THE HONG KONG
INSTITUTION OF ENGINEERS
ELECTRICAL DIVISION

The 31st Annual Symposium

Thursday

17th October 2013

SMART INFRASTRUCTURE
&
MEGA PROJECTS IN ELECTRICAL ENGINEERING

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 Registration and Coffee

09.00 Welcome Address

— Ir C.L. Leung
Chairman, Electrical Division, The HKIE

09.05 Opening Address

— Ir Raymond K.S. Chan
President, The HKIE

09.10 Keynote Speech

— Ir Dr F.C. Chan
Past President
The HKIE

1. Smart Power System

09.40 Initiating Demand Response Events at the Right Time

— Mr C.M. Kwan
Senior Smart Grid Development Manager
Asset Management Department
CLP Power Hong Kong Limited

10.00 Smart Grid Features of Energy Management System & Distribution Management System of HK Electric

— Mr P.C. Tang
System Control Engineer
The Hongkong Electric Co. Ltd.

10.20 Discussion

10.45 Coffee Break

2. Innovative and Mega Projects

11.20 **Cathay Pacific Cargo Terminal – From Franchise to Operation**

— Mr Nick Organ, Executive Director
Meinhardt (Hong Kong) Ltd.

— Ir S.H. Lau, Director
Meinhardt (M&E) Ltd.

11.40 **Energy Saving Measures in Public Rental Housing Estates**

— Ir W.I. Ho
Chief Manager/Management (Support Services 1)
Hong Kong Housing Authority
The Government of the HKSAR

12.00 **Discussion**

12.30 **Lunch**

3. Smart Energy Control and Management

14.10 **Role of Energy Management and Smart Metering in Data Driven Decision Making for Mega Projects**

— Dr Satish Kumar
Vice President
Professional Services
Schneider Electric India Pvt. Ltd.

14.30 **Enhancement of the Lighting and Control System of Aberdeen Tunnel**

— Ir Edward W.Y. Mok
Senior E&M Engineer
Project Division
Electrical & Mechanical Services Department
The Government of the HKSAR

14.50 **Discussion**

15.10 **Coffee Break**

4. Smart Initiatives in Railway Systems

15.40 **Environmental Control System (ECS) and Lighting Energy Saving Initiatives for New Railway Lines**

— Ir Johnny Y.W. Cheng
Senior Engineer – ECS & BS
Projects Division
MTR Corporation Limited

16.00 **West Island Line Sheung Wan 54-hour Changeover Works**

— Ir Paul K.M. Wong
Railway Extension Interfacing Manager
MTR Corporation Limited

16.20 **Discussion**

16.45 **Summing Up**

— Ir Albert W.K. To
Symposium Chairman
Electrical Division, The HKIE

Closing Address

— Ir Dr W.K. Lo, JP
Member (Engineering Functional Constituency)
Legislative Council
The Government of the HKSAR

Acknowledgement

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Speakers / Authors

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Mr C.M. Kwan
Mr P.C. Tang
Mr Nick Organ
Ir S.H. Lau
Ir W.I. Ho
Dr Satish Kumar
Ir Edward W.Y. Mok
Ir Johnny Y.W. Cheng
Ir Paul K.M. Wong

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Paper No. 1

INITIATING DEMAND RESPONSE EVENTS AT THE RIGHT TIME

Speaker: Mr C.M. Kwan
Senior Smart Grid Development Manager
Asset Management Department
CLP Power Hong Kong Limited

INITIATING DEMAND RESPONSE EVENTS AT THE RIGHT TIME

Mr C.M. Kwan
Senior Smart Grid Development Manager
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Paper No. 1

ABSTRACT

The ever increasing peak electricity demand has become one of the most serious problems faced by many countries. However, the peak demand appears only in several days of hot summers and freezing winters. In Hong Kong, we have hot and wet summers. Air conditioning contributes significantly to electricity consumption and peak demands appear only in summers, from July to September each year.

Demand Response, one of the smart grid technologies has been adopted by many utilities to manage weather-sensitive peak demand. To deliver the maximum value of the demand response, accurate peak demand forecasting has become the most critical step in the process chain of demand.

CLP Power Hong Kong Limited (CLP) is one of the two power utilities in Hong Kong providing electric power to over 70% of Hong Kong's population. Managing the critical peak is one of the major tasks to maintain the supply reliability, reduce fuel costs and to keep the environment green.

This paper will first introduce the definition and process of demand response, followed by a systematic way to identify critical factors that affect the peak demand and finally establish a peak demand forecasting model.

1. EXPLORING WAYS TO MANAGE INCREASING DEMAND ISSUES

Traditionally, power utilities reinforce their electric supply chain by expanding their capacity of generation and power grids in order to meet the growing demand. On one hand, the reinforcement involves capital investments that will be passed on to their customers. On the other hand, more generation plant means more direct and/or indirect fuel consumption as well as more emission. Nowadays, power utilities are exploring different smart grid technologies that could better utilise their existing capacity of the whole electricity supply chain - from generation plant to power grids to customers' premises.

Among various smart grid technologies on both supply side and demand side, only demand response (DR) can change the load shape through changing end-users' energy consumption patterns. This approach reduces environmental concern and at the same time enables better utilisation of generation plant and power grids.

DR is ideally suited to provide capacity during peak demand periods, as it can be brought on- and off-line quickly for short periods of time throughout the year. DR programs can provide demand reductions during the 50 to 100 hours of the year when demand is highest, serving as a cost-effective and reliable way to relieve peak demand and improve system stability without needing to build excess supply-side infrastructure.

As construction costs and concerns about climate change continue to increase, so does the value in avoiding or deferring the need for new generation. DR also serves as a type of insurance policy for a system, ensuring that rolling blackouts will not occur should demand exceed forecasts (and available capacity).

1.1 DEFINITION OF DEMAND RESPONSE

In Hong Kong, CLP is socially and environmentally conscious and demand response is defined as:

"An interactive programme that enables end-use customers to take part in managing electricity supply and demand issues. The programme uses financial incentive to encourage the customer to reduce energy consumption during the on-peak period and/or shift their energy consumption to off-peak period. As a result, customers can reduce their bills, contribute to a greener environment; and CLP can improve fuel utilisation, and defer/reduce investments in the whole electricity supply chain."

Levels of automation in demand response:

- Manual DR consists of people initiating changes in electric loads by turning off loads, or switching and changing control settings when they receive communications from an external source (such as a phone call, pager signal, or email).

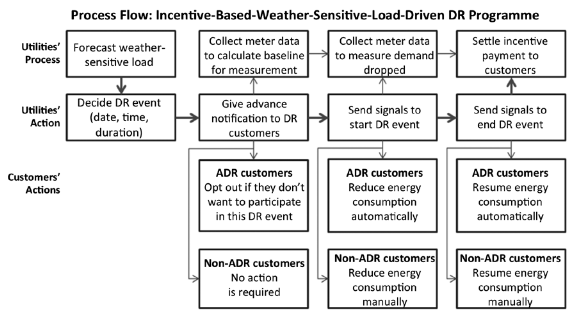
- Semi-Automated DR consists of a person initiating a pre-programmed load shedding strategy when they receive price signal communications from an external source.

- Fully Automated DR (ADR) refers to the use of control and communications technology that listens to an external signal, and then initiates a pre-programmed load shed strategy without human intervention.

1.2 PROCESS OF DEMAND RESPONSE

The first and the most critical step in the process is to forecast peak demands. Meter data will then be collected to calculate system level baseline demand (MW) and individual customer level baseline consumption (kWh) in the DR event.

Figure 1 Process Flow of Demand Response



Right after a DR event, individual customer's energy saving (kWh) will be calculated by subtracting the actual energy consumption from the baseline. Financial incentive will be paid to the customer according to kWh saving times the agreed incentive schedule.

2. FORECASTING THE PEAK DEMAND

As mention in section 1.2, forecasting a weather-sensitive peak demand is the first and most critical step of the process. In order to deliver the maximum value of demand response event, accurately forecast critical peak demand is of paramount importance.

A clear understanding of the formation of peak load is the first step to peak demand forecasting. There are three major components of a daily peak load:

Daily Peak Load = Seasonal Base Load + Weather-Sensitive Load + Random Load

or

DPL = (BL x SF x EF) + (CL x WV) + RL

Where
DPL = daily peak load,
BL = base load,
SF = seasonal factor,
EF = economic factor,
CL = cooling load,
WV = weather variable and RL is Random Load.

In order to analyse the seasonal base load, we have to understand the major component of the seasonal and economic factors.

According to the key economic indicators published by the Hong Kong SAR Government, the GPD (Gross Domestic Product) and PCE (Private Consumption Expenditure) between 2010 and 2012 are relatively stable as compared to the years between 2007 and 2009. An assumption was made that daily peak loads are homogeneous during the period between 2010 and 2012. That is no significant changes in:

- load growth due to the inrush of new customers;
- the local economic climate; and
- customers' energy use habits.

Based on the above assumptions, the base load in the past three summers is assumed constant.

Weather-sensitive load is the major component of a critical peak and the main focus of this paper. It will be analysed after we have a clear understanding on cooling loads.

Random load, the last component, in the Daily Peak Load model is unexplained.

Paper No. 1

2.1 HOW DOES AIR TEMPERATURE IMPACT PEAK DEMAND

The daily maximum air temperature and peak demand (MW) data in the past three summers, from 2010 to 2012, were put into the following regression model to determine their correlation:

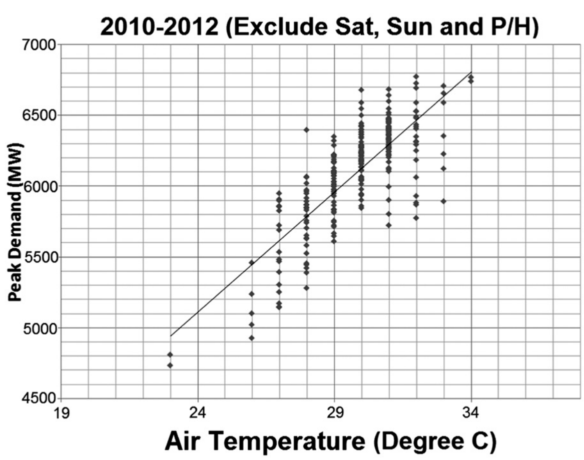
$$Correlation(x,y) = \frac{\sum(x - \bar{x})(y - \bar{y})}{\sqrt{\sum(x - \bar{x})^2 \sum(y - \bar{y})^2}}$$

Where
X = daily maximum air temperature (°C),
Y = daily peak demand (MW)

Since the daily local peak demand on Saturdays, Sundays and public holidays is much lower than weekdays, those data were taken out.

The result is **0.72**. That means the correlation between the air temperature and peak demand is not strong enough.

Figure 2 Correlation Between Air Temperature and Peak Demand



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2.2 HOW DOES HUMAN-PERCEIVED EQUIVALENT TEMPERATURE IMPACT PEAK DEMAND

Many overseas countries are using **Heat Index (HI)** to determine the human-perceived equivalent temperature — how hot it feels. It combines air temperature and relative humidity into a single figure.

Figure 3 Heat Index Conversion Table

NOAA National Weather Service: Heat Index

Relative Humidity (%)	Temperature (Celsius)														
	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
40	27	27	28	29	31	33	34	36	38	41	43	46	48	51	54
45	27	28	29	31	32	34	36	38	40	43	46	48	51	54	58
50	27	28	29	31	33	35	37	39	42	45	48	51	55	58	
55	27	29	30	32	34	36	38	41	44	47	51	54	58		
60	28	29	31	33	35	38	41	43	47	51	54	58			
65	28	29	32	34	37	39	42	46	49	53	58				
70	28	30	32	35	38	41	44	48	52	57					
75	29	31	33	36	39	43	47	51	56						
80	29	32	34	38	41	45	49	54							
85	29	32	36	39	43	47	52	57							
90	30	33	37	41	45	50	55								
95	30	34	38	42	47	53									
100	31	35	39	44	49	56									

Caution | Extreme Caution | Danger | Extreme Danger

The human body normally cools itself by perspiration, or sweating. The evaporation of water needs heat that is absorbed from the body to yield water vapor. However, a higher relative humidity reduces the evaporation rate because of the higher vapor content. This results in a slower heat removal from the body, hence the overheat sensation. This effect being subjective, its measurement has been based on subjective descriptions of how hot subjects feel for a given temperature and humidity. This results in the heat index that relates one combination of temperature and humidity to another one at higher temperature and lower humidity.

In order to convert the air temperature into HI, the figure of daily maximum relative humidity in the same period were then collected and put into the following equation[1]:

$$\mathbf{HI} = {}_{C1} + {}_{C2}\boldsymbol{T} + {}_{C3}\boldsymbol{R} + {}_{C4}\boldsymbol{TR} + {}_{C5}\boldsymbol{T}^2 + {}_{C6}\boldsymbol{R}^2 + {}_{C7}\boldsymbol{T}^2\boldsymbol{R} + {}_{C8}\boldsymbol{TR}^2 + {}_{C9}\boldsymbol{T}^2\boldsymbol{R}^2$$

Where

HI = heat index (in degrees Fahrenheit)

T = ambient dry-bulb temperature (in degrees Fahrenheit)

R = relative humidity (decimal faction of 1.00, i.e. percentage/100)

${}_{C1} = -42.379$, ${}_{C2} = 2.04901523$,

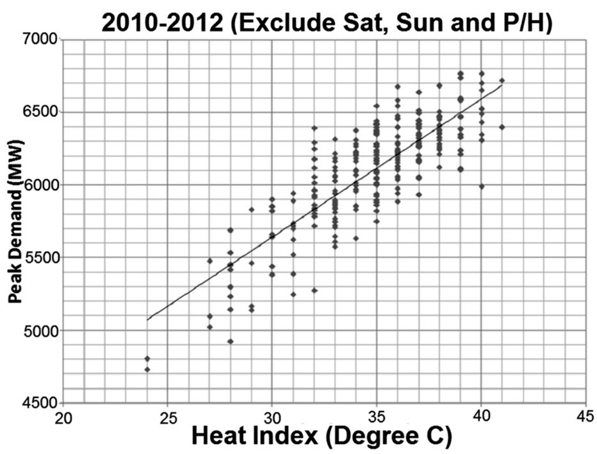
${}_{C3} = 10.14333127$, ${}_{C4} = -0.22475541$,

${}_{C5} = -6.83783 \times 10^{-3}$,

${}_{C6} = -5.481717 \times 10^{-2}$, ${}_{C7} = 1.22874 \times 10^{-3}$,

${}_{C8} = 8.5282 \times 10^{-4}$, ${}_{C9} = -1.99 \times 10^{-6}$

Figure 4 Correlation Between Heat Index and Peak Demand

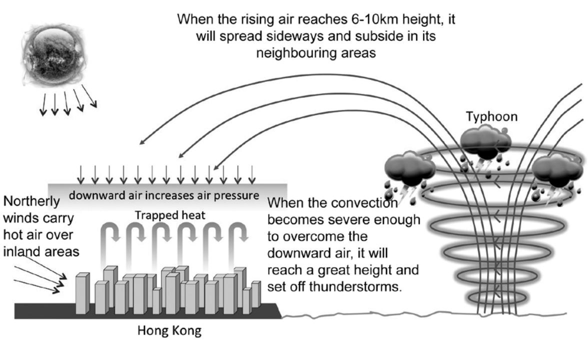


The data of HI and peak demand were analysed again through a regression model as mentioned in section 3.1 and got a result of **0.82**. That means the HI has a much stronger correlation with the peak demand than the air temperature.

2.3 VERY HOT WEATHER AHEAD OF AN APPROACHING TROPICAL CYCLONE

The finding in the previous section proves a strong correlation between HI and Peak Demand. CLP's historical peak demand 6,766MW in 2010 and 6,769MW in 2012 were both recorded during abnormally hot weather ahead of an approaching tropical cyclone. However, there were 17 tropical cyclone approached Hong Kong from 2010 to 2012 and only two of them created historical peaks. This section tries to find out the causes.

Figure 5 Heat Effect Caused by Approaching Typhoons



A typhoon creates severe air convection inside its centre. When it still has a certain distance away from Hong Kong, its rainstorms will not affect us. Instead, when its rising air reaches about 6 to 10 km height, it will spread sideways to Hong Kong. The subsided air increases the air pressure, and trapped the heat inside the city. On the other hand, the high air pressure creates sunny days. Together with the northerly winds, that carry hot air from the inland areas, the air temperature in the city will rise sharply. This kind of effect can last for a few days until the convection becomes strong enough to overcome the downward air, it will reach a great height and set off thunderstorms. It normally happened in late evenings or mid nights.

The tropical cyclone and CLP peak demand data in the past three summers, from 2010 to 2012, were analyzed to determine the correlation between tropical cyclone and hot weather. The following table shows the summary of the finding.

Figure 6 Summary of Typhoon Positions and Their Effects on Heat Index

Date	Typhoon	Location from HK	Distance from HK (km)	Heat Index Increased	Remark
Jul 2010	Chanthu	Southeast-South	600-900	+5	Saturday & Sun
Aug 2010	Mindulle	**South**	**700**	**-4**	
Aug 2010	Lionrock	Southeast	600-700	+6	2nd highest peak in 2010 (6,739MW)
Sep 2010	**Meranti**	**Southeast**	**600-700**	**+9**	**Critical peak created (6,766MW)**
Jun 2011	Sarika	**South**	**500**	**-5**	
Jun 2011	Haima	Southeast	500	+5	Saturday
Jul 2011	Nock-ten	**South**	**500**	**-3**	
Aug 2011	Muifa	Southeast	1,000	+4	
Aug 2011	Nanmadol	Southeast-East	600	+6	2011 peak created (6,702MW)
Sep 2011	Nalgael	Southeast	600-800	-1	
Jun 2012	Mawar	Southeast	1,000	+3	
Jun 2012	Tailim	South-Southeast	300	+4	
June 2012	Doksuri	Southeast	500–1,000	+3	
Jul 2012	Vicente	Southeast	800-1,000	+6	Saturday
Jul 2012	Saola	Southeast	1,000	+4	
Aug 2012	Kai-tak	Southeast	500-800	+1	
Aug 2012	**Tembin**	**East-Southeast**	**500-700**	**+6**	**Critical peak created (6,769MW)**

The finding in the above table shows:

- HI will rise only when a tropical cyclone is at a distance between 500 and 1,000km east to southeast from Hong Kong; and
- The higher the HI rise, the higher probability of a critical peak.

As typhoons in the Northern Hemisphere are swirling in an anti-clockwise sense, when a storm is located at the east – southeast of Hong Kong, it will bring

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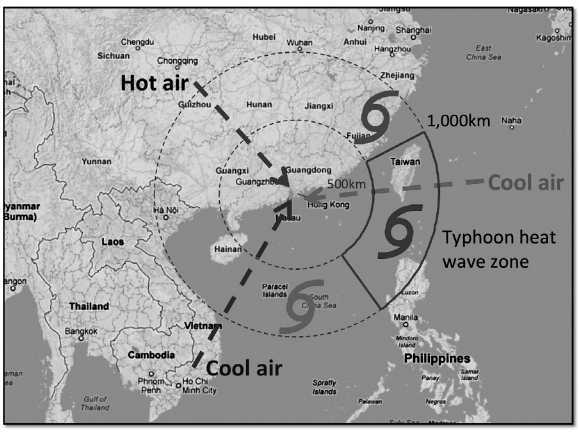
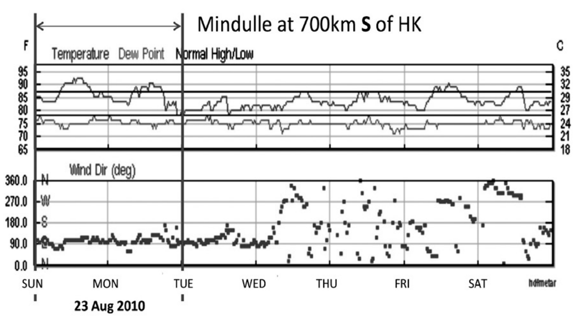
light northerly winds to Hong Kong. These winds carry the very hot air over inland areas to the territory[2]. Instead, when a storm is located at the south or northwest of Hong Kong, the easterly or southerly winds over Pacific Ocean or South China Sea bring cooler air to the territory (the green and blue arrows in the following picture). Based on the finding in the above table and the information from the Hong Kong Observatory, a "Typhoon Heat Wave Zone" is defined (the red area in the following picture). That means once a tropical cyclone enters the Heat Wave Zone, hot air from the inland areas will be brought to Hong Kong.

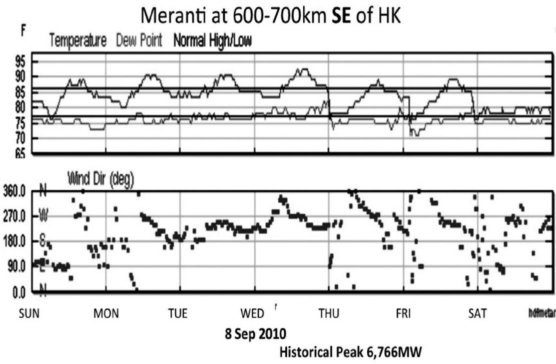
Figure 7 Typhoon Heat Wave Zone



In order to verify the finding, hourly temperatures and wind directions during approaches of three tropical cyclones were collected:



When the tropical cyclone "Mindulle" was at the south of Hong Kong, the easterly wind came from the Pacific Ocean made the air temperature dropped.



When the tropical cyclone "Meranti" was at the southeast of Hong Kong, the northerly and westerly wind brought hot air from the inland to Hong Kong. As a result, the air temperature rose.

2.4 URBAN HEAT ISLAND EFFECT ON PEAK DEMAND

The Urban Heat Island (UHI) Effect refers to the increase in air temperature in the urban city as compared to suburban areas, due to urbanization.

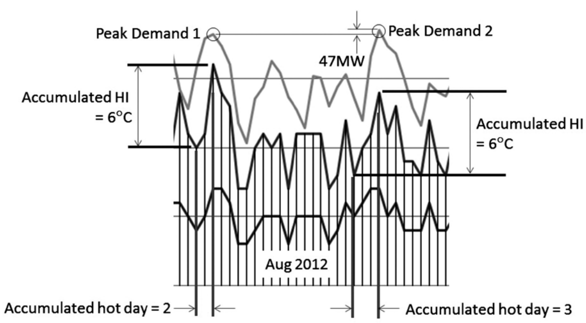
A study[3] from the Hong Kong Polytechnic University found that UHI in summers has a more prominent effect in mornings and evenings than in hot afternoons. This explains why peak demands on sunny days always appear in evening since huge amount of air conditioners are running at hot evenings to cool down building mass and indoor air temperature.

Concrete has been widely used in building construction due to its durability and versatility. Almost all external and internal walls, ground or upper level floors, structural frames (such as columns) and roof of buildings in Hong Kong are made of concrete.

Concrete has very high thermal mass. Thermal mass is measured in 'Volumetric Heat Capacity', or $kJ/m^3/°K$. The high thermal mass of concrete means it is able to absorb thermal energy when the surroundings are higher in temperature than the mass, and give thermal energy back when the surroundings are cooler, without reaching thermal equilibrium.

The following picture illustrates how the heat accumulation effect impacts the peak demand.

