THE HONG KONG
INSTITUTION OF ENGINEERS
ELECTRICAL DIVISION

The 34th Annual Symposium
Tuesday
25th October 2016

INNOVATIONS FOR SMART CITY

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

8.30 Registration and Coffee

9.00 Welcome Address
- Ir C.F. Chan
  Chairman, Electrical Division, The HKIE

9.05 Opening Address
- Ir Joseph K.H. Choi
  President, The HKIE

9.10 Keynote Speech
- Ir Allen T.B. Yeung, JP
  Government Chief Information Officer
  Innovation and Technology Bureau
  The Government of the HKSAR

1. <u>Smart Power Systems</u>

9.40 Smart Power Network in CLP Power
- Ir C.F. Tsui, Deputy Director – Asset Development
- Ir S.P. Lee, Asset Development Engineer
- Ir W.C. Ho, Asset Development Engineer
- Ir S.K. Lau, Asset Utilisation Engineer
  CLP Power Hong Kong Ltd.

10.00 Application of Advanced Technologies for Management of Transmission Cable System in HK Electric
- Ir A.C. Chen, Support Engineer
- Ir Ronald W.C. Chow, Engineer
  Transmission & Distribution Division
  The Hongkong Electric Co. Ltd.

10.20 Discussion

10.40 Coffee Break

2. Smart Buildings & Services

11.10 EcoDistricts

- Mr Jacob Chan
  Managing Principal
  Glumac, Los Angeles, CA, USA

11.30 Smart Building Services Design for Healthcare Building Projects

- Ir C.K. Lau, Chief Building Services Engineer
- Ir Carl M.H. Lam, Senior Building Services Engineer
- Ir Chris W.K. Lee, Building Services Engineer
  Architectural Services Department
  The Government of the HKSAR

11.50 Automatic Meter Reading in Smart City

- Ir C.O. Ng
  Senior Electrical and Mechanical Engineer
  Technical Development
  Water Supplies Department
  The Government of the HKSAR

12.10 Discussion

12.30 Lunch

3. Smart Transport & Traffic Systems

14.00 Intelligent Design on MTR 33kV Automatic Changeover System and Optimization of Overvoltage Protection Device Operation

- Mr Ellis S.C. Chan, Senior Construction Engineer – Power Supply
- Ir M.K. Mak, Senior Engineer, Power Supply & Overhead Line
  MTR Corporation Limited

14.20 Smart Traffic Monitoring System

- Dr Alfred S.F. Wong, Council President
- Ms Edco W.I. Ho, Member
  The Macau Institute of Engineers

14.40 Accelerate the World's Transition to Sustainable Energy

- Ms Isabel C.Y. Fan
  Regional Director
  Tesla Motors Hong Kong, Macau & Taiwan

15.00 Discussion

15.20 Coffee Break

4. ***Smart Energy Use***

15.50 Modern Issues in Smarter Energy Usage

- Professor David J. Hill
  Chair of Electrical Engineering,
  Department of Electrical & Electronic Engineering,
  The University of Hong Kong

16.10 Trial Scheme on Smart Dimming for Lighting System of Footbridge

- Ir Steve K.K. Chan, Senior Engineer, Lighting Division
  Highways Department
- Ir K.K. Wong, Engineer, Projects Division
  Electrical & Mechanical Services Department
  The Government of the HKSAR

16.30 Discussion

16.45 Summing Up

- Ir P.K. Chan
  Symposium Chairman
  Electrical Division, The HKIE

16.50 Closing Address

- Ms Brenda K.Y. Au
  Head of Energizing Kowloon East Office
  Works Branch, Development Bureau
  The Government of the HKSAR

Acknowledgement

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 Allen T.B. Yeung, JP
Ms Brenda K.Y. Au
Ir C.F. Tsui
Ir S.P. Lee
Ir W.C. Ho
Ir S.K. Lau
Ir A.C. Chen
Ir Ronald W.C. Chow
Mr Jacob Chan
Ir C.K. Lau
Ir Carl M.H. Lam
Ir Chris W.K. Lee
Ir C.O. Ng
Mr Ellis S.C. Chan
Ir M.K. Mak
Dr Alfred S.F. Wong
Ms Edco W.I. Ho
Ms Isabel C.Y. Fan
Professor David J. Hill
Ir Steve K.K. Chan
Ir K.K. Wong

Sponsors

Siemens Ltd.
CLP Power Hong Kong Ltd.
The Hongkong Electric Co., Ltd.
The Jardine Engineering Corporation Ltd.
Keystone Electric Wire & Cable Co. Ltd.
MTR Corporation Ltd.
Kum Shing Group
C&K Instrument (HK) Ltd.
Greenland Engineering Co., Ltd.
Mitsubishi Electric (Hong Kong) Ltd.
Meiden Pacific (China) Ltd.
TE Connectivity Hong Kong Ltd.
Gammon E&M Limited
Schneider Electric (Hong Kong) Limited
Metrix Engineering Co. Ltd.
Chat Horn Engineering Ltd.
FSE Engineering Group Ltd.
S.G.H. Electric Wire & Cable Co. Ltd.
The Hong Kong & Kowloon Electric Trade Association
Hong Kong Electrical Contractors' Association Ltd.

34TH ANNUAL SYMPOSIUM ORGANIZATION COMMITTEE

Symposium Chairman:	**Ir P.K. Chan**
Members:	**Ir C.F. Chan**
	Ir Siu-kwong Ho
	Ir T.K. Chiang
	Ir Tommy C.F. Lam
	Ir Tony K.T. Yeung
	Ir Mandy M.Y. Leung
	Ir Y.H. Chan
	Ir C.L. Wong
	Ir Steve K.K. Chan
	Ir Alex T.H. Fu
	Ir Raymond K.M. Sze
	Mr Indi W.F. Wong
Hon. Secretary and Treasurer:	**Ir Y.K. Chu**

Paper No. 1

SMART POWER NETWORK IN CLP POWER

Speakers: Ir C.F. Tsui, Deputy Director - Asset Development
Ir S.P. Lee, Asset Development Engineer
Ir W.C. Ho, Asset Development Engineer
Ir S.K. Lau, Asset Utilisation Engineer
CLP Power Hong Kong Limited

SMART POWER NETWORK IN CLP POWER

Ir C.F. Tsui, Deputy Director - Asset Development
Ir S.P. Lee, Asset Development Engineer
Ir W.C. Ho, Asset Development Engineer
Ir S.K. Lau, Asset Utilisation Engineer
CLP Power Hong Kong Limited

ABSTRACT

CLP Power Hong Kong Limited (CLPP) is one of the key energy providers in Hong Kong, delivering world-class standard electricity supply to 80% of the city's population and supporting the territory's economic growth for over a century. To sustain high supply reliability, CLPP is one of the utilities at the forefront of adopting the latest technology in the development and continuous improvement of its transmission and distribution systems to enhance network performance.

In the past few years, CLPP has introduced various new and smart technologies in its transmission and distribution systems to optimize the network operation effectiveness and enhance power supply reliability and availability. All unremittingly efforts aim to provide quality electricity supply to the customers and support the development of a greener and smarter Hong Kong.

CLPP has implemented a number of pilot projects from 132kV to 11kV and LV system to develop a more holistic approach for the application of smart technology in the power system network with due regard to the operation characteristics of plant and equipment at different voltage levels. Some key smart technology applications include 132kV intelligent substation, smart distribution substation and 11kV overhead line automatic supply restoration system.

This paper mainly shares CLPP's experience in design, engineering and application of these advanced technologies in the transmission and distribution network.

1. INTRODUCTION

CLP Power Hong Kong Limited (CLPP) operates a vertically integrated electricity generation, transmission, distribution and retail business in Hong Kong, providing a highly reliable supply of electricity to 80% of population in the territory. Between 2013 and 2015, CLPP's customer experienced an average of 1.5 minutes of unplanned power interruptions per year which was equivalent to the supply reliability of over 99.999%

As one of the major electricity supply companies in Hong Kong, CLPP is keen to explore various latest and smart technology for application in the transmission and distribution network to further enhance network performance in terms of supply reliability and availability, cost optimization and system resilience.

With the latest technology development in the industry, there are a number of smart systems/functions available for the relevant transmission and distribution equipment to support the objective of enhancing network performance. The focus areas are mainly related to substation automation, self-healing features and condition monitoring technique. As such, a number of pilot technology development projects have been implemented in CLPP in the past few years to gain experience on these smart functions so as to assess their benefits and potential for wider-scale implementation. In addition, such technologies will support the Smart City development of Hong Kong.

2. APPLICATION OF SMART TECHNOLOGY AND RELATED KEY INTELLIGENT FEATURES

CLPP has implemented a number of pilot projects ranged from 132kV to 11kV and LV system to develop a more holistic approach for the application of smart technology in the power system network with due regard to the operation characteristics of plant and equipment at different voltage levels. There are a number of key smart technologies applications in various projects including i)132kV Intelligent Transmission Substation; ii) Smart Distribution Substation; and iii)11kV Overhead Line Automatic Supply Restoration System. The smart features of individual project are further elaborated as below.

2.1 Intelligent Transmission Substation

Two intelligent 132kV transmission substations have been successfully implemented in CLPP by 2014. Making use of the latest IEC61850 standard, the Intelligent Protection Automation Control & Supervision System (IPACS) has been adopted to

SIEMENS

provide a common communication standard for integration of control and monitoring function for substation automation. Also, it enables the interoperability of equipment from different proprietary systems for easy communication.

The use of IEC61850 GOOSE message allows the application of software interlock in 132kV switchgear to get rid of significant wiring work of the conventional hardwired logics.

With dedicated Intelligent Electronic Devices (IEDs), Numerical Auto-switching Scheme (NAS) per IEC61850 standard has been developed for 11kV switchboard to provide additional flexibility for instantaneous power supply restoration to ensure high supply reliability.

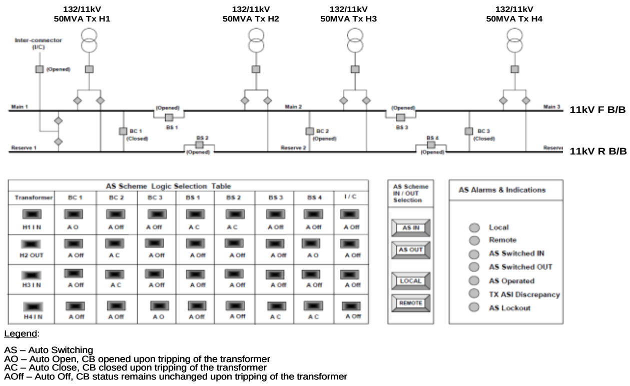


Fig.1 - Logic selection, alarm & indication of 11KV NAS scheme

NAS will be activated when the 132/11kV transformer supplying the substation tripped and it will then open or close pre-selected 11kV bus-coupler, 11kV bus-section and 11kV interconnector under pre-programmed sequence to restore power supply within 250mS. IEC61850 GOOSE message is adopted to send the switchgear status from bay relay to NAS relays as well as to send Close/Open command from NAS relay back to bay relay via the process bus.

The NAS is a smart alternative to replace the conventional hardwired automatic switching scheme employed in CLPP for many years. The main limitation of the hardwired scheme is the system must be run in the several designed configurations with all relevant circuits in service. Any change of the system running configuration, such as either one of the incoming transformers, bus-coupler circuit breakers (CB) and bus-section CBs on outage, the function of the automatic switching scheme will be forfeited for these scenarios. This reduces the flexibility of the automatic restoration function during equipment planned and unplanned outages. In contrast, the NAS is more flexible, which allows the auto-switching scheme to be re-programmable to suit operational arrangement different from the normal designated configurations.

The NAS scheme can also be programmed remotely by System Control engineer to different auto-switching actions to suit both normal and contingent system configurations. With such self-healing functionality the supply reliability can be greatly enhanced, especially during unplanned equipment outage condition.

Condition Monitoring is another critical tool for incipient fault detection and condition based maintenance of electrical plant and equipment. The intelligent transmission substations are equipped with various condition monitoring features for 132kV switchgear including online Ultra High Frequency (UHF) partial discharge monitoring, circuit breaker operation performance monitoring which tracks parameters like opening/closing time and speed, for analysis of CB contact wear. In addition, the SF6 gas condition in terms of temperature, moisture, density and pressure is monitored for any abnormality to give an early warning signal for maintenance or other necessary remedial actions.

Apart from the IPACS, NAS and condition monitoring, an Information Technology System called *Substation Information Portal* (SIP) has been installed to provide a common communication platform for engineering and operation personnel to access the operation condition of the equipment online for system planning and maintenance scheduling. This SIP complied with IEC61850 standard which serves as a hub to collect the information from various digital protection, control and monitoring systems for local and remote access. It greatly supports operation staff to understand the latest plant condition and take necessary actions promptly. Mobile SIP interface with smartphone/ tablet PC applications are also available for convenience of operation staff.

The experience of the project will be helpful in formulating the blue-print of intelligent transmission substation for substations to be built in future.

2.2 Smart Distribution Substation

Pilot project of latest condition monitoring (CM) technologies has been carried out in three existing distribution substations since 2012. Numerous new and smart systems were selected for implementation to achieve the intelligent functions, including condition monitoring on substation plant equipment, substation access supervisory and substation environment monitoring. Similar to the intelligent 132kV transmission substations in the power system network, the communication standard i.e. IEC61850 was used as the common communication platform between the local gateway system and remote backend server.

In order to allow flexibility of CM system implementation, wireless technology of third-generation (3G) mobile network was adopted to provide a rapidly deployable and secure solution for communication and data transmission. All data from local IEDs and system will be transmitted under a private Access Point Name (APN) through the Corporate Mobile Data Infrastructure (CMDI), which supports wireless communications and applications meeting the cyber security requirement.

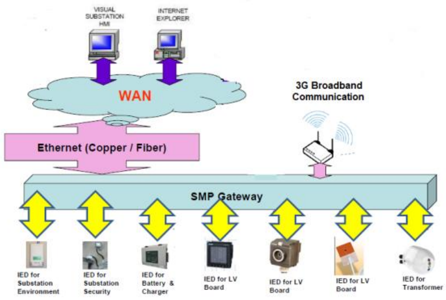


Fig.2 - Architecture of the CM system for Smart Distribution Substation

The details of the on-line condition monitoring technologies trialed for the Smart Distribution Substation are summarized in Table 1.

These CM technologies provide an integrated solution to acquire the latest information and condition of the equipment and substation itself. CM can support frontline staff to detect early incipient fault of equipment such that necessary and prompt remedial actions can be taken before equipment failure which would otherwise lead to significant equipment damage and supply interruption.

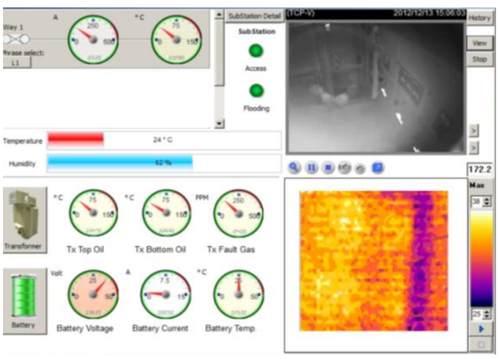


Fig.3 - Graphical user interface of imaging data from Smart Distribution Substation

Type of Condition Monitoring	**Equipment to be monitored**	**CM Technology and its measured parameter**
Substation Plant Equipment Monitoring	LV Fuse Board	• Power meter including current, voltage, harmonic current, power etc. • Infra-red hot spot detection • Cable terminal temperature
	Transformer	• Main tank surface temperature • Dissolved Gas Analysis (DGA)
	Battery and Charger	• Battery cell temperature • Battery cell internal condition • Battery charging condition
Substation Security Monitoring	Substation Access Control	• Substation surveillance • Equipment surveillance
Substation Environment Monitoring	Substation Environmental Condition	• Ambient temperature • Relative humidity • Pollution monitoring • Flooding monitoring

Table 1 – Details of On-line Condition Monitoring

To facilitate the management and logging of the huge amount and wide variety of data from different IEDs (e.g. data points, events, and alarms, etc.) in an effective way, a specific and user-friendly Human-Machine Interface (HMI) was developed to integrate all the information in order to allow easy monitoring of the system performance by users via a common communication platform. Moreover, a tailor-made graphical user interface was established for the imaging and video type data captured from the infra-red hot spot detection equipment and Closed-Circuit Television (CCTV) for real-time monitoring and keeping track of the substation environment.

The advanced indication and warning signal about the healthiness of equipment and substation environment are particularly useful to those substations with heavy loading condition and aged plant in old districts with poor operating environment. As the technology for condition monitoring system of distribution equipment is still evolving, wider application of these systems to other distribution substation is being evaluated and other technologies are also being explored.

SIEMENS

2.3 11kV Overhead Line Automatic Supply Restoration System

Extending from substation automation in CLP transmission and distribution network, Fault Detection Isolation Restoration (FDIR) has been applied in CLPP's 11kV overhead line network as feeder automation to improve the supply reliability of the distribution system. The application comprises intelligent reclosers and load break switches coordinated under an automation scheme. When a disturbance occurs on the power line results a line fault, the system is able to detect and locate the faulty line section, isolate the faulty section and restore the supply to non-faulty line sections from an alternative supply source automatically.

For a supply network with N number of sources, the design of the system will consist of N circuit breakers (CB), N feeder reclosers (FRC) and N-1 Tie pole-mounted sectionalizers (TPMS). Spur recloser (RC) is also deployed for the protection of long spur line.

Inverse time overcurrent relays with appropriate normal inverse and very inverse time settings are used to differentiate overcurrent and earth fault protection settings of various switches at the feeding substation and along the power line. Definite time setting is used for grading the sensitive earth fault protection of the switches.

All CB, FRC and RC are equipped with auto-reclose (AR) feature. FRC is set with additional auto-open (AO) function and TPMS is set with auto-close (AC) function.

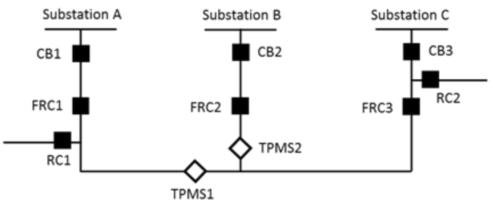


Fig.4 - Three-source network configuration with spur reclosers

Figure 4 demonstrates the typical network configuration of a three-source network with automatic restoration system in place.

When a transient fault occurs on the line, the immediate upstream CB/FRC/RC will trip with regard to the location of fault. They will auto-reclose at their corresponding AR time to restore the power supply.

If a permanent fault occurs on the line between CB1 and FRC1, circuit breaker CB1 will be tripped by overcurrent protection and fail to auto-reclose. Upon supply loss to FRC1, FRC will auto-open after the preset AO time is elapsed to isolate the fault. TPMS1 will auto-close after its coordinated AC time is elapsed to restore supply to the main line and spur lines from Substation C. The AO time of FRC is set to be less than the AC time of TPMS. This enables correct and efficient fault isolation and supply restoration. Besides, there are different AC time settings for various TPMSs. One TPMS will auto-close at a time to restore the supply.

The system is designed such that TPMS will not auto-close on fault. CB and FRC do not have the same AR time. The TPMS will only auto-reclose under the condition that TPMS detects supply on and off again at time intervals matching the dead time of source end CB auto-closing scheme. For the scenario of a permanent line fault in the downstream between FRC1 and TPMS1, the FRC1 will trip and auto-reclose one time. After the FRC1 trips again on reclosing, TPMS1 will not auto-close as the FRC1 reclosing time is longer than the reclosing time of source end CB.

Apart from automatic restoration feature, the system is equipped with phase loss and high impedance fault detection as critical measure of safety enhancement. The reclosers and TPMS detect phase under-voltage and existence of zero-sequence voltage. They are capable of detecting abnormal voltage at both sides of the terminals. When there is open-circuit fault such as broken jumper on pole or bad contact of isolator, or downed conductor fault on one or two phases simultaneously, a phase loss alarm will be initiated so that prompt decision can be made to isolate the fault.

The reclosers and tie switches can be installed one by one in stages to suit available circuit outages without setting changes or reconfiguration of the switches. It is flexible to implement the system on existing power lines. In addition, when there is planned outage work on one line section, only the automatic restoration control of that line section has to be switched out. The automatic restoration of other line sections still remains in service. The automatic restoration system is also designed to cater for multiple sequential faults.

3. CHALLENGES AND EXPERIENCE SHARING

For the application of smart technology in the transmission and distribution networks, there are a number of challenges to be tackled before we can put them into operational use. In general, the challenges could be categorized into three major areas, including Integration of Various Intelligent Components/Systems; Capability of Communication Network; and Change Management.

3.1 Integration of Various Intelligent Components/ Systems

Different intelligent components and proprietary systems could be sourced from different suppliers. Even though a common communication standard IEC61850 has been followed, different suppliers do have their own interpretation and selection for application in their products. It is necessary to align all the data format for integration so as to enable a simple and user friendly HMI interface for final users' application. A lot of efforts have been spent for problem solving and coordination with individual vendors on data sampling work, data recognition and verification. Thus, additional project lead time shall be reserved for alignment and coordination in the project development stage.

In addition, for those self-healing features, a comprehensive testing and commissioning programme shall be established to secure its operation under adverse system conditions and address any associated potential operation risks. Also, cyber security shall be assured throughout the integration process to eliminate any vulnerability to cyber-attack.

3.2 Communication Network

Significant amount of data like the condition monitoring data has to be collected from the smart substation and returned to the back end system for further analysis and assessment. The pilot cable communication network currently used in distribution system for protection and control may not be able to carry such large amount of data if full deployment of the smart system is decided. Apart from capacity, the availability of reliable communication channel in remote areas supplied via overhead line should also be considered. Possible options, like establishment of an extensive fibre optic communication network in distribution system, wireless telecommunication or hybrid system should be further explored.

As an effective and reliable communication network is a key success factor for the application of smart technologies in power system, the communication network capability and reliability issues must be well addressed to enable wider application of smart system in distribution system.

3.3 Change Management

Since most of the smart and intelligent products involved digital technologies, staff competency and skill set are critical to cope with the development for successful project implementation. Thus, early involvement of end-users in the development process is critical to enable a smooth transition from conventional operation mode to the new approach.
To ascertain the quality of the new intelligent provisions and mutual understanding of new functionalities and operational requirements, comprehensive type tests, factory acceptance tests, factory visits, presentation and demonstration by various suppliers followed by in-depth discussion were carefully planned and carried out. On-site training for operation personnel was conducted for them to familiarize with the new equipment and procedures for operation.

4. CONCLUSION

CLPP has continuously explored latest smart technologies in enhancement of its transmission and distribution network to sustain high quality of electricity supply to customers with the development of a smarter power network in Hong Kong.

From the experience of the pilot projects on smart technology application in the past few years, it is noted that significant amount of data transmission and storage for different smart systems are required. Thus, an effective integration platform is vital for data consolidation and analytics. The data could provide useful information for equipment condition analysis to enable more effective risk-based asset management. Early warning and alert on potential equipment problem can be given to operation staff so that prompt action can be taken in advance to ascertain the network reliability. A good communication infrastructure will also play an important role in supporting the wider application of the smart technologies in the next decade.

ACKNOWLEDGEMENT

The authors would like to express their appreciation to the Management of CLP Power for their support and endorsement for publication of this paper.

REFERENCES

[1] KW Ng, WK Wong, MF Chan and SP Lee, Intelligent Substation in CLP Power, ICEE 2014

[2] SK Lau, Automatic Power Restoration System for 11kV Overhead Lines in CLP Power

Paper No. 2

APPLICATION OF ADVANCED TECHNOLOGIES FOR MANAGEMENT OF TRANSMISSION CABLES IN HK ELECTRIC

Speakers: **Ir A.C. Chen, Support Engineer**
Ir Ronald W.C. Chow, Engineer
Transmission & Distribution Division
The Hongkong Electric Co. Ltd.

APPLICATION OF ADVANCED TECHNOLOGIES FOR MANAGEMENT OF TRANSMISSION CABLES IN HK ELECTRIC

Ir A.C. Chen, Support Engineer
Ir Ronald W.C. Chow, Engineer
Transmission & Distribution Division
The Hongkong Electric Co. Ltd.

ABSTRACT

HK Electric provides an electricity supply with a world class reliability and power quality to support Hong Kong as an international financial and commercial centre and in the development into a smart city. Over the years, we have applied advanced technologies for management of our transmission cable system. In this paper, we share our experience in four applications – (1) "Automatic Identification System" which continuously monitors the marine traffic in our submarine gas pipe and cable reserve zones and helps prevent gas pipe / cable damage caused by anchoring of vessels, (2) "Cable Fluid Pressure Remote Monitoring System" which enables early detection of abnormalities in the hydraulic system of the fluid-filled cables, (3) "Partial Discharge Monitoring System" which enables early detection of insulation problem in a transmission cable so that appropriate actions can be taken to avoid transmission cable fault, and (4) "Electro-Magnetic Transients Programme" which helps us calculate the surge voltages in transmission cable sheath bonding system and facilitate the selection of suitable cable sheath protective units taking into account of proper insulation coordination with other components in the transmission cable system.

