A World Class City -
An Electrical Engineering Perspective

The Hong Kong Institution of Engineers – Electrical Division

The 21st Annual Symposium

23rd October 2003

THE HONG KONG INSTITUTION OF ENGINEERS ELECTRICAL DIVISION

The 21st Annual Symposium

Thursday

23rd October 2003

A WORLD CLASS CITY – AN ELECTRICAL ENGINEERING PERSPECTIVE

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 Registration and Coffee

09.00 Welcome Address

- Ir Joseph C.M. Leung
  Chairman, Electrical Division, The HKIE

09.05 Opening Address

- Ir Dr Alex S.K. Chan
  President, The HKIE

09.10 Keynote Speech

- Mr K.C. Kwok
  Regional Chief Economist
  Standard Chartered Bank, Hong Kong

1. Power for Modern Metropolis

09.40 An Integrated Approach to Enhance the Quality of Electricity Supply in a Modern Metropolitan City

- Ir C.P. Cheng, Network Planning Manager
- Mr Cathen Y.K. Ho, Systems Engineering Manager
  CLP Power Hong Kong Ltd.

10.00 First Gas-fired Combined Cycle Power Plant for Hongkong Electric

- Ir Dr C.W. Tso, Chief Mechanical Engineer
- Ir Y.L. Kwan, Senior Mechanical Engineer
  The Hongkong Electric Co. Ltd.

10.20 Discussion

10.40 Coffee Break

2. *World Class Infrastructures*

11.10 Electrical Services Design in the New 88-storey Two International Finance Centre

- Ir Joseph C.M. Leung, Director
- Ir Albert W.K. To, Technical Director
- Ir P.K. Yip, Senior Associate
  J. Roger Preston Ltd., Hong Kong

11.30 Hong Kong International Airport – Hub for the Region, Gateway of China

- Ir Y.F. Wong
  Head of Technical Services and Procurement
  Airport Authority, Hong Kong

11.50 Discussion

12.20 Lunch

3. *Technological Potential*

14.00 Renewable Energy Development in Hong Kong

- Ir Dr K.M. Leung, Chief Engineer
- Ir Dr Y.F. Kwok, Building Services Engineer
  Energy Efficiency Office
  Electrical & Mechanical Services Department
  The Government of the HKSAR

14.20 Application of Nanotechnology in Electro-mechanical Interface

- Prof. P. Sheng, Professor and Head of Department
- Dr Weijia Wen, Assistant Professor
  Department of Physics
  and Institute of Nano Science and Technology
  Hong Kong University of Science and Technology

14.40 Semiconducting Nanowires and Device Applications

– Dr C.S. Lee
Associate Professor
Department of Physics and Materials Science
City University of Hong Kong

15.00 Discussion

15.20 Coffee Break

4. Engineering Knowledge Promotion

15.50 A Web-based Multi-lingual Teaching and Learning Method for Electrical Engineering

– Dr Eric K.W. Cheng
Associate Professor
Department of Electrical Engineering
Hong Kong Polytechnic University

16.10 Hong Kong Disneyland – Engineering Challenges in Providing World Class Family Entertainment

– Mr Tommy J. Jones
Technical Director
Walt Disney Imagineering, USA

16.30 Discussion

17.00 Summing Up

– Ir T.P. Uy
Symposium Chairman
Electrical Division, The HKIE

Closing Address

– Prof. C.K. Poon, JP
President
Hong Kong Polytechnic University

Acknowledgement

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

Speakers / Authors

Prof. C.K. Poon, JP
Ir Dr Alex S.K. Chan
Mr K.C. Kwok
Ir C.P. Cheng
Mr Cathen Y.K. Ho
Ir Dr C.W. Tso
Ir Y.L. Kwan
Ir Joseph C.M. Leung
Ir Albert W.K. To
Ir P.K. Yip
Ir Y.F. Wong
Ir Dr K.M. Leung
Ir Dr Y.F. Kwok
Prof. P. Sheng
Dr Weijia Wen
Dr C.S. Lee
Dr Eric K.W. Cheng
Mr Tommy J. Jones

