Sustainability and Environmental Challenges in Electrical Engineering

The Hong Kong Institution of Engineers - Electrical Division
The 25th Annual Symposium
23rd October 2007

THE HONG KONG INSTITUTION OF ENGINEERS ELECTRICAL DIVISION

The 25th Annual Symposium

Tuesday

23rd October 2007

SUSTAINABILITY AND ENVIRONMENTAL CHALLENGES IN ELECTRICAL ENGINEERING

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 Registration and Coffee

09.00 Welcome Address

- Ir Gary C.W. Ko
  Chairman, Electrical Division, The HKIE

09.05 Opening Address

- Ir Dr W.K. Lo, JP
  President, The HKIE

09.10 Keynote Speech

- Mr Edmond C.H. Lee
  Executive Director and Regional Head of
  Utilities and Infrastructure
  JPMorgan Securities (HK) Ltd.

1. Environmental Technologies

09.40 Optimal Control of the Centralized Air-conditioning System at a Super High-rising Building

- Ir Prof. S.W. Wang, Acting Head of Department
  Department of Building Services Engineering
  The Hong Kong Polytechnic University
- Mr W.K. Pau
  Project Manager
  Sun Hung Kai Properties Ltd.

10.00 Ester Transformer Fluids for Increased Fire Safety, Reliability and Environmental Performance

- Dr Russell Martin, Technical Manager
- Mr James O'Brien, Commercial Engineer
  M&I Materials Ltd., UK

10.20 Discussion

10.40 Coffee Break

2. Sustainability of Power Development

11.10 Caring for Our Environment – Sustainable Development of Transmission System

- Mr Howard K.H. Ng, Manager - Engineering Projects
- Ir C.P. Cheng, Substation Implementation Manager
  CLP Power Hong Kong Ltd.

11.30 From Production to Supply – Total Environmental Management of Electricity

- Ir Dr C.W. Tso
  General Manager (Projects)
  The Hongkong Electric Co., Ltd.

11.50 Nuclear Power Development: Opportunities & Challenges

- Mr W.H. Zhou
  Acting Manager, Safety Department
  China Guangdong Nuclear Power Holding Co. Ltd., PRC

12.10 Discussion

12.30 Lunch

3. Green Projects

14.15 Enhanced Green Building Design – A Brief History of the Latest Design Trend in Building Construction Industry in the USA

- Eur Ing Jacob Chan
  Senior Partner
  MDC Engineers Inc., USA

14.35 Medium Capacity Railway System Proposed for South Island Line (SIL)

- Ir C.L. Leung, E&M Engineering Manager, Project Division
- Ir Samuel S.C. Chan, Senior Engineer (Power and Services)
  MTR Corporation Ltd.

14.55 Discussion

15.15 Coffee Break

4. Renewable Energy

15.45 Renewable Electrical Energy – Potential Application of Amorphous Silicon Photovoltaic Technology in Hong Kong

- Ir Eddie W.K. Wu, Senior Engineer
- Ir Iris P.L. Lau, Engineer
  Electrical & Mechanical Services Department
  The Goverment of the HKSAR

16.05 Renewable Energy Development in Asia Pacific

- Dr K.K. Chan
  Managing Director
  CLP Renewables

16.25 Discussion

16.45 Summing Up

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

Closing Address

- Ir Otto L.T. Poon
  Past President
  The HKIE

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Paper No. 1

OPTIMAL CONTROL OF THE CENTRALIZED AIR-CONDITIONING SYSTEM AT A SUPER HIGH-RISING BUILDING

Speakers : Ir Prof. S.W. Wang, Acting Head of Department
Department of Building Services Engineering
The Hong Kong Polytechnic University

Mr W.K. Pau, Project Manager
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Paper No. 1

ABSTRACT

This paper presents optimal control strategies for the centralized air-conditioning system for online practical applications at International Commerce Centre (ICC). ICC is a super high-rising office building in Hong Kong. The work presented is the joint effort aiming at developing a package of intelligent control strategies and evaluating their energy saving potentials in practical applications and finally implementing these intelligent controls in the building to enhance energy efficiency. The optimal strategy for the cooling water system is developed to automatically and dynamically re-set the condenser inlet water temperature set-point. The number of cooling towers in operation and the frequency of cooling tower fans are determined simultaneously. The optimal strategies for variable speed pumps in secondary chilled water systems are developed to control the pumps to meet the desired water flow rate and pressure set-points with least energy input and good control stability. These strategies are tested and validated in a virtual environment representing the real building system and the chiller plant system prior to the implementation in the real building. The implementation issues of these strategies for practical applications are also addressed.

Keywords: *Optimal control, air-conditioning system, energy efficiency, implementation*

1. INTRODUCTION

Reliable and intelligent control and operation of building HVAC&R (heating, ventilating, air-conditioning and refrigeration) systems are the main achievable approaches to improve building energy efficiency and provide better performance besides proper system design and selection and maintenance of component. Supervisory and optimal control have received growing concern and more attention of building professionals over the past two decades [Wang and Jin 2000, Ahn and Mitchell 2001, Nassif and Kajl et al. 2005, Sun and Reddy 2005]. These controls aim at seeking the minimum energy input or operating cost to provide the satisfied indoor comfort and healthy environment by taking into account the ever-changing indoor and outdoor conditions as well as the characteristics of HVAC&R systems [Wang and Ma 2007].

In conventional chiller plant, cooling tower is usually used in cooling water systems for heat rejection purposes and the fans are equipped with variable frequency drivers (VFD) to control the condenser inlet water temperature at its set-point as intended. There are many existing control strategies for cooling towers. The basic one is to maintain a constant condenser inlet water temperature set-point (i.e., fixed set-point) or maintain a constant difference between the condenser inlet water temperature and the ambient air wet-bulb temperature (i.e., fixed approach) by varying the air flow rate through the cooling towers [Crowther and Furlong 2004]. Several near optimal control strategies have been also proposed to determine the near optimal condenser inlet water temperature set-point, and then utilized this temperature set-point to approximately control the operation of the cooling towers [Braun and Diderrich 1990,

Yao and Lian et al. 2004, Sun and Reddy 2005]. These strategies are simple enough and easy to be implemented in practice. However, the set-points determined by these strategies might significantly deviate from the optimal values, and substantial amounts of energy might be still wasted.

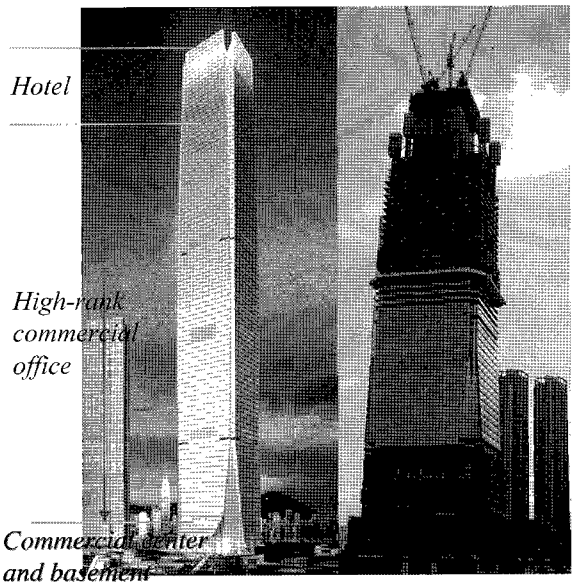
For variable speed pumps in secondary chilled water systems, the speed of pump is often controlled to maintain a constant pressure difference between the main supply and return pipelines or maintain a constant pressure difference at the most remote loop. Both are widely used methods in practice. However, they might be far from optimal and significant amount of energy is still wasted, especially at light partial load conditions.

This paper presents the optimal control strategies for cooling water system and for variable speed pumps in secondary chilled water system in the central chiller plant at International Commerce Centre aiming at improving energy efficiency of chiller plant. The optimal control strategy for the cooling water system is developed based on the performance prediction using semi-physical models of chillers and cooling towers. An exhaustive search method is used to find out the best setting of condenser inlet water temperature set-point within a small search range defined based on a performance map-based near optimal strategy. The setting is used for practical control allowing chillers and cooling towers adapting to the dynamic operation conditions while maintaining high energy efficiency in operation. The optimal control strategy for variable speed pumps is developed to meet the desired water flow rate and pressure conditions with least energy input and good control stability. These strategies are tested and validated in a virtual environment representing the real building system of ICC building and the chiller plant system prior to the implementation in the real building. The issues associated with practical applications are addressed critically.

2. DESCRIPTIONS OF THE BUILDING AND CHILLER PLANT

Figure 1 show an outlook of the building. It is super high-rising building of 490 meter high above the ground with about 440,000m^2, involving a basement of four floors, a block building of 6 floors and a tower building of 112 floors. The basement is mainly used for car parking with about 24,000m^2. The block building from the ground floor to 5th floor mainly serves as commerce center involving restaurants, shopping markets and exhibition halls. The gross area is about 67,000m^2. For the tower building, the 6th and 7th floors serve as mechanical floor (M1) to accommodate chillers, cooling towers, pumps, etc. The 8th is refugee floor. From 9th to 98th floors, there are mainly commerce office floors with each floor of length 66 *m* and width 65 *m* except that the 41st and 77th floors are used as refugee floors, and the 42nd (M2), 78th (M3) and 99th (M4) floors are used as mechanical floors to accommodate mechanical equipments such as heat exchangers, pumps, PAU and fans etc. A six-star hotel is located from the 100th to 118th floors.

Figure 1 An Outlook of ICC Building



Considering the usage characteristics of the hotel, separate air-cooled chillers are used to provide chilled water for this part. Water-cooled chillers located on floor M1 (6th floor) are used to provide chilled water for the remaining part. The design total cooling load of the building except the six-star hotel is 43,000kW, equal to about 125W/m^2 (not including the basement). Six centrifugal chillers of high voltage (10,000V) with the capacity of each one 7,230kW are designed to supply the chiller water at 5.5°C. The nominal power consumption of each chiller is 1,270kW at the full load condition. The schematics of the central chiller plant are described in Figure 2. The heat generated by the chiller motors are taken away mostly by the refrigerant. Heat dissipated from the chillers is rejected by means of evaporative water cooling towers, total eleven units with total capacity of 51,000kW.

Figure 2 Schematic of Chiller Plant

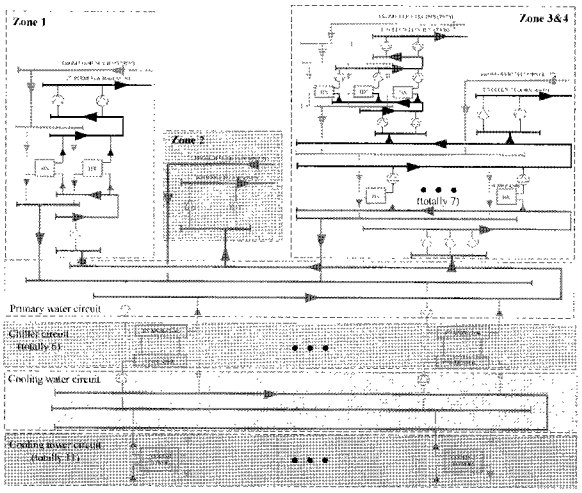
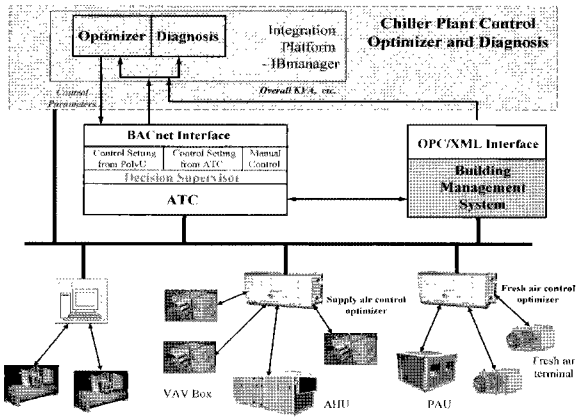


Figure 3 shows the implementation architecture of "Chiller Plant Control Optimizer" and the supplied air control optimizer and fresh air control optimizer. The later two optimizers are programmed in the same local control station. The "Chiller Plant Optimizer" involves the optimal chiller sequencing control, optimal pump control, optimal control of chilled water system and optimal control of cooling water system. The following section mainly presents the optimal control of cooling water system and optimal control of variable speed pumps.

Figure 3 Implementation Architecture of Control Strategies



Paper No. 1

3. OPTIMAL CONTROL STRATEGY FOR COOLING WATER SYSTEM

3.1 FORMULATION OF OPTIMAL CONTROL STRATEGY

In this study, a model-based optimal control strategy for cooling water system is developed. The condenser inlet water temperature set-point ($T_{cd,in}$) is optimized to minimize the total electricity consumption of chillers and cooling tower fans since each chiller is associated with one constant condenser water pump in this cooling water system. The objective function can be expressed as Equation (1). In this formula, the parameter to be optimized is the condenser inlet water temperature set-point.

In the model-based optimal control strategy, the essential issues are the system performance prediction and optimization technique. In this study, two semi-physical models of chillers and cooling towers are developed and used for performance prediction. Both models are developed based on the fundamental principles of thermodynamic and heat/mass transfer processes in chillers and cooling towers taking into account the requirements of practical applications, i.e., simplified model structure, acceptable prediction accuracy, less computational cost and memory demand

[Wang and Ma et al. 2007]. The input parameters of the semi-physical chiller model are chiller evaporator inlet water temperature, condenser inlet water temperature set-point, calculated cooling load, and water mass flow rates in chiller evaporator and condenser. The output parameter of this chiller model is the chiller power consumption. The input parameters of the semi-physical cooling tower model are ambient air wet-bulb temperature, cooling tower inlet water temperature, water mass flow rate and air mass flow rate in cooling towers. The output parameters are heat rejection capacity, fan power consumption, and fan operating frequency.

An exhaustive search method as an optimization technique is used to seek the best setting of condenser inlet water temperature set-point within the defined search range, as expressed in Equation (2), and the search center $T^{n.o}_{w,cd,in}$ in Equation (2) is determined by a performance map-based near optimal strategy, as Equation (3) [Sun and Reddy 2005]. This search center is actually a near optimal solution for changing working conditions. The exhaustive search method may seek the global optimal solution within the limited search range with proper increment, i.e. 0.1°C. The operation of cooling water systems has to comply with a lot of constraints, i.e. the lowest condenser inlet water temperature set-point is bounded to 18°C, the heat rejected in cooling towers is equal to the heat absorbed by the cooling water from the chiller condensers, etc.

$$\min_{T_{cd,in}} P_{tot} = P_{chiller,tot} + P_{ct,tot} \quad (1)$$

$$T^{n.o}_{w,cd,in} - \Delta t \le T_{w,cd,in} \le T^{n.o}_{w,cd,in} + \Delta t \quad (2)$$

$$T^{n.o}_{w,cd,in} = h_0 + h_1 T_{wb} + h_2 \left(\frac{Q_{ev}}{Q_{ev,des}} \right) \quad (3)$$

3.2 PERFORMANCE EVALUATION

In cooling water systems, chiller and cooling tower performances are highly interacted. Figure 4 presents such interactions between chiller and cooling tower performances. It can be observed that both chiller and cooling tower performances are affected in different directions by the condenser inlet water temperature set-point. The lower condenser inlet water temperature set-point can improve the COP of chillers resulting in less electricity consumption while the lower temperature set-point requires more air flow rate to increase the heat rejection capacity of cooling towers.

More power is therefore consumed by fans. Although higher condenser inlet water temperature set-point can save electricity consumption of cooling tower fans, it deteriorates the efficiency of chillers. This deterioration results in more electricity consumption of chillers to meet the same cooling load. Therefore, the condenser inlet water temperature set-point needs to be optimized to minimize the total electricity consumption of both chillers and cooling tower fans, as indicated in Figure 4.

Figure 4 Interactions Between Chiller and Cooling Tower Performance

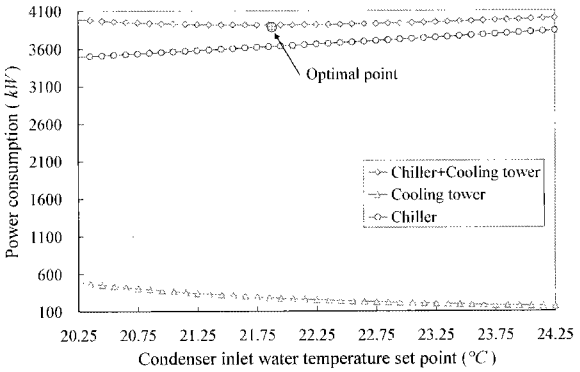
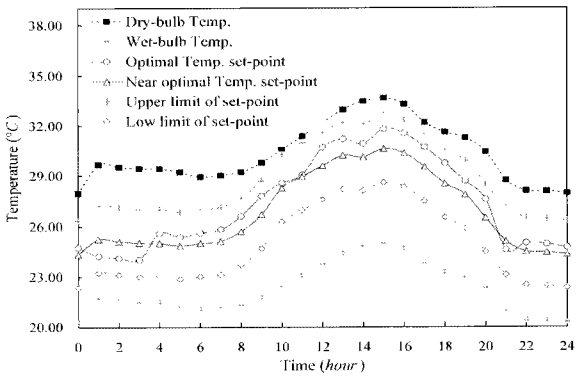


Figure 5 Optimal and Near-optimal Temperature Set-points in the Typical Sunny-summer Day



The performance of this model-based optimal control strategy is evaluated by comparing with that of the performance map-based near optimal control strategy in terms of condenser inlet water temperature set-point and the entire power consumption of chillers and cooling towers. In this study, the performance of the fixed approach control method (approach temperature is 5℃) is used as the benchmark. Figure 5 presents the profile of condenser inlet water temperature set-points obtained by using the proposed model-based optimal control strategy and the performance map-based near optimal control strategy for a typical sunny-summer day. It is obvious that optimal condenser inlet water temperature set-points searched by using the proposed optimal control strategy deviated from the values that using the performance map-based near optimal control strategy. It also can be found that the optimal condenser inlet water temperature set-points are all within the defined search ranges. The performance of this model-based optimal control strategy was further validated concerning system power consumptions.

Figure 6 Savings in Power Consumptions of Optimal Strategies Compared to the Fixed Approach Method in the Typical Sunny-summer Day

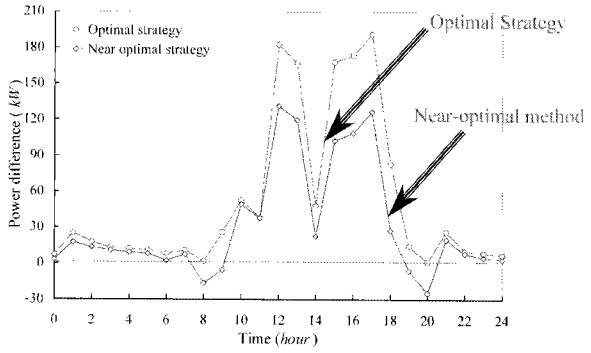


Figure 6 presents the difference between hourly-based power consumptions using the fixed approach control method and the proposed model-based optimal control strategy (indicated as optimal strategy in Figure 6), and the difference between the hourly-based power consumptions using the fixed approach control method and the performance map-based near optimal control strategy (indicated as near optimal strategy in the same figure) in a typical sunny-summer day. It can be observed that the maximum difference between the hourly-based power consumptions using the fixed approach control method and the proposed model-based optimal control strategy was about 191kW while the maximum difference between the hourly-based power consumptions using the fixed approach control method and the performance map-based near optimal control strategy was about 126kW in the typical sunny-summer day. It also can be found that the performance map-based near optimal control strategy was not always better than the fixed approach control method. For instance, at some working conditions, the power consumptions using the performance map-based near optimal control strategy was more than that of using the fixed approach control method, which further reveals that the proposed model-based optimal control strategy can provide much more energy efficient control compared with the performance map-based near optimal control strategy.

Table 1 presents the power consumptions of the cooling water system (chillers+cooling towers) in the typical sunny-summer day when using different control methods. Compared with the fixed approach control method, the porposed strategy can save about 1.416% energy while performance map-based near optimal control method only saves about 0.846% energy. It is worthwhile to note that this part of energy saving was achieved by applying the optimal control algorithm only and without adding any additional cost. It is also worth pointing out that the fixed approach control method used as the benchmark in this study has already somehow optimized the temperature set-point. Therefore the actual energy saving using the proposed model-based optimal control strategy could be significantly more than the energy saving presented above since the control strategies utilized in practice might be more simple and inadequate.

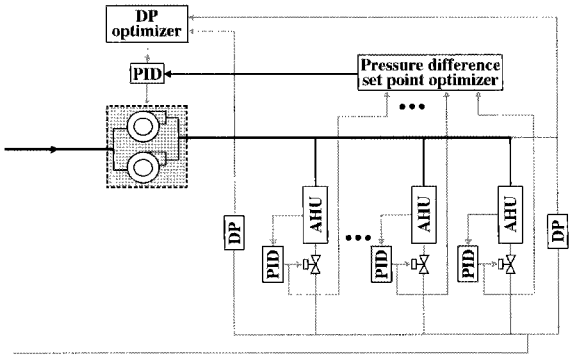
Table 1 Power Consumption of Cooling Water System Using Different Methods in a Typical Sunny-summer Day

Operation strategy	Power (kWh)	saving (kWh)	saving (%)
Fixed approach	91653	---	---
Near optimal	90878	775.44	0.846
Proposed	90356	1297.50	1.416

4. OPTIMAL CONTROL STRATEGIES FOR VARIABLE SPEED PUMPS

Variable speed pumps often contribute a large portion of overall system energy consumption. Proper control of these variable speed pumps can offer significant energy savings and extend their useful life. Figure 7 presents an optimal pressure differential set-point control strategy for variable speed pumps in the distribution system (for pumps in AHU loop). In this control strategy, the pressure differential set-point is optimized based on the online monitoring openings of water control valves (mostly, the control signal is used to represent the valve position).

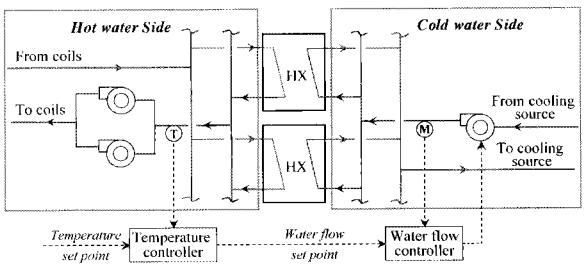
Figure 7 Optimal Pump Speed Control Strategy (For Pumps in AHU Loop)



The set-point is re-set enough and just enough for the most heavily loaded zones. At this situation, the maximum value among the openings of all valves of concern is near fully open. For the reverse-return systems, a differential pressure sensor/transmitter is required to be installed at each end of the loop for each zone. Otherwise, the system may not function properly when most of load is at the beginning end of the loop (Rishel 2003). A DP (Differential Pressure) optimizer is used to determine the reasonable value representing of the actual pressure difference of the system of concern using the measurements of both differential pressure sensors/transmitters. Taking into account the dynamic characteristics of HVAC&R systems and measurement errors caused by the instruments, the average value of both measurements are used. A test based on the virtual building showed that this optimal pressure differential set-point control strategy can save about 60% electricity consumption at 50% cooling load condition while constant pressure differential set-point at the most remote loop can only save 40% electricity consumption at the same condition.