1. INTRODUCTION

The Hongkong Electric Co., Ltd. [HK Electric] was established in 1889 and is a vertically integrated power company supplying electricity to Hong Kong Island, Lamma Island and Ap Lei Chau. The primary fuels for our electricity generation are coal and natural gas. Natural gas is transmitted from Shenzhen via submarine gas pipeline. Electricity generated from Lamma Power Station is transmitted to the load centres on Hong Kong Island and Ap Lei Chau via 275kV submarine cables installed at the seabed across the East Lamma Channel, one of the doorways to Hong Kong for international marine cargo transportation.

In view of the vital importance of the submarine cables supplying electricity to Hong Kong Island and Ap Lei Chau, cable reserve zones have been established with the Hong Kong government. Fishing, anchoring, trawling and dredging are prohibited inside the cable reserve zones. To enhance submarine cable damage prevention, Automatic Identification System (AIS) has been installed for continuous monitoring of the marine traffic in our submarine gas pipe and cable reserve zones which help prevent gas pipe / cable damage caused by anchoring of vessels.

Our transmission network consists of self-contained fluid-filled cables and cross-linked polyethylene (XLPE) cables. For self-contained fluid-filled cables, an important consideration in the design is to ensure the cable fluid pressure inside the cable can be properly maintained under any operating conditions. To provide early detection of abnormalities in the hydraulic system of the fluid-filled cables, we have commissioned a Cable Fluid Pressure Remote Monitoring System (PRMS) to continuously monitor the selected hydraulic sections. For XLPE cables, Partial Discharge Monitoring System (PDMS) in XLPE cable can provide an early indication of defects in insulation of the cables so that proper and timely corrective actions can be taken to avoid transmission cable fault.

To further enhance the reliability of our transmission network, Electro-Magnetic Transients Programme (EMTP) has been used to calculate the surge voltages in the transmission cable sheath bonding system and facilitate the selection of suitable cable sheath protection units for proper insulation coordination with other components in the transmission cable system.

2. AUTOMATIC IDENTIFICATION SYSTEM (AIS)

AIS is widely used in marine transportation industry for identifying and locating vessels. According to the International Maritime Organization, all passenger ships and all ships with gross tonnage of 300 or more are required to have AIS on board. Information provided by AIS, such as unique identification, position, course, speed etc., can be used to assist tracking and monitoring of vessel movements.

In 2014, we commissioned our AIS for continuously monitoring of the marine traffic and provide early warning to the operators against vessels stopping inside the cable reserve zones of our 275kV submarine cables at East Lamma Channel. If a vessel is found not moving inside a cable reserve zone, Harbour Patrol Section

Command Centre of the Marine Department will be requested to remind the vessels concerned not to perform prohibited activities inside the cable reserve zones. The monitoring area of the AIS was extended to cover the cable reserve zone of the 132kV submarine inter-connector cables between Hong Kong Island and Kowloon Peninsula in 2015.

2.1 Operating Philosophy of AIS

AIS is a ship-to-ship and ship-to-shore messaging system transmitting vessels information over marine VHF radio. The VHF channels of our system is 87B (161.975MHz) and 88B (162.025MHz).

Fig. 1 - Configuration of the AIS

The AIS base station consists of one VHF Software Defined Radio (SDR) receiver together with a monitoring processor and one internal GPS receiver, which is mainly used for time synchronization. The AIS base station is connected to one VHF antenna and one GPS antenna, both are erected at the roof of our office building facing the East Lamma Channel.

In the AIS computer, there are two software programmes for AIS monitoring and AIS alarm notification. The AIS monitoring programme tracks the vessels and display the information on the base station.

Fig. 2 - Typical AIS display

Tracking rules such as restriction areas, speeds and vessel types can be set in the AIS for monitoring of the vessel activities. In case a vessel stops in the restricted areas, alarm will be initiated to alert our staff to take appropriate actions.

The AIS is connected to HK Electric's corporate network to allow remote access of the tracking console and automatic notification of AIS alarms, and thus enable 24-hour monitoring.

2.2 Application of AIS on Submarine Cable Damage Prevention

Our AIS aims to detect vessels that have stopped in our submarine gas pipe and cable reserve zones to prevent damages to our gas pipe and submarine cables. The setting for vessel speed in our tracking areas should cater for the movement of vessel due to tidal waves and this information can be obtained from the Hydrographic Office of Marine Department.

2.3 Experiences Gained from AIS

With the commissioning of AIS, around 600 alarms per month were caused by slow moving vessels. 15 of these alarms involved vessels stopping at the cable reserve zones. Each of these 15 cases was reported to Harbour Patrol Section Command Centre of the Marine Department and the captains of the ships were reminded not to perform prohibited activities such as anchoring in the cable reserve zones.

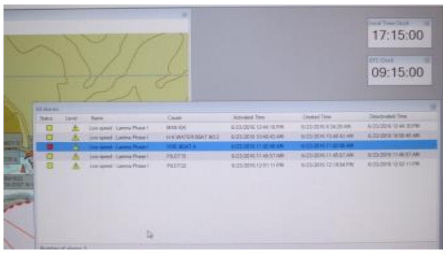


Fig. 3 - Alarms displayed on the AIS workstation

3. CABLE FLUID PRESSURE REMOTE MONITORING SYSTEM (PRMS)

HK Electric is managing over 880km transmission cables. Over 5,000 gauges are used to monitor the cable fluid pressure of the fluid-filled cables. Each pressure gauge relays the pre-set pressure low alarms to System Control via our SCADA system.

Fig. 4 - Gauge panel in underground pit

In 2014, we commissioned an online PRMS for continuous monitoring of the cable fluid pressure of 108 hydraulic sections of Lamma 275kV circuits in order to enhance our response time to verify the pressure low alarms initiated from the pressure gauges on Lamma Island.

3.1 Operating Principle of PRMS

Pressure transducers can provide alarms and pressure trends of the hydraulic sections. The alarms from the transducers can be set either individually or be allocated collectively at the server. The system can also compare the pressure trend of different phases. Leak warning alarm will be initiated if the pressure trend of a particular phase has diverged from the other phases.

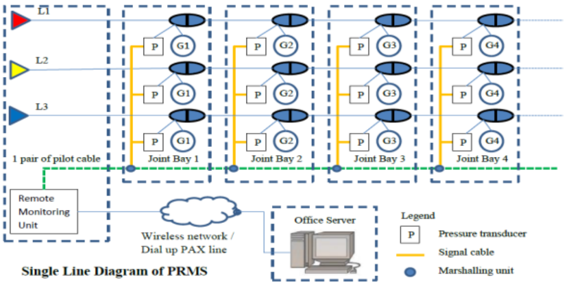


Fig. 5 - Typical arrangement of PRMS

Data in the system are structured in logical and physical manner and its database structure and hierarchy is shown in Figure 6 below:

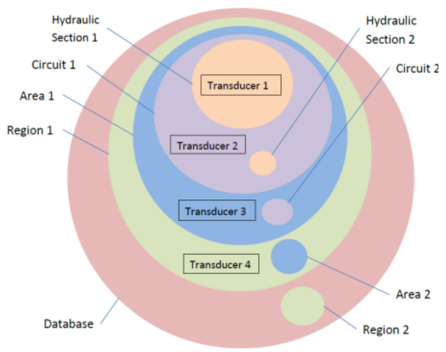


Fig. 6 - Venn diagram showing PRMS data hierarchy structure

The alarms from transducers can be allocated into alarm reporting areas and these areas themselves are subdivisions of regions. This configuration avoids undue centralization of system reporting and allows reporting schedules for different times of a day and different days of a week to be set. Text messages can also be sent to the corresponding engineers via SMS to follow up the alarms.

3.2 Application of Online PRMS

After the commissioning of the online PRMS, the pressure profiles from the hydraulic sections were monitored. Typical displays of a hydraulic section without and with leak are shown in Figures 7 and 8 respectively.

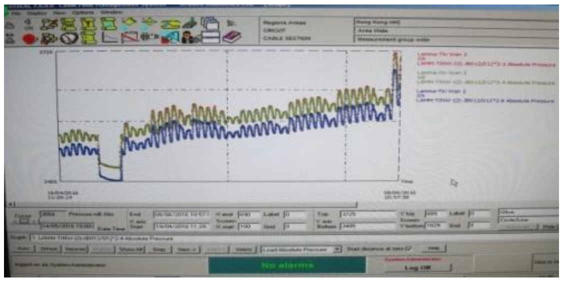


Fig. 7 - Typical pressure-time graph of a hydraulic section without leak.

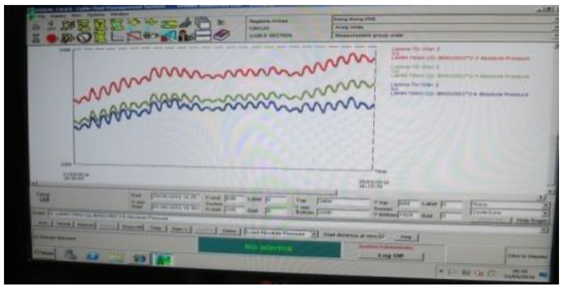


Fig. 8 - Pressure-time graph indicated that there was a slow leak on L3-phase (Blue line)

3.3 Experiences Gained from PRMS

Following are experiences gained from the application of the PRMS for monitoring the integrity of the hydraulic system of a transmission cable.

a. The underground pits where the pressure transducers are installed exhibit high humidity and ambient temperature. Therefore, the pressure transducers have to be designed and manufactured to cope with the arduous operating environments.

b. The online PRMS can give real time pressure of a transmission fluid-filled cable which depends on factors such as temperature and load current of the cable, the healthiness of the hydraulic system can be monitored by comparing the differential hydraulic pressure of different phases.

4. PARTIAL DISCHARGE MONITORING SYSTEM

4.1 Operating Principle of Online Partial Discharge Monitoring System [PDMS]

A PDMS includes PD signal capturing devices (PDCD), local station (LS), master station (MS) and remote station (RS).

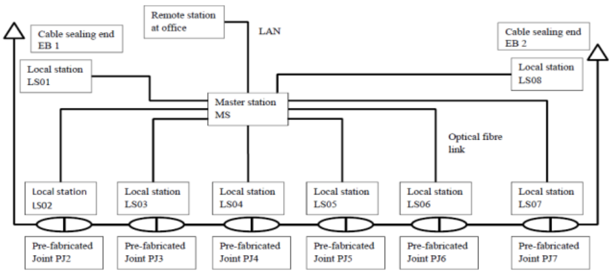


Fig. 9 - Single-line diagram of PDMS

Our PDCD is clamp type high frequency current transformer (HFCT). The HFCTs are mounted on the ground connections of the XLPE cable's metallic sheath.

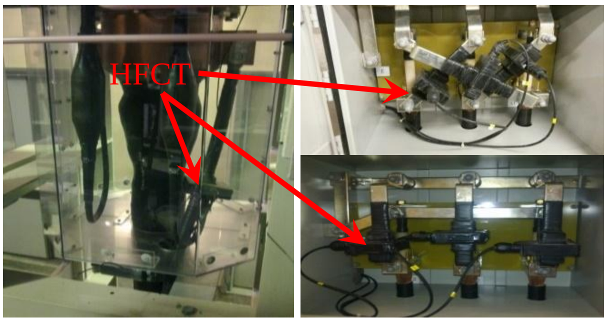


Fig. 10 - HFCT clamped on cable sealing end, cross-bonding and earthing link boxes

The signals captured by the HFCTs are processed by the LS. The digitized output signals from the LS are transmitted to the MS via a dedicated optical fibre link. Our PDMS can detect partial discharge as low as 10pC and ranging from 10m to 1,000m.

MS is the user interface of the PDMS to display the PD measurements including signal quantity and alarm level. In the MS, there is a PD logger. This PD logger is not only for data logging, but also to provide the PD alarm judging function by PD logical gate (LG) and a neural network (NN). The LG and NN operate independently. Based on the algorithms of these two modules, the possibility of different kinds of PD including (a) Floating Electrode; (b) Protrusion of Semi-conductor; (c) Damaged Insulation; (d) Damaged Outer Semi-conductor; (e) Incorrect Position of Stress Cone; and (f) Void in Insulation is evaluated and displayed to the operator.

The LG alarm is based on (a) PD signal level; (b) Phase angle of occurrence; (c) Number of valid pulse counts; and (d) The duration of PD signal against a pre-set alarm level set by user.

The NN judges whether the acquired signal is a real PD by comparing the signal pattern with historical on-site measured PD patterns of the supplier.

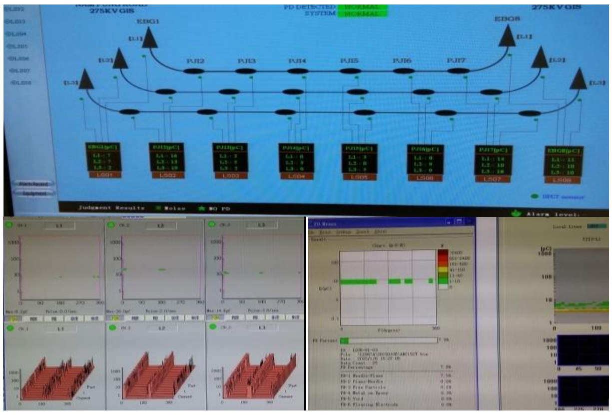


Fig. 11 - Typical display of MS and RS

4.2 Operating Principle of Portable Partial Discharge Monitoring Equipment (PDME)

In 2012, a PDMS including two types of portable partial discharge monitoring equipment (PDME1 and PDME2) was commissioned for a 275kV XLPE cable circuit. PDME1 was procured from the same supplier as the PDMS. An oscilloscope is included in PDME1 for equipment calibration and PD source location.

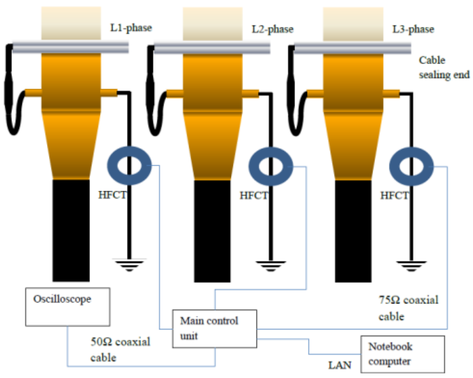


Fig. 12 - Typical configuration of PDME1

PDME2 consists of (a) HFCTs for capturing PD signals; (b) low frequency current transformer [LFCT] for picking up synchronization signals for correlating the PD pulses and voltage; (c) acquisition unit; and (d) notebook computer.

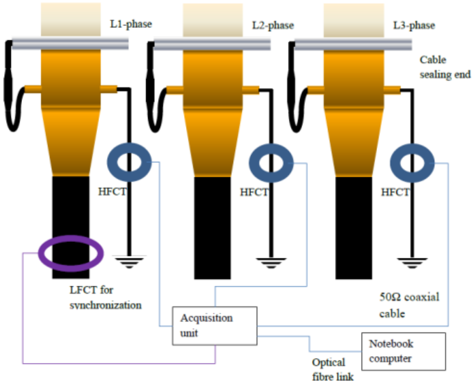


Fig. 13 - Typical configuration of PDME2

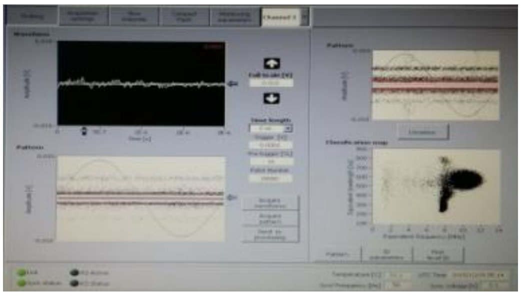


Fig. 14 - Typical PD pattern displayed on the notebook computer

In the acquisition unit, there is an ultra-wide digitizer to digitize the acquired signal and its signal level, phase angle of occurrence, number of pulse count, duration of the signal and waveform will also be evaluated. Those digitized information are then transmitted via an optical fibre link to the notebook computer for storage, processing and display.

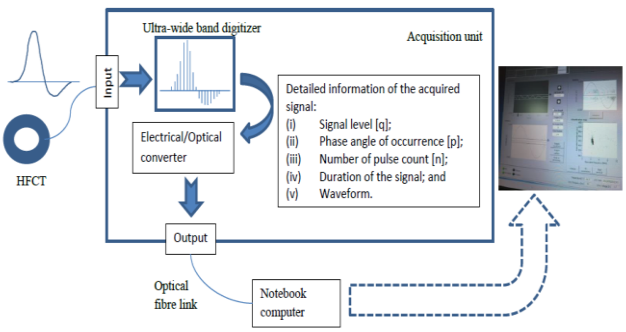


Fig. 15 - Process flow diagram of the acquisition unit

In the display, the operator can obtain the signal pattern and the equivalent time-frequency map of the acquired signal. To facilitate PD identification, the PDME has a built-in PD pattern library. Operator can make use of this database to identify different types of PD.

4.3 Experience Gain on Partial Discharge Monitoring

So far there were no abnormalities in the 275kV XLPE cable circuit being monitored by the PDMS. Following are experiences gained from the application of the PDMS and PDME for monitoring the integrity of the transmission cable system.

a. Other signals generated from nearby equipment may activate the PD signal detection alarm of the PDMS. For example, noise pattern containing 50Hz AC signal which resembled that of a damaged insulator PD was generated from a defective power supply unit. Therefore different PDMEs should be used to counter-check and affirm whether the detected signals are genuine PD signals generated from the cable.

b. The PD pattern recognition algorithm embedded in the PDMS facilitates identification of the captured PD pattern.

5. ELECTRO-MAGNETIC TRANSIENTS PROGRAMME (EMTP) FOR CALCULATION OF SURGE VOLTAGE ON TRANSMISSION CABLE SHEATH BONDING SYSTEM

CIGRE Electra 28 provides a guideline on the calculation of the induced sheath voltage for flat and trefoil cable formations whereas CIGRE Electra 128 gives the guideline on the selection of surge voltage limiter (SVL) for specially bonded cable system against overvoltage during faults.

When selecting a suitable SVL for a transmission cable circuit, the following factors should be taken into account:

a. Induced sheath voltage during fault conditions should be lower than the rated voltage of the SVL;

b. Surge current passing through the SVL should be lower than the energy absorption capability of the SVL;

c. Surge voltages induced on various components of the transmission cable circuit including metal sheath, joint metal case, insulation flanges etc. should not exceed the surge voltage withstanding capacity of each component.

We have arranged to use EMTP to calculate the surge voltage propagated in the transmission cable sheath bonding system during fault condition to facilitate the selection of SVL with suitable rating and proper insulation coordination of the transmission cable circuit.

5.1 Study on Transmission Cable

In analyzing a transmission cable circuit, an EMTP nodal map was prepared.

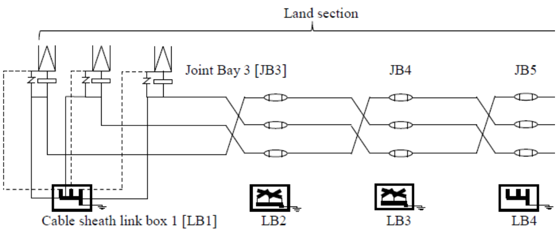


Fig. 16 - Schematic diagram of a transmission cable circuit to be analyzed by EMTP

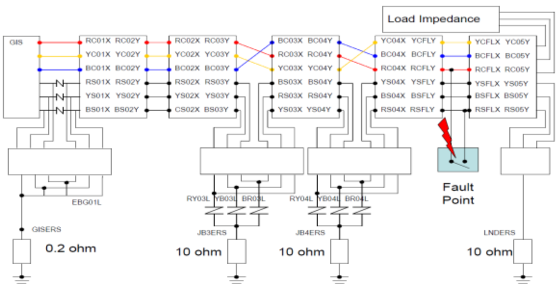


Fig. 17 - EMTP nodal map

After setting up the cable model and parameters, the EMTP was run to obtain the waveforms of the surge on various parts of the transmission cable.

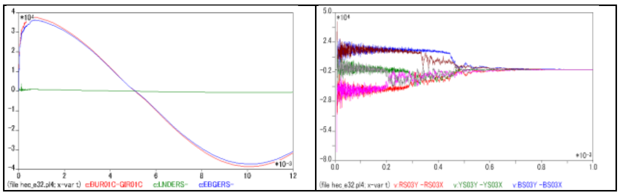


Fig. 18 -Simulated fault current flowing through the transmission cable circuit and the surge voltage across the insulation flange of a cable joint

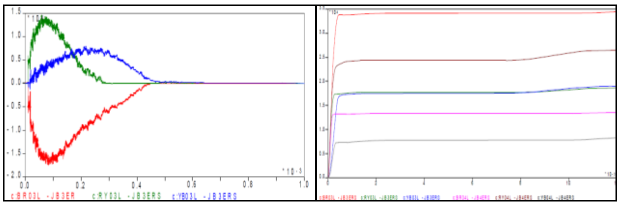


Fig. 19 - Surge current passing through and the energy discharged by the SVL of LB2

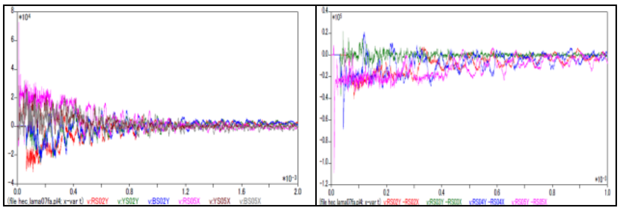


Fig. 20 - Induced voltage on cable sheath and across the insulation flange of a cable joint under through fault condition

5.2 Worked Example on Analysis of SVL for Submarine Cable with Single Point Bonding

5kV rated and 13kV rated SVLs were selected for analysis. Their energy absorption capabilities were 8kJ and 25kJ respectively.

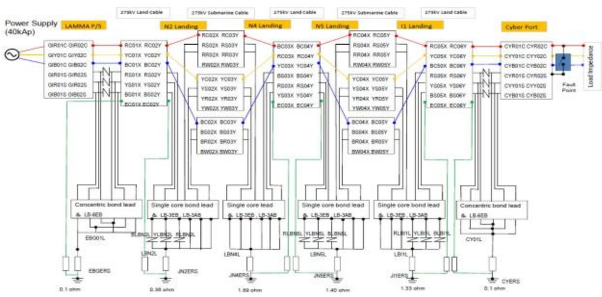


Fig. 21 - EMTP nodal map of a submarine cable with single point bonding

The surge voltage, current and energy to be discharged by the SVLs under the switching surges in two of the study cases are shown in the table below for illustration purpose:

Case	Rated voltage of SVL (kV)	EMTP Results		
		Voltage (kV)	Current (kA)	Energy (kJ)
1	5	9	10	30
2	13	22	3.8	13.5

Table 1 - Summary of EMTP results on different types of SVL under switching surge

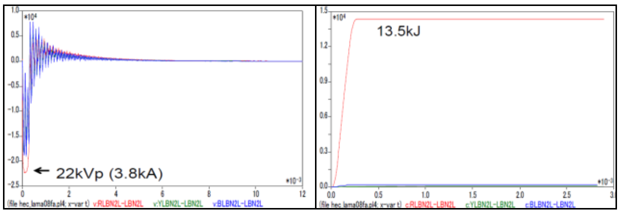


Figure 22 - Surge voltage imposed and discharged by the SVL under the switching surges

The through-fault condition is further studied and the surge voltage, current and energy to be discharged by the 13kV SVL are summarized in the table below:

Case	Rated voltage of SVL (kV)	EMTP Results		
		Voltage (kV)	Current (kA)	Energy (kJ)
2	13	23	5.8	17

Table 2 - Summary of EMTP results on 13kV rated SVL in cable through fault condition

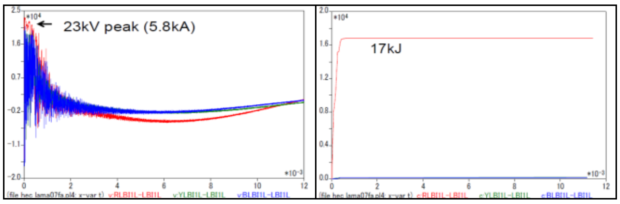


Fig. 23 - Surge voltage imposed and energy discharge by the SVL in through fault condition

From the results of the EMTP analysis, 13kV rated SVL with 25kJ energy absorption capability is more suitable than the 5kV, 8kJ one for this submarine transmission cable with single point bonding.

5.3 Review on Insulation Coordination of The Transmission Cable System

The surge voltages on the cable sheath and across the insulation flange of a cable joint under through fault condition were also reviewed by EMTP. From the EMTP results, it can be concluded that all components of our transmission cables can withstand the induced voltage due to switching surge if 13kV, 25kJ SVL is used.