Sponsors

Siemens Ltd.
Analogue Group of Companies
CLP Power Hong Kong Ltd.
The Hongkong Electric Co., Ltd.
Clipsal Hong Kong Ltd.
Schneider Electric (HK) Ltd.
MK Electric (China) Ltd.
Junefair Engineering Co. Ltd.
Kum Shing Group
ABB (HK) Ltd.
Alstom T & D Ltd.
Greenland Engineering Co., Ltd.
MTR Corporation Ltd.
ME888.COM Ltd.
Mitsubishi Electric (Hong Kong) Ltd.
Raychem (HK) Ltd.
Wenden Engineering Service Co., Ltd.
Au Chow Electrical Co., Ltd.
Metrix Engineering Co., Ltd.
Chat Horn Engineering Ltd.
Thorn Lighting (Hong Kong) Ltd.
The Majestic Electrical Engineering Co. Ltd.
Supremetech Engineering Co., Ltd.
The Hong Kong & Kowloon Electric Trade Association
Hong Kong Electrical Contractors' Association Ltd.

Cover Design of this Booklet by Mr Stephen Barry, Step Design Consultants

21ST ANNUAL SYMPOSIUM ORGANIZING COMMITTEE

Symposium Chairman	:	**Ir T.P. Uy**
Members	:	**Ir Joseph C.M. Leung**
		Ir P.N. Ip
		Ir Henry H.C. Lam
		Ir L. Chan
		Ir K.K. Fung
		Ir S.K. Ho
		Ir C.L. Wong
Hon. Secretary and Treasurer	:	**Ir Y.K. Chu**

Paper No. 1

AN INTEGRATED APPROACH TO ENHANCE THE QUALITY OF ELECTRICITY SUPPLY IN A MODERN METROPOLITAN CITY

Speakers : Ir C.P. Cheng, Network Planning Manager
Mr Cathen Y.K. Ho, Systems Engineering Manager
CLP Power Hong Kong Ltd.

AN INTEGRATED APPROACH TO ENHANCE THE QUALITY OF ELECTRICITY SUPPLY IN A MODERN METROPOLITAN CITY

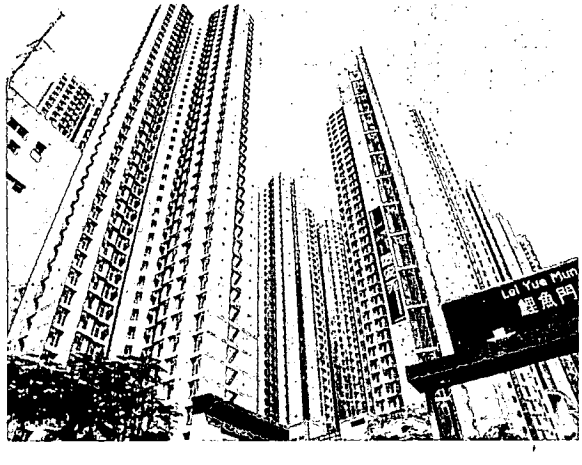
Ir C.P. Cheng, Network Planning Manager
Mr Cathen Y.K. Ho, Systems Engineering Manager
CLP Power Hong Kong Ltd.

Paper No. 1

ABSTRACT

Hong Kong is an international city characterized by its high-rise buildings and dense population. With the high degree of dependence on electricity in business activities as well as our daily life, maintaining an adequate and highly reliable electricity supply is therefore essential to fuel the continuous growth and functioning of the city. To raise the competitiveness of Hong Kong as a leading financial, logistics, technology research, and tourist center, further enhancement in reliability and quality of electricity supply is imperative.

Figure 1 High-rise Residential Estates are Typical in Hong Kong



This paper briefly explains the reasons for the increasing reliance and expectation on reliability and quality of electricity supply. The strategies and approaches adopted by CLP Power for supply reliability and power quality improvements will be discussed. Finally, examples of projects and initiatives currently undertaken are used to illustrate the implementation of the strategies formulated.

1. INTRODUCTION

CLP Power is an investor-owned utility company serving around two third of the territories in Hong Kong SAR. The network of CLP Power, interconnected with the Southern China power grid, comprises 400kV, 132kV and 11kV systems with over 10,000km of overhead lines and cables in total. The peak demand in 2002 was over 5800MW [1]. Also, CLP Power's supply reliability was above 99.99%.

Achieving four "9"s is not the only challenge in electricity supply but also the power quality (PQ). Voltage dips, being the most concerned PQ issue, are caused by system faults that cannot be totally eliminated in a power system, as there are a number of external factors outside utility's control causing such disturbances. CLP Power's transmission and distribution network mainly comprises 400kV, 132kV and 11kV systems with overhead lines and cables. Like other systems in the world, most of the voltage dips are caused by the thunderstorms, lightning, vegetation intrusion and third party interferences.