For pumps in the loop before heat exchangers, the pump speed can be controlled using the hot water temperature leaving heat exchangers. Figure 8 presents a cascade control for these pumps. Compared to use the hot water temperature leaving heat exchangers to control the pump speed directly, the control performance can be improved greatly by using this cascade control. If hot water temperature leaving heat exchangers is used directly to control the pump speed before heat exchangers, seriously over-tuned or down-tuned phenomena might be obvious because of the slow thermal responses of heat exchangers. When the hot water temperature leaving heat exchangers is used to determine the required water flow rate with respect to the temperature set-point and the required water flow rate is compared with measured water flow rate to carry out the pump speed control, the instability of the control process is reduced greatly.

Figure 8 Pump Speed Control Logic (For Pumps in the Loop Before Heat Exchangers)



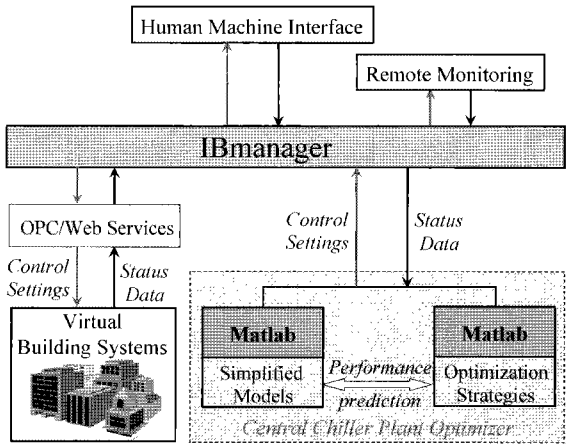
Another issue related to the pump control is pump sequencing. A simple yet near optimal strategy can be used in practice and it is presented as follows. Bring another pump online when the frequencies of operating pumps are larger than 40Hz (this frequency is

specific to this project only and for other projects, it is required to be determined taking into account the pump maintenance cost, operating efficiency, and their useful life). One of the operating pumps is switched off if the system water flow rate and head requirements of concern can be achieved by operating of (N-1) pumps at the frequencies of or below 40Hz (if current operating number of pumps is N).

5. IMPLEMENTATION ISSUES FOR PRACTICAL APPLICATIONS

The practical implementation architecture of these optimal control strategies is illustrated in Figure 3 and Figure 9. The control optimizer is running on a platform namely IBmanager. The communication between the BA system and the IBmanager is achieved through BACnet DLL as shown in Figure 3. This platform, IBmanager, is developed employing middleware technologies to realize data and services integration and interoperation among distributed building automation systems (BASs) on the Intranet/Internet. The computation of the control optimizer is achieved by programming application programs in the environment of commerce software-Matlab. These programs are compiled as dynamic link library (DLL) to be invoked by IBmanager. IBmanager reads status data from real building systems and transfers them to the control optimizer. The control optimizer decides the optimal control parameters (e.g. set-point and operation mode) for the BA system based on the received status data. The control parameters are then transferred to real building systems by IBmanager to achieve energy efficient control and operation. All these control parameters and online operating status are monitored and recorded by IBmanager. The software for control optimization is wrapped as a component running on the IBmanager-based platform. The control logic and software are tested and evaluated by connecting them to the simulated virtual building systems before the real BA systems in building are ready for testing at construction stage as shown in Figure 9.

Figure 9 Implementation Architecture of Control Strategies



6. CONCLUSION

The optimal control strategies for building central cooling water systems and variable speed pumps are presented. The optimal control strategy for cooling water system is developed based on performance prediction using simplified semi-physical chiller and cooling tower models aiming at providing stable and accuracy performance prediction. This strategy employs an exhaustive search method to seek the most energy efficient control settings within a defined search range determined by a performance map-based near optimal strategy. The performance evaluation of this model-based optimal control strategy demonstrates that it can always find the optimal solutions and substantial energy can be saved when compared to the fixed approach control method and other near optimal control method. This strategy is simple and easy to implement in practice as well. These characteristics make it suitable for online practical and real time control applications. The speed of pumps in the AHU loops can be controlled by re-setting the pressure differential set-point enough and just enough for the most heavily loaded zones while the speed of pumps in the loop before heat exchangers can be controlled using a cascade control. These control strategies will be

implemented in ICC building after their performances are tested on the platform in terms of control stability, algorithm stability, computation demand, etc.

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Paper No. 2

ESTER TRANSFORMER FLUIDS FOR INCREASED FIRE SAFETY, RELIABILITY AND ENVIRONMENTAL PERFORMANCE

Speakers : Dr Russell Martin, Technical Manager
Mr James O'Brien, Commercial Engineer
M&I Materials Ltd., UK

ESTER TRANSFORMER FLUIDS FOR INCREASED FIRE SAFETY, RELIABILITY AND ENVIRONMENTAL PERFORMANCE

Dr Russell Martin, Technical Manager
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M&I Materials Ltd., UK

ABSTRACT

The electrical power transmission and distribution industry has for some time expressed a rapidly growing interest and need for environmentally friendly dielectric fluids, as viable alternatives to mineral oil. However, in order for these fluids to have widespread appeal, they must also demonstrate that they are safe, economical, and offer a high standard of electrical performance over a long working life. This paper illustrates the advantages that ester fluids have to offer in terms of fire safety, environmental protection and moisture tolerance. Issues such as the retrofilling of existing equipment and fluid testing are also discussed.

Keywords: Esters, fire safety, biodegradability, environment, moisture tolerance, retrofilling, fluid testing

1. INTRODUCTION

Esters have been used as dielectric liquids since the invention of the oil-filled transformer in the late 1880s. The earliest simple natural ester dielectrics were subsequently found to be incompatible with free breathing equipment, because of their chemistry, and were gradually replaced by mineral oils. Later, silicon oils made an appearance, offering a high fire factor alternative. However, these were found to be environmentally questionable.

In recent years there has been a drive towards finding and using dielectrics which offer good reliability, high fire safety margins, whilst at the same time being environmentally friendly. A sustained R&D effort over many years has resulted in significant improvements in ester performance, and nowadays, modern ester dielectrics, both natural and synthetic, offer these advantages.

Synthetic ester dielectrics have been successfully used for almost 40 years and continue to grow in popularity.

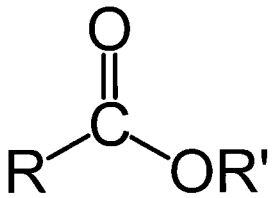
In the last 10 years there has been a resurgence in interest in the use of natural ester dielectrics because of their obvious 'green' credentials.

There is still widespread confusion about the nature of ester dielectric fluids, and how they differ from other types of liquid insulation. This paper attempts to explain some of the misconceptions, and looks in detail at a few of the key advantages that ester fluids have to offer.

2. WHAT IS AN 'ESTER'?

The term 'ester' comes from the chemical linkage, which is formed from the reaction of an alcohol and a fatty acid

Figure 1 The Ester Linkage



In Figure 1 the O represents oxygen, C represents carbon, R and R' represent carbon chains, which may be the same or different. The single line represents a single bond, and a double line represents a double bond. Note that C=O double bonds behave differently from the C=C double bonds found in the chains of natural esters.

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As the name implies, the ester linkage occurs in both natural and synthetic esters, but does not occur in mineral or silicone oils.

3. SYNTHETIC ESTERS

Synthetic esters are derived from chemicals. They are usually the product of a polyol (a molecule with more than one alcohol functional group) with synthetic or natural carboxylic acids to give structures where several acid groups (usually 2, 3 or 4) are bonded to a central polyol structure. Importantly, the acids used are usually saturated (no C-C double bonds) in the chain, giving the synthetic esters a very stable chemical structure.

4. NATURAL ESTERS

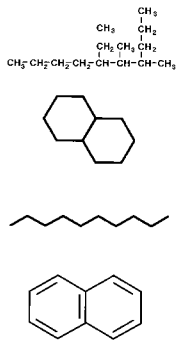
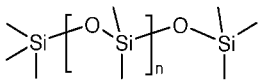
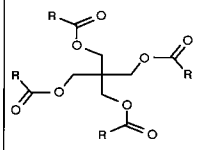
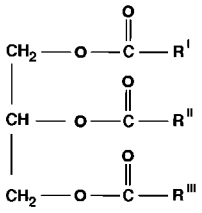
Natural ester dielectrics are produced from vegetable oils, which are themselves manufactured from renewable plant crops.

The structure of the natural esters is based on a glycerol backbone, to which is bonded to 3 naturally occurring fatty acid groups. Again, these fatty acids may be the same or different. Plants produce these esters as part of their natural growth cycle. They are stored in the seeds, and can provide a valuable high calorific foodstuff when harvested.

5. COMPARISON BETWEEN ESTERS AND OTHER TYPES OF TRANSFORMER OILS

For the majority of transformer applications,

Table 1 Common Fluid Properties

Name	Mineral oil	Silicone oil	MIDEL 7131	MIDEL eN
Type	Refined oil based distillate	Synthetic oil	Synthetic ester	Natural ester
Principle components	Complex mixture of hydrocarbons	di-alkyl silicone polymer	Pentaerythritol tetra ester	Plant based natural ester
Chemical structure				
Source	Purified from oil	Made from chemicals	Made from chemicals	Extracted from crops
Biodegradability	Very slow to biodegrade	Effectively does not biodegrade	Readily biodegradable	Readily biodegradable
Moisture behaviour	Performance Sensitive to moisture	Performance sensitive to moisture	Excellent moisture tolerance	Good moisture tolerance
Water saturation at ambient (ppm)	55	220	2600	1100
Flash point, °C	160	>300	>250	> 300
Fire Point, °C	170	>350	>300	>350
Fire Classification	O	K	K	K

mineral oil is an acceptable, cost-effective insulating fluid, and this situation is likely to continue well into the future. In applications where fire safety and protection of the environment are important considerations, transformer fluids based on esters can be a more attractive alternative.

Briefly, ester dielectrics are:

- Less Flammable (K-Class fluids)
- Very moisture tolerant
- Excellent cooling fluids
- Non toxic
- Readily biodegradable
- Able to be used to retro-fill mineral oil transformers
- Safe - synthetic ester has more than 25 years flawless safety record.

The structural and key properties of the common currently used transformer fluids are summarised in Table 1.

6. FIRE SAFETY

Fire safety is a key concern of today's users of dielectrics. This is especially so when considering their use in areas where a fire would be highly undesirable and difficult to control, for example in subway tunnels or aboard ships. Equally this applies where they will be used in populated areas such as near offices, shops and in the workplace.

Both natural and synthetic esters can offer a high degree of fire safety, due to their low fire susceptibility.

Table 2 Fire Properties of Fluids

Fluid type	Flash point °C	Fire point °C	Class
Mineral oil	160	170	O
Silicone oil	>300	>350	K3
Natural ester	>300	>350	K2
Synthetic ester	>250	>300	K3

Insurance companies are increasingly aware of the fire potential of transformer fluids, and are encouraging end users to specify fire safe fluids, especially in areas where a fire is potentially very damaging. A serious fire originating from a flammable oil transformer, such as the one that occurred in the basement of a block of flats in Madrid in 2004, causes many problems:

- Risk to human life
- Evacuation of surrounding area
- Down-time costs
- Transformer replacement time and cost.
- Costly insurance claims

Picture 1 Flammable Oil Transformer Fire, Madrid 2004

Among the advantages of using the less flammable K class fluids are:

- Less costs for installation & maintenance safety equipment: "for electrotechnical equipment installed in areas of particular fire hazard (e.g.Buildings), less stringent measures are required in the case of less flammable liquids" IEC 60695-1-40 7.1
- No fire risk in event of major electrical fault; "even if spray ignites(..)the resulting pool of liquid rapidly ceases to burn" IEC 60695-1-40 7.1
- Low density, non toxic smoke

7. BURNING TRAY TESTS [1]

In an attempt to demonstrate the difference in the burning behaviour between synthetic ester and the more flammable mineral oil, trays of

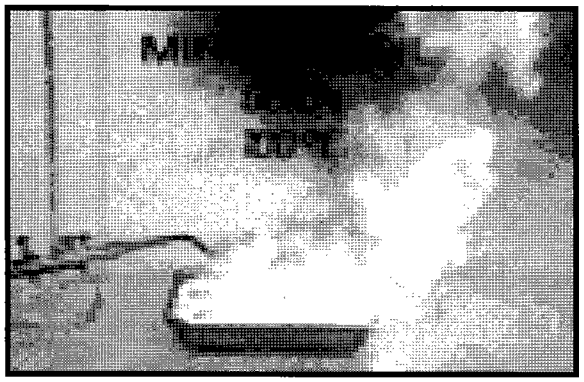
each oil where heated with an oxy-acetylene torch flame (>2000°C) in the laboratory. The more flammable mineral oil is alight within 4 minutes as shown in the photographic sequence.

Picture 2 The Case of Mineral Oil

Time 1 min - the mineral oil is flashing under the flame

Time 3 min - the mineral oil is well on the way to igniting.

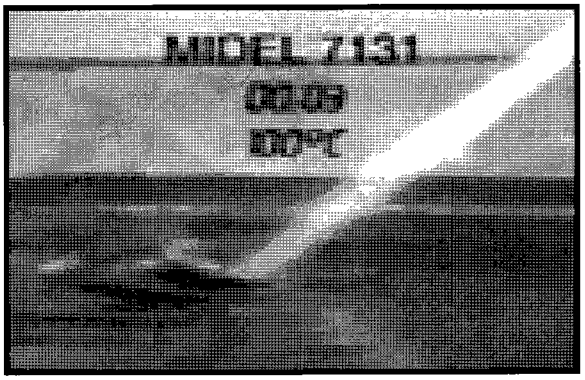
Time 4 min - the mineral oil is alight and smoking



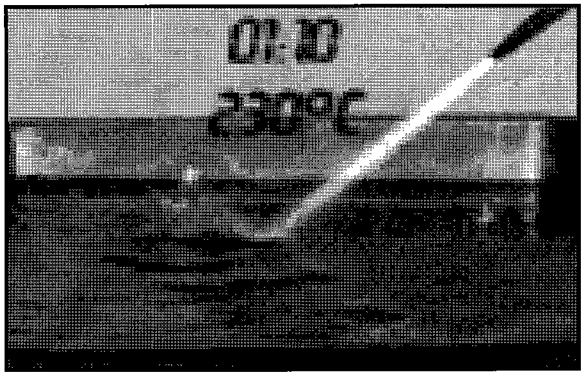
In contrast the synthetic ester proves more fire resistant:

Picture 3 The Case of Ester

Time 3 min - the ester shows no sign of flashing



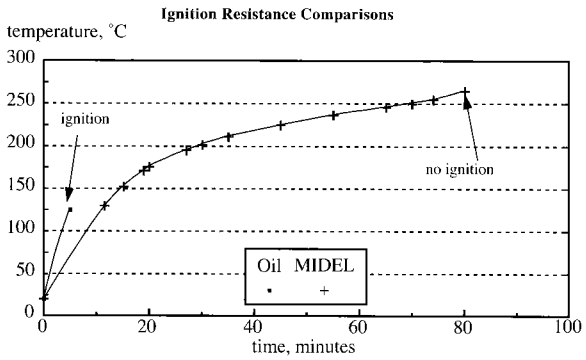
Time - 70 min small amount of flashing in the vicinity of the flame



Eventually, under the intense heat of the flame, the ester burns but with very little smoke.

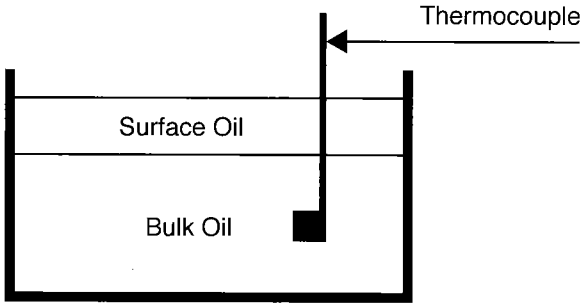
Graphically the burning behaviour of the two fluids can be expressed as follows

Figure 2 Burning Behaviour of Fluids



8. SELF-EXTINGUISHING PROPERTY OF ESTERS [2]

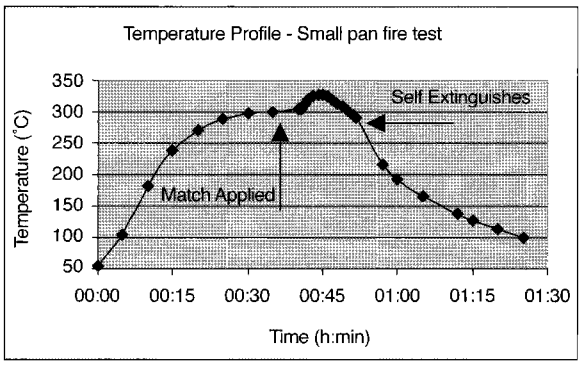
Figure 3 Self Extinguishing Test Apparatus



A brass cup of synthetic ester (80ml) was placed on a hot plate and heated in a fume cupboard until the bulk oil temperature exceeded 300°C. At a bulk oil temperature of 304°C a flame (match) was applied and the Midel 7131 was set alight. The temperature was then monitored every minute. Once the pot was alight, the bulk oil temperature rose rapidly initially until a temperature of 327°C was reached. After 5 minutes of being on fire, the bulk oil temperature began to reduce. When the oil temperature cooled to 291°C the flame self extinguished.

It must be remembered that in this experiment, the measured temperatures of 304°C and 291°C do not represent accurate fire point temperatures, as this experiment was not carried out under strictly controlled Fire Point determination conditions. These temperatures are of the bulk liquid temperature where the temperature probe was placed. The fluid burning at the surface of the oil would be expected to be hotter than the bulk oil temperature.

Figure 4 Temperature Profile of Small Pan Fire Test



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9. FIRE SAFETY TESTS IN SITU

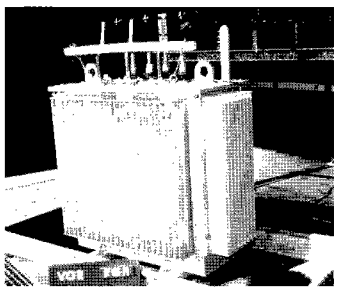
To compliment the laboratory tests, a synthetic ester (MIDEL 7131) filled transformer was sacrificed to demonstrate that in the event of a serious electrical fault, the fluid does not contribute to any resulting fire [3].

The transformer, installed in a test rig, was subjected to a massive power overload, designed to simulate a lightening strike or serious fault. It was intended that the transformer be destroyed to simulate worst-case conditions.

The transformer is set up in the test rig:

Picture 4 Transformer Under Test

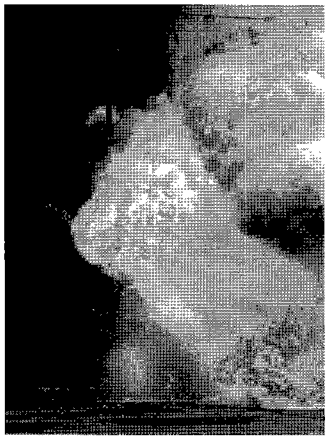
Time = 0



SIEMENS

The overload is introduced causing an initial flash. The tank ruptures due to the initial pressure surge:

Time = 1 second

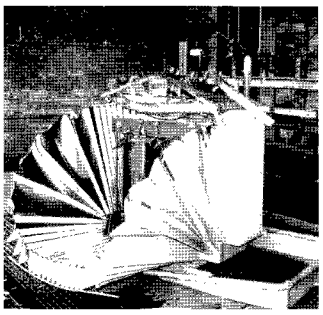


The tank splits and the fluid pours onto the floor:

Time = 3-4 seconds

After 3-4 seconds, the initial flash caused by igniting fault gases and vapourised oil starts to rapidly die away:

Time = 7 seconds



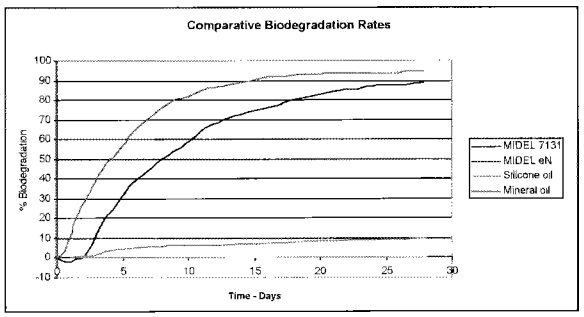
After 7 seconds, the initial flash has extinguished. The pool of MIDEL 7131 on the floor rapidly cools below its flash point, and hence cannot contribute to a fire. In critical areas, esters are often the most appropriate fluid because of their high fire safety credibility.

10 ENVIRONMENTAL BEHAVIOUR

Being environmentally friendly is now a vital characteristic of today's dielectric fluids. It is one of the properties of esters, which makes them attractive alternatives to mineral oil.

Both natural and synthetic esters are officially classified as being ***'readily biodegradable'***. This means they pass strictly controlled degradation tests carried out according to OECD methods [4]. These test methods are internationally established and recognized. The behaviour contrasts markedly with mineral oil (very slowly biodegradable) and silicone oil (practically non-biodegradable).

Figure 5 Comparative Biodegradation Rates



In addition, esters have demonstrated that they are also non-toxic to land and water based life. These key factors have prompted the German Federal Department of the Environment (Umweltbundesamt, UBA) to classify these esters as ***"non water hazardous"*** [5,6].

Rapid biodegradability and non-toxicity are two key factors that allow esters to be used in environmentally sensitive areas, such as near watercourses, or in close proximity to people.

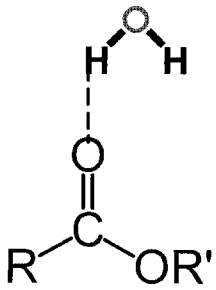
11. MOISTURE TOLERANCE

The ester linkages present in both natural and synthetic esters make these fluids 'polar'. Like

a magnet, these molecules contain regions (the ester linkages), which are able to attract other polar molecules.

Water, a polar molecule, is made up of two very different types of atom, hydrogen and oxygen Consequently, esters have a particular affinity for water molecules in a way that mineral and silicone oils cannot.