Figure 8 Heat Accumulation Effects

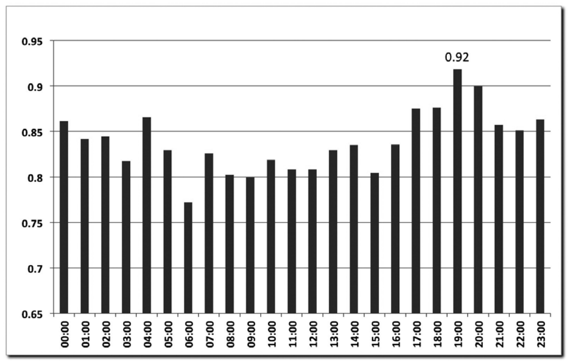


There were two demand peaks in 2012. Although the HI on peak demand day 1 is higher than the day of peak demand 2, peak demand 1 is 47MW lower than peak demand 2. The accumulated HI's of two peak demands are the same (6°C) and the only difference is the number of accumulated hot day.

2.5 CORRELATION OF HOURLY HEAT INDEX AND PEAK DEMAND

The Hong Kong Observatory provides hourly air temperature forecast. However, we have to identify which hour has the strongest correlation with the peak demand. Since the Hong Kong Observatory provided only the air temperature and relative humidity but not the HI. The data collected were transformed into HI manually. The hourly HI and daily peak demand from 2010 to 2012 were analysed through regression and the result is shown in the following chart.

Figure 9 Correlation Between Hourly Air Temperature and Peak Demand



The above result shows that the HI at 19:00 hours has the strongest correction with peak demand.

3. FACTORS THAT IMPACT PEAK DEMANDS

Based on the findings on the previous sections, the following factors should be considered when forecasting a peak demand:

- Weekday and holiday effects;
- The maximum heat index on that day;
- The number of accumulated hot day;
- The air temperature at evening (19:00 hours);
- The accumulated heat index; and
- Whether a typhoon is located in the Heat Wave Zone.

4. LIKELIHOOD OF A CRITICAL PEAK DEMAND

After repeated analysis and testing, a CLP Critical Peak Demand Forecasting Model was developed to calculate the likelihood of a critical peak demand happens on a specific day:

$$\mathbf{CP} = W + H_m + D_a + H_a + T_f + Z$$

Where

CP = Likelihood of a Critical Peak Demand (45-47 = likely; 48-50 = very likely)
W = Weekday effect (weekday = 10; Holiday = 5)
H_m = Max Heat Index (≥39°C = 10; 36-38°C = 8; 33-35°C = 5; <33°C = 3)
D_a = No of HI accurate day (≥3 days = 10; 2 days = 9; 1 day = 7; 0 days = 6)
H_a = C of accurate Heat Index (≥6C = 10; 4-5C = 9; 2-3C = 8; <2C = 7)
T_f = Maximum air temperature at 19:00 hours (≥32°C = 0; 31°C = -2; ≤30°C = -3)
Z = Typhoon Heat Wave Zone effect (Typhoon in Heat Wave Zone = 10, otherwise = 5)

4.1 LIMITATION OF THE FORECASTING MODEL

Since the weather forecasting data in the past three years could not be obtained for this study, the forecasting model was developed based on the actual weather information (air temperature and humidity). The accuracy of the model depends on the accuracy of the weather forecasting by the Hong Kong Observatory. Further study is required in order to automate the calculation process and to improve its accuracy.

5. CONCLUSION

The foreseeable economic and population growth, the climate change and the Urban Heat Island Effect will gradually increase electricity peak demand.

Demand Response has been proved by overseas utilities to effectively manage peak demand, maintain the stability of the whole electricity supply chain, improve load factor, defer investment to meet the critical peak and reduce customers' bills.
By switching off or rising the temperature setting of air-conditioning equipment during critical peak days, we can reduce the peak demand and the waste heat, minimise the impact on the Urban Heat Island Effect.

The most critical part in the demand response process is the Critical Peak Demand Forecasting. In order to deliver the maximum value of demand response, peak demand event must be accurately forecasted and inform DR participates in advance. The CLP Peak Demand Forecasting Model considers various factors that contribute to critical peak demand and enables a systematic way to calculate the likelihood of a Peak Demand on a specific day. Due to the time limitation, the model can be refined and automated throughout pilot projects.

REFERENCES

[1] NOAA (National Oceanic and Atmospheric Administration) National Weather Service

[2] C.C. Chan, Hong Kong Observatory, 2012

[3] Characterizing Urban Heat Island and Its Effects in Hong Kong, Fung Wing-Yee, 2010.

Paper No. 1

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Paper No. 2

SMART GRID FEATURES OF ENERGY MANAGEMENT SYSTEM & DISTRIBUTION MANAGEMENT SYSTEM OF HK ELECTRIC

Speaker: **Mr P.C. Tang**
System Control Engineer
The Hongkong Electric Co. Ltd.

SMART GRID FEATURES OF ENERGY MANAGEMENT SYSTEM & DISTRIBUTION MANAGEMENT SYSTEM OF HK ELECTRIC

Mr P.C. Tang
System Control Engineer
The Hongkong Electric Co. Ltd.

Paper No. 2

ABSTRACT

Modern smart grid incorporates information and communication technologies into the power system to improve the reliability, efficiency, economics and sustainability of electricity supply. In view of the ever increasing importance of supply reliability and power quality in Hong Kong, one of the smart grid features essential to the customers is the capability of fault detection and self-healing of the supply network in an automated fashion. Besides, it is desirable to have automatic reactive power and voltage control to enhance efficiency.

This paper shares HK Electric's experience of developing and applying smart grid features through software application customization in Energy Management System (EMS) and Distribution Management System (DMS) which aims at improving reliability and quality of power supply to customers. Software application customization has the advantage of enhancing the overall reliability performance without revamping the established power network infrastructure.

In HK Electric, there are a number of customized software programmes to facilitate automatic supply restoration and control. For illustration purpose, the paper presents the system design and functionality for some of them to demonstrate how automation and digital processing could be integrated to address various needs in grid modernization.

The Automatic Busbar Re-configuration (ABR) scheme identifies the faulted equipment during a 275/11kV or 132/11kV transformer tripping at a zone substation based on the relevant and crucial information extracted from the EMS. When the pre-defined logic for positive indication of a genuine transmission fault is fulfilled, the ABR scheme will automatically re-configure the 11kV busbars at the zone substation by selecting and operating the most suitable circuit breaker(s) to restore supply and/or relieve equipment overload.

The DMS Fault Identification Expert System (DFIES) filters the large amount of DMS/EMS alarms and data generated during an 11kV distribution feeder tripping to extract the relevant and crucial information. The system then analyzes the information based on the logic of an established set of rules to identify the faulted equipment in the tripped feeder. System upgrade of DFIES is being deployed to include the function of automatic fault isolation and supply restoration.

The Intelligent Volt-VAR Regulation System (IVAR) tackles the reactive power and voltage control by the approach of global parameter optimization in the entire power system instead of local reactive power compensation at zone substation level.

1. INTRODUCTION

One of the most comprehensive descriptions of Smart Grid is that it will bring together the operational and information technology infrastructure of a utility to create a more intelligent,

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efficient and reliable grid. Growing sophistication of IT and computer technologies, along with their decreasing costs of deployment, are providing the power engineering designers with many new opportunities to incorporate greater intelligence in the transmission and distribution systems. In recent years, more and more attention is drawn towards substation and feeder automation because it provides great benefit in the improvement of supply reliability, reduction in the restoration time after unplanned outage, and most importantly, saving of economic losses caused by interruption.

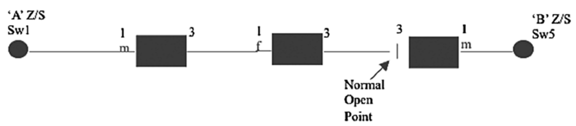
In The Hongkong Electric Co., Ltd. (HK Electric), many applications have been developed in the Energy Management System (EMS) and Distribution Management System (DMS) for substation and process automation. Three in-house developed applications are selected and presented here as examples. All of them tap into the high degree of penetration of remote controllable switchgear at 11kV level to deliver their unique automation capability. The DMS Fault Identification Expert System (DFIES) is an advanced decision support system for distribution fault location and subsequent supply restoration. It extracts the huge amount of data generated during a distribution feeder tripping and transforms the data into meaningful information that can be used by System Control Engineers to quickly locate the faulted equipment and then carry out optimal isolation and restoration. The Intelligent Volt-VAR Regulation System (IVAR) is a real-time voltage and reactive power control scheme with closed-loop feedback control. Based on real-time data collection, it dynamically manages power quality and prevents excessive voltage excursions that can affect quality of service, cause damage to equipment or reduce their useful life. Automatic Busbar Re-configuration system (ABR) has the intelligence of identifying the faulted equipment during a 275/11kV or 132/11kV transformer tripping and reconfiguring the 11kV busbars at the respective zone substation to restore supply and relieve equipment overloading.

2. DMS FAULT IDENTIFICATION EXPERT SYSTEM (DFIES)

2.1 OVERVIEW OF FAULT HANDLING PROCESS

11kV distribution system of HK Electric mainly adopts the open-ring network design (Figure 1). In this network design, if one or more components of a feeder go faulty, the supply source of the feeder will trip. There will be power interruption to customers.

Figure 1 Typical 11kV Network Configuration



Earth Fault and Phase Fault Indicators are strategically installed on all switchgear along an 11kV feeder. These indicators will operate when fault current with sufficient duration and magnitude passes through the switches on which they are installed. In addition, for a particular type of switchgear with higher historical switchgear fault rate, switchgear fault alarms are also installed. These fault indicator alarms and switchgear fault alarms will be sent back to DMS via remote terminal units (RTU) installed in all distribution substations for fault location.

It is believed that fast re-energization of a cable joint with soldered ferrules immediately after it has experienced a high through fault current associated with phase to phase fault could cause the joint to fail due to insufficient cooling time for the soldered ferrule to recover and could result in multiple faults. To avoid this, a set of rules relating to the magnitude of the through fault current are established to determine the waiting time before the tripped circuit breaker at zone substation can be re-closed for supply restoration.

Before the launch of DFIES in 2007, distribution feeder tripping was handled by System Control Engineers who would manually extract the necessary information from a large pool of data, and then analyze these data using established rules and determine the most probable faulty equipment. He/she would also carry out fault isolation and supply restoration with remote switching. New fault indicators, relays, switchgear are continually introduced in the HK Electric's network as times go by. This means that System Control Engineers have to deal with a growing variety of source data plus a set of frequently updated rules.

To improve the reliability and efficiency of distribution fault identification, DFIES was launched in August 2007, which automatically generates a detailed 11kV tripping incident analysis report immediately after an 11kV tripping incident based on the current instructions and rules. The faulty equipment or cable section is then highlighted in the respective feeder group diagram. The waiting time required for supply restoration (if any) is also recommended by the program.

2.2 DATA PRE-PROCESSING

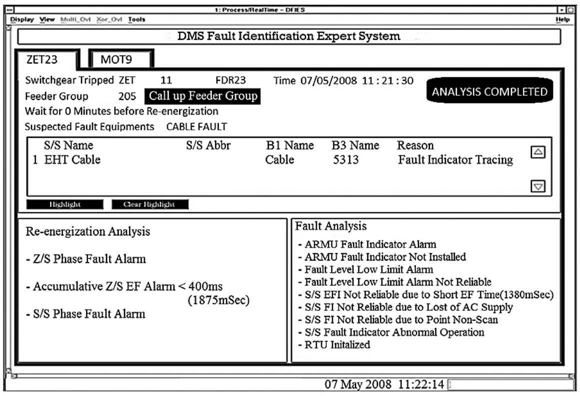
Various data are required at different stages of the fault handling process. These data form the building blocks that are crucial for the correctness of fault identification and speediness of supply restoration. The speed and reliability of capturing these characteristics data are affected by the operation of the sensing devices and the communication protocol and equipment. Unique measures have been programmed into the data collection process of each building block with due regard to the characteristics of the RTU equipment, fault indicators and switchgear.

Our DMS uses broadcast and 5-minute periodic scan to communicate with over 3,600 distribution RTUs through 96 communication routes. If an RTU failed and could not respond to broadcast or if it self-initialized during a tripping incident, it may lead to incorrect fault identification and prolonged customer loss of supply. To handle such problem, DFIES checks for "RTU initialized" alarm and sends force scan command to all the associated RTUs in the tripped feeder.

2.3 FAULT TRACING AND FAULT ANALYSIS

Fault analysis in DFIES is divided into 4 stages. The first stage is collection of zone substation alarms and the 11kV earth fault duration. The second stage is collection of distribution substation fault alarms. The third stage is RTU health check. The fourth stage is analysis of the collected information and presentation of the result in the DFIES Display (Figure 2).

Figure 2 MMI of DFIES



2.4 AUTOMATIC FAULT ISOLATION AND SUPPLY RESTORATION

According to our statistics, more than half of the 11kV tripping in the distribution system of HK Electric is caused by single-phase-to-earth cable fault. DFIES will be upgraded in 2013 to perform automatic prompt for fault isolation and supply restoration of the tripped feeder circuit breaker in zone substation when a single cable is identified as the faulted element and the fault nature is single-phase-to-earth. The switches to be operated will be highlighted in a one-line diagram for verification by System Control Engineer before execution of switching program. The new function is scheduled to be launched in the fourth quarter of 2013.

3. INTELLIGENT VOLT-VAR REGULATION SYSTEM (IVAR)

3.1 DESIGN PHILOSOPHY OF IVAR

Before IVAR was fully launched in 2011, busbar voltage regulation at zone substation level was done by the Automatic Voltage Regulation (AVR) by raising or lowering the zone transformer taps according to the differences between transformers' secondary voltages and the desired values. The desired values are calculated by using sets of preset load centre target voltage values and formulas representing the equivalent impedance of the loaded feeders. The load center voltage (LCV) is a static and fictitious value which does not have direct association with the real time fluctuation of distribution voltages and network. Periodic data maintenance of the LCV is necessary for AVR to keep up with changes in connectivity of the distribution system and distribution transformer load profile over time.

Reactive power regulation at zone substation level was done by manual 22kV/11kV capacitor switching performed by System Control Engineers. However, the voltage regulation function of AVR may be affected since the zone substation busbar voltage will also be affected by these capacitor switching.

To resolve the possible conflicts between these two processes, IVAR was designed to integrate capacitor switching and voltage regulation control with closed loop feedback into one program module. It has the intelligence to determine when to perform capacitor switching and when to adjust tap positions. IVAR tackles the reactive power regulation and voltage control by system-wise optimization rather than local compensation.

Local voltage and reactive power output of zone transformers are collected for the decision of capacitor switching while global voltage and reactive power conditions are closely monitored to prevent over-compensation of reactive power at zone substation level.

3.2 SYSTEM ARCHITECTURE AND SOFTWARE DESIGN

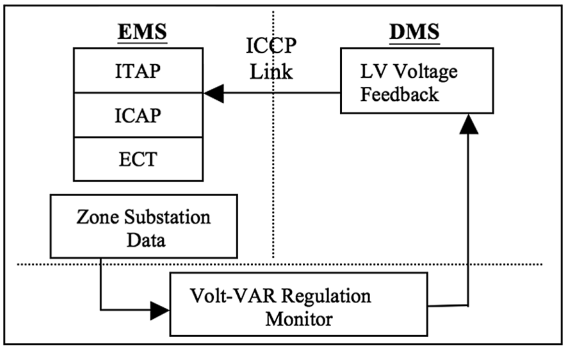
IVAR can be divided into three sub-functions:- ITAP, ICAP and ECT.

- Intelligent Tap Control (ITAP)
  The ITAP replaces the role of AVR to regulate the busbar voltages at zone substations by adjusting transformer tap positions. In order to improve the quality of voltage regulation and in turn improving the system power quality, the algorithm of ITAP is designed to monitor the overall LV distribution voltages at distribution substations fed from the respective zone substation busbar to ensure that the voltage variation at customers' side are within the desirable range.

- Intelligent Capacitor Switching (ICAP)
  The daily operation of manual capacitor switching is over 200 times per day. The ICAP can take up this routine workload.

- Emergency Capacitor Tripping (ECT)
  Emergency Capacitor Tripping performs automatic capacitor switching when there is a rise in system voltage caused by load rejection. The operation of ECT and ICAP are mutually exclusive. Hence, when the ECT is activated, the ICAP will be immediately suppressed and the ECT will take over the control of the capacitor switches.

Figure 3 Architecture of the Intelligent Volt-VAR Regulation



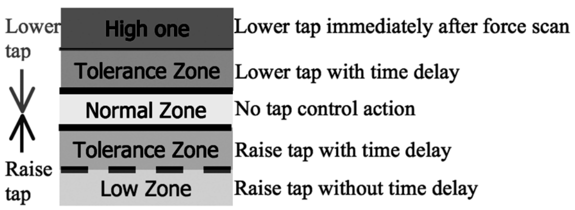
Although the IVAR is implemented in EMS, it requires information from DMS in its normal operation mode. The EMS and DMS are connected by a data link using Inter-Control Center Communication Protocol (ICCP). A software module known as Distribution Low Voltage Monitor is dedicated to process the real-time and the historical data of DMS before sending them in a specific structure to EMS through the ICCP link.

3.3 PROGRAM CONTROL

Under the normal Closed Loop Feedback Control Mode, distribution transformer voltages at low voltage side of distribution substations will be used as feedback data to the IVAR. Distribution Low Voltage Monitor running on the DMS performs recursive search of the network connectivity between the source busbars and the distribution transformers and to provide voltage feedback to the IVAR through ICCP link. To avoid excessive tap actions and probable feedback control hunting, the voltage measurement of the distribution substation with the highest value among the distribution substations connecting to the source busbar group will be passed to IVAR for the closed loop feedback.

When the voltage data obtained above fluctuate within the normal zone, no control signal will be sent to ITAP (see Figure 4). When the voltage data fall into the tolerance zone, control signal will be sent to ITAP with a time delay. When the data fall into the high zone / low zone, control signal will be sent to ITAP without any time delay.

Figure 4 Voltage Zone for Tap Control

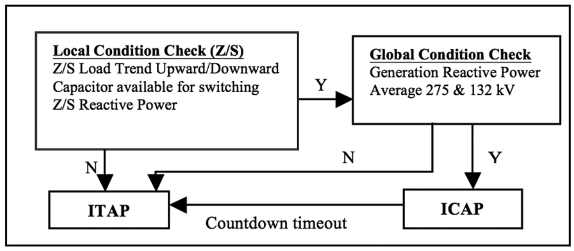


The availability of distribution low voltage data are critical for the Closed Loop Feedback Control Mode. Therefore, when the highest transformer voltage is not available, for example due to RTU out-of-service or route failure, command will be automatically sent to the IVAR to trigger the corresponding transformer group to change to Constant Busbar Voltage Mode under which the IVAR adjusts the transformer taps and carries out capacitor bank switching according to a set of pre-set target busbar voltages of the zone substations in the EMS.

Moreover, a Voltage Limit Violation Detection feature will be triggered whenever a LV voltage has exceeded the operating limits, the DMS will immediately communicate with the corresponding RTU again to retrieve a new set of data. If the limit violation persists, command will be sent to the ITAP to adjust the tap position of the corresponding zone transformer.

3.4 CONTROL ALGORITHM

Figure 5 Determination of Tap & Cap Control



IVAR will choose between capacitor switching with ICAP or tap adjustment with ITAP based on the result of local condition check at zone substation level and global condition check at transmission level, including total MVAR output of generators and average voltages at 275/132 kV level as shown in Figure 5.

Local conditions are employed for the selection of capacitors used for reactive power compensation at a particular zone substation. These conditions include:

- Capacitor control direction
- Availability of capacitors
- Reactive power of zone substation

The global voltage and reactive power conditions will be closely monitored to prevent over-compensation of reactive power at zone substation level. If all local conditions for capacitor switching are fulfilled, the global conditions will be checked.

The ITAP is designed to co-ordinate with the ICAP and takes appropriate action to smooth out the voltage spikes induced by capacitor switching and at the same time to reduce unnecessary tap changing actions. The ICAP will not issue switching command to a particular capacitor until the voltage of the source busbar is within a desired range. If the voltage criterion cannot be met within a pre-set countdown timeout period, the ITAP will adjust the tap position of the zone transformer to provide a suitable voltage condition for capacitor switching.

3.5 IVAR OPERATION REVIEW

Since the implementation of IVAR in April 2011, customer side voltage sample distribution in 2012 was found to be closer to the target voltage comparing to 2011 (Figure 6). The average power factors at 11kV zone transformers were higher after the full operation of IVAR (Figure 7).

Figure 6 Distribution of S/S Tx LV Sample

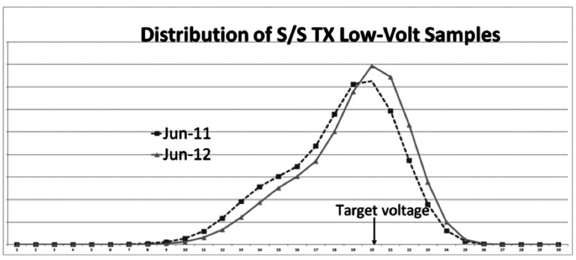
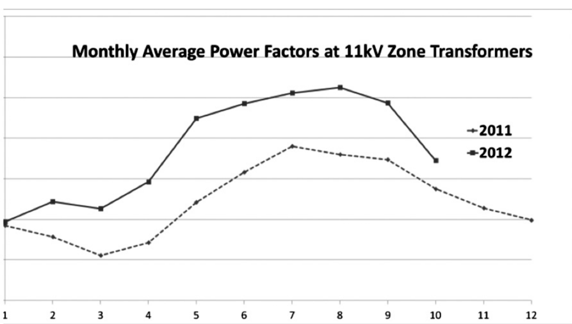


Figure 7 Monthly Average Power Factors at 11kV Zone Transformers

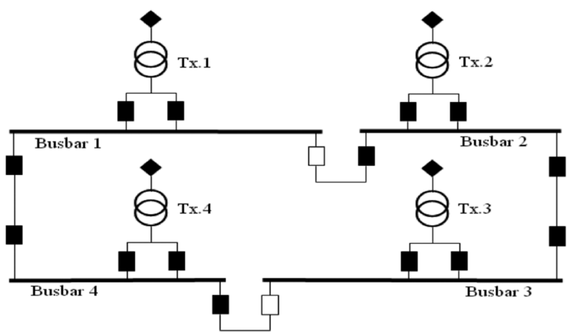


The tap control counts were also reduced by 30-40% due to the full operation of IVAR. Moreover, the total number of manually capacitor switching has been reduced by around 80%.

4. AUTOMATIC BUSBAR RECONFIGURATION (ABR)

4.1 ZONE SUBSTATION BASIC BUSBAR CONFIGURATION

Figure 8 Typical Layout of Zone Substation with Four 40MVA Zone Transformers



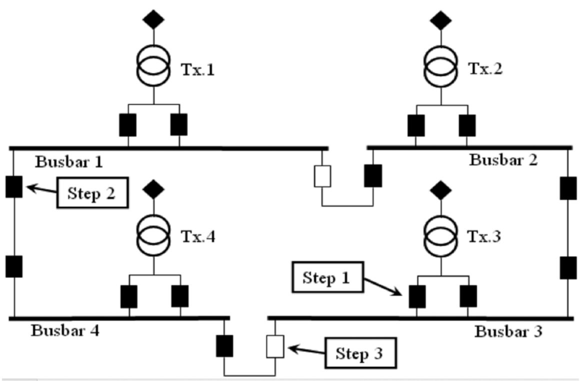
In HK Electric, there are two typical layouts of zone substation – one with four 40MVA zone transformers that operate in two parallel groups, one with eight 30MVA transformers operating in two separate rings and four parallel groups. A typical layout of the zone substation with four 40MVA transformers is shown in Figure 8.