Despite of these uncontrollable factors, CLP Power adopts an integrated approach to tackle both the reliability and PQ issues from both the supply side and demand side.

2. SUPPLY RELIABILITY

In simple term, supply reliability is related to

the ability of the power network to satisfy customer's load requirement in a continuous manner. In order to have high supply reliability, CLP Power is required to ensure that adequate generation is always available as well as to ensure that electricity can be delivered to customers through the transmission and distribution network.

The function of the transmission and distribution (T&D) systems is to deliver electrical energy from the generation sources to end use customers. Any problem within the T&D network may cause supply interruption to customers. It is therefore important that the T&D systems should be robust enough such that it can meet customer electricity demand without exceeding component's technical limits under normal and contingency conditions. To meet the high reliability requirement, the power network at 132kV and above is designed to accept the possible loss of any network component(s) without a corresponding supply loss.

The T&D systems of CLP Power consist of the EHV/HV bulk transmission system, the area transmission system and the distribution system. The bulk transmission system transports power in bulk from the generating sources to the area transmission system. The area transmission system then sends the power to the distribution system, where it is distributed to the customers. The T&D systems are described below together with the planning standards to explain how the increasing reliance and expectation on reliability and quality of electricity supply are met.

CLP Power uses a set of network planning standards in planning the T&D systems. In general, (N-1) security criterion is adopted to avoid supply interruption under most single contingency, e.g. losing a power cable or a transmission transformer. Being the distillation of years of experience with the performance of the power system, the planning standards adopted by CLP Power are on par with world best practices. The standards serve as the guidelines for the system planners in their network design to ensure a high supply reliability network.

Bulk Transmission Network

CLP Power transmission network mainly consists of a 400kV system superimposed on a 132kV system. The 400kV system is the backbone of the transmission system formed by a double-circuit overhead line ring system encircling the New Territories of Hong Kong. It brings power from the main generating sources at Castle Peak and Black Point in Hong Kong and also from the Daya Bay Nuclear Power Station and Guangzhou Pumped Storage Station in mainland China.

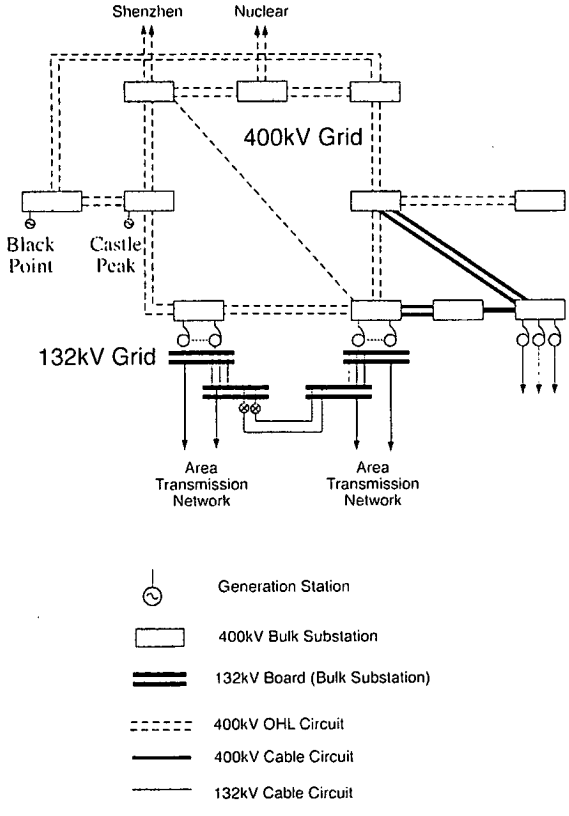
The power handled by the bulk transmission system is large and its failure may lead to widespread supply loss. To provide high supply reliability, 1-1/2 breaker for 400kV switchgear and double-busbar for 132kV switchgear are employed as standard design to minimize widespread system outage due to busbar fault which has not been covered by (N-1) security standard.

To maximize the use of valuable wayleave, 400kV double-circuits overhead line is employed. To cater for possible loss of a 400kV pylon, although very unlikely, the planning standards specified that loss of any 400kV double-circuit overhead line would not impose any restriction on the generation output or cause supply interruption to any 132kV group.