Figure 6 How Esters Attract Water Molecules



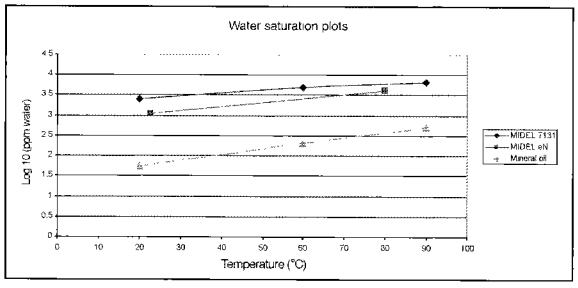
Natural esters have 3 ester linkages per molecule, whilst synthetic esters may have 2-4 linkages per molecule. These differences become evident when we consider the amount of water that will dissolve in these fluids.

Table 3 Solubility of Water in Esters

	Ester linkages	Approx water saturation at 23°C (ppm)
Mineral oil	0	55
Natural ester	3	1100
Synthetic ester	4	2600

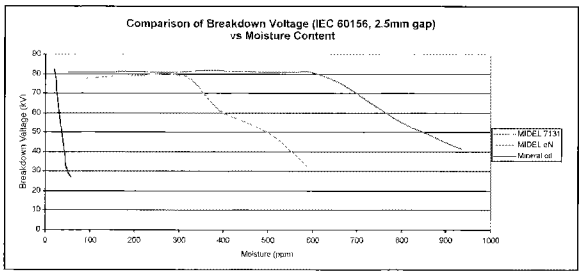
The solubility of water in all these fluids increases with temperature. A logarithmic plot of the water solubility against temperature shows an approximately linear relationship, with different materials having different gradients [7,8]. Clearly the more polar esters are able to absorb more water across the temperature range.

Figure 7 Log Plot of Water Content VS Temperature



The absolute amount of water that a dielectric fluid contains can have a dramatic effect on its electrical properties. Polar fluids have significantly more water tolerance, and this can be clearly seen in the effect of water content on breakdown voltage [9,10]. Non-polar fluids such as the mineral oil are particularly sensitive to the absolute moisture content.

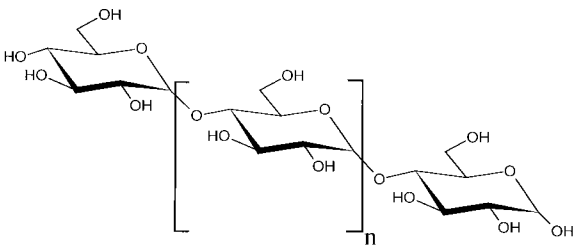
Figure 8 Plot of Breakdown Voltage vs Absolute Water Content



Paper No. 2

12. EXTENDING TRANSFORMER LIFE

Paper (cellulose) is still the most common form of solid insulation used in transformers. Cellulose is a polymer structure made up of many glucose units arranged in chains:



The average number of glucose units in the polymeric chains, called the 'degree of polymerisation' or DP, dictates how mechanically strong the paper is: the longer the chains, the stronger the paper.

A key indicator of the potential working lifetime of a transformer is the condition of the paper insulation. In a new transformer, the DP of the cellulose insulation is typically between 1000 and 1200. As a transformer ages, the paper (cellulose) begins to degrade and de-polymerise, forming chains of shorter length (lower DP). The overall effect of this is that the

paper becomes progressively weaker [11,12, 13,14,15]. When the average DP reaches 200, the paper insulation is said to have reached the end of its working life. This means that it should be completely replaced, or the transformer scrapped.

A by-product of this de-polymerisation process is the formation of water, which accumulates in the paper structure. Worse still, the presence of water causes an acceleration of the rate at which the paper degrades. This leads to a situation where older transformers, or those in poor condition may deteriorate rapidly towards the end of their working life, ultimately leading to failure. There is now a wealth of scientific papers which show that a reduction in the amount of water held in the cellulose insulation significantly extends the useful life of the paper.

In this regard, the affinity of esters for water has been put to good use [16].

In new transformers, the ester fluid is able to protect the cellulose paper by drawing moisture into itself, rather than let it accumulate in the paper. The paper insulation therefore stays drier longer and hence has a longer life. Esters do this both by absorbing the moisture from the degrading paper itself, and are also able to protect the paper from moisture entering from the outside in the case of free breathing equipment.

In a similar type of application, a previously redundant wet mineral oil transformer was retrofilled with a synthetic ester, MIDEL 7131.

Follow up studies [17,18] show that the ester absorbed the water from the cellulose, and that after a few fluid cycles; the transformer was able to be returned to active service.

13. RETROFILLING MINERAL OIL TRANSFORMERS

Both natural and synthetic esters are miscible with mineral oil in all proportions. This allows them to be used to retrofill mineral oil equipment. Ester fluid manufacturers will provide printed guidelines for exactly how this can be done easily and safely.

When retrofilling mineral oil equipment, it is important to remove as much mineral oil as possible during the draining and flushing procedure. This is because relatively large amounts (greater than say 4%) of mineral oil can compromise the high fire safety characteristics of the ester fluids [19]. It should also be noted that silicone oil is not miscible with ester fluids, and that even small amounts of silicone fluid contamination in ester fluids can cause foaming when charging a transformer under vacuum.

14. MAINTENANCE OF ESTER FLUID EQUIPMENT

The standard set of tests to determine fluid quality for mineral oil can also be used with ester fluids. Typical examples are: breakdown voltage, neutralisation value and moisture content, among many others. However, test results will be different to those expected from mineral oil, and the appropriate standards for ester fluids should be consulted [20,21].

The range of DGA gases produced by esters are the same as for mineral oil, namely hydrogen, methane, ethane ethylene, acetylene, etc. When diagnosing transformer faults, the diagnostic charts of ratios (e.g. Rogers ratios or Duval triangle) can be used with the mineral oil values to give a reasonable guide [22,23]. For example a strong arcing fault will produce acetylene from both mineral oil and esters. However it is true to say that the amount and proportion of the fault gases produced are slightly different from mineral oil, and some care needs to be taken, especially in the diagnosis of borderline cases.

The CIGRE group TF15 headed by Michel Duval [24] is currently investigating DGA in alternative fluids and is due to issue a formal report in due course. The University of Manchester in the UK has also carried out excellent work in this area [25,26].

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Paper No. 3

CARING FOR OUR ENVIRONMENT – SUSTAINABLE DEVELOPMENT OF TRANSMISSION SYSTEM

Speakers : Mr Howard K.H. Ng, Manager - Engineering Projects
Ir C.P. Cheng, Substation Implementation Manager
CLP Power Hong Kong Ltd.

CARING FOR OUR ENVIRONMENT – SUSTAINABLE DEVELOPMENT OF TRANSMISSION SYSTEM

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ABSTRACT

Reliable and adequate supply of electricity is a necessity for a metropolitan city like Hong Kong, In order to support the fast development of Hong Kong in the years to come, CLP Power's (CLP) transmission network will be extended and reinforced to meet the new and increased electricity demand required for the healthy growth of our city. In the recent years, an average of three transmission substations and around 100 kilometers of new transmission circuits are being constructed per year.

Today our community continuously requests for a greener and sustainable living environment. Recognising the importance to balance the coexistence of people and natural environment, CLP takes initiatives to develop the transmission system in an environmental friendly manner by adopting a holistic framework of sustainable development. This sustainable development framework serves as a guideline for the development of both substations and circuits in CLP so as to achieve: -

- Conservation of environment;
- Energy efficiency; and
- Balance the social, economic and environmental interests.

With more than three decades of experience in developing transmission system, a green protocol for substation design has been initiated and developed into a total environmental solution since 1997. The environmental features of green substation design include adoption of natural ventilation & lighting, landscape design, deployment of low loss & low noise transformers, adoption of renewable energy, and water recycling. Moreover, CLP adopted oil minimum system such as the use of oil-free cables and switchgear, and the best practice of green construction approach including pre-fabrication technology for building, horizontal directional drilling method and trenchless technique for cable installation and use of cable tunnels. Such sustainable and holistic approach has acquired much appreciation from the community in reducing the disturbance to our environment to a minimum.

Energy conservation is the main theme for design and construction of the building services installations inside the substation building. In 2005, by incorporating various energy efficient design of building services equipment, CLP is the first Hong Kong's power utility company to obtain the Registration in the Energy Efficiency Scheme of lighting, electrical system and air-conditioning installations for newly built substations as accredited by the Hong Kong SAR Government.

CLP has pioneered the adoption of the best practice of Life Cycle Analysis (LCA) in our substation design and development. As an optimal design and assessment tool, LCA appraises life cycle cost and performance of building materials and components. With the photovoltaic panel and water recycle system at a newly commissioned substation, an integrated system of renewable energy and rain water conservation was developed for irrigation of green plant on the roof of the substation. CLP also endeavors to maintain the substations in a green manner throughout its life-cycle through research and development of green roof system for utility buildings in Hong Kong.

In order to reduce the environmental impact throughout the construction stage of transmission projects, an innovative environmental management tool is developed to help the site construction team to implement various environmental protection measures effectively in our construction sites.

Supported by detailed analysis of cost and benefits to our society and environment, this sustainable design approach for the development of our transmission

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system is found to be fully worthwhile. Our community will not only benefit from the secure and stable electricity supply, but also a greener and sustainable living environment.

Keywords: Environmental, Transmission System, Sustainable Development, Green Substation

1. INTRODUCTION

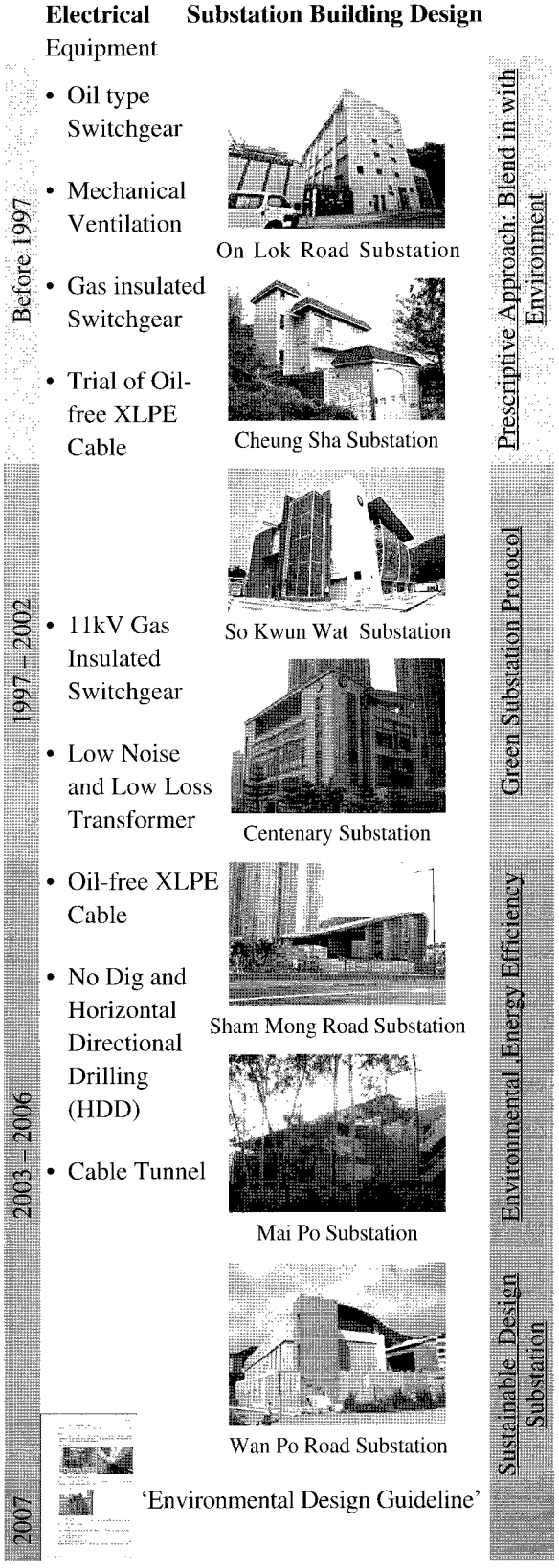
Reliable and adequate power supply is essential for a vibrant city like Hong Kong. CLP Power Hong Kong (CLP) is committed to providing a secure, efficient and economical supply of electrical power to its customers within the supply territory of Hong Kong. In order to be in pace with the fast development of Hong Kong, CLP will continue to develop and enhance the transmission system. CLP's transmission system development is a continuous process which requires innovative engineering solutions to cope with a range of unique challenges present in Hong Kong. In recent years an average of three transmission substations and about 100 kilometers of new transmission circuits are being constructed per year.

CLP cares for our environment and develops the transmission system in a sustainable manner. Such development is based on a holistic design framework that helps to achieve the balance of economic, social and environmental aspects. The objectives of sustainable development of the transmission system are to enhance efficiency, engage stakeholders in a responsible relationship and provide a safe, secure and reliable electricity supply. This paper aims to describe the developments, applications and achievements of the sustainable design framework for the development of CLP's transmission system.

2. SUSTAINABLE DEVELOPMENT IN CLP

In the past, CLP adopted oil filled electrical

Figure 1 Road Map for Development of Electrical Equipment and Substation Building



plant & cable and a prescriptive approach to the substation building design. Oil sumps or oil interceptors had been installed to prevent leakage of oil from the equipment into the environment. Heavy grade noise abatements were installed to restrict the noise impact to the noise sensitive receivers in the vicinity.

In the recent years, various green features have been incorporated in the development of the power transmission system. These green features balance social, economic and environmental interests of both the present and the future generations with needs for the electricity supply. Figure 1 briefly summarizes CLP's roadmap of environmental design adopted during the past 10 years.

In these 10 years, valuable experience and knowledge have been gathered during processes of design, implementation, review and improvement of the green design features. Under the direction of CLP's environmental strategy, together with the regular review of design code of practices for transmission system, green substation protocol, Safety, Health and Environment substation protocol, international standards, our versatile experience in the sustainable development of transmission system is captured in an 'Environmental Design Guideline'. This marks an important milestone of CLP since embarking on the journey of sustainable development ten years ago. Table 1 summarizes the framework of CLP's Environmental Design Guideline for transmission system established in early 2007. This Guideline provides a comprehensive design review of environmental issues arising from a transmission system projects. It embraces the concept of green initiatives to the potential environmental impacts associated with the construction and operation phase of the transmission system. It emphasizes on the importance of design considerations in the planning and design stages of the transmission system which will help to minimize any potential environmental impact in an effective way.

The Guideline focuses on:

- Site Selection (legislative requirements);
- Substation Layout (size, access, equipment layout, utilities);
- Architectural, Structural and Building Services; and
- Other Considerations (i.e. indoor air quality, innovations, enhancing productivity).

Table 1 Framework of CLP's Environmental Design Guideline for Transmission System

• Site Selection and Planning • Well-integrated Design • Resource Management	Planning
• Daylight and Sunlight Control • Natural Ventilation Strategy • Sustainable Landscape Design • Low Loss & Low Noise Design	Architectural
• Energy efficiency Management • Renewable Energy • Water Management	Renewable and Recycle
• Reduction of Disposed Material • Containment System • Environmental Friendly Materials • Green Construction	Technical
• International Standards	Benchmark

The best way to illustrate the key features of this newly established Guideline is by highlighting some of the environmental initiatives including:

- Natural ventilation and lighting
- Landscape design
- Renewable energy, Material & Water Recycle
- Low loss and low noise transformer
- Management of SF_6 Gas Insulated Equipment

- Life Cycle Analysis
- Substation Design Optimization
- Best Practice of Green Construction
- No Dig Installations and Tunnels

2.1 NATURAL VENTILATION AND LIGHTING

The building is configured to allow for adequate natural ventilation. Special features such as the 'roof wind catcher' which is based on the fluid dynamic theory had been developed to facilitate natural ventilation for transformer heat dissipation.

The heat dissipation capacity of the building is predicted by Computational Fluid Dynamics (CFD) modeling technique during the design stage in order to ensure adequate natural ventilation is provided and to minimize the volume of the transformer bays. Ventilation by natural means mitigates the requirement of large ventilation fans and the associated noise abatement installations. Adequate ventilation to remove heat generate from the transformer can provide a better working environment for our operational staff and lengthen the life span of the transformers. Minimizing the volume of the transformer bays reduces the quantity of the building materials required for the substation building, and hence, can reduce the economical cost as well as the environmental cost of the substation building.

Figure 2 Computational Fluid Dynamics Model of Natural Ventilation at Sham Mong Road 132kV Substation

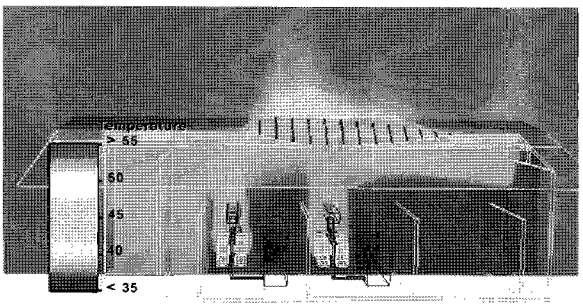
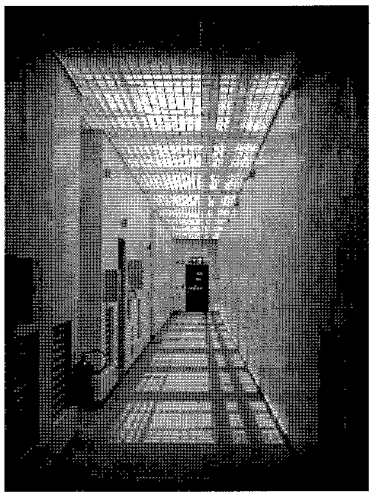


Figure 3 Natural Daylight Effect in Corridor of So Kwun Wat 132kV Substation



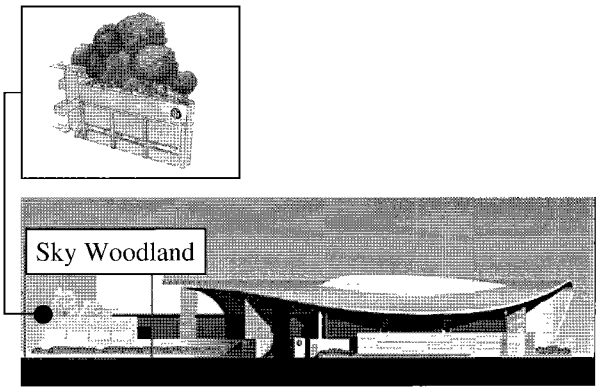
On the use of natural lighting, skylight and glazed staircase are designed in the substation building to capture the sunlight and reduces the energy consumption for lighting requirements.

Figure 2 and 3 indicate the CFD simulation for the natural ventilation of the transformer bays and the daylight effect of a corridor respectively in the substation building.

2.2 LANDSCAPE DESIGN

CLP launched the project Sky Woodland in 2006. A woodland with 10~20 number trees will be planted on the special designed roof of an equipment building at the Sham Mong Road 132 kV substation as shown in the Figure 4.

Figure 4 Sky Woodland on the Roof of a Building at Sham Mong Road 132kV Substation



This is a pilot project that aims to study the feasibility of establishing woodland on roof of a building under the local environment. It is expected that planting trees on the roof can reduce the temperature inside the building and hence can reduce the cost for air-conditioning and lengthen the life of the roof.

For slope associated with our substations, seasonal complementary planting system is adopted for the landscape design. Climbers and creepers with flowering at different seasons are planted on the slope. The ecological system on the slope will be self-balanced and self-sustained.

In the rock-fill slope, bio-geotechnical approach is provided for reinforcement purpose. Plants with deep roots are planted on the slope to enhance the stability of the slope.

All plants on the slope are with minimal maintenance requirement. The following Figures 5 and 6 show the seasonal complementary green wall system and the rockfill slope in substations respectively.

Figure 5 Seasonal Complementary Green Wall System at Chuk Yuen 132kV Substation

2.3 RENEWABLE ENERGY, MATERIAL & WATER RECYCLE

Three sets of Photovoltaic (PV) panel installations have been built on roofs of the substation buildings/offices at different locations. Table 2 summarizes the key features of these renewable energy installations.

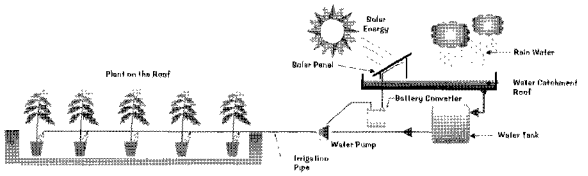
Figure 6 General View of Rockfill Slope behind Sham Shui Kok 132kV Substation

Table 2 Summary of Renewable Energy Installations in Transmission Substations/Offices of CLPP

Locations	Rated Capacity	Type of PV Cell	Connection
Wan Po Road 132 kV S/S	0.32 kW	Poly-crystalline	Stand alone
Tsz Wan Shan Depot Office	2.2 kW	Mono-crystalline	Grid connected
System Control Centre at Taipo	2.2 kW	Mono-crystalline	Grid connected

A piece of roof on the Wan Po Road Substation is designed to collect rain water for irrigation purpose. The collected rain water is stored in a tank for irrigation of plants at the roof of this substation in an automatic manner. Figure 7 is the schematic diagram of the rainwater irrigation system which is powered by solar energy in Wan Po Road 132kV Substation.

Figure 7 Schematic Diagram of Rain Water Recycle Irrigation System powered by Solar Energy at Wan Po Road 132kV Substation



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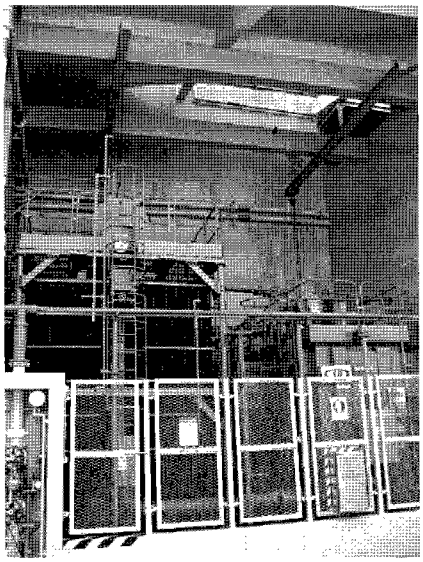
2.4 LOW LOSS & LOW NOISE TRANSFORMER

Mechanical fans on the high voltage transformers (Tx) generate excessive noise in the past. The cooling method of these Tx has been changed from ONAN/ONAF (oil natural air natural/oil natural air forced) to ONAN (oil natural air natural) such that cooling is achieved by mechanical means. By elimination of those fans, level of noise generated by the transformer has been reduced from 62dBA (for 35MVA Tx) and 67dBA (for 50MVA Tx) to 52dBA, thus reducing the nuisance to the public.