6. CONCLUSION

Application of advanced technologies and condition monitoring systems plays an important part in the management of transmission cable network. Cable damages and pre-mature failures of transmission cables can be effectively prevented. This paper introduces our development in transmission cable management and how we applied advanced technologies to aid our daily operation and maintenance of transmission cable system.

ACKNOWLEDGEMENT

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.

REFERENCES

[1] CHAN, L Geoffrey 2009, “Condition Monitoring for Safe and Reliable high voltage power delivery – Technology and Management” unpublished. Presented at EMSD Symposium 2009.

[2] Min CHEN, Koji URANO and Teng-biao CHEN, 2014 “Study of a Partial Discharge Localization Drifted Across a 110kV GIS Cable Sealing End” International Conference on Condition Monitoring and Diagnosis 2014 Jeju Korea

[3] Shoji MASHIO and George BUCEA, 2014 “Long AC Underground Power Cables Safety Considerations for Application of Special Bonding Systems”, APRC Technical Meeting 2014

Paper No. 3

ECODISTRICTS

Speaker: **Mr Jacob Chan**
Managing Principal
Glumac, Los Angeles, CA, USA

ECODISTRICTS

Mr Jacob Chan
Managing Principal
Glumac, Los Angeles, CA, USA

ABSTRACT

EcoDistrict is a powerful strategy for sharing infrastructure that benefits one environment, our communities and our budget. These emerging district system approaches are ideal for mixed-use developments, universities, hospitals and large corporate campuses and broaden the traditional focus on energy, water and waste.

1. INTRODUCTION

The following paper outline is what an EcoDistrict is and its components discuss the benefits of an EcoDistrict system approach in an environmental term.

Explain how advance energy and water system can become affordable when costs are spread across multiple buildings?

2. WHAT IS AN ECODISTRICT?

EcoDistrict provides a means for sharing building and infrastructure environment and optimizing the operation costs among the neighborhood.

EcoDistrict scales can apply to a region, a district, a neighborhood, a campus and within a building.

3. POWER IN THE USA

Over 50% of energy comes from coal, nuclear is just under 20%, and renewable energy is about 10%. Unfortunately, more than 2/3 of the fuel used to generate power in the US is lost as heat. For a typical commercial office building, on average 50% of energy is for heating and air conditioning the environment and 40% every is for electric loads.

To implement an EcoDistrict concept, we need to have support from the local communities, local government agencies, local utility providers, building owners/developers, plant owners/ developers, design and construction teams, tenants and consumers.

Each of the participants will have their own expectations, contributions, and cost benefits. An EcoDistrict trust should be set up then it will provide the investment of the EcoDistrict plant and acts as an overall leader for the EcoDistrict programme.

For utility provider, the demand for gas will increase and therefore, greater sale volume. The electricity power will have lower peak demand and distributed utility infrastructure. The building owner/developer will have less building equipment, less maintenance, higher quality building, more space for sale or lease and increased incentive potential.

The benefit for Tenant & Consumers is that it is a sustainable lifestyle, better comfort level for residents and for commercial tenants, less equipment maintenance and replacement. The design and construction team have reduced equipment space. The plant owner/developer will have the benefit of effective and efficient central plant equipment. Therefore, provide commercial incentives on their investment.

A financing mechanism will need to be set up through local bond, local city and developer. Some of the pact case study. Hassalo on 8th project, where a non-potable water was re-used for cooling tower, wetland and dry wells.

As a future potential, engineers are developing to a potential net zero scenario for potable water reuse. By applying reverse osmosis, we could potentially achieve net zero water use on projects. Many to the power supply, more than ⅔ of the fuel to generate power in the US lost as heat. By combining heat & power, we could use the heat from the generator and supply up to 50% of the building heat.

EcoDistrict can also apply within a building, for example, Glumac LA office, an engineering office located on 23rd floor of a 62 story high rise building. It demonstrates that a net zero energy is achievable.

Paper No. 4

SMART BUILDING SERVICES DESIGN FOR HEALTHCARE BUILDING PROJECTS

Speakers: **Ir C.K. Lau, Chief Building Services Engineer**
Ir Carl M.H. Lam, Senior Building Services Engineer
Ir Chris W.K. Lee, Building Services Engineer
Architectural Services Department
The Government of the HKSAR

SMART BUILDING SERVICES DESIGN FOR HEALTHCARE BUILDING PROJECTS

Ir C.K. Lau, Chief Building Services Engineer
Ir Carl M.H. Lam, Senior Building Services Engineer
Ir Chris W.K. Lee, Building Services Engineer
Architectural Services Department
The Government of the HKSAR

ABSTRACT

To meet the increasing demand on the standard and quality on healthcare services and the growing environmental awareness in Hong Kong, it is always necessary to have a well-thought-out design of building services systems for a healthcare building. With the aid of modern technology, designers can now have more tools to develop a smart building services design not only to meet the operational requirements of clinical services, but also to take care of the system reliability, maintainability and efficient use of energy through an interactive smart monitoring platform.

This paper will discuss the smart engineering design on system reliability and efficient use of energy in healthcare buildings. It will cover the digital power metering, electrical supply and distribution, back-up power supply arrangement, critical electrical loading management, and power quality monitoring system. Besides, the principle in the development of the energy monitoring and management system as well as the potential utilization of energy data in healthcare buildings will also be discussed.

1. CLINICAL SERVICES IN A HEALTHCARE BUILDING

A healthcare building generally consists of various types of clinical services and facilities, which includes accidental & emergency services, community nursing services, specialist out-patient clinic, radiology, operating theater, pharmacy, central sterile supplies department, endoscopy unit, renal analysis unit, general / isolation wards, physiotherapy, occupational therapy and clinical pathology departments.

Clinical services require a wide variety of the building services engineering systems for supporting the clinical services. The engineering installations generally include Electrical Installation, Lighting Installation, Low Voltage Switchboard Installation, Generator Installation, Mechanical Ventilation and Air-Conditioning Installation, Medical Gas Installation, Pneumatic Tube Installation, Steam and Hot water installation, Lift and Escalator Installation, Fire Services Installation, Nurse Call Installation, Security Installation, Plumbing and Drainage installation, Power Quality System, Building Energy Management System and Central Control & Monitoring System.

2. SMART DESIGN OF MAJOR BUILDING SERVICES INSTALLATION

2.1 Electrical Installation

Electricity supply is the fundamental requirement for maintaining the normal operation of a building. In a healthcare building, the failure of power supply to the various building services installation and medical equipment can cause inconvenience to the patients.

Safety, reliability, and maintainability of power supply are the key consideration in the design of electrical installation. The respective loads and circuits are designed so as to achieve a high degree of electrical power supply reliability with proper back up power capacity for the critical loads.

2.1.1 Power supply sources

The primary power supply source will be provided by the power company. Because of the nature of a healthcare building, the high security of power supply has been recognized by the relevant parties. 11kV feeders in ring circuits are fed from two different primary substations of power company (Figure 1).

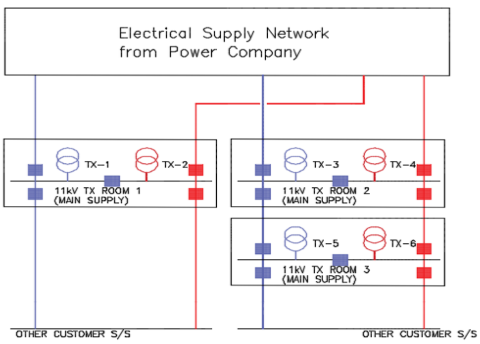


Fig. 1 - 11kV feeders in ring circuits fed from two different primary substations

A double end feed from power company 11kV network is connected to the healthcare building. The design prevents a single point failure at the power supply side. Moreover, emergency generators are installed as a back-up power supply to the critical medical equipment and building services installation.

2.1.2 Main power distribution system

Individual power supply distribution system for the normal and essential electrical loads will be provided. The normal and essential electrical distribution systems are physically separated in the electrical room in order to minimize the knock-on effect on the healthy distribution system in case of damage of other electrical system.

In addition, dual electrical risers are installed so that the spare capacity from either electrical riser can serve as a backup power supply for critical loads.

Dual electrical risers are furnished with manual transfer switch (MTS) for the interconnection of the two risers (Figure 2). Power supply can be switched to its secondary riser when the primary riser is damaged or maintenance works are required on the particular floor (Figure 3). The real-time electrical loads in each electrical riser will be recorded by the smart power meters. Thus, the operator can easily decide the adequacy on the switching to secondary power supply after the examination of the historical electrical loads on the electrical riser.

For the special medical equipment, automatic transfer switch (ATS) will be installed to meet the immediate power supply requirements in case of power failure at original supply (Figure 4).

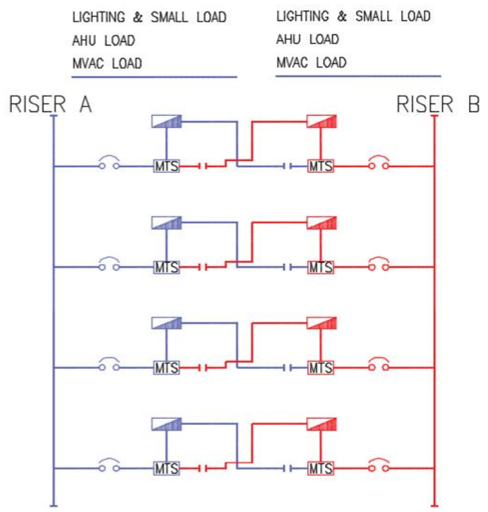


Fig. 2 - Electrical configuration of dual electrical risers

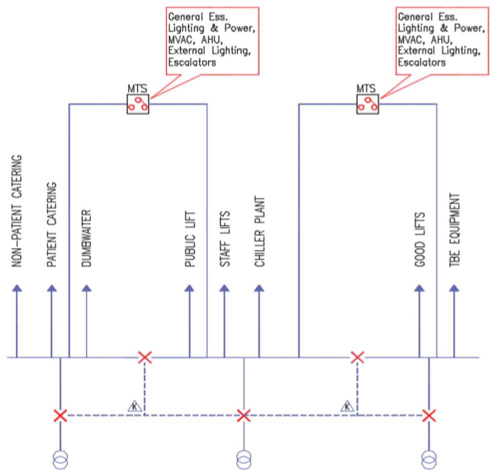


Fig. 3 - Dual electrical risers with manual transfer switch (MTS) on normal and essential loads.

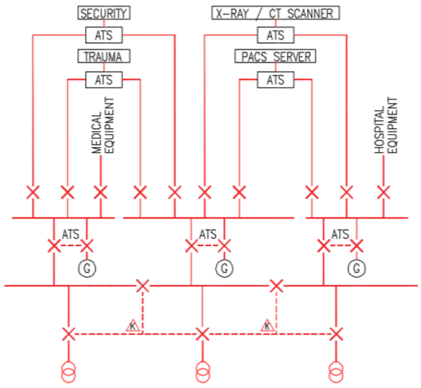


Fig. 4 - Dual electrical risers with automatic transfer switch (ATS)

2.1.3 Sub-main power distribution system

Large area of power interruption will be encountered if a single sub-main power distribution system is provided on each floor.

For higher reliability of power supply on each floor, the sub-main power distribution circuits will typically be divided into zones from their respective sub-main switch rooms. Zoning will also be determined in accordance with the user group or department. This design eliminates the power interruption in a large area on each floor when a sub-main power distribution system / power feeder is in fault.

Moreover, the dedicated MCB boards completed with smart digital multifunction power meter will be provided for each department so that the power consumption of lighting, small power, medical equipment and air-conditioning system can be recorded (Figure 5).

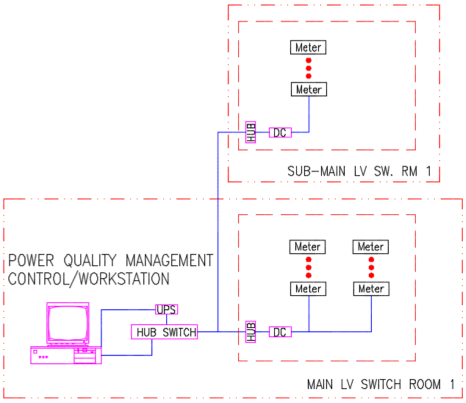


Fig. 5 - Smart digital multifunction power meters in different switchrooms.

2.1.4 Uninterruptible power supply (UPS) system

Backup power by emergency generator cannot offer the instantaneous power supply to the data center and sensitive clinical equipment. UPS system has to be provided to the computing servers in data center, security system, and CCMS system. Moreover, the Operating Theatre (OT) would be equipped with UPS and isolated-power supply (IPS) system for the power circuit, general lighting, and OT examination lamps.

All components of the UPS systems are provided with duty and standby units for the purpose of supply reliability and maintenance. In normal operation, both UPS units are operated evenly to share the load between two units. Upon failure of either one UPS, the healthy unit would take up the load automatically via automatic static transfer switch. For the ease of maintenance, the UPS system is provided with external manual bypass such that the UPS unit can be disconnected to the system without interrupting the system operation.

The UPS and IPS system can also ride through any momentary voltage dip resulted from system surge or unstable power supply from power company.

2.1.5 Critical electrical loading management

The critical electrical loading management aims to transfer the loading demand by critical electrical and medical equipment to another healthy power distribution system when the normal power distribution system is interrupted or under regular maintenance.

Both designer and end-user should identify the critical electrical loads and medical equipment so that the adequate planning and sizing of power feeders and distribution circuits can be taken into account in the design stage.

Smart power meters are installed to provide the useful historical record for the analysis of electrical loading profile of each distribution system.

2.2 MVAC Installation

Providing a thermal comfort environment for building users is a basic function of the mechanical ventilation and air-conditioning installation (MVAC). However, MVAC installation plays another important role in a healthcare building. The system should be specially designed to maintain the high-cleanliness of air, directional air flow, and adequate pressurization in the sensitive clinical areas, such as isolation wards, operating theaters, resuscitation rooms, consultation rooms (fever), clinical laboratory, and sterilized supply areas.

To safeguard these critical operation requirements, a number of design features for the enhancement of system reliability are adopted in both the air-side and water-side system.

2.2.1 Normal and essential chilled water distribution system

The sizing of the chillers is determined by the estimated cooling load of the building. Adequate additional capacity of the chillers is provided for future expansion, but it serves as backup cooling capacity also in case of the breakdown of a chiller or the deterioration in chiller capacity.

To avoid single point failure in the chilled water supply, the water supply circuits are separated into normal circuits and essential circuits with independent chilled water risers (Figure 6). Normal circuit provides the chilled water to the non-clinical areas, including public areas, office and administrative areas, while the essential circuits serves the clinical areas, such as isolation wards, operating theater, resuscitation rooms, etc.

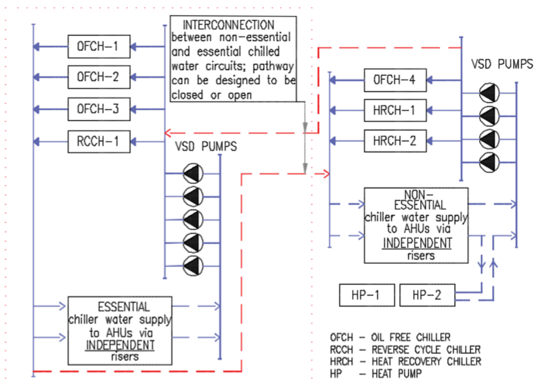


Fig. 6 - Water supply circuits are separated into normal and essential circuits

Moreover, the reliability of chilled water supply to the air-side equipment is further enhanced by the inter-connection between normal and essential chilled water risers. The inter-connection pipes are provided at particular floors where the air-handling equipment situated in the critical clinical areas (Figure 7). The isolation valves at the inter-connection pipes will be normally closed, but it can be opened by the CCMS such that chilled water can be supplied from another healthy water supply circuit. The on/off status of the isolation valves will be indicated and smartly monitored/controlled in the CCMS system. Certainly, the sizing of the normal and essential chilled water pipes should cater for the overall chilled water flow rate during the emergency operation mode.

Furthermore, the branch-off point completed with isolating valve at the chilled water risers is strategically installed in plant room. The facilities offer a greater flexibility for the future improvement works on the air-side system as it minimizes the interruption of chilled water supply to the existing equipment. The isolating valve at the branch-off point can be controlled automatically by CCMS or manually by operator whenever necessary.

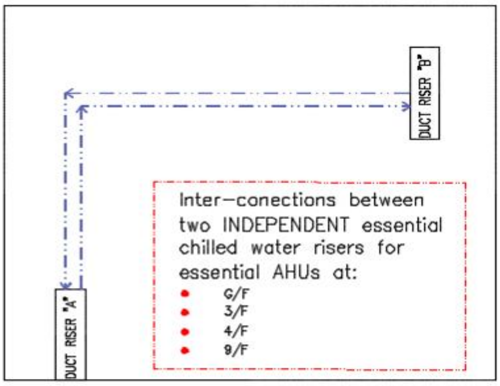


Fig. 7 - Inter-connection pipe between two independent chilled water risers

2.2.2 Dedicated air-distribution system

Dedicated air-handling unit (AHU) system is provided to those sensitive clinical areas in order to minimize the air cross contamination among different clinical areas, in particular the infection disease controlled areas. Dedicated AHU system has to be provided in isolation rooms, operating theatres, clinical laboratory, sterilization supplies room, and pharmacy. The dedicated AHU system for different clinical areas can also avoid the interruption of air-conditioning supply in a large clinical area in case of the breakdown of a single air-distribution system.

In the critical areas, dual motors/fans are also adopted in the AHU system so that the failure of the motor/fan in AHU will not result in the loss of air supply or the required room pressure and the directional flow can be maintained to such areas.

3. BIG DATA IN BUILDING SERVICES INSTALLATION

High performance of the engineering system relies on the interconnectivity of sub-systems for operation and system optimization. It is not surprising that there are large amount of data transmitted among different equipment and sub-systems. Through the sensor, meter, receiver, actuator, and computing programme, the system can be automatically controlled and adjusted to meet the operational requirements.

3.1 Smart Applications of Monitoring Data

The smart engineering design for reliability relies on the full understanding of the operational requirements of the clinical services in a healthcare building.

The associated control and monitoring parameters as well as the collected data are utilized for the automatic system control, system monitoring, system analysis and implementation of various emergency operation. The smart use of these data can facilitate the operators and clinical officers to take an immediate action for the emergency clinical services.

The provision of monitoring signal and operational status allows the operators to have a better understanding of the system operational status. The Central Control and Monitoring System (CCMS) is provided as a central platform where the operators can obtain these information at the CCMS workstation.

Some critical monitoring parameters and system operational status are shared in Table 1 on next page for illustration purpose.

In the attempt of shortening the time of emergency repair and prompt resumption of engineering system, the operators can work with the designer to determine a set of specific monitoring parameters/alarms which should draw the special attention to operators and clinical staff in daily operation.

Currently, these monitoring, operation and alarming status are ready in the CCMS platform. The information can be further transmitted to mobile device for more effective monitoring. Different engineering operators and clinical staff can determine their concerned parameters/alarms and select the pre-set alarming value for instant messaging by internet connection through web server. Alert message will acknowledge the responsible engineering personnel and/or clinical staff via the mobile applications when the pre-set alarming value is reached. The alarming messages, for instance, include the abnormal change in chilled water supply temperature, insufficient room pressure or the failure of normal power supply in an operating theatre should concurrently alert the engineering personnel and clinical staff for their timely execution of emergency plan.

Sensitive critical areas/installation	Possible critical monitoring parameters /alarm for building operators/clinical staff
1. Operating theatre and isolation wards, CT scanner room, clinical laboratories	High/low room pressure and temperature, AHU power supply status, duty / standby fan running status, UPS/IPS power supply status
2. Medical gas supply system	Medical gas pressure, high / low gas cylinder capacity
3. Data Center and UPS room	Normal and essential power supply status, changeover switch status, room temperature and water leakage detection status
4. Cold rooms, drug fridges, cold body chambers	Power supply status to specific equipment, high/low room temperature
5. Electrical system including lighting, power supply system, etc	Normal and essential power supply status, and transfer switch status; centralized battery system (CBS) status of emergency and essential lighting installation.
6. UPS systems	Operating mode, low level battery, common alarm
7. Chiller and associated chi lled water pumps	Equipment running & fault status and chilled water supply/return temperature
8. Emergency generator and fuel oil tank installation	Fuel oil tank low level & leakage, fuel oil pump status, generator & engine fault status, running/idling status, common alarm from generator control panel
9. Low voltage cubicle switch-board installation	ACB/MCCB open/close status and battery failure alarm
10 Fire service installation	Pump running/fault status and common fire alarm
11 Plumbing installation	Pump fault status, high/low level in water tank for specific clinical areas; water leakage detection status in critical areas

Table 1 - Monitoring parameters and system operational status for illustration

3.2 Smart Metering and Energy Management System

Long operating hour is the characteristic of a healthcare building. The medical equipment and engineering system could consume significant amount of energy throughout a year.

With a view of effective use of energy, various energy efficient building services equipment will be considered, such as oil-free chiller, heat recovery chiller, heat pump, free-cooling system, variable speed drive for air handling system, demand controlled ventilation system, solar hot water system, high efficiency motor, steam boiler with built-in economizer and condensate recovery, energy efficient lamps, occupancy and light sensor for the control of lighting installation.

Clear understanding of the energy flow and usage in a building is essential. The energy consumption data is the raw material for energy auditing which can be utilized for identifying the potential areas for the energy savings.

3.2.1 Smart metering and strategy

The locations of power meter and power analyzer should be strategically determined (Figure 8). Separate groups of MCB/MCCB distribution boards will be so designed that the separate metering of major building services plant, major medical equipment, lighting and small power circuit for wards, clinical and non-clinical services areas can be installed.

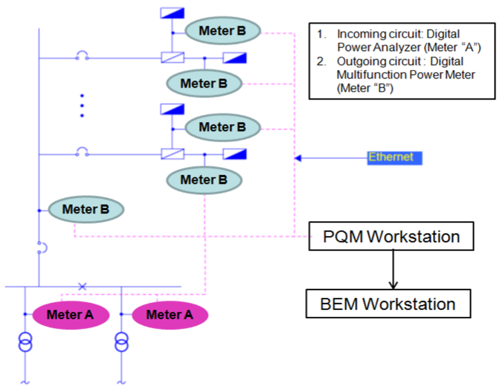


Fig. 8 - Typical configuration of power meter and power analyzer installation.

3.2.2 Smart energy management system

Power meter and power analyzer instantaneously measured and recorded the energy use and power quality in the building. All power meters and power analyzers will be networked to the Smart Energy Management System for all building services installations. Both the electrical and thermal energy consumption will be recorded. Smart Energy Management System consists of Power Quality

SIEMENS

Monitoring (PQM) system and Building Energy Management (BEM) system. The energy data of MVAC installation will be collected in CCMS system, and can be integrated with the BEM system (Figure 9).

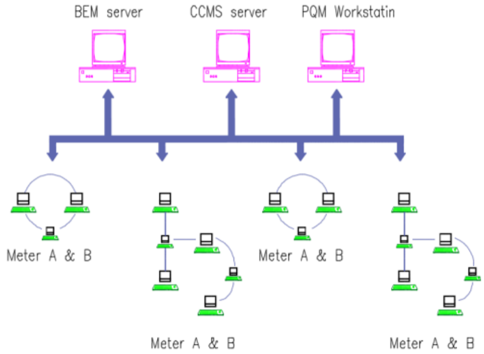


Fig. 9 - Typical configuration of BEM, PQM system and CCMS system.

PQM system would measure various electrical parameters, such as supply voltage (V), running current (A), electrical maximum demand (kVA), electrical consumption (kWh) and total harmonic distortion (THD) at main/ sub-main level for each individual building services installation and other energy user groups, while the BEM System would be a working platform for energy monitoring and auditing. The BEM should allow various studies and analysis of electricity energy consumption data. All collected energy data can then be categorized by data mapping in the BEM system for further analysis.

3.2.3 Energy data and analysis

The Smart Energy Management System enables the big data analysis for different building services installations in a healthcare building.

(i) Energy data for building end-user

In the past, individual energy user group cannot monitor their energy consumption since the monthly energy bills will be settled by their accounting department instead of by themselves. Without the knowledge of amount of energy use, they cannot identify any improper use of energy in their department.

With the BEM system, the specific Energy Utilization Index for individual user group, including lighting, small power, medical equipment and MVAC installation can be generated. The energy user group can then easily understand the variation in energy consumption by comparing the past energy records. These energy data can also formulate a benchmark among different user groups for their self-initiation on continuous monitoring on energy use. The energy consumption records can now become an indicator for raising their awareness on the effective use of energy. Moreover, the monthly energy data can also be transformed to monetary value in terms of energy costs per floor or user group. This will motivate the specific user group to set the energy saving target.