To allow for better utilization of transformer capacity, the load distribution ratio of the four busbars in each ring is about 2:1:2:1, such that the total loading can be evenly shared by the remaining three transformers when a transformer is taken out of service.

When there is a zone transformer outage, the busbar configuration will have to be re-arranged to avoid overloading of the remaining transformer which is now feeding two busbars. The switching sequence for taking out Tx3 is illustrated in Figure 9. The load of Busbar 3 is now shared by Tx2 and Tx4.

This can be done at light load period to avoid overloading of Tx2 during the intermediate stage between Step 1 and Step 2. In the situation of a forced outage, after the tripping of Tx3, Tx2 could be overloaded and busbar reconfiguration needs to be carried out expeditiously and correctly to relieve the overloading situation.

Figure 9 Switching Sequence for Taking Out Tx3 as Example



Step 1: Tx3 breakers were opened for planned outage or tripped in a forced outage; Tx2 may experience temporary overload in the tripping incident.

Step 2: Open the breaker of the interconnector circuit to avoid three transformers in parallel operation in the final configuration which may lead to violation in fault level limit.

Step 3: Close the selected breaker to relieve overloading of Tx2; the breaker is selected on the criteria of avoiding overload of bus-interconnector breakers.

4.2 AUTOMATIC BUSBAR RECONFIGURATION (ABR)

This switching sequence was automated in 1985 and the feature was named Automatic Busbar Reconfiguration (ABR). The program had a proven record of successful operations. In the original version, the program could only be enabled if the zone substation was operating in the standard configuration where four transformers were operating in two parallel groups. ABR execution would be triggered by a transformer breaker tripping event.

Switching operation would be aborted if any one of the following conditions was encountered:

a. Non-zero voltage/current reading on the tripped transformer circuit; or

b. Further network configuration changes in the zone substation during this check period; or

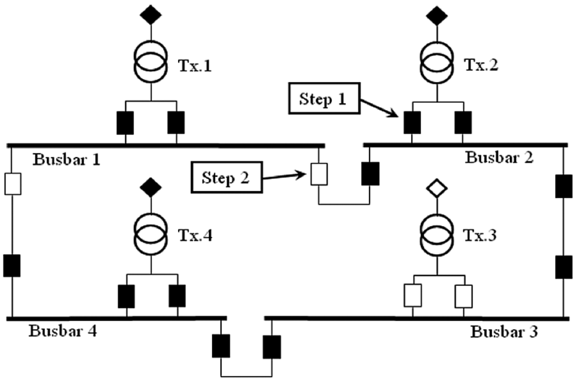
c. Detection of busbar protection operation.

4.3 AUTOMATIC BUSBAR RECONFIGURATION ENHANCEMENT (ABR2)

In order to further enhance supply reliability, HK Electric launched an ABR enhancement project (ABR2) in January 2008 to cover the situation of one zone transformer or one busbar under outage while keeping ABR when there is no transformer/busbar outage.

Under the enhancement program (ABR2), one zone transformer or busbar outage initial condition is assumed, and the program can handle tripping of either a parallel running or a single running transformer. In handling the tripping of one of the transformers operating in parallel, ABR2 will check for protection operation record and if there is no evidence of busbar fault, a selected breaker will then be closed to form an open-ring such that the two remaining transformers will feed the four busbars. The breaker is selected on the criteria of avoiding overload of bus-section or bus-interconnector. The switching sequence of ABR enhancement on tripping of a parallel running transformer (Tx2) is illustrated in Figure 10.

Figure 10 Switching Sequence upon Tripping of the Parallel Running Transformer (Tx2)

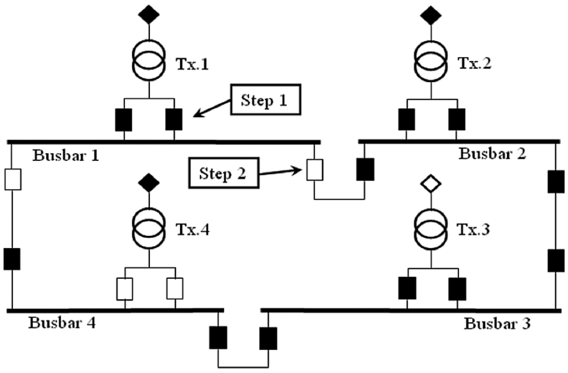


Step 1: Tx2 breakers trip in a forced outage; Tx.4 may experience temporary overload in the tripping incident.

Step 2: Close the selected breaker to relieve the overloading of Tx4; the breaker is selected on the criteria of avoiding overload of bus-interconnector breakers.

When the transformer which operate in single trips, the busbar connected to the tripped transformer will lose its input source. ABR2 will search for protection operation records within the specified time range before and after the tripping to determine whether to trigger any automatic switching operation or not. ABR2 will not initiate any breaker operation if there is no positive identification of protection operation. If the tripping is clearly identified to be initiated from the transmission side or transformer circuit, and not from the busbar or distribution side, supply can be restored by the direct re-energization of dead busbar by closing the bus-section or bus-interconnector switch. The switching sequence of ABR2 enhancement on tripping of single running transformer (Tx1) is illustrated in Figure 11.

Figure 11 Switching Sequence upon Tripping of the Single Running Transformer (Tx.1)



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Step 1: Tx1 breakers trip in a forced outage; ABR2 checks if Busbar 1 can be re-energised based on protection operation records.

Step 2: Close the selected breaker to re-energise Busbar 1; the breaker is selected based on the criteria of avoiding overload of bus-interconnector breakers.

5. CONCLUSION

The benefits of a self-healing grid for electricity consumers and suppliers are easy to recognise. By minimizing or eliminating interruptions, a self-healing grid can dramatically reduce the outage cost and time. The DFIES provides the decision support tool based on an adaptive strategy to identify the faulted equipment after an 11kV tripping. Since its full production, the system has achieved 100% accuracy in fault identification. The average time for DFIES to complete the fault analysis is 16 seconds. With its satisfactory track record in terms of both speed and accuracy, a system upgrade is scheduled to deliver 11kV network self-healing capability by performing automatic prompt for fault isolation and supply restoration for a positively identified single-phase-to-earth cable fault.

When the IT professionals and System Control Engineers in HK Electric set off to tackle the task of real time voltage and reactive power control, it was realised that the conflicting functionalities of LV voltage regulation and reactive power control should be combined and handled as an integrated problem under a customized application. Moreover, a universal volt/var parameter optimization approach has been taken, whereby LV voltages, zone substation voltages, load trend and reactive power demand, total generator reactive power output, average 132kV and 275kV voltages are all taken into account by IVAR to generate control signal for transformer tap adjustment and capacitor switching.

After launching IVAR in 2011, the voltage profiles of distribution transformers are closer to the targets and reduction in tap control operations is observed. Moreover, the total number of manual capacitor switchings has been reduced by around 80%. By relieving such routine workload, the System Control Engineers can focus more on high value tasks and system improvement studies.

ABR/ABR2 facilitates quick response to zone transformer circuit tripping in HK Electric. Zone transformer overloading could be rapidly relieved which may otherwise deteriorate into cascade tripping, resulting in larger scale of supply interruption. These features also free the System Control Engineers from the entire process and allow them to concentrate and respond to other problems associated with the tripping.

As compared to the implementing of other localised smart grid features, development of customized programs in EMS and DMS can achieve a better coordination among various control regimes which is easier to deploy, modify or upgrade with the ability to attain global optimization. Some of these customizations initiated by users are gradually absorbed into the core functionality of new generations of EMS/DMS as their software and hardware capability increase rapidly. More importantly, setting up of centralized pool of smart grid data stored under EMS and DMS may pave the way to realise higher business value and to better serve our customers.

6. ACKNOWLEDGMENT

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Paper No. 3

CATHAY PACIFIC CARGO TERMINAL - FROM FRANCHISE TO OPERATION

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Meinhardt (M&E) Ltd.

CATHAY PACIFIC CARGO TERMINAL - FROM FRANCHISE TO OPERATION

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ABSTRACT

The new Cathay Pacific Cargo Terminal (CPCT) at Hong Kong International Airport (HKIA) is located between the Hong Kong Air Cargo Terminal Limited (HACTL) and the Asia Airfreight Terminal (AAT) and has a total Gross Floor Area of 240,000 sqm sited over an area of 109,000 sqm, and was constructed at a total cost of HK$5.9 billion. Being one of the biggest and most sophisticated terminals in the world, CPCT provides an air cargo throughput capacity of 2.6 million tonnes per annum, increasing HKIA's annual capacity by 50 percent to 7.4 million tonnes, with potential for an ultimate capacity of around 4 million tonnes when Phase 2 of the Terminal is developed.

CPCT, developed under a 20-year operator's franchise agreement awarded by Airport Authority Hong Kong (AAHK), is designed, constructed and operated by Cathay Pacific Services Limited (CPSL) and is helping to further reinforce Hong Kong's position as the world's premier international airfreight hub.

Section 2 of this paper describes the role of the lead consultant supporting CPCT in their procurement of the cargo terminal, from initially applying for and obtaining the 20-year operator's franchise, through planning, design, construction of the facility, to occupation, operation trials and into commercial operation.

Section 3 describes the use of Building Information Modeling (BIM) during the design and construction phases.

Section 4 describes interfacing with other trades for this project.

Section 5 describes the electrical system design considerations for the Terminal.

1. INTRODUCTION

CPCT has set new standards globally in operational efficiency, environmental design and service levels. The state-of-the-art Materials Handling System (MHS) running ceaselessly round the clock enables CPSL to adopt a "Just-in-time" operation philosophy that reduces the waiting time and processing time for cargo handling substantially. The cargo terminal supports advanced facilities such as cold room for temperature-sensitive and perishable shipments, strong room for valuable cargo, live animal handling centre for live stock as well as DG room for dangerous goods, etc.

Customs clearance is streamlined by a fast and efficient process via Electronic Data Interchange linkage between the air cargo operator and the Customs & Excise Department. Moreover, Agriculture, Fisheries and Conservation Department, Food and Environmental Hygiene Department are stationed within CPCT enabling them to integrate their requirements into the cargo inspection processes.

2. LEAD CONSULTANCY SERVICES

Lead consultant services to support CPSL in the procurement and development of the cargo terminal included project management, multi-discipline engineering, architecture and design and the integration of specialist sub-consultant inputs for most notably MHS planning and design, as well as specialist fire engineering and security systems.

Lead consultant services commenced in 2006 in support of the submission to secure the cargo terminal operator franchised from the AAHK.

During this initial period the focus was on planning, commercial and business case development with the CPSL's operations team, and also detailed review of schedule and construction sequencing and logistics in conjunction with a separate pre-contract consultancy.

After a planned hiatus in lead consultant services during the franchise tender period, a dedicated design team was remobilized to a project office in Dragonair House upon award to CPSL of the cargo operator franchise.

From here the detailed design of the cargo terminal was carried out, and tenders were called for both building and MHS contract scopes.

Much time and effort was put in establishing the most appropriate contracting and procurement strategies in conjunction with CPSL and the Project QS.

After a further hiatus period caused by the financial downturn in 2008-9 which resulted in the project being suspended, (although piling and sub-structure works were already underway), the team remobilized for the tendering / award of the main contract and building services sub-contracts.

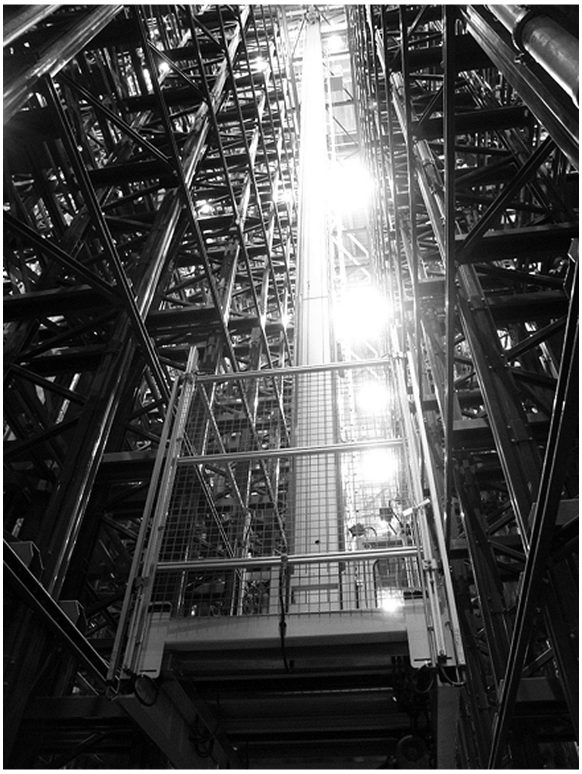
Figure 1 Cathay Pacific Cargo Terminal

MHS fundamentally consists of Container Handling System (CHS) and Bulk Handling System (BHS) and is a vast and highly complex process engineering installation.

Figure 2 Container Handling System (CHS)

Fully automated multi-floor CHS provides 2,445 storage positions. All unit load devices (ULDs) are directly transferred into the system from the airside.

Figure 3 Bulk Handling System (BHS)



BHS provides 4,224 computer-controlled storage positions for import, export and transhipment cargo. It links with the Customs Examination Hall to facilitate the retrieval of bulk cargo for customs inspection.

(Source: CPSL webpage)

3. BUILDING INFORMATION MODELING (BIM)

In 2006-7, BIM was in its infancy in Hong Kong and whilst CPCT was not the first project to embrace BIM technology (Meinhardt and others had previous BIM project experience), this was the largest and most complex model built at the time. CPSL's decision to model the entire cargo facility in the early design stages through to the end of construction was a wise one. The integration of both huge main services all the way to final pipe and cable containment legs to coordinate with structure, architecture and crucially the MHS was fundamental to producing a buildable design.

Where possible the MHS was allocated to dedicated zones to accommodate its lifts, conveyors, stackers and other machinery; however these zones had to be encroached by a number of building systems most notably fire services which required in-rack sprinklers and the like.

The BIM technology enabled fast and comprehensive coordination checks and the model was further developed during construction by the main contractor. CPSL now has a valuable tool and data base held within the BIM model which they can use for various purposes across the operation of the cargo terminal, and also through the future development of Phase 2 of the Terminal.

Figure 4 Building Information Modeling

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Figure 5 Building Information Modeling

4. INTERFACING WITH OTHER TRADES

As the MHS is the most vital element of the cargo terminal, it is crucial that all services, such as architectural, structural and building services must be properly interfaced with the handling system for its proper operation.

The following are some of the salient interfacing issues:-

4.1 VERTICAL CLEARANCES

As the unit load devices (ULD) will be conveyed and maneuvered by the MHS equipment, it is therefore important that a minimum clearance be maintained between the highest points of the MHS equipment during operation and the services at the soffits of ceiling slabs. The vertical clearance is 3.2m, which had to be taken into account in determining the floor to floor heights of the cargo terminal.

4.2 FLOOR SLAB LOAD

The floor slabs in CPCT are subject to very heavy structural loading imposed by the MHS equipment, container trucks, heavy services, such as busways, fire services pipes, bulky air ducts, etc. hanging from the soffit slab of a floor by means of hangers and anchor bolts.

It was crucial that the structural slab be adequately designed to cater for such loading requirement etc. particularly areas of specific high or point loading. Liaison with structural engineer at early design stage was required for the weight of the building services elements to be catered for.

5. ELECTRICAL DESIGN

Apart from the above mentioned interfacing, the following are salient design issues related to the electrical systems for this particular project:-

5.1 DIVERSITY FACTOR

The electrical demand of the MHS is determined by the total power demand of the handling equipment after diversity.

The diversity factor is in turn determined by the operational mode of various MHS equipment.

As determined by MHS vendor, the total estimated electrical demand for MHS is 8,133 kVA with a diversity factor of 0.635.

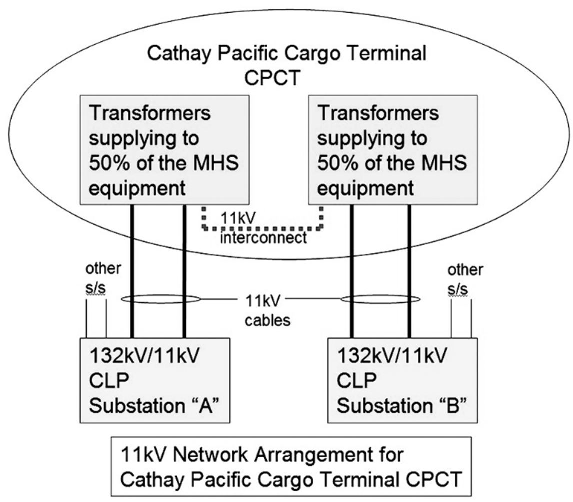
There are a total of 23 nos. 1,500 kVA CLP's dry type transformer installed in 8 transformer rooms.

5.2 RELIABILITY

Reliability and resilience of the power supply system are crucial in maintaining effective and efficient operation of this world-class terminal 24x7 round the clock. The following provisions have been strategically designed and incorporated in CPCT to achieve an excellent service level:-

5.2.1 Dual feed HV power supply from CLP – The MHS system of CPCT is served with 2 dedicated 11 kV interconnectors from different 132/11 kV primary substations. In case of supply failure in either primary substation, the other healthy primary substation will provide full backup and maintain the MHS to its full capacity.

Figure 6 Dual Power Supply



5.2.2 In addition, backup generators are provided to keep the MHS equipment in essential operation in case both sources of CLP supply fail.

In essential mode, about 50% of the power supply to MHS equipment are kept running by emergency generator to maintain the cargo terminal in operation.

Totally, there are 12 nos. of 2 MVA generator installed on roof of the CPCT serving both the MHS and building essential load, giving an installed capacity of 24 MVA for the whole development. As the total installed generation capacity exceeds 5 MW, it is defined by law as an electricity plant, resulting in the need to apply for and obtain a specific operation license.

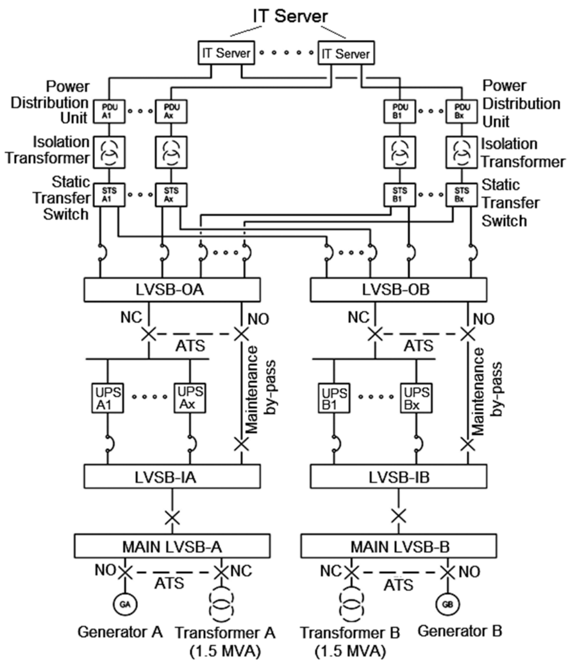
5.3 BUSWAY TRANSPOSITION

All insulated busways are installed in a side by side busbar arrangement. The busbars have inherent small difference in reactance per unit length with respect to adjacent busways and the difference will increase with the busway length. When current is distributed through busways, the difference in reactance leads to the phase voltages becoming unbalanced amongst the busbars which cannot be ignored for long busway lengths. Therefore, at the early stage, design considerations were taken resulting in busway transpositions being installed at strategic locations to avoid unbalanced voltages that affects the operation of MHS.

5.4 ELECTRICAL FACILITIES FOR CRITICAL EQUIPMENT

As there is massive data exchange and storage for handling the transshipment, import and export cargo, two server rooms (viz. primary and secondary server rooms) are built with provision of 2-N power supplies. Each N of a 2-N supply is fed from different transformers to provide 100% back-up. Distribution routes are diversified to avoid any single point of failure. 2N UPS power supplies are also provided in such a way that the IT equipment can always be fed from a well-conditioned electrical supply free from contamination such as harmonics.

Figure 7 2N Power Supply



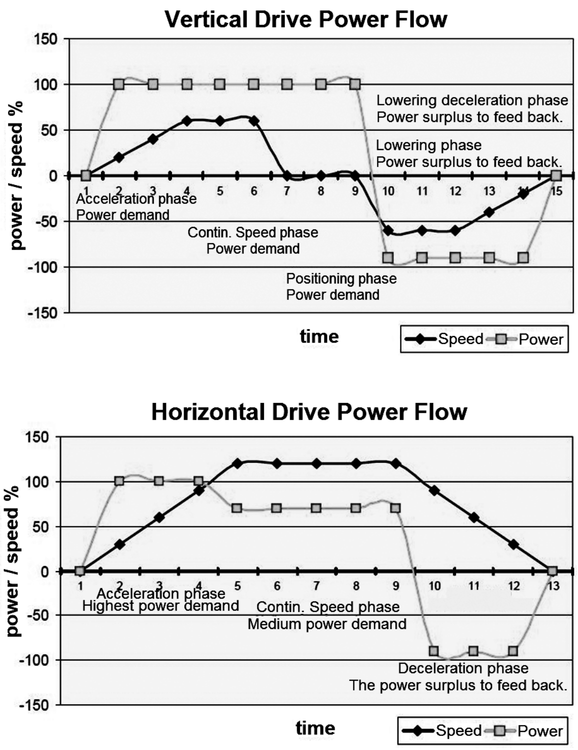
5.5 REGENERATIVE POWER

In the MHS, due to the large number of the electric conveyors operating in both vertical and horizontal motions, there exists a considerable amount of regenerative power. Consequently the electric motors work in a generator operation during the following conditions whilst loading and unloading the hubs:-

- Speed reducing
- Load lowering

The following graphs depict the predicted power flow for both vertical drive and horizontal drive in the course of their operations.