Figure 8 Low Noise Type High Voltage Transformer Installation at Wan Po Road 132kV Substation



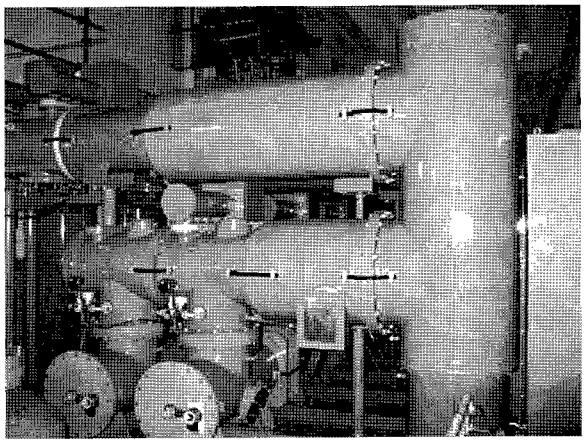
2.5 MANAGEMENT OF SF_6 GAS INSULATED EQUIPMENT

In order to minimize environment pollution, CLP has committed to reduce the release of SF_6 gas to the environment. Continuous exploration of the latest technology to achieve the release target is underway.

2.6 LIFE CYCLE ANALYSIS

CLP is the first power utility company in Hong Kong to apply Life Cycle Analysis (LCA) in the substation design in order to measure the cradle-to-grave operating and maintenance

Figure 9 A SF_6 Gas Insulated 132kV Switchgear Installation



costs, and merits in terms of global and local environmental issues for all building members.

The LCA model, originated by Electrical and Mechanical Services Department (EMSD) of HKSAR Government was firstly applied to assess Wan Po Road 132kV Substation. A relative low score of 205.4 x 10^{12} was obtained. This means that the design of Wan Po Road Substation has little impact on the environment. Figure 10 shows the result of the LCA assessment for the Wan Po Road 132kV Substation and the approximate score allocations for the 10 different environment impact categories.

Figure 10 LCA Results of the Wan Po Road 132kV Substation

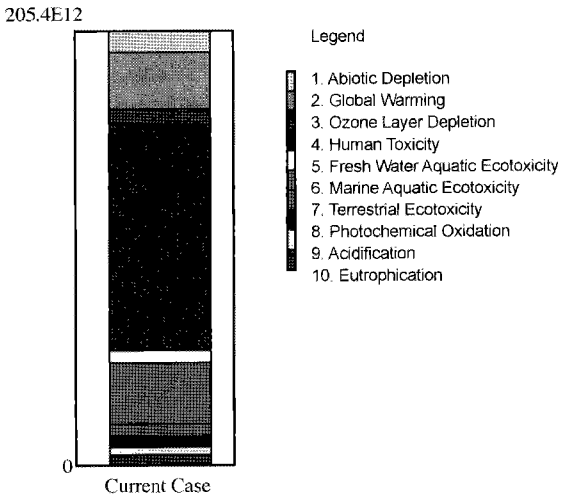


Figure 11 LCA Scores of Wan Po Road 132kV Substation Building during its Various Life Stages

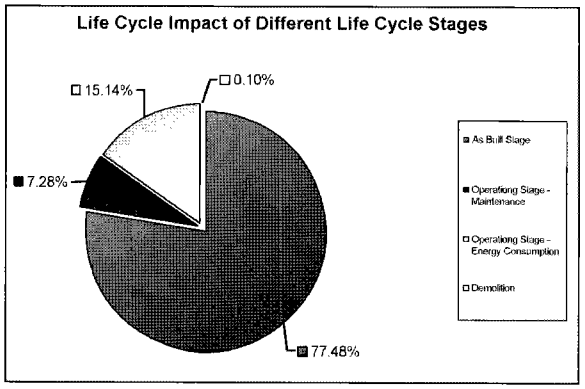


Figure 11 indicates the LCA scores of the substation building during its various stages of life. The building material/installation constitutes the major life cycle impact (77.46%). Life cycle impacts for the 'demolition', 'maintenance' and 'energy consumption' are 15.14%, 7.28% and 0.10% of the life cycle impact respectively.

2.7 SUBSTATION DESIGN OPTIMIZATION

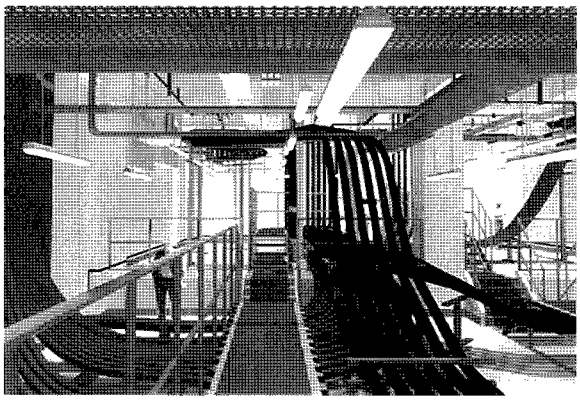
The Substation Design Optimization enhances the substation design process in an interactive integration approach. Through this process, the use of space in a substation can be optimized. Creative media is an effective tool to communicate with people from different backgrounds such as plant, cable, building services & civil. They can visualize and offer their views to the plant layout during the early planning and design stages.

The future layout of cables inside the basement of Junk Bay Road 132kV Substation is presented in Figure 12. Valuable opinions from different stakeholders can be sought for improvement of the installation.

2.8 BEST PRACTICE OF GREEN CONSTRUCTION

Soil and water management is a common challenge for all construction sites in Hong Kong. CLP has taken a proactive approach in working with strategic contractors in the development of 16 Construction Best Practices.

Figure 12 Future Layout of Cables inside Basement of Junk Bay Road 132kV Substation



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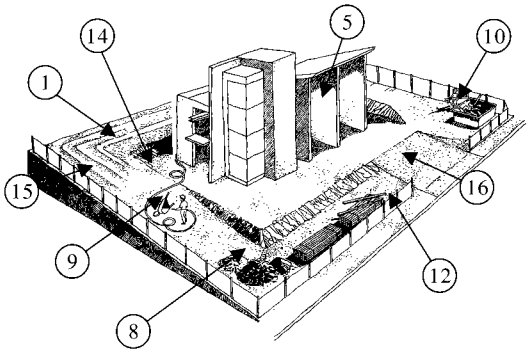
This has resulted in the production of environmental protection guidance notes for workers on site and monitoring measures for supervisors to ensure system effectiveness and encourage continuous improvement. The 16 Construction Best Practices elements are:-

1. Diversion of Upslope/Upstream Water
2. Dust Control
3. Stagnant Water Control
4. Excavation Pump Out
5. Protected Concrete, Brick and Tile Cutting
6. Protected Concrete Delivery
7. Protected Service Trenches
8. Protected Stockpiles
9. Protected Wash Areas
10. Protected Waste Management and Chemical Storage
11. Protected Vegetation
12. Protection of Gutter and Street Stormwater Drains
13. Protection of Site Stormwater Pits
14. Sediment Controls
15. Soil and Water Management Plans
16. Stabilized Site Access



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With the successful implementation of these environmental initiatives on one of CLP's construction work sites at Junk Bay Road 132kV Substation, there have been savings in construction waste disposal (16%), energy (10%), water consumption (4%), concrete and steel wastage at 1.3% and 1.8% respectively in comparison with the industry norm.

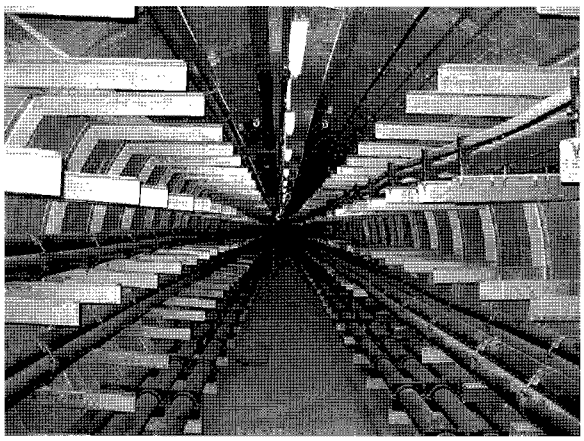
Based on the positive outcome, CLP is continuing to work with these contractors on environmental initiatives on air and noise management best practices in Year 2007.

2.9 NO DIG INSTALLATIONS AND TUNNELS

During the recent years, CLP has completed two horizontal directional drilling projects and five cable tunnels. Figure 13 shows the general facilities inside a cable tunnel. Over forty no-dig crossings by pipe jacking or micro-tunneling methods had also been built under heavy traffic roads.

Cable tunnels improve the supply reliability by providing protections to cables inside the tunnel. Congestion of other underground utilities, disruption by the condition above the ground level and repeated road opening for cable laying at different period can be avoided. Hence leading to less environmental impact and reduction in future installation cost to the laying of cables.

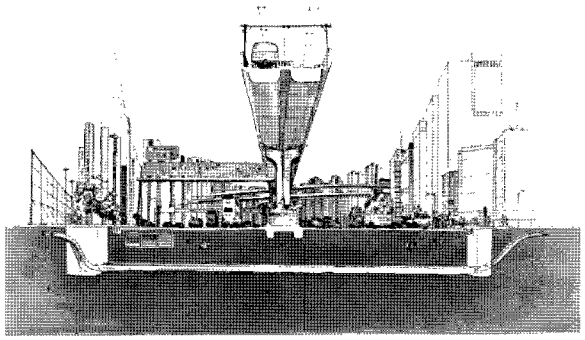
Figure 13 General Facilities inside a Cable Tunnel



The no-dig method as shown in the Figure 14 is an effective method to install the underground utilities under a road with heavy traffic.

Green approach for transmission cable work also includes the use of low noise equipment, noise abatement chamber, use of cable tiles made from furnace bottom ash, adoption of oil-free XLPE cable, non-timber shoring and excavation soil recycling.

Figure 14 Pipe Jacking Installation at Kwun Tong



3. RECOGNITIONS

Numerous achievements have been made by the continuous effort in sustainable development of the transmission system in CLP. Public recognitions on the environmental achievements of the substation buildings with 11 Energy Efficiency Registrations have been made successfully to the Electrical & Mechanical Services Department of HKSAR Government. In 2006, Wan Po Road 132kV Substation received the international Asian Power Awards 2006 due to the contributions in the environmental building features.

4. CONCLUSION AND WAY AHEAD

Energy efficiency and conservation has an important role to play in maintaining a healthy environment. CLP strives to use limited resources in an efficient way and improve the

efficiency of our operations. The green approach has reduced the energy consumption and maintenance cost of the substation building by about 34% and 20% respectively.

CLP upholds core values of 'care for the community' and 'care for the environment' to its operations. Development of the transmission system in a sustainable manner supports these core values.

The design of Wan Po Road 132kV Substation demonstrates a promising saving in LCA result for 50 years and reduces the long term operation and maintenance requirements.

Green building provides long term cost benefit in terms of monetary, social and cultural rewards. Environmental design approach reduces the electrical and mechanical equipment thus improving the reliability of the supply network.

Instead of dogmatically judged by the initial cost, the total life cycle cost of the development is considered. Some design tools have to be used to balance the cost benefits of various green initiatives.

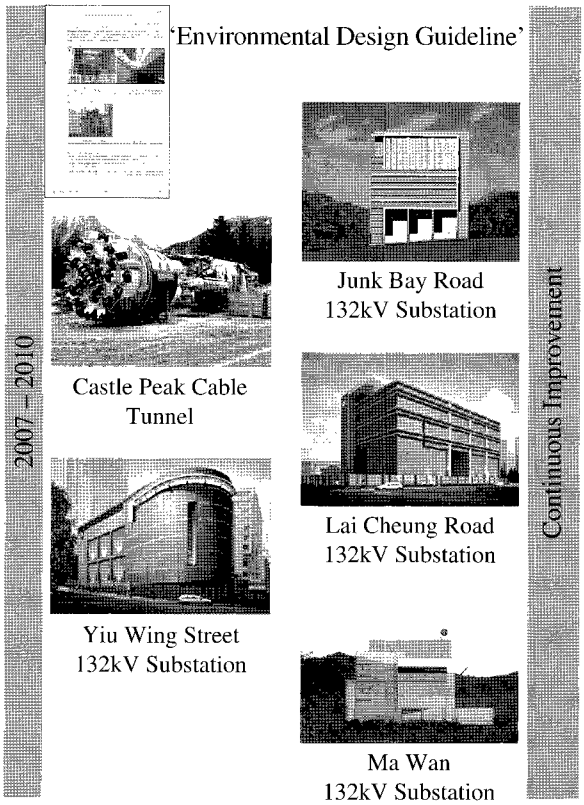
We have consolidated our experience and knowledge during the development of the 'green' transmission network, and formulated a comprehensive framework - 'Environmental Design Guideline' in 2007. This has marked a key milestone of CLP in the journey of sustainable development.

To continue our effort on environmental protection, such environmental design guideline will be promoted to office, slope, new transmission substation & network projects as well as brown field projects

This Guideline will be implemented on all future substation & network developments. Figure 15 indicates some of our future developments in the near future.

Moreover for continuous improvement purpose, the Guideline will be communicated to relevant parties and benchmark with International Standards or Best Practices. Customers' feedbacks, comments received and the benchmark findings will provide a way to shape and improve and enrich our design in future.

Figure 15 Road Map for Near Future of Some Substation & Network Developments



5. ACKNOWLEDGEMENT

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Paper No. 4

FROM PRODUCTION TO SUPPLY – TOTAL ENVIRONMENTAL MANAGEMENT OF ELECTRICITY

Speaker : Ir Dr C.W. Tso
General Manager (Projects)
The Hongkong Electric Co., Ltd.

FROM PRODUCTION TO SUPPLY – TOTAL ENVIRONMENTAL MANAGEMENT OF ELECTRICITY

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ABSTRACT

Care for the environment is at the centre of considerations surrounding all decision-making of The Hongkong Electric Co., Ltd. (HEC), from plant location and design to equipment selection, installation and operation of all its electricity generation, transmission, distribution and supply infrastructures.

Extensive equipment has been installed at HEC's plants, and processes are well in place, to minimize emissions and discharges, ensure that air and water quality are preserved and waste is treated at source or recycled wherever possible. Major initiatives include the commissioning of Hong Kong's first flue gas desulphurisation (FGD) plant for a 350 coal-fired unit in 1993, and Hong Kong's first generating unit fuelled by liquefied natural gas in 2006.

To explore the technical feasibility of and promote public awareness of using wind as renewable energy for power generation, HEC commissioned Hong Kong's first grid-connected 800kW wind turbine in February 2006. To further improve the air quality of Hong Kong, HEC has commenced to retrofit FGD plant and low NOx burner system to two 350MW coal-fired units and is planning to further retrofit an older 250MW unit with FGD. This together with the wider use of natural gas for power generation will put HEC firmly on track to meet the emission targets for 2010 set by the Hong Kong Government, whose Action Blue Sky Campaign HEC also actively supports..

HEC expects all its employees to buy into the ethos on environment and practise it as well. Volunteerism and active company participation in projects dedicated to both enhancing the environment around us and also to educating the public about using energy responsibly, are all examples of HEC adhering to the spirit of the highest levels of care for the environment. HEC publishes an Annual EQHS Report in which its environmental performance during the preceding year and commitments for the following year are presented.

1. INTRODCUTION

The Hongkong Electric Co., Ltd. (HEC), one of the two power utility companies in Hong Kong SAR, is responsible for supply of electricity to Hong Kong Island and Lamma Island. Today, HEC's power station on Lamma Island including Lamma Power Station, Lamma Extension and Lamma Wind has a total installed capacity of 3,756MW, serving more than 550,000 customers with a supply reliability rating of 99.999% since 1997.

HEC's business objectives is to balance the eco-efficiency of its operations with its long-term corporate profitability, while making a strong contribution to sustainable business, social and environmental development in Hong Kong. This paper outlines the policy and measures adopted by HEC in its total environmental management of electricity operations that has resulted in:

- A cleaner Hong Kong environment
- An eco-efficient and highly reliable electricity supply at competitive prices, helping to stimulate and sustain economic growth and to improve living standard.
- World-class electricity generation and supply systems

2. ELECTRICITY PRODUCTION

2.1 POWER STATION GENERATION CAPACITY

HEC's electricity supply is produced at Lamma

Power Station (LPS) which has been undergoing continual development in phases to meet the energy demand over the past two decades. LPS, with his first generating unit commissioned in April 1982, now has an installed capacity of 3,755MW. It comprises 2,500MW coal-fired units (3 x 250MW and 5 x 350MW), one 365MW oil-fired combined cycle unit and 555MW gas turbine units (1 x 55MW and 4 x 125MW) on the original 50 hectares site, and a 335MW gas-fired combined cycle on the 22 hectares extension site.

2.2 LNG FOR POWER GENERATION

The introduction of liquefied natural gas (LNG) and commissioning of HEC's first 335MW combined cycle gas fired (CCGT) generating unit in June 2006 was to fulfill the pledge in providing cost effective generating facilities with the least environmental impacts. Five more CCGT generating units will be built in phases to meet Hong Kong system load demand.

Supply of LNG is secured through a 25-year contract. LNG originates from Australia's North-West Shelf and is shipped to the Guangdong Dapen LNG Receiving Terminal in Shenzhen where it is gasified and delivered to LPS via a 92km long 510mm dia. submarine gas pipeline. Figure 1 shows the existing Lamma Power Station and Extension whereas Figure 2 shows the 335MW CCGT unit.

Figure 1 Lamma Power Station and Lamma Extension

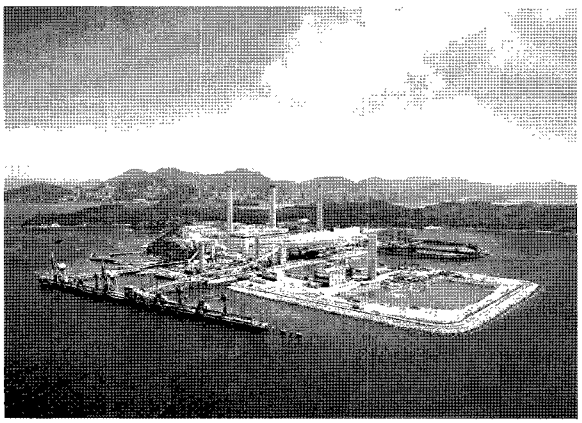
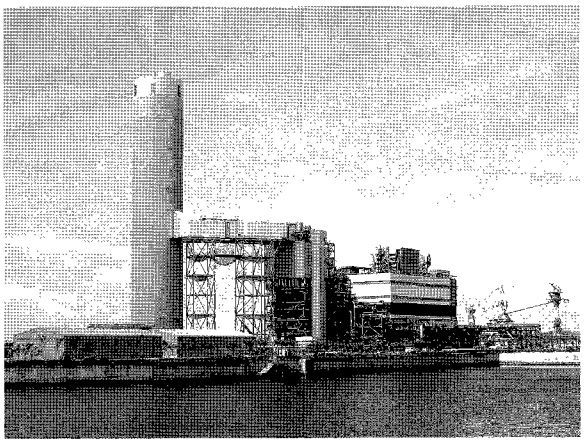


Figure 2 335MW CCGT Unit



HEC's 335MW CCGT at LPS extension has scored three "first" in Hong Kong, namely, the first unit powered by LNG; the largest output capacity; and the highest overall efficiency (56.5%.at design point). It is also the most environmentally friendly generating unit with almost no emissions of SO_2 and RSP whereas its CO_2 emission per kW output is less than 50% of that from coal-fired generating unit.

Green resources are again emphasized in the development of the LPS extension. A solar photovoltaic system provides street lighting and the design of the Main Station Building and 275kV Switching Station includes translucent cladding to introduce natural light. Nearly 10% of reclamation materials for site formation come from the recycled coal ash. Rubble-mounted seawalls on the south and west edges of the extension site enhance colonization of marine organisms. Rainwater is collected from rooftops for gardening and cleaning purposes while pre-cast concrete paving is laid for transport and pedestrian access.

2.3 EMISSIONS REDUCTION MEASURES FOR COAL-FIRED GENERATING UNITS

Electricity generation by burning coal inevitably produces sulphur dioxide (SO_2), nitrogen oxides (NOx) and respiratory suspended particulates (RSP). To minimize the adverse impact of these pollutants on the environment, HEC has taken a number of

mitigation measures. First of all, purchasing policy has been set in the past 20 years to use only high quality coal with less than 1% sulphur content. This initiative alone has greatly limited the amount of SO_2 produced.

As a further step, HEC introduced the first Flue Gas Desulphurization Plant (FGD) in South East Asia to Hong Kong in 1993 (Figure 3) and arrange to install low-NOx burners (Figure 4) for all the coal-fired boilers commissioned from 1992 onwards. These two mitigation measures have reduced SO_2 emissions by more than 90% and NOx emissions by two-thirds.

Moreover, the use of wet scrubbing in the desulphurization process also helps reduce particulate emission. This together with the highly efficient electrostatic precipitators and flue gas conditioning agent employed, removes more than 99.9% of particulates from the flue gas.

Figure 3 Hong Kong's First FGD Plant For Coal Fired Unit

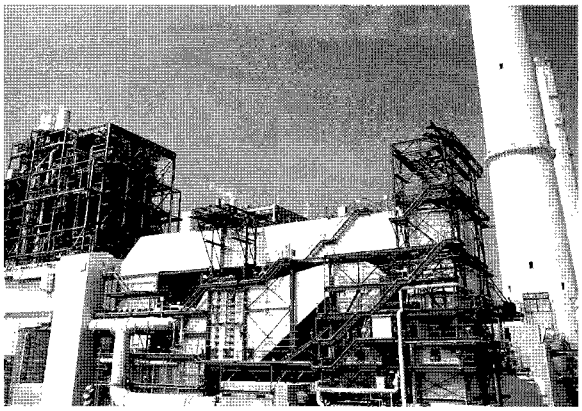
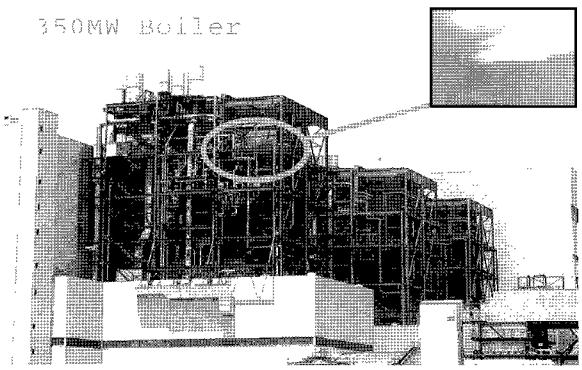


Figure 4 Low NOx Burner for Coal Fired Unit



It is worth noting that the FGD plants have adopted a non-regenerative wet limestone-gypsum scrubbing process to reduce flue gas SO_2 by conversion to gypsum. In 2006, about 67,000 tonnes of gypsum were produced as a by-product and shipped out for cement production. This arrangement not only eliminates the disposal of solid waste and helps reduce the mining of natural gypsum, but also supports the Hong Kong's Waste Reduction Framework Plan and sustainable development of the community.