As the 400kV substations are of strategic importance to the power system and each substation can carry up to 1000MVA load, appropriate 132kV interconnections will be established to provide mutual backup between 400kV groups to allow supply restoration under credible outage conditions.

A typical grid and 132kV bulk transmission arrangement is shown in Figure 2.

Figure 2 A Simplified Representation of CLP Power's Transmission Power Grid



Area Transmission Network

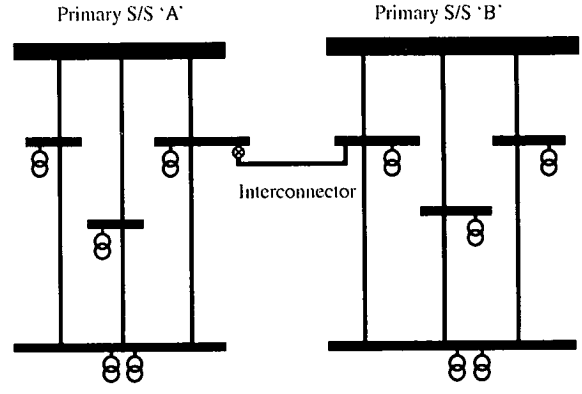
CLP Power's area transmission system is mainly made up of 132kV network. They are usually in the form of a group of two to four feeder circuits supplying the 132/11kV transformers of three primary substations via 132kV ring-main-units, which are backed up by 132kV interconnections when appropriate.

Occurrence of 132kV cable fault would trip the whole circuit by the circuit breaker at the 132kV board. According to (N-1) security standard, supply to customers could be maintained while one of the transformers at each primary substation of the group would lose at the same time.

Distribution Network

In CLP Power distribution network, 11kV cable circuits run in closed loops (closed ring system) and are protected by high-speed feeder protection or pilot-wire differential protection. A fault on a section of cable feeder will result in the automatic disconnection of the faulty feeder with no supply interruption. Similar to 132kV, 11kV interconnectors play an important role in restoring supply under emergency conditions.

Figure 3 Typical Diagram of 11kV Interconnector



Power System Protection

To avoid cascading failure, a sophisticated protection system is installed to identify and isolate the faulty equipment. To improve reliability and security, two independent, high-speed protection systems are provided for 132kV and 400kV networks, supplemented by a backup protection system to ensure that faulty equipment can be isolated promptly and correctly.

3. POWER QUALITY

CLP Power achieves the availability target of 99.99% and is amongst the best when compared to utilities in USA, Australia and New Zealand. Most of the customers are satisfied with 99.99% availability. In fact, typical availability for utilities is three to four "9"s. Table 1 below summaries the supply availability in terms of number of "nines". Even at nine "9"s availability, customers on average would expect a power loss of 31 milliseconds per year. For those customers with sensitive loads, it is recommended to install protective equipment (e.g. uninterruptible power supply) before connecting to the normal supply.

Table 1 Supply Availability Standard

Number of 9	*Availability (percentage)*	*Unavailability (Time per year)*
2	*99%*	*3.65 days*
3	*99.9%*	*8.76 hours*
4	*99.99%*	*52.56 mins*
5	*99.999%*	*5.256 mins*
6	*99.9999%*	*31.536 secs*
7	*99.99999%*	*3.1536 secs*
8	*99.999999%*	*0.31536 secs*
9	*99.9999999%*	*0.031536 secs*

Voltage dips are by far the most concerned power quality issues. It is a very short duration (typically 80-200ms) of depression in supply voltage (50-90%) caused by various reasons e.g. lightning. Unlike system availability, there is no international standard or best practice for reference. It is quite dependent on the type of supply network and the weather conditions. According to EN50160, a general customer could experience voltage dips from a few 10s to a 1000 time in a year.

Since some external factors cannot be totally controlled by the utility, customers are bound to experience such voltage dips. To reduce the voltage dip impact, both utilities and customers are responsible. Utilities should improve the power quality while customers should install voltage dip mitigation device for sensitive facility or equipment. Improvements on equipment voltage dip ride-through capability are usually the most cost-effective method e.g. dynamic voltage restorer or uninterruptible power supply.

4. NEW INITIATIVES

4.1 SUPPLY RELIABILITY

Other than a well-designed power network, other aspects such as selection of appropriate equipment, effective protection against lightning etc. are also important in minimizing the risk of supply interruption.