(ii) Energy data for building operator

Large batch of energy data from various building systems have to be collected by the PQM and BEM system. However, the energy data will be meaningless until the collected data can be wisely used. The collected data should enable in-depth energy consumption analysis and allow the operator for planning and decision making on system operation, such as implementing the critical electrical loading management among transformers, the emergency procedure for backup power supply to critical medical equipment, and performing the electrical loading management for the annual system testing or overhaul maintenance works. Moreover, the smart use of energy data can help the operator to identify the area for improvement on system operation for higher efficiency.

(iii) Building energy index

Similarly, it is desirable for the building operator to construct the Building Energy Utilization Index by working out the building energy consumption per construction floor area (CFA). Making reference to similar type of building, an energy consumption yardstick can be established for easy understanding of the building energy performance.

(iv) Energy consumption analysis

The analysis of the energy data is actually an effective tool for the assessment of the energy performance of the engineering system.

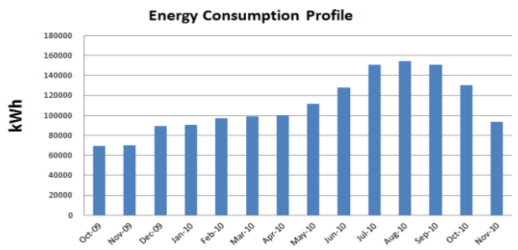


Fig. 10 - Annual energy consumption profile

The BEM system is able to produce the energy usage pattern, graphic and summary of data, including monthly/annual energy usage (Figure 10), and the distribution of total building energy use for each individual building services installations (Figure 11). This information will certainly help the operator to identify the major energy consumers.

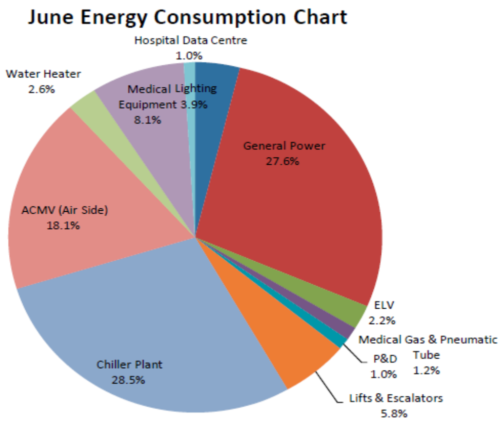


Fig. 11 - Different energy consumers in a healthcare building.

Through the studying of the energy usage pattern and trend of individual building services installation, it will be easier to identify any irregularity of energy use. The irregular energy consumption may be due to the inappropriate system setting, extra operating hours of equipment / plants and inadequate maintenance or deteriorated equipment.

(v) Data for system energy performance assessment

MVAC system is normally the major energy consumer in a building. Close monitoring on its energy consumption will assist to identify the potential areas for energy saving.

The BEM & CCMS system can continuously measure, record and monitor the useful data, such as the electrical energy consumption of AC equipment, output cooling capacity, and ambient air dry-bulb, condenser water, chilled water supply & return temperature data for analysing the energy performance.

The energy performance of MVAC installation can be assessed by evaluating the coefficient of performance (COP) of individual chiller/chiller plant. The COP can be calculated by using the electrical energy data of chillers, chilled water pumps, cooling towers, and the output of cooling capacity of the chiller/chiller plant. The COP value of chiller/chiller plant will be affected by the external environmental factors. By correlating the COP data with the ambient air dry-bulb temperature for air-cooled chiller plant; or the condenser water temperature for water-cooled chiller plant, the COP values under different conditions can be derived (Figure 12).

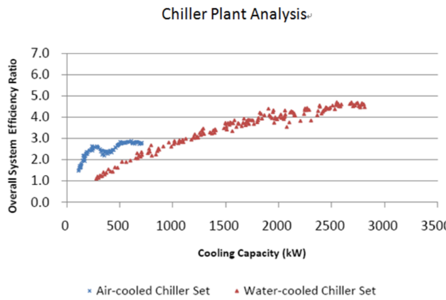


Fig. 12 - Chiller plant analysis

Through the analysis of the COP, the operator could identify the optimization control sequence for the chiller plant; and determine the system operating point with the highest energy efficiency.

In general, the cooling demand in a building would mainly be affected by ambient air temperature (Figure 13). By comparing the total building cooling load profiles with the ambient air temperature, the abnormal loading demand and energy consumption of air-conditioning installation can be revealed. The operator can then be able to review the overall AC operation.

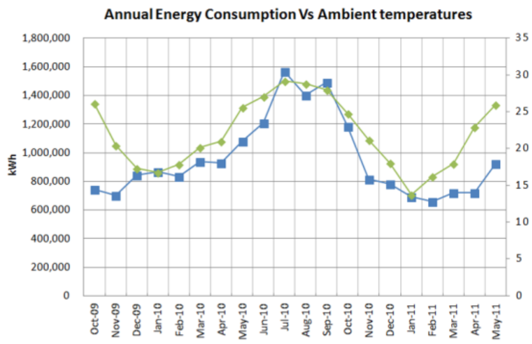


Fig. 13 - Correlation of energy consumption profile with ambient temperatures.

(vi) Data for tariff analysis

Different tariff schemes are categorized for different power consumption classes. The tariff charges are composed of energy charge and demand charge; and will be varied by the electrical maximum demand (kVA), power consumption (kWh), and average power factor during on-peak and off-peak periods. These kinds of energy and electrical data will be recorded by the PQM and BEM system.

By performing the analysis of monthly maximum demand (kVA), it can help to lower the tariff charge by fine-tuning the operating schedule of major equipment during the on-peak periods (Figure 14).

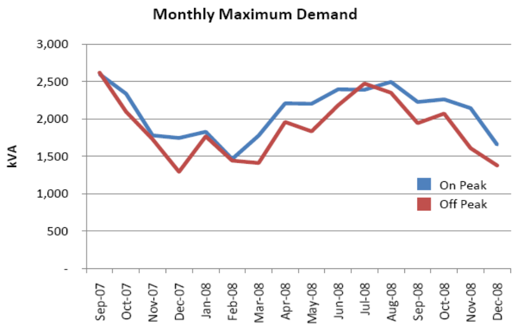


Fig. 14 - Monthly maximum demand (kVA) profile.

For the in-depth tariff analysis, the average bill charge per day, average bill charge per kWh, average daily kWh consumption and average energy utilization index can also be provided in the electricity account profile by the BEM system. This offers a close look on the daily change of the energy consumption for the operator and energy users.

4. CONCLUSION

Smart building services design can enhance the quality and reliability of the healthcare building for the clinical staff, patients, operators and maintenance engineers. The smart use of building data, system operating status can provide the useful information for both clinical staff and operators for timely implementation of appropriate procedures and repair of the system. With the aid of smart metering, the building operator can have a better understanding on the round-the-clock energy usage in the building and identify the potential areas for more effective use of energy as well as reduction of the overall energy expenditure.

Paper No. 5

AUTOMATIC METER READING IN SMART CITY

Speaker: **Ir C.O. Ng**
Senior Electrical and Mechanical Engineer
Technical Development
Water Supplies Department
The Government of the HKSAR

AUTMOATIC METER READING IN SMART CITY

Ir C.O. Ng
Senior Electrical and Mechanical Engineer
Technical Development
Water Supplies Department,
The Government of the HKSAR

ABSTRACT

In support of the government's initiative of forging a Smart City in Kowloon East (KE), Water Supplies Department (WSD) will implement an Automatic Meter Reading (AMR) pilot project as one of the smart initiatives. With AMR system, water consumption data can be read automatically from the smart water meters and transferred to a central database electronically for billing and better planning of water supplies. In addition, timely water consumption information and related alerts can be made available for the attention of customers through web portal and mobile app. Such information platforms will be effective in raising the awareness of the customers on water conservation and alerting them of suspected water leakage in their plumbing.

In this paper, the basic design of smart water meters, protocols of data transmission from smart water meters to AMR Outstations, components of the AMR System and the anticipated benefits will be discussed. Moreover, the experience from the previous AMR pilot scheme together with the challenges in implementing AMR in Hong Kong will be covered.

1. INTRODUCTION

In Hong Kong, fresh water supply for domestic units are metered and billed every four months. Various types and sizes of water meters with local mechanical registers are used to suit different requirements, plumbing configurations and water demands.

WSD commenced studying the application of smart water meters and Information and Communication Technology (ICT) in building an AMR system in 2001. The AMR system employed smart water meters to collect metering data of consumption at regular intervals. The metering data were then transmitted via various methods and tools such as hand-held unit, drive-by receiver or other radio communication to the backend computer system for data storage and processing.

Whilst the performance and reliability of AMR has been markedly improved since then, Advanced Metering Infrastructure (AMI) has also been developed fast enabling more efficient communication between the smart water meters and the backend system, as well as the provision of an integrated network infrastructure for wider use of smart water meters in a city scale.

Recognising the potentials of AMR/AMI system in the era of cyberculture, WSD has been keeping abreast of the technology development and market trend of smart water meters and conducting studies for identifying a viable AMR/AMI system. In 2013, WSD embarked on a small scale pilot scheme by installing 357 smart water meters in three residential high rise buildings to evaluate the technical performance of the smart water meters, communication network and data handling reliability.

As one of the initiatives for Smart City, AMR/AMI system will be deployed in new developments in KE and around 50,000 smart water meters will be installed in new private and public developments in KE from 2018 to 2023.

2. WATER METERS – FROM LOCAL TO REMOTE READING

Water meters are measuring device to register the amount of water consumption of customers for charging purposes. There are a variety of water meters employing different measurement principles and technology available in the market.

2.1 Traditional Mechanical Water Meters

Traditional mechanical volumetric water meters have been widely used in Hong Kong for domestic water supplies for decades due to its simple design, low cost and high reliability. At present, meters readings of domestic customers are taken manually by meter readers every four months. The readings, initially stored in a hand-held data logger are then extracted by the Customer Care and Billing System (CCBS) for billing in WSD.

Fig.1 - Traditional mechanical volumetric water meter (by Itron)

2.2 Smart Water Meters

Various types of smart water meters are developed and made available in the market. It is quite common that a traditional mechanical water meter can be converted to a smart water meter by add-on features. To identify the most suitable type of smart water meter for use in Hong Kong, WSD has conducted studies and trial uses as detailed on the following sections.

2.2.1 Mechanical water meter with Reed Switch

By inserting a reed switch to the mechanical water meter, a pulse signal proportional to the volume of water flow can be produced. A pulse counter is used to calculate the water flow through the water meter.

Fig.2 - Mechanical water meter with reed switch

Fig.3 - Trial use of mechanical water meter with reed switch in WSD

2.2.2 Mechanical water meter with optical encoder

Another option is to make use of opto-electronic encoder in which infrared transmitter and receiver is installed on top of the mechanical counter of the water meter. The meter reading is captured by the opto-electronic encoder placed over the mechanical counter. This technology gets rid of any mechanical influence, such as frictional loss inside the water meter. The meter reading is then digitalized for data transmission.

Fig.4 - Volumetric water meter, counter with opto-electronic encoder (by Sensus)

2.2.3 Mechanical water meter with Meter Interfacing Unit (MIU)

Water meter installed with a clip-on meter interfacing unit (MIU) are one of the advanced models for smart water meter. This type of AMR/AMI-ready mechanical volumetric water meter with a pre-equipped "target" is to be adopted for domestic water supplies in KE. Meter readings can be obtained by a clip-on meter interfacing unit (MIU) that detects the rotation of the target by electromagnetic principle (see Fig.6) when water flows through the meter measuring mechanism. In the AMR pilot project, the recorded metering data will be transmitted to a data concentration unit (DCU) via the M-Bus communication protocol, and sent to the backend system in WSD over Virtual Private Network (VPN).

Fig.5 - Smart water meter with clip on MIU (by Elster)

Fig.6 - Smart water meter with pre-equipped targets (by Itron)

Fig.7 - MIU for smart water meter (by Elster)

Key features of an MIU are as follows:

- Water volume with timestamp
- Tampering detection (MIU removal)
- Leakage detection (continuous minimum flow over the past 24 hours)
- Reverse flow alarm (water flow in reverse direction)
- Low battery alarm (battery inside MIU exhausted)

With an AMR/AMI system, meter readings can be remotely collected from smart water meters and transmitted to the backend system in WSD at a pre-defined frequency through fixed network.

2.2.4 Electromagnetic water meter

Electromagnetic water meters are used by WSD for customers with large water consumption. In an electromagnetic (EM) water meter, a magnetic field is created across the pipe. When water, which is an electrical conductor, passes through the magnetic field, a voltage is induced and detected by the electrodes. The voltage is directly proportional to the flow velocity and associated flow rate can be determined. The voltage is measured by two electrodes placed at right angles to the magnetic field. Although higher accuracy can be achieved, the cost of the EM water meter is high and is not competitive in domestic applications.

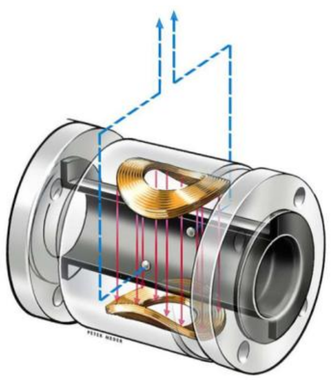


Fig.8 - Working principle of an EM water meter

2.2.5 Ultrasonic water meter

Ultrasonic water meter is based on the phenomenon that sound waves slow down when moving against the flow and speed up when they move with the flow. An ultrasonic meter has two sound transducers mounted at opposite sides of the pipe with an angle to the flow (see Fig. 9). Each of these sound transducers will in turn send out an ultrasound signal to another transducer. The differences in the transit times of the signals are then used to determine the flow velocity, and subsequently the flow rate.

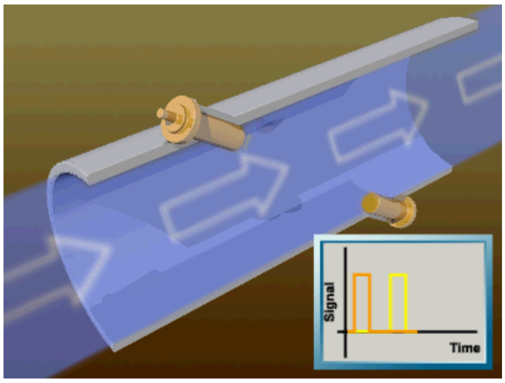


Fig.9 - Working principle of an ultrasonic water meter

Although the electromagnetic and ultrasonic water meters have good performance in terms of accuracy and reliability and are suitable and ready for use in AMR/AMI system, their cost are much higher than that of mechanical water meter with MIU. In consideration of technical viability and cost benefits, the latter is selected for AMR/AMI system in KE developments.

3. PROTOCOLS FOR SIGNAL TRANSMISSION

For sustainable development of the AMR/AMI system, a standard signal transmission protocol has to be specified for the procurement of smart water meters as well as for the construction of the AMR/AMI infrastructure under an open competition environment. The following protocols from different smart water meters in the market have been studied and tested in various stages:

3.1 Pulse Counting

The simplest output from a smart water meter is in the form of pulses that are proportional to the volume of flow. By counting the pulses generated, the amount of water passing through a water meter can be recorded and used for billing purposes. Unless incorporated with suitable software for analyzing the pulses, the

SIEMENS

advantages of using AMR/AMI cannot be delivered to customers.

3.2 De Facto Standard Protocols Developed by Water Meter Manufacturers

With suitable circuitry and software, the pulse output from the water meter can be converted to different formats and transmitted via different communication protocols and transmission frequencies.

Protocol such as Radian with radio frequency carrier at 433 MHz and modulated via frequency shift keying is a typical example.

Fig.10 - Water meter and gas meter fitted with MIU (by Itron)

3.3 Meter Bus (M-Bus) Protocol

The M-Bus is a European Standard (EN 13757) developed for the remote reading of utility meters. M-bus fulfils the special requirements of remotely powered or battery driven systems. When interrogated, the meters deliver the collected data to a common master, which can read the meters in a building at intervals and transmit metering data via a communication modem. A subset of the M-Bus standard series has been selected to form the Open Metering System (OMS) Specification.

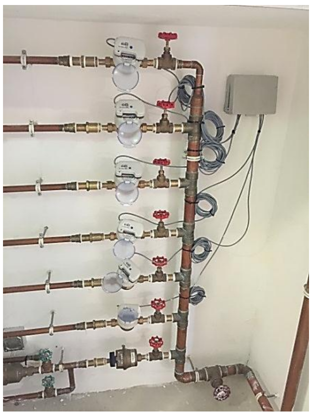


Fig.11 - Smart water meters with MIU installed in the WSD small scale pilot scheme

Fig.12 - Clip on wM-bus MIU

For wireless M-Bus (wM-Bus), the signals are modulated in different modes in accordance with EN 13757-4. The signals are encrypted to AES 128 Mode 5 with a radio frequency of 433 MHz or 868 MHz. In some countries, the wM-bus products for water meters and gas meters are developed and operated in N mode to EN13757 with a long range radio frequency of 169 MHz.

Fig.13 - wM-Bus system in Europe

The Office of the Communications Authority (OFCA) has allocated the frequency channel of 169MHz to the land mobile service. Therefore this channel cannot be used for fixed point to point applications such as smart water metering in Hong Kong.

In consideration of a long term development of AMR/AMI, M-bus protocol is selected for the smart water meters to be used in KE developments.

The advantages of M-Bus are as follows:

- M-Bus is an Open Bus System (OMS) specifically designed for remote reading of utility meters including water, electricity, gas and heat meters.
- M-Bus is based upon the European standard EN 13757 with regard to data exchange and interfaces.

- M-Bus Gateways can be cascaded to form a large metering system.
- M-Bus only requires one pair of wires for data transmission and power supply for reading of meters.
- The bus topology is very cost-effective.
- It is simple to add or remove smart devices.

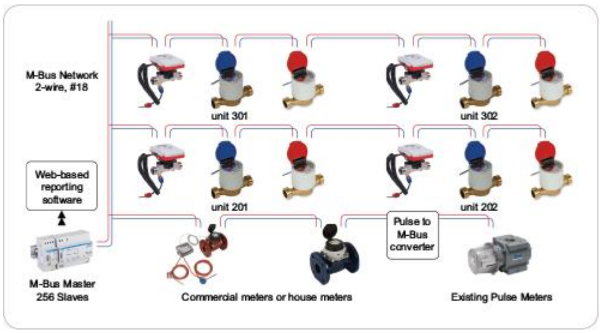


Fig.14 - M-Bus network

4. ANTICIPATED BENEFITS OF AMR/AMI

The implementation of AMR/AMI systems enables the availability of massive water consumption data not only for billing purposes but also analysis, enhancement of customer services and better planning of water supplies. The benefits may not be seen at this early stage of development but when more AMR/AMI systems come into play, the advantages brought about will become more eminent. Here below are some of the anticipated benefits:

- Improved meter reading efficiency (i.e. automatic reading of water meters and reduced human error);
- Detection of abnormal water consumptions (e.g. suspected pipe burst and leakage of customers' plumbing);
- Provision of timely consumption data for interfacing with district metering for water balancing and leakage detections
- Demand forecast and planning;
- Enhanced customer services through provision of timely water consumption information via a web portal or mobile app; and
- Ideal platform for promoting water conservation.

The environmental benefits in regard to water conservation and reduced electricity costs will be further discussed in Section 7 of this paper.

5. SMALL SCALE PILOT SCHEME

To ascertain the potential benefits and feasibility of implementing AMR/AMI, WSD carried out a small scale pilot scheme in 2013 to evaluate the technical performance of 15 mm smart water meters in high rise buildings. An AMR Master Station was installed at WSD Headquarters for collecting metering data transmitted from three outstations in the high rise buildings with a total of 357 smart meters installed. From the metering data obtained, it was concluded that the performance of the system was promising in terms of meter reading accuracy and system reliability.

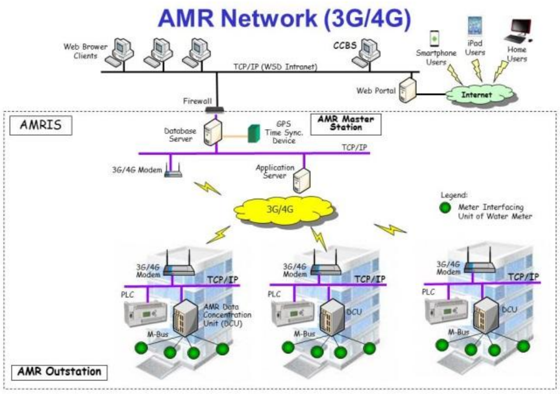


Fig.15 - System schematic of the small scale MR/AMI Pilot System

The following components and setup of AMR Outstation were tested, verified and evaluated to prepare for further trial involving customer billing.

5.1 Smart Water Meters

Smart water meters fulfilling all the requirements of water flow measurement for billing purposes, ie with accuracy class equivalent to that of the traditional mechanical water meter in service, and equipped with MIU in wired M-Bus protocol were selected for pilot scheme. Compared with the local counter of the meters, the AMR readings were found to be generally in line with the local readings except that some meters had errors in the last digit for cases of very low consumption.

5.2 Wiring for M-Bus

WSD had considered the wireless option before but found that the cost of wireless smart water meter is high compared with the wired ones. Also, the requirement of associated repeaters for ensuring a smooth and reliable wireless data transmission may introduce more maintenance problems. Wired smart water meter with M-Bus network was ultimately selected for the domestic use in the project in view of its reliable performance and cost benefits.

Hard wires in conduit were extended from the meter room to the AMR panel in which the DCU,

SIEMENS

Programming Logic Controller, and Communication modem were installed. The maximum distance between the MIU and DCU was specified to be not more than 300m. In this small scale pilot scheme, 1.5 mm^2 copper cables were used and the maximum distance on site was about 100m.

5.3 Data Concentration Unit (DCU)

A DCU (also called Gateway) was used to convert the signal received from the MIUs (M-Bus protocol), to Transmission Control Protocol/ Internet Protocol (TCP/IP). The data package was transmitted to the backend system via standard File Transfer Protocol (ftp) over the 3G mobile network. The DCU was a standard product available on the market.

5.4 Programming Logic Controller (PLC)

In order to reduce on-site service maintenance, a PLC was installed for monitoring and auto/manual reset of the DCU and the communication modem in case of minor faults in the DCU or communication lines.

5.5 Communication Modem

Communication modems were installed to transmit the data package from the DCU to the backend system in WSD. VPN routers were used to ensure data security during transmission.

Fig.16 - AMR Outstation in residential building

In conclusion, the performance of the small scale pilot scheme is satisfactory in terms of measurement accuracy and system reliability. Riding on this successful experience, WSD decides to implement a city-scale AMR/AMI system in KE.

6. PROPOSED AMR/AMI SYSTEM IN KOWLOON EAST (KE)

The Smart City in KE comprises a number of smart features. The AMR/AMI system for water supplies is one of the smart initiatives. Apart from the smart water meters, a number of AMR Outstations, communication infrastructure and backend servers are to be provided to form an integrated system.

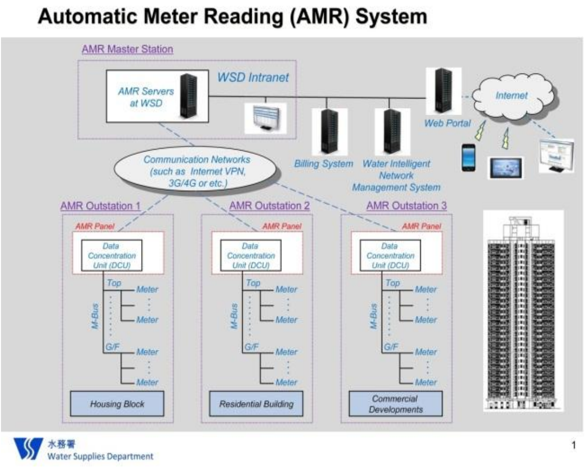


Fig.17 - Proposed schematic for the AMR/AMI system in KE

The division of responsibilities amongst WSD and the developers in KE for providing the AMR/AMI equipment components will be as follows:

6.1 Equipment to be Provided by WSD

The following equipment for the AMR/AMI will be provided by WSD:

- Smart water meters equipped with MIU;
- An AMR/AMI backend system for collecting the metering data from AMR Outstations, managing the collected information for billing, water supplies management and disseminating the water consumption information to customers. The system is also capable of receiving readings from IoT metering devices if applicable in future.

6.2 Equipment to be Provided by the Developers

The following equipment, which forms an AMR Outstation in the development, shall be provided and installed by the developers:

- Cabling infrastructure and bus wiring from the smart water meters to DCU
- AMR Panels
- DCU
- PLC
- VPN routers, communication modems
- UPS
- Communication lines for data transmission

The AMR Outstations will be handed over to WSD for operation and maintenance after the outstations are satisfactorily commissioned.