To further improve the air quality of Hong Kong and in support of Government's Action Blue Sky Campaign, HEC has commenced to retrofit FGD plant and low NOx burner system to two 350MW coal-fired units and is planning to further retrofit an older 250MW coal-fired unit with FGD. When all retrofit projects are completed in 2010, Lamma Power Station will have 2,000MW coal fired capacity equipped with FGD and among which 1,750MW will have Low-NOx burners in place.

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2.4 ENHANCED COAL AND ASH HANDLING SYSTEMS

In 2006, Lamma Power Station consumed about 4.3 million tones of coal. The handling of large volume of coal and ash with minimum adverse environment impact is a great challenge for HEC. To effectively reduce fugitive coal dust, 8,600m of pipe conveyors (Figure 5) has been installed for the conveyance of coal within the power station. Dust suppressant sprays (Figure 6) have also been installed at strategic points along the coal-conveying route and in the storage yard.

Figure 5 Pipe Conveyor Containing Coal Dust During Conveyance

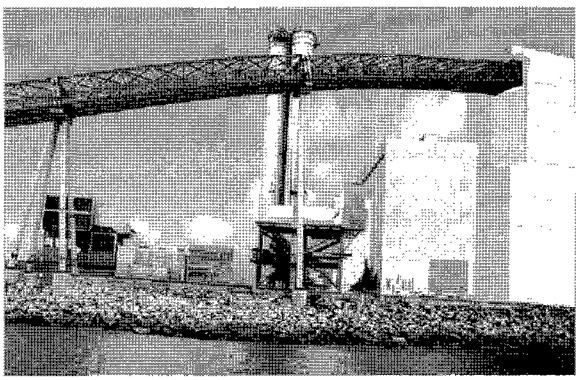
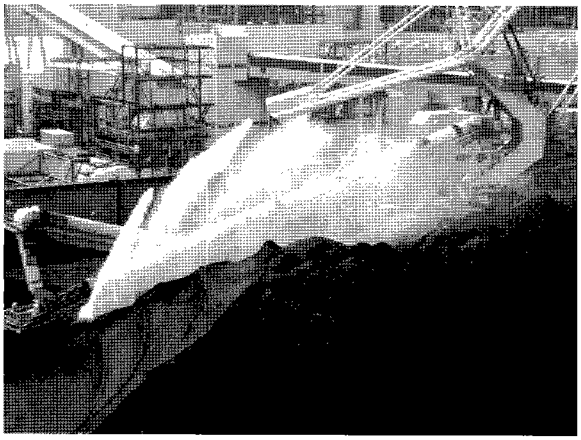


Figure 6 Coaly Yard Spray System Using Rainwater to Suppress Dust Emission



For the handling of furnace bottom ash, sluicing systems have been replaced by submerged scraper conveyors (Figure 7) which adopt a freshwater close-loop circulation system. This eliminates the use of 10,000m^3 seawater per day that would otherwise have to be processed before being discharge to the sea. Freshwater but not seawater furnace bottom ash produced by submerged scraper conveyors can also be reused by the cement industry.

In 2006, about 355,000 tonnes of pulverized fly ash were produced as by-product of coal combustion. HEC has arranged for most of the ash to be reused in the region as a substitute for cement in concrete making or as a feed material in cement making. To further enhance ash utilization, a target at 420,000 tonnes has been set for land use during the construction of Lamma Extension. To date, 340,000 tonnes of ash have already been used for such purpose to relieve the demand for sand in land reclamation. This has reduced the construction cost of the new extension.

2.5 RECYCLING WASTEWATER AND UTILIZATION OF RAINWATER

The operation of coal-fired units, particularly those equipped with FGD plants, requires a huge amount of freshwater. Since most of the freshwater consumed in Hong Kong imported from Mainland China, reducing freshwater requirement in power generation not only economizes the operation of Lamma Power Station but also helps preserve water as a precious resource.

Figure 7 Submerged Scraper Conveyor

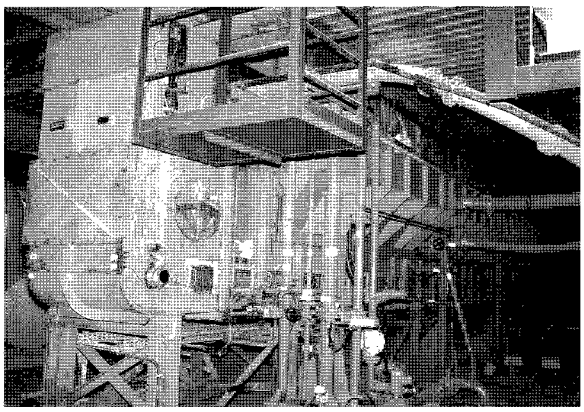
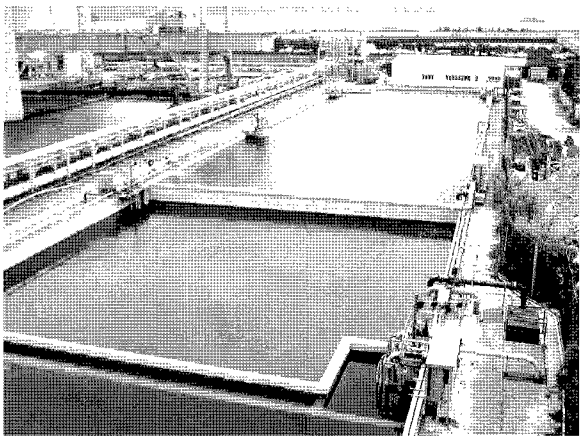


Figure 8 Storage of Recovered Rainwater & Wastewater



HEC has taken the initiative to build a wastewater reuse system and a rainwater collection system in the power station (Figure 8). More than 100,000 tonnes of wastewater recovered from various operating processes and rainwater collected can be reused every year. The reusing of wastewater and rainwater collected can be reused every year. It also allows a drastic reduction in effluent treatment requirements as well as making zero discharge to the sea not far from reality.

2.6 ENVIRONMENTAL MONITORING SYSTEM

The environmental performance of LPS has been very much strengthened by the establishment of an Environmental

Management System which continuously gauges actual performance against set targets. Furthermore, monitoring and auditing exercises involving third-party auditors have also been carried out for both monitoring and improvement purposes.

Figure 9 Locations of Air Monitoring Station

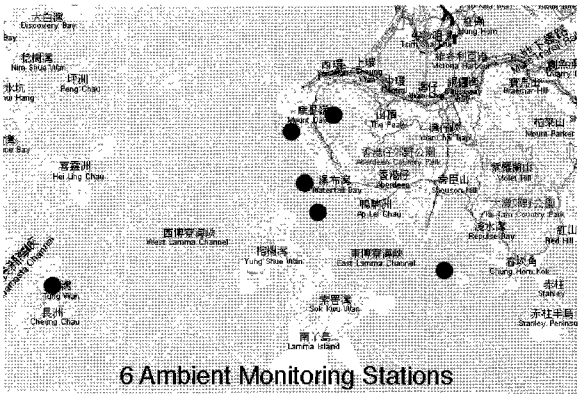
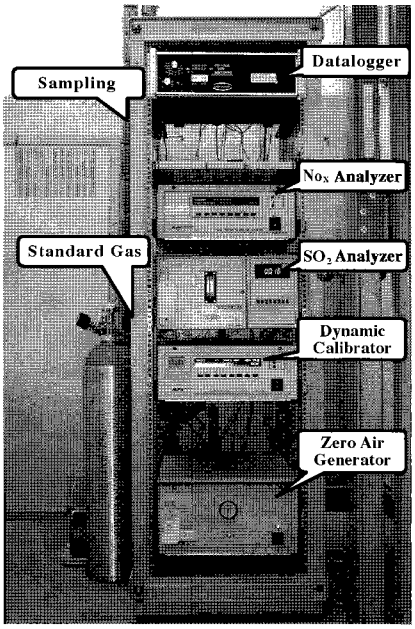


Figure 10 Air Monitoring Station



Furthermore, there is a network comprising six air-monitoring stations on Lamma Island and Hong Kong Island (Figures 9 & 10) to monitor the impact of LPS on the ambient air quality. The monitoring results over the last 17 years indicate that the environmental performance has been well within limits set in the Hong Kong Air Quality Objectives. Within LPS there is another network comprising five real-time air monitoring stations and five noise monitoring stations to warn the operators of dust and noise nuisance.

3. ELECTRICITY TRANSMISSION & DISTRIBUTION

3.1 ELECTRICITY SUPPLY NETWORK

Power generated at LPS is transmitted at 275kV to switching stations on Hong Kong Island, where it is stepped down to 132kV before it is merged with the 132kV transmission network, or stepped down directly to 11kV or 22kV for distribution. 275kV submarine cables have been laid below the East Lamma Channel with a 40m water depth. This installation is one of the highest capacity submarine cable networks in the world.

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Up to end 2006, there were 58 cable circuits with a total circuit length of 141km, 11 switching stations and five zone substations in the 275kV transmission network. For the 132kV network, there were 12 switching stations, 21 zone substations and 266km of circuit lengths. HEC's 22kV/11kV/LV network comprises cables are buried directly underground, and the total length of cables is about 5,039km in 2006. HEC currently has 3,617 distribution substations serving 559,000 customers. The total rating of transmission and distribution transformers is 12,198MVA.

3.2 ENTIRE CABLE SYSTEM FOR 275kV TRANSMISSION NETWORK

To preserve the natural landscape and eliminate visual intrusion, HEC has adopted an entire cable system (submarine and underground cables) for its extensive 275kV transmission network (Figure 11) to deliver electricity from LPS to the load centres on Hong Kong Island. This environmental initiative has eliminated the need of constructing at least 30km of overhead lines and 100 transmission towers on Hong Kong Island. Furthermore, concerted efforts have always been devoted to the aesthetic impact of

the infrastructures. The outlook of all major buildings and structures in the substation buildings in urban area have been carefully selected and designed to harmonize with the surrounding environment and natural landscape. Figure 12 shows the greening feature of Cyberport Substation.

Figure 11 275kV Transmission Network

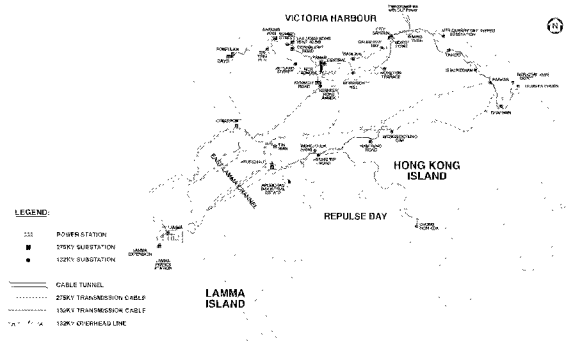
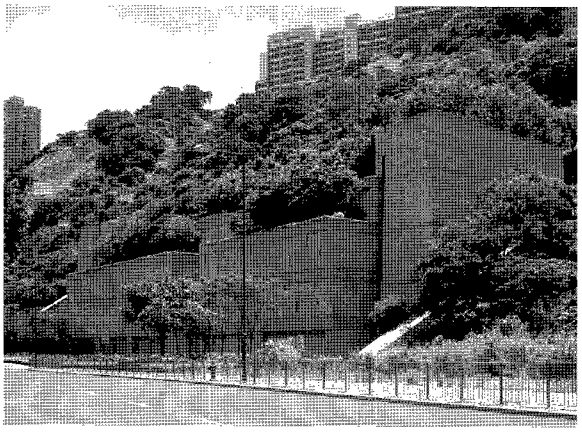


Figure 12 Cyberport Substation with Green Roofing



The use of the 275kV cable system completely eliminates any disruption of electricity supply from faults/damages in the overhead line system during lightning and other adverse weather conditions. As a result, the overall power quality and electricity supply reliability is greatly enhanced.

3.2 ADOPTION OF CABLE TUNNELS

Because of the congested underground services and narrow roads on Hong Kong Island, traditional open trenching for transmission cable laying often has severe impact on traffic and causes great inconvenience to the public. To overcome these drawbacks, HEC pioneered the adoption of cable tunnels for major transmission circuit installation.

In addition to the preservation of the natural landscape, tunnel construction effectively eliminates dust and noise pollution, traffic disruption and inconvenience to the public. As compared with open trenching on carriageways and footpaths, which is seriously constrained by government restrictions and traffic conditions, tunneling takes less construction time. By avoiding the substantial road excavation work, cable tunnels also have the long-term benefit of providing a ready, cost saving and environmentally friendly means for addition of new circuits to meet the load growth,

Figure 13 First Cable Tunnel in Hong Kong Wah Fu - Bowen Cable Tunnel

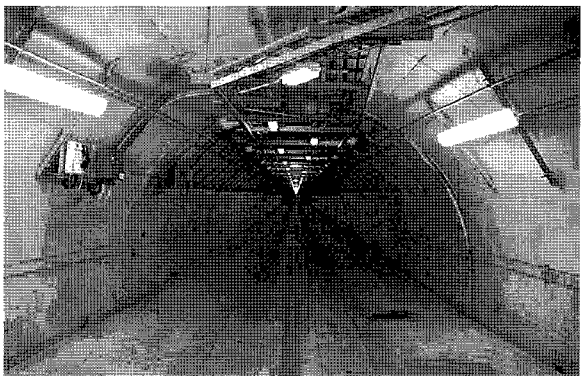


Figure 14 Nam Fung/Parker Cable (One of the World's Longest Cable Tunnel)

At present, HEC has in place the following six 275kV cable tunnels with the first one

completed in 1988:

- 3.1km Wah Fu-Bowen Cable Tunnel
- 5.7km Nam Fung-Parker Cable Tunnel
- 0.8km Tin Wan-Wah Fu Cable Tunnel
- 0.8km Cyberport-Wah Fu Cable Tunnel
- 0.2km Yung Shue Wan Cable Tunnel
- 0.1km Pak Kok Tsui Cable Tunnel

3.3 USE OF SF_6 INSULATED SWITCHGEARS & TRANSFORMERS

Hong Kong is characterized by dense population and crowded high rise buildings. To eliminate environmental impact on and fire hazard to its customers, HEC has been replacing its oil-insulated transmission and distribution equipment by the gas insulated ones. Gas insulated transformers (Figure 15) and switchgears are oil-free, fire-hazard free, highly efficient, low noise, maintenance-free, more compact and have longer life span. These features, in particular the lesser space requirement, make them ideal for installation in the densely populated urban areas in Hong Kong.

Figure 15 The World's First SF_6 Gas-Insulated Transformer at Sheung Wan S/S

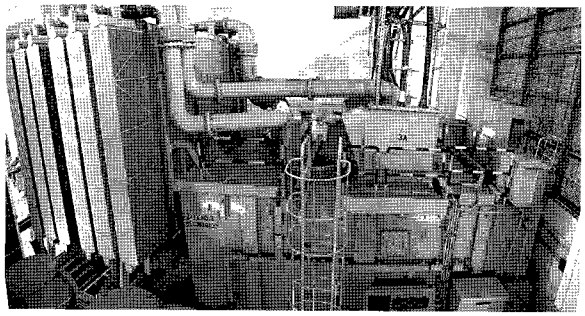
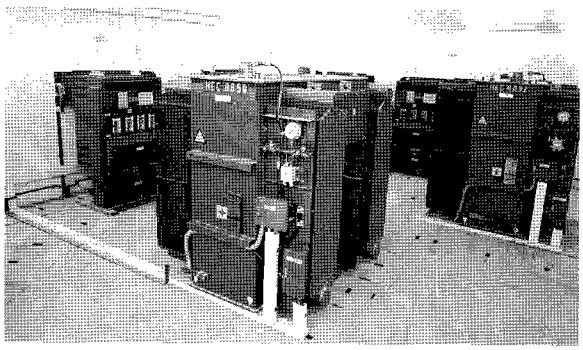


Figure 16 Compact Design & Oil-Free SF_6 Distribution Transformers



From conservation perspective, the SF_6 gas insulated equipment do not contaminate the environment with oil during their installation, operation, maintenance and decommissioning. As for the handling of SF_6 gas, due to HEC's stringent enforcement of its policy on the recycling and reuse of spent SF_6, loss of the gas to the atmosphere has been negligible.

From business perspective, the SF_6 gas insulated equipment has eliminated the need for routine insulating oil sampling test, underground oil containment and environmentally unfriendly CO_2 fire protection systems in HEC's substations. The fire-hazard-free and compact design of SF_6 gas insulated equipment (Figure 16) also enables distribution substations to be installed on the upper floors or basement of high rise buildings, which reduces electricity distribution loss and cable cost.

Paper No. 4

4. RENEWABLE ENERGY & COMMUNITY PROGRAMME

4.1 RENEWABLE ENERGY FOR POWER GENERATION

Recognizing the importance of sustainable development and the pressing need to improve air quality in Hong Kong, HEC took an initiative in 2000 to explore the feasibility of utilizing wind as renewable energy to supplement fossil fuel for power generation. Having completed a one-year wind monitoring programme in November 2002, HEC proceeded with the site selection exercise and environmental impact study for a pilot wind turbine project on Lamma Island.

The launch of *Lamma Winds* (Figure 17), Hong Kong's first grid-connected wind power station, in February 2006 began an important new chapter in the history of local electricity generation. The 800kW wind turbine is the first renewable energy facility ever built by power companies in Hong Kong. Based on an average wind speed of 5.5m/s, the 800kW wind turbine can produce about one million kW of green electricity annually.

Figure 17 Hong Kong's First Grid-Connected Wind Power Turbine at Tai Ling

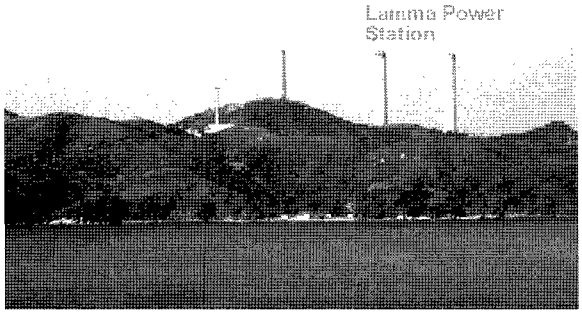
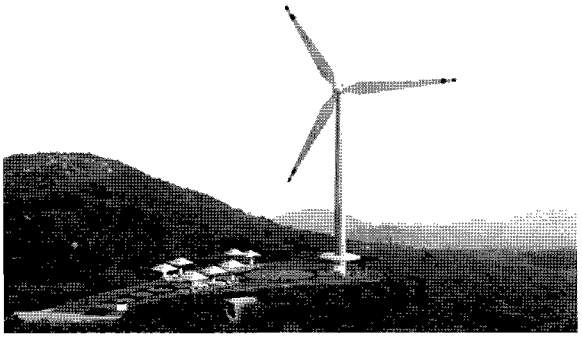


Figure 18 Lamma Winds with Education Centre



As shown in Figure 18, *Lamma Winds* also houses an exhibition area that provides a wealth of information on renewable energy. Exhibition panels are clustered to display information about wind, solar and other common forms of renewable energy, including their natures, beneficial roles, strengths and limitations, and examples of their applications worldwide. It offers a unique educational attraction for Hong Kong. It has received not only keen support of the Government and green groups, but very positive and enthusiastic responses from the public.

This pilot project has provided HEC invaluable practical experiences in planning, design, construction, operation and maintenance of wind turbine, and better understanding of the benefits and limitations of using wind energy for power generation. As a continuous effort in utilizing wind power to supplement fossil fuels, HEC is working on the feasibility study of developing a 100MW offshore wind farm in the southern part of Hong Kong waters.

HEC's plan is to build a total 40 wind turbines, each has an output capacity of 2.5MW, at the offshore wind farm which can potentially produce about 175 million units of green electricity every year. This is enough for about 50,000 families of 4 in Hong Kong, representing about 1.6% of Hongkong Electricity output in 2006. This would avoid the use of 62,000 tonnes of coal every year and means to reduce emission of 150,000 tonnes of carbon dioxide.

EIA study now underway covering areas like impacts on the environment, ecology, fisheries, marine and aviation traffic, etc. is expected to complete in 2008. For the project to succeed, it must not only be environmentally acceptable and technically feasible, but must have the full support of the Government and the community and the willingness of consumers to pay more. The offshore wind farm will be ready for operation in 2012, base on the lead time required for statutory approval, design, procurement and construction.

4.2 COMMUNITY EDUCATION & GREEN GROUP PROJECTS

HEC's commitment in environmental protection and energy conservation is reflected not only in its business operations, but also in its community programmes. Over the years, HEC has planned or sponsored the planting of over 100,000 trees on Hong Kong Island and Lamma Island. HEC has also sponsored the establishment of an energy efficiency centre in Science Museum and various studies on renewable energy.

Figure 19 2006/07 Smart Power Opening Ceremony

Figure 20 Green Lamma Green Project

On the education front, a series of programmes targeting the younger generations have been implemented to achieve long-term cultural shift through changes in energy consumption habits. These include the production of a web-based energy efficiency education kit for primary school students and sponsoring the production of Hong Kong's first education kit on renewable energy and energy saving for pre-schoolers. HEC has also been organising an annual education campaign, the Smart Power Campaign, since 2003 (Figure 19) where a range of activities including visits, exhibitions and competitions have been organized to help students and the public at large develop good habits of using electricity more efficiently. Energy audits, for instance, have been conducted for schools to improve energy efficiency.

HEC has been supporting various projects conducted by different green groups. In 2005, HEC joined hands with Green Power to launch Hong Kong's first website on some of the most valuable ecological sites in the territory, which aimed to encourage the public to learn more and help preserve these natural resources. HEC has also been the sponsor of Green Power's annual "Clean Up the World in Hong Kong" campaign since 1996 to remind local citizens to reduce waste and keep the environment clean during festivals. Another 3-year project, Green Lamma Green (Figure 20), has been carried out in joint efforts with The Conservancy Association since 2005 to enhance the natural environment and sustainability development of Lamma Island.

To support the study and development of renewable energy in Hong Kong, HEC launched the HK Electric Clean Energy Fund in 2006 to provide funding for schools and tertiary institutes to carry out renewable energy projects on campus. The Fund attracted 45 applicants out of which three primary schools, six secondary schools and three tertiary institutes were subsequently selected to receive a total of HK$1.06 million to finance projects on the use of solar, wind and wave energy. All 12 wining projects were recognized for their innovation, technical feasibility, educational and environmental benefits, sustainability and cost effectiveness.