Equipment

To maintain high supply reliability and improve system performance, the obsolete and aged 66kV system has been phased out completely and the replacement of ageing 33kV equipment are in progress. New equipment adopting latest technologies with high performance and reliability will be introduced to the power network.

Protection of Overhead Line against Lightning

To minimize the occurrence of voltage dips due to lightning, line arresters are installed on selected overhead lines. These line arresters, fitted with an air gap, are connected between phase conductors and the towers. Upon a lightning stroke on the OHL, these arresters will discharge the lightning energy in a controlled manner such that system voltage can be reasonably maintained.

Operational

CLP Power cannot completely safeguard the multi-contingency situations. Fast and effective recovery actions are therefore important to minimize the extent and duration of the failure. With the implementation of DA (distribution automation) and the new EMS (Energy Management System), the operation staffs can response quickly to every emergency situation to restore supply promptly. CLP Power also operates 24-hour emergency service teams that can be deployed quickly to the scene to provide quick supply restoration.

Vegetation Management

Vegetation management (VM) has been set up in year 2000 as vegetation is a problem for some remote and densely vegetated areas. Unlike tree trimming, VM has a much wider scope and perspective including: hiring of horticultural experts, identification of vegetation species, development of tree trimming methodology and frequency, application of herbicide, transplanting of trees away from the overhead lines and re-planting of different low growing tree species.

Apart from reliability improvement, this initiative can also enhance safety and lower the operational cost.

Helicopter Applications for Live OHL Maintenance

CLP Power has undertaken various initiatives to continuously improve supply reliability in a cost effective manner. The introduction of the helicopter live line insulator washing technique is one of these initiatives. This technology has been successfully deployed in North America and Australia for more than 10 years. CLP Power is the first utility in Hong Kong to adopt it for transmission overhead line insulators on poles and towers at 132kV and 400kV.

The technique brings about significant benefits, including enhancement to the security of the transmission network, and improvement in the effectiveness and efficiency of insulator cleaning. With the aid of the helicopter, the time and effort spent by the linesmen in climbing up and down the towers, and travelling from one tower to another, can be saved. The overall productivity is thus improved.

Mechanical Pole Testing

Other initiatives include mechanical pole test on overhead line poles to ensure their integrity. In addition to reduce overhead line pole outage, this preventive maintenance methodology can also enhance safety of personnel and lower the operational cost.

Mobile Generators

In addition to the active initiatives undertaken, CLP Power has also adopted reactive measure to enhance supply security. Since 1999, Temporary Supply Connection Procedures as well as the purchase of 3MVA and smaller rating mobile generators have been established to restore supply to customers promptly in case of prolonged fault repair time.

4.2 POWER QUALITY

To address customers' concern on PQ, CLP Power has set up a dedicated team to help customers/manufacturers improve the performance of their equipment.

To cope with the ever-increasing demand on PQ services, there is a need to have new initiatives. Some of these are on the demand side to improve customers' equipment ride through capability.

Air-conditioning Equipment Improvement Project

Paper No. 1

Air-conditioning equipment is sensitive to voltage dips and is believed to be the main contribution to load rejection after voltage dips. Instead of managing thousands of customers on the same type of equipment, CLP Power works with a handful of air-conditioning equipment manufacturer to achieve a more cost effective result. Significant cost and effort can be reduced in developing mitigation measures and investigations.

There are two major focus areas:

i) Forming strategic partner network with major air-conditioning manufacturers on improving voltage dip ride through capability of drive /pump/chiller/AHU.

ii) Carrying out demonstration projects of PQ solutions.

Power Quality Monitoring and Management

Unlike reliability, there is no international standard or best practice on PQ. Each utility has to monitor its own PQ performance and define their baseline. In this connection, PQ monitoring equipment will be installed at strategic sites for baseline establishment.

PQ baseline performance is the crucial information for formulating plans for improvement and providing regular statistics on power quality which shows where we are and whether the problem is getting better or worse over time.

Explore Power Quality Mitigation Measures

Like the world's most successful utilities, resources are allocated for earlier evaluation and application of the potential mitigation measures from research and development in terms of customers and utility prospects.

Should these solutions be proved promising, we shall advocate their deployment to our customers. CLP Power also works closely with other peer utilities, PQ consultants and academic institutes to share experience and successful cases. Ultimately, an inventory of mitigation measures, case studies and products could be built.