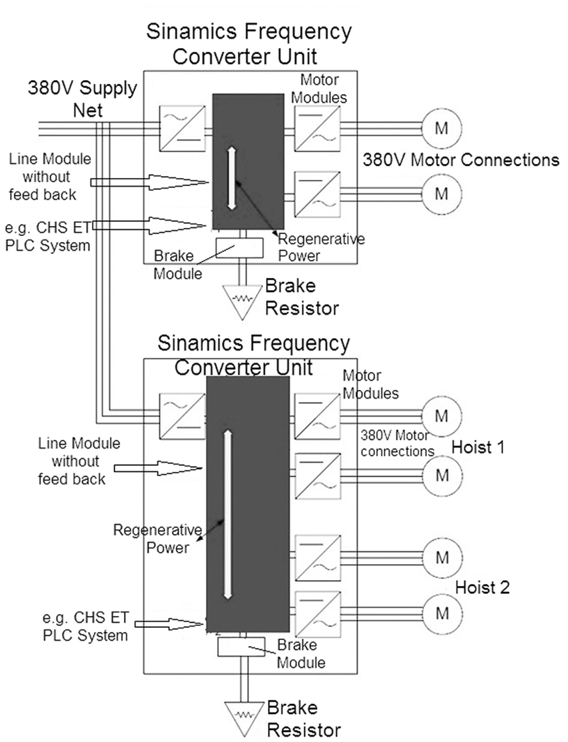
Figure 8 Predicted Power Flow for Drives



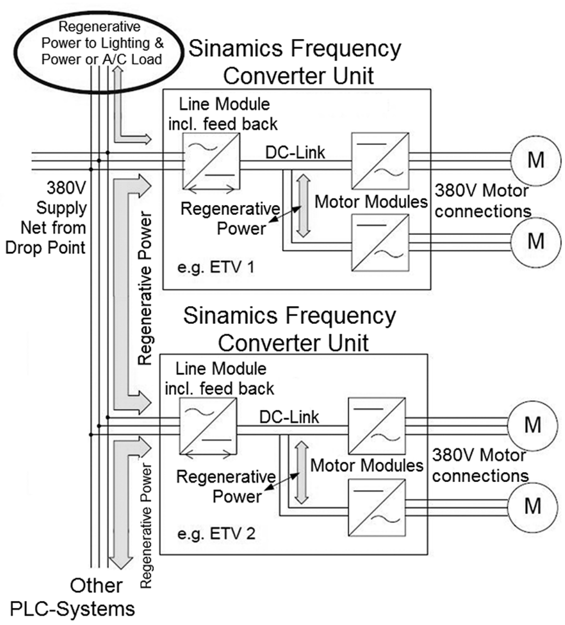
(Source: Siemens)

The regenerative power so produced can be either dissipated as heat via a brake resistor or harnessed to supply power back to other equipment connected in the same system. At CPCT this available energy is not wasted as heat but is harnessed by the state-of-the-art frequency converter technology that feeds the energy back to the LV supply network.

Figure 9 Regenerative Power Absorbed by Drives



Regenerative Power Dissipated via Resistors



(Source: Siemens)

The amount of potential regenerative power in a particular mode of operation is estimated as follows:-

Figure 10 Estimated Potential Regenerative Power

Transformer Designation	Equipment Power Demand	Estimated Potential Regenerative Power	%
TX1	726.9	46.9	6.5%
TX2	868.4	202	23%
TX3	639.9	184.8	28.8%
TX4	1008.7	241.4	23.9%
TX5	925.6	110.3	11.9%
TX6	962	202	21%
TX7	901	306	34%
TX8	555.6	171.7	30.9%
TX9	559	171.7	30.7%
TX10	986	110.7	11.2%
TOTAL	**8133.3**	**1747.5**	**21.5%**

All values are in kVA unless given.
(Source: Siemens)

In the above table, as the regenerative power is less than the overall power consumption, it is absorbed entirely within the LV power system without back feeding further to the CLP network.

The reuse of the 21.5% regenerative power has very significant environmental and operating cost benefits:-

- Substantial reduction of CO2 footprint.
- Reduced energy demand for MHS and reduction in tariff of 21.5%.
- Reduced heat load to the building.
- Reduced operating cost of electricity.

5.6 COLD ROOM

There are other facilities inside the cargo terminal to support the specific cargo types, such as cold room to maintain the temperature-sensitive goods in good condition and the temperature has to be maintained at -20ºC for the coldest compartment at cold room. All the building materials used must be able to withstand such severe environment.

5.6.1 Cable

The commonly used cable such as PVC insulated cables cannot be used in such an environment as it will become brittle at such low temperature. Therefore, silicone-based insulated cables are specified which can work properly from -50ºC to 180ºC.

5.6.2 Lighting

When fluorescent lamps are selected for use in the cold room, special care is taken to avoid lamp flickering at low temperature.

Therefore, special low temperature light fittings are selected.

6. CONCLUSION

CPCT is one of the largest air cargo terminal of its type in the world and has been developed to house and support the operation of the very latest technology available in this field.

Great effort has be expended by all involved in the project from securing the Operator’s franchise through planning, design, construction and testing and commissioning, to the ongoing operational trails and commercial operation.

To make the project a success, it was essential to properly interface among the MHS, architectural, structural and building services installations. In addition, BIM was used to ensure comprehensive co-ordination between all trades.

There were many challenges in designing such a large capacity electrical installation with the necessary reliability and efficiency to accommodate and support the demands of a truly state-of-art MHS.

CPCT is now under phased operation since 21st February 2013 and the adjacent area has been reserved for Phase 2 expansion in the future.

Paper No. 4

ENERGY SAVING MEASURES IN PUBLIC RENTAL HOUSING ESTATES

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ABSTRACT

Low carbon life achieving through reduction of Greenhouse Gases (GHG) emission is critical to combat climate change worldwide. To cut down emission of GHG, the Hong Kong Housing Authority (HA) [Note 1] has implemented a series of energy saving measures in both the design and operation of communal building services (BS) installations of public rental housing estates (PRH estates).

In view of the large PRH stock accommodating about 30% of the population in Hong Kong, the design and upkeep of PRH estates are of great challenge to the HA, particularly in striking a balance between saving of energy and provision of adequate services fulfilling the needs of tenants. This paper presents different types of energy saving measures in the three major communal BS installations i.e. lighting, lift and water pump installations under such context.

The new two-level lighting system which has been adopted to address the requirements of the Design Manual: Barrier Free Access 2008 in an energy saving manner is presented in details to give an overview of its effectiveness.

The pilot installation of LED lighting and grid connected regenerative power in lift services in Kai Ching Estate and Tak Long Estate respectively are briefed in the paper.

The overview of the grid connected photovoltaic (PV) systems in Lam Tin Estate Phases 7 & 8, Yau Lai Estate, and Kai Ching and Tak Long Estates are given in the paper.

A brief account of the conducted energy audits in the past few years have been included in the paper.

Apart from the above, the paper gives a brief of the HA's experiences in the development and implementation of Energy Management System (EnMS) to ISO 50001:2011.

The paper also introduces the HA's Environmental Protection Window Scheme which is newly developed with an aim of nurturing PRH tenants' energy saving culture in their daily life.

Finally, a prediction of energy performance of PRH estates in 2016/17 (i.e. 699 kWh/flat per year) is clearly stated at the end of the paper to signify the HA's commitment in continuous improvement of energy performance.

1. BACKGROUND

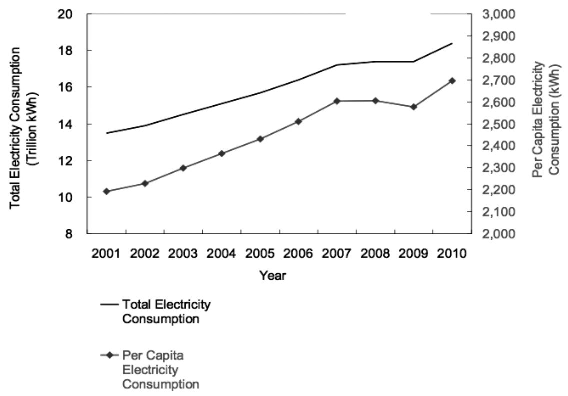
The excessive emission of GHG has been globally recognized as the culprit of climate change.

In general, the use of energy would involve consumption of fossil fuel which in turn would emit GHG. Efficient use of energy, wider use of cleaner fuels, and adoption of renewable energy sources are the pragmatic approaches in reducing emission of GHG.

In Hong Kong, fossil fuels are the major sources of primary energy. Based on information in Hong Kong Energy End-Use Data 2012, buildings consumed 68% of primary energy; and 80% of energy consumed in buildings is in the form of electricity [Note 2]. Obviously, reduction of electricity consumption in buildings will have significant effects in cutting down the overall GHG emissions (i.e. carbon footprint) of Hong Kong.

Figure 1 below shows the trends of total and per capita electricity consumption in the world during the period from 2001 to 2010 [Note 3]:

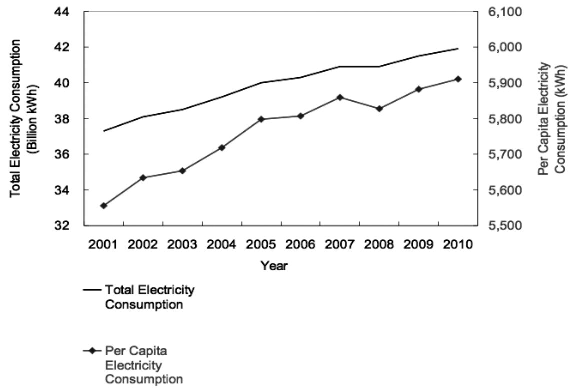
Figure 1 Total and Per Capita Electricity Consumption in the World



The persistent increase of total and per capita electricity consumption during the period from 2001 to 2010 as shown in Figure 1 above indicates that efforts by the international community in combating GHG emissions need to be reinforced.

Figure 2 below shows the trends of the total and per capita electricity consumption of the HKSAR [Note 2] during the period from 2001 to 2010:

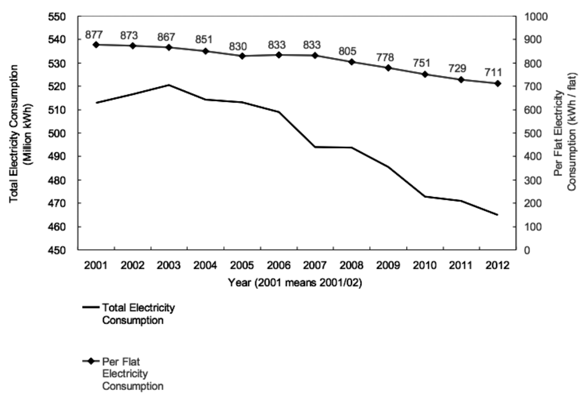
Figure 2 Total and Per Capita Electricity Consumption in Hong Kong



A persistent increase of total and per capita electricity consumption during the period from 2001 to 2010 is observed. The HKSAR government launched the Building Energy Efficiency Ordinance for mandatory implementation of the Building Energy Code and Energy Audit Code on 21 September 2012 with an aim of reducing the overall electricity consumption in Hong Kong.

Figure 3 below shows the trends of total and per flat electricity consumption of communal building services installations in the HA's PRH blocks during the period from 2001/02 [Note 4] to 2012/13 [Note 5]:

Figure 3 Total and Per Flat Electricity Consumption in HA



The downward trends in both the total and per flat electricity consumption during the past twelve years as shown in Figure 3 above indicates that the energy saving measures so far taken by the HA have been effective and successful.

Table 1 below shows the comparison of per flat annual electricity consumption of communal BS installations in some private residential estates with those of a PRH block in 2008 [Note 6]:

Table 1 Comparison of Per Flat Annual Electricity Consumption of Communal BS Installations in Some Private Residential Estates with those of a PRH Block

Residential Estate	Per Flat Annual Electricity Consumption of Communal BS Installations (kWh per flat)
Private Estate A	6,834
Private Estate B	6,725
Private Estate C	4,359
Private Estate D	3,409
Private Estate E	3,294
Private Estate F	3,127
PRH Block	807 [Note 7]

Apparently, the energy performance of communal BS installations of a PRH block is better than those of the private residential estates.

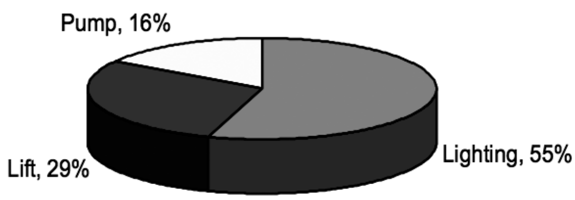
2. APPROACHES TO SAVE ENERGY

The annual electricity consumption of communal BS installations of all existing PRH domestic blocks for Year 2012/13 was 465 million kWh. A small percentage of consumption reduction would mean a sizeable saving of energy. In the past twelve years, the HA has pioneered many energy efficiency and conservation programmes tailored to suit the needs of PRH estates with an aim of cutting down the energy consumption.

2.1 SHARE OF ENERGY CONSUMPTION BY COMMUNAL BS INSTALLATIONS AND EFFORTS IN CUTTING THEIR CONSUMPTION

The results of energy audits conducted for 34 nos. of PRH domestic blocks covering all typical types of blocks in 2009/10 and 2010/11 indicate that the three major energy consuming BS installations i.e. lighting, lift and water pump in a typical PRH domestic block are in the proportion of approximately 55%, 29% and 16% respectively. These portions have also been affirmed by a number of studies and measurements in the past few years.

Figure 4 Distribution of Electricity Consumption in a Typical PRH Rental Blocks



Over the past twelve years, the HA has spent a lot of efforts to cut down the energy consumption through implementation of various energy saving measures in these three communal BS installations with the greatest in lighting and the least in water pump. Details are elaborated in Section 3.

2.2 USE RENEWABLE ENERGY SOURCES TO OFF-SET ENERGY FROM FOSSIL FUELS

In parallel with the efforts on reducing energy consumption of the three BS installations, the HA has also explored the possibility of introducing renewable energy sources to reduce energy from fossil fuels by off-setting portion of energy consumed by communal BS installations. Among the available alternatives, solar power is abundant in Hong Kong, as such, the HA has adopted different photovoltaic (PV) technologies to generate electricity in the new development of PRH estates. Details are described in Section 4.

2.3 ENERGY AUDITS TO AFFIRM THE HA'S ACHIEVEMENT IN ENERGY SAVING AND EXPLORE FURTHER ENERGY SAVING OPPORTUNITIES

To affirm HA's achievement in energy saving in the previous years and explore further energy saving opportunities, the HA appointed external energy auditors to conduct two batches of energy audits in two financial years (i.e. one in 2009/10 and one in 2010/11). Details of the audits are given in Section 5.

2.4 ESTABLISHMENT OF ENERGY MANAGEMENT SYSTEM TO CONTINUOUSLY MONITOR THE ENERGY PERFORMANCE

Since 2010/11, the HA has adopted an energy monitoring system by adopting a Reference Index (RI) to monitor the energy performance of each PRH domestic block. A saving of approximately 6% of energy was recorded in a year later. To further enhance energy performance through continuous improvement, the HA has committed to establish a structured energy management system with an aim of obtaining ISO 50001 certification within the coming two years. Details of its implementation are given in Section 6.

3. THE HA'S EFFORTS ON THE IMPLEMENTATION OF ENERGY SAVING MEASURES

The HA's efforts on the implementation of energy saving measures in lighting, lift and water pump are detailed in the following sub-sections and paragraphs.

3.1 ENERGY SAVING MEASURES IN LIGHTING

In response to the rising expectation of PRH tenants and the changes of statutory requirements on illumination criteria, the HA always takes into consideration of the following criteria in the design and provision of public lighting in PRH estates: (i) improving illumination level; (ii) achieving energy efficiency; and (iii) formulating cost effective solutions.

Taking into account of these criteria, the four major variables affecting the efficiency of lighting energy namely lamp types, illumination level, ballast types; and control circuitry for the design and provision of public lighting in PRH estates shall be examined in turn. In addition, the new two-level lighting system, LED, Exit Sign, and photocell/timer are also briefed in the following sub-paragraphs.

3.1.1 ENERGY SAVING THROUGH THE USE OF APPROPRIATE LAMP TYPES

The lamp types used in general lighting has been changed, in tandem with technological advancement, from incandescent lamps in the 60s to twin 8-watt T-8 fluorescent tubes in the 80s, and to the use of Compact Fluorescent Lamps (CFL) since 90s as a standard in the latest design to date. The comparison of efficacy of these lamp types are shown in Table 2 below.

Table 2 Efficacy of Different Lamp Types

Lamp Types	Efficacy (lm/W)
Incandescent lamp	3 - 15
T-8 fluorescent lamp	45 - 60
Compact Fluorescent bulkhead lamps	60 - 80
T5 fluorescent lamp	80 - 100

For existing PRH estates, all fluorescent tubes installations would be replaced with either compact fluorescent bulkhead lamps or T-5 fluorescent tubes when they are approaching the end of their service. For new development of PRH estates, compact fluorescent bulkheads lamps and T-5 fluorescent tubes have already been part of the HA's general lighting provision.

To further enhance energy efficiency in the use of lamp types, the HA has recently tried out some types of LED bulkhead lamps in corridors and staircases of typical domestic floors. Taking the experiences from these trial installations, a pilot installation of LED Bulk lamps for Block 2 of Kai Ching Estate has been implemented and completed recently. The results shall be monitored and reviewed for wider use in other PRH estates. Details are elaborated in paragraph 3.1.6.

3.1.2 ENERGY SAVING THROUGH THE DESIGN OF APPROPRIATE ILLUMINATION LEVEL

To maximize the illumination level of the luminaries, the HA has used luminaries with clean prismatic diffusers instead of opal diffusers for years. In addition, all diffusers are cleaned regularly to maintain the optimal efficacy of the luminaries.

Before the end of 2008, the changes of illumination levels at various public areas of PRH blocks completed during the last five periods (i) from 1960s to 1970s; and (ii) in 1980s; (iii) in early 1990s; (iv) in late 1990s; and (v) from 2000 to 2008 are summarized in Table 3 below.

Table 3 The Illumination Levels of Buildings Completed in Different Period

	Period of Completion of PRH Blocks Note 8				
Locations	HA Standard in 1960s – 1970s	HA Standard in 1980s	HA Standard in early 1990s	HA Standard in late 1990s	HA Standard (2000 – 2008)
Lift Lobbies	< 20 lux	30 lux	85 lux	150 lux	85 lux
Corridors	< 20 lux	30 lux	50 lux	120 lux	50 lux Note 9
Staircases	< 20 lux	30 lux	45 lux	120 lux	40 lux

During the first three periods, the illumination levels were progressively increased from just to satisfy the minimum security requirements to a satisfaction level. In late 1990s, the illumination levels were upgraded to tally with the recommendation of Design Manual: Barrier Free Access 1997 (BFA 1997) promulgated by the Building Department. However, after those PRH domestic blocks using the standard of BFA 1997 were completed for occupation, there were comments on over-illumination. HA conducted a review on the acceptable illumination levels by surveying private developments; and making reference to the latest CIBSE Guides. A new standard on illumination levels in new

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PRH estates was then established and adopted from 2000 to 2008.

In the end of 2008, the new edition of the Design Manual: Barrier Free Access 2008 (BFA 2008) specifies a minimum illumination level of 85 lux along communal passageways in buildings to take care of persons with special needs. When compared with the HA's original design illumination level i.e. 50 lux, the adoption of the new requirements to BFA 2008 would lead to the communal lighting energy consumption almost doubled and hence associated GHG emission. The HA has developed a two-level lighting control scheme which can meet the requirements of BFA 2008 with a comparable saving in lighting energy. Details of the two-level lighting control scheme are elaborated in paragraph 3.1.5.

3.1.3 ENERGY SAVING THROUGH THE USE OF ADVANCED BALLAST TYPES

The advancement in the technology of electronic ballasts enables them to consume approximately 20% less electricity when compared with their electromagnetic counterparts. In late 2003, electronic ballasts have already been specified as part of the HA's general lighting provision for new development of PRH estates. For existing PRH estates, the HA has implemented a **42 months Retrofitting Programme** to replace approximately 1 million sets of luminaries with a total cost of $260M from April 2012 till September 2015. It is anticipated that there would be an annual saving of about $33M.

3.1.4 ENERGY SAVING THROUGH APPROPRIATE CONTROL CIRCUITRY

To make the best use of daylight in some open corridors, staircases and lift lobbies, the associated lighting circuits have been modified/separate in different zones in accordance with the layout arrangement such that lighting in the vicinity of windows is controlled by timers and photocells to ensure effective use of daylight. Flexibility is also allowed for estate management staff to manually switch either on or off those light fittings to suit actual daylight conditions.

3.1.5 ENERGY SAVING THROUGH THE USE OF TWO-LEVEL LIGHTING CONTROL SCHEME

In the end of 2008, the new edition of the Design Manual: Barrier Free Access (BFA 2008) was released and had presented great challenges to building services engineers. The manual specifies a minimum illumination level of 85 lux along communal passageways in buildings to take care of persons with special needs. When compared with the HA's original design illumination level i.e. 50 lux, the adoption of the new requirements to BFA 2008 would lead to the communal lighting energy consumption almost doubled and hence associated GHG emission.

To minimize the environmental impact of the new requirement, a new on-demand lighting control system providing two different levels of illumination has been developed. The new design comprises two sets of lightings along the communal passageways. One is constantly powered to provide a minimum illuminance of 30 lux at floor level of typical corridor and staircase and 50 lux for typical lift lobby; the other set is normally switched off as standby. With different means of control, the resultant illumination level could be raised to 85 lux by switching on those standby lightings for an adjustable period (e.g. 10 minutes).

To avoid prolonged, but unnecessary operation of the standby lighting, those of the triggered zone would be automatically switched off after a pre-set lapse of time.

Table 4 The Basic and Elevated Illumination Levels of the New Two-Level Lighting System

	HA Standard (2009 onward)	
Locations	**Basic illumination level**	**Elevated illumination level**
Lift Lobbies	50 lux	85 lux
Corridors	30 lux	85 lux
Staircases	30 lux	85 lux

By adopting this new lighting control system, it is estimated that the HA can reduce the annual energy consumption of approximately 121,000 kWh for a typical 40-storey domestic block with 799 flats.

3.1.6 ENERGY SAVING THROUGH THE USE OF LED BULKHEAD LIGHTING INSTALLATION

LED lighting is becoming more popular due to its potential merits in luminous efficacy, longer service life, energy saving and environmental friendliness. Since 2008/09, the HA has implemented a number of small scale of pilot installations. The results indicated that further evaluation on the following aspects are required:

(i) The long term lumen depreciation and colour stability of LEDs; and

(ii) Endurance of major components like the LED driver etc.

Based on the results of the above study, the HA has further implemented a pilot installation of LED bulkheads at corridors, staircases and lift lobbies of typical floors of Block 2 in Kai Ching Estate to evaluate the performance of LED in terms of the above aspects during its full operation in the coming two years.

It is anticipated that the average annual energy saving of a typical harmony block from the use of LED bulkhead lightings would be in the range of 20 to 30% (i.e. 31,000kWh to 47,000kWh). The long-term benefits will be further evaluated with reference to not just energy saving, but also on lumen depreciation and endurance.

3.1.7 EQUIP EXIT/DIRECTIONAL SIGNS WITH ENERGY EFFICIENT LIGHT FITTINGS AND BALLAST

For new development of PRH estates, T5 fluorescent tube has been used for all Exit /Directional Signs since 2008. For existing PRH estates, a 3-year retrofitting programme for replacing the electromagnetic ballast with electronic ballast of a total of 80,800 sets of Exit/ Directional Signs was completed in March 2011, with an annual cost saving of around $8M [Note 10].

3.1.8 ENERGY SAVING THROUGH THE USE OF PHOTO SENSOR AND TIMER

Timer and photocell have been the standard provision for automatic control of the general lighting in particular for those lightings in the vicinity of windows to ensure effective use of daylight in PRH estates.

The frequency of adjustment of timer for lighting circuits has been increased to every two months from the previous three months period in order to minimize any premature switching on or delayed switching off of light fittings for better utilization of sunlight. The average annual energy saving of a typical harmony block is approximately 1,845kWh.

3.2 ENERGY SAVING MEASURES IN LIFT SERVICES

Lifts in domestic buildings account for a significant portion of total communal energy consumption. Basically, there are several approaches to improve energy efficiency of lift operation namely: (i) use of energy efficient lift equipment/ systems for lift installations; (ii) use of light weight lift decoration; (iii) optimization of the number of lifts; and (iv) partial shutdown of lift services during night time.

