration Department, Customs & Excise Department, Food and Environmental Hygiene Department and Agriculture Fisheries & Conservation Department. A common RF radiating infrastructure (antenna and leaky coaxial system) will be provided for all government radio systems as well as the station O&M radio system in WKT.

Basestation sites will be set up in various ventilation buildings to provide the necessary tunnel coverage. Radio Frequency (RF) redundancy coverage similar to the arrangement for the Guangzhou-Shenzhen section will be provided to ascertain a compatible design and reliability level. Each point in the tunnel will be covered by RF signals from two basestation sites configured in an overlapped manner.

Seamless radio operation between Mainland and Hong Kong - GSM-R MSC connectivity is the most important issue to deal with in this system as this involves the communication of signaling related information. Other than that, frequency planning, radio channel usage and radio control facilities will also need to be further addressed and coordinated with the local telecommunications authorities.

2.2.6 MAIN CONTROL SYSTEM

The control philosophy in Hong Kong and Mainland are different. In Hong Kong, the main control system (MCS) will act as an integrator for the control and monitoring of equipment within XRL. Whereas, separate systems; Building Automation System (BAS 環境與設備監控系統), Fire Automation System (FAS 火災自動報警系統) and Power SCADA system (PSCADA 電力電氣化設備監控系統); will be used to control and monitor in the Mainland section. MCS will interface with Mainland's systems to achieve coordinated control and monitoring of line-wide systems, including traction power and TECS equipment, as well as provisions for central control and monitoring at the Guangzhou OCC.

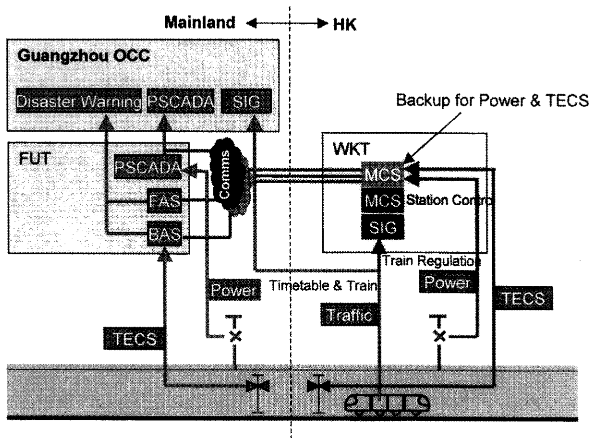
Paper No. 4

The interface design will have to ensure a high level of compatibility between the two sets of systems for a seamless operation of XRL.

The physical interface between MCS and BAS, FAS and PSCADA will be via the transmission network and network equipment provided by the Fixed Communications system. Mainland's BAS and FAS will interface with their Disaster Warning System (DWS) to relay relevant BAS/FAS information (including tunnel ECS and group fire alarms for the Hong Kong section) to the Guangzhou OCC. PSCADA will also be equipped with the capability to control and monitor the traction power of the Hong Kong section.

The interface arrangements as described are summarized in the schematic below.

Figure 1 Iuterfaee Arraugemeut



SIEMENS

2.2.7 ROLLING STOCKS

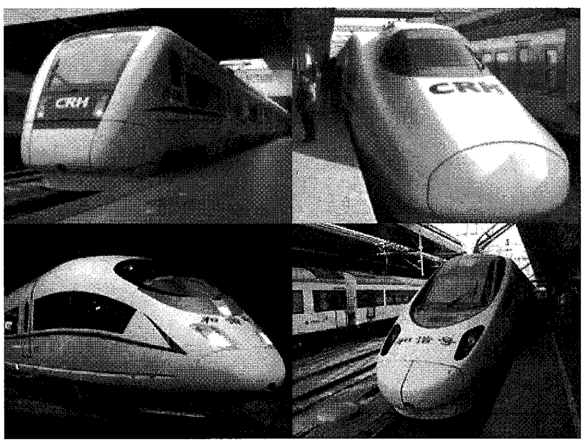
There will be 2 types of passenger trains operating on XRL, namely the shuttle trains operating between WKT and Shibi and the long haul trains operating between Hong Kong and other major cities of Mainland. New trains will be purchased for providing shuttle service across the border. Shuttle trains will be of 8-car consists, with cab on the end cars. Long haul trains will be of 16-car trains, configured either by coupling two 8-car consists together or a 16-car train with cab at both ends.

The design of the shuttle trains will follow the CRH trains currently being operated on high-speed railway lines in Mainland, with modifications to meet Hong Kong statutory requirements and to be able to operate in the environment specific for the Hong Kong section.

Currently four types of CRH trains are operating in Mainland, namely CRH1, CRH2, CRH3 & CRH5. The 4 types CRH trains are:

- CRH1, maximum speed > 200km/h
- CRH2, with two series,namely:
  - 200 series (CRH2-200), maximum speed > 200km/h
  - 300 series (CHR2-300), maximum speed > 300km/h
- CRH3, maximum speed > 300km/h
- CRH5, maximum speed > 200km/h

Figure 2 CRH Trains



2.2.8 SIGNALLING AND CONTROL SYSTEM

The XRL mainland section has adopted the Chinese Train Control System Level 3 (CTCS-3) as its normal train control system with CTCS-2 system as a backup. CTCS-3 is a radio based train control system utilizing GSM-R technology with continuous transmission between the train control on-board system and the wayside signalling system. CTCS-2 is a balise based system with intermittent transmission between train control on-board equipment and wayside signalling equipment. For operational compatibility, XRL Hong Kong section will have to follow the system adopted by the Mainland, i.e. to employ CTCS-3 train control system with CTCS-2 system as a backup.

The XRL Signalling and Train Control system will achieve a design signaling headway of 3 minutes or 20 trains per hour per direction (tphpd). The maximum train speeds in XRL Hong Kong section are as follows :

- Maximum operation speed in mainline normal direction = 200kph
- Maximum operation speed in mainline reverse direction = 160kph
- Maximum operation speed for turnout reverse direction = 45kph

One-train-rule will be adopted for each ventilation section of the XRL Hong Kong section. Single line working along the section with train service interruption shall be allowed to maintain 4 tphpd as the minimum degraded line capacity.

The CTCS-3 and CTCS-2 signalling system comprises wayside and on-board subsystems. The CTCS-3 onboard system contains 11 operation modes of which 9 of them are common for both CTCS-3 and CTCS-2 control and the remaining 2 operation modes are for CTCS-2 control only.

Amongst all the subsystems, the Radio Block Centre (RBC) is one the most vital element of the signaling system. It will be designed based on the safety principles with dual redundant configuration. Based on the current design parameters, one RBC shall be capable of controlling the entire XRL Hong Kong section and hence the importance of location of RBC - whether to place one RBC at WKT or to use the existing one in Mainland.

The Train Control Centre (車站列控中心) (TCC) will be the core system for the CTCS-2 wayside train control system and will be located at the GZ OCC.

3. UNIQUE FEATURES OF OTHER SYSTEMS

In this section, systems with distinctive features are described. These are systems that have no interface with the Mainland but have unique features due to the nature of this XRL.

3.1 POWER SUPPLY SYSTEMS

This includes Traction Power Supply and Station and Ancilliary Buildings Power Supply System.

1. Traction Power Supply System

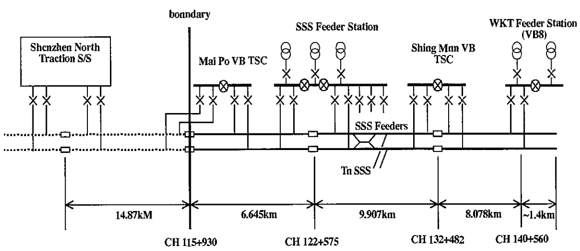
   With rolling stock parameters and a design minimum headway of 3 minutes at 200kph, the traction power supply system was designed. It was also designed not to be affected under a single traction transformer failure. If an outage of a traction substation within Hong Kong section, the train services will be degraded to a 7 minutes headway. The same 25kV single phase a.c. direct-feed system which is similar to the configuration normally used in Hong Kong will be adopted; to be consistent throughout the Mainland and Hong Kong sections.

   Based on the above mentioned assumptions, the electricity demand for the XRL Hong Kong Section is estimated to be about 51MVA as per the simulation result. 2 nos. 25kV traction substations will be established to provide the 25kV a.c. traction supply for XRL. One traction substation with 2 x 26.5MVA traction transformers will be located near the West Kowloon Terminus (WKT) and the other with 3 x 26.5MVA traction transformers at Shek Kong Stabling Sidings (SSS). The 25kV infeed traction substation will be connected to the 132kV network of the CLP power system via 132/25kV transformers. The schematic diagram of the 25kV supply network is shown below.

   A neutral section will be provided at the boundary as the demarcation of the systems between Hong Kong and Mainland. In addition, a Track Section Cabin (TSC) will be installed at the Mai Po Ventilation Building (VB). This would allow traction power to be supplied from Shenzhen North Traction Substation to Shek Kong via the Mai Po TSC in case the whole SSS traction substation fails.

Paper No. 4

Figure 3 Traetion Power Supply System



2. Station and Ancillary Buildings Power Supply System

   The design of the power supply system for station and ancillary buildings will use the nominal voltage level used in Hong Kong at 380V/ 220V to provide electrical power to the various low-voltage electrical loads for WKT, SSS, ventilation buildings and trackside services along the XRL. The LV power supply will be derived from the 11kV sources fed by CLP.

   The essential power within the stations, SSS and ancillary buildings will be supplied by two independent 11kV sources which are fed from two separate CLP 132/ 11kV primary substations. In case one of the independent sources fails, the non-essential load will be shed. In order to achieve the dual sources arrangement, the following options have been considered :

Option 1 – Dual sources for each station/ stabling siding/ancillary building direct from CLP

Option 2 – Dual sources for a group of demands with interconnected 11kV closed ring network

After careful considerations, it was concluded that :

Option 1 will be adopted for the power supply for WKT station due to the large power demand and the availability of two independent 11kV sources from CLP.

Option 2 with 11kV cables running along the tunnel will be adopted for the power supply for ventilation buildings and other ancillary buildings due to the following considerations:

a. It is not feasible to provide second independent source for each ventilation building as there are limited 132/11kV primary substations near the XRL alignment as per discussion with CLP.

b. The 11kV cables can be laid inside the tunnel rather than laying the cables by road excavation.

3.2 DEPOT EQUIPMENT AND AUXILIARY VEHICLES

Maintenance requirement for high speed trains are divided into 5 levels. Only level 1 and level 2 maintenance works (primarily visual inspections) will be performed in SSS for shuttle trains. Depot equipment for XRL will be required to facilitate the daily upkeep of passenger trains to be ready for the next service.

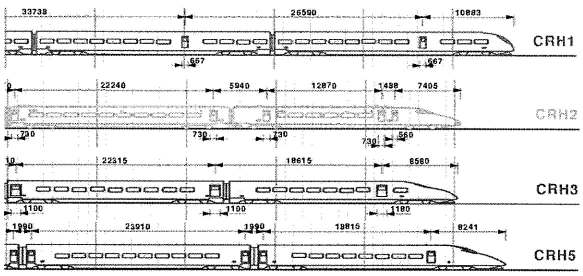
Out of these depot equipment, special equipment such as the wheel monitoring system and sewerage system of higher and faster capacity will be installed.

3.3 PLATFORM SCREEN DOORS

The XRL project has many features different from metro projects and creates technical difficulties in the provision of PSDs/APGs in the WKT platforms. Some of the problems are:

i. There are different types of trains coming from China with different door spacing, quantity and size. Therefore for PSD or APG to meet operation need, it would be very complex. (See below)

Figure 4 Different Types of Trains



ii. The CTCS signalling system, unlike other signalling systems in use in Hong Kong, has no provision to interface with PSD/ APG. Other means of communication would be required to ensure safe operation of PSD/APG with the train doors.

iii. The trains would be manually operated during berthing along the platforms and there is no guarantee on the stopping accuracy, thus it is difficult to optimize the PSD/APG door locations and door widths. It is anticipated that the stopping accuracy will be worse than the performance of metro EMU ± 500mm and may be over ± 1m.

iv. APG system if provided has to be setback from the platform edge for safety reason irrespective of the train types and therefore reduces the effective width of the platforms.

After careful consideration, PSD/APG will not be installed in WKT. In order to mitigate risks of falling objects onto track, other means has been employed.

4. COORDINATION WITH MAINLAND

MTR has been appointed to design and construct the XRL on behalf of the Government. In the early stage of design, MTR has already realized the complexity of the project specifically due to Mainland interface issues. Hence, after signing the agreement for the commitment of the construction of Guang-Shen-Gang dedicated passenger line by both the Hong Kong and Mainland Government (Ministry of Railway - MoR), MTR assisted the Government to further set up regular liaison meetings. As a result, the Main Liaison Meeting was born with 3 sub-group meetings, namely : the Operation & Maintenance Sub-group meeting, the E&M Sub-group meeting and the Civil Works for the Interface Section Sub-group meeting. These sub-group meetings are used as a tool to discuss and resolve all technical issues; which in the end, would report to senior officials in the Main Liaison Meeting.

5. CONCLUSION

E&M design progress has so far been satisfactory. This has been achieved with support from various stakeholders, including relevant government departments from both HK and the Mainland, Ministry of Railways, Guangzhou-Shenzhen-HongKong Passenger Dedicated Line Co Ltd, the Design Institutes etc. The interface requirements have imposed a big challenge on the project team in view of the different design principles and standards being adopted in the Mainland and Hong Kong. Partnering spirit has been obvious among all the parties, with an aim to complete the project on time, within the approved budget and to achieve the highest quality possible. In addition, it is of paramount importance that the design can cater for a seamless operation of the railway.

- Notes and Questions -

Paper No. 5

RAILWAYS FOR METROPOLITAN CITY

Speakers : Ir Raymond W.F. Ho, Government Engineer
Ir Jimmy W.W. Hui, Senior E&M Engineer
Ir Dennis K.H. Wan, Senior Engineer
Railway Development Officc
Highways Department
The Government of the HKSAR

RAILWAYS FOR METROPOLITAN CITY

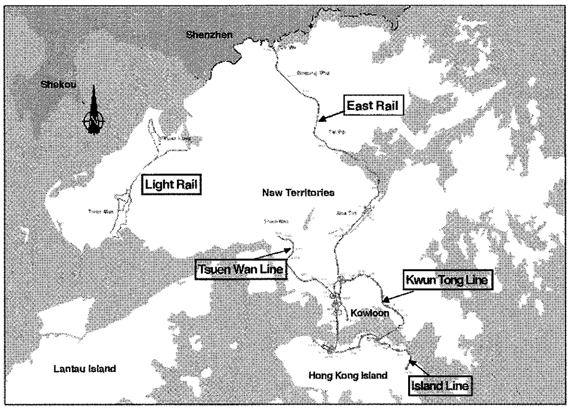
Ir Raymond W.F. Ho, Government Engineer
Ir Jimmy W.W. Hui, Senior E&M Engineer
Ir Dennis K.H. Wan, Senior Engineer
Railway Development Office
Highways Department
The Government of the HKSAR

ABSTRACT

This paper outlines the strategic development of the railway network in Hong Kong to serve the urban developments in the last 30 years. There is a long history of railway developments in Hong Kong, as the first railway project was commissioned in 1910, when the single-track East Rail (previously known as Kowloon-Canton Railway) was running with a limited service of sparse schedule.

The major railway development in Hong Kong started in 1970s when the local road systems could not cope with the rapid increase of traffic demands coming from the rising living standard of the Hong Kong people. The Modified Initial System (now part of the Kwun Tong Line and Tsuen Wan Line) was completed in 1979, followed by the Tsuen Wan Line in 1982 and Island Line in 1985. In 1986, the Island Line was extended to Sheung Wan Station (from Central Station). The Kwun Tong Line was extended across the harbour in 1989 to Quarry Bay Station. In addition, a light rail network was put into operation in 1988 to serve the local communities of Tuen Mun and Yuen Long in the New Territories. The railway development then resumed in great vigour in 1990s, when we were working for the Airport Railway, West Rail and Tseung Kwan O Line. Figure 1 shows the railway network before opening of the Airport Railway.

Figure 1 Railway Network Prior to Opeuiug of Airport Railway



This paper reviews the efforts that we have made, and presents the lessons that we should have learned from our efforts, and describes the way forward and how our railway network can meet the future developments of Hong Kong, and Pan-Pearl River Delta Area.

Paper No. 5

1. INTRODUCTION

Railway is critical to our everyday life, especially for a densely populated metropolitan city like Hong Kong. Railways are safe, efficient, reliable, comfortable and environmentally friendly as compared with other modes of road passenger transport. Its importance was formally recognized in the Transport Strategy "Hong Kong Moving Ahead: A Transport Strategy for the Future" announced in 1999, that we should make *"better use of railways as the backbone of our passenger transport system"*.

Because of the hilly terrain in most parts of Hong Kong, only about 25% of the land in Hong Kong can be developed and inhabited. Hence, the public transport in Hong Kong is characterized by its low car ownership as compared with other major cities in the world (see Figure 2), and over 90% of the trips made by the general public are made with public transport. In 2009, railway accounted for about 35% of public transport in Hong Kong, carrying an average of 4.2 million passengers every weekday (see Figure 3). Railway transport also accounted for 61% of cross-boundary passenger trips daily, carrying about 0.35 million cross-boundary passengers (see Figure 4).

Figure 2 Car Ownership (2006)

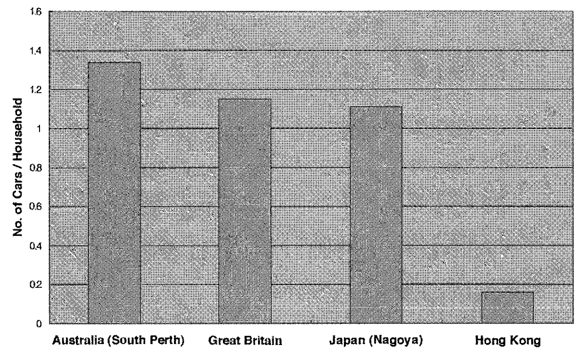


Figure 3 Pnbilc Transport Market Shares

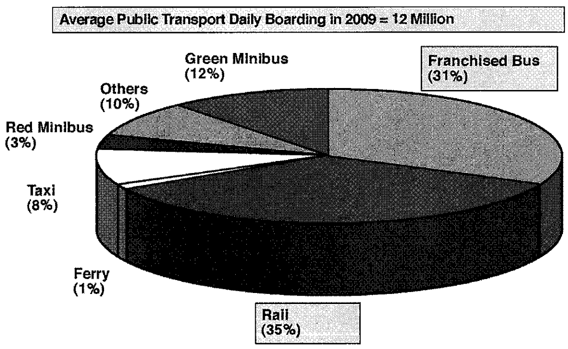
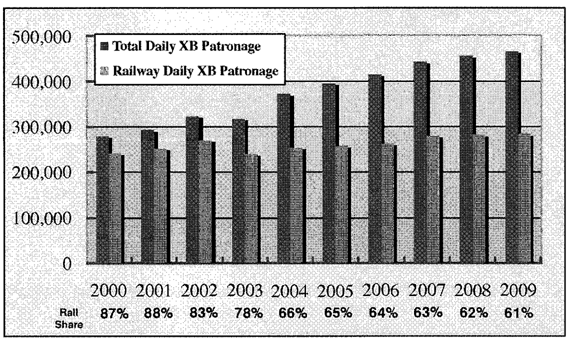


Figure 4 Cross Boundary Passenger Growth Trend



There are significant environmental benefits to adopt railway transport as dominant mode of public transportation. While most of other forms of public transport use fossil fuel (diesel/ petrol/LPG) directly in the streets, railway transport uses electricity and emissions within the city are zero. At the source of electricity generation, i.e. power stations, the raw energy use and emissions for each passenger-km moved by mass transit trains are lower than other modes of road transport.