SIEMENS

7. ENVIRONMENTAL BENEFITS

7.1 Water Conservation

The use of smart water meters is one of the signature features in smart cities. In the context of Hong Kong, a smart metering system for water supply enables both customers and WSD to monitor the water consumption and to help stimulate behavioural change of customers to use less water. It is also beneficial to WSD for better management and operation of the water supply system.

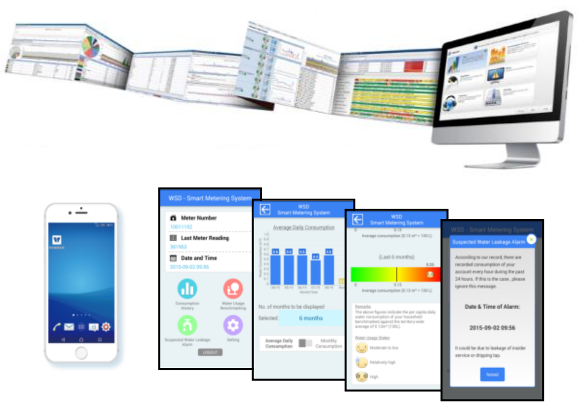


Fig.18 - Web and app interfaces for water consumption information

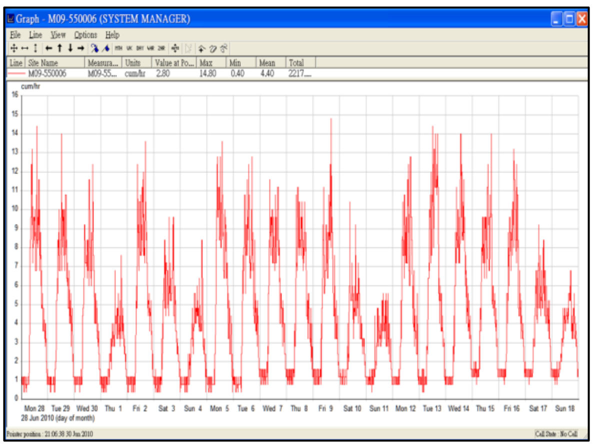


Fig. 19 - Water Consumption Monitoring

With a web portal and mobile app providing the water consumption information from the AMR/AMI system, customers can monitor their water consumption and review their water consumption in a proactive manner. This behavioural change of customers at large may help optimise utilization of water resources and reduce overall wastage. According to a UK study, a 3% or more water saving can be resulted.

Fig.20 - Water saving in using of smart meters

7.2 Electricity Costs

In the electricity market, demand side management can be introduced via the tariff system to encourage load shifting to the off-peak period. It may be difficult to apply directly in water supply system in Hong Kong. However, some savings on electricity costs can be achieved if more pumping for the water supply can be shifted from the on-peak period to the off-peak period when the consumption pattern can be predicted more accurately from the AMR data.

8. CHALLENGES FOR IMPLEMENTING AMR/AMI IN HONG KONG

Developing a new system from scratch is never an easy task. The conventional manual meter reading mechanism for water customers has been working effectively in Hong Kong for years. Implementation of a brand new city-scale AMR/AMI system will be subject to a lot of challenges.

8.1 Finance Considerations

8.1.1 Capital cost of AMR/AMI system

- Higher cost of smart water meter compared with that of a traditional mechanical water meter.
- Additional cost due to the installation of AMR Outstations (DCU, PLC, router, UPS system, etc.)
- Additional cost of backend computer system
- Additional cost of infrastructure such as on-site cabling system including concealed conduits and wiring for smart water meters and AMR panels

8.1.2 Operations cost

- Staff cost for operation of the AMR/AMI system with advanced features
- Resources for follow up works after dissemination of the water consumption information and alerts to customers via web pages and mobile app
- Additional cost of communication links for meter data
- Additional electricity cost for operation of AMR/AMI system and outstations

8.1.3 Maintenance cost

- Staff cost for maintenance of AMR/AMI system
- Maintenance cost of AMR information system including the hardware and software of backend computer system
- Additional maintenance cost of AMR outstations (around 300 AMR outstations will be installed in the AMR pilot project in KE)

8.1.4 Considerations for cost justifications

- Cost benefit analysis
- Green measure for water conservation
- Other intangible benefits

8.2 Technology of Smart Water Meters

- The life of the MIU is limited by the service life of the built-in battery.
- Wider adoption of smart water meters will be subject to technology and market development.
- Wireless solution is one of the methods for providing AMR/AMI system to existing buildings without the cabling requirements. However, apart from the high cost for the wireless solution, the transmission distance and availability of a frequency band for transmission of the meter information complying with the requirement of OFCA of Hong Kong has to be considered.
- Radio mesh solution such as those adopted in electricity energy meters can solve the wireless transmission problem. However, it is difficult to adopt it in smart water meters as power supply is normally not available.

8.3 System Security

As the meter readings or data will be transmitted through the Internet, system security issues shall be addressed. To this end, VPN and firewalls will be adopted in accordance with The Government IT Security Policy and Guidelines for transmission, storage and dissemination of data issued by the Office of the Government Chief Information Officer (OGCIO).

8.4 Provision of AMR to Existing Buildings

8.4.1 Provision of infrastructure for smart water meters and AMR Outstations

In the new developments in KE, water meter rooms will be provided to house the smart water meters and the AMR Outstations. However, in existing buildings, many water meters are installed in open areas without any water meter room and it is difficult for the existing tenants or WSD to install the necessary bus wiring for the AMR system. The difficulties of deploying AMR system in existing buildings are yet to be resolved.

8.4.2 Legal framework

In the Smart City in KE, a legal framework has been established for the provision and installation of the AMR Outstations by developers under the land lease conditions. However, it is difficult to establish a similar legal framework for existing buildings.

9. CONCLUSION

A small scale AMR/AMI pilot scheme on assessing the technical performance of the smart water meters and communication network had been conducted and the result was satisfactory.

A large scale AMR/AMI pilot project for water supply will be implemented in the Smart City in KE. In this pilot project, around 50,000 smart water meters will be installed from 2018 to 2023.

Upon the completion of the pilot project, customers in the Smart City can view their water consumption information from the web portal or mobile app. It is expected to have 3% or more saving in water consumption due to behavioural change of customers with the provision of timely consumption data.

Due to financial and technical limitation in adoption of smart water meters using wireless transmission and provision of AMR system in existing buildings, effort will be focused on extending the AMR system to new development areas such as Anderson Road Quarry development. Further implementation of the AMR/AMI in WSD will be reviewed based on the experience learnt from the pilot project in the Smart City in KE.

ACKNOWLEDGEMENT

The author wishes to thank the Director of Water Supplies for his kind permission to publish this paper.

Obligations are also due to colleagues in WSD for their unfailing assistance in implementing the project and valuable comments in the preparation of this paper.

REFERENCES

[1] JE Van ZYL, Introduction to Integrated Water Meter Management, Water Research Commission (South Africa), 2011.

[2] Product information and catalogues from smart water meter manufacturers including Itron, Elster, Zener and Sensus etc.

[3] Table of Frequency Allocations for Hong Kong, Office of the Communications Authority, Hong Kong. (http://www.ofca.gov.hk/filemanager/ofca/common/Industry/broadcasting/hk_freq_table_en.pdf)

Paper No. 6

INTELLIGENT DESIGN ON MTR 33KV AUTOMATIC CHANGEOVER SYSTEM AND OPTIMISATION OF OVERVOLTAGE PROTECTION DEVICE OPERATION

Speakers: **Mr Ellis S.C. Chan**
Senior Construction Engineer – Power Supply
Ir M.K. Mak
Senior Engineer – Power Supply & Overhead Line
MTR Corporation Limited

INTELLIGENT DESIGN ON MTR 33KV AUTOMATIC CHANGEOVER SYSTEM AND OPTIMISATION OF OVERVOLTAGE PROTECTION DEVICE OPERATION

Mr Ellis S.C. Chan, Senior Construction Engineer – Power Supply
Ir M.K. Mak, Senior Engineer – Power Supply & Overhead Line
MTR Corporation Limited

ABSTRACT

An automatic changeover of power loads at the 33kV level to the healthy infeed(s) in case one infeed source fails is provided to maintain normal service without interrupting station services and traction power supply. This is one of the critical systems to maintain a high reliable power supply in Hong Kong underground railway. Sophisticated hard-wired relay logic design was employed for this changeover function in the existing urban lines. Intelligent design using programmable logic controller (PLC) system had been adopted for the 33kV automatic changeover and interlocking system since the Airport Railway project. The control logic is software programmable to cope with various failure scenario and interlocking requirements and capable to suit for the expansion of the power system network with software modification.

Overvoltage protection device is one of the safety features to constrain the rail to earth potential at station platform areas. In the conventional design, the overvoltage protection device will operate even though there is no train staying at platform which causes unnecessary operation of the device. An intelligent design which can reduce the number of operation of the device by checking the rail to earth potential with the presence of train is adopted. This design will have advantage in minimizing the d.c. current entering into the earthing system due to the operation of the overvoltage protection device.

PART I

INTELLIGENT DESIGN ON MTR 33KV AUTOMATIC CHANGEOVER SYSTEM

1. INTRODUCTION

The power supply in Hong Kong underground railway is one of the critical systems to maintain high reliability of train and station services. The power supply system of MTR was designed with N-1 failure redundancy, i.e. any failure of one power supply equipment will not have impact on train or station services.

MTR stations' LV main supply and traction power sources are dually fed from two power companies or the two independent power supply sources of the same power company. Different infeed power supply sources are fed from different 275 /132kV substations. In case of failure of one infeed source, the train and station services will be affected although the automatic changeover at the LV main switchboard will be taken place. The normal services will be resumed by remote switching at Operations Control Centre (OCC). In order to maintain normal service without interrupting station power supply and traction power supply under failure of one infeed source, automatic changeover of loads at the 33kV level to the remaining infeed(s) is designed. The 33kV automatic changeover will be completed before the operation of the LV changeover so as to avoid unnecessary disruption.

The 33kV power transmission system is provided to facilitate automatic changeover of power supply from one ring to the other should the pre-defined failure conditions occur. Upon restoration of the failure conditions, the 33 kV power transmission system can be restored automatically to its normal network configuration initiated by the power system controller (PSC) in OCC. Interlocking facility is provided to avoid paralleling of different infeed sources under all circumstances, including automatic changeover and manual switching operations.

2. DESIGN OF NEW 33kV AUTOMATIC CHANGEOVER AND INTERLOCK SYSTEM

Since the operation of MTR in 1979, the 33kV automatic changeover and interlocking system was implemented with relay logic and hardwires as shown in Figures 1.1 and 1.2. The design is rigid and caters for only infeed source failure scenarios.

There is no flexibility and requires substantial wiring modification works in case of expansion of the power system network. Starting from Lantau Airport Railway project, programmable logic controller (PLC) had been utilized for 33kV automatic changeover and interlocking as shown in Figure 2. The control logic is software programmable for user requirements and capable for expansion of the power system network with software modification. The control algorithm can be designed to cater for infeed source failure or any equipment / cable fault scenarios and provides interlocking conditions under possible system configuration.

The PLC for automatic changeover and interlocking system will utilize the dedicated communication channels using optical fibre cables. Two communication channels, functioning at the same time, which can be operated independently as two individual channels as shown in Figure 3.

3. SYSTEM CONFIGURATION OF PLC SYSTEM

The PLCs provided in each location consists of two identical central processing units, each connected to a communication link via communication modules, which is operated in full duplex mode as shown in Figures 2 and 3. On detection of trouble or maintenance of one of the two central processing units or communication modules, the faulty CPU or communication module will be detached and other healthy CPU or communication module will continue to operate automatically without loss of data.

The PLC system will be able to monitor the healthiness of active and standby communication links. In case of detection of failure of active connection, the standby connection will be switched into operation automatically and providing local and remote alarm to OCC.

4. FUNCTIONAL REQUIREMENTS

The automatic changeover and interlocking system for 33kV network will meet the following requirements. The control algorithm is detailed in Figures 4.1 to 4.3.

4.1 Controlled Closing

(a) For the interlocking scheme, two independent criteria will be used, namely the absence of a voltage and remote feeding circuit breaker open. For 33kV interlocking design, checking one condition (CB status or U/V) is not enough.

(b) For controlled closing, the 33kV CBs will not be closed under normal or failure conditions if it causes different infeed sources in parallel operation.

(c) The control algorithm of controlled closing will allow 33kV CBs to close to maintain the supply as far as possible in case of normal or equipment outage conditions.

(d) The input signals to the PLC system will be of double bits. When there is abnormality of input signals or PLC I/O unit, remote and local alarm will be provided.

4.2 Automatic-changeover

(a) The operation mode of circuit breaker for 33kV automatic changeover under normal system configuration will be defined. The automatic changeover scheme will be carried out successfully under the pre-defined failure scenarios.

(b) The conditions for automatic changeover will be monitored at any time. Once the failure conditions are satisfied, the automatic changeover scheme will be carried out.

(c) Time delay for processing of 33kV automatic changeover will be allowed for discrimination of disturbances on the power system network of power companies and MTR's power supply network and the operation of LV automatic changeover.

PART II

OPTIMISATION OF OVERVOLTAGE PROTECTION DEVICE OPERATION

1. INTRODUCTION

Overvoltage protection device (OVPD) is provided at passenger station for lines with 1500V d.c. traction system to constrain the rail to earth voltage to ensure the voltage at the platform screen doors which are directly connected to rail is less than the threshold limit. Another purpose of the OVPD is to provide a return path for overhead line to earth fault current flowing from earth to negative pole of the traction substation via the running rails.

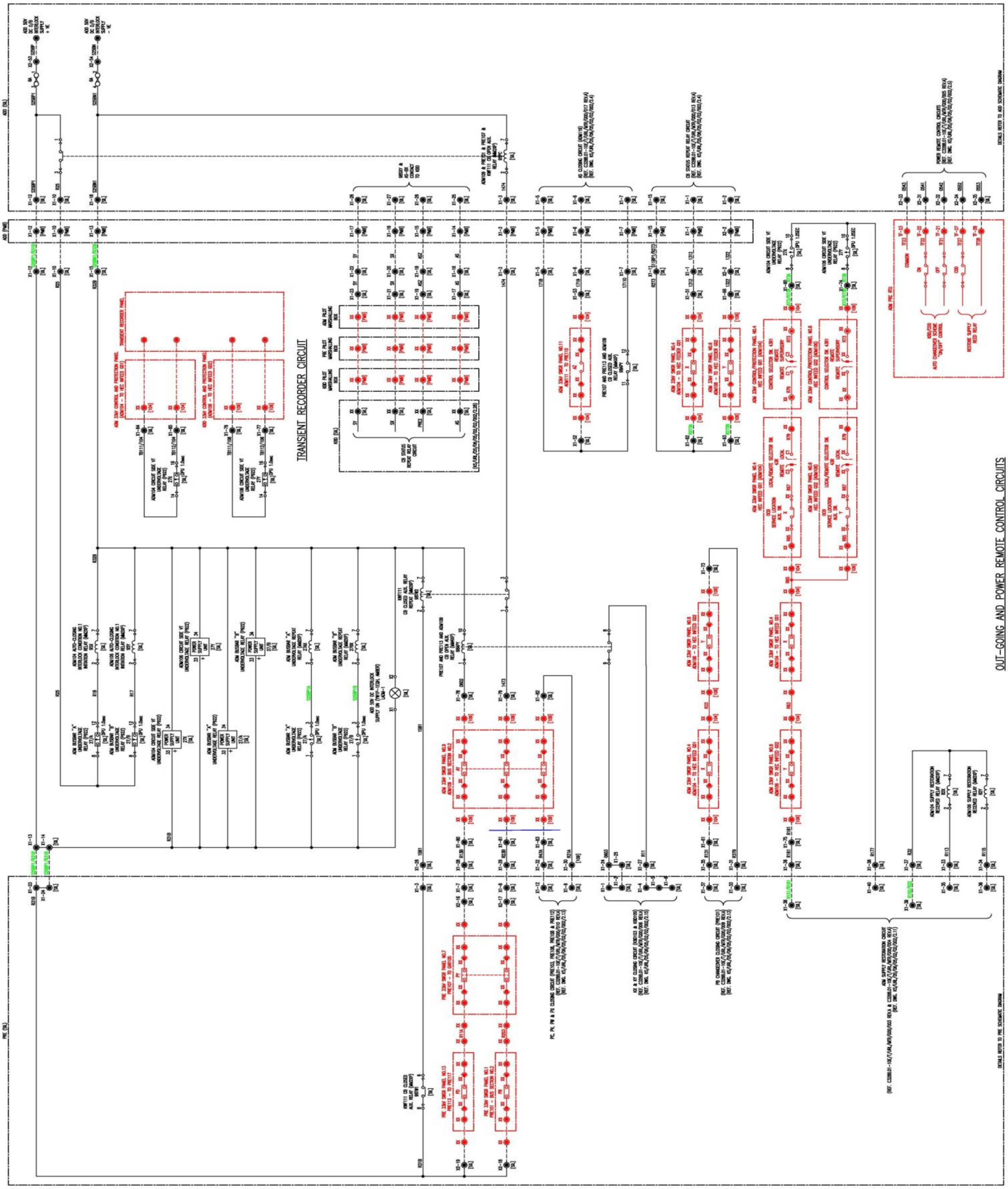
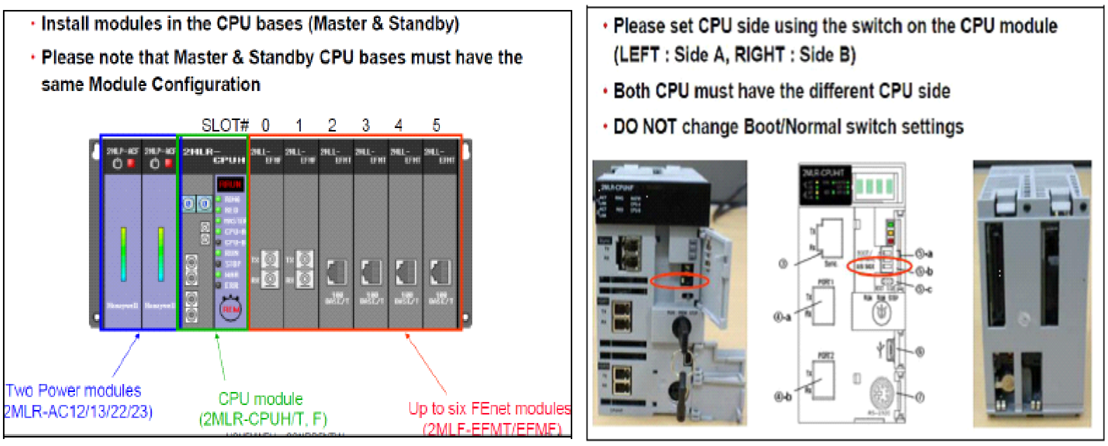


Fig. 1.1–Relay wiring diagram for 33kV automatic changeover and interlock system

Fig. 1.2 – General appearance of 33kV automatic changeover and interlocking relay panel

SIEMENS



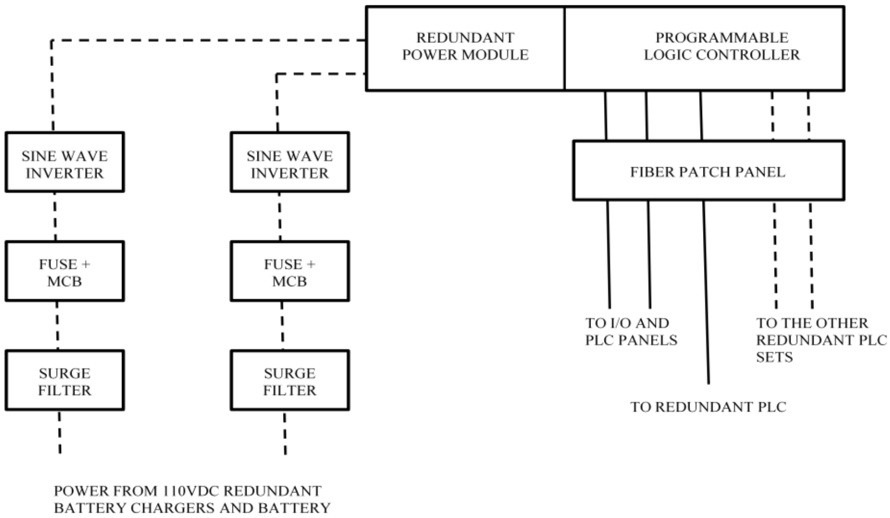


Fig. 2 – Redundant arrangement of CPU and power supply for 33kV PLC system

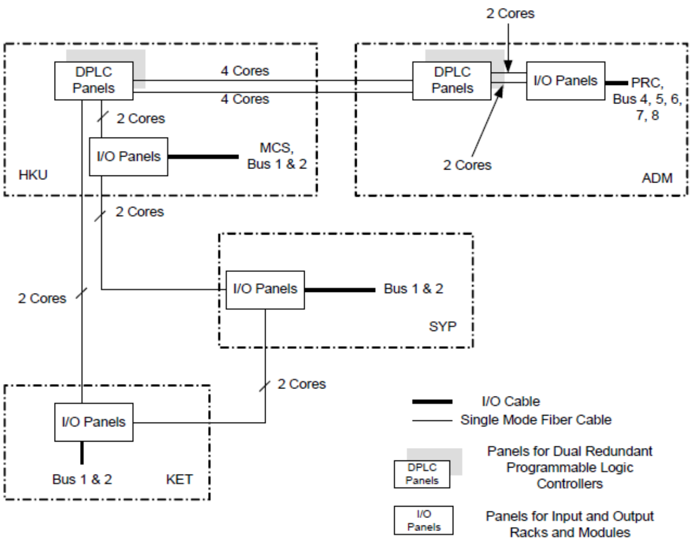


Fig. 3 – Duplex arrangement of communication network for 33kV PLC system

SIEMENS

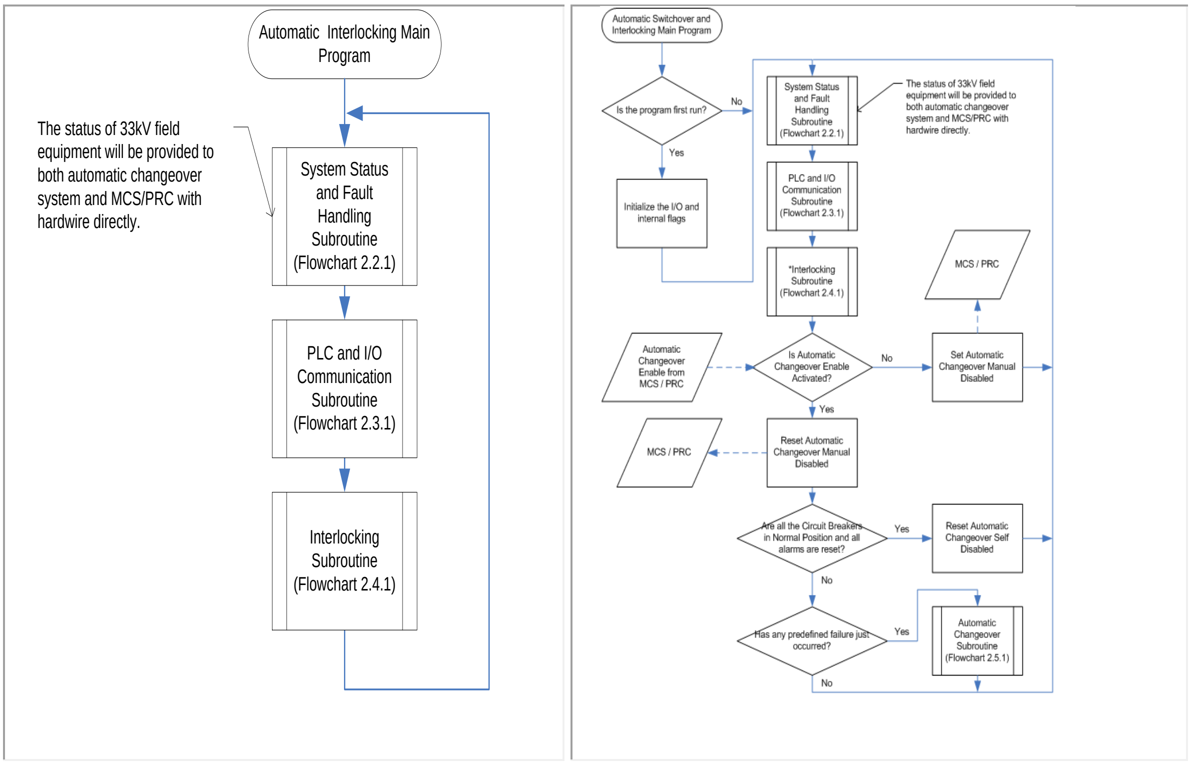


Fig. 4.1 - Flowchart for main programme

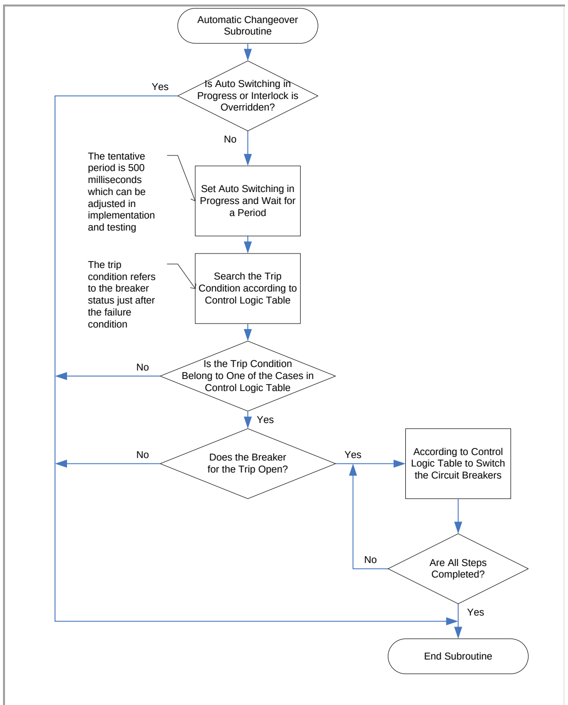


Fig. 4.2 - Flowchart for automatic changeover

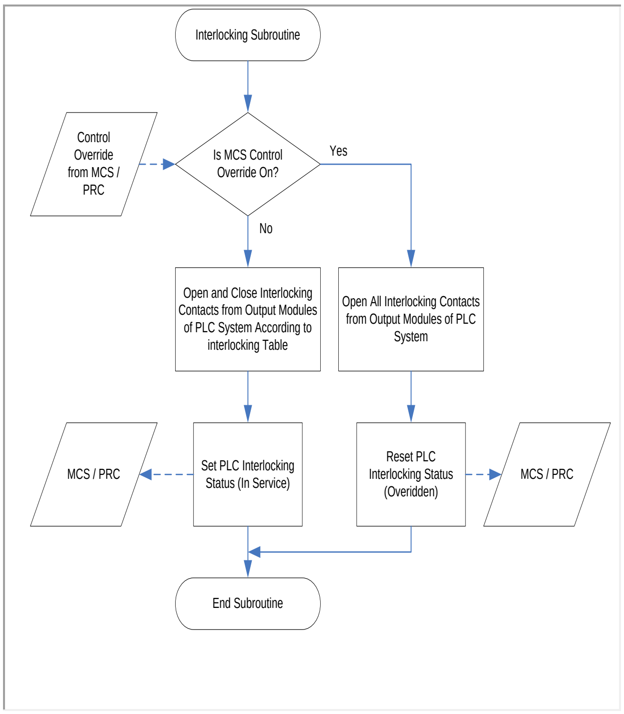


Figure 4.3 - Flowchart for interlocking

SIEMENS

In the conventional design, the OVPD monitors the rail to earth voltage continuously and connects the rails to earth when the measured voltage exceeds the threshold limit even though there are no trains staying at platforms for passenger boarding or alighting. An intelligent design is developed to reduce the number of OVPD operations by checking the rail to earth potential with the presence of trains at platforms. The advantages of adopting such design can significantly reduce the number of OVPD operations and thereby reducing d.c. current flowing from rails to earth resulting from each OVPD operation. The device which incorporates the above design is named Platform Screen Door Bonding Device (PBD).