3.2.1 ENERGY SAVING THROUGH LIFT MODERNIZATION SCHEME

Currently, approximately 5,000 nos. of lifts are being operated in around 1,200 nos. of PRH blocks which were installed at different periods in the past forty to fifty years. Improvement to the energy performance of these existing stocks of low energy efficiency lift systems could be pursued through modernization.

Due to technological advancement, several types of motor drive control as listed below were developed and adopted in lift installations at different times in the past forty to fifty years:

(i) DC motor drive with generator set (DC M-G drive);

(ii) DC motor drive with solid state controller (DC SS drive);

(iii) AC 2 speed drive (AC-speed drive);

(iv) AC motor drive with variable voltage controller (ACVV drive); and

(v) AC motor drive with variable voltage and variable frequency controller (ACVVVF drive)

Among these five types of motor drives, DC M-G drive is the least energy efficient motor drive while ACVVVF drive is the most energy efficient motor drive.

Comparing with the energy consumption of a lift with AC 2-speed drive for the same output, the lift using ACVV drive consumes approximately 30% less energy whereas ACVVVF drive consume approximately 50% less energy. If regenerative power could be fed back into the mains supply, a further reduction of 5% of energy can be achieved for ACVVVF drive [Note 11] (i.e. only 45% of the AC 2-speed drive).

To enhance the vertical transportation for PRH estates as well as the overall energy performance of lift services, the HA has implemented the lift modernization programme since 1988 with the current target of replacing and upgrading 100 nos. of aged and low energy efficient lifts of more than 25 years old and having deteriorated performance in term of routine operation and energy use in each financial year.

Since then, some 600 aged lifts have been replaced with new and energy efficient lifts. Currently, modernization of 477 lifts in 21 estates is in progress with scheduled completion in 2013 to 2017. Tender for another 481 lifts in 25 estates shall be arranged accordingly.

For lift modernization in existing PRH estates, the average energy saving in each modernized lift would be around

30% to 40% depending on the type of motor drive control of the aged lifts.

3.2.2 ENERGY EFFICIENT FEATURES/ SYSTEMS IN LIFT INSTALLATION

Energy efficient features/systems in lift installations currently available in the industry include variable voltage variable frequency drives, permanent magnet synchronous motor (PMSM), gearless system and grid-connected regenerative power.

The HA has adopted the following energy efficient lift features/system in Kai Ching Estate which has commenced in-take in August 2013:

(i) variable voltage and variable frequency drives;

(ii) permanent magnet synchronous machine; and

(iii) gearless.

For Tak Long Estate (which is anticipated to be completed by late 2013), apart from all the above energy efficient features/systems, the trial on grid-connected regenerative power is now being conducted for all lifts in the estate.

Experiences gained shall be extended to lift modernization and lift addition for existing PRH estates; and lift installations for new development of PRH estates.

3.2.3 ENERGY SAVING THROUGH THE USE OF LIGHT WEIGHT DECORATION

Decorative load in lift car forms part of the loading on the lift driving motor. A heavier decorative load would require a larger driving force from the driving motor which in turn would require larger electrical power input for the driving motor. The HA has adopted light decorative load for all lift installations.

3.2.4 ENERGY SAVING THROUGH OPTIMIZATION OF THE NUMBER OF LIFT PROVISION

The previous allowed 6 number of lift provisions in standard block design has been suspended since 2003/04. Instead, the designed number of lift provisions has been optimized according to international standards to suit the unique requirements of individual non-standard PRH domestic block. It is expected that considerable amount of energy could be saved with this optimization.

3.2.5 ENERGY SAVING THROUGH PARTIAL SHUTDOWN OF LIFT SERVICES DURING NIGHT TIME

Further saving of energy could be achieved if parts of the lift services are temporarily suspended during non-peak hour. However, the utilization of lift services in some PRH estates is still high during non-peak hour i.e. after mid night, shutdown of lift services for these estates may not be appropriate. Thus, shutdown of lift services during non-peak hour has to be reviewed block-by-block prior to implementation.

3.3 ENERGY SAVING MEASURES IN WATER SUPPLY

Indirect water supply system has been widely adopted in PRH estates. Water from town mains is pumped to the roof storage tanks by up-feed water pumps and then supplied to tenants by gravity.

When adequate water pressure cannot be provided by means of gravity to the topmost floors of a PRH block, a fresh water booster pump system comprising centrifugal water booster pumps and pneumatic pressure vessels would be used.

The following two approaches which are now becoming the HA standard fresh water supply system design for new development of PRH estates have also been adopted in enhancing energy performance of water supply system in existing PRH estates i.e. (i) using the highest energy efficiency motor for water pump i.e. EFF1 instead of previous specified EFF2 motor, and (ii) the adoption of Variable Speed Drive (VSD) for water booster pump system.

3.3.1 ENERGY SAVING THROUGH THE USE OF EFF1 MOTOR

For new installation, EFF1 motor has become the HA's standard provision for fresh water pump.

For existing installation, the HA has commenced a long term pumping system renovation programme in existing PRH estates with a view to enhancing the reliability as well as energy efficiency of the water supply system since 1994. The HA has taken this opportunity to adopt the higher efficiency motor specified at EFF1 in all renovation and/ or replacement works to enhance the energy performance. Technically, EFF1 motor could save approximately 1 to 2% of energy when comparing with EFF2 motor.

3.3.2 ENERGY SAVING THROUGH THE USE OF VSD BOOSTER PUMP SYSTEM

With the advancement of technology, there is room for improvement in the energy performance of water pumping system. The HA has adopted Variable Speed Drive (VSD) for booster pumps with success. By varying the speed of the pump motor, the energy-efficient VSD can respond quickly and efficiently to the varying water demand by maintaining a stable water supply pressure at the tap-off points under all operating conditions. Moreover, the number and capacity of associated pneumatic pressure vessels and hence plant room space can be substantially reduced. This feature has now become the HA's standard fresh water booster pump system for both new installation and renovation of existing installation.

When compared with the existing system i.e. pneumatic booster system, VSD system could save up to 70% of energy.

4. THE USE OF RENEWABLE ENERGY TO REDUCE CONSUMPTION OF FOSSIL FUELS

Renewable Energy (RE), being an inexhaustible natural resource, includes solar, wind, biomass, geothermal, wave, hydro and tidal power, etc. Among these alternatives, solar power is abundant in Hong Kong. Though the cost effectiveness of using solar power to generate electricity is still low, the HA has adopted different photovoltaic (PV) technologies in some of the PRH domestic blocks as well as external areas in a bid to evaluate their effectiveness for wider application, reduce consumption of building energy and raise tenants' awareness in energy conservation.

4.1 RENEWABLE ENERGY FROM THE USE OF GRID-CONNECTED PHOTOVOLTAIC (PV) SYSTEMS

The photovoltaic system is connected to the utility grid to operate in parallel with the grid is called grid-connected photovoltaic system. The electricity generated from the system will be consumed by the communal BS installations. As such, the demand of electricity from power companies would be reduced.

4.1.1 LAM TIN ESTATE PHASES 7 & 8

Lam Tin Estate Phases 7 & 8 was in-take in June 2009. The total installed PV capacity is 33.2 kWp; the total designed yearly energy generation capacity is 43,000kWh; and the actual yearly energy generation capacity is 34,125kWh, 38,400 kWh and 30,496 kWh for 2010, 2011 and 2012 respectively. Only mono-crystalline PV panel has been adopted.

Figure 5 PV Panels at Lam Tin Estate Phases 7 & 8

4.1.2 YAU LAI PHASE 5

Yau Lai Estate was in-take in October 2011. The total installed PV capacity is 27.6 kWp; the total designed yearly energy generation capacity is 32,300 kWh. Two different types of PV panels i.e. Poly-crystalline and Amorphous have been adopted as part of the study for evaluation/exploration of the most suitable type of PV panel in Hong Kong.

4.1.3 KAI CHING AND TAK LONG ESTATES

Currently, two large scale grid-connected PV systems have been installed in Kai Ching Estate and Tak Long Estate. Kai Ching Estate has been in-take in August 2013 while Tak long Estate is anticipated to be completed for in-take in late 2013. The total installed PV capacity of Kai Ching Estate and Tak Long Estate are 57.6kWp and 130.35 kWp respectively. The total anticipated yearly energy generation capacity of PV system in Kai Ching Estate is 67,237 kWh while the same in Tak Long Estate is 116,207 kWh. For Kai Ching Estate, only the typical type of PV panel i.e. mono-crystalline has been adopted. For Tak Long Estate, four different types of PV panels i.e. CIGS, mono-crystalline, Amorphous and Poly-crystalline have been adopted as part of the study for evaluation/exploration of the most suitable type of PV panel in Hong Kong.

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4.1.4 FUTURE PROJECTS

Subsequent to the trial installation of grid-connected PV system at Redevelopment of Lam Tin Estate Phases 7 & 8 (Figure 5), the HA has committed to the implementation of such system in all new public rental housing developments to cater for at least 1.5% of the communal electricity demand since May 2011.

4.2 RENEWABLE ENERGY EXTERNAL LIGHTING

For education purpose, the HA has committed to provide 1 to 2 numbers of solar powered lighting to those existing PRH estates which are under the Estate Improvement Programme and a small number of solar powered lightings in each new estate to serve the purpose.

5. ENERGY AUDIT TO AFFIRM THE HA'S COMMITMENT IN ENERGY PERFORMANCE

Energy audit serves to ascertain the energy utilization pattern, explore energy management opportunities of a building. Major energy consuming BS installations including electrical supply, lighting, lift services and water pump are the main focal areas for domestic blocks. During the financial years i.e. 2009/10 and 2010/11, two batches of energy audits including 34 nos. of selected PRH blocks which cover a wide spectrum of HA's existing stock in terms of age and block type were conducted by external energy auditors to give an objective assessment on energy performance of these 34 nos. of selected PRH blocks. The results of these independent checkings have affirmed HA's commitment in raising energy awareness and achievement in energy saving in the previous years.

The following are the summary of the recommended energy saving initiatives:

Lighting –

(i) Use of LED lighting;

(ii) Use of T5 tube in Exit Signs and all Plant rooms

Lift -

(i) Use of Permanent Magnet Synchronized Machine;

(ii) Use of Gearless for Mechanical Power Transmission;

(iii) Use of Light Weight Lift Car Decoration;

(iv) Use of Grid-connected Regenerative Power; and

(v) Shutdown of Lift During non-peak hour

6. ENERGY MANAGEMENT SYSTEM TO ISO 50001

The ISO 50001 on Energy Management System was launched in June 2011. This enables organizations to establish management system and process to improve their energy use and consumption performance, and hence reduction of GHG emissions, other related environmental impacts and energy cost through a systematic approach.

To ensure energy management approach to be sustainable, reliable and consistent throughout the organization, the HA has decided to build up a structured energy management system through certification to ISO 50001. This energy management system enables the HA to identify clear energy saving objectives and targets as well as the energy performance of HA's operations in a systematic manner. It also strengthens HA's communication on energy issues with other stakeholders.

Accordingly, the HA obtained ISO 50001 certification on the domestic building design in June 2012, and the pilot estate i.e. Kwai Shing West Estate obtained ISO certification in June 2013. As advised by HKQAA, the HA was the first organization in Hong Kong obtaining ISO 50001 certification on the domestic building design while Kwai Shing West Estate was the first existing domestic estate with ISO 50001 certification.

ISO 50001 certification for all existing estates is planned in two phases. Phase One, comprising 632 PRH domestic blocks in 92 existing estates, is scheduled to obtain certification to ISO 50001 by October 2014 while Phase Two, comprising 524 PRH domestic blocks in 72 existing estates, is scheduled by April 2015.

7. ENHANCEMENT OF TENANTS' AWARENESS OF ENERGY SAVING BY ENVIRONMENTAL PROTECTION WINDOW

The saving by households is pivotal in bringing down the electricity consumption of the residential sector. It could be demonstrated by making reference to the residential consumption figures given by CLP Holdings [Note 12], the annual electricity consumption of all the households in a typical PRH block of 799 flats is approximately 6 times that of the consumption of its communal building services. It implies that 1% saving of annual electricity consumption of all households in a typical PRH block of 799 flats would be equivalent to approximately 6% saving in electricity consumption of its communal building services installations.

To further raise the awareness in energy conservation among households in PRH blocks, the HA has introduced the "Environmental Protection Window" Scheme at Kwai Shing West Estate (KSWE). This trial scheme is in the form of electronic information display [Note 13] at the ground floor lobby of 10 domestic blocks in KSWE. Apart from cascading energy saving measures and related promotional information to the tenants, the following consumption data are also displayed:

(i) Periodical household and/or communal utility consumption (such as electricity, water and Towngas) of the PRH block;

(ii) Comparison of the consumption figures in current and previous year; and

(iii) Comparison of the consumption figures of a particular PRH block with those of the entire estate as well as the averaged figures of all public housing blocks.

(iv) Environmental protection and energy conservation related videos from Green Groups, Other Government Departments, Utility companies, etc.

Figure 6 The "Environmental Protection Window" Installed at Lift Lobby of KSWE

Figure 7 Sample Statistic of Block 1 on Electricity Saving

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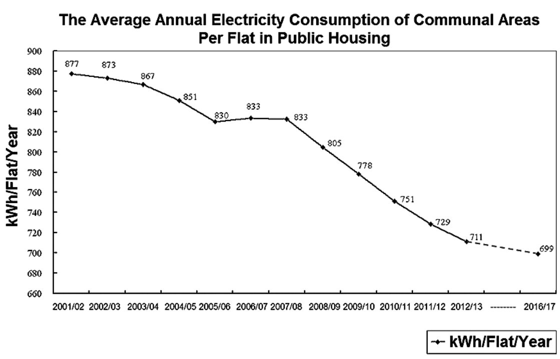
8. CONCLUSION

Climate change and the pressing need of reducing carbon emission have become a global issue and generated worldwide business. It is high time for each of us to action before too late.

In the past, the HA successfully reduced the averaged electricity consumption of communal areas of existing PRH blocks from **877** kWh/flat per year in 20001/02 to **711** kWh/flat per year in 2012/13 through the implementation of a large number of energy saving measures in communal BS installations. In future, with wider use of LED bulkhead lamps in PRH domestic blocks in the coming few years, the HA is targeted to further reducing the averaged energy consumption to **699** kWh/flat per year by 2016/17. Figure 5 below shows the average annual electricity consumption of communal areas during the past twelve years and the projected consumption in the coming five years.

Figure 8 The Projected Per Flat Electricity Consumption in HA



The HA's success in rolling out various measures to promote, reinforce and ensure continuous improvement of energy performance in the design, installation, operation and maintenance of communal BS installations of housing blocks demonstrates that private residential buildings in Hong Kong should have higher potential to improve their energy performance.

We hope that with the concerted effort of all people, the climate change could **be slowed down**!

NOTES

1. The HA was established as a statutory body in 1973 for implementing public housing programmes of Hong Kong. Currently about 30% of the total Hong Kong population live in public rental housing.

2. The information is derived from the energy data shown in the Hong Kong Energy End-use Data 2012 which was issued by EMSD in September 2012.

3. The data are extracted from U.S. Energy Information Administration (EIA) and Minnesotans For Sustainability (MFS).

4. The total and per flat annual electricity consumption of communal building services installations in 2001 /02 are 513 Million kWh and 877 kWh respectively.

5. The total and per flat annual electricity consumption of communal building services installations in 2012/13 are 465 Million kWh and 711 kWh respectively.

6. Data are from Green Peace as reported by Ming Pao in September 2009.

7. The quoted electricity consumption at 807 kWh per flat of a PRH block sourced from Green Peace as reported by Ming Pao was slightly higher than that of the HA's figure i.e. 805 kWh per flat.

8. All new PRH blocks completed in early 2012 have been designed and installed

with 2-stage lighting control to achieve the newly required illumination level (i.e. 85 lux) as stipulated in the Barrier Free Access Manual 2008

9. The lighting level at 50 lux for existing rental blocks was designed based on the previous BFA's requirements which were in force during the construction stage of those existing rental blocks.

10. The estimated cost saving in the amount of $8M was based on data from the concerned lighting fitting suppliers.

11. Reference has been taken from "Guidelines on Energy Efficiency of Lift and Escalator Installations 2000 Edition. The actual saving depends on the lift traffic patterns.

12. 3,941 kWh electricity consumption per household in 2007 (1,960,000 number of residential customers consumed 7,724 gWh from CLP Holdings 2007 Annual Report), and 4,132 kWh per household in 2009 (2,016,000 number of residential customers consumed 8,331gWh from CLP Holdings 2009 Annual Report) indicates 2.4% annual increment. The projected electricity consumption in 2012 is 4,437kWh (i.e. 1.074 x 4,132kWh). 799 households in a typical PRH block would hence consume 3,545,000kWh (799 x 4,437kWh) which is approximately six times the projected electricity consumption of 572,883 kWh (i.e. 717 kWh x 799) of communal facilities.

13. Tentatively, recycled TV sets shall be used for display purpose.

Paper No. 5

ROLE OF ENERGY MANAGEMENT AND SMART METERING IN DATA DRIVEN DECISION MAKING FOR MEGA PROJECTS

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ROLE OF ENERGY MANAGEMENT AND SMART METERING IN DATA DRIVEN DECISION MAKING FOR MEGA PROJECTS

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ABSTRACT

As the field of energy management matures, so do the tools and best practices available to ensure that the energy required by an organization is used in the most efficient way possible. In the past, energy management practices consisted primarily of replacing inefficient equipment and then using any number of methods to estimate the savings gained. Studies performed by the Department of Energy (DOE) and the Texas State Energy Conservation Office (SECO) have shown, however, that energy savings can be dramatically increased and maintained over time by adopting and implementing consistent energy management practices and recognized measurement and verification procedures.

As energy management standards and best practices begin to see widespread adoption, the information systems required to support them will play a crucial role in their implementation and success. These enterprise energy management (EEM) systems can provide the detailed data and analysis capabilities required to ensure energy management strategies and conservation measures are on track throughout an organization. Organizations can apply EEM systems to gain a comprehensive understanding of current energy performance, plan and select cost-effective energy conservation measures, track performance of measures that have been implemented and verify the savings realized.

1. INTRODUCTION

What is Energy Management? The answer to this rhetorical question depends on the context in which this question is asked. The response, therefore, will depend whether the question is posed to a homeowner, an energy policy maker, a plant head of a large manufacturing facility, a building design and engineering firm, a data center owner or a technology and service providing company. Even though the response may elicit unique perspectives, at a fundamental level, everyone will agree that they would like safe, reliable, affordable, and increasingly clean sources of energy supply while consuming it in the most energy-efficient fashion. While energy management, in general, will encompass, major sources of energy such as oil, coal, nuclear, gas, renewable, for the purpose of this article, we will largely restrict the topic to electricity.

For energy management to achieve and deliver its full potential, the following three factors are important:

- Enactment of energy policies and regulations that should keep the public interests in mind and at the same time provide a business friendly environment;

- Innovation and execution by technology and service providers to address the energy challenges in a simple and cost-effective fashion;
- A performance driven market and a conscious customer that encourages competition, values innovation and rewards companies on the value delivered rather than first cost.

2. ROLE OF THE GOVERNMENT AND STANDARD SETTING BODIES

From a policy standpoint, much attention has largely been focused on supply side as developing countries have raced to bridge the gap between demand and supply. However, because of increasing concerns about global warming and major advancements in technologies, many governments are starting to take a much more proactive approach on demand side energy management. This makes a lot of sense considering that only one unit of useful energy reaches end customers for every 3-4 units of fuel that is used to generate power depending on generation and transmission and distribution efficiency. This, coupled with the fact that, the levelised cost of energy (in cents/kWh taking into account Capex, fixed and variable O&M, environmental compliance, land and water, load dispatch costs, etc.) for many energy-efficient technologies such as compact fluorescent lamps, variable frequency drives, energy management systems (if properly used) etc. is less than the thermal power generation cost. Further, as oil and coal prices continue to rise in international markets and concerns about CO_2 emissions rise, many countries face a vexing energy security and environmental compliance issue and energy efficiency and management is widely seen as a major regulatory and policy tool to counter a very high likelihood of energy poverty that many developing countries are likely to face in the future.

3. ROLE OF TECHNOLOGY AND SERVICE PROVIDERS

The volatility and high price of energy has put an increasing pressure on the facility managers and the executives in the energy intensive industries. Organizations now realize that they need to optimize the operations of their own facilities to reduce the cost and consumption of energy. This is particularly important in case of countries where increasing energy costs adversely impact the competitiveness of their businesses and economy. Cost reduction through effective energy management is critical in energy intensive industries where energy cost forms a large percentage of the total operational costs. In such a scenario the ability to cut even a small percentage of total energy consumption can significantly boost the bottom line of the organization.

Energy Management can be described as the judicious and effective use of energy to maximize profits and enhance competitiveness. It is the management of the energy use through measurement, monitoring, and control that affects a positive change in the way activities are carried out. In this paper, I'll discuss the importance of power quality and energy management in the subsequent sections.

3.1 ENSURING POWER QUALITY[1]

Design engineers and facility managers are now required to pay more attention to saving energy and improving the availability of clean electricity at their work sites. Much like bumps and holes in a road impede the progress of an automobile, distorted voltage in AC distribution systems negatively impacts operations and drives up expenses. This section analyzes the potential negative impacts of power factor and harmonics on energy efficiency and offers practical approaches for improvements.

In AC distribution systems, the maximum active power is transmitted to a load when voltage and current are in phase and undistorted. When voltage and current are phase-shifted, the instantaneous power P = V x I is negative when the signal signs are opposite. The average power is then reduced compared to the situation where the signals are in phase. When a current is distorted, the instantaneous power fluctuates significantly. The average power is then reduced compared to a situation where the current is undistorted. The current distortion means that harmonics are present, generated by non-linear loads. The Total Harmonic Distortion (THD) is the usual parameter to evaluate the distortion of current (THD_i) or voltage (THD_u).

Another major consequence of harmonics is the deterioration of the supply voltage quality. The circulation of harmonic currents through the system impedance creates voltage harmonics resulting in voltage distortion. The negative impact may remain un-noticed, with adverse economic results. Power Factor Correction and proper harmonic mitigation can contribute to improved operations within companies in several ways:

- reduced overloading on the electrical system thereby releasing useable capacity
- reduced system losses and demand power
- reduced risks of outage
- extended equipment lifetime

Numerous approaches can be deployed to address harmonics and power factor issues in a facility. The following section illustrates some of the main categories of options.

Capacitor banks improve power factor correction and help to avoid reactive energy penalties charged by the utility. Capacitor bank equipment may be connected at the following levels of the facility's power infrastructure installation: medium voltage (MV) substation, low voltage (LV) main switchboard, LV secondary switchboard, and machine terminals.

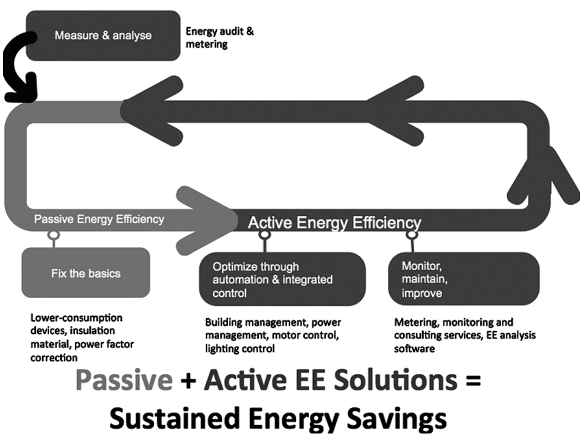
Active filters are systems employing power electronics which provide the harmonic currents required by nonlinear loads thereby avoiding distortion on the power system.