Because of the historical institution arrangements for railway development, the railway lines in the urban areas (i.e. the urban lines) are owned by the MTR Corporation Limited (MTRCL), and are designed and run at 1,500V DC. The railway lines serving mainly the New Territories, previously owned by the Kowloon-Canton Railway Corporation (KCRC), are hitherto designed and run at 25kV AC. On the other hand, the light rail system in Tuen Mun and Yuen Long is operating at 750V DC.

After the Rail Merger in December 2007, there is now only one Railway Corporation, namely the MTR Corporation Limited (MTRCL), responsible for the operation of the railway network in Hong Kong. The MTRCL is a listed company with the Hong Kong Government holding nearly 77% of the shares. It is only one of the several few railway corporations in the world able to make profits based on its railway operation. Also, its operation track record is top of the world, with 99.9% passenger journeys on time and over 99.8% train service delivery in 2009. From 2005 to 2009, MTRCL was able to reduce electricity consumption per revenue car-km by 18.2% from 5.94kWh to 4.86kWh in 2009, mainly through the implementation of various energy saving initiatives such as the replacement of motor alternators with static inverters for trains, optimization of train regulation, and optimization of station environmental control systems. In the benchmarking performed by the 12-member international Community of Metros (CoMET) for 2008, MTRCL maintained the leading position in the areas of customer service, service reliability, business performance and safety.

2. RAILWAY EXPANSION AND DEVELOPMENT SINCE THE 1990s

The formulation of the Railway Development

Strategy is led by the Hong Kong SAR Government, in consultation with the railway corporations. Recognizing the benefits of railway transportation to the society, the first Railway Development Strategy was formulated in 1994. It sets out the development programme for the priority implementation of West Rail Line, Ma On Shan Line, Tseung Kwan O Line, and extension of East Rail Line from Hung Hom to Tsim Sha Tsui. The Second Railway Development Strategy was formulated in 2000. It sets out the development programme for the further development of our railway network, including those lines currently under construction.

With such strategic planning, in the last fifteen years we saw a massive expansion programme for our railway network to serve the rising demands in the domestic and cross-boundary traffic needs, with the following lines completed within the period:

- Airport Express / Tung Chung Line (1998)
- Tseung Kwan O Line (2002)
- West Rail Line (2003)
- Ma On Shan Line and East Rail Line Tsim Sha Tsui Extension (2004)
- Disney Resort Line (2005)
- Lok Ma Chau Spurline (2007) and Airport Express Line Asia-World Expo Extension (2007)
- Tseung Kwan O Line Lohas Extension (2009) and Kowloon Southern Link (2009)

The railway systems in Hong Kong have already been undergoing rapid technology advancements in recent years. The Modified Initial System was equipped with a train control and signaling system based on fixed-block speed codes. In a move to improve the capacity of the existing railway lines in early 1990's, the distance-to-go SACEM system developed by a French consortium was adopted, on top of the fixed block system so that both systems could be operated together without affecting the train operations. The first SACEM-equipped train was put into operational service on Tsuen Wan Line in 1996. Nowadays, all of the urban lines operate on SACEM.

In 2003, the first moving-block train control and signaling system - SelTrac, commenced operation with the opening of West Rail Line. The system is able to achieve a minimum signaled headway of 90 seconds, although service headway is higher taking into other operational constraints and requirements. Since then, the SelTrac moving-block signaling system has also been installed for the Ma On Shan Line and Kowloon Southern Link.

The earliest urban line trains used camshaft control for DC traction motors. In the early 1990s, these trains were modified for GTO chopper control with regenerative braking capability, while still using DC traction motors. In the late 1990s, East Rail trains were also modified for thyristor phase-angle control, for DC traction motors. Later trains, from Airport Railway onwards, use AC traction motors with VVVF (variable-voltage variable-frequency) drives. Performance of new train fleets had also been elevating over those years, with the Airport Express trains capable of a maximum speed of 135km/h.

The Airport Railway is the first line to adopt platform screen doors in Hong Kong. In 2006 the platform screen doors retrofit programme was completed, encompassing the installation of platform screen doors in thirty existing underground stations. Now, platform screen door has become standard provision for underground stations.

3. FURTHER DEVELOPMENT OF OUR RAILWAY NETWORK

With the support of the community, we have embarked on the further expansion of our local network and cross-boundary lines, with four lines already under construction or in an advanced stage of design: West Island Line, South Island Line (East), Kwun Tong Line Extension, and the Express Rail Link.

The West Island Line (WIL) will extend the full Island Line service from Sheung Wan Station to serve three new stations of Sai Ying Pun Station, Hong Kong University Station, and Kennedy Town Station, adding approximately 3.3km of underground route length to the Island Line. The project cost is estimated to be HK$15.4 billion (December 2008 prices). Construction works already commenced in 2009, for completion by 2014.

The South Island Line (East), SIL(E), is a new extension of a total length of about 7.3km, connecting the existing Island Line and Tsuen Wan Line from Admiralty Station to the Southern District of Hong Kong with five stations altogether. A depot will be provided at Wong Chuk Hang. The railway scheme was gazetted under the Railways Ordinance in July 2009, with construction planned to commence in 2011 for completion in 2015.

The Kwun Tong Line Extension (KTE) is a 2.6km extension of the existing Kwun Tong Line from Yau Ma Tei to Whampoa with one intermediate station at Ho Man Tin. The railway scheme was gazetted in November 2009 to enable construction to commence in 2011 for completion in 2015.

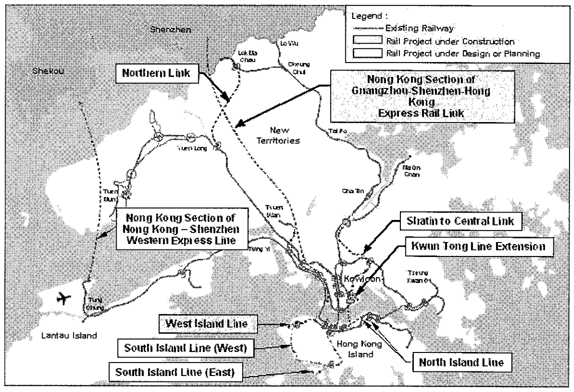
To open up the railway dimension in Hong Kong from city metro to inter-city high-speed railway, the HKSAR Government has embarked on a strategic move to link up our city with the national high-speed railway network. Nationally, it has been planned that by 2015, most of the 16,000km of high-speed railways will be in place linking the various major cities in the Mainland. The Express Rail Link (XRL), or more specifically Hong Kong section of the Guangzhou-Shenzhen-Hong Kong Express Rail Link, comprises 26km long underground twin tunnels with a new terminus at West Kowloon and stabling sidings at Shek Kong, linking Kowloon centre to the boundary at Huanggang to connect with the Mainland section of the line. Trains will operate at 200km/h over the line, running also underground in Shenzhen City for another 11km before emerging onto open sections, going over viaducts and a number of tunnels along the way to Guangzhou South Station, with maximum speed of up to 350km/h. On the Mainland section of the line, there will be six stations, with connections to the national high-speed passenger network at Guangzhou South Station and Shenzhen North Station. Project cost for XRL railway works plus non-railway works is estimated to be HK$67 billion (money-of-the-day prices). Construction commenced in January 2010 for the line to be operational in 2015. Upon its completion, a journey from West Kowloon to Futian of Shenzhen will take about 14 minutes, and to Guangzhou 48 minutes, or less. No doubt, it will consolidate the strategic function of Hong Kong being the southern gateway to the Mainland China, and foster more intensive integration of the people in Hong Kong and Mainland.

In terms of funding for railway projects, it could be wholly funded by the Railway Corporation, or with funding support from the Government. The support provided by the Government to the Railway Corporation could be in a number of ways such as granting property development rights (the "rail-plus-property" model), providing cash grant or equity injection, and funding some of the railway works as public works projects, depending on the project-specific characteristics and arrangement. Traditionally, the success of railway projects in Hong Kong has often been attributed to the rail-plus - property financial model. Nonetheless, the nature and purpose of some railway projects may dictate the need for different means of financing the construction. For example, the Government waived the cash dividends payable by the MTRCL to the Government for two years in the MTR Disneyland Resort Line project (where there was no property development). In the West Rail Line project, the Government provided equity injection to the ex-KCRC so that the KCRC would raise commercial loans itself with more preferable terms. For the new lines, KTE and SIL(E) will be delivered on a rail-plus-property model. WIL will receive capital grant from the Government, while the XRL is being implemented as a public works project under public funding.

Looking ahead, we will see the implementation of another mega-project, the Shatin to Central Link (SCL), which is now under the early design stage. The SCL is also one of the ten large-scale infrastructure projects announced by the Chief Executive in his 2007-2008 Policy Address, alongside SIL(E) and XRL. When completed the SCL will form a strategic railway corridor from Shatin to Central, comprising of two sections with a total length of 17km: the Tai Wai to Hung Hom section which will extend the Ma On Shan Line to link with the West Rail Line at Hung Hom via Diamond Hill and Southeast Kowloon; and the cross-harbour section from Hung Hom to Central which will extend the East Rail Line to Hong Kong Island. Just like the XRL, the SCL will also be implemented as a public works project under public funding.

Looking into the medium or longer term, some other lines are under the early feasibility planning study stage - Northern Link, North Hong Kong Line, South Island Line West, and Western Express Line. Their implementation programme will be kept under review. Figure 5 provides an overview of all these new lines and lines under early planning.

Figure 5 Railway Projects under Constrnction and Planning



4. CHALLENGES IN DEVELOPING RAILWAY NETWORK

4.1 PUBLIC CONSULTATION AND ENGAGEMENT

Views and support of the community are of primary importance in the development of railway schemes. During the planning and implementation stages of a railway project, public consultation and engagement is conducted through all possible channels, such as: presentation to Legislative Council and District Councils, conducting public forums; meeting locals and stakeholders; conducting roving exhibitions; organizing site visit and community liaison group meetings, and making use of the media. Even during construction, we try to keep the public informed about the progress of the project through websites. For example, there is a dedicated website for the XRL, both in MTRCL and the Highways Department websites so that information would be better disseminated to the public.

Public consultation and engagement for railway projects are jointly carried out by Transport and Housing Bureau, Highways Department and MTRCL, with the bureau performing the advisory and supervisory role while Highways Department and MTRCL assuming the implementation role.

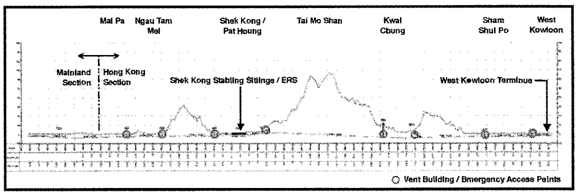
We need to engage the public so that we would be able to locate the ventilation buildings, entrances and other supporting facilities for the construction of railway projects, such as barging points and magazine sites for temporary storage of explosive. The general public usually shows concern about the potential air pollution and health hazard that might be caused by the ventilation buildings and construction nuisance for other supporting facilities. The local citizens usually consider the above facilities as "unwelcome" facilities and are reluctant to have them located nearby their communities. Despite our efforts in addressing and resolving those technical issues through proper design, we have to make enormous efforts in easing the public's concerns. So far, we have enjoyed enormous support from the HKIE in explaining the engineering facts to the public, and we hope with better collaboration with the relevant professional bodies, we would be able to explore how we would deal with these political issues through better exposition of engineering assessments.

4.2 DIFFICULTIES IN ROUTING THE NEW RAILWAY LINES AND LOCATING THE STATIONS PRESENT ENGINEERING CHALLENGES TO DESIGNERS

New lines invariably have to be routed through densely populated areas. It is becoming more and more difficult to route the lines and locate the stations. The XRL, WIL, and KTE are all underground. For SIL(E), nearly three-quarter of the route is using tunnels, the rest being viaduct sections with only two stations being above grade.

For new railway projects, long tunnels are often involved. For XRL, we have the 26km twin tunnels. Our tunnel ventilation section is based on push-pull design, and at any time the design aims to allow only one train running per section ("one-train-rule"). From Huanggang Ventilation Building across the boundary to Mongkok West Ventilation Building, there will be eight ventilation sections in each tunnel utilizing push-pull ventilation (see Figure 6), in between is the open-air Emergency Rescue Siding at Shek Kong. Furthermore, there is a long section under the Tai Mo Shan for which emergency accesses are separated by about 6km. These long tunnel sections pose special challenges in terms of ventilation design (with ventilation buildings housing a number of large fans each rated at 120m^3/sec capacity), fire services installations, and emergency escape provisions (in terms of walkway, cross passages etc).

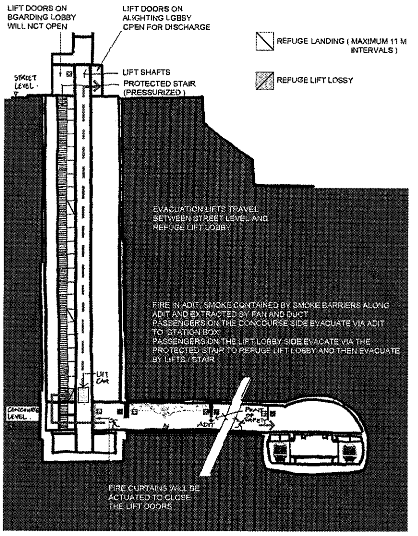
Fignre 6 Gnangzhon-Shenzhen-Hong Kong Express Rail Link



For SIL(E), the Nam Fung Tunnel at 3.3km long will be divided into two ventilation sections for each tunnel tube. For SCL, the cross-harbour section will be about 2.9km long from Hung Hom Station to Exhibition Station, and the Lion Rock section will be about 4km in length from Diamond Hill Station to tunnel portal at Hin Keng. Again, long tunnels require special considerations in terms of tunnel ventilation design and fire safety provisions.

Because of site constraints, a number of stations have to be built deep underground, and to adopt special designs, which may be of new technology application in Hong Kong, in order to minimize site requirements above ground. For WIL, because of the hilly grounds above the line, track level at the middle of the Sai Ying Pun Station will be more than 60m below ground level directly above, with this figure increasing towards one end and decreasing towards the other end. Lift landing at Bonham Road entrance will be some 87m above the concourse adit landing. Obviously, for this entrance we do not expect passengers to use stairs, and a bank of four high-speed lifts will be provided. These lifts also serve the purpose of assisting the evacuation of passengers inside the long adit in case of fire. A refuge floor will be provided above concourse adit lift landing, in case lift-assisted evacuation is required (see Figure 7 for this lift-assisted evacuation concept). Furthermore, unlikely usual metro stations for which ventilation shafts are located at both ends of the station, the structure for the Bonham Road entrance is designed to accommodate all the ventilation shafts of the Sai Ying Pun Station, because of difficulties in finding sites for locating shafts at both ends of the station. That means the ventilation ducts have to rise as high as the lifts.

Figure 7 Lift-Assisted Evaeuation for Adit



For Hong Kong University Station, track level at one end of the station is more than 50m below ground level directly above, with this figure increasing towards the other end. Lift landing at Pok Fu Lam Road Haking Wong Building podium level will be some 73m above lift landing at the concourse adit landing. A bank of eight high-speed lifts will be provided, and the concept of lift-assisted evacuation with refuge floor will be applied to facilitate evacuation of passengers in the adit in case of incidents.

For all these deep stations, in order to ensure the safety of passengers, dynamic smoke control and sprinklers will be provided for all of the public areas, and adequate means of escape (as well as means of firemen access) will be provided. We can rest assured that the stations are designed to a very high fire safety standard.

4.3 FIRST HIGH-SPEED RAILWAY IN HONG KONG, AND FIRST LARGE UNDERGROUND MULTI-FUNCTION TERMINUS

The XRL is the first high-speed railway in Hong Kong, which differs from commuter railway in many aspects, other than speed. To ensure interoperability with Mainland railway systems, XRL will adopt Chinese Train Control System (CTCS), which is a state-of-the-art signaling system for mainline railways. The Chinese Train Control System is very similar to the European Train Control System being adopted for tran-European railway operation. XRL will adopt CTCS Level 3 which employs GSM-R to transmit movement authorities, with CTCS Level 2 as backup which employs track circuits to transmit movement authorities, and both are distance-to-go systems.

High-speed trains differ from commuter trains in many aspects such as motor power, aerodynamics, train sealing against pressure variations, train stability and ride comfort requirements, seating arrangement, fire safety standards, toilets, bistro areas, etc. Furthermore, high-speed trains rely on manual driving with ATP protection, unlike commuter trains which are often equipped with ATO function.

As mentioned before, there will be a number of ventilation buildings along the XRL tunnels, which also serve as emergency access points for firemen. Some are very deep. Ground floor of the Shing Mun Ventilation Building is some 120m above track level, and 80m for Ngau Tam Mei Ventilation Building.

The 11-hectare underground West Kowloon Terminus will be located in West Kowloon next to the West Kowloon Cultural District and connected to the MTRCL Kowloon Station and Austin Station. There will be four major underground levels - concourse level (B1), arrival level (B2), departure level (B3), and platform level (B4). There will be boundary control facilities and duty-free shops on B2 and B3. In B4, there will be six station tracks for

8-car trains, and nine station tracks for 16-car trains. In order to ensure the safety of passengers, all these levels will be protected by smoke control facilities and sprinklers in the public areas. Furthermore, the terminus will be designed to stringent environmental standards. Seawater cooling will be employed for heat rejection of the air-conditioning system, together with energy-efficient lighting.

4.4 DESIGNING FOR RAILWAY SAFETY

As our railway network is always operating in high capacity, we spare no efforts to ensure railway safety. The standard for railway safety in Hong Kong is almost second to none in the world.

The case in point is the XRL project where a long underground tunnel of about 30km would be constructed from West Kowloon to Futian in Shenzhen. We would provide an Emergency Rescue Siding (ERS) in Shek Kong (nearly the mid-point of the long tunnel) so that the incident train would stop at the ERS for evacuation of passengers and handling of emergency incident. Emergency rail buses will be stationed at West Kowloon Terminus and Shek Kong Stabling Sidings for firemen to attend to incidents inside tunnels. Furthermore, dual-mode (road/rail) fire engines would also be planned. Based on the train schedule, we locate our ventilation buildings in nearly every 3-6km so that there would only be one train in operation between any two ventilation buildings, or between ventilation ducts extended from these ventilation buildings (one-train-rule). Within the tunnels, 1.2m wide evacuation walkway will be provided, with cross passages between tunnel tubes in 250m spacing. Trackside phones at cross passages will let evacuating passengers talk to control room. For the terminus, smoke extraction will be provided for all underground station trackways and all underground levels including platforms. Also, all public areas in the terminus will be provided with sprinkler suppression.

5. IMPORTANCE OF CROSS-BOUNDARY RAILWAY CONNECTION

While we have the through-train to Guangzhou and en-route towns/cities, as well as to Beijing and Shanghai, it has to operate on the East Rail Line within Hong Kong with the commuter trains, leading to rather long travel time within Hong Kong. On the other hand, the XRL adopts dedicated corridor to connect directly to the national high-speed railway network. The national high-speed railway network has been developing with an astonishing pace in recent years. According to the Medium and Long Term Railway Network Plan (2008 Adjustment), the national high-speed railway network is planned to reach 16,000km, mostly by 2015. By end 2012, 13,000km will have been completed. This is of an unprecedented scale anywhere in the world. The high-speed railway network will mainly be constructed to Passenger Dedicated Line standards, adopting dedicated corridors without sharing with freight trains, and without level crossings with roads. The Ministry of Railways has promulgated a series of high-speed railway standards for Passenger Dedicated Lines. This will enable the design, construction and operation of safe and efficient high-speed railway connections throughout the country.