2. OVERVIEW OF PLATFORM SCREEN DOOR BONDING DEVICE

The PBD comprises two bonding units including the rail bonding unit (RBU) and the earth bonding unit (EBU). The rail bonding unit connects the platform screen door (PSD) to rail and the earth bonding unit connects the PSD to earth. The connections of the RBU and EBU are shown in the diagram below.

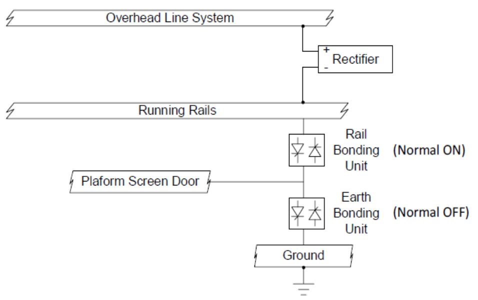


Fig. 5 - RBU and EBU connection diagram

The RBU will provide equipotential bonding between train and PSD.

The EBU will ensure the voltage of the PSD relative to earth is less than the threshold limit.

Each bonding unit is rated at 3000A with 3 minutes on state and 2 minutes off state, 19 hours a day. The static power switch of each bonding unit comprises two bi-directional silicon controlled rectifiers and an electromechanical d.c. contactor as shown in the below diagram. The static power switch can turn on and off in less than 10ms upon receipt of the control signal.

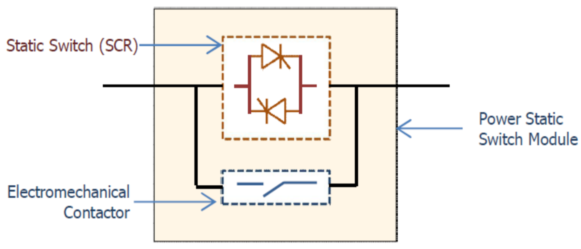


Fig. 6 - Static power switch

The rating of the PBD is summarised in the table below:

Maximum operation voltage	1800V d.c.
Current Duty for the RBU and EBU	3000A for 3 minutes followed by 2 minutes of cooling for 19 hours per day
Rated short circuit withstand current	80kA for 20ms

Table 1 – PBD rating

Each bonding unit has its own microprocessor based control system to control its operation and interface with the Signalling System to detect the presence of train at platform or not and interface with the Main Control System for the remote monitoring of the status of the PBD. The bonding units are able to be communicated together to exchange status and the open/close control request.

The control of the rail bonding unit and the earth bonding unit of the PBD is according to the following operation conditions:

Operation Condition	RBU status	EBU Status
Normal	On	Off
Vpsd > Vpreset - Train not at platform and - PSD doors are closed	Off	On
Train at platform	On	Off On if Vpsd > Vpreset
Any PSD door is open	On	Off On if Vpsd > Vpreset
OHL to rail/earth fault	On	On

Table 2 – RBU and EBU status under different operation condition

The rails will only be connected to earth via the RBU and EBU on the following conditions:

(a) Vpsd > Vpreset + train at platform
(b) Vpsd > Vpreset + PSD door is open
(c) OHL to rail/earth fault leading to rise of earth/rail potential

The RBU is of fail to safe design. The mechanical contactor in parallel with the rail bonding unit will close upon failure of the RBU.

An OVPD in parallel with the EBU is also provided. The OVPD will operate independently to the EBU to ensure the voltage at PSD is within the limit in case of the failure of the EBU.

3. APPLICATION OF THE PLATFORM SCREEN DOOR BONDING DEVICE

The provision of the PBD can significantly reduce the number of operations to connect the running rails to earth and thereby reducing the d.c. current flowing from rails to earth. This device can be applied to the particular location that high d.c. current following from rail to earth is expected due to the operation of the OVPD. One set of PBD has been installed and put in service in North Point Station of Tseung Kwan O Line. Another set of PBD was installed in the Ho Man Tin Station under the current constructed Kwun Tong Line Extension project.

CONCLUSION

a. The 33kV automatic changeover and interlocking system using PLC is a smart design to allow high flexibility on the expansion of power supply network and extension of railway. It provides a high level of reliability not less than hardwire system. Self-diagnosis feature for monitoring the healthiness of the PLC system is also provided. The maintenance regime of the PLC system is simple in comparison with the hardwire relay system. The 33kV automatic changeover and interlocking system has an interface with the Main Control System on the smart decision support system which enables the Power System Controller to manage the power supply system in an effective and efficient manner.

b. The design of platform screen door bonding device can reduce the number of operation of overvoltage protection device to connect running rails to earth and still maintaining the required safeguards to passengers boarding or alighting the trains.

Paper No. 7

SMART TRAFFIC MONITORING SYSTEM

Speakers: **Dr Alfred S.F. Wong, Council President**
Ms Edco W.I. Ho, Member
The Macau Institute of Engineers

SMART TRAFFIC MONITORING SYSTEM

Dr Alfred S.F. Wong, Council President
Ms Edco W.I. Ho, Member
The Macau Institute of Engineers

ABSTRACT

Closed Circuit Television (CCTV) is commonly used to monitor the areas that need to be under surveillance, especially in monitoring the traffic condition. However, manpower is necessary all the time for monitoring it, and the risk of human mistake exists. Surveillants need to look out for any abnormal situation which is appeared from many images at the same time. Time is therefore wasted for searching the specific scene back as evidence, or the abnormal situation is totally missed if there is any mistake. Thus, an automatic function of monitoring system can greatly enhance the accuracy and efficiency.

The automatic function of RFID just offset the shortcoming of CCTV monitoring system; furthermore, how to integrate these two technologies and obtain the optimal performance in monitoring the traffic condition is a great challenge. On the other hand, moving situation is considered in this study which is an innovative point for RFID experiment. Identification of traffic violation, vehicle with violation, or forecasting of pavement behavior etc., are expected to be achieved by the smart traffic monitoring system automatically, which can enhance the traffic management for the whole city.

1. INTRODUCTION

Macau, such a small city with high population and number of vehicles, traffic management is a vital task for the government. Until April in 2016, there are 248,492 registered vehicles in Macau, and keep on increasing from the pass 184 months. In 2016, there are 649,100 people in Macau and one in 2.6 people owns a vehicle. Compare to 16 year ago in 2000, there were 430,100 people in Macau and 113,814 registered vehicles, one in 3.8 people owned a vehicle. It indicates that the demand of private vehicle is increasing; it may due to the increasing travelers and the inconvenient public transportation system. As a result, the total amount of vehicle continues upward trend, and it brings pressure to the traffic management of the government.

Until now, the main transportation vehicles in Macau are bus, taxi, motorbike and private car, those vehicles are not easy to be monitored as the MTR system. Thus, some problems or difficulties exist, and there is room for improvement:

a. Insufficient Traffic information

Traffic information, including traffic flow, traffic jam or any accident, is vital information for drivers, pedestrians or even the government. For the driver, time consuming or be late is caused by traffic jam deeply, especially the roads are quite narrow in Macau, traffic jam exists when any accident happens.

b. Traffic signal control

The traffic signal in Macau is not centralised controlled by computer, and cannot match with any emergencies, such as accident, emergency vehicles, or even the Grand Prix Macau.

c. Traffic rule violation

The numbers of the vehicles to the parking spaces are not proportional. Illegal parking and traffic accidents keep on increasing. Until 2012, there are 95,063 private cars but only 24,875 parking spaces, it indicates that only 26% of private car can be parked at the same time. For the heavy duty truck and motorbike, the percentages of legal parking space are 11% and 43%. All the percentages are quite low, and drivers are impossible to find the legal parking space.

From the above problems, manpower is necessary all the time for observing the monitor, and CCTV is used to aid with the monitoring. Although CCTV system is widely used in the world, there are some shortcomings which hinder the development of security system. Proactive monitoring is a demanding task and imposes a high level of workload upon the controller which makes the whole surveillance task even more difficult. A study has mentioned that after 12 minutes of continuous video monitoring an operator is likely to miss up to 45% of screen activity, and, after 22 minutes of viewing up to 95% of activity is overlooked [1]. Even if the proactive monitoring is as part of the CCTV operators' responsibilities, it is very demanding and impossible for a long time. Thus the dramatic increase in the number of CCTV cameras cannot guarantee increase in security. On the other

SIEMENS

hand, a CCTV image may often be difficult to interpret, with the effects of camera and video quality, perspective, lighting, motion and position creating problems [2]. As the shortcomings of the monitoring system, many researchers pay efforts to study about the intelligent monitoring systems, and some of those methods are mentioned in the next section.

2. LITERATURE REVIEW

CCTV is studied combining with various technologies, for the purpose of achieving an automatic and intelligent security system. Those studies can be separated into different categories as below:

2.1 CCTV with wireless system

GPS and RFID are two famous wireless systems being used nowadays, and both of them have been assigned to aid with the CCTV system:

For the GPS, a digital video recorder which is primarily installed in commercial vehicles to keep a track of all activities happening inside the vehicle while the vehicle is in motion with hidden analog cameras.

For the RFID, W. Wen [3] proposed to obtain traffic data by using RFID, RFID readers are installed on the roads and RIFD tags are installed in the car, a management system is established and tested. The average speed or average flow etc. information can be calculated by the data obtained from RFID.

Apatcha et al [4] proposed to monitor the behavior of juvenile by attaching the RFID tag with the juveniles, but no data is provided.
From the above applications, RFID is just used with the simple communicate function, and the CCTV security system is necessary to be monitored by operators. Thus, CCTV combined with RFID is still an innovative method and valuable to be studied.

2.2 Image Processing

Many automatic security systems are purposed and most of them are automatic because of the image processing. Josh et al [5] proposed to use landmark for facial identification. A system produces 37 linear and 25 angular measurements across the two viewpoints. Unfortunately, this method cannot be used in CCTV system as the front view of the head is hard to be captured in CCTV system, and even the quality of the image from the CCTV system is not so high to be calculated point by point.

Shih-Chia and Fan-Chieh [6] proposed to utilize spectral, spatial and temporal features to generate a pyramidal structure of the background model, then the moving targets can be accurately detected at each frame of the video sequence.

2.3 Motion

Motion detection is the main part of an automatic security system as it is the main part to know what is happening. Sergio et al [7] proposed through the CCTV system to detect overcrowding, direction of motion and stationary of objects automatically, and this system has been tested in the London Underground network.

Arnold et al [8] proposed to establish a system for judging the normal/abnormal situation automatically. There are three main components in the system; the first component is the context space model which provides the features used for describing different contexts. The second component is a data stream clustering algorithm. Finally, the proposed inference algorithm allows the system to make detection.

From the above studies, it indicated that the quantification definition or the case setting is different for each case. If there are various cases, manual operation may also necessary for selecting the variables, unless a selecting algorithm is provided by the system.

Closed Circuit Television (CCTV) is commonly used to aid monitoring of the areas that need to be under surveillance. However, manpower is necessary all the time for monitoring it, and the risk of human mistake exists. [9]. A study has mentioned that after 12 minutes of continuous video monitoring an operator is likely to miss up to 45% of screen activity, and after 22 minutes of viewing up to 95% of activity is overlooked [10].

Radio Frequency Identification (RFID) is the wireless use of electromagnetic fields to transfer data, for the purposes of automatically identifying and tracking tags attached to objects [11]. The automatic function of RFID just offset the shortcoming of CCTV monitoring system; furthermore, RFID has various advantages and can be used in a wide range of applications. As a result, how to integrate these two technologies and obtain the optimal performance is a great challenge.

Path loss model is vital for the RFID installation. The three forms of models are better to find the propagation path losses: The reflection and diffraction laws were being use is calling Maxwell’s equations [12]. Probability analysis is finding the probability density function is calling the statistical model [13]. Using the results of several measurements to obtain the existing equations is calling empirical models [14]. In this model, it can give better accurate results, however this type of model have a main problem and cause computational complexity.

3. METHODOLOGY

A complete security system is vital for achieving fully automatic operation. The complete procedure of an intelligent security system can be divided into the following steps:

a. Raw Video

Raw Video is the key input of the security system, the quality of the raw video is depending on the hardware and the final result is affected by the quality of the raw video deeply. Although the raw video is vital to the final result, the selection of the hardware is not the main factor in this study as it is related to user, budget or technology; on the other hand image processing analysis is focused.

b. Moving Region

For motion or behavior tracking, the target objects need to be detected first. As a result, edge detection is in the forefront of image processing for object detection. Some mathematics filters can achieve the separation well by the original mathematics properties, for example, Sobel, Canny, Prewitt, Fuzzy logic, LoG(Laplacian of Gaussian), etc.. However, the majority of different methods can be grouped into two categories: gradient based edge detection and laplacian based edge detection. The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image (Figure 1), and the laplacian method searches for zero crossings in the second derivative of the image to find edges (Figure 2), which are corresponding to the changes of pixel intensity.

Although a lot of algorithms exist, there are both advantages and disadvantages due to various algorithms. Gradient based algorithms are simple and with orientations, but sensitive to noise and inaccurate, such as Sobel, Prewitt etc. Laplacian based algorithms are a little bit complex but still sensitive to noise. LoG or Canny etc. algorithms are more accurate and less sensitive to noise but without the orientation and complex computations.

Even if the performances are mentioned as the above theoretically, the result is related to the category of the original image deeply. As shown in Figure 3, when the contrast is strong, the performance of Sobel is better than that of Laplacian. On the other hand, as shown in Figure 4, when the change of grayscale is not clear, the performance of thresholding is better than both Sobel and Laplacian.

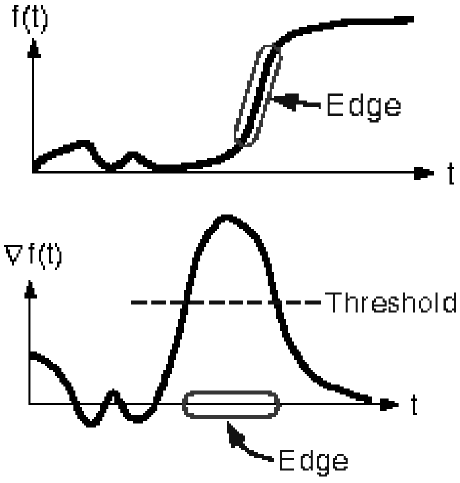


Fig. 1 - Gradient based edge detection

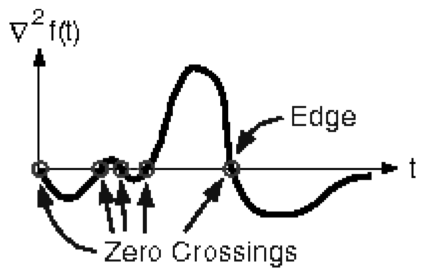


Fig. 2 - Laplacian based edge detection

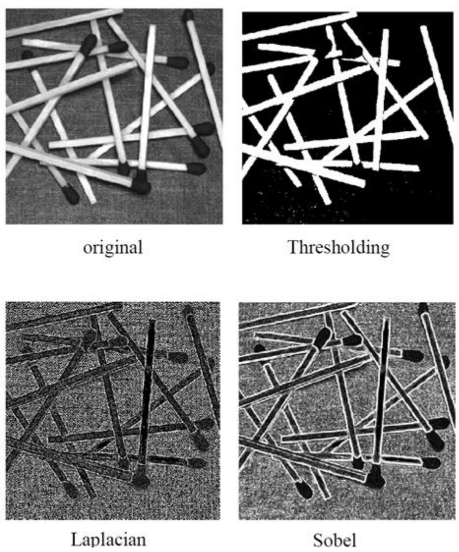


Fig. 3 - Strong contrast image

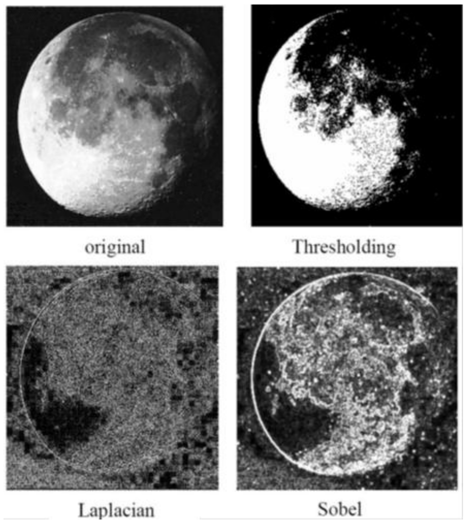


Fig. 4 - Image with not clear grayscale

c. Object Detection

The traditional method of object detection is using mask, but for the image of CCTV system, and even with a complex environment, the performance of this method is poor. As a result, the identification function of RFID is a great help. Experiments are necessary for testing the performances of the target situation, for example transportation system, the velocity or the material of vehicles may also affect the result. On the other hand, for avoiding the tags are destroyed or not attaching on the targets, a no-tag detecting module is necessary.

d. Annotated Action and Conceptual Predicate

Annotated Action and Conceptual Predicate are also related to motion vector. As shown in Figure 5, motion vector is involved to describe the motion of the target object. As the VLT method, the locations of the target object are tracked continuously. The location of the target is (x_1, y_2) at time t_1, and is (x_2, y_2) at time t_2. Thus, (x_1, y_1) is the reference location for (x_2, y_2) in the searching region, and the displacement of the point (x, y) is the motion vector. Motion estimation is the process of determining motion vectors that describe the transformation from one image to another.

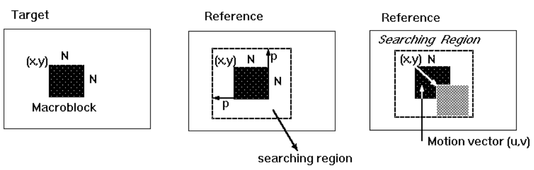


Fig. 5 - Motion vector

Intelligent CCTV monitoring system can be used in transportation system, hospital, casino, etc. As those targets are moved or moving, the experiment in this research is separated into two parts, static and dynamic. About the frequency, 433 MHz series is chosen, as there is more noise with higher frequency range. Signal loss experiment is taken as the signal loss related to the distance, and distance is vital to the whole system. First of all, the distance between the reader and the target object is important when the RFID tag is installed, as it is still a trial and error method. On the other hand, distance is related to the location of the target object.

The RF-CODE 433 MHz M250 Reader interprets and reports the radio frequency messages emitted by RF Code tags. The read range is around 45 meter. Once the tags get in the detecting area, over 100 tags can be read per second. As there is dynamic part in the experiment, the faster beacon rate is necessary for the tags. In this study, M100 asset tags which have 2 seconds motion alert and 10 second beacon time are chosen.

The experiment is separated into two parts:

Part 1

Static: A ruler was stuck on the floor in the corridor of E11-1060 of University of Macau, as the ruler was assumed to be fixed on the ground. Then, reader was put on the zero point, which was in front of the 0m of the ruler, and right angle ruler was used to make sure the antenna of the reader was vertical to the ground, as the angle of the antenna can influence the SSI value of the test. The router and the reader were connected by using the Cat5 cable, and the router was the agency between the reader and the server. Therefore, the router was not necessary to be connected to the internet. Explorer was opened to get into the reader, which was the previous setting IP. On the page, tag filter was found and tags' IDs were added which the tags' information were referred to. There were the tag's ID, Group ID, FCC ID and model type on the tag label. Since there was unique ID for each tag, all the tags can be filter by the reader except the testing one. Also, Secure Socket Layer (SSL) is set by the company so that the information inside the tag can be protected. "Tag" was selected and then "Add group" was clicked to enter the tag's group ID, which the testing tag was belonged to. After the data is got from the zero point, the tags were moved to 1 meter, and then meter by meter until to 30 meters. Log Distance Path Loss Model and Hata Model were used to compare with the new model. There were 3 different heights in the experiment, 0m, 0.5m and 1m, as in Figure 6. As using in the transportation system, generally there was a difference height between tags and reader. As a result, there were different heights and the SSI values of the static state in different height were determined.

Fig. 6 - The base of the reader

Part 2

Dynamic: The first step was same as the static experiment, for the driving machine, the 12 volt motor which the rpm was 77 was used. A power supply (220 AC to 12 DC) was used to let the driving machine to work at the same voltage. The rope was used to connect a car which a tag was put on the top and as the belt to connect to the driving machine. There was a pulley and a roller to make sure the rope can only be moved in one direction. The driving machine was put behind the reader, and the pulley was put on the 5m, 10m or 15m, as shown in Figure 7. The browser was opened to get into the reader; the same procedure with the static experiment was set. In the webpage, there was a payload column which the tag can be displayed moving or not. The tag was shown to be moving when the value was 1f4 (default value of RFID reader which means the detecting tag was moving) or 764, and the tag was static when the value was 1f0 or 760.

Fig. 7 - Setup of dynamic experiment

Result

The signal loss with various conditions has been obtained and compared with the other path loss functions, as shown in Figure 8 and Figure 9.

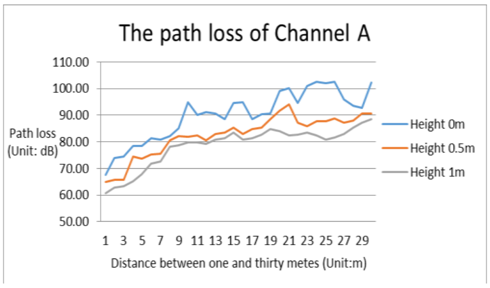


Fig. 8 - Compared path loss of channel A when height is 0m, 0.5m and 1m

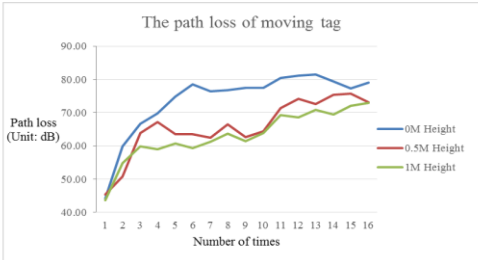


Fig. 9 - Compared path loss of channel A when tag moving far away from the reader and height is 0m, 0.5m and 1m (Distance between one and five meters)

The static situation with different heights of base is shown in Figure 8, the dynamic situation with different heights of base and testing distances is shown in Figure 9.