Passive filters are implemented when Power Factor Correction is requested with a high level of existing harmonic distortion. These filters consist of reactors and capacitors set up in a resonant circuit configuration, and are tuned to the frequency of the harmonic order to be eliminated.

3.2 ENERGY MANAGEMENT SOLUTIONS

As shown in the figure below, energy improvement strategies can be grouped into two broad categories: active and passive. The energy management process begins with fixing the basics. The apparent sources of energy wastage need to be identified and rectified. This may include measures like replacing incandescent lamps with CFLs, installing insulation in buildings or in a boiler jacket or in steam and chilled water pipes, etc. These processes do not require large investments and yet help in achieving considerable energy savings. This category of energy management measures are referred as passive energy efficiency measures. Active energy management measures include monitoring and control systems and automation techniques to further fine-tune the operation of energy consuming systems. For example lighting makes up about a quarter of the energy consumed in Indian commercial buildings and lighting control solutions that enable optimization in terms of both function (visual comfort by reducing glare) and energy usage are available in the market.

Figure 1: Achieving Energy Efficiency Through Passive and Active Energy Management Strategy



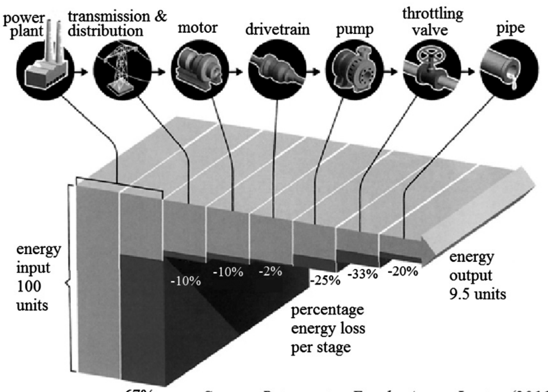
The solutions to the energy challenge are multiple and complex. In most cases, these solutions rely on a stronger and more efficient collaboration between the key stakeholders (facility and building managers, IT managers, factory supervisors, plant engineers). A true understanding of energy management reveals that component level efficiency is only the first step and does not necessarily translate into efficiency gains as expected by customers. The levels of efficiency required must involve system dynamics across segments, platforms, and providers like never before. Recent advancements in Energy Management hardware and software is creating intelligent, simplified systems that save money, and most importantly, reduce waste by enabling a guaranteed compatibility between the management of power, white space, process and machines, building control, and security.

Today's Energy Management Systems (EMS) allow trending of real time and historical data to perform a load flow analysis of a particular load or a complete installation. This helps in evaluating how close is the energy consumption of a plant or an installation to its design capacity. This is very useful information for anyone considering upgradation in facilities or reducing operating costs. EMS also facilitates study of variation in electrical load profile and thus provide faster response to periods of peak demand. The energy costs can be reduced by pinpointing the source and length of peak demand. The load can be staggered or planned in order to reduce this peak demand and thus it is a very good tool for controlling the costs. They also have advanced communication capabilities and enable access to the energy data of a facility from a remote location. Remote energy management increases the visibility of energy consumption by providing real time access to data on a 24 X 7 basis. It enables an energy manager to undertake predictive maintenance tasks rather than being reactive to unscheduled power outages. Energy managers or outside experts can remotely monitor energy consumption via wired or wireless links to the electrical installations. Based on data collected, these experts make recommendations that can help in adopting a proactive approach rather than a reactive approach.

4. ROLE OF THE CUSTOMER

Managing energy for large and medium-sized enterprises is an increasingly complex and specialized activity in today's world. As Amory Lovins so eloquently explains in the following figure (saving energy all the way downstream, at the point of consumption, turns compounding losses (left to right) to compounding savings (right to left) of both energy and capital), a typical Plant Manager will have to fully understand the inefficiencies in the entire value chain of a typical pumping system to make a proper assessment and arrive at the correct decision.

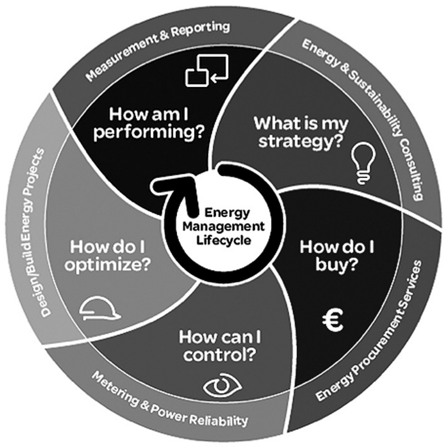
Figure 2: Energy Inefficiency in a Typical Pumping System



Source: Reinventing Fire by Amory Lovins (2011)

Therefore, effective energy management for today's organization can be seen as a lifecycle approach that begins with a high level energy management strategy encompassing energy efficiency, sustainability, and cost reduction goals of any organisation. Today, the owner of a large enterprise need to look at its connected load and at the procurement choices based on the existing regulations while thinking about the different interventions that can be done starting with a Energy Monitoring and Controls system, focused energy assessment of sites which are worst performing, and then developing solutions that will be implemented on site.

Figure 3: Energy Management Lifecycle Approach for Large Organisations



With customers' requirements becoming increasingly complex, they are demanding elegant and innovative solutions for the mega projects that are being commissioned today. One of the things that I have observed in our best customers is a move to "Data Driven Decision Making" approach. This starts with the creation of a basic metering network to identify clearly where all forms of energy is getting consumed. This is followed by identification and installation of an Energy Management System at the design stage since the

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cost of implementation in a Greenfield project can be substantially lower than retrofitting an existing facility which may even require plant or facility shutdown, which is never a pleasant option. While creating the metering network and selection and installation of an energy management system, it is an excellent idea to pay close attention to the utility bills and any demand-side management or demand response programs on offer by the local utilities. This knowledge can greatly help in the selection of the smart meters that can help the customer in taking advantage of any of the above programs. By taking into account some of these basic energy management principles, some of the challenges posed by today's mega projects can be addressed.

4.1 USING ISO 50001 TO ENABLE ENERGY MANAGEMENT IN ENTERPRISES

Realizing the importance of Energy Management, International Standardization Organization has introduced an energy management standard to its vast portfolio of globally accepted standards. ISO 50001:2011 specifies requirements for establishing, implementing, maintaining and improving an energy management system, whose purpose is to enable an organization to follow a systematic approach in achieving continual improvement of energy performance, including energy efficiency, energy use and consumption. It offers clear and practical help to introducing an EMS, no matter what the status quo of energy consumption, size of the organisation or which industry. ISO 50001 supports organizations in all sectors to use energy more efficiently, through the development of an energy management system. ISO 50001 standard introduced the first-ever uniform criteria for certified EMS which is valid in every country and for every company and organisation. Companies can use to develop and introduce energy policy, to set strategic and operative goals, and to determine action plans. By adopting the standard, companies and organisations can determine their energy savings potential and improve energy efficiency. Energy consumption can be rapidly reduced, and long-term efficiency is clearly improved. According to German Federal Environmental Agency[2], there were approximately 3000 businesses worldwide that were ISO 50001 certified with more than half in Germany (1624 businesses), followed by UK (315), Sweden (143), India (71), Korea (54), France (36), Denmark (32), Japan (31), USA (20), and China (2) in June 2013.

5. CONCLUSIONS

This paper has addressed the importance of energy management in today's resource constrained world where government, consumer, and technology and service providers are all interested in energy efficiency creating a win-win-win situation. It also looks at the power quality and energy management challenges that are faced by a large number of businesses and offers practical and off the shelf technologies that can be deployed to address these challenges. Finally, the paper looked at ISO 50001, a new energy management standard that provides an excellent framework for businesses to institutionalize energy management at their facilities by adopting a very systematic approach and through the installation of energy management systems

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Paper No. 6

ENHANCEMENT OF THE LIGHTING AND CONTROL SYSTEM OF ABERDEEN TUNNEL

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ENHANCEMENT OF THE LIGHTING AND CONTROL SYSTEM OF ABERDEEN TUNNEL

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ABSTRACT

Tunnel Lighting and Control System (TLCS) is one of the most critical systems of a road tunnel to ensure safety and to provide visual comfort for the motorists. Aberdeen Tunnel, a 1.9 km long two-tube road tunnel, linking the north and the south of Hong Kong Island, was commissioned in 1982. The existing TLCS has been put in service for over 30 years. Its failure in any aspects will cause inconvenience to tunnel users and adversely affect the traffic to the Southern District or even the whole Hong Kong Island. To enhance reliability and efficiency, the TLCS will be replaced in order to meet current energy efficiency requirements, to provide better lighting control and to be in compliance with the latest design standards. The project will involve the replacement of about 3,600 sets of tunnel luminaries, a lighting control system, and modification of the power supply with dual supply sources.

This paper presents the background information, design criteria, system enhancement and the anticipated challenges in this replacement project.

1. BACKGROUND INFORMATION

Aberdeen Tunnel marks an important improvement in road communications between the southern side and the commercial areas on the north shore of Hong Kong Island. The two-tube tunnel, with the carriageway measuring 6.75m wide and the clear headroom of 5.1m, runs through Mount Cameron and Mount Nicholson. Each tunnel tube has two traffic lanes and carries traffic from Aberdeen to the northern part of Hong Kong Island and the Cross-Harbour Tunnel, thus relieving congestion on the road at the western Mid Levels. The daily flow was 65,000 vehicles in 2012.

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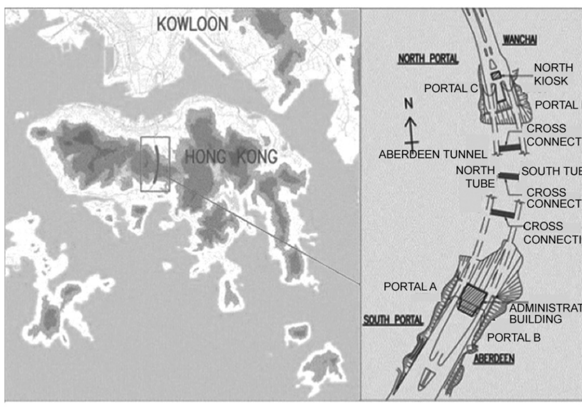
Figure 1 Location of Aberdeen Tunnel



The existing tunnel lighting system has been in use since 1982 following the tunnel commissioning. The TLCS has reached the end of its serviceable life. Any failures in the lighting system will cause inconvenience to tunnel users and adversely affect the traffic between the Southern District and other parts of Hong Kong Island. It will also very likely have a knock-on effect on other major road networks on the Island. To enhance the reliability and efficiency of the tunnel lighting system as well as the safety of tunnel users, replacement of the system is deemed necessary.

2. TUNNEL LIGHTING SYSTEM

The objective of a tunnel lighting system is to ensure that traffic can enter, pass through and leave the tunnel, day and night, with the same level of safety as on the approaching open roads. To achieve this, it is necessary for the carriageway to be clearly visible throughout the length of the tunnel, and that the carriageway and tunnel walls give a clear view of the road. In further details, the lighting must meet the following requirements[1]:

- The lighting shall give the carriageway an adequate luminance level, and the luminance shall be uniformly distributed over the carriageway, in wet and dry conditions;
- The lower part of the tunnel wall must receive an adequate level of luminance;
- The lighting must not give rise to glare; and
- The lighting must not produce flicker.

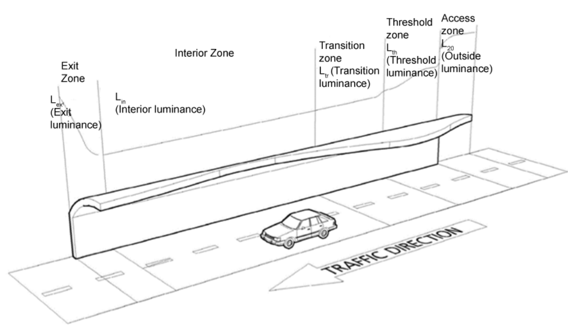
The most important function of tunnel lighting is to illuminate the tunnel sufficiently to enable the drivers to see all that needs to be seen during the entire passage of the tunnel. Tunnel lighting is most critical during daytime because the eye, accustomed to daylight, cannot immediately adapt to the relative darkness of the tunnel. As it takes time for the eye to adapt, it is necessary for the light intensity to decline from daylight to the lower level in a tunnel over a certain distance. If the lighting level is not high enough, the driver will be unable to see inside the tunnel, the so-called "black hole effect"[2].

3. DESIGN CRITERIA

3.1 LIGHTING ZONES

In designing tunnel lighting systems, it is necessary to take care of good visibility conditions for the motorists, which require lighting levels that match the adaptation of the motorists' eyes. As the adaptation level gradually changes throughout the tunnel, for lighting purposes, a tunnel can be divided into five lighting zones[3], namely the access, threshold, transition, interior and exit zones.

Figure 2 Light Zones of a Road Tunnel



3.2 LUMINANCE REQUIREMENTS

STOPPING SIGHT DISTANCE

It is the forward distance required by a motorist, driving at a designated speed, to bring a vehicle to a complete standstill safely. It covers the distance for perception, reaction and breaking. The stopping sight distance is a function of design speed as shown below:

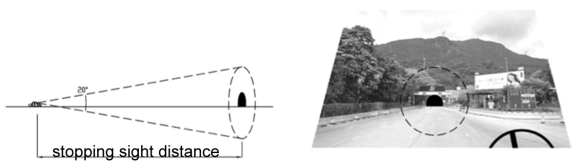
Table 1 Stopping Sight Distance vs Design Speed

Design Speed (km/h)	50	60	70	85	100
Stopping sight distance (m)	50	70	90	120	160

LUMINANCE OF THE ACCESS ZONE: L_{20}

Luminance of the access zone can be determined by direct measuring the average luminance from surroundings, sky, tunnel entrance and road in a visual cone of 20° centred on the line of sight of the driver from the beginning of the access zone[4].

Figure 3 Measurement of Luminance at Access Zone



Alternatively, L20 can be estimated during the initial design stage by using typical luminance values of different types of background surrounding the entrance of the tunnel.

Typical luminance ranges from a few thousand to tens of thousand Cd/m^2.

LUMINANCE OF THE THRESHOLD ZONE: L_{th}

The maintained average road surface luminance over the first half of the threshold zone $L_{th(1)} = k\ L_{20}$ where k equals to:

Table 2 K Values

Design Speed (km/h)	k value
50	0.04
60	0.04
70	0.05
85	0.05
100	0.07

The lighting level for the other half of the threshold zone ($L_{th(2)}$) may gradually and linearly reduce to 0.4 $L_{th(1)}$ at the end of the threshold zone.

LUMINANCE OF THE TRANSITION ZONE: L_{tr}

The minimum lighting level required is depicted by the formula[5]:

$L_{tr} = L_{th(2)}\ (1.9 + t)^{-1.4}$ where t is the time in second a motorist enters the transition zone. The end of the transition zone is determined by the lighting level that has been dropped to three times the lighting level in the interior zone.

LUMINANCE OF THE INTERIOR ZONE: L_{in}

The lighting level in the interior zone at various design speeds is stipulated as follows:

Table 3 Lighting Level in Interior Zone

Design Speed (km/h)	Daytime Interior Zone maintained Average Luminance (Cd/m^2)
50	4-5
60	4-5
70	5-6
85	5-6
100	8-10

LUMINANCE OF THE EXIT ZONE: L_{ex}

Exit zone lighting shall be provided to assist egress adaptation and enable motorists to view the following traffic by rear view mirrors. The lighting level over the last 60m of the tunnel shall be 5 times the level of the interior zone.

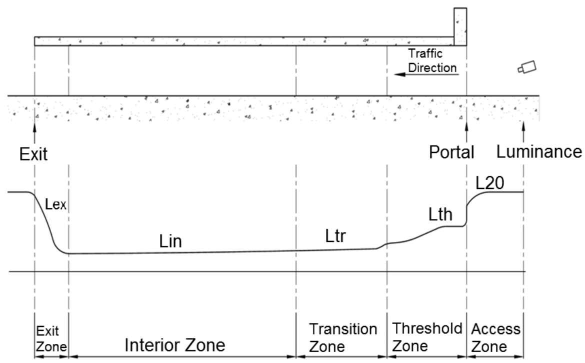
The luminance requirements for the different lighting zones of a road tunnel are summarized as follows:

Table 4 Luminance for Different Lighting Zones

Zone	Luminance	Remark	Typical (Cd/m^2)
Access	L_{20}	By measurement / Estimation	5,000
Threshold	1st half: $L_{th}(1)$: 0.04-0.07 L_{20} 2nd half: $L_{th(2)}: L_{th(1)} \rightarrow 0.4L_{th(1)}$	Reduction of lighting level between successive steps shall not exceed 3:1	250 → 100
Transition	$L_{tr} = L_{th(2)}\ (1.9 + t)^{-1.4} \rightarrow 3L_{in}$		100 → 15
Interior	L_{in}	4-10 Cd/m^2	5
Exit	$L_{ex} = L_{in} \rightarrow 5\ L_{in}$	-	5 → 25

The lighting level at the entrance of a tunnel, i.e. threshold zone, is much higher than that at the exit zone because the adaptability of the eye on between entry to a tunnel from daylight and leaving from a tunnel into daylight is not symmetrical. The eye adapts far more quickly to the higher luminance level for the latter case.

Figure 4 Typical Longitudinal Section of a Tunnel



4. SYSTEM ENHANCEMENT

4.1 LIGHTING LUMINARIES

All existing T8 luminaries will be replaced by T5 luminaries. Under normal conditions, T5 luminaries have a higher luminance efficacy (lm/W) than that of T8 luminaries and are designed for operating with electronic ballasts with greater efficiency. For instance, a 28W T5 luminaire consumed only 30W circuit power and achieved a saving of 36% as compared with 36W T8 luminaire with conventional ballast[6].

As the diameter of T5 tubes is much smaller than its T8 counterparts, and is closer to a line source, optical control of luminaries with T5 lamps can be more precise and efficient, and hence result in less glare.

4.2 LIGHTING CONTROL SYSTEM

At present, all the tunnel lighting luminaries are controlled by hard-wired contactors. The lighting control can be determined either manually or automatically by means of photometers, installed at both ends of the tunnel, which detect the lighting level outside the tunnel. There are altogether 6 lighting stages in accordance with different lighting intensities outside the tunnel. However, such control system lacks the flexibility in meeting the change in programmed scene, re-grouping of luminaries and integration of settings in a daylight-dependent control system.

The new TLCS will be operated with DALI (Digital Addressable Lighting Interface) as the communication interface for the lighting system. A DALI network consists of a controller and one or more lighting devices such as ballasts and dimmers that interfaced with DALI. The controller can monitor and control each light by means of a bi-directional data exchange. The DALI protocol permits devices to be individually addressed and it also incorporates broadcast messages to simultaneously address multiple devices, leading to the flexibility in the control of the lights, without the need for formidable wiring connections.

On the other hand, the TLCS will be equipped with a powerful and versatile 32-bit CPU. The master CPU will switch over to the standby CPU within 50ms when the master CPU fails. Redundancy will also be provided for the power supply and the network communication.

Four modes of operation will be provided:

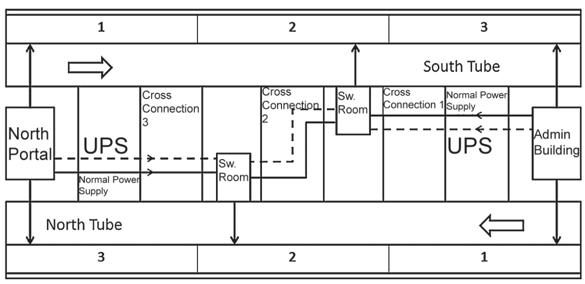
- Automatic Mode with 6 lighting stages;
- Remote Manual Mode;
- Local Manual Mode;
- Traffic Operation Mode.

The new TLCS will feature distributed intelligence for flexible and reliable control. The control of lighting can be applied to both individual lights and groups of light. In case of changing circumstances, configuration and reconfiguration will be simple by changing the settings of the system without any re-wiring. One added advantage of the system is that the logarithmic dimming behaviour of the system matches the characteristic of human eyes and results in a much smoother transition between different stages of lighting.

4.3 MAIN POWER SUPPLY SYSTEM

The power supply system of the tunnel is composed of two separate municipal main power sources and two Uninterruptible Power Supplies (UPS).

Figure 5 Existing Power Supply Arrangement



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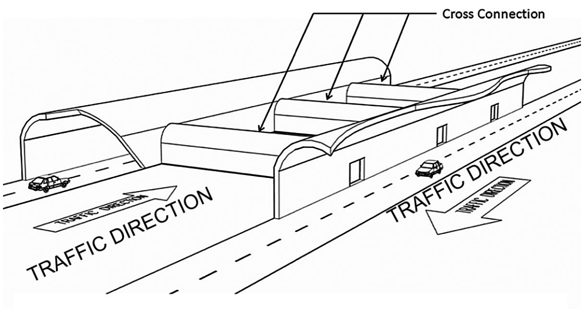
For the existing design, tunnel lighting luminaires of the proximal end of approximate two-thirds of the South Tube and one-third of the North Tube are fed from the main power source at the Administration Building (South Portal) and similar arrangement for the rest fed by the main power source at the North Portal. Should either one of the main power sources fail, approximately 60% of the lighting can be maintained; and in case of both of them fail, about 20% can be maintained by means of the UPS.

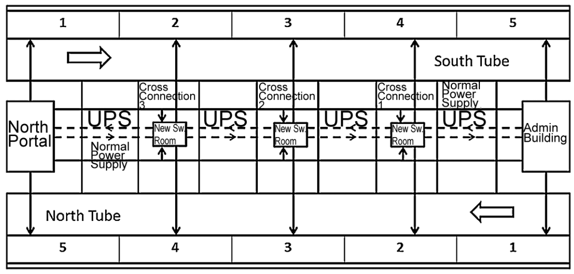
Nevertheless, the existing arrangement lacks the integrated support by the two separate municipal main power sources, and the two UPS sources. In this project, the reliability of the tunnel lighting system will be further enhanced by rearranging the municipal main power supply sources and the UPS. In re-designing the power supply system, we make use of the three cross connections between the North Tube and the South Tube of the tunnel as shown below:

Figure 6 Cross Connections of Aberdeen Tunnel



New switch boards will be erected inside the three cross connections so that the municipal main power supply from the North Portal and the South Portal can reach the whole length of the tunnel and provide power to any part of the tunnel.

Figure 7 New Power Supply Arrangement



In the new design, about half of the luminaires in the whole length of the South Tube and those of the North Tube will be fed from the municipal main power sources at both the North Portal and the South Portal. In case where either one of the main power sources fails, the tunnel luminaires will be 100% supported by the other healthy main power source by automatic transfer switching. Even when both main power sources fail, 40% of the lighting can be maintained by the UPS.