In this way, the XRL will enable us to reach most of the major cities in the Mainland through high-speed railway, and bring visitors from those cities to Hong Kong. Most parts of the high-speed railway corridor from Beijing to Shenzhen will be constructed to 350km/h Passenger Dedicated Line standard, enabling us to reach Beijing in less than 10 hours. Needless to say, the convenience to Hong Kong citizens and the economic benefits to Hong Kong will be enormous.

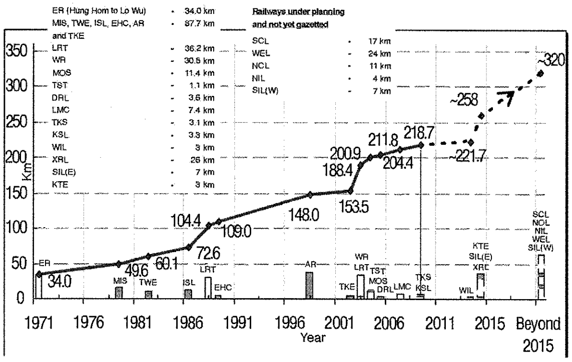
Furthermore, regional railway development is another priority of the Mainland. According to the Pearl River Delta Intercity Rail Transit Network Plan (2009 Amendment), 1478km of new rapid rail lines are planned to be constructed, connecting major cities within the

Pearl River Delta within one-hour reach of each other, with Guangzhou, Zhuhai, and Shenzhen as the hubs. Cross-boundary railway connection (or road connection) will be very important for Hong Kong to tap onto the convenience offered by this regional railway network.

6. LOOKING AHEAD

We will do our best to deliver world-class railway lines to Hong Kong. With the completion of the new lines, our railway network will expand by approximately 40km by 2015 (see Figure 8). With the completion of the XRL in 2015 and the Hongkong-Zhuhai-Macau Bridge in 2016, we will achieve an unprecedented degree of integration with the Mainland transportation network. Beyond that, we will see the completion of the Shatin to Central Link, and other lines looking into the future as well. The new technologies to be used in the high-speed railway will open up a new era for the engineers in Hong Kong, as we believe. With the integration of the technical expertise in the Mainland and the management skills and international exposure in Hong Kong, we would be able to market the high-speed railway technology to many parts of the world. Also, with the advanced fire services facilities in Hong Kong railway network, we would be able to put ourselves amongst the major forerunners in the world as to how the railway network should be made even safer to the travelling public.

Figure 8 Honk Kong's Railways Projects Total Route Length



Paper No. 5

SIEMENS

- Notes and Questions -

Paper No. 6

PREPAREDNESS AGAINST SUPER TYPHOON

Speakers : Ir Steven K.H. Chan, Asset Utilization Engineer
Asset Management Department
Ir Panl C.F. Chan, Projeet Manager
Engineering Projeets Department
CLP Power Hong Kong Ltd.

PREPAREDNESS AGAINST SUPER TYPHOON

Ir Steven K.H. Chan, Asset Utilization Engineer
Asset Management Department
Ir Paul C.F. Chan, Project Manager
Engineering Projects Department
CLP Power Hong Kong Ltd.

ABSTRACT

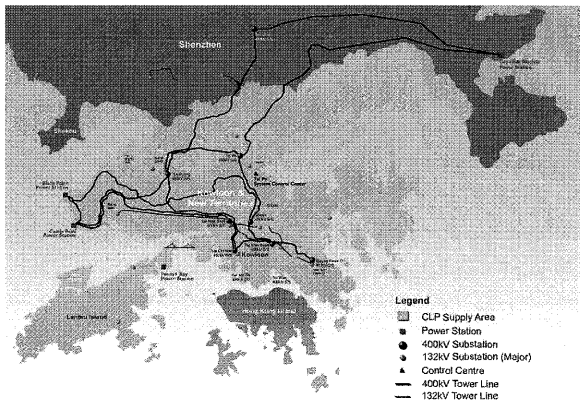
High intensity wind is one of the major causes of failure of overhead lines (OHL) network. According to the available records from the Hong Kong Observatory, in the past eighty years, Hong Kong was attacked by three "super typhoons" of maximum wind gust above 260km/h in 1937, 1962 and 1983 respectively. From other utilities' experience, transmission OHL is vulnerable to super typhoon attack. Total restoration time could be very long if such electrical infrastructure is damaged.

To mitigate the high risk to CLP Power(CLPP) transmission system due to head-on attack by super typhoon, CLPP have initiated a project "400kV Tower Lines Reinforcement for Super Typhoon" to reinforce the integrity of the 400kV tower lines against such possible attacks. This paper summarises the selection criteria for tower reinforcement, project approach and planning considerations in execution of the project.

1. INTRODUCTION

CLPP supply electricity to over 2.3 million customers in Hong Kong. The company's current installed generation capacity is 8,888 MW. A network of transmission tower lines consists of 400kV and 132kV OHLs measured around 600km in circuit length forms the backbone of the Company's transmission network. CLPP 400kV OHLs are responsible for delivering bulk electricity from the company's power stations to the load centres whereas CLPP 132kV OHLs are used to deliver bulk electricity between major substations in Hong Kong. Across the border in Shenzhen 400kV OHLs are used to transmit power from Daya Bay Nuclear Power Station to Hong Kong. Figure 1 shows the CLPP transmission tower line network.

Figure 1 CLPP Transmission Tower Line Network



In Hong Kong, typhoon attack normally happens between July and September every year. According to records available from the Hong Kong Observatory, in the past eighty years three super typhoons of maximum wind gust above 260km/h attacked Hong Kong. They were typhoon Ellen in 1983, Wanda in 1962 and a huge nameless typhoon in 1937. Typhoon Ellen damaged two of CLPP 400kV towers, shortly after they were built in 1981. From other utilities' experience, transmission OHL is vulnerable to super typhoon attack. Total restoration time could be very long if such electrical infrastructure is damaged.

As an international city, supply reliability is vitally important to Hong Kong's society and economy. To mitigate the high risk to CLPP 400kV tower lines due to devastating attack by a super typhoon, CLPP have initiated a project "400kV Tower Lines Reinforcement for Super Typhoon" to reinforce the integrity of the 400kV tower lines including conductors, earthwires, tower structures, foundations and the associated slopes against such attacks.

2. RECENT EXPERIENCE ON SUPER TYPHOON ATTACK

In the past few years, there were super typhoons around the world. Some of them attacked nearby regions to Hong Kong. These super typhoons caused damage to the electrical infrastructure resulting in loss of supply in wide-spread areas and long outage time for repair. The social cost was huge and normal life of people was seriously affected. Some examples of super typhoon attack are shown below:-

- In August 2005, a super typhoon "Katrina" devastated south-eastern Louisiana, Mississippi, and Alabama of U.S.A. as a Category 5 storm, causing catastrophic damage to New Orleans. It is one of the most costly natural disasters in U.S. history. Power supply to over one million of people was interrupted.
- In August 2006, a super typhoon "Saomai (桑美)" attacked Zhejiang province in the eastern part of mainland China. The wind gust was over 300km/h at sea, and reduced to 260km/h after landing. The super typhoon brought severe damage to the area, including extensive damage to 500kV, 220kV & 110kV transmission lines and towers (Figure 2).

Figure 2 Tower Collapsed Duriug the Passage of Super Typhoou "Saomai"

- In September 2008, a super typhoon "Jangmi (薔蜜)" struck north-eastern part of Taiwan with a maximum wind gust of 225km/h recorded at sea level. OHL insulators, conductors and OPGW of a 345kV double circuit OHL were damaged during the typhoon period causing double circuit outage for over 2 weeks.

From others' experience, transmission OHL is vulnerable to super typhoon attack. Equipment failure such as damage of insulators, breakage of conductors or even collapse of towers can occur if wind stress exceeds the design limits. Total restoration time may be very long after the passage of super typhoon if not fully prepared. It is, therefore, only logical and necessary to invest on the enhancement of the electrical infrastructure to face the more frequent and powerful super typhoon conditions.

3. CURRENT SITUATION IN CLP POWER

In CLPP transmission network, 400kV tower lines are more important than 132kV tower lines in term of supply availability. It is because delivery of electricity from power stations to load centres relies on the 400kV tower lines. Loss of supply in widespread areas may occur if any of the 400kV tower lines are damaged. As for 132kV tower lines, supply to major substations can still be maintained through 132kV cable circuits if some 132kV tower lines are damaged. In view of the importance of 400kV tower lines and the possible attack by super typhoon in coming years, there is an urgent need to reinforce the 400kV tower lines.

To assess the impact of super typhoon on 400kV tower lines, preliminary study by a consultant in England with support from a wind expert in Canada was started in 2005. From the past records, typhoon attack to Hong Kong of wind gust above 260km/h is possible. This is higher than the design wind gust of 240km/h for the existing OHLs. To withstand super typhoon attack, a maximum of 300km/h 3 second wind gust at gradient height of 500m P.D. was used for the study.

As a generic study, structural analysis on 8 typical types of 400 towers (angle and straight line towers) and gantry have been selected for assessment. Since 400kV tower lines are largely constructed in extremely rugged terrain, local topographical effects causing local speed-up of wind are considered to be extremely important. Wind expert has undertaken detailed investigation of the topographical wind speed-up factors at 23 sites, chosen as being representative of the system in general. These speed-up factors are applied to the wind speed to take account of the exposure of each tower site. With different tower structure type, speed-up factor and OHL span length, the loading on individual tower under super typhoon condition can be obtained.

As a result of the study, there is a need for reinforcement of 400kV tower lines in Hong Kong and Shenzhen. In addition to electrical components, tower structures and the associated foundations, improvement work on some tower slopes is required to ensure landslide will not happen and the stability of tower can be maintained under super typhoon condition (Figure 3).

Figure 3 Tower Slope Stabilisation is Required under the Projeet

4. TOWER SELECTION FOR REINFORCEMENT AND PROJECT SCOPE

The main objectives of this project are to ensure public safety and 100% supply restoration under a catastrophic failure situation resulting from a super typhoon. To meet these specific needs, towers which are close to public and tower line circuits which are critical for supply restoration are prioritised for reinforcement to withstand super typhoon attack.

The design of OHL reinforcement was started in 2009 and site work is scheduled to commence in the last quarter of 2010. It is anticipated that around 170 towers in Hong Kong and Shenzhen need to be reinforced. The final volume of work can be determined following the completion of all design work towards the end of 2011. All reinforcement work is planned to be completed in 2014.

5. PROJECT APPROACH

This project is implemented by adopting an approach of design by consultant and build by contractor.

Civil engineering design consultants in Hong Kong have only limited OHL design capability and experience, and it is necessary for them to seek additional support from their home-based company or other international OHL consultants. The design consultant carries out detailed assessment and calculation on wind pressures under super typhoon conditions exerted on OHL conductors and earthwires, tower structure and other accessories, which then transfer the loading to tower foundations. For those towers located on or adjacent to a slope, slope stability due to additional foundation loading under super typhoon condition is also assessed. Unlike the preliminary study, the assessment is tower specific which considers not only the tower type, tower location and wind effect due to different topography but also the soil information obtained from ground investigation. Based on the assessment results, the consultant will provide detailed design on reinforcement, e.g. conductor restringing, tower steel member reinforcement, foundation strengthening, and slope upgrading by installation of soil nails. The design consultant will also carry out site inspection and work quality check during the construction phase.

The contractor at construction stage shall have adequate competence and capability to perform both OHL tower work and civil work. The contractor shall also possess relevant work qualifications to perform respective works such as structural work, foundation work and site formation work to comply with local laws and regulations. Although the design of reinforcement will be provided by the design consultant, the contractor is required to plan and propose temporary measures to prevent instability of tower structure or slope during the whole course of work.

In addition to CLPP internal resources, an Independent Checking Engineer is employed for this project. The Independent Checking Engineer is to check the design and conduct site audit on contractor's work in order to enhance quality assurance and to ensure cost effective solutions are developed for both the design and construction work.

6. PROJECT PLANNING AND INSTALLATION PROGRAMME CONSIDERATIONS

As the programme of this project is tight due to the requirement to complete reinforcement of critical 400kV tower lines before possible super typhoon attack, close monitoring of the progress and full co-ordination between relevant working parties are required. The following aspects are considered in the planning and installation phases:-

6.1 SUPPLIER BASE IN SHENZHEN

There are a number of towers in Shenzhen that need reinforcement and work on these towers shall follow relevant PRC laws and regulations. For example, conductor restringing and tower structure reinforcement fall into the "Regulations on Permits for Installation, Maintenance and Testing of Electrical Facilities" whereas foundation strengthening and slope upgrading fall into the "Construction Law of the People's Republic of China". Contractor undertaking conductor restringing and tower structure reinforcement work shall obtain level-one permit to conduct the installation and maintenance work for the 400kV transmission OHL. Contractor undertaking foundation strengthening and slope upgrading work shall obtain the qualification certificates as a construction company and also be qualified to undertake electricity project within the permitted business scope. All these laws and regulations limit the supplier base and most of the Hong Kong and international contractors are not eligible for work in Shenzhen. To resolve this problem, CLPP have approached several mainland contractors, evaluated their capabilities and assessed their performance on similar works. Some of them are identified as potential contractors to undertake the required works in Shenzhen.

6.2 RELEVANT HONG KONG GOVERNMENT DEPARTMENTS' SUPPORT

This project involves a large volume of works at various tower locations. It is anticipated that communications with relevant government departments on design submissions, work permits and land applications are frequent. To facilitate the process and maintain a good working relationship, reach out meetings to relevant government departments such as Lands Department, Buildings Department, Environmental Protection Department and Geotechnical Engineering Office of Civil Engineering and Development Department have been held in the early stage of the project to introduce the project objectives, scopes of work and project programme.

In addition, the regulator of power industry in Hong Kong - Electrical and Mechanical Services Department is also provided with updated project status from time to time.

6.3 OUTAGE AVAILABILITY

Due to supply reliability and system security concerns, it is difficult to obtain outages in the high load season from May to September. In order to secure outages for necessary works, it is essential to work and co-ordinate closely with other internal departments about activities on transmission network such as maintenance work or other refurbishment works.

6.4 WORKFORCE

From the past OHL projects experience, recruiting sufficient number of skilled linesmen had been a difficult task for contractor due to the labour importation policy in Hong Kong. Fortunately, overseas foremen and engineers of contractor were able to obtain work permits to facilitate the OHL project work. In Shenzhen, the linesmen supply for OHL project work should be sufficient based on the recent market research. However, CLPP have to manage mainland contractor to ensure that they can perform the work at the same high SHEQ standard as in Hong Kong which is another challenge to the project team.

6.5 CLIMATE AND WEATHER

Nearly all OHL reinforcement works are to be carried out in mountainous areas. These works cannot be conducted under heavy rain, thunderstorm or typhoon, which is very common during April to September in Hong Kong. Therefore, adequate float or 'down time' has to be included in the installation programme.

6.6 SAFETY, HEALTH, ENVIRONMENT AND QUALITY (SHEQ) REQUIREMENTS

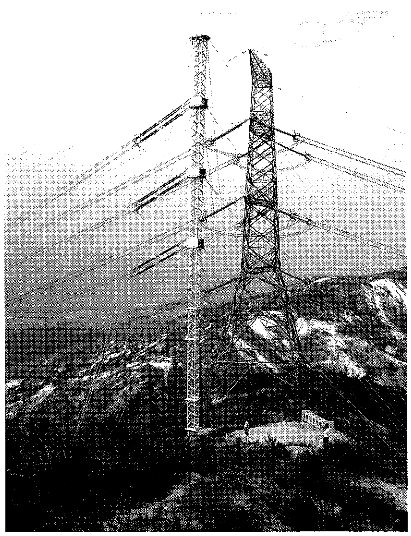
Safety is the top priority of all CLPP projects and SHEQ is always one of key performance indicators to assess the success of a project. OHL reinforcement work involves activities on existing tower structure at a great height, restringing of OHL conductors across roads or tracks, strengthening existing foundation with temporary tower stabilisation measures which are all classified as high risk tasks especially under a tight programme. Protection of the environment is also another important factor that needs to be addressed during site reinforcement work where most towers are set in the natural scene.

7. EMERGENCY RESTORATION SYSTEM

The 400kV tower lines reinforcement for super typhoon will be carried out in several years. Before the project is completed, there is a risk of tower damage if super typhoon comes. As a contingency measure, CLPP have purchased several sets of Emergency Restoration Systems (ERS) in Hong Kong and Shenzhen to cater for post-super typhoon emergency restoration during this transitional period before completion of the reinforcement project.

ERS is a temporary structure which can be used to bypass the OHL conductors from a damaged tower (Figure 4). Erection of ERS requires about 1 to 2 weeks which is much less than the time required for re-building or repairing a tower structure and therefore, the transmission OHL can be restored more quickly. However, ERS is still unable to restore 100% supply in case there is catastrophic damage of the transmission OHL network due to super typhoon attack.

Figure 4 Use of ERS to Restore Supply under Emergeney Situation



8. CONCLUSION

High intensity wind is one of the major causes of failure of OHLs. Proper management of risks is essential to OHL assets. When the risk due to predictable events is deemed too high, proactive action such as upgrading of structure and foundation is appropriate which can help decreasing the probability of failure. CLPP have determined to address the above risks to ensure reliable electricity supply under such onerous weather conditions. In this connection, CLPP have initiated a project "400kV Tower Lines Reinforcement for Super Typhoon" to reinforce the integrity of the 400kV tower lines against such possible attacks.

The project has a tight programme and extensive work scope including conductor restringing, tower structure reinforcement, foundation strengthening and associated slope upgrading for existing 400kV towers in Hong Kong and Shenzhen. Through selection of an experienced, competent and co-operative consultant and contractor, application of critical safety and quality control in design and work implementation together with comprehensive project planning and good project management system, it is expected that the project can be completed at the highest SHEQ standards and the excellent standard of CLPP supply security and reliability of the transmission line network ean be reassured.

ACKNOWLEDGEMENT

The author would like to thank the management of CLPP for the support and permission to publish this paper.

REFERENCE

[1] Tower Structure Study for Super Typhoon Conditions - CLP Power 400KV Overhead Line Network by Balfour Beatty E&M Limited.

[2] Hong Kong Observatory Website.

[3] National Oceanic & Atmospheric Administration (NOAA) Website (For Hurricane Katrina).

[4] China Electricity Council Website (For Typhoon Saomai).

Paper No. 7

CHALLENGES AND OPPORTUNITIES IN DELIVERING ENERGY INFRASTRUCTURE PROJECTS TO ACHIEVE A LOW-CARBON ECONOMY FOR HONG KONG

Speaker : Ir S.H. Chan
Corporate Development Direetor
CLP Power Hong Kong Ltd.

CHALLENGES AND OPPORTUNITIES IN DELIVERING ENERGY INFRASTRUCTURE PROJECTS TO ACHIEVE A LOW-CARBON ECONOMY FOR HONG KONG

Ir S.H. Chan
Corporate Development Director
CLP Power Hong Kong Ltd.

ABSTRACT

Recent years have seen an increase in the awareness of, and appreciation for, air quality and climate issues among the general public of Hong Kong. In response, the Hong Kong SAR Government pledged to formulate a better air quality and carbon reduction strategy that includes the use of clean, renewable energy. CLP is also keen to play an active part in helping Hong Kong become a low-carbon economy.

In 2009 CLP unveiled its Energy Vision, a roadmap to lower-carbon power generation for Hong Kong for the next decade. A key pillar underpinning CLP's Energy Vision is the integration of infrastructure to ensure that more energy is available for Hong Kong. To accomplish this, CLP has been planning and developing a number of energy infrastructure projects.

Moving to lower-carbon power generation will take commitment, visionary planning, and investments in the right technologies and infrastructure. At the symposium, CLP will discuss the challenges and opportunities surrounding its energy infrastructure projects, both within Hong Kong and in mainland China, with a view to supporting Hong Kong's transition to a low-carbon economy.