5. CONCLUSION

HEC has attained a unique combination of accomplishments - it is a leader in environmental protection combined with one of the world's highest reliability ratings for power supply, and it is also a successful and caring business and employer. The reliability of HEC's power supply is over 99.999% - meaning that its customers on average without power for only about a minute every year - an impressive record by any standards.

HEC places the environment at the centre of all decision-making, and has equipment and systems in place to minimize the environmental impact of its business operations, It actively participates in a number of programmes relating to environmental preservation and community education on an ongoing basis. HEC is proud of its balanced approach that places equal emphasis on environmental sustainability with business sustainability.

Paper No. 5

NUCLEAR POWER DEVELOPMENT: OPPORTUNITIES & CHALLENGES

Speaker : Mr W.H. Zhou
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China Guangdong Nuclear Power Holding Co. Ltd., PRC

NUCLEAR POWER DEVELOPMENT: OPPORTUNITIES & CHALLENGES

Mr W.H. Zhou
Acting Manager, Safety Department
China Guangdong Nuclear Power Holding Co. Ltd., PRC

ABSTRACT

This paper presents an outline of the State's plan of developing nuclear power up to 2020. Accordingly, it also depicts the situation of energy reserves and market demand in Guangdong province. It highlights the benefits of nuclear power to environment and the challenges to meet the development goals.

1. INTRODUCTION

The State Council approved the Nuclear Power Development Plan 2005~2020 on March 22, 2006. By this strategic plan the capacity of Nuclear Power Plants (NPP) in operation is expected to be 40,000MW, representing 4% of the total generating capacity and 6% of the total generating power over the country by 2020. Further development of 18,000MW NPPs is expected to be in construction around the end of 2020. In addition to the existing NPPs in operation and construction, a total of 30,000MW NPP capacity is planned to operate in the next twenty years. More important is that the state program is based on the full-blown self-reliance principle, that is, domestic suppliers and operators will be the leading actors from engineering, manufacturing, construction to commissioning and operation, even though foreign investors and counterparts are also expected to join in the programs.

As far as technical matters are concerned, the so-called Second-and-half generation technology as represented as CPR1000, modeled on Ling Ao NPP with significant modifications, and Third generation technology as represented as EPR (European Pressurized Reactor) and AP1000 (the American design featured with passive safety functions) are adopted with higher reliability in safety and availability and lower investment. Obviously, the plan gives rise to huge opportunity to all the potential participants in the industry with the benefits not only for economy but also for environment. On the other hand, this huge opportunity demonstrates huge challenges as well.

2. SITUATION IN GUANGDONG

As well known, Guangdong is a province lacking primary energy with a big population and boosting economy. It is reported that the amount of energy resources per person in Guangdong is equivalent to thirty-three tons of normative coal, a twentieth of the national average. More than 85% energy of the province relies on the import from other provinces and overseas market. The coal reserve in the province is about 0.006 of the country. As regard with hydro-electric power the total of exploitable capacity is around 8330MW, and 63% has been tapped already and the rest of the reserves lies in the tributaries with low economic efficiency. On the other hand, the Province is a big consumer of energy. It is reported that the energy consumption of 2003 is equivalent to 130,099 million tons of normative coal, about 8% of the national consumption. Today, the provincial energy consumption still principally relies on imported coal and oil, which, from a stable energy supply point of view, places the provincial economy at a very vulnerable and risky situation and threatens the ever-rising economy. It is disclosed that more than 5 billion additional USD were spent to meet the fluctuation of crude oil on the market last year.

3. ENVIRONMENT CONCERNS

In regard of environment over the province as well as the country as a whole, coal burning, which is the major source of air pollution of the country, emits into air huge amount of smoke dust with carbon dioxide and other toxic products. It is forecast that China's emission of carbon dioxide will exceed that of USA in the period between 2020 and 2030 unless energy production and consumption structure is drastically transformed. The analysis discloses that 80% sulfur dioxide, 45% air suspending particles and 20% nitrogen-oxide products come from burning fossil fuels. The reduction of the reliance on the fossil fuel and change to green energy is an ever-pressing issue for the nation.

Nuclear power is safe, clean, economically efficient and reliable without emission of the air pollutants as those by the coal fired power plants. Although the application of current coal cleaning technology can lead to the reduction of emitting dust and sulfur-dioxide, it cannot help reduce carbon dioxide and nitrogen-oxide pollutants in addition to the solid waste which calls for large area of land to dispose. At present, the realistic solution in view is only to change to nuclear power and regeneration energy.

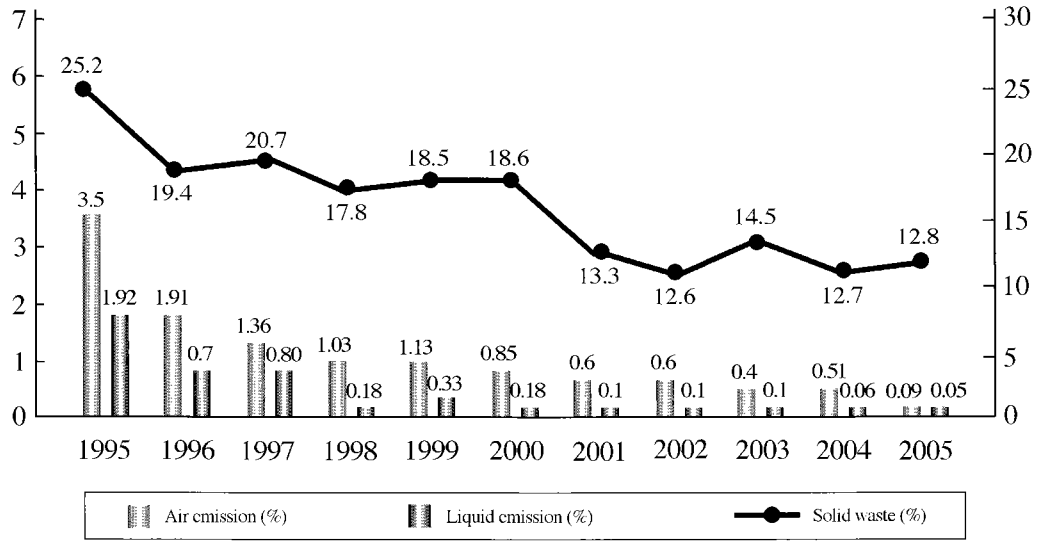
Globally, nuclear power has been a large-scaled commercial clean energy and its benefits to the environment have been widely recognized. Just take France for instance. From 1980 to 1996, the electric power generated by nuclear power stations rose from 24% to 70% as against the total output of electricity of the country which increased by 47% while the emission of sulfur-dioxide was reduced by 71%, nitrogen-oxide products by 60% and dust by 57%. Consequently, the quality of air has been improved significantly.

Look at our own nuclear power plants. At Daya Bay the annual power output of the four units is equivalent to that of burning 12 million tons of normative coal which would otherwise have emitted 27 million tons of carbon dioxide, 100,000 tons of sulfur dioxide, 60,000 tons of nitrogen-oxide products and 1.20 million tons of solid waste.

Since commercial operation the airborne and liquid pollutant emission of the four units have been far below the limits as stipulated by the regulatory authority and the annual solid radioactive waste is below the design criteria.

Continuous measurement by the ten fixed detection stations in the radius of ten kilometers of the power plants demonstrates that no deviations of background radiation level has been detected since the past ten years, and the land and marine biology in the area remains the same.

Table 1 Annual Emission of Per Unit Average



4. CHALLENGES

China Guangdong Nuclear Power Holding is one of the major national team to carry out the central government's plan of developing nuclear energy. The Holding owns three specialized companies, the China Guangdong Nuclear Design Institute, specializing in engineering of NPP, the China Guangdong Nuclear Engineering Corporation (CNPEC) specializing in construction of NPP, the Daya Bay Nuclear Power Management Corporation specializing in operation. In addition, a new company is set up recently specializing in the supply of uranium. At present, the Holding is working on four sites, two CPR1000 units at Daya Bay as the second phase of Ling Ao Project, four CPR1000 units at Hong Yanhe, Liaoling Province, the First Concrete Drum (FCD) being scheduled in the mid-September this year, two CPR1000 units at Ning De, Fujian Province, the FCD being scheduled in April next year, and two EPR1500 units at Yangjiang, Guangdong Province, the negotiation with French counterparts being in progress and FCD being scheduled next year. Meanwhile, the Holding has signed agreements with a number of provincial governments to develop nuclear power such as Guangxi, Anhui, Hainan, etc.

To develop nuclear power according to the above said plan we face great challenges. Above all, quality is the primary concern for the construction and safety for operation, and both are inter-related. And that's why we must keep on maintaining our tenet: SAFETY FIRST, QUALITY FIRST. In practice, among others, we have upgraded our quality assurance program in line with the revised codes and guidelines of International Atomic Energy Agency (IAEA), incorporating safety culture into our program which covers all the project participants including engineering institutes, manufacturers and construction contractors. We provide, for instance, safety and quality management training sessions for all the contractors that supply safety related items and services, we adopt risk-informed and performance based QA surveillances and audits, we revise our KPIs and extend them to the contractors' activities. Transparence of non-conformance is still our major concern. We keep a blame-free policy in regard to the self-report of anomalies and the openness of anomaly disposal. All in all, we know safety is the basis of the development of our industry and we must and can live up to our commitments to the public as well as the government and the industry.

5. CONCLUSION

We are having a historical opportunity of developing nuclear power industry in China. This opportunity means not only the strategic safety of energy supply and national economy in the next two decades but also the protection and improvement of environmental quality and thus to ensure a basis for sustainable development. The success of realizing this strategic plan relies on the results in the quality assurance of the programs, which require all the participants to enhance the safety culture with substantial actions.

Paper No. 5

SIEMENS

Paper No. 6

ENHANCED GREEN BUILDING DESIGN – A BRIEF HISTORY OF THE LATEST DESIGN TREND IN BUILDING CONSTRUCTION INDUSTRY IN THE USA

Speaker : Eur Ing Jacob Chan
Senior Partner
MDC Engineers Inc., USA

ENHANCED GREEN BUILDING DESIGN – A BRIEF HISTORY OF THE LATEST DESIGN TREND IN BUILDING CONSTRUCTION INDUSTRY IN THE USA

Eur Ing Jacob Chan
Senior Partner
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ABSTRACT

This paper introduces the latest sustainable design trend in the construction industry of the United States of America and the US Green Building Council. It explains the mechanism of green building rating and its application to building design and construction. It also outlines the benefit of sustainable design and the methods in achieving a sustainable design of building.

1. INTRODUCTION

Sustainable design or Green Building design has become a major design trend in America especially in California. California as a State is very unique where it has led the Nation on many environmental issues. From the energy compliance requirement in building design some 20 years ago, to no smoking policy inside buildings, to car emission policy, all have helped to establish new trends and policies in America and, later, the world. Below are the personal experience and views of the author on the evolution of Green Building Design in the USA and on the value that such design brings to all who are in the building construction industry.

2. GREEN BUILDING DESIGN

Green Building Design, also known as sustainable building design, consists of a broad range of architectural, landscape and engineering design philosophies. It encourages owners, designers and contractors to develop building projects in a manner that minimizes negative environmental impacts which, in turn, allows natural ecological systems to fully recover from that impact. The aim of the green building design is to maintain healthy environments and ecosystems: clean air, water and soils, and stable climate. It also generates positive environmental impacts in the construction of human habitats. The predecessor of US Green Building Council first started from a group of professionals in Sacramento, capital of California when they pressed for sustainable design in buildings. Their idea was later picked up by others in Washington DC when the US Green Building Council was subsequently established in 1993. One of the goals is to establish a clear definition and a recognized standard of green building design.

US Green Building Council is a non-governmental, non-profit organization and runs a voluntary program. However, more and more public institutions and agencies are adopting their policy as part of their design requirements. Hence, many municipal cities as well as State agencies have adopted this set of policy as mandatory in their buildings. Realizing the advantage of certified LEED buildings which provides extra marketability values, lots of private and commercial developers in California as well as in other part of the world such as India, China have followed the trend.

3. LEED RATING SYSTEM

LEED (Leadership in Energy and Environmental Design) Green Building Rating

System was created by the US Green Building Council. LEED is a design tool that allows building teams to score points for:

- the location of a building on site
- treatment of property such as minimum site disturbance, storm water management, increase landscape by reducing heat island effect and light pollution
- economic use of energy and water
- creative use of environmentally preferred materials
- protection of indoor environmental quality for its occupants

LEED determines environmental performance from a whole building perspective over a building's life cycle, provides a definitive standard for the elements constituting a Green Building.

The above-mentioned rating system is based on currently accepted industrial energy and environmental principles, and provides a balance between general common practices and emerging concepts. It is also determined by the credits being earned, and certain criteria being satisfied. Different levels of green building certification awarded are also based on the total credits earned.

There are four established LEED certification programmes. They are specified for New Construction, Existing Buildings, Core and Shell building and Commercial Interior. Also shown below is the under development fifth programme for Homes, Neighborhood Developments.

1. LEED for New Construction is for owners and design team that address new buildings and major renovations.
2. LEED for Existing Buildings is for owners and service providers to address building operations, on going upgrades and performance improvements.
3. LEED for Commercial Interiors is for building owners, tenants and design teams that address commercial interior design and installation process.
4. LEED for Core and Shell is for developers and design teams that address new building design and construction process where the interiors are not part of the initial design process.
5. LEED for Homes is for residential home owners, developers and design teams new building design and construction process.

The following is a summary of projects that are registered and certified with LEED program within the USA as on February 9, 2007:

	Project Status	Number of projects	Million Gross Square Feet
New Construction	Registered	4,144	560
	Certified	560	60
Commercial Interior	Registered	511	28
	Certified	103	5
Core & Shell	Registered	393	97
	Certified	28	9
Existing Buildings	Registered	260	81
	Certified	42	15

Notes:

i. Total LEED Registered Projects: 5,308 numbers of 766 million gross square feet.

ii. Total LEED Certified Projects: 733 numbers of 89 million gross square feet.

Out of these projects, there are LEED certified projects in Canada, China, India and United Arab Emirates, Spain, Mexico, whereas in other countries such as Japan and Italy, there are registered projects only.

The high number of LEED certified projects is a testimony that Green Building has already aroused public consciousness, and is now making a big move into the mainstream of building industry. Simultaneously, the diversity of LEED projects initiated in schools, laboratories, corporate headquarters, manufacturing plants, and even in major convention centers is now showing the breadth and depth of environmentally responsive building and demonstrating how well the LEED Green Building Rating System is applied throughout various building types.

4. CATEGORIES OF LEED

The LEED Green Building Rating System is organized into five environmental categories, which comprises Sustainable Sites, Water Efficiency, Energy and Atmosphere, Indoor Environmental Quality and Materials and Resources. Besides, there is an additional category of Innovation and Design Process covering exceptional building design and performance.

Category 1: Sustainable Site

It focuses on site selection. It aims at minimizing building impacts on the surrounding areas when the construction is completed, and the building is occupied. On the other hand, it also addresses heat island effects to reduce lighting pollution on the project site.

Category 2: Water Efficiency

It addresses the consumption of water. Since using large volumes of water will increase running costs for building owners and operators, and will also increase consumer cost for city water supply and treatment facilities, this category addresses water efficiency through lowering the water charges and the sewer volumes to treat, and in turn, it will also lead to energy savings and chemical reductions. In the same time, it evaluates water efficiency, landscaping, innovative wastewater technologies, and water use reduction.

Category 3: Energy and Atmosphere

This category will improve the energy performance of buildings and encourage the occupants to reduce costs for energy consumption. For example, energy loads can be reduced through improved glazing, insulation, day lighting and the use of passive solar features. As a result, this will allow the mechanical equipment to be downsized. It also looks at green power like solar and wind power.

Category 4: Materials and Resources

To choose building materials is crucial in sustainable design because of the extensive network of extraction, processing and transportation elements. In considering of the recycled content materials, the use of rapid renewable materials can benefit the project in many ways. Appropriate materials being used for the project will reduce the initial cost as well as creating an eco-friendly building.

Category 5: Indoor Environmental Quality

The design strategies in this category are highly correlated with the indoor air quality, such as ventilation effectiveness and control of contaminants. Automatic sensors and controls can be integrated as parts of the air conditioning system to adjust temperature, humidity and the percentage of outside air introduced to occupied spaces.

Category 6: Innovation in Design

The objective of this category is to provide opportunities for the project team members to obtain their greatest achievements in building industry. Points are awarded to exceptional performance above requirements set by LEED Green Building Rating System.

5. CLASSIFICATION AS A LEED BUILDING

LEED rating system is a self-certifying system designed for new and existing commercial, institutional, high-rise buildings and many other buildings. To qualify for LEED building, the potential buildings must satisfy all the prerequisites and a certain number of credits for attending different LEED building ratings as shown below. Having satisfied the basic prerequisites of the program, potential buildings are rated according to their degree compliance within the credit system.

A total of 69 points are available within the six categories of certification for new construction:

- LEED Platinum for buildings that earned 52 or more if the available points

- LEED Gold for buildings that earned 39 to 51 points
- LEED Silver for buildings that earned 33 to 38 points
- LEED Certified for buildings that earned 26 to 32 points

5.1 CERTIFICATION PROCESS

The process takes the following steps:

1. Eligibility
2. Registration
3. Credit Interpretations
4. Certification and Documentation
5. LEED Technical Reviews
6. Certification Award
7. Appeal

5.2 PERSONAL EXPERIENCE

Application to LEED used to be a tedious exercise where a submission for a relatively small project could end up with a two full 3" think binders. Nowadays, the process is done on line and is therefore more convenient to collect data and reproduce data for submission.

As LEED is still a relatively new program and more often, the LEED consultant will be running long work shops to educate everyone on the design and construction team. Time commitments from all practitioners is essential because it is not uncommon to have long meetings which may last for days.

The most challenging effort is to develop a LEED check list in the beginning of a project. The developing process usually goes through endless meetings and long draw discussions. The final outcome is always a compromise between budget and goals.

There is an appeal process which is quite useful sometimes. The owner of one project near Los Angeles decided not to flush the mechanical system for 2 weeks but protected all the duct work during the installations. USGBC granted this process as an acceptable alternative and saved the owner lots of time and cost.

The on line web site is very useful as it is full of project case studies, reference guides. This is particular useful when one is submitting a project for the first time. For those who may submit a project for LEED, it is recommended to visit the website.

Passion to green building design supported by patience is the key to go through the entire process of LEED application.

6. IMPACT TO ELECTRICAL DESIGN

As electrical engineers, designers and installers, the following points should be noted as part of Green Building Design because of the heavy involvement in lighting - which includes natural daylight and artificial lighting.

1. Introduce quality daylight throughout the building, but avoid direct sunlight on task areas.
2. Artificial lighting should be used for the tasks; ambient and accent purposes.
3. Make sure that the building is properly oriented, so as to maximize the use of daylight.
4. Use energy efficient lamps.
5. Use a combination of automatic and electronic lighting controls, such as dimmers and photocells.
6. Use central switch for building lights that can be shut down at nights.
7. Use variable frequency drives on motors for fans, pumps and elevators.
8. Use electronic sensors or ceiling sensors for toilets flushing.
9. Being a more well informed with other designers and architects, LEED process is a holistic approach on design and construction. Provision is also made for the emergence of new technology and integration with other disciplines.

7. CONCLUSION & RECOMMENDATION

LEED application process is setting the project goals in the beginning and document the design and construction process. It is a voluntary system and requires professional self-discipline and performs the submission in an honor professional standard which in turn demands considerable time and effort in subsequent documentation and record keeping. In addition to large institutes such as major universities, municipal and state government agencies, a lot of developers in both the USA and the rest of the world believe that their buildings will have commercial benefits by getting their buildings certified.

The author took the LEED test a few years ago and concluded that it was one of the best investments. Business opportunities have increased not only just in California, but also in other states within the USA and overseas including Kuwait and India. The author is currently working on a project in Mumbai, India that intends to have platinum rating while a hotel developer in Pasadena has decided that his hotel project would be applied for silver ratings. Anther project in hand is a museum for one of the Ivy League universities that intends to have a gold certification.

The commercial success of environmental friendly buildings certified under LEED will no doubt lead to more projects to be LEED certified. It is envisaged that the trend of Green Building design will bring benefits to the building industry and the community in the USA when more buildings are LEED certified.

Paper No. 7

MEDIUM CAPACITY RAILWAY SYSTEM PROPOSED FOR SOUTH ISLAND LINE (SIL)

Speakers : Ir C.L. Leung, E&M Engineering Manager, Project Division
Ir Samuel S.C. Chan, Senior Engineer (Power and Services)
MTR Corporation Ltd.

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ABSTRACT

MTR Corporation Limited has commenced a study of the South Island Line (SIL) in response to an invitation from the Government to investigate the feasibility to extend its service to the southern part of the Hong Kong Island. Due to the stringent alignment and also the lower patronage requirement of the area, a medium capacity railway system has been proposed. The proposal considered an application of alternative technologies like a rubber-tyred system, a linear induction motor system or a conventional steel wheel system with smaller cars. While the vehicle size and the number of vehicles used per train is smaller, the station sizes and the scale of the power supply system will be smaller than a traditional heavy metro system. This paper introduces the idea of such application in Hong Kong and the environmental challenges facing the implementation of the system, including a revolutionary metro system design including station facilities, power supply facilities, and the type of proposed vehicles used. Higher degree of automation will be adopted to improve operation and energy efficiency and to raise customer service level.

1. BACKGROUND

In mid 2004, the Corporation commenced a study on the potential schemes for West Island Line (WIL) and South Island Line (SIL) in response to an invitation from the Government. Further review commenced in 2006 to refine the scheme for SIL.

The SIL project comprises two lines as shown in Figure 1. The eastern one, namely SIL(E), would interchange with the existing Island Line at Admiralty Station and terminate at South Horizons station (SOH) adjacent to the South Horizons development on Ap Lei Chau Island. Three intermediate locations are proposed at Ocean Park (OCP), Wong Chuk Hang (WCH) and Lei Tung (LET). SIL(E) is about 7.3km long comprising 4.9km of tunnels and 2.4km of elevated viaduct structure.

The western one, namely SIL(W), would interchange with SIL(E) at WCH station in one end and interchange with WIL at the University station (UNI) in the other end. SIL(W) would be built at a later date and there would be three intermediate stations at Cyberport, Wah Fu and Aberdeen. SIL(W) is about 8.2km long comprising 6.3km of tunnels and 1.9km of elevated viaduct structure.