5. ANTICIPATED CHALLENGES IN PROJECT MANAGEMENT

5.1 INTERFACE BETWEEN EXISTING AND NEW SYSTEMS

In order to maintain the normal operation of the tunnel in daytime during the replacement period, the interface between the existing and the new system has to be well planned ahead. As there will be difference in the luminance and zoning between the existing system and the new system, the way to ensure a seamless transition from the existing system to the new system, and to ensure no interruption of tunnel service by maintaining a reliable TLCS during the installation period has to be carefully devised. One of the possible ways may be that the new system is to be installed without disrupting the integrity of the existing system and in case of any hiccups, the TLCS can be reverted to the existing system right away until the problem is solved. However, this is subject to the constraints of space, additional work and prolonged work period.

5.2 NIGHT TIME WORK

Nearly all the works have to be carried out at tunnel closure time in order not to affect the normal traffic during daytime. In this regard, most of the site work has to be carried out around the midnight period. Work programme has to be carefully planned ahead in order to tally with the tunnel closure time on one hand, and to ensure that work can be completed in time on the other.

5.3 WALL PANELS

Preliminary design indicates that both power cables and control wires will have to be laid on cable ladders to be installed inside the wall panels. In order to facilitate the erection of cable ladders, the laying of cables and the installation of saddles and cleats, a number of wall panels will have to be taken apart during the working period. Normally, the wall panels can only be taken apart during inspection checks arranged by the tunnel maintenance party. Extensive coordination work will be required to match our installation programme with the inspection check schedules.

5.4 LUMINANCE MEASUREMENT

In order to capture the existing luminance profile of the tunnel, a number of measurements will have to be carried out during the tunnel closure period. However, in case where measurements have to be taken in daytime with tunnel closure such as the measurement of the luminance of the Access Zone (L20), the operator will definitely disapprove of such proposal because of the heavy traffic unless the measurement can be done in a really short period. In this regard, adequate preparation with detailed method statement approved by all stakeholders including the relevant government departments and the tunnel operator is necessary. In order to minimize any possible muffs during actual measurement, prior arrangement with trial runs by the measuring team will have to be planned.

6. CONCLUSION

Despite the constraints mentioned above, we have confidence that after completion of the work in late 2015, the new TLCS will become more environmentally friendly and flexible in operation, and the new power supply system will be more reliable. All in all, the reliability and efficiency of the TLCS will be significantly enhanced.

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Paper No. 7

ENVIRONMENTAL CONTROL SYSTEM (ECS) AND LIGHTING ENERGY SAVING INITIATIVES FOR NEW RAILWAY LINES

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ENVIRONMENTAL CONTROL SYSTEM (ECS) AND LIGHTING ENERGY SAVING INITIATIVES FOR NEW RAILWAY LINES

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ABSTRACT

ECS and Lighting are two of the major power consumption components in railway operation. If electrical power can be saved through the use of energy saving devices and system, this will help to save a lot of electrical energy and contribute to green environment. The Paper is to address the various means of green initiatives in these two aspects that will be implemented in the new lines of West Island Line (WIL), South Island Line (East) (SIL(E)), Express Rail Link(XRL), Kung Tong Line Extension (KTE) and Shatin to Central Link (SCL), and other future railway extension projects.

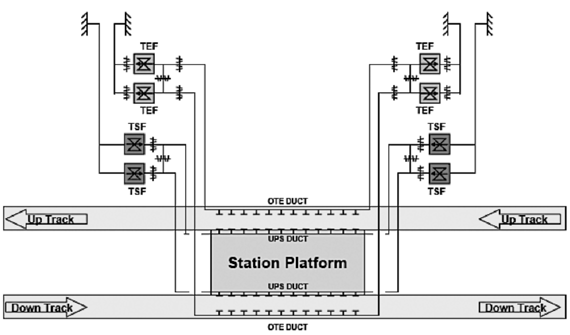
1. INTRODUCTION

Air-conditioning and Mechanical Ventilation, and Lighting are major components of electrical energy users in railway premises. The former is used to provide a comfort environment to the passengers and equipment serving the railway lines, and the latter furnish a suitable illumination level so that various activities can be performed. Every measure is used to reduce the electrical energy consumption arising from these means. Energy efficient device and system emerge with the advance in technology, and hence help to protect the environment.

2. TRACKWAY VENTILATION SYSTEM

In the open system, the platform of the enclosed stations will be separated from the trackway by platform screen doors. The ventilation inside the trackway will be served by the Trackway Ventilation System. It comprises of Trackway Exhaust Fans (TEF) and Trackway Supply Fans (TSF), and is used to remove the heat generated from train when it is stopped inside the station's trackway. During the non-peak periods, part of these ventilation fans can be switched off without affecting the temperature inside the trackways. There are three ways that electrical energy can be saved.

Figure 1 Typical Trackway Ventilation System for Underground Stations



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2.1 TEMPERATURE CONTROL

Temperature-controlled Trackway Ventilation System is to install temperature sensors inside the trackway just outside platform. Ventilation fans shall respond to the temperature measured instantaneously from trackway, and start / stop the trackway ventilation fans, and hence electrical energy saving can be achieved through stopping the ventilation fans when the trackway temperature is below an adjustable set point temperature. This will be installed in SCL project and future railway extension projects.

The advantage of this provision is that it is automatic, and this can be overridden by the emergency mode.

2.2 HALF-PLANT MODE

Half plant mode is to operate half of the fan plants to achieve electrical energy saving during mild and winter seasons. The provision is to allow the Operator to start / stop fan plants manually in accordance with the operation needs.

This mode can provide a back-up to the temperature control. Also, it can be overridden by emergency mode.

The estimated saving using the two types of controls are as shown in Table 1.

2.3 HIGH EFFICIENCY MOTORS

Motors with highest efficiency are specified in order to further reduce the electrical energy consumption. This is particular true for a motor around 70 kW each, such as those motors used for tunnel ventilation. Usually, high efficiency motors can provide 3-5% improved efficiency over conventional motors.

Table 1 Estimated Electrical Power Savings with Temperature-controlled Trackway Ventilation System and Half-plant Mode for a Typical Under-ground Station

Estimated Savings	Temperature-Controlled Trackway Ventilation System	Trackway Ventilation System with Half-plant Mode
Annual Saving During Hot Seasons in Non-Peak Periods (from May to Oct)	296 MWh	148 MWh
Annual Saving During Mild Seasons (from Nov to April)	1,483 MWh	1,252 MWh
Annual Saving per Station	1,780,000 KWh	1,400,000 KWh
Annual Saving in Electrical Costs per Station	HK$ 1,602,000	HK$ 1,260,000

Note: Typical Power of TEFs and TSFs at each station is 540 kW.

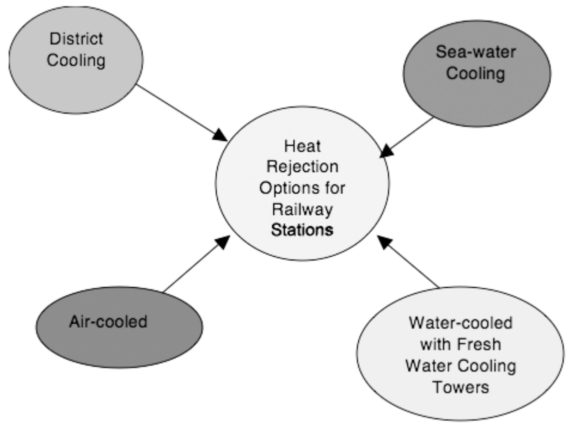
3. STATION ECS

3.1 AIR-CONDITIONING HEAT REJECTION SYSTEM

There are various heat rejection schemes for air-conditioning system in railway stations, namely Air-cooled, Water-cooled with Fresh Water Cooling Towers, Sea-water Cooled and District Cooling.

The selection depends on a number of factors such as proximity to nearby residents, sea-side, district cooling site, and cooling capacity required. For the five new lines, there are various heat rejection schemes adopted suiting various considerations.

Figure 2 Various Heat Rejection Options for Railway Stations

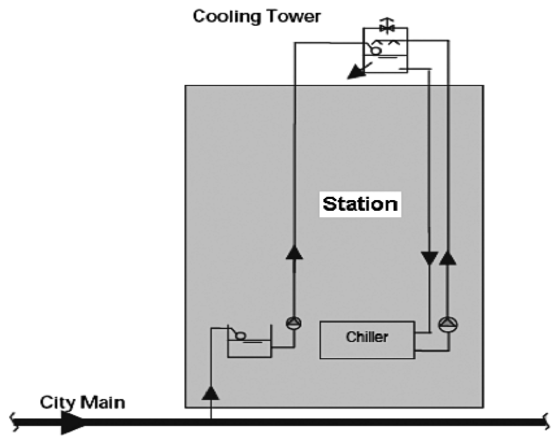


Cooling Options	New Lines	Stations
Water-cooled using Fresh Water Cooling	WIL	Sai Ying Pun, Hong Kong University, Kennedy Town
	KTE	Ho Man Tin, Whampoa
	SIL(E)	Admiralty, Lei Tung, South Horizons
	SCL	Hung Hom, Diamond Hill, Admiralty, Exhibition
Sea-water Cooled	XRL	West Kowloon Terminus
District Cooling	SCL	Kai Tak, To Kwa Wan
Air-cooled	SIL(E)	Ocean Park, Wong Chuk Hang
	SCL	Ma Tau Wai

3.2 WATER-COOLED CHILLED WATER SYSTEM

For new railway lines, the chilled water system to serve the air-conditoning system in stations will adopt the water-cooled system as a first choice. Compared with air-cooled system, water-cooled system is more energy efficient. In the five lines under construction, most of the stations are adopted water-cooled for cooling the heat rejection circuit.

Figure 3 Fresh Water Chilled Water Plants for New Extension Projects



3.3 DISTRICT COOLING

This is more efficient due to bulk production of cooling at one location and provides chilled water over the district. Kai Tak District Cooling Scheme is available for SCL's stations in the vicinity. Savings were found in both energy costs and plant space. There is also no maintenance requirement for chillers. Transformer requirements in stations can be less.

Two EWL stations, namely Kai Tak Station and To Kwa Wan Station, which are close to Kai Tak District will make use of District Cooling System for providing chilled water to serve the public area's air-conditioning system.

3.4 WATER-COOLED VRV (VARIABLE REFRIGERANT VOLUME) SYSYEM

Water-cooled VRV System is employed to serve the Back-of-House air-conditioning. This has the advantage of being more energy efficient than the ones with air-cooled. The cooling tower plant serving VRV System will be common to the central plant serving the water-cooled chillers.

3.5 COOLING TOWER WITH TWO SPEED FANS

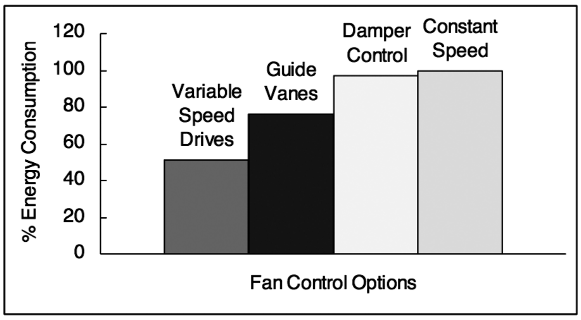
Fresh water cooling towers are frequently used to cool the condensing water from water-cooled chillers. Two speed fans are used to serve the cooling towers by detecting the incoming cooling water temperature. Higher speed can be selected to cater for the peak load, and lower speed for partial load to save the electrical demand of fan motors under light duty.

3.6 VARIABLE SPEED DRIVES (VSD)

Nowadays, variable speed drive is commonly used in many areas of air-conditioning and mechanical ventilation system. The application of Variable Speed Drives (VSDs) can reduce power consumption in the Air-conditioning and Mechanical Ventilation system.

As the motor power consumption varies approximately with $(\text{Motor Speed})^3$, a 20% reduction of motor speed can achieve 50% saving in power consumption.

Figure 4 Comparison of Energy Consumption Amongst Various Fan Control Options if Fan Speed Reduces by 20%



Air-conditioning systems are not usually required to operate at full load. By using VSDs in the fans and AHUs, the ventilation provided is reduced to better match with the space requirements over time of the day, and can significantly reduce energy consumption. VSDs can also be used in pump motors in the chilled water system and the cooling tower, if water-cooled chiller is adopted. The pump can reduce its speed to operate below its maximum rating to control the water flow to meet the load requirement when the cooling demand is low.

3.7 DEMAND SIDE FRESH AIR SUPPLY

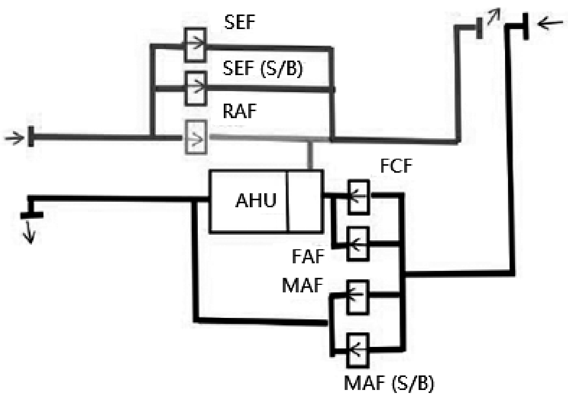
The temperature and humidity of outside fresh air is high during the summer seasons. If the amount of fresh air induced into the space can be reduced, there will be a lot of saving in cooling load. Demand side control is to install carbon dioxide sensor in space to control the amount of fresh air intake to space. This will not affect the oxygen content in stations, but at the same time can reduce the cooling load in stations.

3.8 FREE COOLING MODE

During the mild and cold seasons, the outside air temperature is relatively low. Free cooling mode will make use of the relative cool outside air to cool the concourse and platform of the underground stations. As internal heat is still generated during mild seasons and cold winter, free cooling makes use of FCF (Free Cooling Fan) to introduce cold outside air to cool down the internal environment, and RAF (Return Air Fan) to extract inside air to outside through ventshafts for air exchange. Electrical energy can be saved on not operating the chillers and chilled water pumps in stations.

Temperature and humidity sensors shall be used and located in strategic locations to monitor the outdoor and indoor conditions and to control the Station ECS.

Figure 5 Stations with Free Cooling Provisions

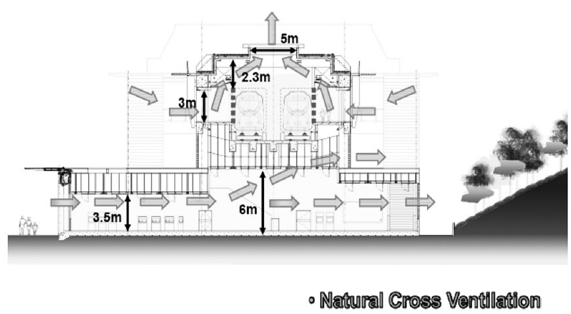


3.9 NATURALLY COOLED STATIONS

Platforms of elevated stations such as Ocean Park Station and Wong Chuk Hang Station of SIL(E) and Hin Keng Station of East West Line of SCL are designed for natural ventilation. Automatic platform gate and louvers are provided so as to facilitate air movement from ambient.

Spot cooling using variable refrigerant volume units or linear fans can enhance the localized thermal comfort of passengers waiting at the platforms for boarding trains.

Figure 6 Natural Ventilation for HIK Station



4. LIGHTING SYSTEM

4.1 HIGH EFFICIENCY LAMPS

T5 lamps are designed for lighting in WIL, SIL(E), XRL, and KTE. Approx 27% of station lighting energy consumption can be saved. As LEDs are developed rapidly over recent years, energy efficient LED lamps are proposed to be used to serve the public areas of stations of SCL. With this move, more electrical energy can be saved by adopting LED lamps.

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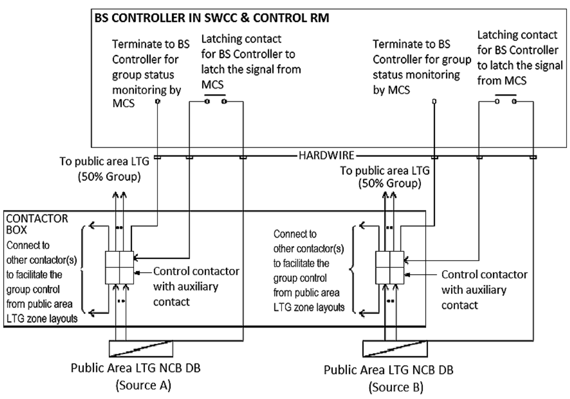
Figure 7 Use of High Efficiency Lighting for New Extension Projects

4.2 LIGHTING CONTROL

Public areas can be divided in zones for lighting control on demand. Approx. 7% saving of station lighting energy consumption will result. Each lighting zone shall be designed to cover 1,000 m^2 approximately to suit the operating requirements for traffic hours, non traffic hours, maintenance and cleaning purposes.

Figure 8 Typical Lighting Control & Monitoring for Platform and Concourse



4.3 USE OF DAYLIGHT

For areas where daylight can be used, photo sensors will be engaged to switch off the lighting. When the photo sensors detect the illumination reaching the predetermined lux level, its control system will send out a signal to switch off the lighting accordingly. Energy saving can then be achieved.

Daylighting will be adopted in the G/F entrance and atrium of West Kowloon Terminal. Ocean Park Station and Wong Chuk Hang Station of SIL(E) are above-ground stations which provide a good opportunity to maximize the use of daylight. Skylights are used to induce daylight into the station during daytime.

Figure 9 Use of Daylight in Stations (Station's Facades with Glass Panels to Allow Sun Light Going into Station)

4.4 SOLAR PHOTOVOLTAIC PANELS

Solar Photovoltaic Panels were used in Government Projects, such as, Kennedy Town Swimming Pool Re-provision entrusted under WIL. The use of it in stations will require further study in aligning with the building facades.

4.5 LIGHT-PIPE

Light-pipe is being used in some of the site offices to illuminate the public corridor of site offices. Light-pipe is a simple passive device mounted on a roof top allowing sunlight to be piped down into a room through highly reflective silverised mirror-finished aluminium tube. This system maximizes the utilization of renewable energy by reflecting and intensifying direct sunlight and/or normal daylight down through the tube.

4.6 SOLAR LIGHTING

Installation of solar lights for the external area of new stations or ancillary buildings could be considered. Street lights with integrated solar panels as well as wind turbines are now commercially available. This will be further investigated to be used in future railway lines where lighting on external areas can be employed.

5. CONCLUSION

This paper highlights some energy saving measures adopted for ECS and lighting systems in stations of new railway lines. A lot of electrical energy can be saved through implementing these measures. For other energy saving measures not adopted yet, this will be put into further technical review. Successful systems and measures will be stated in the Design Standard Manual and fully implemented for all future new lines.

Paper No. 8

WEST ISLAND LINE SHEUNG WAN 54-HOUR CHANGEOVER WORKS

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WEST ISLAND LINE SHEUNG WAN 54-HOUR CHANGEOVER WORKS

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ABSTRACT

The MTR Corporation, being the operator of the transportation backbone in Hong Kong, is dedicated to keeping up the pace of urban development and addressing the increasing demand for passenger service. Apart from continually improving the throughput and effectiveness of the existing lines, MTR is in the midst of building five new lines/extensions, which are progressively scheduled for completion from 2014 to 2020. These projects, targeted to extend the coverage of existing railway network, all require the implementation of substantial enabling and interfacing works on existing infrastructure to facilitate connections to the operational railway lines. Such works must be carried out meticulously and with detailed planning in order to avoid undue disruption to the public.

In this paper, the entire course of the West Island Line Sheung Wan 54-Hour Changeover Works is presented, which includes various aspects of the preparation, planning and implementation.

Figure 1 West Island Line

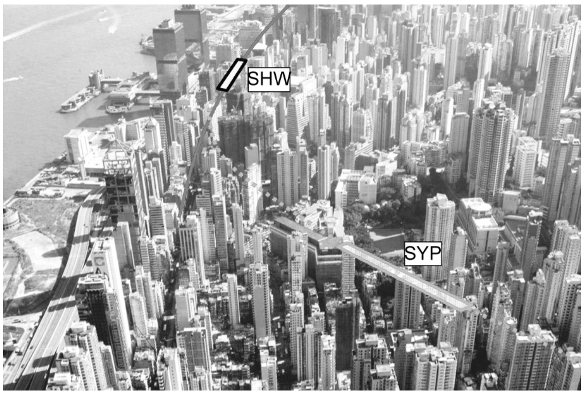
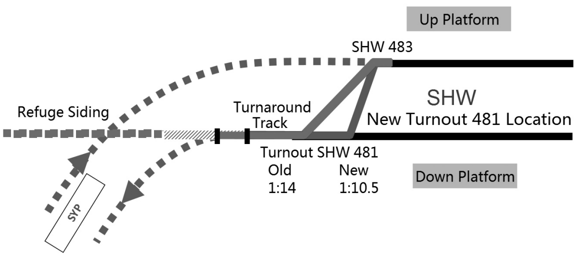


Figure 2 West Island Line Alignment



1. BACKGROUND

The alignment of the West Island Line under construction is such that Sheung Wan (SHW) Refuge siding has to be abandoned and the turnaround track leading to it shortened and realigned to give way. This means that turnout SHW481 leading from SHW down platform to the turnaround track and then back to SHW up platform has to be relocated 15 metres closer to SHW and replaced by one with a sharper curve. And the overhead line has to be realigned in unison and the signalling system modified.

Once the track is taken out, there is nothing on which trains may run, therefore, Island Line (ISL) train service can only be maintained between Chai Wan and Admiralty (ADM) and SHW has to be closed with a free shuttle bus service run between ADM and SHW. And for the same reason, there can be no return even if the works encounters unexpected problems, and works must

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continue until completion, including testing and commissioning and a test run.

This complicated and prolonged piece of engineering works requires up to 52 hours for hundreds of site staff to complete. Taking into consideration the programme of the WIL's construction and the need to limit the impact on the train service, a weekend in early August 2011, viz. Saturday, 6th and Sunday, 7th, was chosen for the implementation of the works. And in order to build in some margin which otherwise would not exist at all, the works were allowed to start early at 2330 hrs on Friday evening, 5th August. Even so, there was only a margin of up to 2 hours (< 4%) before the Monday morning traffic hours, effectively meaning that no error or delay could result from the works or else the train service to and from the CBD (Central Business District) on a busy normal weekday would have to be suspended, to the detriment of the Corporation's reputation and image.

2. SCOPE OF WORKS

The multi-disciplinary engineering works include the following:-

- Removal of trackside signalling equipment
- Removal of existing turnout
- Installation of new turnout, related rails and support assemblies
- Adjustment of the overhead line
- Installation of trackside signalling equipment
- Signalling static test
- Rolling stock dynamic test

Figure 3 Scope of Engineering Works

With the affected track length of over 150 metres, adjustment of overhead line of 200 metres and replacement of rail supporting assemblies of nearly 500 pieces, the entire works were targeted to be finished within a 54-hour window. When work was in progress, the section between ADM and SHW of the ISL had to be temporarily closed.

With painstaking and elaborate prior planning, immaculate implementation by dedicated staff supplemented by a detailed communication plan and contingency planning to cater for the worst case scenario, the works were completed on time to the acclaim of the Corporation with zero accident/injury, zero incident, zero complaint and zero negative media reporting.

3. PLANNING OF ENGINEERING WORKS

In fact, the design of the new track alignment was kicked off nearly 4 years before the works, followed by procurement of the unique turnout and other long lead-time materials. Detailed planning of the engineering service and communication aspects of the works began in earnest a year-and-a-half before the works.