1. A NEW PARADIGM FOR THE MAINLAND AND HONG KONG

1.1 A BALANCING ACT: GREEN vs GROWTH

Climate issues are an active agenda across the world. During the Copenhagen Conference in December 2009, China pledged to reduce its CO_2 emissions per unit GDP by 40-45% by 2020 from the 2005 level. To meet the dual needs of having sufficient capacity to fuel the nation's growth while achieving carbon reduction, the Central Government has planned not only improvements in energy efficiency but to increase the use of renewable energy to 15% of its primary energy requirement by 2020. Furthermore, it is undergoing an aggressive plan to increase its nuclear power capacity from about 9GW in 2010 to 70-80GW in 2020.

1.2 WHERE HONG KONG STANDS

Here in Hong Kong, with the completion of the SAR Government's consultation process on tightening the Air Quality Objectives (AQOs) in late 2009, it is clear that the public is in general supportive of the proposed air quality control measures, including the increase of use of natural gas in local electricity generation. Furthermore, the SAR Government commissioned a Climate Change study in 2008 to assess the impacts of climate change on Hong Kong and to explore additional measures to further reduce Hong Kong's greenhouse gas emissions. While the findings are yet to be unveiled later this year, the Government has recently indicated their intention to follow the national carbon intensity reduction target. It is anticipated that the tightened AQOs and climate change target will encompass an increase in the ratio of clean energy (including natural gas and nuclear power) for local electricity generation to a higher level, thereby reducing the role of coal.

In 2009, Hong Kong's generation mix was made up of 53% coal, 24% natural gas and 23% nuclear power. As for CLP, the generation portfolio is a diversified fuel mix with the respective ratio of 44:25:31 in 2009. The fuel diversification strategy has been implemented since 1990s, with which CLP has been providing a highly reliable electricity supply to our customers whilst substantially reducing emissions from our generating plants. Securing sufficient clean energy to meet expectations from the more stringent / tightened emission targets will pose huge challenges for CLP.

2. CLP's ENERGY VISION AND THE WAY FORWARD TO BRING THIS STRATEGIC ROADMAP TO LIFE

In 2009, CLP unveiled its Energy Vision, which provides a roadmap for a greener future for Hong Kong. It guides us towards efforts on both the supply and demand sides of power generation. On the supply side, we seek to bring sustainable clean power generation through strengthening infrastructure links with the Mainland and adopting a cleaner fuel mix. On the demand side, we will continue promoting energy efficiency and conservation. We believe, with the concerted effort of all, that we shall be able to make Hong Kong greener.

2.1 CLP's ROADMAP FOR A GREEN FUTURE: ENERGY VISION

- Strengthening of infrastructure integration : this would allow us to tap into the fast-expanding gas supply network in the Mainland and import more nuclear energy to Hong Kong.
- Adopting a cleaner fuel mix : with the increased gas supply and more nuclear power import, we would be able to reduce the role of coal in power generation, thus achieving a greener fuel mix. In the meantime, we are exploring a commercial scale offshore wind farm. We also support smaller-scale, renewable micro-generation in Hong Kong by providing easier grid-connection and technical advice.
- Promotion of energy efficiency : effort on the demand side is equally important to changes made on the supply side. Through public education and energy efficiency-related services to our commercial and industrial customers, we are encouraging our customers to change their behavior and contribute to a better environment by boosting energy conservation. We think electric vehicles (EVs) have real potential to turn the vision for a cleaner and greener Hong Kong into reality by reducing road-side pollution. As such, we aim to promote the wider adoption of EV in Hong Kong. This would also help optimize the overall energy efficiency of the community.

3. INFRASTRUCTURE PROJECTS: CHALLENGES

One of the key success factors for CLP's clean power generation and low carbon emission strategy is the infrastructure development that takes years to plan and complete.

3.1 GAS SUPPLIES

- Project : A new pipeline connecting Shenzhen and Black Point Power Station will be needed to allow CLP to tap into the natural gas sources stipulated in the government to government memorandum of understanding on energy supplies, i.e. the natural gas sources from the West-to-East Pipeline Phase II and a new liquefied natural gas (LNG) terminal in Shenzhen.
- Status : While negotiations on long-term gas supplies are underway, CLP is already carrying out extensive work in the development of the pipeline. We received the Environmental Permit for the Hong Kong section of the pipeline between Dachan Island and Black Point Power Station in May 2010. The front-end engineering design for the LNG terminal in Shenzhen was completed in March 2010.
- Challenges : (1) Extensive effort and close collaboration among government authorities and business partners is required to implement such cross-border project; (2) gas from different sources will have different gas properties and a gas quality

management system is therefore required so that our generation plants can burn gas from diversified sources despite their different characteristics; (3) as our current supply of natural gas from Yacheng will start depleting soon, these gas supply projects must come on-stream quickly to provide an adequate gas supply to meet Hong Kong's needs.

3.2 REDUCING THE ROLE OF COAL

- Projects : Increasing gas-fired generation capacity allows us to use more natural gas for power generation, thereby reducing the carbon emission intensity of our operations. Consideration needs to be given to either building new gas-fired combined cycle gas turbine units or the conversion of existing coal-fired generators to gas-fired units. Furthermore, 70% of the output from Daya Bay Nuclear Power Station is currently supplying about 25% of the electricity needs of Hong Kong. In the next decade, Hong Kong will need incremental generation capacity to meet its increasing needs. Importing additional nuclear power from future nuclear power stations being planned in Guangdong is an option that warrants detailed evaluation.
- Status : We are yet to start the feasibility study for additional gas-fired capacity, and are exploring opportunities and assessing the feasibility of importing more nuclear power to Hong Kong.
- Challenges : When looking at adding extra gas-fired capacity, it is technically challenging to implement a brown-field project at the vicinity of operating units and machines, without adversely affecting the reliability and operability of the existing generators. For additional nuclear power import, (1) it is understandable that the public may be concerned about nuclear safety despite the existence of international and national authorities regulating the operation of nuclear power plants and the many safety protocols already in place. It is therefore essential to continue provide more information about nuclear power to the publie so as to instill eonfidence in nuclear safety and operation in China; (2) in order to maintain a reliable and stable system, the supply and demand of electricity must be balanced simultaneously. While imported nuclear power is generally utilized for baseload generation, our local generators will serve to balance supply and demand and so have to be able to operate flexibly and reliably; (3) enhanced network connection will have to be taken carefully into consideration when planning for the import of additional nuclear power, both in terms of distance and capacity. The application for wayleave for this significant infrastructure project is a potential issue that needs to be carefully addressed; (4) long lead time from planning to commissioning will also be a factor in ensuring the timely delivery of additional nuclear power to Hong Kong.

3.3 WIND FARM

- Project : CLP is planning a 200MW offshore wind farm in the southeastern waters off Sai Kung as part of the Company's effort to diversify the energy mix of the generation portfolio and to support the Hong Kong SAR Government's renewable energy targets. The Environmental Permit was granted in August 2009. An economic study of the Project is being carried out.
- Timescale : The feasibility study to confirm meteorological data in 2012-13 is yet to be completed. Construction would start at the earliest in 2015.
- Challenges : (1) Wind power output is intermittent in nature. Output from other generators must be able to match that from the "varying" wind power; (2) there are construction and logistic challenges for an offshore wind farm project, which would be a first for Hong Kong.

3.4 EV CHARGING INFRASTRUCTURE

- Project: The trial program on an EV charging network was launched in May 2010. The availability, accessibility and reliability of the EV charging network are key to the more widespread adoption of EV in Hong Kong. CLP has already installed 21 charging stations in high-traffic public car parks and in strategically located shopping malls.

- Challenges: To continuously enhance and perfect the EV charging network, there needs to be a critical mass of EV users who can test and provide feedback.

4. PROJECT MANAGEMENT: OPPORTUNITIES

Each of the projects which have been outlined above face different challenges. Yet they also present opportunities for governments, operators, stakeholders and the community to look at energy generation and environmental performance in a holistic manner so as to meet the ever increasing demand for a low-carbon environment.

- The current focus on the environment has encouraged investment in and application of clean energy technologies around the world, which are essential to the future development of clean power generation in Hong Kong.
- The many massive infrastructure projects in Hong Kong (such as Western Kowloon project) will put pressure on the existing pool of professional and experienced human resources in engineering, technical and construction work. However, they also provide opportunities to attract and retain bright students to enter the engineering field. The industry and Hong Kong's tertiary educational institutions can work more closely together to provide a good training ground and development opportunities.
- Community engagement is essential in building understanding of and support for these projects, which will lay the foundation for the long-term development and prosperity of Hong Kong. It is widely understood that some of these projects such as renewable energy development are costly. With an increasing awareness of the importance of environmental conservation and protection, there are opportunities for us to engage key stakeholders and the wider community in a dialogue so that an informed discussion about the balance of cost and benefits for these projects can take place in an informed way. This process is essential to the reaching of consensus on the future development of the power sector and our society as a whole.
- The increasing cross-border collaboration provides ample opportunities for governments and corporate partners to work together. A concerted effort in the planning and development of projects in the Pearl River Delta will provide consistency and synergy, which will in the long term benefit communities in Hong Kong and South China.
- With clarity on the Central Government's energy sector development and goal to reduce carbon emission intensity, the Hong Kong SAR Government is developing policies on energy which will provide clear guidelines so that the power sector can best develop plans to meet the needs of the community.

Paper No. 8

UTILIZATION AND INTEGRATION OF CONDITION MONITORING TECHNIQUES IN MODERN POWER SYSTEM ASSET MANAGEMENT

Speakers : Ir Tony K.T. Yenng, Senior Area Engineer (Eastern)
Ir Andrew K.W. Yan, Area Engineer (Central)
Transmission and Distrihntion Division
Constrnetion & Maintenanee Department
The Hongkong Eleetrie Co., Ltd.

UTILIZATION AND INTEGRATION OF CONDITION MONITORING TECHNIQUES IN MODERN POWER SYSTEM ASSET MANAGEMENT

Ir Tony K.T. Yeung, Senior Area Engineer (Eastern)
Ir Andrew K.W. Yan, Area Engineer (Central)
Transmission and Distribution Division
Construction & Maintenance Department
The Hongkong Electric Co., Ltd.

ABSTRACT

For a world class city like Hong Kong, a reliable electricity supply is essential to maintain its position as a leading financial centre. The increasing expectation from the customer on supply reliability and availability for high value-added business as well as the continuous driver for longer service life and higher utilization of power system assets have posed new challenges for the power system operator and asset owner.

To tackle these challenges, new techniques in asset management are emerging. Among the various techniques available, condition monitoring has become one of the widely adopted techniques in power industry. In addition to adopting off-the-shelf system designed for specific plants by equipment manufacturers, such as partial discharge monitoring for high voltage switchgear, dissolved gas analysis for oil insulated power apparatus, distributed temperature sensing for power cable etc., Hongkong Electric has also developed and integrated other unique condition monitoring systems to its transmission and distribution system, such as loss of vacuum detection scheme, dust contamination analysis etc., to help determining the asset conditions and the maintenance strategies.

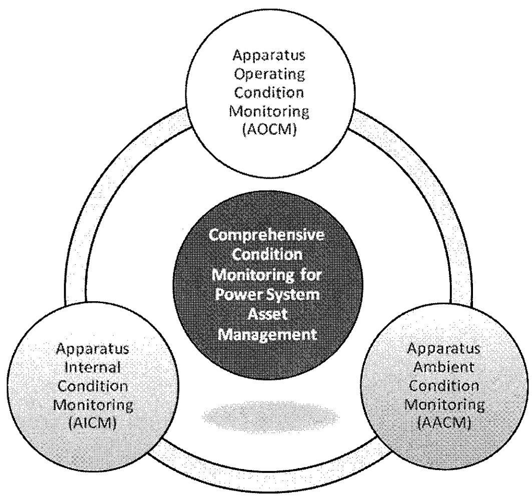
This paper presents the condition monitoring techniques that have been employed by the Hongkong Electric, the experiences gained in applying such techniques and the ways to integrate the data collected into the asset management plans.

1. INTRODUCTION

HK Electric (HEC) is one of the two power companies in Hong Kong supplying electricity to Hong Kong and Lamma Islands and Apleichau. For a world class city like Hong Kong, a reliable electricity supply is essential to maintain its position as a leading financial centre. The increasing expectation from the customer on supply reliability and availability for high value-added business as well as the continuous driver for longer service life and higher utilization of power system assets have posed new challenges for the power system operator and asset owner.

Condition Monitoring (CM), by detecting problems with the use of suitable technologies and monitoring the condition parameters of the apparatus before they result in a major malfunction breakdown, provides the solution to tackle these complex challenges and plays a vital role in providing higher reliability and availability of the power system assets.

Fignre 1 HK Electric's Comprehensive Condition Monitoring Approaeh for Power System Asset Management



2. UTILIZATION AND INTEGRATION OF CONDITION MONITORING TECHNIQUE

HK Electric adopts a comprehensive CM approach in her asset management plan to improve reliability and utilization of her power system assets. The CM is divided into 3 major categories, Apparatus Operating Condition Monitoring (AOCM), Apparatus Internal Condition Monitoring (AICM) and Apparatus Ambient Condition Monitoring (AACM).

With the advancement in technology, increase in popularity and reduction in manufacturing cost, a wide range of CM tools and systems are now available in the market. Other than adopting these off-the-shelf systems and tools, HK Electric also developed her own CM systems based on her power system characteristics, such as loss of vacuum detection scheme, dust contamination analysis and etc., to monitor the assets' condition and determine the maintenance strategies.

2.1 APPARATUS OPERATING CONDITION MONITORING (AOCM) OF POWER SYSTEM ASSETS

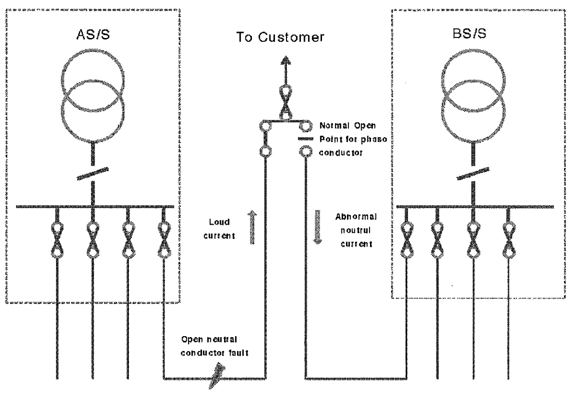
HK Electric employs Energy Management System (EMS) and Distribution Management System (DMS) to control and capture the important operation data, such as operating temperature, gas pressure, voltage and loading, of the power system assets. With the use of AOCM technique, the system operator can detect the abnormalities of the assets and prevent them from failure. Below is one of the examples of using AOCM method in HK Electric.

2.1.1 LOAD MONITORING OF POWER SYSTEM ASSET

The EMS and DMS help to maintain the utmost availability and maximize the performance of the assets. Moreover, by continuous surveillance of operating characteristics of the assets, some incipient faults or defects can be identified and rectified before the catastrophic failure happens.

For example, most of the LV cable feeders in HK Electric network are interconnected between two distribution substations with normal open point in the middle. In the past, only phase currents were recorded for load management purpose. Since 1990's, the neutral current of LV feeders has also been captured and the monitoring of neutral current not only helps to detect the unbalance loading between 3-phase of the feeder, but also helps to detect the defects and incipient faults, like open neutral or high resistance fault, before the customer supply is interrupted by the asset failure.

Figure 2 Typical LV Supply Network of HK Eleetrie



Typical LV supply network of HK Electric

2.2 APPARATUS INTERNAL CONDITION MONITORING (AICM) OF POWER SYSTEM ASSETS

AICM is to measure and monitor the condition parameters of the apparatus such that it gives an accurate picture of what is happening in the apparatus and is the most commonly adopted technique by most of the utilities like HK Electric in their asset management system.

2.2.1 AICM FOR SWITCHGEARS

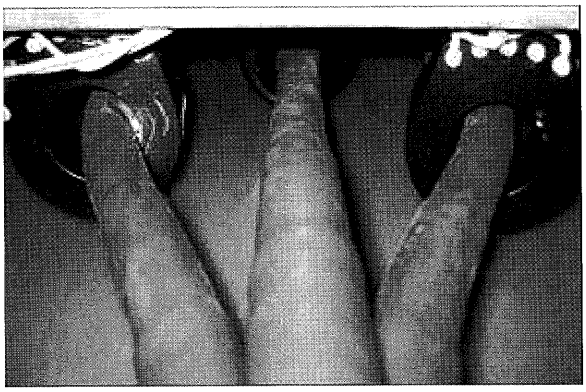
A number of AICM techniques, like partial discharge monitoring, infrared scanning, loss-of-vacuum monitoring and decomposed products detection, are adopted for switchgear CM. Below are some examples of applying AICM techniques in switchgear assets.

a. *Partial Discharge Monitoring*

Measuring partial discharge (PD) signal is one of the most commonly adopted methods to predict the condition of in-service switchgears. In HK Electric, both offline and online PD monitoring methods are adopted to monitor the PD activities in progress. For distribution switchgears, the portable PD detector is chosen in view of the less favorable site condition to install the online PD monitoring system and the site personnel can handily detect the PD signal inside the switchgear when they visit the substation for other routine activities. [1]

Figure 3 Portable PD Detector Employing Ultrasonic & TEV Sensor

Figure 4 PD Deteeted on Cable Termination by Portable PD Deteetor



For the high voltage Gas Insulated Switchgear (GIS), online monitoring system using non-intrusive external UHF couplers with built-in fuzzy logic detection algorithm is selected to provide early warning signals. Together with the advanced portable PD detection system with built-in PD pattern recognition system, the location and type of PD inside the GIS can be determined effectively.[2]

Figure 5 External UHF PD Sensor

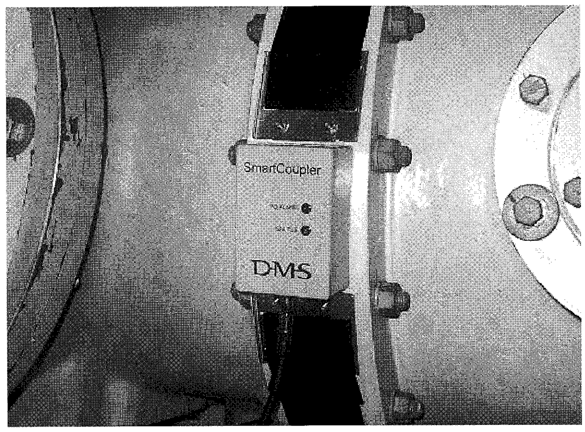
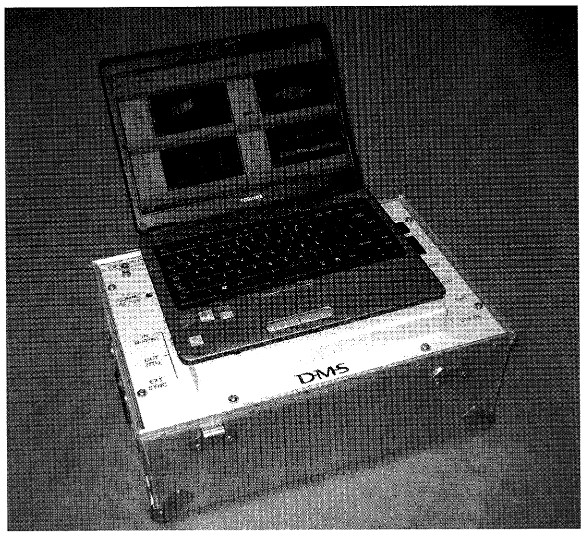


Figure 6 PD Detection System with Built-in PD Pattern Reeognition System



b. *Loss-of-Vacuum Detection for Vacuum Circuit Breakers and Vacuum Switches*

Vacuum switch (VS) and vacuum circuit breaker (VCB) are commonly adopted in HK Electric 22kV and 11kV network and

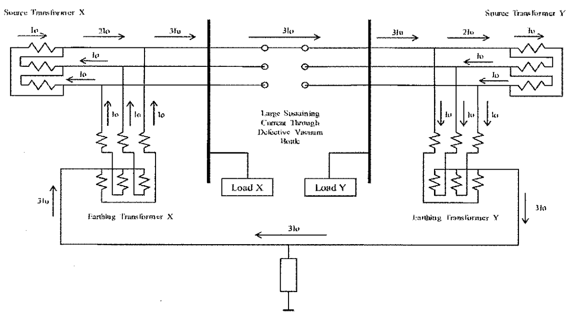
Paper No. 8

SIEMENS

there are over 10,000 VSs and VCBs, i.e. over 30,000 vacuum bottles are now installed in HK Electric's power system. Although their performance is considered stable, online CM for vacuum bottle is considered necessary due to the severe consequence that could be caused by vacuum bottle shattering.