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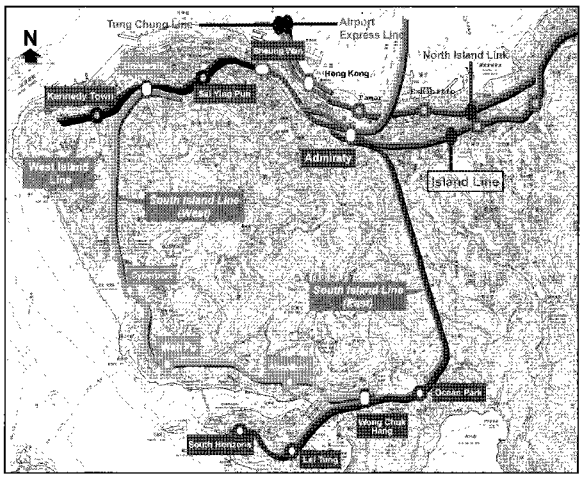
Figure 1 Alignment of SIL



Both SIL(E) and SIL(W) are envisaged as a medium density railway system and have some alignment sections with steep gradient up to 5-6% and sharp turns down to 150m radius. The projected initial and ultimate peak flows for SIL(E) are around 13,000 and 18,000 persons per hour per direction respectively.

As a result, the traditional heavy metro system

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adopted in existing MTR network would not be suitable for SIL(E) and SIL(W). A separate medium capacity railway system would be built for SIL(E) and SIL(W) with a common depot located at Wong Chuk Hang. This paper describes the different technologies that can be adopted for this project with particular emphasis on the environmental considerations, including the minimization of environment impact and energy efficiency.

2. RAILWAY SYSTEM TECHNOLOGIES

A guided transportation system is usually classified by its line flow capacity and the extent it shares its "Right of Way" (ROW) with road traffic, as shown in Tables 1 and 2.

Table 1 Classification by Line Flow

Guided Transportation System	Line Flow Capacity (pphpd)	Example
Low Capacity System	2,000 - 10,000	Commuter Rail, Tramway, Airport Automatic People Mover System, Articulated Low Floor Vehicles.
Medium Capacity Railway System	10,000 - 30,000	Monorail, Maglev System, Rubber-tyred System running on guide-ways, LIM System, or Steel Wheel System using narrower car-body and shorter train-set.
Heavy Metro System	25,000 - 90,000	Underground Metro System, Regional Rapid Transit.

Table 2 Classification by ROW

Right of Way	Advantages	Disadvantages
1. **Shared Road Surface** (e.g. Tramway)	• Lowest cost • Easy to build	• Light capacity • Occupies road surface • Less reliable due to traffic jam • Can be involved in road accident
2. **Partial Right of Way** - Partially separated from road traffic (e.g. Tuen Mun Light Rail)	• Higher capacity than 1 above. • More efficient and reliable • Higher commercial speed	• Higher cost. • Longer project lead time • Occupies some road surface - affected by traffic jam; can be involved in road accident
3. **Full Right of Way** - Fully separated from road traffic	• Highest capacity • Very efficient and reliable • Highest commercial speed • Not affected by traffic jam • Will not be involved in road accident • Fully Automatic Operation possible	• Highest cost • Longest project lead time

It is considered that a medium capacity system with full ROW, i.e. completely separated from the road network, is required for SIL to ensure its effective, efficient, and safe operation.

The following types of transit may be considered for a medium capacity system: monorail, low speed urban maglev system, rubber-tyred system running on guide-ways, conventional steel wheel system with narrower car-body and shorter train-set, or a Linear Induction Motor (LIM) steel wheel system.

Elevated monorail system is very common in Japan. The supporting girder for the elevated section is very slim when compared with a viaduct for other systems. In fact, the major selling point for adopting a monorail system is the reduction of the massive elevated structure hence minimising the visual impact. However, the vehicle cost and maintenance cost is relatively high because of its complexity and the propriety nature of such systems.

To minimise environment impact, majority of the SIL alignment is inside tunnel, there is not much benefit in reducing the size of the superstructure by adopting a "train on girder" arrangement. Furthermore, the civil cost will be increased as a bigger tunnel is necessary to accommodate the girder.

In case of an incident, passengers cannot detrain and evacuate to the adjacent stations by walking on the girder. Hence, a separated evacuation path must be provided. This leads to an even bigger tunnel in underground section, and the structure to hold the walkway for above ground section spoils the aesthetic view of the slim girder. It was therefore not considered further in the study.

Figure 2 Mono-rail Line in Las Vegas

A low speed (up to 100kph) urban maglev system (short stator system) has not been

considered either, due to the limited number of operating systems and available suppliers. Furthermore, the capital investment and operational cost will be high due to the complexity of the technology, and the additional energy required to lift the vehicles. Similar to the aircraft design, weight management in maglev vehicle design is crucial. A relatively light weight vehicle will not have the same asset life as a conventional steel wheel system.

Figure 3 Maglev Vehicle in Nagoya

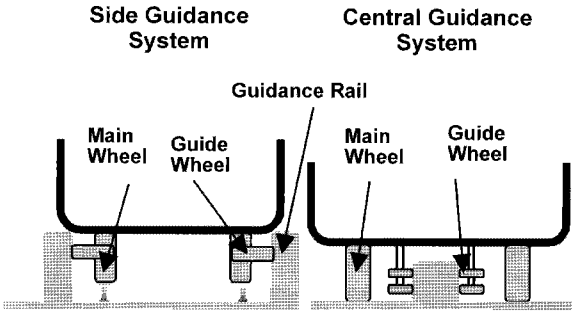
A conventional steel wheel system has difficulty in achieving the necessary gradient but a medium size system with smaller cars with all motor cars arrangement may be possible to achieve 4% gradient. Therefore, in addition to a rubber-tyred system and a Linear Motor (LIM) steel wheel system, a medium capacity conventional steel wheel system can also be a candidate for SIL.

3. RUBBER-TYRED SYSTEM

A rubber-tyred system is characterised by its guidance system with horizontal guide-wheels restrained by the guide-ways, whether 'side-guided' or 'central-guided'.

Because of the better adhesion between the running wheels and the running surface, it is possible to achieve greater higher stopping accuracy, better control of acceleration and deceleration, and steeper gradients. All these are crucial to SIL design. Noise performances are also slightly better than the steel wheel systems.

Figure 4 Side-guided and Central-guided Vehicles



Most of the systems are able to operate at a 90 sec headway, some even less. This allows the required line capacity to be carried on short trains, thereby reducing the size of the stations.

Furthermore, a train-set is usually formed in terms of single cars or "married-pairs" with individual motoring. Obviously, train formation can be then be more flexible. The vehicle collects traction power through a third rail.

With a reduced headway, the waiting time of passengers can be reduced; hence the customer service level can be improved. This is particularly important during non-peak hours when passengers waiting time will be very long if large heavy metro trains are used.

Figure 5 Rubber-tyred Vehicles

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The LRT systems in Singapore, Medium Capacity Systems in Japan, France, and Taipei, and various Airport APM systems, are some of the many examples of rubber-tyred systems.

3.1 RIDE QUALITY

In general, both speed variations and the quality of the running surface attribute to passenger ride comfort. In theory, acceleration and deceleration rates can be similar to those achieved by a road vehicle. In practice, they are limited to 1.3m/s^2 for passenger comfort.

Two types of running surfaces are widely adopted - steel or concrete. Most systems in Europe adopt a steel surface while those in Japan use concrete. It has been reported that a metal surface, although it provides less adhesion, is more durable and more easy to maintain, and also extends the life of the tyres. Nevertheless, some concrete systems in Japan have already been in service for more than 15 years and are still providing a reliable and comfortable ride.

In general, it is considered that a steel surface is easier to control. If a concrete surface is adopted, high standards of workmanship and maintenance are essential.

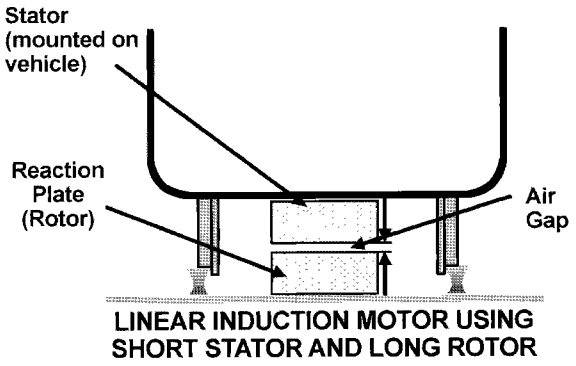
3.2 PROTECTION AGAINST FLAT TYRE

The tyres are usually filled with nitrogen. Apart from tyre pressure detection, there are different designs to cater for tyre bursts, e.g. using back-up steel wheels, emergency metal discs, or metal core tyres. They allow a vehicle with a flat tyre to move to the next station to unload passengers, and then to a siding or back to the depot using its own power, in order that normal train services can be recovered with minimal disruption.

4. LIM SYSTEM

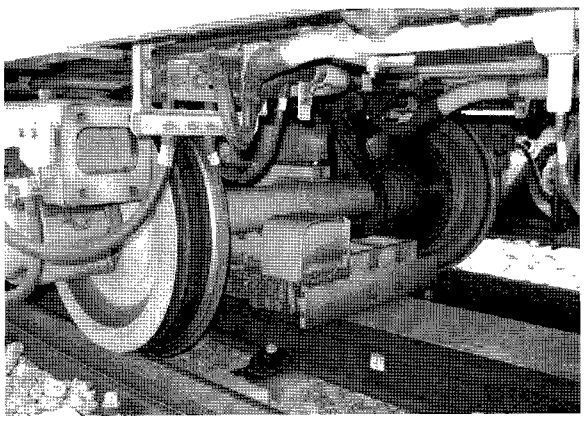
The main feature of a LIM system is that "adhesion" is provided by the LIM, and wheel adhesion is no longer a major concern. Motoring and braking forces are directly transmitted between the vehicle and the trackway through the LIM. The basic system consists of a short primary stator on the underside of a train, and a continuous rotor known as the 'reaction plate' installed between the rails on the trackway. The stator and the reaction plate combine to form the LIM, and the gap between them has to be maintained within a very small range. The vehicle collects traction power through a third rail or an OHL system.

Figure 6 Linear Induction Motor (LIM) Vehicle



Although the reaction plate on the guide-way is simple and easy to maintain, the stators cannot be mounted on the car-body in order to minimize any variation in the air gap between the stator and the rotor. It is also not preferable to mount the stator on the axle, as this will increase the "un-sprung weight" of a vehicle. For most modern systems, the stators are mounted on bogies, and the train has a rigid primary suspension and soft secondary suspension system so as to balance the need to minimize the air-gap and passenger comfort.

Figure 7 Stator and Reaction Plate Arrangement



With the elimination of motors, the size of a LIM bogie can be reduced. This helps to reduce the height of the train, hence the overall tunnel diameter and the wheel size. In theory, a LIM system should have all the advantages of both steel wheel and rubber-tyred systems, such as the capability of working on tight curves due to smaller wheels and also on steep gradients due to better adhesion, while eliminating the problems associated with tyre replacement.

Vancouver Skytrain and Kuala Lumpur PUTRA Metro are examples of systems using this technology.

5. CONVENTIONAL STEEL WHEEL TRAINS

The conventional steel wheel trains suitable for SIL application will be similar to the heavy metro trains except for possibly smaller car sizes and only with 3-4 cars per train. This will allow the train to negotiate sharper curves. The train set will have all axle powered so as to improve its capability to work in steep gradient. However, the maximum gradient will have to be limited to 4%.

There is a big and mature market for steel wheel rail vehicles, and spares can be sourced from different suppliers worldwide, as such, the capital and operation costs for conventional steel wheel trains are in general lower than that of the proprietary LIM and rubber-tyre systems. This is important, in particular, for a system with phased development. To negotiate with a proprietary system supplier for a good deal in extending an operating line is not easy. With a conventional steel wheel system, it is possible to buy new trains for extension in open market by competitive tender.

6. TRACTION ENERGY CONSUMPTION COMPARISON

Though rubber-tyred vehicles are slightly better in noise performance, the traction energy consumption are in general much higher than the conventional steel wheel trains as shown in Table 3.

The energy consumption of a rubber-tyre system is higher due to the high resistance between the tyres and the running surface.

The power consumption of a LIM system is also high. This is because the air gap between the stator (on train) and rotor (reaction plate on 4 foots) is 10 times that of a conventional system (10mm for LIM and 1mm for a conventional motor). This bigger air gap also results a much lower power factor (0.5 to 0.6) when compared with that of a conventional motor.

Nevertheless, all three systems for SIL will result in much lower energy consumption compared to road traffic. Railway systems remain the most sustainable option in meeting public transportation needs.

Table 3 Traction Energy Consumption Comparison

Conventional Steel Wheel	LIM System	Rubber-tyre Vehicles
100%	~130%	~160%

7. OPERATION MODE

High degree of automation is intended to be introduced in SIL. The advantages of fully automatic operation (FAO) are:

- Higher system availability due to equipment redundancy for automatic operation.
- More flexible operation on dispatching and removing vehicles to suit service demand.
- Better customer service with more human resources available.
- Energy Saving due to better control of station dwell time. The station dwell time can be reduced by eliminating the human delay in carrying out the platform duty. As

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such, the inter-station run time can be longer with lower peak speed required. Traction energy consumption is nearly proportional to the square of peak speed during the inter-station run.

The safe operation of the trains will be monitored and controlled at the control centre. The control centre will maintain contact with passengers on board by using a digital radio system. Controllers can broadcast audio, video or text messages through a wireless channel. Likewise, passengers can contact the controllers in an emergency.

8. STATION AND POWER SUPPLY FACILITIES

As shorter trains will be used in SIL, the platform length can be reduced to around 60m. As a result of the reduction in station footprint, the civil construction cost and ongoing operation and maintenance cost can be greatly reduced. Furthermore, this helps to release the constraints in line alignment design and station locations selection.

Two power supply sources will be provided for the SIL stations to maintain the reliability and security of the power supply system. One supply source can be taken from local supply. Depending on the required power demand, the local power supply can either be 380V low voltage supply or 11kV (or 22kV) high voltage supply. The other station power supply source will be obtained from the internal 33kV supply network to supply the traction loads. The internal high voltage supply network be interconnected with the existing MTR power supply network to reduce the required number of new power infeeds. A new power infeed at Wong Chuk Hang is being planned to provide bulk supply to the traction load and part of the station services.

The traction supply arrangement is dependent on the type of railway systems selected. 750V d.c. conductor rail system is required for the rubber-tyre vehicles. For the conventional steel wheel trains or the LIM system, either 750V d.c. third rail or 1500V d.c. OHL system can be adopted.

The following energy saving measures are also considered in SIL to promote the clean environment and sustainable development:

- Install regeneration absorbing or storage device at traction substations to improve regeneration effectiveness for the standalone SIL system.
- Utilize solar power to supply part of the services load in above-ground stations and depot.
- Install variable speed escalators in selected locations.

9. CONCLUSION

As a result, if the gradient and tight curvature constraints can be overcome in the alignment design, medium capacity conventional steel wheel system with high degree of automation will be the most preferable option for SIL. This system is also considered to be the most cost and energy efficient.

With the introduction of a Medium Capacity System for SIL, the Corporation believes that an optimum railway scheme can be provided to better serve the Western and Southern Districts by relieving their traffic congestion and by providing an environmentally friendly, efficient and reliable transport system.

10. ACKNOWLEDGEMENT

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Paper No. 8

RENEWABLE ELECTRICAL ENERGY – POTENTIAL APPLICATION OF AMORPHOUS SILICON PHOTOVOLTAIC TECHNOLOGY IN HONG KONG

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RENEWABLE ELECTRICAL ENERGY – POTENTIAL APPLICATION OF AMORPHOUS SILICON PHOTOVOLTAIC TECHNOLOGY IN HONG KONG

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ABSTRACT

The use of fossil fuels to generate electricity has already been identified as a major contributor to global warming and climate change. Many countries have already made plans to reduce their fossil fuel consumption and increased the contribution of renewable energies in total energy supply. One of the commonly used renewable energy sources is the sun and the use of photovoltaic cells to convert solar radiation into electricity is rapidly expanding throughout the world.

Photovoltaic cells available in the commercial market can be classified into two main categories - crystalline silicon cells and thin-film cells. Crystalline silicon cells are generally more popular than thin-film cells as they have been developed and in use for over 20 years. However, the demand for modern amorphous thin-film cells is increasing in recent years due to their low embodied energy resulting in a substantial saving in manufacturing cost. Furthermore, amorphous thin-film cells are lightweight, flexible and vandal resistant which made them particularly suitable to be used in buildings. Some overseas researches suggest that thin-film cells perform better in low irradiance and high temperature conditions. Coupling with the fact that flexible amorphous thin-film laminates are more aesthetically pleasing than their predecessors. The technology shows a great promise for the future.

The paper will explore the potential application of adopting amorphous thin film technology as an integral part of building design and construction. The likely performance of amorphous thin-film cell operating under typical local conditions will also be discussed in the paper.

Keywords: thin-film amorphous cells, embodied energy, application of amorphous thin film technology

1. INTRODUCTION

The burning of fossil fuels gives rise to emission of greenhouse gases and air pollutants. The most significant greenhouse gas is carbon dioxide, which has been realized as a potential major contributor to global warming and climate change. The consequence of global warming has far-reaching impacts on our environment as well as our ecosystems.

Introducing more renewable energy sources may help containing fossil fuel use, thereby reducing greenhouse gas emissions. Solar energy is one of the renewable energy being widely used over the world mainly due to its clean and emission free properties. Solar energy can be used in many ways. One of the most common methods is to convert solar radiation into electricity through the use of photovoltaic (PV) technology. Over the past few years, photovoltaic technologies have been developed rapidly.

To promote greater adoption of renewable energy technologies in Hong Kong, the Energy Efficiency Office (EEO) of the Electrical and Mechanical Services Department (EMSD) always seeks opportunity to promote the use of new renewable energy technologies. Attention is now being paid to the flexible amorphous thin-film technology in view of the increasing popularity for its applications in overseas countries.

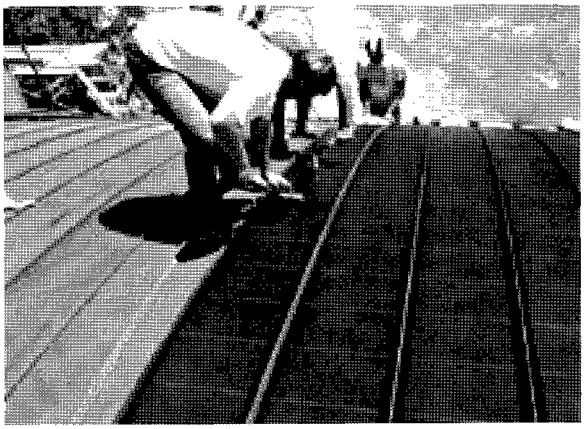
A trial unit of flexible amorphous thin-film PV laminate was set up to investigate the likely performance of such technology under the geographical and climatic conditions of Hong Kong.

2. FEATURES

PV cells available in the commercial market can be classified into two main categories. They are crystalline silicon PV cells and thin-film PV cells. Crystalline silicon PV cells are generally more popular than thin-film PV cells as the former have been developed and used for over two decades. However, unstable raw material supply and high production costs are key drawbacks for crystalline silicon cells. Producing crystalline silicon ingots is a lengthy and energy intensive process as slicing the ingots into wafers is a precise process. The wafers are very fragile and must be mounted and housed in robust metal and glazed casings. Mounting supports for the crystalline silicon modules are also required for deployment these PV panel array onto buildings. The cells, metal casings and mounting supports will altogether add extra structural loading to the building. Sometimes, structural strengthening and steel reinforcement will need to be carried out in order to make possible for installations of crystalline PV modules in the existing buildings.

Contrary to crystalline silicon modules, flexible amorphous thin-film PV cells are encapsulated in UV-stabilized polymer therefore they are light in weight. The weight density is about 3.5kg/m^2 which is only one quarter of the weight density of the crystalline counterpart. As a result, flexible amorphous thin-film PV cells do not require mounting racks for fixing onto building structure. The flexible amorphous thin-film PV laminates do not impose excessive additional weight to the buildings. For existing buildings, costly structural modifications for installation of thin-film PV laminates will not normally be required. The overall installation cost is usually much less than the crystalline silicon modules which are embedded in glass layers. Another advantage of amorphous thin-film PV laminates is that they can be installed on the roof structure easily by "peel-and-stick" process. By using a series of "clamping batten system", flexible amorphous thin-film PV laminates can be installed in buildings easily and less costly.

Figure 1 Flexible Amorphous Thin-film PV Panels Installed on Curved Surface (Photo Source: NREL)



The flexible thin-film amorphous PV laminates are form-flexible and glass-free, allowing them to be harmonized into the building easily. They can be hung on the facades surface of buildings, bonded to metal roofing, adopting well to the curved architectural features and building forms.

3. EFFICIENCY AND PERFORMANCE

In terms of efficiency, flexible amorphous thin-film PV laminates have around 6% of module efficiency, which is lower than crystalline cells (11% to 19%). In other words, flexible amorphous thin-film PV laminates have a lower energy density than crystalline modules. To build the same capacity of PV power system, the flexible amorphous thin-film PV laminates will require larger installed area. For example, constructing a 1-kW PV power system, flexible amorphous thin-film PV laminates will require an area of around 17m^2 whereas crystalline modules will require an area of around 6m^2 to 9m^2. Therefore, flexible amorphous thin-film PV laminates will usually not be favoured where there are space limitations.

However, some overseas research suggests that flexible amorphous thin-film PV laminates could perform better at high temperature and

low solar radiation conditions. Flexible amorphous thin-film PV laminates can have up to 20% better performance on hot environment and up to 12% better performance in low and diffuse light conditions when compared equally rated crystalline modules. Bird droppings, leaves, water puddling, and dirt can shade or soil PV panels. 3% of shade or soil on crystalline modules can reduce output by more than 50% while only 3% output reduction is found on the laminates [1]. Therefore, crystalline cells can reduce efficiency more dramatic at high temperatures which are often experienced in rooftops, where PV panels get its most frequent deployment.

4. APPLICATIONS

Although the flexible amorphous thin-film PV laminates are rather new to Hong Kong, they have already been introduced into overseas market and the Mainland for over 3 years. Applications of such technology include residential houses, commercial buildings factories, schools, parking lots etc. This technology is particularly suitable to be applied to light weight roofs or curved roofs. It also allows serving dual function of a weatherproof skin and a power generator.