As mentioned above, the engineering works mainly covered 3 disciplines, including permanent way, overhead line and signalling. To ensure the whole piece of works could be completed within the designated 54-hour span, a changeover plan was prepared which covered scope of works, working parties, communication arrangements, possession arrangements, site safety, site security, site logistics, contingency plan, adverse weather arrangements, publicity arrangements, etc. Furthermore, a detailed 'Minute-by-Minute' programme was prepared to keep track on the project progress throughout the course of the works. Following numerous revisions and fine-tuning with the effort of engineers and operators, the finalized programme was in place ahead of the works and was then verified by numerous 'Table Top Exercises'.

There were three key elements in the planning of the engineering works apart from the detailed works schedule, namely:-

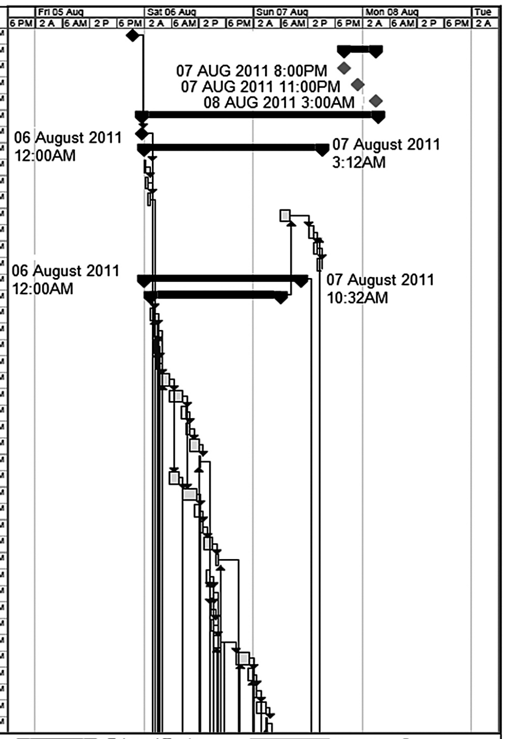
- **Possession Plan**
  The plan clearly divided the work site into three engineering possessions, and was well understood by all working parties. This helped to establish better control on engineering trains and test trains. The clear demarcation of energized and de-energized regions was essential and safety critical to the works. With the shared roles and responsibilities among the Operational Control Centre (OCC) and the Engineering Person in Charge (EPIC), the protection of the working team could be ensured.

- **Manpower Plan**
  Huge manpower resources were deployed over the course of the works. With over 200 engineering staff involved, a well prepared roster was important to not only ensure work progress, but also allow staff to have enough rest between shifts. Furthermore, managers and engineers in charge of different disciplines had to be ready for ad-hoc professional advice and decision making.

- **Access Control Plan**
  To achieve good management on the huge workforce, restricted access within station and track area was adopted. This control could prevent unauthorized access and minimize headcounts on trackside. From the record, 1100 access passes were issued with unique access rights assigned according to roles and nature of works.

Figure 4 Minute-by-Minute Programme

ID	WBS	Task Name	Duration	Predecessors	Resource Initials	Start	Finish
1	1	Briefing and equipment checking	120 mins		D,G,B	Fri 9:30 PM	Fri 11:30 PM
2	2	Triggering point for alternative transport arrangement on Monday morning	420 mins			Sun 8:00 PM	Mon 3:00 AM
3	2.1	First Triggering Point	0 mins			Sun 8:00 PM	Sun 8:00 PM
4	2.2	Second Triggering Point	0 mins			Sun 11:00 PM	Sun 11:00 PM
5	2.3	Third Triggering Point	0 mins			Mon 3:00 AM	Mon 3:00 AM
6	3	Changeover Work	3120 mins			Fri 11:30 PM	Mon 3:30 AM
7	3.1	Possession arrangement and wagon positioning	30 mins	1		Fri 11:30 PM	Sat 12:00 AM
8	3.2	Signaling Work	2352 mins			Sat 12:00 AM	Sun 3:12 PM
9	3.2.1	Dismantle existing stretcher bars	25 mins	7		Sat 12:00 AM	Sat 12:25 AM
10	3.2.2	Dismantle existing point machine	30 mins	9		Sat 12:25 AM	Sat 12:55 AM
11	3.2.3	Dismantle existing trackside Signalling Equipment	30 mins	10		Sat 12:55 AM	Sat 1:25 AM
12	3.2.4	Install and set up new point machine	120 mins	17		Sun 6:04 AM	Sun 8:04 AM
13	3.2.5	Reinstall, set up, T&C Track Circuit, beacon and CT Loop (D/T)	60 mins	12,98		Sun 12:12 PM	Sun 1:12 PM
14	3.2.6	Reinstall, set up, T&C Track Circuit, beacon and CT Loop (X-over)	60 mins	13		Sun 1:12 PM	Sun 2:12 PM
15	3.2.7	Reinstall, setup, T&C new track circuit & axle counter	60 mins	14		Sun 2:12 PM	Sun 3:12 PM
16	3.3	P-Way Work	2072 mins			Sat 12:00 AM	Sun 10:32 AM
17	3.3.1	Section 1 - Existing Switch and Stock	1719 mins			Sat 1:25 AM	Sun 6:04 AM
18	3.3.1.1	Remove existing switch and stock (LH)	45 mins	11,87	R	Sat 1:25 AM	Sat 2:10 AM
19	3.3.1.2	Remove existing baseplates & studs LH (34 nos)	54 mins	18,88	B	Sat 2:10 AM	Sat 3:04 AM
20	3.3.1.3	Install temporary support at existing slots (4 nos)	25 mins	18,88	B	Sat 2:10 AM	Sat 2:35 AM
21	3.3.1.4	Install temporary support at existing slots (4 nos)	30 mins	20	B	Sat 2:35 AM	Sat 3:05 AM
22	3.3.1.5	Placing front part plain rail and setting alignment (LH)	150 mins	21,53	R	Sat 3:10 AM	Sat 5:40 AM
23	3.3.1.6	Drill holes for HD bolts at new T/O front part LH (52 nos)	175 mins	22	D	Sat 5:40 AM	Sat 8:35 AM
24	3.3.1.7	Holes cleaning and treatment (52 nos)	54 mins	23FS-20 mins	G	Sat 8:15 AM	Sat 9:09 AM
25	3.3.1.8	Install HD bolts at new front part LH (52 nos)	54 mins	24	G	Sat 9:09 AM	Sat 10:03 AM
26	3.3.1.9	Grout setting	120 mins	25		Sat 10:03 AM	Sat 12:03 PM
27	3.3.1.10	Tightening baseplate and clipping to rail (26 nos)	18 mins	26,91	B	Sat 12:03 PM	Sat 12:21 PM
28	3.3.1.11	Placing new S/S (LH) and setting alignment	120 mins	22	R	Sat 5:40 AM	Sat 7:40 AM
29	3.3.1.12	Drill hole for HD bolts at new S/S LH (56 nos)	175 mins	28,23	D	Sat 8:35 AM	Sat 11:30 AM
30	3.3.1.13	Holes cleaning and treatment (56 nos)	57 mins	29FS-20 mins	G	Sat 11:10 AM	Sat 12:07 PM
31	3.3.1.14	Install HD bolt at new S/S LH (56 nos)	57 mins	30	G	Sat 12:07 PM	Sat 1:04 PM
32	3.3.1.15	Grout setting	120 mins	31		Sat 1:04 PM	Sat 3:04 PM
33	3.3.1.16	Tightening baseplate and clipping to rail (26 nos)	21 mins	32,70	B	Sat 3:53 PM	Sat 4:14 PM
34	3.3.1.17	Remove existing switch and stock (RH)	45 mins	61	R	Sat 1:40 PM	Sat 2:25 PM
35	3.3.1.18	Remove existing BP & stud RH (34 nos)	54 mins	34,27	B	Sat 2:25 PM	Sat 3:19 PM
36	3.3.1.19	Remove temporary support at new point machine slot	25 mins	34,27	B	Sat 2:25 PM	Sat 2:50 PM
37	3.3.1.20	Install temporary support at existing slots (4 nos)	30 mins	36	B	Sat 2:50 PM	Sat 3:20 PM
38	3.3.1.21	Placing front part plain rail and setting alignment (RH)	90 mins	37,69	R	Sat 3:20 PM	Sat 4:50 PM
39	3.3.1.22	Drill holes for HD bolts at new T/O front part RH (52 nos)	175 mins	38,62	D	Sat 8:15 PM	Sat 11:10 PM
40	3.3.1.23	Holes cleaning and treatment (52 nos)	57 mins	39FS-20 mins,64	G	Sat 10:55 PM	Sat 11:52 PM
41	3.3.1.24	Install HD bolts at new front part RH (52 nos)	57 mins	40	G	Sat 11:52 PM	Sun 12:49 AM
42	3.3.1.25	Grout setting	120 mins	41		Sun 12:49 AM	Sun 2:49 AM
43	3.3.1.26	Tightening baseplate and clipping to rail (26 nos)	21 mins	42,60	B	Sun 2:49 AM	Sun 3:10 AM



Project: Turnout 481 Min by Min (Rev.J)
Date: Fri 4:26 PM

Task | Progress | Summary | External Tasks | Deadline
Split | Milestone | Project Summary | External Milestone

Page 1

Figure 5 Possession 1 Overview

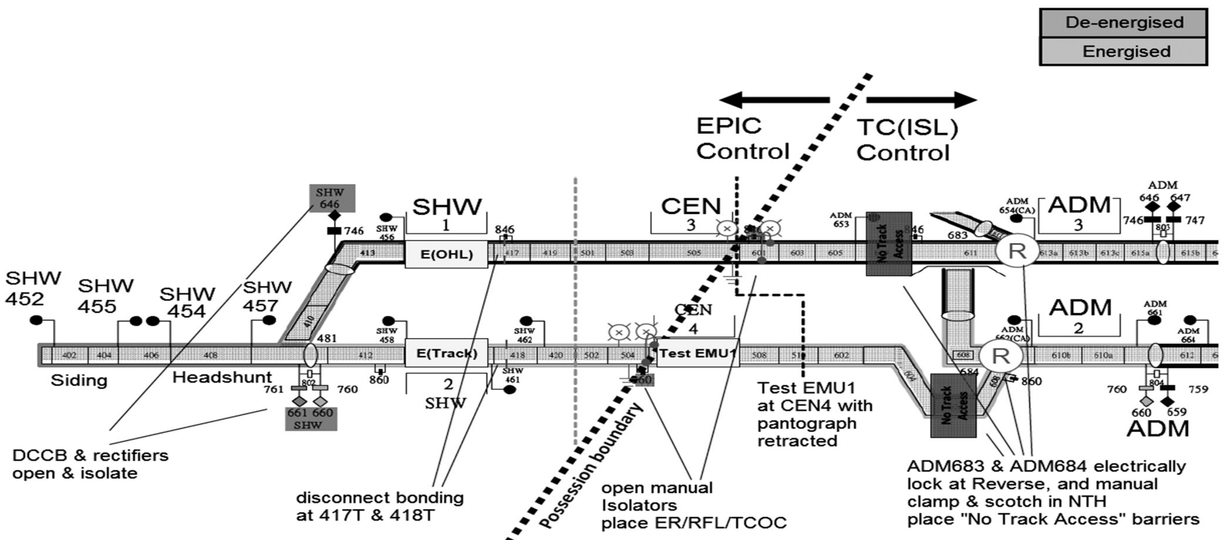


Figure 6 SHW Station Access Limit / Access Zones During 54-hour Changeover

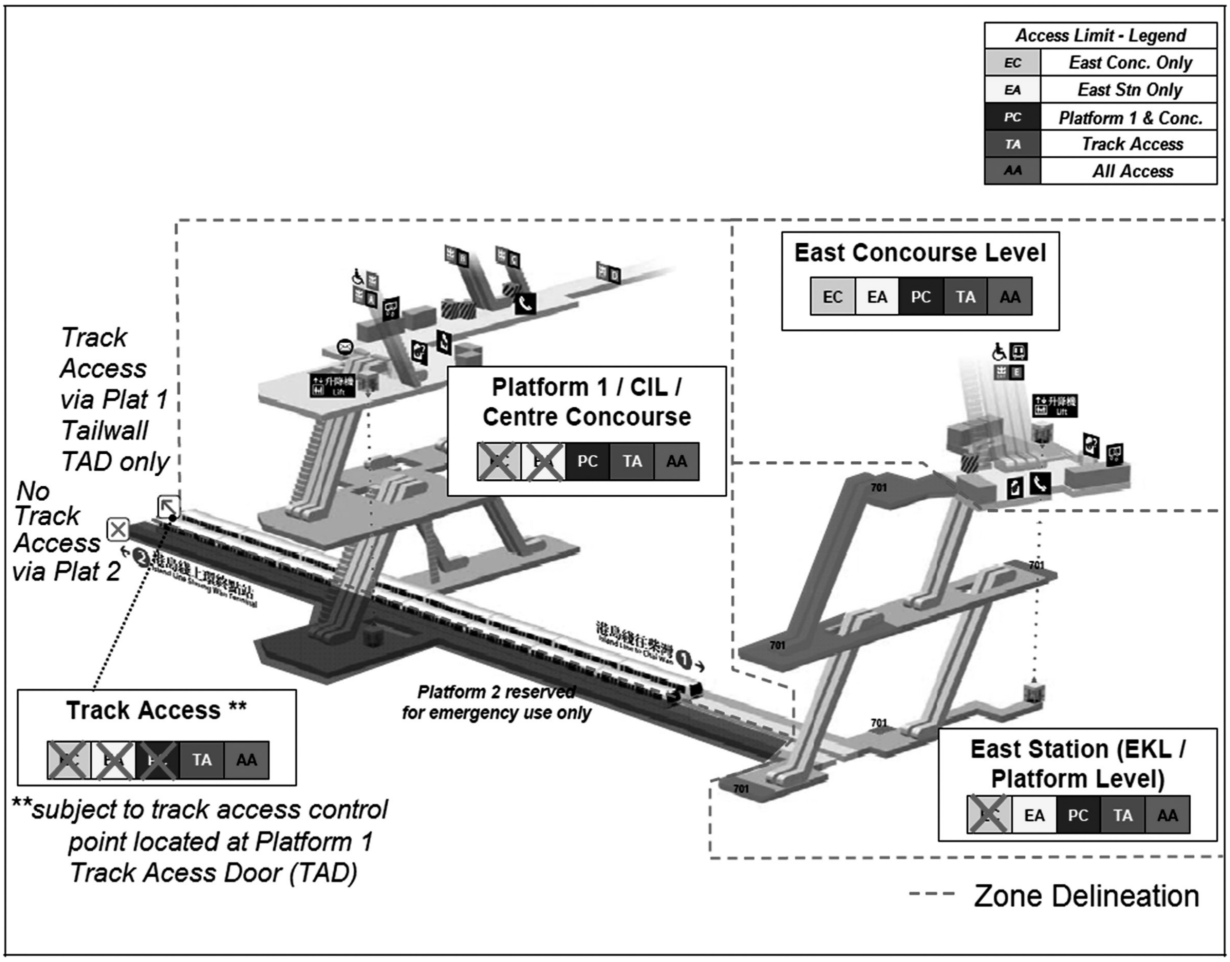


Figure 7 Access Zones

- Different access zones will be set-up to better control the works across different teams.

Permit Levels			Access Allowed?				
Abb.	Colour Code	Access Limit	East Concourse	EKL/East Platform Level	Platform 1	Centre Concourse/ CIL	Track Area
EC	Grey	East Conc. Only	Yes	No	No	No	No
EA	Yellow	East Stn Only	Yes	Yes	No	No	No
PC	Blue	Platform 1 & Conc	Yes	Yes	Yes	Yes	No
TA	Green	Track Access	Yes ##				
AA	Red	All Access	Yes##(plus unrestricted access to, e.g. SHW Meeting Rm, Platform 2)				

"TA" and "AA" holders are subject to track access control at the control point at TAD on Platform 1 Tailwall.

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4. IMPLEMENTATION OF ENGINEERING WORKS

4.1 DECOMMISSIONING TRACKSIDE SIGNALLING EQUIPMENT

The engineering works were kicked off by the decommissioning of trackside signalling equipment, including the point machine and its peripherals, track circuit equipment, beacons and transmission cable loops. After dismantling them, the track was clear of signalling connections and the works on permanent way could proceed.

Figure 8 Decommissioning Works

Figure 9 Decommissioning Works

4.2 DISMANTLING TURNOUT AND RAILS AND INSTALLING NEW TURNOUT

The track components to be removed included switch and stock rails, closure and lead rails, crossing, and the crossover plain tracks. After removing the rails, the existing baseplates and fastenings were also removed. Since most of the fixing holes of these baseplates could not be reused, new ones had to be drilled precisely on site. New rails were then installed and fastened.

Before proceeding to the next stage, there was a checklist of measurements and condition checks to be completed, the allowable tolerance on various parameters are limited to magnitude of mm, such as gauges and flangeways.

The duration of this works process required a substantial amount of time, reaching 30 hours. Since manpower and progress management was crucial at this stage, the whole stage had been further divided into more than 80 sub-stages in the 'Minute-by-Minute' work plan.

Figure 10 Dismantling Works

Figure 11 Installing New Turnout

4.3 OVERHEAD LINE ADJUSTMENT

Since the alignment of the track was changed as a result of the turnout replacement, the overhead line had to be adjusted correspondingly. The height and stagger of the OHL had to be fine-tuned, followed by a pantograph passing test to ensure no infringement to minimum electrical clearance as well as smooth and confined lateral running of the contact wire on the carbon strip of pantograph. In addition, insulation tests were conducted to ensure compliance with design parameters.

Figure 12 Overhead Line Adjustment

Figure 13 Overhead Line Adjustment

4.4 INSTALLING NEW TRACKSIDE SIGNALLING EQUIPMENT

When the permanent way modification works were being completed, the reinstallation of signalling equipment was undertaken in parallel. All the equipment removed in the first stage had to be reinstated back to the system.

Figure 14 Installing New Trackside Signalling Equipment

4.5 SIGNALLING SYSTEM STATIC TEST

Functional tests on all the affected signalling equipment had to be conducted, including axle counter, beacon, transmission cable loops, return channel cable loops, and track circuit equipment. Apart from hardware, the automatic train control software was also upgraded to cater for the modification and thus had to be verified and tested.

4.6 ROLLING STOCK DYNAMIC TEST

Before the newly installed and modified equipment could be released for service, dynamic tests with passenger trains were arranged to simulate the actual working scenario at the site. The tests included data checking of the new location of turnout and beacons, verification of new reduced speed limit at the turnout area, and the functionality of automatic train turnaround.

Throughout the whole process, many kinds of work produced heat inside the narrow underground tunnel, especially during the hot summertime. Ice and big fans were used as a cooling system for the work site, so as to reduce the temperature and improve the working environment. Moreover, resting zones and energy-rich food was prepared for engineering personnel. 1.5 tonnes of ice and 1,100 litres of drinking water were consumed during the course of works.

Figure 15 Cooling System for Work Site

Figure 16 Rest Area

5. TRAIN SERVICE ARRANGEMENTS

During the 54-hour changeover, the train service between ADM and SHW of ISL was suspended, while passengers could reach Central Station (CEN) via Tsuen Wan Line. A free shuttle bus service was arranged between ADM and SHW during the said period.

In the scope of the temporary train service arrangement, several key tasks were planned and implemented, namely:-

- Service arrangements between ADM and SHW on ISL
- Interchange management at CEN and ADM
- Shuttle bus service and operation
- Information to the public
- Manpower and staff deployment plans

Figure 17 Information to the Public

Figure 18 Information to the Public

Figure 19 Information to the Public

Figure 20 Shuttle Bus Service

6. STAKEHOLDER COMMUNICATION AND PUBLICITY PLAN

Early stakeholder communication was crucial to address the concerns of the public and other parties. More importantly, proper stakeholder communication enabled a smooth work process and thus minimized potential adverse effects and disruptions. Key stakeholders includes:-

- **Transport Department**
  The first meeting on this project was held 18 months before the works. After that, the two parties had numerous meetings and discussions to ensure a diversified coverage of potential issues had been considered. Moreover, TD also provided great assistance on the planning and implementation of shuttle bus arrangements.

- **Railways Branch of Electrical and Mechanical Services Department**
  RB of EMSD had been working closely along with the Transport

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Department on various support issues.

- **Bus Operators**
  Early communication allowed better allocation of resources from both parties, ultimately minimizing the effect of the temporary suspension of train service during the works.

- **Hong Kong Police Force**
  The HKP ensured the smooth implementation of the project through providing professional views on road traffic control and crowd control arrangements.

- **Transport & Housing Bureau**
  Early communications with the THB enabled an on-time submission of briefing paper to Railways Sub-committee of Legislative Council Transport Committee.

- **Central & Western District Council**
  With adequate briefing, special meetings, and a supplementary paper submitted, the C&WDC and MTR had reached satisfactory consensus long before the project. The council also assisted and facilitated the arrangements for shuttle bus trial.

- **Disabled Groups**
  Briefing sessions were given to Visually Impaired Group and Hearing & Mobility Impaired Group well before the works.

- **Press Briefings and Releases**
  Press briefings and releases were made from time to time to keep the mass media and the public updated on the works planning and the actual works progress during the long weekend.

Figure 21 Press Briefing

Figure 22 Services to the Disabled

Figure 23 Shuttle Bus Service

7. THE CHALLENGES, CONSTRAINTS, AND ACHIEVEMENTS

The works faced both internal and external challenges: doing an unprecedented piece of complicated multi-disciplinary engineering works continuously over a weekend and assuring the regulator and stakeholders including passengers, politicians and the nearby community that the works would be conducted with minimal inconvenience and completed on time as planned.

The works were subject to time limitations, resource constraints and environmental difficulties. Through ingenious and innovative planning as well as in-depth consideration of all challenges with practical solutions drawn up, all challenges and constraints were overcome through colleagues' commitment, "Can Do" spirit and excellent team work.

Projects and Operations Divisions of MTR exhibited exemplary collaboration with the former entrusting these works to the latter. As a result, the works were accomplished in the most professional manner. Planning staff worked long hours to devise some innovative approaches to overcome the technical difficulties of having to complete the track removal and relocation work and similar overhead line work in a fraction of the usual time in a hot tunnel cooled by innovative means. Site work was conducted with immaculate collaboration among the various disciplines with everybody putting in their best efforts to get the job done.

With a special train service arrangement for ISL down trains to turn short at ADM supplemented by a free shuttle bus service plying between ADM and SHW, and strengthened service on the TWL, Hong Kong was kept moving with the least impact on the travelling public.

The well-planned communication work explaining the need for and benefit of the works to the community and the alternate arrangements put in place for passengers resulted in good understanding of what was happening and no adverse reaction from the public either prior to or during the works.

8. CONCLUSION

With immaculate planning and careful execution, supplemented by detailed communication and contingency arrangements, the works were completed successfully within the allocated 54-hour time slot, thanks to the hard work of everyone involved and the support of passengers and other stakeholders.

From now till Year 2020, new extensions of the MTR railway network are scheduled to be progressively put into service. The success story of West Island Line Sheung Wan 54-Hour Changeover Works has become a role model for the challenges ahead, and most importantly, encouraged the staff of the Corporation to continue to strive for delivering their service professionally, and in a timely and safe manner.