However, most manufacturers opine that there is no practical means to monitor the vacuum condition for those in-service vacuum bottles online without replacing them by new ones with pre-installed vacuum checker or retrofit modern numerical relays with built-in broken-conductor logic and/or other unbalance current detection elements. Since HK Electric adopts the resistive earthing arrangement in her 11kV and 22kV network, instead of spending huge investment for replacing the vacuum bottle or retrofitting the new numerical relays, HK Electric develops her own monitoring scheme to monitor the integrity of the VSs and VCBs in the network by monitoring the neutral current of zone transformers with surveillance schemes in a more cost-cffective manner. [3] By revealing the VS/VCB which suffers from the loss-of-vacuum just after opening under normal loading condition and taking appropriate action promptly, vacuum bottle shattering and its most severe consequence, i.e. tripping of primary substation busbar, may be prevented.

Figure 7 Zero Sequeuce Current Flow betweeu Two Trausformers of Same Primary Substation due to Loss of Vacuum



2.2.2 AICM FOR POWER TRANSFORMERS

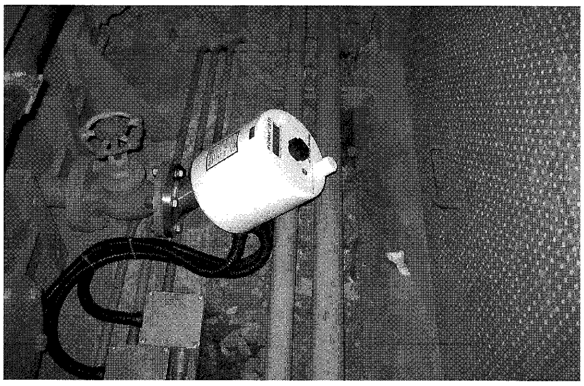
Similar to the switchgear asscts, a number of AICM techniques are applied to power transformer assets in HK Electric to ensure the assets are operated in a safe and reliable condition. Selected examples of AICM systems adopted for power transformers are described below.

a. *Oil Condition Monitoring*

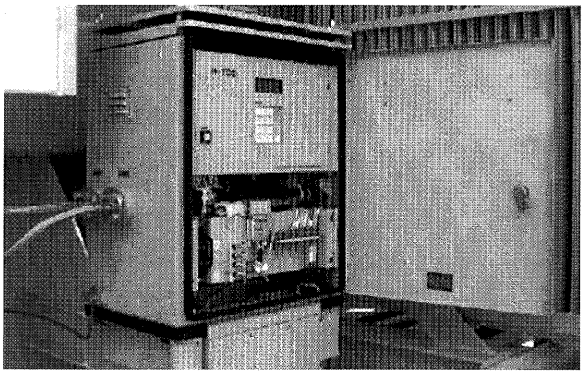
The internal condition of the power transformers can be reflected from insulating oil analysis. In HK Electric, various techniques, including both online and offline approach, for oil analysis are adopted. Online Total Combustible Gas (TCG) sensors have been retrofitted in most of the transformers to provide early warning for the incipient fault. Also, online Dissolved Gas Analysis (DGA) system is being retrofitted for some of the critical transformers.

Other than these online oil analysis systems, HK Electric performs the periodic DGA, moisture, dielectric breakdown and screen test for the transformer insulating oil to monitor the healthiness of the assets. Moreover, the level of Furanic compound in the insulating oil, which reflects the degree of polymerization of paper insulation of the transformer, is also monitored to assess insulation aging and to estimate the remaining life of the power transformers.

Figure 8 Online TCG Scnsor for Power Trausformer Asset



Fignre 9 Online DGA System for Critical Transmission Power Transformer



b. Frequency Response Analysis

Frequency Response Analysis (FRA) is another technique adopted by HK Electric to determine the internal condition of the power transformer asset. FRA makes use of the electrical characteristic of the transformer winding under different input frequency to detect the deformation of transformer winding. By comparing the FRA result of the transformer with its past record or other transformer with the same design, the internal condition of the transformers can be deduced.

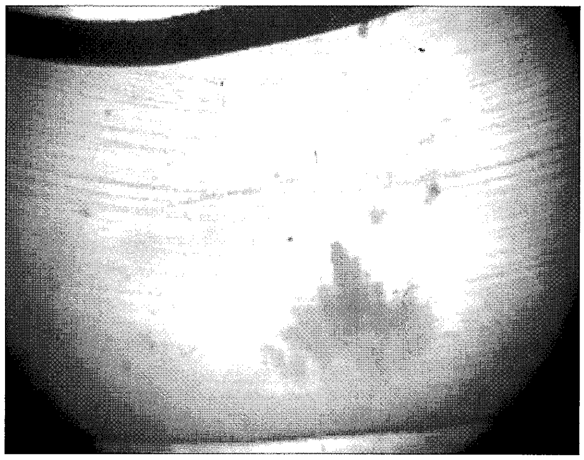
2.2.3 AICM FOR POWER CABLE

In the past, CM for cable asset is very few. With the technological advancement, different kinds of CM techniques and systems are developed for the power cable assets. In HK Electric, CM methods by both physical and electrical means are adopted for the power cable asset management.

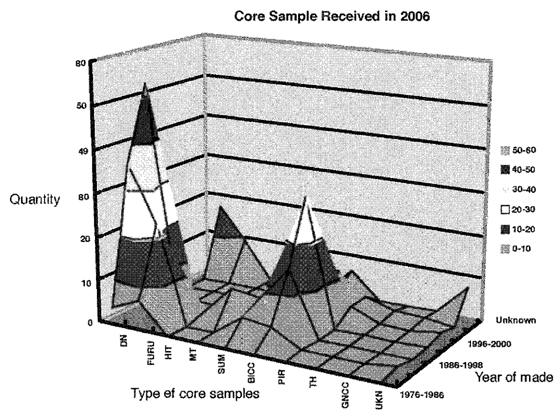
a. Water Tree Analysis for 11kV XLPE cable

11kV XLPE cables have been widely adopted in HK Electric distribution network since late 70's and the early vintage XLPE cables are found vulnerable to the forming of water tree when the XLPE is in contact with water. As it takes time to develop water tree in XLPE into electrical tree and to cause cable fault, supply interruption to customer can be avoided if the existence of water tree in cable insulation is identified in the early stage. Instead of relying on the support of cable manufacturers, HK Electric, as an asset owner, acquired the examining skill from cable manufacturer and started to examine the presence of watcr tree in cable core since 1996. Core samples are collected from routine cable work.[1]

Fignre 10 Water Tree located at XLPE Cahle Insnlation



Fignre 11 Statistie for Core Sample Analyzed with Water Tree



Once water trees are found in the cable core, the concerned cable section will be overlaid with priority to mitigate risk of cable failure.

b. Partial Discharge Mapping and Loss Angle Measurement for 11kV XLPE cable

Although the water tree existence in the XLPE cables could be identified by analyzing the cable core sample, it is not possible to conduct full length analysis on every water tree prone cable, especially for

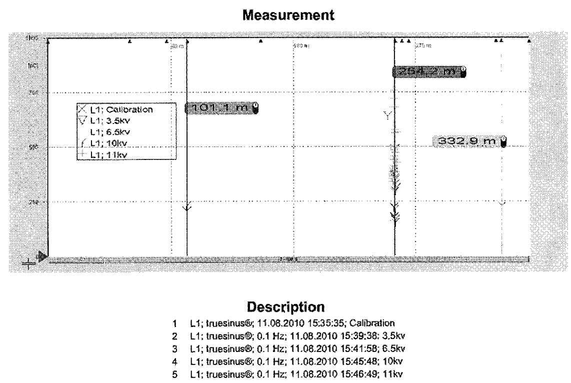
Paper No. 8

SIEMENS

those sections without any cable work. To further enhance distribution cable reliability, HK Eleetric introduced two partial discharge mapping systems, Very Low Frequency (VLF) testing system and Oscillating Wave Test System (OWTS), to measure the PD and loss angle of the water tree prone XLPE cable in 2009.

With the introduction of these two systems, the analysis of cable condition could be carried out systematically and the weak joints and potential cable body fault due to water tree could be actively identified.

Figure 12 Sample VLF PD Mapping Report



2.2.4 AICM FOR AUXILIARY PLANTS

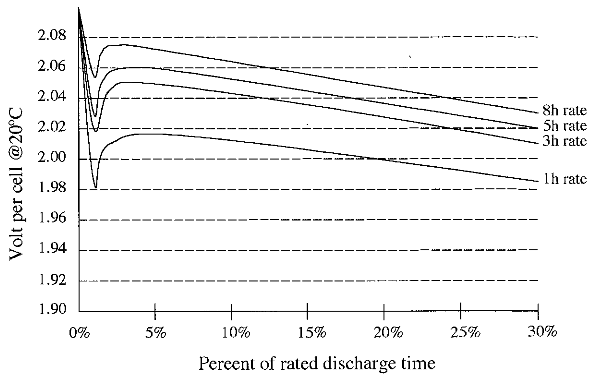
AICM is applied not only to the main plant assets. For the important auxiliary plants, like battery system, HK Electric also applies the same approach to monitor the plant condition.

a. Capacity Monitoring of Battery Systems

Stand-by battery plays a critical role in the supply reliability of the power system. However, its capacity decays naturally after being put into service. Therefore, monitoring the battery condition is a critical step nowadays in power system asset management.

Valve Regulated Lead Acid (VRLA) batteries are commonly used in HK Electric distribution substations in view of its compact size, high energy density and other advantages. However, the major disadvantage of VRLA battery is that it becomes open circuit when it fails. The most effective means to measure the battery condition is through a discharge test. The discharge test not only helps to monitor the battery condition, but also helps to refresh the battery cells. To reduce the effort for performing the periodic battery discharge test, all HK Electric's distribution battery chargers are equipped with the battery capacity monitoring device to ensure the batteries are all in good condition without excessive internal impedance and capable of providing at least 80% of its designed capacity when the A.C. supply fails. The device is designed to discharge not less than 10% of the battery capacity through system load and/or dummy load in a pre-defined period and if the battery volt drops dramatically during the discharge test, the test will be terminated automatically and the output load voltage can be maintained at ± 10% of nominal value within 10ms.

Figure 13 Typieal Diseharge Curve for VRLA Type Battery



By determining the battery capacity actively, the severe result of protection failure due to loss of D.C. supply during equipment failure can be avoided.

2.3 APPARATUS AMBIENT CONDITION MONITORING (AACM) OF POWER SYSTEM ASSETS

AICM is an important tool to monitor the integrity of the assets and to prevent the asset from unexpected failure and severe damage. However, according to past records, most of the power system asset failures were due to the influence of environment and such failure can be completely avoided if the root cause is eliminated. Therefore, HK Electric also actively adopts the ACCM in her asset management plan to eliminatc those potential risk factors leading to asset failure and to ensure that the assets can operate in a sound and reliable condition.

2.3.1 AMBIENT TEMPERATURE MONITORING OF POWER SYSTEM APPARATUS

Ambient temperature can affect the performance as well as the reliability of a power system apparatus significantly. Nearly all assets of HK Electric are installed indoor, semi-door or underground. In Hong Kong, the substation size is relatively small and the underground is full of utilities installation. Thus, monitoring the ambient temperature of the installed asset becomes important to ensure the asset can function properly.

a. *Ambient temperature monitoring for power transformers*

According to the IEC standard, for every rise of 6K in ambient temperature, the rate of life consumption of the transformer becomes doubled. To ensure the transformer can deliver its designed rating without excessive life consumption, monitoring of the transformer ambient temperature is necessary. Especially in HK Electric, the primary stations are usually accommodated in multi-storey buildings and the power transformer bay has walls on its 3 sides. The average ambient temperature of some transformer bays can rise over 40°C in summer. Since the top oil/gas temperature of these transformers does not reach the high alarm level under the normal loading condition, the operator may not be aware of such high ambient temperature which will result in abnormal life consumption of the transformers.

To address the problem and to identify the transformer bays with potential ventilation problem in a more systematic manner, HK Electric retrofitted the temperature sensors at all transformer bays to record the average ambient temperature of transformers since 2008. The bay temperature data obtained is then compared with the average ambient from Hong Kong Observatory (HKO) and action will be taken if the difference between the average bay temperature and average ambient from HKO is larger than a pre-defined value.

Fignre 14 Summary Table for Average Transformer Bay Temperatnre for HK Eleetric Primary Station Bnildings

Tx Bay Temp in			MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	2016-JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
HKO		AVG	25.5	28.1	29.0	29.3	28.5	26.2	20.5	17.5	16.8	17.9	20.2	21.0	25.6	27.1	29.2	28.5	
ADM	Tx1	MAX	35.2	39.3	[illegible]	37.2	38.5	33.7	32.1	25.8	26.2	28.9	29.3	30.7	34.3	[illegible]	[illegible]	36.2	
		MIN	24.6	27.8	27.2	27.7	27.7	25.4	11.4	12.5	11.9	9.3	10.7	16.9	23.6	23.1	27.8	27.6	
		AVG	28.8	31.7	32.8	33.0	32.2	29.1	23.4	20.1	19.0	19.9	22.7	23.5	28.1	29.0	32.5	32.1	
	Tx2	MAX	33.6	36.8	37.2	36.5	36.5	33.4	32.3	25.1	25.8	26.2	29.3	29.7	31.2	35.3	36.1	36.2	
		MIN	23.4	27.0	26.3	27.2	26.6	24.0	11.0	12.0	12.2	9.0	[illegible]	16.4	23.3	22.8	29.2	26.7	
		AVG	27.9	31.9	32.0	32.2	31.4	28.6	22.9	19.0	18.5	19.5	22.2	23.1	27.5	29.5	31.8	31.5	
AIE	Tx1	MAX	30.7	32.2	35.5	34.9	34.4	32.9	31.0	25.1	25.4	26.4	27.1	27.6	30.2	31.7	32.9	34.1	
		MIN	21.4	24.7	23.5	25.9	25.1	24.1	[illegible]	11.3	11.6	6.9	[illegible]	15.5	21.5	22.4	24.5	25.4	
		AVG	26.1	28.8	29.9	30.4	30.2	27.4	22.1	18.5	18.0	19.0	21.2	22.1	26.5	27.5	29.9	29.9	
	Tx2	MAX	30.9	32.9	36.9	35.4	33.3	33.4	31.1	25.3	26.0	26.9	28.0	28.1	30.8	32.3	35.6	34.9	
		MIN	22.3	25.1	34.1	25.6	25.7	24.7	12.0	12.1	12.2	9.2	10.8	15.2	22.8	21.0	23.9	25.8	
		AVG	26.7	29.9	30.6	31.2	30.9	28.1	22.8	19.4	18.5	19.5	21.9	22.8	27.2	28.5	30.6	30.8	
	Tx3	MAX	34.7	33.2	37.8	36.4	34.6	33.3	30.6	25.2	25.8	26.6	28.0	28.1	33.7	32.3	37.6	[illegible]	
		MIN	22.3	25.1	23.5	23.8	25.5	24.8	12.2	11.5	12.2	9.5	10.9	16.0	32.2	22.0	25.9	25.9	
		AVG	26.8	29.8	33.2	31.7	31.1	29.2	22.8	19.5	18.5	19.5	21.9	22.9	27.3	28.5	30.8	30.9	
	Tx4	MAX	36.1	[illegible]	[illegible]	38.0	34.4	33.2	30.0	24.8	25.5	26.4	27.5	28.1	37.5	[illegible]	[illegible]	[illegible]	
		MIN	22.5	25.9	26.2	28.0	26.7	24.9	13.2	12.0	12.6	10.1	10.0	16.6	22.3	22.9	26.2	26.9	
		AVG	26.9	29.7	31.3	31.6	31.0	28.0	22.8	19.5	18.6	19.8	22.0	23.0	27.3	28.6	30.8	30.7	
CRZ	Tx1	MAX	36.4	39.0	39.1	39.6	38.6	36.3	34.6	29.5	28.3	32.1	33.1	34.5	34.5	35.7	39.2	37.8	
		MIN	26.0	29.7	29.9	25.0	29.6	[illegible]	17.0	15.2	13.5	10.3	11.8	18.3	24.6	34.6	28.4	27.8	
		AVG	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31.7	[illegible]	[illegible]	19.7	21.0	23.6	24.4	29.3	30.8	32.6	32.2	
	Tx2	MAX	35.9	37.8	39.3	39.1	38.3	35.5	33.5	29.7	27.6	31.7	33.4	33.9	33.7	36.0	37.2	37.2	
		MIN	25.8	29.2	30.0	29.0	29.4	0.1	17.9	16.5	13.8	9.8	11.8	18.0	23.6	29.2	28.4	28.7	
		AVG	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	19.9	20.9	23.6	23.8	29.2	30.9	32.9	32.3	
	Tx3	MAX	36.7	38.3	39.9	[illegible]	38.9	36.7	35.1	30.4	28.8	39.0	34.5	35.3	35.5	36.7	38.1	38.0	
		MIN	26.6	29.9	30.7	30.0	30.3	0.0	18.3	17.3	15.1	11.4	12.6	19.1	25.1	25.1	29.3	28.7	
		AVG	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	20.5	21.6	24.5	25.2	30.2	31.8	33.7	33.2	
	Tx4	MAX	36.2	37.4	39.2	39.5	38.6	36.1	34.7	29.5	27.7	32.6	33.8	33.7	35.3	37.1	38.2	38.9	
		MIN	24.9	25.9	28.3	26.7	28.6	[illegible]	18.5	14.9	14.9	11.3	12.7	18.5	20.7	25.1	25.9	29.8	
		AVG	30.1	32.6	33.8	33.2	33.5	[illegible]	[illegible]	22.6	20.1	21.3	24.1	24.8	29.8	31.6	35.5	35.0	
		MAX	34.6	36.6	39.1	38.9	38.3	35.9	32.2	25.6	25.4	28.5	30.0	29.7	33.5	36.5	37.7	38.7	

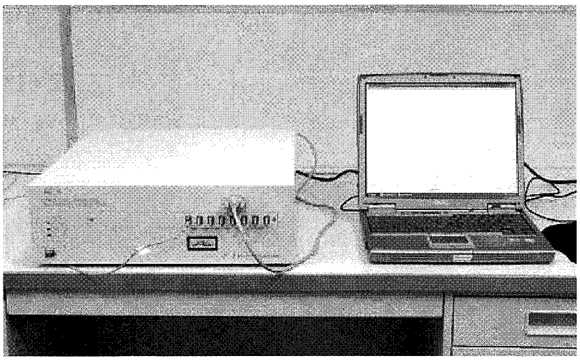
The effectiveness of the action can be seen from the monitoring result. After improving the bay ventilation of a primary substation by replacing the folding shutter with a stainless steel grill gate, the average bay temperature has significantly come down by a few degrees. The above table shows that reduction in average bay temperature of the concerned primary substation was successfully achieved.