4. DISCUSSION

For the moving region, there are problems of false edge detection, missing true edges, edge localization, high computational time and problems due to noise. Thus, comparing with different filters or threshold, integrating different models or methods, or even automatic selecting filter analysis can greatly enhance the performance of finding moving region. In this research, gradient based algorithms are preferentially studied. Although Laplacian based algorithms are more accurate and less sensitive to noise, complex computations are fatal to outdoor environment as changes are so fast. On the other hand, Gaussian smoothing filter is applied to reduce noise, but the edges in outdoor environments may not so clear and may be smoothed together. If improving by reducing the computations, accuracy or sensitivity to noise may be affected. Therefore, Gradient based algorithms are simple and with orientation, sensitivity to noise induces inaccurate result. Thus, a new noise cancellation method is necessary. CEO (Choosing Edge Orientation) is proposed in this study. Using the advantage, orientation, to enhance the performance can avoid new disadvantage. How to choose the orientation, and match with the threshold are the essential of noise cancellation.

For the part of object detection, the result of part moving object is vital to the result of this part. Many previous studies can only detect or classify the target object roughly. Therefore, detecting object specifically is a difficult work. RFID can be used to aid with this task, so how to match the RFID signals with the results in part moving object is vital. Gradient based method is chosen in this part, as less computational work and fast response, especially suitable for outdoor complex environment with rapid changes. Static pictures are tested or compared in many researches with different mathematics models, but for using in monitoring system, the testing targets are dynamic. Therefore, dynamic factor should be added and the framework of the new edge model is as Figure 10. The input image I(a,b) is added a filter F(a,b) with dynamic factor δ related to velocity as threshold, and output O(a,b) is obtained.

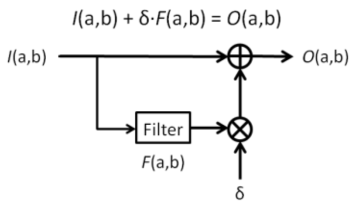


Fig. 10 - Edge model

For the experiment part:

a. Static with different heights

As Figure 8 shown, the height between tags and reader is a main factor to influence the signal strength. Basically, the higher the height is, the less the signal loss is. Thus, it indicated that the signal loss is inversely proportional to the height of the base.

b. Dynamic with different heights and testing distances

As Figure 9 shown, the signal loss in dynamic situation is less than in static situation. The maximum signal loss in static situation is more than 100 dB, but the maximum signal loss in dynamic situation is around 90 dB, which is reduced around 10%. Also, the height between tags and reader influences the signal strength, the signal loss is inversely proportional to the height of the base.

RFID system is easily affected by many factors. For the mathematic methods, the curve of the change of the signal strength can be predicted. However, the calculation is complicated when more factors are necessary to be considered. Therefore, the experimental method can easily solve this problem and the empirical formula can reduce plenty of complicated calculation, as Table 1.

Table 1
Empirical formula under different conditions

Situation	Height	Empirical formula
Static	0m	y = 10.239ln(x) + 64.649
	0.5m	y = 8.631ln(x) + 61.066
	1m	y = 8.4273ln(x) + 57.58
Dynamic (5meters)	0m	y = 11.53ln(x) + 51.701
	0.5m	y = 9.7154ln(x) + 47.167
	1m	y = 9.05ln(x) + 45.826
Dynamic (10 meters)	0m	y = 11.009ln(x) + 48.896
	0.5m	y = 9.0996ln(x) + 45.952
	1m	y = 8.4168ln(x) + 47.056
Dynamic (15meters)	0m	y = 8.8546ln(x) + 55.247
	0.5m	y = 8.7821ln(x) + 49.397
	1m	y = 8.7995ln(x) + 45.472

5. CONCLUSION

An automatic and intelligent monitoring system is vital for reducing manpower and enhancing the accuracy and efficiency, and RFID technology is used to aid with this according to the advantages of it. As a result, the property of RFID signal is necessary to be studied in advance. Since the existing path loss model is not suitable for the conditions in this study, which is available for transportation system, hospital or casino, new signal loss model is necessary. Therefore, some empirical formulas are found in this study for more accurate signal prediction, and there are some contributions of this study can be concluded:

a. Short distance
For those existing Path Loss Models, mostly are using in the long distance such as above 100m or 1km. Therefore, signal loss model can also be used for short distance.

b. Low frequency
Besides the long distance, the existing models are using in high frequency only also, as the higher the frequency is, the longer the distance is. In addition, the new signal loss model is suitable in low frequency.

c. Indoor measurement
As the Tele transmission need to be set outside. Therefore, it is suitable for the indoor area such as tunnel and subway.

d. The antenna position
From the previous models, the height of the base of the antenna is set to be so high, as signal loss models are used in outdoor before. In this study, the height of the antenna can much smaller than other models.

e. The Simpler formula
Compare to mathematic model, empirical model is usually more complex and the calculation is more complicated. Therefore, the simple empirical formula can reduce the time of calculation.

f. Suitable in dynamic
When the target object is moving, the signal strength is weaker than it is in static. Therefore, the empirical formula in this study can be applied in the dynamic situation.

And for the whole smart monitoring system, there are some expected contributions as follow:

a. Traditional image processing methods cannot be used in the scene of CCTV, new image processing method is proposed to solve this problem.

b. RFID, which has not been used to aid with CCTV system, can enhance the automation and reduce the manpower or error.

c. Dynamic loss path function is obtained.

d. Standard RFID Installation.

e. Automatic matching system for RFID signal and Image.

f. New ME analysis can enhance the accuracy of the final result.

REFERENCES

[1] W. Wen (2010) ‘An intelligent traffic management expert system with RFID technology’ Expert Systems with Applications, vol.37, no.4, pp.3024-3035.

[2] Apatcha Sirichai, Oranutda Chinnasri, Warrachai Wiriyaromp, Yusaku Fujii and Preecha P. Yupapin (2011) ‘Surveillance Behavior of Juvenile by using RFID and CCTV Monitoring’ The 2nd International Science, Social Science, Engineering and Energy Conference 2010, vol.8, pp. 328-331.

[3] Josh P. Davis, Tim Valentine, Robert E. Davis (2010) “Computer assisted photo-anthropometric analyses of full-face and profile facial images”, Forensic Science International, vol.200, no.1-3, pp.165-176.

[4] Shih-Chia Huang and Fan-Chieh Cheng (2012)“Motion detection with pyramid structure of background model for intelligent surveillance systems” Engineering Application of Artificial Intelligent, vol.25, no.7, pp.1338-1348.

[5] Sergio A. Velastin, Boghos A. Boghossian and Maria Alicia Vicencio Silva (2006) “A motion-based image processing system for detecting potentially dangerous situations in underground railway stations” Transportation Research Part C: Emerging Technologies, vol.14, no.2, pp.96-113.

[6] Arnold Wiliem, Vamsi Madasu, Wageeh Boles and Prasad Yarlagadda “A suspicious behavior detection using a context space model for smart surveillance systems” Computer Vision and Image Understanding, vol.116, no.2, pp.194-209.

[7] Ainsworth (2002)“Buyer Beware” In: Security Oz, 19, pp.18-26.

[8] Caroline Wilkinson and Raymond Evans (2009) “Are facial image analysis experts any better than the general public at identifying individuals from CCTV images?” Journal of The Chartered Society of Forensic Sciences, vol.49, no. 3, pp. 191-196.

[9] Heba A., “Review of Closed Circuit Television (CCTV) Techniques for Vehicles Traffic Management”, International Journal of Computer Science & Information Technology (IJCSIT), vol. 6, no. 2, 2014.

[10] Ainsworth, “Buyer Beware” In: Security Oz, 19, pp.18-26, 2002.

[11] Weis, Stephen A. "Rfid (radio frequency identification): Principles and applications." System 2, 2007

[12] Bräuer, Ralf, and Olof Bryngdahl. "Electromagnetic diffraction analysis of two-dimensional gratings." Optics communications 100.1-4:1-5, 1993.

[13] Saleh, Adel AM, and Reinaldo A. Valenzuela. "A statistical model for indoor multipath propagation." Selected Areas in Communications, IEEE Journal on vol. 5, no.2, pp.128-137, 1987..

[14] Abhayawardhana, V. S., et al. "Comparison of empirical propagation path loss models for fixed wireless access systems." Vehicular Technology Conference, 2005. VTC 2005-Spring. 2005 IEEE 61st. Vol. 1. IEEE, 2005.

Paper No. 8

ACCELERATE THE WORLD'S TRANSITION TO SUSTAINABLE ENERGY

Speaker: **Ms Isabel C.Y. Fan**
Regional Director
Tesla Motors Hong Kong, Macau and Taiwan

ACCELERATE THE WORLD'S TRANSITION TO SUSTAINABLE ENERGY

Ms Isabel C.Y. Fan
Regional Director
Tesla Motors Hong Kong, Macau and Taiwan

ABSTRACT

This paper will give an overview of Tesla's past, present and future highlighting the technology that has made the company successful. It will cover exciting recent developments such as Autopilot, Tesla Energy, the Model S and the Gigafactory, the world's largest battery factory.

1. INTRODUCTION

Tesla Motors was founded in 2003 by a group of engineers in Silicon Valley who wanted to prove that electric cars could be better than gasoline-powered cars. Each new generation would be increasingly affordable, helping the company work towards its mission: to accelerate the world's transition to sustainable transport.

Fig. 1 – Tesla electric vehicle

2. TESLA ARCHITECTURE

Built on the Tesla platform, the battery's location on the floor gives Model S an extremely low center of gravity, greatly reducing the risk of rollover while at the same time enhancing handling and performance. Without an engine, Model S has a crumple zone much larger than other performance sedans to absorb the energy of a front end impact.

3. SAFETY

Model S is designed with safety as the first priority. Much of its safety is owed to the unique electric drivetrain that sits beneath the car's aluminum occupant cell in its own subframe. This unique positioning lowers the car's center of gravity, which improves handling and minimizes rollover risk, and replaces the heavy engine block with impact absorbing boron steel rails.

Much of the Model S safety is owed to the unique electric drive train that sits beneath the car. Model S has a low center of gravity, minimizing rollover risk. Model S's safety record is proven by its NHTSA and Euro NCAP 5-star safety rating along with setting a record of the lowest likelihood of injury to occupants when tested in the United States.

The standard active safety features include automatic emergency braking, collision warning, blind spot detection, lane departure warning, and optional convenience features like traffic-aware cruise control, autosteer, autopark, and summon.

Fig. 2 – Active safety features

4. ELECTRIC ALL-WHEEL DRIVE

With two motors, one in the front and one in the rear, Model S digitally and independently controls torque to the front and rear wheels. The result is unparalleled traction control in all conditions.

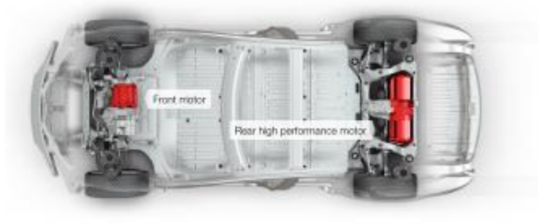


Fig. 3 – Electrical all-wheel drive

Unlike conventional all-wheel drive vehicles that sacrifice fuel efficiency for increased traction, Tesla’s Electric All Wheel Drive system increases efficiency.

5. PERFORMANCE

Reaching 0-60 mph in a mere 2.8 seconds, Model S is the quickest four-door sedan ever built.

Superior handling is the result of an extremely low center of gravity, thanks to the battery pack along the floor pan, centered between the axles. No other production car has a more ideal placement of mass for optimal handling.

6. AUTOPILOT

Autopilot was designed to give drivers more confidence behind the wheel by adding a layer of safety, all while making highway driving more enjoyable and reducing the driver’s workload. While Model S can’t make traffic disappear, it can make it a lot easier, safer, and more pleasant to endure.

Tesla’s autopilot feature is a hands-on experience, and we expect drivers to keep their hands on the wheel and maintain responsibility of the car. With Tesla’s over-the-air software updates, we can continue to improve and enhance Autopilot functionality.

Autopilot allows Model S to use a combination of cameras, radar, ultrasonic sensors and navigation data to automatically steer down the highway, change lanes with the flick of a turn signal, and adjust speed in response to traffic.

The instrument panel provides a visualization of the road as detected by the car’s sensors, giving drivers the information their car is using for features including lane departure, blind spot detection, speed assist, collision warning, adaptive cruise, and autosteer.

Fig. 4 – Instrument panel

7. EFFICIENCY

Model S allows you to travel anywhere without using a drop of gasoline. The EPA rates the efficiency of Model S as equivalent to 90 mpg.

8. CHARGING

A critical component of the adoption of electric vehicles is to create a seamless and convenient charging experience wherever customers choose to travel. Tesla owners can enjoy the convenience of plugging in at home or public charging stations to charge.

Fig. 5 – Charging arrangement

9. OVER-THE-AIR SOFTWARE UPDATES

Over-the-air software updates add functionality, enhance performance, and improve the driving experience of Tesla vehicles. Similarly to how you receive updates to your smartphone, Tesla owners receive updates to their car remotely without visiting a service center. The ability to receive these updates is free for the life of the vehicle. Software update 7.0 included Autopilot capabilities. This is just one example of how the entire Tesla fleet can receive an update and provide revolutionary new features for the owner in just a few hours.

Fig. 6 – Over-the-air software updates

10. GIGAFACTORY

Tesla’s mission is to accelerate the world’s transition to sustainable energy through increasingly affordable electric vehicles and renewable energy storage. At the heart of these products are batteries.

Tesla has seen enormous demand for our energy products and electric vehicles. Today, there are more than 140,000 Tesla vehicles on the road. Through our energy products, we have delivered more than 25 MWh of energy storage to customers on four continents.

With the acceleration of Tesla's vehicle build plan to 500k cars by 2018, the Gigafactory timeline is also accelerated to ready cells and packs ahead of vehicle production. By 2018, we plan to produce more lithium ion batteries annually than were produced worldwide in 2013.

We will reduce the cost of lithium ion batteries through economies of scale and innovative manufacturing, reduction of logistics waste, optimization of co-located processes and reduced overhead. By the end of the first year of volume production of Model 3 in 2018, the Gigafactory will have driven down the per kWh cost of our battery pack by more than 30 percent.

Fig. 7 - Gigafactory

By 2020, the Gigafactory will reach full capacity and produce more lithium ion batteries annually than were produced worldwide in 2013.

Tesla is not just an automaker, but also a technology and design company with a focus on energy innovation. With more and more viable electric vehicle models over the next few years, we look forward to growing the number of electric vehicles in our city for a greener, progressive Hong Kong.

Paper No. 9

MODERN ISSUES IN SMARTER ENERGY USAGE

Speaker: **Professor David J. Hill**
Chair of Electrical Engineering
Department of Electrical and Electronic Engineering
The University of Hong Kong

MODERN ISSUES IN SMARTER ENERGY USAGE

Professor David J. Hill
Chair of Electrical Engineering
Department of Electrical and Electronic Engineering
The University of Hong Kong

ABSTRACT

The paradigm for electrical energy delivery and usage is likely to undergo dramatic revision. This is especially compelling in terms of new distributed energy technologies, particularly for distribution network control while allowing much greater customer engagement. This paper gives a somewhat personal review of these developments with comments on how they might affect Hong Kong.

1. INTRODUCTION

It is hard to imagine a time in the history of electrical power systems when there has been more discussion about a larger number of technologies and scenarios related to what the future electricity supply might look like. Following the initial competition of ideas between the pioneers Edison and Tesla (over the famous choice between DC or AC transmission), there has been about a century of incremental changes towards larger and larger systems (enabled by better HV technology and control) and more economic efficiency (via electricity markets). Now we face a new era, which can be defined by the aim to provide electrical supply with less carbon emissions. The term sustainability is used often (without acknowledging what strict conformity to that term may mean). Another term which is frequently used without a strict definition of what it means is the term 'smart' as for example in smart homes, smart grids and even smart cities. In this paper, the key issues in all this potential change are briefly reviewed and some attention is given to how such issues affect the future of Hong Kong. Note: The use of the word 'smarter' in the title refers to the way in which governments and utilities can respond to the inevitable major changes.

From an international perspective, the paradigm of electrical energy delivery usage is being revised quite dramatically in terms of new technologies and structures, which are largely based on new ways for consumer engagement. These include new ways to generate energy, e.g. efficient rooftop PV, process the energy, e.g. storage, deliver the energy, e.g. microgrids, and control the energy, e.g. demand-response, and use the energy, e.g. EVs. Significantly, the role of the consumer moves from being a 'passive' random load to one who produces as well as consumes energy; hence the idea of a *prosumer*. These new entities on the grid can also play an active role in grid services. In this new era, consumers, or prosumers, can also choose to optimize their situation with much greater control including the extreme option of grid defection.

Several major studies have explored the *future grid*. Here two are briefly described. In Australia, the Government funded Commonwealth Scientific and Industrial Research organization (CSIRO) convened a forum of industry participants meeting for over a year to present and discuss the future with a consultant analyzing the consequent electricity prices, emissions, grid costs and so on over several decades. The conclusions reported in [1] are based on four meta-scenarios and many sensitivities to particular movements, e.g. a carbon price, rooftop PV. The scenarios are: 1) Set and forget (minimal consumer involvement); 2) Rise of the prosumer; 3) Leaving the grid; and 4) Renewables thrive. Given the reputed conservativeness of the electricity industry, it was quite telling that in the context of the Forum (away from their offices), the industry participants foresaw a future way different to the present. They could not say what it would be, but it would be very different. The scenarios allow for varying degrees of consumer participation, renewables and externalities like energy prices and policy options.

The second future grid study is mentioned because it was driven by academics from leading USA universities at the Power Systems Engineering Research Centre (PSERC) in a project funded by the Department of Energy (DOE) [2]. It is less comprehensive in scope and more detailed on technologies. Nevertheless, the picture presented is again of a vastly different looking grid in terms of similar issues as raised in [1]. A very recent special issue of the IEEE Power and Energy Magazine [3] takes an international perspective on "The Utility and Grid of the Future" again with the general message of accelerated change.

The author's own research programme at HKU and previously at The University of Sydney, where he led one of the four projects in a University Cluster supported by the CSIRO to follow-up the above-mentioned Forum with development of the tools needed to give more comprehensive comparisons of scenarios, deals directly with issues of future grids. The paper will build on this experience to introduce the issues one by one.

In this paper, the future will be defined in terms of *distributed energy resources* (DER), new issues, new architectures, and just briefly the new systems level research needed. It is not possible to provide an exhaustive presentation of the new ideas and so the presentation is inevitably somewhat personal. Only a brief discussion for each topic chosen will be possible. Further, the emphasis is on structures and operational aspects. The planning of such systems will also require new ideas.

The structure of the paper is as follows. Section 2 will introduce distributed energy resources. Section 3 will introduce some of the main issues and some problems that need solving. Section 4 looks at some new ideas for future grid structures and Section 5 will make some comments on how all these changes might relate to Hong Kong. Section 6 will make some conclusions.

It also needs to be pointed out that referencing is very minimal and just meant to indicate the type of articles being presented.

2. DISTRIBUTED ENERGY RESOURCES

A major part of the drive for change, which is already well on the way in futuristic thinking, is the spread of DER [4]. Most developments in one way or another are motivated by the goal of sustainability. These refer to smaller power resources for generation, energy storage and energy management. They facilitate the greater involvement of people in homes and industries to exercise some control over their energy environment. They represent a bottom-up involvement to co-exist with the large utility driven control, which has been the prior paradigm. Many utilities worldwide are also being proactive in adoption of large-scale new resources, although these might not get called 'distributed'.

2.1 Distributed Generation

The impact of distributed generation (DG) has been felt in many grids for decades. So-called independent power producers (IPP) below a certain MW output are not dispatchable and so have made the operation of a high voltage grid harder when appearing in high levels.

These days we think of DG as mostly renewable and as a given for studies of small scale systems – see below. The essential characteristic is its wide-scale location from one end of the grid to the other and variable levels of controllability.

2.2 Storage

The most discussion recently has been about storage with highlights being the Tesla Powerwall (home battery), but there are and will be many competitors. So when we think what mobile phones used to look like only ten years ago, and note all the research worldwide on new storage technologies (including in Hong Kong) we can be sure this is a game changer sooner rather than later.

Part of this story is the role electric vehicles (EV) can play. There is a lot of talk for years about how big a resource V2G can be for the grid with mobile stored energy. It has even been suggested in research at HKU that EVs can form a kind of energy network transporting power [5]. But the facility for V2G adds cost to the infrastructure and car at a time when this is already an expensive option, so the question of willingness of car owners to participate aside, it is not likely to be anytime soon that we see this in action.

2.3 Prosumers

A concept emerging in corporate terms (and reports like [1]) is that of the prosumer, i.e. a consumer who also produces power. They may also store energy in home battery systems (or EVs). The term smart load also gets used for a nominal demand point where other capability, even contribution to grid services like frequency control, are possible. The electric spring (ES) developed at HKU, is an example which addresses power balancing, voltage control and frequency control simultaneously and automatically [6]. A prosumer might install such capability (set and forget in [1]) and then also be involved in more proactive terms. These changes raise many questions and issues ranging from technical to social aspects. For example, in Australia the pricing of electricity for such consumers is contentious after recognition that they cause some of the problems the new grid has to solve but do not like the idea of being asked to pay for it (given their contribution to sustainability).

The next section will discuss some more issues that arise at a scientific level and are often overlooked in newspaper type discussions.

3. NEW PROBLEMS AND ISSUES

The new energy era with anticipated high levels of *renewable energy* (RE) and DER comes with, inevitably, many new challenges. They include the following problems and issues.

3.1 Bilateral Flows

The first alarms that RE needs new ideas came in situations where excess power could be sent to the grid. (Incidentally, one of my favourite trick questions to students is to explain how this is possible; aren't we doing something like pushing water uphill without a pump?) Transformer overloads and misfiring protection (designed for one-way flow) has led to conservative limits and maybe even prevention altogether.

3.2 Uncertainty

A key word in areas of systems analysis lately is 'uncertainty'. The planning and operation of future grids will require methods, which can systematically deal with greater uncertainty. One major source derives from the RE generation and demand being both now weather related. This drives the analytical methods needed to make the new systems work and some comments will be made on this towards the end of the paper.

3.3 Stability

Power grids in lay terms (and some non-electrical engineers also) are often seen as pipes delivery energy, cf. gas, water. Then so-what if the generation is now variable? But this ignores completely the fundamental dynamics in terms of frequency and voltages. The author prefers the analogy of driving a car on a hilly highway. As the car climbs (descends) the accelerator is pushed down (eased off) to maintain the speed. Cruise control hands this over to a feedback loop which ensures that a set-point speed is achieved no matter what the road circumstances. But we all know that a major disturbance to the car (like avoiding kangaroos that suddenly jump from the road-side in Australia) can lead to instability (so-called fish tailing) and the car running off the road. So there is already a stability issue. Now add to this the complication that the accelerator is randomly moving; it can be relaxed but not increased. Then the control and stability problem becomes much harder. (The analogy breaks down when we add that the inertia of the system is changing, making the problem even harder, and in a grid we can effectively change the 'road profile' – see demand management below, making the problem easier.)

3.4 Planning

Planning processes will need to change in the future. Now the game changers might occur within the lifetime of major plant. There is already investor uncertainty especially in places where Government policy is not settled.

The advent of the so-called economic 'double death spiral' following energy efficiency measures and rooftop PV in countries like Australia where poles and wire businesses have reduced income (based on grid energy used) and increasing costs (based on peak power demand) is unsustainable.

Then we add to this the issues with large-scale renewables. It seems to this author that the backbone grid cannot export variability and remain well utilised. We will need processes at the sending end to keep the transmitted power in a range.

Analytical methods must respond with new ideas like scenario-based planning, statistical measures of security such as being explored in recent research, including in Hong Kong.

4. NEW CAPABILITIES

The famous Einstein quote roughly says that problems are never solved by thinking as you did at the beginning of the story and we could add that bigger problems require bigger changes.

Here follows a view of the main new capabilities which need to be developed.

4.1Operational Flexibility

This author sees the big new capability needed as in terms of operational flexibility (OF) throughout the whole grid from HV to household (or kW to GW), but in terms of energy, power and ramping dimensions [7]. This means new models, seamless methods in terms of space, time and voltage level (granularity). The old timescales are not going to be there with fast acting storage.

With fossil fuels, energy use equates to emissions. With renewables this nexus is largely broken, especially with solar. Energy is now more a variable of interest in consideration of the role of storage.