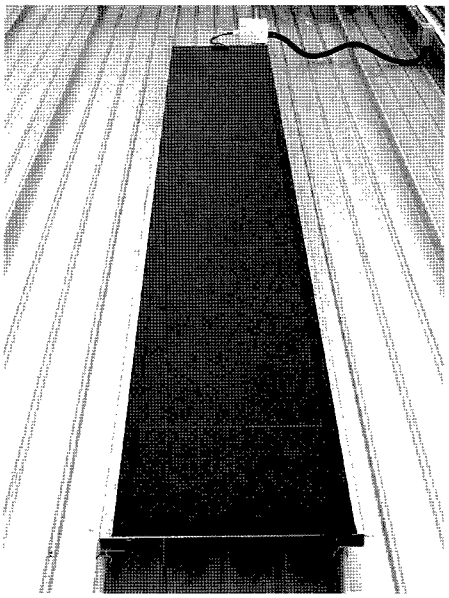
The rated capacity of the projects over the World range from 68W to 700kW [2]. This technology has also been applied to new projects like the Beijing Capital Museum. Flexible amorphous thin-film PV laminates with rate capacity of 300kW were applied directly to the stainless steel roofing of the Beijing Capital Museum using the "peel and apply" adhesive fixing method. The system was expected to deliver more than 360,000kWh of clean energy every year [3].

5. TRIAL SETUP FOR FLEXIBLE AMORPHOUS THIN-FILM PHOTOVOLTAIC LAMINATES

5.1 DESCRIPTION AND CONFIGURATION

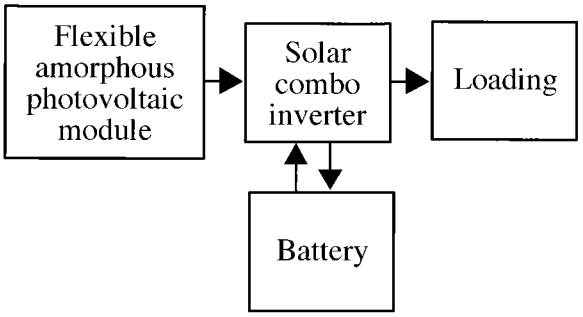
In order to find out the likely energy performance of the flexible amorphous thin-film PV laminates under the geographical and climatic conditions of Hong Kong, a trial unit was set up to measure the energy yield of the system. The measurement was conducted for a period of two 5-day weeks during July and August 2007. The set up involved a piece of 68W flexible amorphous thin-film PV laminate, a charge-controlled inverter (or combo inverter), a battery, a light bulb which acted as a dummy load, and a multi-meter.

Figure 2 Performance Test of Flexible Amorphous Thin-film Photovoltaic Module Trial Unit



The direct current (DC) electricity generated from the flexible amorphous thin-film PV laminate was converted into alternating current (AC) by the inverter.

Figure 3 Block Diagram to Illustrate the Trial Unit for Flexible Amorphous Thin-film Photovoltaic Laminate



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5.2 DATA COLLECTION

Key monitoring parameters including voltage, current, power factor, frequency input and output power were automatically recorded and collected at 5-minute intervals by the multi-meter.

Climatic data such as the global solar radiation (GSI), mean air temperature, relative humidity, etc. were obtained from the weather station of Hong Kong Observatory (HKO) located in King's Park over the monitoring period.

The measurement was carried out from end July 2007 and early August 2007. During this period, a mono-crystalline silicon photovoltaic system was also being operated at the same place. The energy performance of the mono-crystalline silicon photovoltaic system was also recorded for comparison.

5.3 DATA ANALYSIS

5.3.1 GLOBAL SOLAR RADIATION

The global solar radiation recorded by the HKO during the measuring period is shown below:

Figure 4 Daily Global Solar Radiation, July 2007

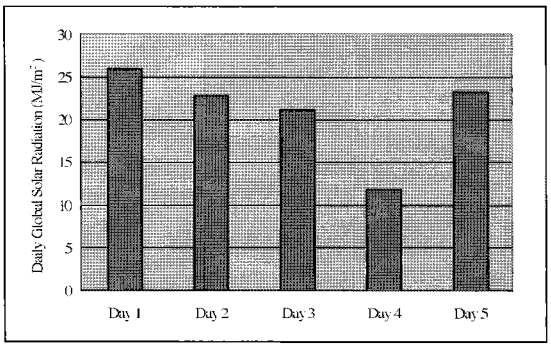
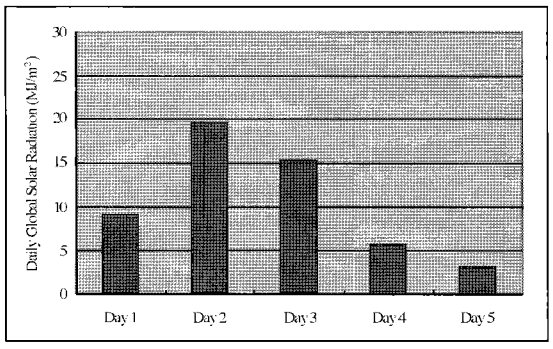


Figure 5 Daily Global Solar Radiation, August 2007



Most of the time on week 1 was sunny day with high solar radiation and most of the time on week 2 was cloudy day with few patches of rain during the daytime. These two weeks were selected especially to compare the performance of the two systems under two different weather conditions.

5.3.2 FINDINGS AND OBSERVATIONS

Based on the measurement collected, the performance of the two PV systems can be evaluated using an indicator called the Overall System Efficiency which is defined as:

Overall System Efficiency (OSE)
= Total Net AC Energy / Total In-plane Irradiation

The OSE of the flexible amorphous PV system was 5.69% on a sunny week (i.e. end July 2007) and 5.61% on a cloudy week (i.e. early August 2007), whereas the OSE of the mono-crystalline system during the same period were 8.53% and 9.04% respectively.

The OSE of the flexible amorphous PV system appeared to be fairly stable despite the system was operated under a hot weather during the first week and was operated under a diffuse light condition during the second week. The good thermal stability and high performance for diffuse condition of the flexible amorphous thin-film PV system were clearly observed.

The module efficiency of the flexible amorphous thin-film PV laminates and mono-crystalline PV panels being measured was around 6% and 12% respectively, the amorphous PV laminates appeared to be operated at optimum conditions for most of the measuring time.

6. CONCLUSION

Flexible amorphous thin-film PV laminates are suitable for integrating into building roof because they are light weight in construction and installation and offer good performance in high temperature and diffuse light conditions.

The stable performance shown in the recorded data from the trial unit of the amorphous thin-film PV laminates exhibited a potential application of this technology under local weather conditions.

7. RECOMMEDATIONS AND THE WAY FORWARD

Based on the findings from oversea researches, the performance of flexible amorphous thin-film PV laminate has been affected less by shadowing or soiling than their crystalline counterpart. The performance in shadowing effect can further be evaluated by deliberately covered up part of the laminate.

Data collection of this project will be continued for verifying the year-round performance. A pilot project would be considered as a showcase to allow an in-depth study on sustainable operation of the flexible amorphous thin-film PV technology in Hong Kong context.

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Paper No. 9

RENEWABLE ENERGY DEVELOPMENT IN ASIA PACIFIC

Speaker : Dr K.K. Chan
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RENEWABLE ENERGY DEVELOPMENT IN ASIA PACIFIC

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ABSTRACT

Business opportunities for Renewable Energy (RE) development in the Asia Pacific region have been growing rapidly for the past few years due to the awareness of global climate change issues. More and more investors from utilities, equipment suppliers, engineering firms, technology providers and financiers are pursuing RE projects, particularly in fast-growing developing countries such as China, India and Southeast Asia. This paper gives an overview of the investment criteria, natural resources, technologies, governmental supports, financings which are required to make RE projects happen. Characteristics of RE projects will be compared with other conventional thermal power projects and challenges of developing RE projects will also be highlighted.

1. INTRODUCTION

Global climate change, including the rise of the earth's average temperature as a result of human beings' activities affecting the environment through the build up of greenhouses gases, has become a worldwide discussion topic. The average temperature of the earth's surface has risen by 0.74°C since the late 1800s. It is expected to increase by another 1.8°C to 4°C by the year 2100[1]. The various impacts of global climate change have caused increasing concerns globally - governments, science and business communities, green groups, and the public have started to realise the issues and actions are being considered or implemented. It is widely recognised that now is the critical timing to address global climate change issues, not only because of the economic activities in developed economies such as the US and Europe, but also the current and future growth in developing countries particularly China and India.

Today, we are seeing China and India growing at very high growth rates. China's GDP grew by 10% annually and India had an over 7% annual growth in the past 5 years[2], and the trend is expected to continue in the foreseeable future. To fuel the strong economic growth, reliable electricity supply is required and therefore both China and India have aggressive developments plans for power plants (mostly coal-fired). The real challenge is how to continue economic growth in a sustainable manner and minimise the global climate change impacts. Using China as an example, it has an average 76GW new electricity capacity commissioned every year during the period between 2003 and 2006[3] and this is equivalent to the overall electricity capacity installed in the entire United Kingdom[4]. The situations require proactive and urgent management. This paper does not intend to cover all the possible solutions globally but will focus on how to utilise renewable energy in the overall electricity generation mix to reduce (or avoid) green house gases emission, mainly carbon dioxide, in the world's two biggest developing countries of China and India.

CLP Holdings, a leading international private sector power company in Asia-Pacific, is committed to generating 5% of our total capacity from renewable energy sources by 2010. With this target, CLP Renewables was formed in June 2005 to oversee the development of our renewables portfolio in the region. The paper provides a brief overview of

1 United Nations Framework Convention on Climate Change (UNFCC)
2 International Monetary Fund (IMF)
3 China's Power Sector Reform, International Energy Agency (393GW in 2003), Xinhuanet (622GW in 2006)
4 US Energy Information Administration (UK's total electricity installed capacity was 76.187 GW in 2004)

renewable energy potentials, project development, government supports and challenges in these two countries. Since projects will not be able to go ahead without financing, the paper also provides a briefing on key aspects of project financing and carbon finance.

Table 1 Renewable Energy Development in China[6]

RE Technology	Exploitable	By end 2004	2010 target	2020 target
Hydro	400GW	100GW	160GW	300GW
Wind	1,000GW - 250GW onshore - 750GW offshore	760MW (1,260MW by end 2005)	5,000MW	30,000MW
Biomass (power generation)	Agriculture waste: 700m tons p.a. Wood waste: 800-1000m tons p.a. Urban Waste: 130m tons p.a.	2,000MW	5,000MW	20,000MW
Solar PV	3,340 - 8,400MJ per m^2 land	60MW	NA	1,000MW

2. CHINA

The Chinese economy has experienced an annual reported GDP growth rate of more than 9% over the past two decades[5]. A massive increase in electricity demand and consumption due to economic surge, however, presents the country with some serious challenges, notably how to ensure that power infrastructure is accessible to its population across the whole country and how to sustain growth with due care for the local and global environment. China government is fully aware of the challenges and it has taken a proactive approach to develop renewable energy. In 2005, it enacted a renewable energy legislation which took effect on January 1, 2006. This legislation is very comprehensive and ahead of many other developing and even some developed countries. With the benefits of the new legislation, China presents a great opportunity for both local and foreign companies in the renewable energy industry.

2.1 RENEWABLE ENERGY POTENTIAL

The Chinese government, through National Development and Reform Committee (NDRC), has indicated its focus on various preferred renewable energy technologies and has set ambitious targets for renewable energy development up to 2020 (see Table1).

Currently, hydropower accounts for more than 20% of total installed power generation capacity in China. This represents approximately 25% of the estimated potential at 400GW which is the largest potential in the world.

The greatest potential among all four preferred renewable energy is wind energy which is about 1,000GW. It is estimated that 25% of the total is onshore and offshore makes up the rest. High wind resource areas are concentrated along the coast and in the north and west of the country. However, it should be noted that not all exploitable potential will be able to implement and so its target is much smaller than hydro.

Biomass also offers considerable opportunities for power generation throughout the country. The country's main biomass resources include agricultural wastes, residues from forestry and forest product industries. Municipal solid waste and landfill gas are also classified as biomass from the view of energy utilisation.

China has good solar resources which provides good potential for developing solar energy applications in remote parts of the country such as Tibet, Xinjiang, Qinghai, and Inner

5. China's Power Sector Reform, International Energy Agency
6. Chinese Renewable Energy Industries Association

Mongolia. However, generally speaking, these areas are not easily accessible to power grid and are economically underdeveloped.

2.2 POLICY ENVIRONMENT

As discussed previously, the Chinese Government has set strong medium and long-term targets for renewable energy development. To provide a national policy framework for renewable energy development, the Renewable Energy Law was endorsed by National People Congress's Standing Committee in February 2005 and came into effect on 1 January 2006. Some notable clauses include:

1. Renewable energy facilities will enjoy an on-grid priority status, which ensures all renewable energy[7] generated electricity will be connected to their local grid for despatch. Grid companies are also obliged to purchase all renewable energy generated electricity.
2. The electricity tariff of a specific renewable energy project will receive a government directed price according to their types, locations, benefits to the local community, the average costs among the same type of technology, as well as the project developer bidding price.
3. Once the renewable energy facility is connected to the grid, the costs are spread and shared among users of the grid.
4. Special fund will be considered for the development of renewable energy projects in rural areas.
5. Banks, depending on the potential of the project, should provide preferential loans to project developers in order to encourage renewable energy development.

3. INDIA

Over the past five years, India has been experiencing an annual growth rate of 7%[8]. Similar to China, India is experiencing surging economic growth and, hence the need for electricity demands. Challenges of building a reliable supply of electricity and diversification of fuel mix have become a key focus for India. India has been seeking strategic alternative options, and renewable energy is a solution being pursued. India has ranked as the 4th largest wind energy producer in the world, and the country's wind power market is the most developed in Asia. It shows a good example of how important government supports are in developing renewable energy.

3.1 RENEWABLE ENERGY POTENTIAL

India has vast potentials in renewable energy sources, and especially in the area of hydro power, biomass power and wind power. With an existing 7,100MW of installed renewable energy capacity, the Indian government sets an objective of achieving a target of 10,000MW of installed renewable energy capacity by the year of 2010. Table 2 lists various types of existing installed renewable energy capacity and its potential in India.

Table 2 Existing Installed Renewable Energy Capacity and Potential in India[9]

RE Technology	Existing Installed Capacity	Potential
Wind	~4,400MW	45,000MW
Small Hydro (up to 25MW)	~1,700MW	15,000MW
Biomass power/cogeneration	~950MW	19,500MW
Solar PV	Very low exploitation	20MW/sq.km
Urban and Industrial Waste-based power	Very low exploitation	2,700MW

7. Renewable energy in the Renewable Energy Law refers to non-fossil energy of wind energy, solar energy, water energy, biomass energy, geothermal energy, and ocean energy, etc.
8. International Monetary Fund (IMF)
9. Ministry of New and Renewable Energy, Government of India

3.2 POLICY ENVIRONMENT

In order to reach the country renewable energy target, several policies and regulatory frameworks were implemented:

1. A mandatory minimum percentage for purchase of energy from renewable energy source, which was made applicable by April 1, 2006.
2. Renewable energy sources should be offered with a preferential tariff until a particular renewable energy technology has been evolved and able to compete with conventional sources of electricity generation.
3. A series of fiscal benefits, such as duty exemptions, income-tax holidays, accelerated depreciation for taxation purposes, have been extended.
4. Extended financial support will be provided by the Indian Renewable Energy Development Agency.

4. PROJECT FINANCING

Renewable energy project is usually built at a premium cost in comparison to traditional energy plant, and thus various types of funding option are available at various stages of project development to facilitate renewable energy investments as shown in Table 3.

Table 3 Funding Options

Development Stage	Construction and Operation Stage
Developer/Sponsor equity	Developer/Sponsor equity
Government grant	Corporate finance loan
Soft loan	Non-recourse project finance loan
Venture fund	Lease finance for equipment
	Carbon finance
	Project bundling and portfolio financing

During the development stage, funding sources such as developer or sponsor equity funds reflect the risk profile of development projects in their early stages. Government grants or soft loans, particularly for small to medium-sized projects are usually through government's renewable energy initiative programmes, to assist renewable energy developers 'off the ground'.

In the construction and operation stage, developers or project companies will rely on other third parties financings such as corporate loan, limited-course and/or non-recourse project finance loans, lease finance for equipment and carbon finance. Carbon finance is closely associated Clean Development Mechanism which will be discussed further in the next section.

5. CLEAN DEVELOPMENT MECHANISM (CDM)

CDM is a flexible tool which was developed under the Kyoto Protocol (KP) from the United Nations. As renewable energy emits no carbon dioxide or much less than traditional fossil fuel sources during the electricity generation process, the difference of carbon emission between burning fossil fuel to obtain the same amount of electricity from a thermal power plant becomes a "carbon credit" (Certified Emission Reduction or CER). For those parties who are under emission reduction obligations, they can acquire CERs to meet with their requirements, hence creating a market for CERs. Since CERs are tradable under the European Union Emission Trading Scheme (EUETS), it has become a hot financial instrument particularly for European buyers and sellers from China and India.

Many financial institutes, such as the World Bank (PCF carbon fund), Deutsche Bank (KfW carbon fund) or Japan Bank for International Cooperation (JBIC carbon fund) have entered into the "carbon" market and shown strong carbon finance interest which in turn enhances the return on climate-friendly investments such as renewable energy projects. With the combination of carbon finance, CDM provides extra revenue and cashflow to projects which were not profitable originally.

Like many other financial instruments, CER prices fluctuate but are rising. Depending on

the structure of the sale, CER is currently trading at Euro 7-11 per ton of CO_2. For a typical renewable energy project (depending on technologies), the availability of CER can potentially boost up the investment return by about 1-4%.

6. CLP's RENEWABLE ENERGY EFFORTS

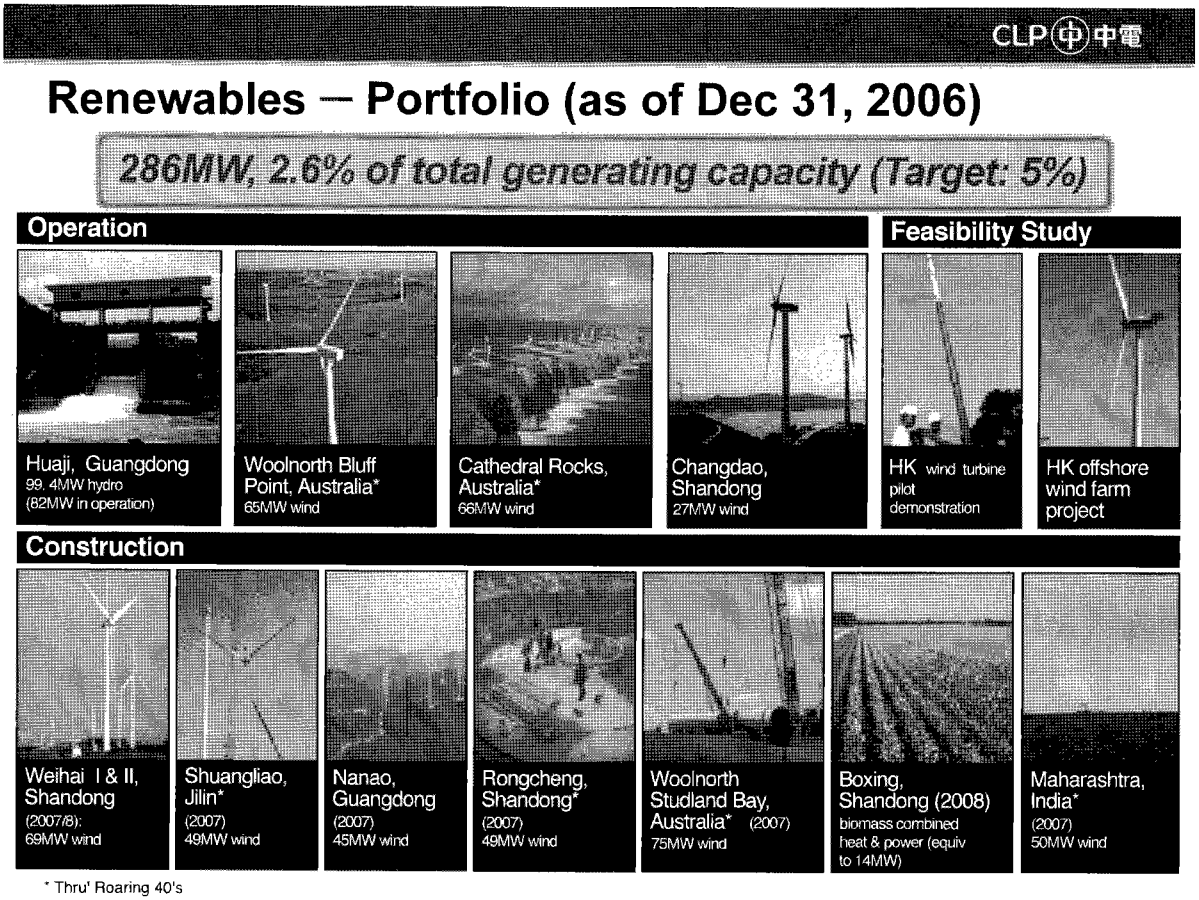
CLP Holdings, a leading international independent power producer (IPP) in Asia-Pacific, is committed to generating 5% of our total capacity from renewable energy sources by 2010. With this target, CLP Renewables was formed in June 2005 to oversee the development of our renewables portfolio in the region. We have diversified fuel mix from hydro, wind to biomass. Currently we have operating and under-construction projects in China, Australia and India. We have successful joint ventures with Hydro Tasmania in Roaring 40s, China's Huaneng Group and other local partners. In addition, we are exploring the feasibility of a major offshore wind power project in the eastern seawater of Hong Kong, close to the Ninepins Islands.

We have achieved good progress during last year. To date, we have approximately 286MW (our equity portion) of renewable energy in our portfolio (see Figure 1) and another 500MW in the pipeline. This represents 2.6% of our total generation capacity. Our efforts have been recognized internationally and in September 2006, we were named "Corporate Developer of the Year" in the prestigious "Global Renewable Energy Awards" by Euromoney and Ernst & Young.

7. CONCLUSIONS

To support development of renewable energy,

Figure 1 CLP Renewables Portfolio



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both Chinese and Indian governments have taken major steps in establishing strong legal frameworks to encourage and protect renewable energy investment. Various incentive measures are also provided to renewable energy investors to ensure a sustainable investment return. The availability of CER and carbon finance is also critical to the successful development of renewable projects which are typically more expensive than traditional thermal generation.

In summary, various actions are required by the whole world to mitigate or improve global climate change issues. As far as electricity generation is concerned, renewable energy is an effective way of reducing or avoiding green house gases emission. Positive movements are now taking place in China and India. CLP will continue our efforts in renewable energy in the region and we are fully committed to the 5% generation target by 2010.