Fignre 15 Improvement of Transformer Bay Ventilation by Door Gate Replaeement

Paper No. 8

SIEMENS

Figure 16 DTS System for Soil Temperature Mouitoring

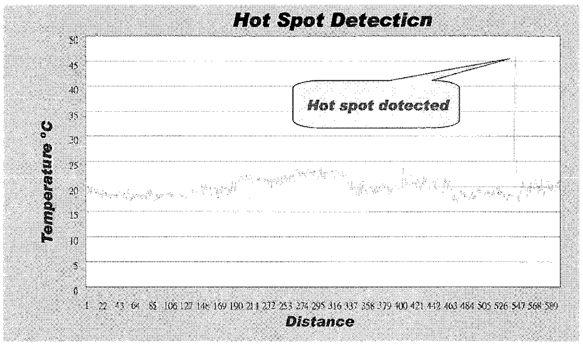


b. Ambient temperature monitoring for power cable and soil resistivity measurement

According to a survey, there are more than 10 kilometers of underground utilities' installations, like cable ducts, drainage, piping and power cable, in every kilometer of footpath in Hong Kong Island. Cases of pre-mature failure of cable joints were reported due to thermal runaway in 1990s. To ensure the cable installed can deliver its designed rating without overheating, HK Electric has set up clear design criteria for cable route planning. Moreover, heat dissipation analysis for major transmission cable routc will be conducted during the route planning stage. However, due to site limitation and frequent road works, the actual site condition may deviate from the original design criteria. To avoid mutual overheating of cables in the congested location, a prudent approach is to de-rate the cables, but it will also reduce the cable network capacity and hence the utilization of asset.

To maximize the utilization of asset, HK Electric started to install the distributed temperature sensing (DTS) system for some critical transmission cable routes since 2002. By means of Raman-effect that occurs in optical fiber due to temperature variation along the cable route, the temperature profile along the cable route can be obtained and the location with highest ambient temperature could be effectively monitored.

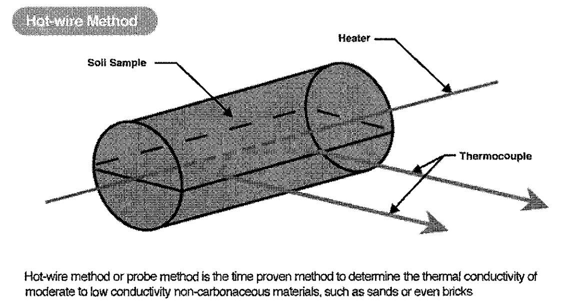
Figure 17 Temperature Profile of a Transmission Cable Route



The pre-requisite requirement for adopting DTS is the availability of optical fiber. However, for the existing cable system, it is not feasible to install the DTS fiber next to the cable and in this case direct measure of soil temperature with thermal coupler or temperature sensor next to the in-service cable is adopted by HK Electric to monitor the thermal condition of the cables in congested area and to prevent the cables from overheating.

Figure 18 Tools for Measuriug the Soil Resistivity

Figure 19 Prineiple of Caleulatiug the Soil Resistivity

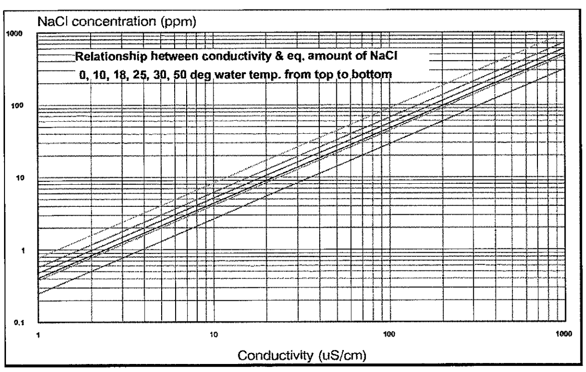


Besides, the soil resistivity is another critical factor affecting the cable temperature as well as the heat dissipation model used to estimate the temperature rise of cable under fully loaded condition. HK Electric conducts soil resistivity measurement for congested areas or areas identified with potential cable overheating problem to obtain a more realistic figure for the heat dissipation model.

2.3.2 CONTAMINATION LEVEL MONITORING FOR POWER SYSTEM APPARATUS

HK Electric introduced Air-Insulated Switchgear (AIS) in 1970s to replace the oil-insulated switchgear. Some premature failures had occurred and they were found caused by air borne dust which mixed with salty moist air and contaminated the insulator surface. Since the rate of dust accumulation affecting the insulation of switchgear and the lubrication degradation of operating mechanism depends on the location of equipment installation and varies greatly in various parts of Hong Kong Island, to analysis the issue in a more scientific manner, the internal dust level of the switchgear is measured during routine maintenance work[1]. Dust contamination level is determined by means of measuring the conductivity of the dust collected inside the switchgear which is then converted to equivalent amount of Sodium Chloride on the surface. The rate of dust contamination is deduced from the time lapse between the two dust collection exercises.

Figurc 20 Relationsbip between Conductivity and NaCl Conccntration



The rates of dust contamination are divided into three classes - high, medium and low. The switchgear maintenance frequency and other dust level related activities, such as substation cleaning and inspection, will be adjusted in accordance to the measured class.

2.3.3 SUBSTATION CONDITION MONITORING FOR POWER SYSTEM APPARATUS

For all basement and sunken distribution substations, sump pumps and flooding monitoring devices are installed and the substation condition and the operation of sump pump system are continuously monitored. By reviewing the operation log of the sump pump periodically and before the rainy season, abnormalities, such as continued water leakage or damage of sump pump piping, can be identified. This can effectively avoid apparatus failure caused by flooding and reduce the asset deterioration due to water damage.

On some occasions, the occurrence of corona discharge was reported at the insulators of AIS in some low load substations. To find out the root cause of the defect, the humidity was also monitored and based on the monitored result, the ventilation arrangement of these substations was revised to avoid accumulation of moisture inside the switchgear and hence prevent the corona discharge from happening.

Paper No. 8

3. CONCLUSION

HK Electric has maintained a world renowned supply reliability figure of better than 99.999% since 1997. The utilization and integration of different CM techniques in the power system asset management plan is one of the key factors which helps the company to achieve this high supply reliability standard, which is essential for a world class city like Hong Kong.

ACKNOWLEDGMENT

The authors would like to express their sincere thanks to the Management of The Hongkong Electric Co. Ltd. for the permission to publish this paper.

REFERENCE

[1] Ir Geoffrey L. CHAN, "Condition Monitoring for Safe and Reliable high voltage power delivery - Technology and Management" in *EMSD Symposium 2009.*

[2] Ir K.W. Yan, "Total Solution Approach for Managing the High Voltage Gas Insulated Switchgear in Hongkong Electric" in *International Conference of Electrical Engineer 2009.*

[3] Ir C.W. Chiu & Mr. K.W. Yeung " Zone Transformer 11kV Neutral Current Surveillance Schemes for Monitoring Integrity of Vacuum Circuit Breakers at Primary Substations" in *The 17th Conference of Electric Power Supply Industry.*

Paper No. 9

TALL BUILDINGS IN SOUTH CHINA – CASES OF CHALLENGES

Speakers : Ir Simon F.W. Chung, Direetor
Ir Y.L. Cheng, Direetor
Ir Tom W.K. Cheung, Assoeiate
Ove Arup & Partners Hong Kong Ltd.

TALL BUILDINGS IN SOUTH CHINA – CASES OF CHALLENGES

Ir Simon F.W. Chung, Director
Ir Y.L. Cheng, Director
Ir Tom W.K. Cheung, Associate
Ove Arup & Partners Hong Kong Ltd.

ABSTRACT

Modern tall buildings have sprung up all over China in the past 20 years. Without exception, the Southern part of China has numerous very exciting tall buildings being developed in the past several years. This paper provides an overview on the design philosophy of electrical systems as well as the specific sustainable, energy savings and efficient systems for three key new tall buildings in Southern China. The tall buildings included in the case studies of this paper are Guangzhou International Financial Centre, Guangzhou TV & Sightseeing Tower and Shenzhen Kingkey Finance Tower, with building height ranging from 400m to 600m. Such tall buildings are rapidly gaining and welcoming publicity in the press in the regions even when they are under construction.

This paper will also highlight the challenges in distributing electrical power in tall buildings, and explore the adoption of energy savings and efficient system designs such as energy recovery and ice storage systems in the design.

1. INTRODUCTION

Following rapid growth of China's economy, construction sites are easily found in China's major cities. The appearance of super-high-rise skyscrapers symbolizes the growth of the regions to the international standards.

Where introduction to every high-rise project in the Southern China is not possible, the following key projects are picked to demonstrate the latest development of electrical designs in the tall buildings of Southern China:

- Guangzhou International Financial Centre
- Guangzhou TV & Sightseeing Tower
- Shenzhen Kingkey Finance Tower

A brief introduction of the characteristics of these landmark tall buildings in Southern China is as follows, while the design philosophy of electrical systems and the specific sustainable, energy savings and efficient systems for these three key new tall buildings will be described in the upcoming sections.

1.1 GUANGZHOU INTERNATIONAL FINANCIAL CENTRE

Paper No. 9

Guangzhou International Financial Centre (Previously known as Guangzhou West Tower) is a 432m tall tower which has become one of the tallest buildings in Guangzhou. Located at the new CBD - the Pearl River New City (珠江新城), the development consists of Class-A office floors, 5-star hotel, shopping mall, exhibition centre and 4-storeys of basement.

Figure 1a Guaugzhou International Financial Centre

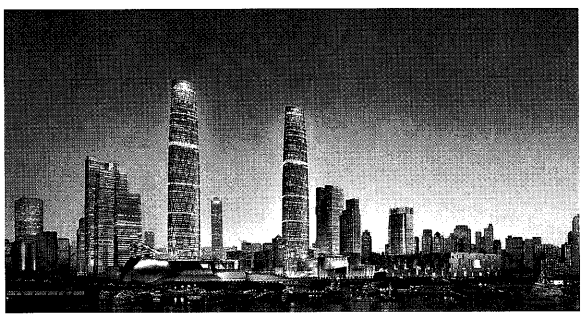


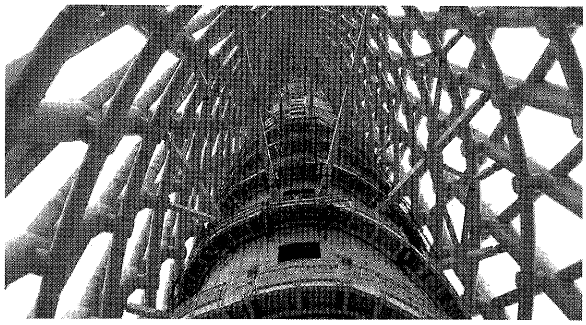
Figure 1b Gnangzhon International Financial Centre

1.2 GUANGZHOU TV & SIGHTSEEING TOWER

Guangzhou TV & Sightseeing Tower is situated on the south bank of the Pearl River and at the new city central axis. Its overall height is 612m and it comprises of a 454m main tower and a 162m tall mast antenna. The tower is completed for broadcasting the 2010 Asia Games. The Tower is the tallest TV Tower in the world.

Fignre 2a Gnangzhon TV & Sightseeing Tower

Fignre 2b Gnangzhon TV & Sightseeing Tower



1.3 SHENZHEN KINGKEY FINANCE TOWER

Shenzhen Kingkey Finance tower is 439m high with 98-storeys. The floors of the tower are divided into three major functions.

The lower floors from levels 2 to 4 are designated for corporate banking trading floors for two major prestigious banks. The middle floors from level 5 to 72 in the main body of the tower will be Grade-A office space for occupancy by financial institutions such as fund management corporations, insurance corporations, futures companies and securities companies. The uppermost floors will be occupied by a 6-star luxury business hotel and will include executive suites, restaurants, fitness club, business centre and other luxury hotel support facilities.

Fignre 3a Shenzhen Kingkey Finance Tower

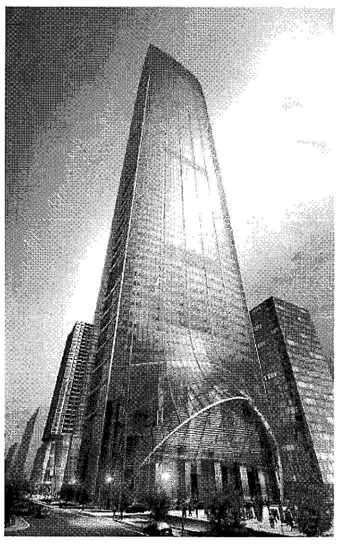
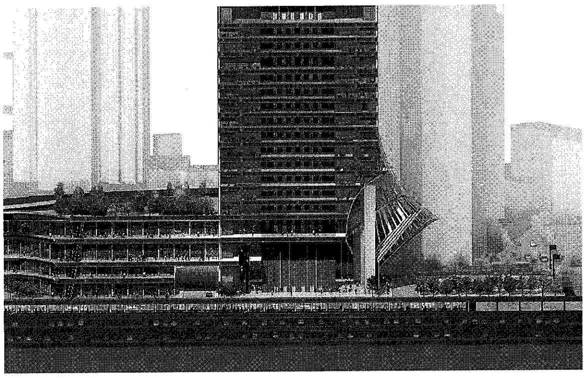


Figure 3b Sheuzheu Kingkey Finanee Tower



2. CHALLENGES IN ELECTRICAL SYSTEM DESIGN

2.1 DESIGN CRITERIA

It is always the efforts of humanity to strive for the recognition of the world, while building taller and taller buildings and being the "highest" in the world is always a way to acknowledge this. In 1998, the tallest buildings, Petronas Twin Towers, were 451.9m in height. In 2004, the tallest building in the world was the Taipei 101 with 509.2 m and in 2009; the record was broken by Burj Khalifa, which is 828m. As the tall buildings are always the landmark of the city, all of the international brands would like to set their headquarters at these skyscrapers as a sign of their prestige.

To serve the demanding tenants such as the highest class banks and hotels, challenges mainly include high requirements of reliability in electrical system designs and stringent space planning due to the characteristic of high building height to floor area ratio in the tall buildings.

2.2 RELIABILITY

On one hand, tall buildings accommodate a high population density (large area concentrated in same footprint) as compared with general building; any power failure, no matter owing to the city power outage or equipment failure, would cause a great impact to both people and equipment inside the building. Hence, a secure power supply and distribution system is very important. The main concerns could be the safety and the operational requirements.

On the other hand, tall buildings commonly have mixed functions such as hotel + office, service apartment + office, etc. No matter what combination it is, the operators of the hotels or offices would impose very high standards to the power supply and distribution system. For hotels in this type of tall building such as the ICC in Hong Kong, the International Financial Centre in Guangzhou or the Kingkey Finance Tower in Shenzhen, the hotel would be usually operated by the most prestige hotel operators. They will demand very secure power supply and distribution system so as to avoid any disturbances to their guests in any situation. For offices, those office floors will probably be occupied by the most famous international investment banks, accounting firms, etc. All those tenants demand the highest electricity reliability and sustainability to support their operation of their business, 24-hours per day, 7 days per week. Thus, the reliability of the power supply and distribution system in tall buildings is an essential design consideration.

Paper No. 9

To achieve the highest reliability of power supply and distribution system, three main systems should be particularly paid attention to. They are Medium Voltage (MV) network system, Low Voltage (LV) network system, and emergency backup power supply system.

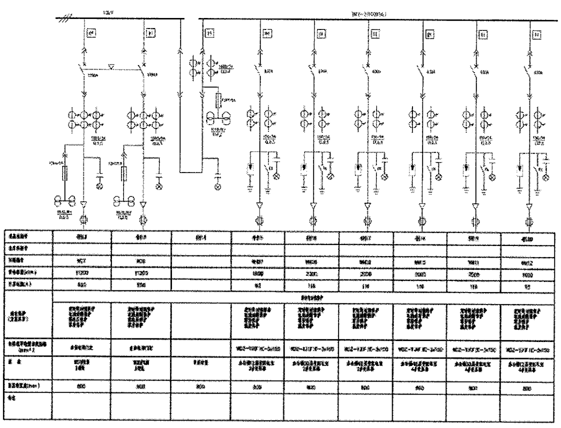
MV network system

Despite most tall buildings being located at cities where the power supply system are very stable, such as Hong Kong, Shanghai, Guangzhou and Shenzhen, dual MV sources from different substations are still essential to avoid any utility power outages due to any occasions. As shown in Figure 4 and Figure 5, dual feed power intake from different substations of the Power Supply Company is adopted in different tall buildings. Apart from the utility power supply network, different MV paths within the building at separate risers and routes are the key concerns, as most of the financial sectors will erect data centres within the building and this is one of the critical criteria to achieve minimum Tier 3 configuration. This is to secure the MV power supply from the power company to the customer substations such that either one of the sources fail, there is still another source available to take up all the essential loads originally fed from the failed source. This arrangement allows switching over of loads from the failed source to the healthy source at the LV network. Furthermore, the separated MV cable risers can eliminate any possibilities of single point failure either caused by accidental damage to cables or malfunction of the electrical equipment. Detailed arrangements of Kingkey Finance Tower and GZ International Financial Centre are shown in the Figure 4 and Figure 5 below.

Figure 4 MV/LV Network Arrangements for Kingkey Finance Tower and International Finaneial Centre

Building	*MV network*	*LV network*
Shenzhen Kingkey Finance Tower	*Dual 10kV sources from different 110kV Substations*	*Dual riser arrangement*
GZ International Financial Centre	*Dual 10kV sources from different 110kV Substations*	*Three riser arrangement*

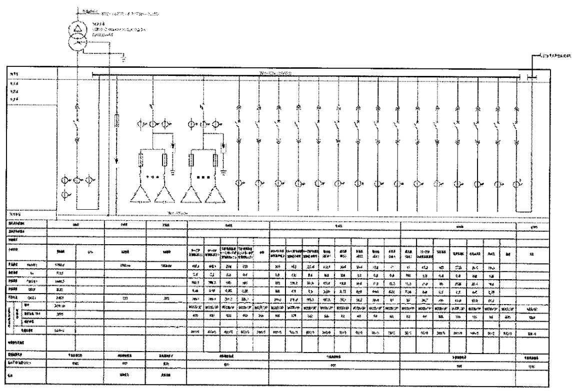
Figure 5 Typieal MV Network Arrangement for GZ International Finaneial Centre



LV network system

In addition to the very reliable and healthy utility power supply network, a proper LV distribution system which could safely and reliably distribute the power supplies to the entire development is essential for tall buildings. For essential loads, dual feeders from different paths are usually adopted. In case there is power failure of either one of the sources, all the essential loads could be switched to the other source to maintain the normal operation of at least the essential equipment. Typical LV schematic is detailed in Figure 6.

Figure 6 LV Network Arrangement for Office Sky-substation in GZ International Financial Centre



Emergency power supply

There are two ways of providing emergeney power supplies, they are:

- UPS and CBS
- Emergency power generator

UPS and CBS System:

As there will be a lot of essential loads whieh are sensitive to power stability, an Uninterruptable Power Supply (UPS) system are required for this kind of essential loads. The major concern is reserve adequate structural load to allow siting of the UPS systems and associated batteries and CRAC units of the operator and tenants. In mainland, the emergency lighting is commonly backed up by Central Battery System (CBS), instead of the self-contained battery. The advantage of using

CBS is to minimize the maintenance works of the operator. Imagine if battery routine maintenance inspection is required every 6 months, such works are huge especially for a building with 80+ storeys. Certainly, both UPS system and CBS will further backed up by the emergency power generator to further raise up the reliability.

Emergency power generator

There are two types of emergency power generators. They are LV and MV emergency power generators.