Analytically, OF may require that mismatches will occur and be allowed for. Various approaches based on robust and stochastic optimization, risk-based methods and the like are being considered in Hong Kong.

4.2 Demand Control vs Response

Some basic *demand management* (DM) mechanisms are already standard practice, e.g. off-peak water heating, and others are being trialed such as in the recent CLP advanced metering infrastructure (AMI) demonstration in Hong Kong, e.g. *time-of-use* (ToU) pricing. These exemplify approaches based on direct control (by the control centre) and user choice respectively. Both can have an economic aspect depending on the formal arrangement between supplier and customer.

4.3 Demand Following Generation

DM needs to play a bigger role when using high levels of RE. Obviously, one way to deal with variable generation is to make the load more controllable. If the traditional power balancing paradigm is generation following load (GFD), then the new one could be DFG.

Again there is a huge question about the best way that consumers will participate, something that was overlooked in early attempts to install so-called smart meters. (The case of Victoria in Australia comes to mind as an example of not getting customers on-side first.)

ES were mentioned above; in DFG terms they implement a distributed mechanism at lower voltages without guarantees. Other control layers appear to be needed to build OF. This architecture is the subject of a major project based at HKU and involving HKUST, PolyU, Sydney University and Imperial College London.

4.4 Distributed Control

A variation is the idea of 'seamless control'. Traditional control is based on two 'balancing acts', namely real power balancing (frequency), cf. the cruise control problem, and reactive power balancing (voltage). This breaks down at lower voltages where the losses are high and real power asserts a larger effect on voltages. Thus you see in microgrids – see the next section – that the control across voltage and frequency needs to be coordinated.

Given the variable inertia as RE is dispatched or not, the idea of distributed virtual inertia control as arisen. This whole question of the importance of inertia (what about a grid that is totally inverter driven?) is a hot topic for research and is being studied at HKU.

4.5 Data Analytics

The early promise of smart grids was that they would develop in stages of better observability of the grid, analytics, e.g. condition assessment, more automation, e.g. self-healing, and new economic options, e.g. energy exchanges. Later came the idea of Big Data which seemed to turn the idea of unlimited data into a positive. This is not how control people see it. Too much data can be a huge problem.

What is for sure though is the need for the right data to give good estimation and prediction capability of many kinds.

4.6 Resilience

This is a very recent development driven largely by concerns about extreme weather events and adds to ongoing study by researchers on how to prevent cascading collapses (an unsolved problem). We refer to the capability to survive and recover from major events. It implies the need for inbuilt intelligence to predict, assess, adapt, prevent, correct and recover. Work at HKU [8] is at the forefront of this recent hot topic.

5. NEW ARCHITECTURES

Appropriately, to meet the above challenges, there has been a major revival in research and development mainly oriented to new DER devices. What is rarely posed as a problem to solve is just what the optimal shape of the future grid will be in a holistic sense. As suggested in [1], for some countries this will be substantially in the hands of non-utility parties, one might even say 'organic' and so for the future 'que sera, sera'. However, in more centrally controlled counties like China the optimization view is realistic.

Firstly, it can be said that all the above problems can be solved with today's technologies. The problem is the cost. Solar thermal power plants already exist with very high availability figures, but with expensive storage facilities attached.

5.1 Grid Defection

At this stage, the extreme alternative structure (in terms of 'small is beautiful') of grid defection tends to appeal to early movers on the idea of being self-sustainable. Recent reports from the USA and Australia [1] have acknowledged high levels of grid defection as a realistic scenario for the future. The more realistic situation is that most such defectors will want to keep some connection to the grid as a backup. This will require different pricing strategies much like we are used to for mobile phone plans, i.e. a trade-off between a connection fee (for power capacity) and energy usage charges (normal kW-hrs) depending on usage.

5.2 Nanogrids, Microgrids

There is no clear distinction between nanogrids and microgrids although of course the general idea is that nanogrids are small, almost at household and farm level.

These represent the most established alternative structure where semi-autonomous systems with their own DG, maybe storage, often a backup conventional generator and a grid connection that can be made or unmade. The most talked of example appears to be Bornholm Island in Denmark around which a major research programme has been built.

5.3 Smart Grids

There has been a lot said about what so-called smart grids consist of (more sensors, communications and sometimes other things that are simply new, but not necessarily smart) and will do, most notably the announcements by DOE, USA. But actually not much has been done on what good structures will be or even what we mean exactly by 'smart'. Many people resent the term as offensive to the very clever processes that make today's grid work so well in its classical way.

The sober view of smart grids is that they simply represent bring feedback control to the distribution systems [9]. While transmission level control has needed feedback control to make them work at scale (AGC, CVC), control at distribution levels is relatively quite primitive; for example, voltage control is usually 'open-loop' just relying on setting OLTC taps so loads at each end of the feeder have acceptable voltage. This gets upset by household generation and feedback control is imperative. Even without RE, there are benefits of advanced metering infrastructure (AMI) for better condition assessment and recover mechanisms after faults. There can be savings in simple mundane areas like maintenance truck rolls.

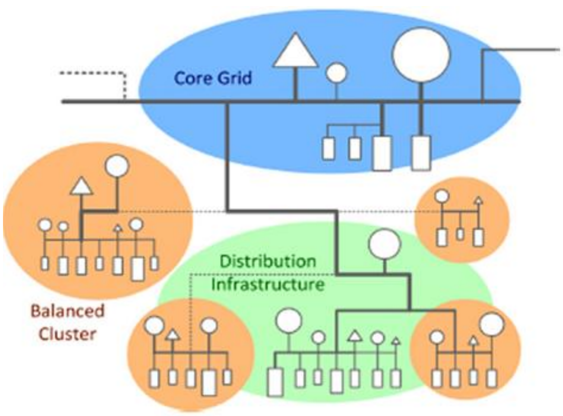


Fig. 1 - Smart Grid as a clustered structure [10]

5.4 GRIP

The proposal for a grid with intelligent periphery (GRIP) has been very influential in our research at HKU. (It is co-authored by Emeritus Professor Felix Wu with nine other USA colleagues.)

a. Structure

The structure complements the presentation in [10] for a distributed control view by adding more detail of how the legacy grid and new structures could merge together with a novel information structure. Whereas classical systems have all the intelligence at the centre, here the idea is to move it out to the clusters – see Figure 1.

b. Clusters

The clusters are envisaged to be collections of DER with two basic types, namely 1) a resource cluster (RC) such as a solar farm, a virtual power plant (VPP) or an aggregated storage facility; and 2) a balanced cluster (BC), which is less clearly defined but microgrids will be used here to illustrate. The idea is that they can balance generation and demand in a substantial way and so present a quite new presence on the grid to conventional loads.

The core or legacy grid may or may not be major part of the system long-term. This leads us to consider networked microgrids (or scalable microgrids) where the microgrids rely more on their cooperation to achieve the system operation and the legacy grid plays a minor and/or backup role.

5.5 Energy Internet

Another term for new energy structures is the Energy Internet (EI). To the best of the author's knowledge, this term has two major views. One is motivated by the Internet and envisages a routing system for energy at distribution level [11]; the research focuses on new devices. Some recent results at HKU are building a systems level facility for power flow routing (PFR). The second view from China is of a merged energy system across conventional renewable, transport, information all made to work like a (super) smart grid of sorts.

5.6 Supergrids

To the other extreme from grid defection are proposals for supergrids (or mega grids, supersmart grids etc), which span continents and even connect continents. The archetype is DESERTEC which could shift large amounts of solar energy from sunny Africa to Europe.

Comments and more questions

Given the wide range of options from grid defection to supersmart grids, one could be quite confused about what the future will hold or even about whether we will need grids at all. This can mean that political and other agendas will dominate in the decisions. However, we suggest that it is a scientific question that will have a different best answer in different situations, depending on the circumstances such as isolation, available RE and so on.

So nanogrid could just be a new name for remote area power supply in outback Australia and a supergrid could just be what is needed to shift large amounts of RE across a large heavily populated country like China or the USA. (The intercontinental option has been surely damaged by the prospect of terrorism attacks.)

In each of these special situations there are general questions, which need to be answered. Again, in all cases we see no reason why scientific methods cannot present the options (think Pareto fronts in multi-objective optimisation)

As a few examples, we could ask:

- Is it more effective to use market mechanisms or central control for dispatch?
- What is the point of tradeoff between installed and control based capability for reliability? (Western countries have previously leaned to the former more conservative approach.)
- What is the level if renewable power that can be integrated while preserving security?

In the next section, we will briefly comment on the situation in Hong Kong.

6. FUTURE HONG KONG

Hong Kong is an affluent city, which has natural beauty and human-made beauty, notably in its architecture. But its performance in sustainability is mixed. While you will not find a speck of dust on the floor of Central shopping centres, its coastline and rural areas are strewn with rubbish. While taxis contribute to roadside pollution, we have one of the highest uptakes of Tesla EVs. Its utilities have world-class emissions targets, but the Government is quite conservative in clean energy policy, which amounts to the right words but little noteworthy action. The recent fuel-mix consultation hardly mentioned renewable energy options.

Studies [12] show that Hong Kong could have 10 percent of its fuel mix from solar power just with current technology and no additional land requirements. (This is half the extra energy being talked about in the consultation.) With offshore wind farms, this option can rival the others considered.

Allowing for China (currently the largest installer of renewable power in the world) aiming to reduce its carbon emissions per unit of GDP by 45% in 2020 compared to the level in 2005 and the interconnection to China's grid also brings another avenue of improved sustainability for Hong Kong.

Then there are other possibilities. The author was recently excited to see the Pearl River Tower in Tianhe District, Guangzhou [13]. The design allows for carbon neutrality and actually selling power back to the grid (but the latter is disallowed by the local utility.) Bringing such novel high building ideas to Hong Kong could change the energy equations dramatically.

7. CONCLUSION

This paper has attempted to summarise the new concepts that have arisen recently in discussions (by industry and academia) about the future electrical power grid. Consideration is given to how these might affect developments in Hong Kong. Some contributions being made by Hong Kong universities in these areas were noted.

ACKNOWLEDGEMENT

The ideas presented here have benefited from discussions for some years with too many people to name, but most recently the associated research is funded by the Hong Kong RGC Theme-based Research Scheme through Project No. T23-701/14-N where Co-PIs Professors Ron Hui and Victor Li at HKU and several Co-Is, including Professor Zhaoyang Dong at Sydney University, Drs Jin Zhong and Yunhe Hou at HKU and Dr Zhao Xu at PolyU are engaged with these topics in their research.

REFERENCES

[1] Change and Choice: The Future Grid Forum's Analysis of Australia's Potential Electricity Pathways to 2050, CSIRO Report, December 2013.

[2] FUTURE GRID: Public Report on the Future Grid, PSERC Report for USA DOE, 2016.

[3] IEEE Power and Energy Magazine, Vol 14, No 5, Sept/Oct 2016.

[4] http://www.epri.com/Our-Work/Pages/Distributed-Electricity-Resources.aspx

[5] A.Y.S. Lam, K.-C. Leung, and V.O.K. Li, "An Electric-Vehicle-based Supplementary Power Delivery System," *Proceedings of the 6th IEEE International Conference on Smart Grid Communications*, Miami, FL, Nov. 2015.

[6] S.Y.R. Hui, C.K. Lee and F.F. Wu, "Electric springs: A new smart grid technology", *IEEE Transactions on Smart Grid*, Vol.3, No.3, Sept. 2012, pp: 1552-1561.

[7] A. Ulbig and G. Andersson, "Analyzing operational flexibility of power Systems", *Int Journal of Electrical Power and Energy Systems*, Vol.72, pp.155-164, 2015.

[8] L.Liang, Y.H.Hou, D.J.Hill and S.Y.R.Hui, "Enhancing resilience of microgrids with electric springs," to appear *IEEE Trans on Smart Grids*.

[9] D.J.Hill, T.Liu and G.Verbic, "Smart grids as distributed learning control," *Proceedings 2012 PES General Meeting*, Invited Panel on Distributed control – bringing together the power and control communities, San Diego, July 2012.

[10] D.Bakken et al., "GRIP – Grids with intelligent periphery: control architectures for Grid2050," *Proc Smart Grid Communications (SmartGridComm)*, 2011.

[11] A.Q.Huang et al., "The future renewable electric energy delivery and management (FREEDM) sytsem; the energy Internet," Proceedings of the IEEE, Vol.99, No.1, January 2011, pp.133-148.

[12] J.Peng and L.Lu, "Investigation on the development potential of rooftop PV system in Hong Kong and its environmental benefits," *Renewable and Sustainable Energy Reviews*, Vol.27, pp.149-162, 2013.

[13] https://en.wikipedia.org/wiki/Pearl_River_Tower

Paper No. 10

TRIAL SCHEME ON SMART DIMMING FOR LIGHTING SYSTEM OF FOOTBRIDGE

Speakers: **Ir Steve K.K. Chan, Senior Engineer**
Lighting Division, Highways Department
Ir K.K. Wong, Engineer, Projects Division
Electrical and Mechanical Services Department
The Government of the HKSAR

TRIAL SCHEME ON SMART DIMMING FOR LIGHTING SYSTEM OF FOOTBRIDGE

Ir Steve K.K. Chan, Senior Engineer
Lighting Division, Highways Department
Ir K.K. Wong, Engineer, Projects Division
Electrical and Mechanical Services Department
The Government of the HKSAR

ABSTRACT

For sustainable development of Hong Kong, Highways Department (HyD) has been continuously collaborating with Electrical and Mechanical Services Department (EMSD) to explore energy saving initiatives for public lighting systems at footbridges and subways. One of the recent initiatives is to use "Smart Dimming" technology for footbridge lighting.

This paper describes the roles of HyD and EMSD in the new installation, replacement and maintenance works of public lighting, the latest status of using light-emitting diode (LED) lighting in public facilities, and a trial scheme on "Smart Dimming" at one selected footbridge at Choi Hung, including the difficulties during project implementation and initial findings will also be discussed.

1. INTRODUCTION

HyD is responsible for management of public lighting facilities for carriageways, footbridges, subways, public transport interchanges (PTIs), underpass and tunnels, with a total of 230,000 public lighting points as at December 2015, of which 80,000 lighting points, mainly at non-carriageway areas, are under EMSD's maintenance service provisions. On the other hand, EMSD carries out modification and improvement to those aged public lighting systems.

2. NEW PUBLIC LIGHTING DESIGN MANUAL

All new lighting system designs of public facilities have to follow the guidelines and requirements as stipulated in the Public Lighting Design Manual (PLDM) issued by HyD, which is the main reference handbook for local lighting professionals on their designs of public lighting installations. The manual includes the latest international standards, local conditions and statutory requirements, the development of lighting technology, and the energy and environment management.

The first edition of PLDM was issued in 1996, and revised in 2006 as the second edition. The third edition (i.e. New PLDM) will be issued by the end 2016.

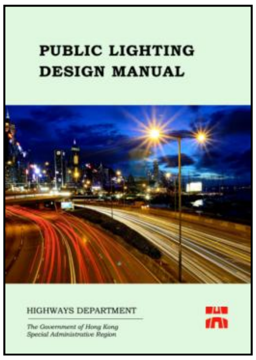


Fig. 1 - Public Lighting Design Manual issued by HyD

3. DIFFERENT ENERGY SAVING TECHNOLOGIES APPLICATION

In the past 10 years, HyD and EMSD have conducted full scale implementation of different lighting technologies to public lighting facilities in Hong Kong, including:

a. Since 2005, metal-halide high bay lamps (CDM-TT) with better color rendering have been used in PTIs.

b. Since 2009, T5 fluorescent tubes have been used to replace their T8 counterparts in footbridges and subways.

c. Since 2012, all electromagnetic ballasts have been replaced by electronic ballasts with dimming features.

In the meantime, other energy saving initiatives, such as LED lighting, have been explored and put into trials in some selected locations.

4. LATEST STATUS IN USE OF LED LIGHTING

The market of indoor LED lighting products has been growing rapidly since the 2000s. For HyD's used outdoor lighting products which require higher lumen output, equipment durability and operation flexibility, more and more outdoor-use LED lighting products have been emerged in the market in recent years. Some project locations have been selected for trial use of different types of LED lighting:

a. Road Lighting – Trial scheme has commenced since 2009, currently 171 nos. of LED road lights have been put into service. However, concerns in lumen maintenance, price level maintainability and glare control are yet to be settled before full scale implementation.

Fig. 2 - Trial-use of LED road lighting in Causeway Bay

b. Gantry and Directional Signs – Trial scheme has commenced since 2015, LED wall washer lighting was used to replace traditional metal halide (CDM) floodlights. The initial findings revealed that the lighting performance was better with at most 70% of energy saving.

Fig. 3 - Trial-use of LED wall washer

c. PTIs – Hung Hom PTI was the first PTI installed with high bay LED lighting to replace the aged sodium discharge lamps (SON) in 2015. The initial energy saving performance is about 30%.

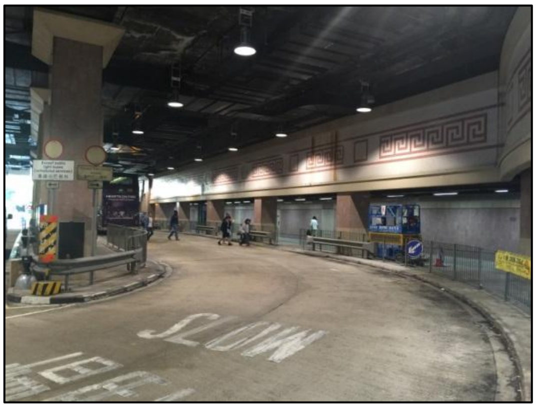


Fig. 4 - Trial-use of high bay LED lighting at Hung Hom PTI

d. Underpass – LED road lightings were installed in one 66-meter long underpass at Tuen Mun in 2015. Apart from energy savings, the new individual lane lighting layout design has minimized the traffic disruption for lamp replacement.

Fig. 5 - Trial-use of LED road lighting at underpass at Tuen Mun

e. Footbridges and Subways – Over 1,700 nos. of T8 LED tubes (with integral/built-in control driver) have been installed at different selected footbridges and subways since 2010. About 30% energy saving was achieved but this design has limitation to introduce the dimming control capability.

Automatic dimming is considered as our next generation of lighting system especially for those footbridges with low patronage.

Fig. 6 - Trial-use of LED tubes at San Po Kong

5. LIMITATIONS OF CONVENTIONAL LEDs IN FOOTBRIDGE LIGHTING

In the trial scheme development of footbridge lighting design using LEDs, both design and maintenance points of views were taken into consideration. The following limitations were encountered when conventional LEDs were selected:

a. Length/Shape of lighting fitting: Not standardized among different models of LED products available in the market.

b. Uniformity: Layout design will be fully dependent on the selection of lighting fitting models.

c. Lamp unit / LED module: Unlike fluorescent tubes, we can easily source T5/T8 fluorescent tubes from different suppliers, but LED modules are usually the proprietary designs of different suppliers, the original supplier is required to be approached to source spare LED modules.

d. Compatibility with existing metallic trucking installation: Additional trucking modification may be required during installation of replaced lighting fittings from different suppliers.

e. Spare parts management: Under the rapid product development, the same LED module may not be sourced after several years of operation. It is required to keep different spare parts for different locations.

6. MERITS OF USING LED TUBES

Judging from the above mentioned limitations, the way out is to adopt T5 LED tubes with external control drivers:

a. Length/Shape of T5 LED tubes: Fully compatible with T5 fluorescent tube in length (e.g. 1149mm for 28W T5 tube) and connection pin (type: G5)

b. Operation/Replacement: Similar to those of T5 fluorescent tubes

c. DC input with external control driver: Enable dimming features by adjusting the input current to the tube

d. Uniformity: Similar layout design of using T5 fluorescent tube lighting fittings

e. Metallic trucking: Additional modification will NOT be required as the lighting fittings need not be replaced

f. Spare parts management: Not required as we are able to source tubes from different suppliers

g. Dimming capability: Wider range than that of T5 fluorescent tubes from 0% – 70%

h. With appropriate controllers and control programme: Enable Smart Dimming Control System

Fig. 7 - T5 LED tube lighting fitting at Footbridge KF77, Choi Hung

7. TRIAL SCHEME OF SMART DIMMING SYSTEM WITH LED TUBES

A footbridge at Choi Hung (KF77) was chosen to conduct the trial scheme using LED tubes, motion sensors and Smart Dimming Control System. Here are the project outlines.

a. The original lighting installation of this footbridge was of 150 nos. of 1 x 36W T8 lighting fittings, with using traditional timer and photocell control.

b. With the new lighting layout design, the no. of lighting fittings was reduced from 150 to 104. The power rating of each lighting fitting was reduced from 36W to 29W, and the operation hour requirement was enhanced from 20,000 hours to 50,000 hours.

c. The LED tubes adopted in this project were operating on DC voltage, each of them was retrofitted with DALI addressable control drivers and connected to a programmable logical controller (PLC). In this connection, a smart dimming control system was developed using motion sensors for controlling the lumen output of these LED tubes.

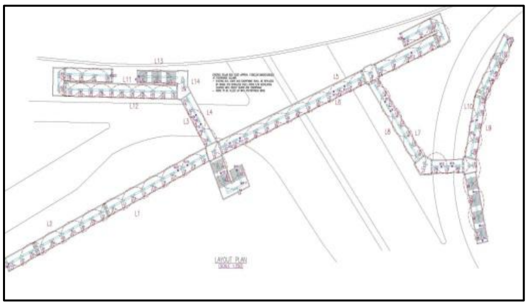


Fig. 8 - Lighting layout design of Footbridge KF77, Choi Hung

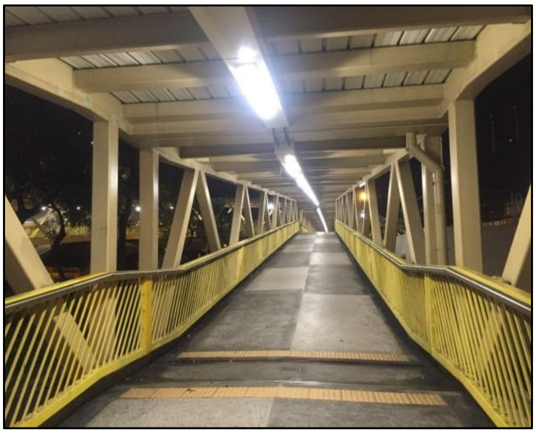


Fig. 9 - Lighting installation at Footbridge KF77, Choi Hung

8. DIMMING OPERATION WITH USING PLC, MOTION SENSORS AND LED TUBES

In order to simulate the users' pattern of the footbridge, the 104 nos. of lighting fittings were divided into different controlled lighting groups/zones with 7 entrance/exit points and 3 junction zones. Motion sensors were installed accordingly and connected to the PLC. DALI was chosen to be the communication protocol

Fig. 10 - Motion sensor installed at Footbridge KF77, Choi Hung

In the PLC control programme settings, each motion sensor was allocated its pre-set controlled lighting group/zone. Assume all lighting fittings were operating at default dimming mode (i.e. idle), when the user is entering and walking along the footbridge, different motion sensors will be triggered and their status change signals will be sent back to the PLC. Then the PLC will send the control signals to the lighting fittings under the preset controlled lighting zone to tune up/down the lighting outputs for a time period (say 3 minutes). This enables only those corresponding lighting fittings will be "ON' when that particular zone is under usage. It is the working principle of the smart dimming system.

Apart from the controlled lighting groups, the PLC programme can also fine-tune other system parameters such as time duration (i.e. dim up time), operation time period, lighting output settings, etc. in order to suit to the actual site conditions.

Fig. 11a - PLC at Footbridge KF77, Choi Hung

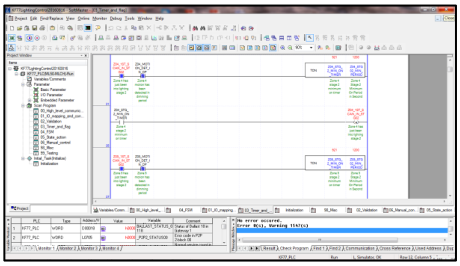


Fig. 11b - PLC control programme interface at Footbridge KF77, Choi Hung

9. INITIAL FINDINGS

The site installation of the LED tube lighting fittings and smart dimming control system equipment was completed in August 2016. After a period of field tests and follow-up system fine-tuning, the smart dimming system was formally rolled-out in late September 2016.

Although the system has just been put into service, the actual system performance is under review. It is expected that the energy saving due to the adoption of LED tube will be nearly 40% and another 10% more saving will be brought by the smart dimming system.

10. WAY FORWARD

Apart from footbridge KF77, another 6 footbridges have been selected for lighting improvement using LED tubes and smart dimming control system, which are planned to be completed by 2017Q2.

ACKNOWLEDGEMENT

The authors wish to thank the Director of Highways and Director of Electrical and Mechanical Services for permission to publish this paper. Any opinions expressed or conclusions reached in the text are entirely those of the authors.