- *LV emergency power generator*

  LV emergency power generator system is the most common method with lower cost, high flexibility and also lower risk of failure because of no further step-down required. LV generators also allow greater flexibility during coordination and design, because there are various different capacities from 200kVA up. However, in tall buildings, the LV emergency power system should cater the difficulties of voltage drop in power distribution and resulting large cable size in power distribution.

- *MV emergency power generator*

  In tall building, the use of MV emergency power generator system is usually taken into consideration in the design stage. Concerns on voltage drop and energy loss in MV system is less significant than LV system. Besides, MV generators are usually available in higher capacity in the commercial industry and thus the number of generators could be reduced. However, independent transformers are required for emergency loading to secure the power supply at emergency state and thus this imposes higher requirements on spatial coordination, particularly at refuge floors where plant spaces are limited. At the same time, since small capacity of MV generators are less common in the generator market, the design team has to closely coordinate with all tenants on how much emergeney power is required by the different tenants, how to share the large MV generator capacity and liability issues concerning equipment maintenance. Early involvement of the potential tenants who have special requirements would considerably reduce the difficulties associated with alteration works, as their requirements could be incorporated in the early stage of the design.

For the case of Guangzhou International Financial Centre, the challenge for the electrical system was the voltage drop problem in emergency power supply distribution system. The 400+ m height of the building leading the voltage drop across the main bus bar riser exceeded the acceptable voltage drop range of ± 5%. Hence four options were being studied:

a. 10kV diesel generator
b. Boost up transformer
c. Sizing up main risers
d. Select higher output voltage for diesel generators.

As discussed before, there were a number of difficulties faced in adopting option "a". Firstly, small rating MV diesel generator are seldom adopted in Guangzhou, the adoption of MV generators also imposed high requirements on spatial, cost, and technical competence of the maintenance personnel, but also imposing difficulties in obtaining local authorities' approval. Regarding option "b", since this imposed additional technical requirements and this is not economical in terms of energy cost, this scheme was not adopted.

Finally, the combination of options "c" and "d" were adopted and was found to be the most feasible solution among the four schemes. As in the option "d", the output voltage of the diesel generators are set at 400V, allowing a larger range of voltage drop. However, attention should be paid to prevent overvoltage of the connected equipment which are closer to the sources.

2.3 SPATIAL PLANNING

Spatial planning is another important issue in tall buildings. There are a few factors that should receive particular attention. These are building efficiency, operational concerns, voltage drop challenges, reliability concerns, equipment delivery considerations.

Building area efficiency

As the core of the building is so compact such that the spatial allocation of different functional parts of the building/ plant-room and the risers could greatly affect the building area efficiency. For tall building, even an extra 1 to $2m^2$ to the pipe duct area may lead to 100 ~ $200m^2$ area loss for the entire building.

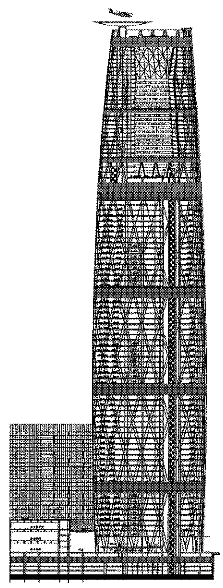
Operational concerns

Other than the building area efficiency concern, the operational concerns should also be taken into consideration. Since tall buildings usually consist of two or more main functional areas, there may be more than one operator operating the building at the same time. It may include hotel operator, office operator and service apartment operator, etc. Dedicated systems and plant spaces for each operator are usually requested. Detailed and careful spatial planning in plant spaces including risers allocation in core space not only fulfill the requirements from the operators, but also improve the building area efficiency.

Voltage drop challenges

As mentioned in the previous section that voltage drop is one of the great challenges in power distribution system. Prudent consideration should be gone through during allocating the MV switch room, LV switch room and determination of the needs of sky-substation in the development. The optimization of the distribution network scheme could minimize the cables size and thus the spatial requirement in the riser duct. Usually sky-substation is adopted in tall building since radius of LV distribution networks more than 150m has already imposed demanding requirement on cables size to withstand the voltage drop. Sky-substation also allows more flexibility in spatial arrangement for additional transformers required by specialized tenants. The sky-substation is a much preferable choice comparing implementing the boost-up transformer in terms of maintenance concerns, operational concerns, cable and spatial cost, and demanding on spatial arrangement.

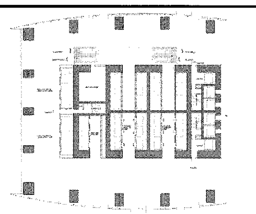
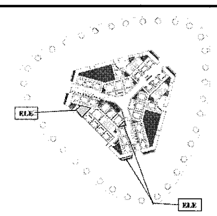
Figure 7 Location of Substation for International Financial Centre



Reliability concerns

Reliability of the power supply is one of the key concerns during spatial planning. From the point of view of securing the dual power supply sources, the cables from the two independent sources should be allocated in different cable risers, and thus in case of single point failure of the power cables, cables from another riser normal operation should still remain. Detailed arrangement of Kingkey Finance Tower and GZ International Financial Centre are illustrated in the below Figure 8.

Figure 8 Typical Riser Arrangements for Kingkey Finance Tower and International Financial Centre

	
Kingkey Finance Tower	**International Financial Centre**

Equipment delivery considerations

As there are sky-substations and plantrooms in the upper part of the tall building, equipment delivery is another challenge for tall buildings. A few tips to tackle the challenge are as follows:

- Deliver through lift shaft

  For Shenzhen Kingkey Finance Tower and Guangzhou International Financial Centre, selected lift shafts will be used for equipment delivery, such as transformers. Closely work with the whole design team to confirm the feasibilities of using the lift shafts as the delivery route.

- Accommodation of large capacity of lift

  As in some of the tall buildings in Hong Kong, a large elevator with capacity up to 4,500kg was adopted to deliver the power transformers of the sky-substations, which is a requirement from the local power supply company. While the optimization and coordination are required to lower the transformers capacity to each of 1,000kVA to 1,250kVA so that the weight of the transformers is within the maximum delivery loading of the lifts. Of course, this solution is the simplest way but more expensive approach. The lift itself is very costly and it will occupy more space which is a great cost to the project.

- Overloading the lift

  Nowadays, there are some lift suppliers that are able to allow their lifts to support loading which is 150% of their rated capacity for equipment delivery. Whether this is applicable to a specific project, shall be subjected to the design of all related disciplines. Thus before adaptation of this choice, closely work and coordinate with the whole design team is required.

3. ENERGY SAVING AND EFFICIENT MEP SYSTEM DESIGN

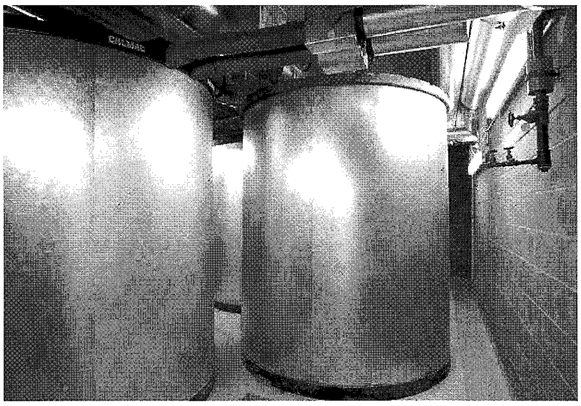
Apart from the challenges in power distribution system designs, energy use and its associated cost are also of great concerns in the design of such kind of large scale project.

Dedicated studies should be carried out for each tall building. The energy saving and efficient MEP systems adopted in the three developments are briefly introduced in the follow sections.

3.1 ICE STORAGE

There is an off-peak electricity tariff period (from 22:00 to 06:00) in Shenzhen. An ice making chiller will make use of the off-peak period to produce ice. Chillers will operate in full load and convert water into ice through low temperature Glycerol. A certain amount of performance degrade is foreseen when the chiller is operated in ice making mode. When the design capacity is reached, the ice making chiller will change to cooling mode or switch off automatically. Basically, night time cooling load is catered by essential chillers.

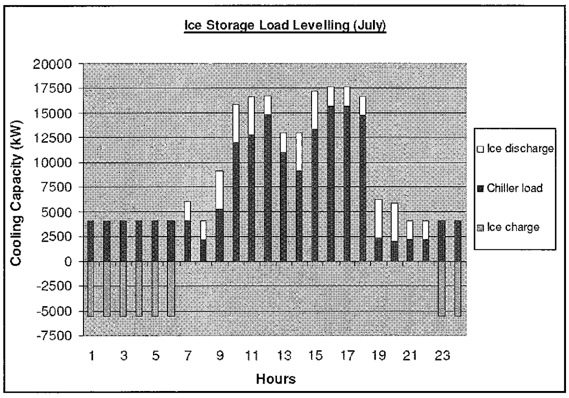
Figure 9 Iee Storage Plant



Since Guangzhou is hot in the summer and hence cooling load is relatively high there. Multi-cooling supply by ice making chillers, essential chillers and ice storage tank may be operated simultaneously during peak cooling load time. The ice making chiller will be operated in cooling mode. Part of the cold Glycerol will run through a by-pass pipe, while the other part will go inside the ice storage tank to absorb cold energy from ice. The mixture will enter the plate type heat exchanger to act as a cold source for the chilled water.

For the Shenzhen Kingkey Finance Tower, total cooling capacity stored in the ice tank is approximately 44,366kWh if ice making chiller is operated for 8 hours, according to the design requirements. The estimated operation profile of the chiller plants and ice storage plants during the month with highest cooling demand is illustrated in the figure below:

Figure 10 Iee Storage and Chiller Plant Operation Profile



Operation modes of the ice storage system are shown in Figure 11.

Figure 11 Operation Modes of Iee Storage System

Operation mode	Direct supply (chilled water production)	Cold storage (ice making)	Cold discharge (chiller switch off & ice melt in icc storagc tank)	Dual supply (chiller operate and ice melt in ice storage tank)
Chiller	Cooling	Ice making	off	cooling
Ice storage tank	off	operate	operate	operate
Operation period	When ice is completely melted and chilled water is required, or during off-peak electricity tariff period	During off-peak electricity tariff period	Make use of ice for chilled water supply during peak electricity tariff	When ice is not sufficient and normal chiller capacity is not capable to handle the required cooling load, ice making chiller operate as chilled water production

For the Shenzhen Kingkey project, by using the ice storagc system, estimations show that an annual saving of more than 21% in the energy cost can be achieved.

Similar studies were carried out in the Guangzhou International Financial Centre and significant saving was foreseen, where the payback time for the installation was estimated to be 3.5 years. However, as the establishment of peak / off-peak electricity tariff in Guangzhou was suspended, the ice storage plant was not adopted at the construction stage.

3.2 PHOTOVOLTAIC

Thin film type Building Integrated Photovoltaic (BIPV) system is adopted at the Guangzhou TV & Sightseeing Tower. A PV module of 8.4m high is installed at the facade near the top of the tower (438.4m - 446.8m), which covers an area of about 1,120m^2 and could generate capacity of 20kWp. The expected energy generation by this photovoltaic system is around 12,000kWh per annum. One of the challenges incorporating PV into this project is the curved surface of the building.

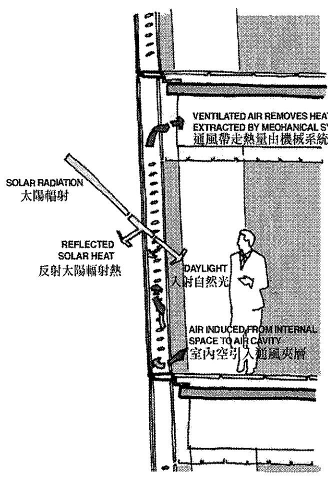
3.3 ACTIVE AIRFLOW CURTAIN WALL

An interactive facade system is proposed for the Guangzhou International Financial Centre, which is generally referred to as an Active Airflow Curtain Wall. This comprises of an economical single skin unitized curtain wall, which has been enhanced to provide a simulated double skin facade. The external glass would be comprised of a clear 12mm Low-E outer pane, 12mm air space and clear 10mm inner pane. This results in a very transparent appearance to the building. The performance enhancement is achieved by the incorporation of a side pivoted 12mm tempered glass panel attached to the internal face of the mullions and the installation of silver reflective perforated mechanically operated venetian blinds within the 300mm air cavity that is created between the external glazing and the internal glass panel. These automated blinds can be linked to the Building Management System and therefore provide controlled tilting of the blinds resulting in a consistent external appearance and to provide internal shading and a medium for absorbing and dissipating thermal energy.

The inclusion of the venetian blinds within the curtain wall system allows it to be included in the shading coefficient calculation thus allowing for a more economical glass choice.

The thermal enhancement and operational savings are achieved by "drawing" conditioned room temperature air through the air cavity that assists in cooling the air in the cavity and venetian blinds and drawing the heated air into a ducting system above the ceiling using low speed fans that is exhausted to the outside. Since the internal air is being circulated at the air cavity, the air temperature is very close to the room temperature, thus reducing the energy consumption for cooling and heating and provides thermal comfort even directly adjacent to the window line.

Figure 12 Concept for Active Airflow Curtain Wall



The active airflow curtain wall can effectively reduce external heat gain and cooling demand. By adopting the active airflow curtain wall, the estimated achievable saving in the running cost for HVAC equipment for the office portion of the tower can be as high as 14%. Also, the required plant space for central air conditioning can be reduced by approximately 9%, which is also one of the merits of using active airflow curtain wall.

3.4 HEAT RECOVERY

For Guangzhou TV & Sightseeing Tower, a heat wheel heat recovery device is adopted in the HVAC system at various areas in the development, in order to recover the waste energy in the exhaust air. Bypass fans were adopted to prevent contamination of the supply air in times of infectious diseases. Potential savings in the energy use in cooling / heating is estimated to be approximately 20%.

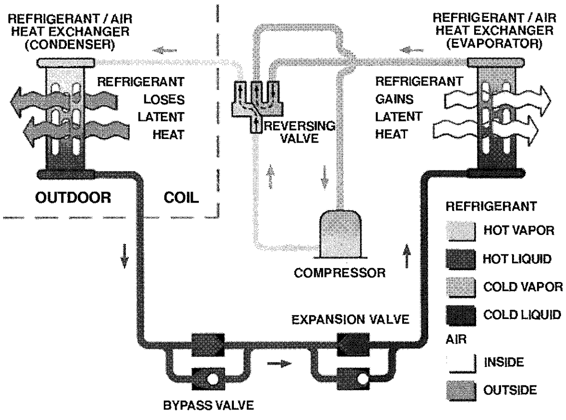
3.5 HEAT PUMPS

Boilers are usually used for the hot water supply and area heating in the developments. However, for Guangzhou TV & Sightseeing Tower, because of the high building height and limited heating demand for each functional area, the adoption of boilers at the basement and lengthy hot water risers and pumps is proven to be costly and inefficient.

Paper No. 9

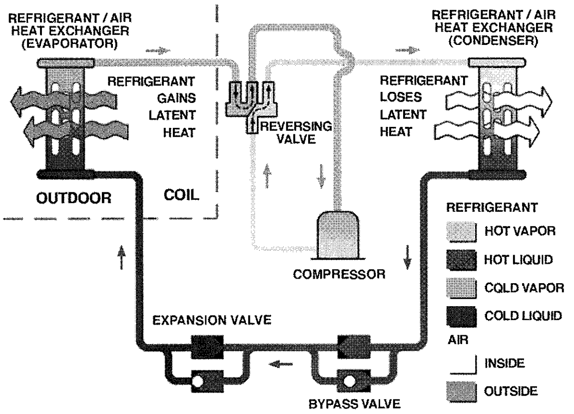
Air cooled heat pumps are therefore provided at the equipment floor at 355.2m to provide hot / cold water at different seasons, the operation principle of the heat pumps at different seasons is illustrated in the diagram as follows:

Figure 13 Cooling Mode for Air Cool Heat Pumps



SIEMENS

Figure 14 Heatiug Mode for Air Cool Heat Pumps



As compared to boilers, the air cooled heat pumps generally have higher COP, meaning that it is more energy efficient.

3.6 TRI-GENERATION

Tri-generation is the utilization of waste heat, where the waste heat are extracted from the exhaust gas from turbine of the generating set to produce cooling, heating and electricity simultaneously. Heating can be provided with the use of a heat exchanger in the tri-generation system to extract the waste heat whereas cooling is produced with the use of adsorption chiller. As a result, the combined heating, cooling and electricity can be produced with the full utilization of the fuel sources. Thinking that using tri-generation to produce both chilled water and heated water to the tower could reduce the transformer size, emergency generators size and oil tanks capacity that was originally serving the chillers and boilers. It could also solve the problem of emergency power voltage drop to the chiller and reduce plant place. The feasibilities were carried out in number of tall buildings like the Shenzhen Kingkey Finance Tower to adopt the tri-generation.

Under the investigation, the tri-generation is more efficient than separate generation of electricity, heating and cooling, when all three products are needed in the project simultaneously. For the case in Shenzhen Kingkey Finance Tower, the considerations for tri-generation were as follows:

- The utility power supply is generally stable and thus it is not a usual practice to have normal power generator.
- The power company in China discourages paralleling any local power source with the utility power.
- Interlocking of the generator power source and the utility source increases the complexity of the electrical system design.
- If tri-generation only used for generation of hot water and production of chilled water, as the COP of the absorption chiller is around one third of that of electrical chiller, it is not efficient and not economic to generate heat for absorption chiller use.

Due to the factors above, tri-generation was considered but not adopted in the project. But for cases where abundant waste heat is available, tri-generation must be an economical option to be explored.

4. CONCLUSION

Whether in the design of electrical systems or in other MEP aspects, the design in each of the tall buildings is unique: Starting from the fundamental design parameter review, loading calculations, system and plant selections, services distributions to the specific reliability requirements, etc. It is this uniqueness which brings challenges and satisfaction to the engineers in the design and construction processes.

For electrical system design in tall buildings, engineers shall always bear in mind the fundamental elements such as reliability and accessibility in their coordination with the architects and engineers.

As the front line to deal with matters concerning energy usage and power consumptions, sound knowledge to the energy saving / sustainability initiatives can certainly help electrical engineers to optimize their designs as well as to keep up with the latest trends.

The completion of tall buildings like the three key projects mentioned is not the goal but a milestone for the development of China. With the experience gained in these projects, it is sure that engineers shall continue to strive for excellence in the MEP designs and sustainable designs for the upcoming tall buildings and mega-scale development projects.

- Notes and Questions -

Paper No. 10

VERTICAL TRANSPORTATION CHALLENGES FOR SUPER HIGH RISE BUILDINGS

Speakers : Mr Jeremy Yonker, Senior Manager
Mr King H. Chan, Senior Sales Manager
Otis Elevator Company (H.K.) Limited

VERTICAL TRANSPORTATION CHALLENGES FOR SUPER HIGH RISE BUILDINGS

Mr Jeremy Youker, Senior Manager
Mr King H. Chau, Senior Sales Manager
Otis Elevator Company (H.K.) Limited

ABSTRACT

Since the introduction of the first 'Safe' lift in 1853 by Elisha Graves Otis, the shape of our skyline has changed forever. Building designs are no longer limited by heights. The advancement of technology has made new skyscrapers possible. Vertical transportation solutions are readily available for Architects and Engineers whose designs are limited by their imaginations only.

Although solutions for super high rise buildings are available, they must be well understood and carefully applied in order to ensure best system performance to meet traffic demand. This paper will examine the challenges and solutions that are available to designers a vertical transportation system that will meet tomorrow's skyscrapers' needs. Other innovative designs and associated equipment will also be discussed in the paper.

1. INTRODUCTION

The Sky is the limit. Building owners around the world are racing to build the world's tallest building. While Hong Kong has witnesscd the completion of its famous International Commerce Centre (ICC) last year reaching a height of 484m, another taller skyscraper which is not too far across the border, the Guangzhou TV tower is quickly becoming a landmark in Guangzhou with a height of 450m (610m with a TV antenna). In Dubai, another record breaking building, Burj Khalifa (formerly known as Burj Dubai), is reaching up the sky at a height of 828 meters. Apparently, the race to be the tallest building in the world is not going over yet. New technologies together with new concepts are created to challenge the limits of these super high rise buildings.

The vertical transportation system is the prime consideration in the design of these super-structures in terms of space planning, comfort and efficiency. The success implementation of a brilliant building design lies in the co-operation among architects, consultants, engineers and lift contractors throughout the entire design and construction process. Irreversible damages may not be resulted if the above are not well coordinated.

2. PRELIMINARY DESIGN

2.1 LIFT TRAFFIC SIMULATION

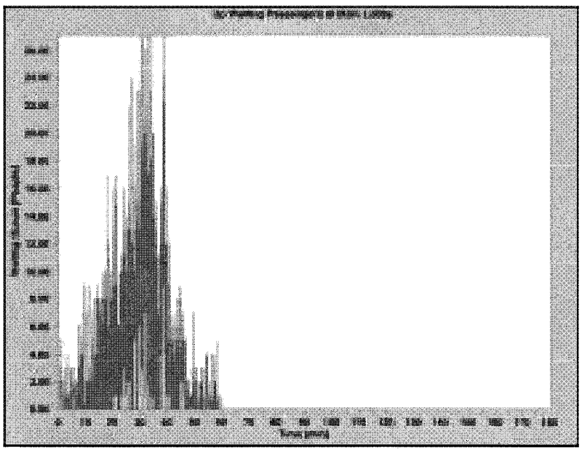
In designing a lift system, the first step is to perform a standard traffic analysis. "Transportation Systems in Buildings - CIBSE Guide D" is a reference guide that is widely used by engineers and professionals in the industry. Simple formulas are extracted from it and used to calculate the average waiting interval and 5-minute handling capacity of the proposed lift system. These two criteria are the two commonly used figures in determining whether adequate lifts are allowed. The advantage of using these criteria to determine traffic requirement is obvious. We can test different scenarios with different combinations of numbers of lifts and speed in a matter of minutes. The shortcoming of these formulas is that passengers and lift movements are only considered on a static basis. We all know that both passengers and lift movements are dynamic in real life.

It is often that specific traffic information may be required which is not readily available by simple calculations. Important information such as call registration time and occurrence of exceptional long waiting time are sometimes needed for a thorough lift performance study. There is another tool that we can use to accurately determine lift traffic requirements - it is the lift traffic simulation.

A lift traffic simulation is a computer program that predicts performance of a real system by observing the behavior of a mathematical model of that system. Simulation finds its greatest use in determining the effect of traffic patterns on a building's transportation requirement. A typical graph showing the number of people waiting at the lift main lobby versus time as generated by the simulation program is shown in figure 1.

Simulations allow the proposed lift system to be tested under various passenger incoming patterns which are critical in ensuring that it performs satisfactorily under different traffic conditions. A realistic and clear prediction of the lift performance can be viewed in front of us so that the most cost effective solution can be chosen.

Figure 1 Number of People Waitiug at Maiu Lobby vs Time



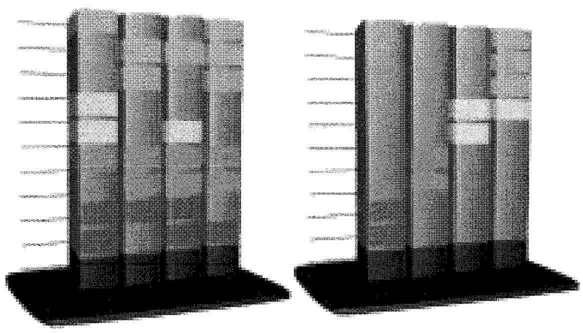
2.2 DISPATCHING SYSTEM

There is a common requirement amongst all super high rise buildings - a highly efficient lift system. The dispatching system plays an important part in the efficiency of a lift system.

We have seen the evolution of the dispatching system from the simpliest form of 'Call and Send' to today's popular Destination Dispatching System.

The Destination Dispatching System uses passenger destination information to improve traffic flow and tavel time in busy mid- and high-rise buildings. In stead of using standard hall call buttons, passengers enter the specific floor they want to travel to before they enter the lift. The system assigns passengers tarvelling to nearby floors to the same car. This minimizes the number of stops per trip and significantly reduces car crowding, as well as passenger waiting and travel times. The effect of Destination Dispatching System is illustrated in figure 2.

Figure 2 Lift Served Floors of Conventional System vs Destiuation Dispatebing System



Conventional Up/Down buttons The Latest Destination Dispatching System

The Destination Dispatching System continuously monitors passenger demand to implement the most effective dispatching method at any given moment. It constantly assesses real-time passenger origin and destination data to dynamically assign cars. As a result, the system is able to better accommodate changing traffic patterns throughout the day.

By grouping passengers by common destinations, the system delivers personalized service, increasing tenant satisfaction and delivering an array of benefits:

- Less passenger waiting time

- Less lift travel time
- Fewer stops per trip
- Improve lobby traffic flow
- Increased operational efficiency

The destination dispatching system does come with another important but not so obvious solution to one of our vertical transportation needs. In designing buildings, there are always needs to have a group of lifts serving non-identical floor. Some lifts may serve all floors above ground while others may need to serve basement floors below ground. The destination dispatching system will careful select the right lift for the passengers according to their destination without having the passengers to change lift at ground floor.

2.3 DOUBLE DECK LIFTS

Super high-rise buildings often accompany with large building population. Using traditional lift calculation, the number of lifts is proportional to the height of building. The higher the building, the more number of lifts is required and so more lift cores are needed. Increasing the speed of lifts may offer some help but not always be the best solution. The solution rests on a lift system that carries substantially more passengers and allows them to ingress and out of the lift car quickly. Double deck lifts will just fit this requirement. If a building's lift core is allowed to remain unchanged despite the increase in height of the building, the total usable floor area for the entire building will increase. Because fewer hoistways are required to serve a building with double deck lifts, less core space is devoted to the lift system. Rentable space is increased. Double deck system makes possible more creative use of street and lower level floors, accommodating atrium lobbies and dual level malls, and affording more rentable commercial space.

Here's an example comparing the lift performance between single deck lift and double deck lift based on identical speed and capacity per lift car.

<u>Basic building data:</u>

Floors above lobby: 12

Average floor height: 4m

Total building population: 1,080

<u>Lift specifications:</u>

Capacity: 1,600kg (21 persons)

Speed: 5 mps

Table 1 Comparison of a 4-Car Single Deck and Donble Deck Lift

	Interval	5-min Handling Capaeity
Single deck	38.7 sec	11.5 %
Double deck	35.8 sec	24.8%

In the example shown in table 1, we can see that the handing capacity of double decks not only double that of single deck, the interval has also improved as the number of probable stops reduces.

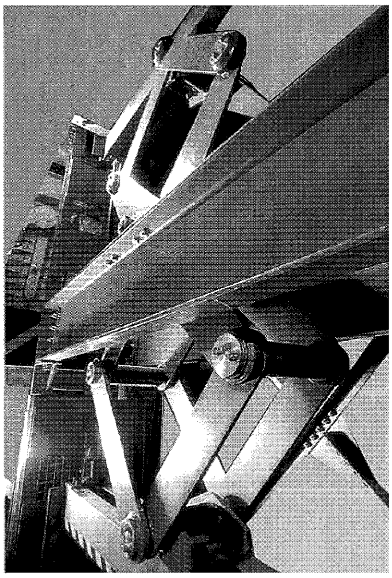
The application of double deck lifts must be considered in the original building design in order for it to work smoothly. The following need to be fulfilled:

- The floor heights served by the double deck lift must be equal.
- Adequate headroom and/or pit depth to be allowed if the top and bottom floors are to be served by all decks.
- Clear signage to be placed at suitable locations to direct passengers to the appropriate lobbies.
- Escalators to be placed at suitable locations to direct passengers to the appropriate lobbies.

Nowadays, the Architects would not constrain themselves to the old conventional designs. They have many creative and innovative ideas. The lift technology must be able to develop further to cope with their new design concept. One of the challenges the lift industry has been facing is a high ceiling at the main lobby to have a grand impressive entrance or a shorter floor height at the mechanical floors. In other words, the floor heights at different floors are not equal. How can this be overcome?

In the market, we now have a flexible Double Deck Lift. The concept is simple. Between the decks, there is a mechanism capable of adjusting the decks to the right floor heights on it way up or down. One typical example is illustrated below in figure 3:

Fignre 3 Mechanism hetween Donhle Deck Lift Cars accommodate Unequal Floor Heights



This flexible Double Deck Lift would therefore allow:

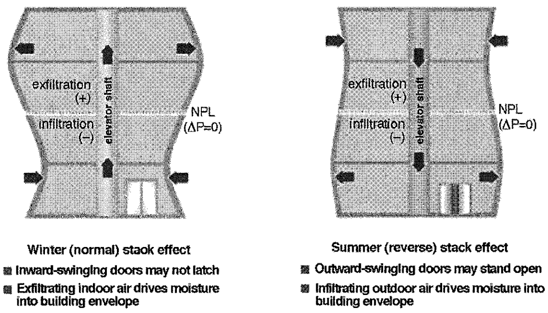
- Improvement on traffic
- No sacrifice on the building usable core area
- More flexibility on building design
- An ideal solution for a super high rise building

3. OTHER CHALLENGES - RIDING QUALITY

3.1 STACK EFFECT

On super high-rise buildings, the effect of 'stack effect' has often been experienced in the hoistways, lift lobbies and stairwells. However this phenomenon has sometimes been neglected in the preliminary study of a building design. Stack effect is created due to disparate temperature between the inside and outside of a tall building which forces pressure differences between the lift lobbies and lift hoistway, particularly troublesome during winter in northern part of the world where there is a big temperature difference between heated lift lobby and the snowed street outside. This is typically illustrated below in figure 4 in a simplified form.

Figure 4 Stack Effect at Different Times



Fundamentally, the primary source of the stack effect is the buoyancy of the tall columns of warm air in the building, such as in the lift hoistways and stairwells. On a cold day, the outside air flows into the building on the lower floors and the warmer building air exits the top. This airflow creates various pressure differentials across the lift, stairwell and outside doors. The maximum pressure differential of a building is proportional to its height and to the temperature differential between the building and the outside.

On cold days, high rise buildings may experience pressure differentials over 125Pa resulting in a 50kg force on standard door. Lift doors may bind when the door pressure is in excess of 25Pa and noise through door gaps becomes noticeable when the pressure on a door reaches about 30Pa (60dBA about 0.5m from the door). A site investigation on a building in Roppongi Hills was carried out in Japan on a 0°C day which was considered as a typical worst case. An analysis showed that the pressure forces exceeding 50Pa have been experienced on lift doors and 100Pa on machine room doors to the outside.

Furthermore when the outside doors are opened, a large draft will cause discomfort for occupants and increase the energy load of the building. Calculations for a conservative Roppongi scenario with plain sliding doors shows the infiltration of air through open outside doors on the lower levels reaching 120,000 cfm. This is double the infiltration that occurs when the revolving doors are used and equivalent to the amount of outside air normally supplied by the HVAC system for four floors.

With such dilemma, what are the mitigations?

The mitigations can only be resulted from the cooperation of many different parties. This is an effort of entire building design with all building services, HVAC contractor, architecture, E&M consultant and lift contractor.

- To reduce the source of the stack effect, the hoistway air can be conditioned (or mixed with outside air) to have a closer temperature match to the outside. To completely eliminate the source, the hoistway air temperature must be exactly matched with the outside temperature. In practice, warm building air will still infiltrate into the hoistway which then rises resulting in a weak stack effect.

- To reduce the impact of the stack effect, the flow of the air can be reduced by impeding its path. Tighter doors are one impediment, but the resulting pressure on the door may be very high. Another method is to utilize a series of doors such as lift lobbies or double-door corridors. This reduces the airflow and reduces the pressure load on the doors. This is particularly effective when they are synchronized to create an air lock. A typical example is at the Roppongi Hills building in Tokyo which has already used the practice of closing its fire shutter doors around the lift lobbies during winter months to counter the stack effect. In general the challenge is to restrict the building airflow without overly affecting its occupants. Revolving doors are popular as entrances since they are always closed.

Here are a few site studies:

In Shanghai Financial Building, there have been several proposed several concepts that were analyzed including cooler air in the hoistways which was found to be quite effective and fan pressurization of the hoistways found to be ineffective. When the cooling the hoistway with outside air, it must be added through the bottom of the hoistway to avoid dissipation of the cool air into the building.

Analysis revealed several locations in the building where standard methods would be beneficial such as adding lift lobbies with tight doors or replacing the revolving doors with sliding doors which have smaller door gaps.

Several new concepts have been proposed by Otis for consideration and were analyzed. These new concepts are:

- Triple Outside Door Air Lock System
- Integrated Building System Pressure Management
- Vertical Air Lock System

The Triple Door Air Lock which could be applied to Roppongi Hills consists of three sets of synchronized sliding doors and will effectively function as a closed sliding door relative to air infiltration. Preliminary calculations show that this system may allow higher traffic flow than with a revolving door. This will be analyzed further. Implementation risks include the psychological effect of the airlock door system and the space needed particularly when doubled to achieve the two-way traffic flow.

Integrated building pressure system management seeks to approach the ideal situation of eliminating the source of the stack effect by matching the hoistway and the stairwell temperatures to the outside and by matching the pressure between the building and the outside with the HVAC system. This concept would require a building control strategy which first establishes cool temperatures in the hoistway and stairwells. Active floor-by-floor HVAC control should then be applied to match the hoistway and stairwell pressures. Energy issues with the cold hoistways need to be addressed in more details, but preliminary calculations shows that standard fans can reduce hoistway temperature by 10° to 15°C and the energy load on the building would increase by about 2-3%. Risks include the effect of cold air in the hoistway and stairwells on the occupants of the building and lift cabs.

The vertical air lock system consists of a set of low-rise lift with independent hoistways that isolate the entrance doors and garage from the remainder of the building. All such entrances are located on the floors below the vertical airlock. Above the vertical airlock, the building should be as airtight as possible. Airflow calculations show that this concept essentially eliminates air infiltration at the floor levels below the Vertical Air Locks.

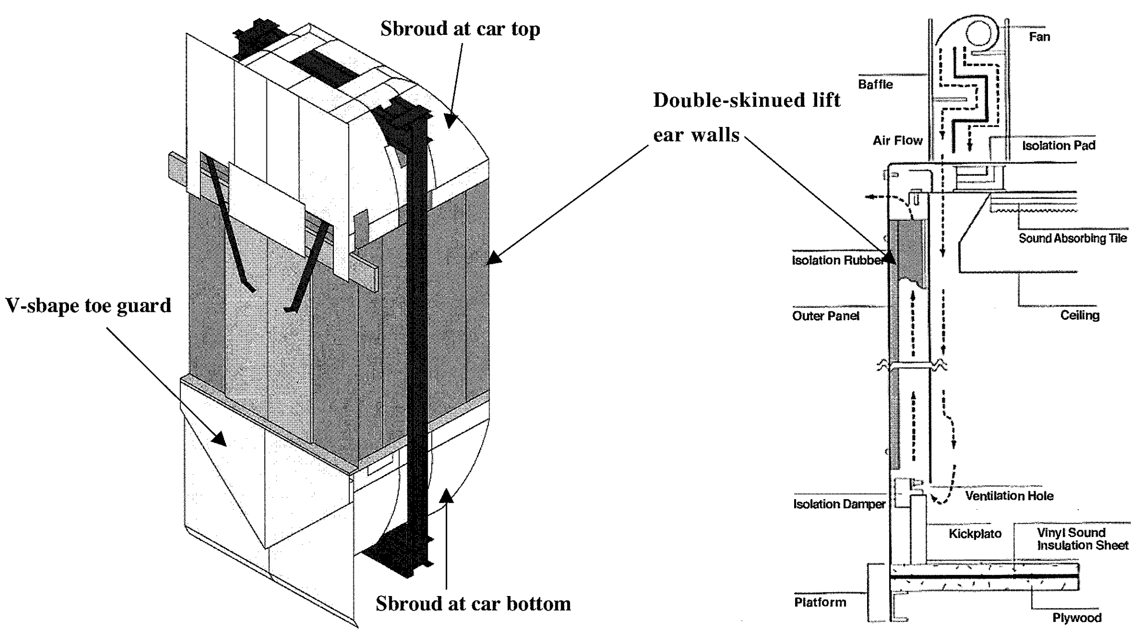
3.2 NOISE ELIMINATION

Aerodynamic noise is a potential source of detrimental ride quality in a lift. The strength of this source increases with the effective lift speed. Increasing the lift speed and/or increasing the hoistway efficiency results in an increase in the effective speed. This is of particular concern for high-rise lifts where high speed is needed to minimize ride times and high hoistway efficiencies are desired in order to maximize usable building space. Minimizing aerodynamic noise sources are therefore important for achieving noise and vibration targets for high-rise lifts. Thus the aerodynamic properties of the lift must also be considered.

Ideas to reduce aerodynamic noise (see figure 5)

- Shrouds on the lift car top.
- Double-skinned lift car walls
- Toe guard shaping (V shape)

Figure 5 Meaus of Reducing In-Car Noise

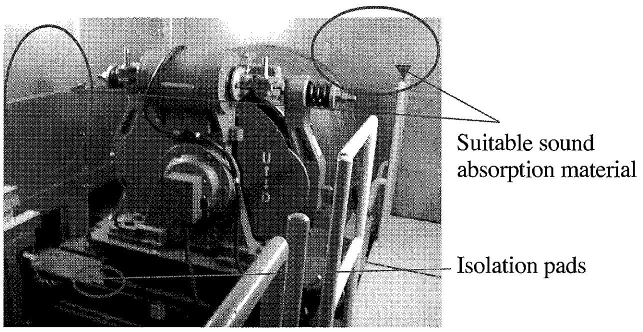


The Structure-borne noise is also a source that we need to eliminate. The strength of this source is heavily influenced by the characteristics of large hoisting machines, especially when installed directly among the structural wall and floor slab. This is of particular concern for lift machines installed near the apartments and/or hotel guess rooms. Minimizing the structure-borne noises is also important for achieving noise and vibration elimination control.

Ideas to reduce structure-borne noise (see figure 6)

- Structural isolation using isolation pads or springs

Fignrc 6 Typical Noisc Redncing Provisions in Lift Machinc Room



4. CONCLUSION

Architects and engineers have taken up the challenge to reach for the sky. Today's advances in technology and resurgence in super skyscrapers have inspired the lift manufacturers to reinvent the lift that will meet tomorrow's challenge. Around the world and especially in Asia, the need for super high-rise buildings is driving the demand for more customized solution for the vertical transportation system in the context of performance and quality. At the same time, customers are demanding for more efficient system technology that delivers superior performance with uncompromising safety and comfort. As long as new technologies are invented to overcome challenges for new skyscrapers, the height limit of skyscrapers shall remain a mystery.

REFERENCE

[1] CIBSE Guide D (2005)

[2] Gregory P. Lorsbach, Analysis of Elevator Ride Quality, Vibration, Elevator World (June 2003)

[3] Dr. Vijay Jayachandran, Ride Quality and MASC Team, Otis Worldwide Engineering, Elevator Vibro-Acoustic Interfaces to the Building Design for variation, October 2006

[4] Patrick Sheen, Otis Internal Documents (July 2009)

[5] Jeremy Youker, Jeffrey Chan, Otis Internal Documents (September 2009)

Paper No. 10

SIEMENS

- Notes and Questions -