Formulate PQ Guideline with Regulatory Bodies

PQ is an issue that requires regulatory bodies, utilities, equipment manufacturers and customers to work together. There is also growing awareness and demand from our customers regarding better PQ.

Overseas experience showed that it would be easier to manage customer expectation when the basic PQ requirements are specified in the guideline. In addition, a clear responsibility for the utility and customer will help each other to perform their duties.

Communicate Proactively with Internal and External Customers on PQ Issues

To further enhance communications between customers and frontline staff, a PQ Demonstration Room has been planned for visit by our engineers and customers. Scaled-down models of different PQ cases and solutions will be shown in the PQ Demonstration Room. Chiller, commercial lighting, escalator and flywheel UPS are some of the examples. To share knowledge on equipment PQ performance, case study will be published. In order to educate more customers within a short period of time, Internet PQ website and new pamphlets/brochures on PQ will also be provided.

5. CASE STUDIES FOR POWER QUALITY

There are several successful cases on improving customers' equipment ride-through capability. These include lighting improvement, escalator improvement and quay crane improvement projects.

Case 1: Lighting Improvement Project

High pressure discharging lamp is well known for its susceptibility to voltage dips and its prolonged re-ignited time. After a detailed study, three proposals were suggested for customer's considerations.

a) Employ lamp circuit with better voltage dip ride-through capability, e.g. employing the Constant Wattage Auto-transformer (CWA) circuit.

b) Employ lamp with double tube feature, which can ignite the side tube when the main tube extinguishes.

c) Voltage dips seldom happen on all three phases of the supply, so, evenly distributing the lamps to three phases of supply can reduce the chance of lamp extinguish during voltage dips.

After evaluation of these options in terms of performance, cost and ease of retrofit, the customer finally went for the CWA option.

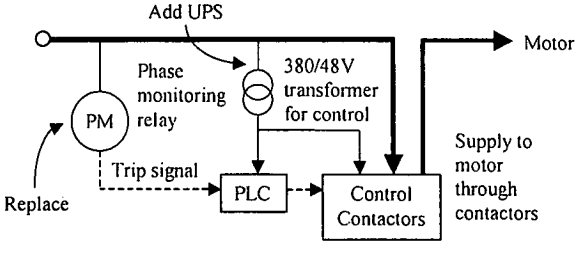
Case 2: Escalator Improvement Project

A railway company owns over 500 escalators inside their stations. 400kV system faults caused by lightning may cause momentary voltage dips in the entire supply system. Many escalators were found tripped during the voltage dip. In addition to the need of manual reset on hundreds of escalators, passenger injury might also occur during the sudden stopping of the escalator.

After investigation, it was found that the control contactors and programmable logic controller (PLC) dropped off during voltage dip. Moreover, the phase monitoring (PM) relay was not equipped with any time delay setting, such that the escalator was tripped by the PM relay even the contactors and PLC did not drop off.

The railway company was recommended to add an uninterruptible power supply (UPS) to secure the supplies to the control contactors and PLC. In addition, the phase monitoring relay was replaced with a new relay that equipped with a short time delay in order to allow the escalator to ride through the voltage dip for 0.15 sec (Figure 4). Regulatory body evaluated the case and finally approved this modification.

Figure 4 Simplified Control Scheme for an Escalator

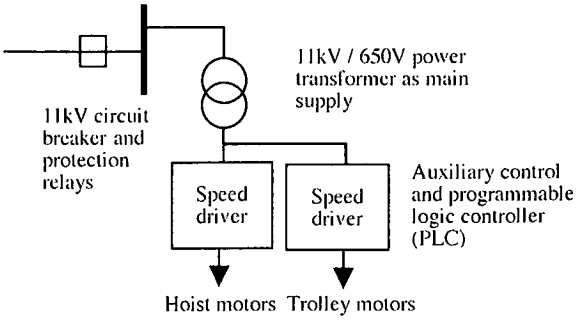


Case 3: Quay Crane Improvement Project

Quay crane is one of the essential gears in container port terminals. A container port terminal suffered from operation disruption during voltage dip. The quay cranes tripped and required long recovery time.

Crane is a very complicated machine. The electrical part of a 11kV crane comprises of HV switchboard, power transformer, speed drivers for the main hoists and trolley, and various secondary controls and protections (Figure 5).

Figure 5 Arrangement of an 11kV Quay Crane



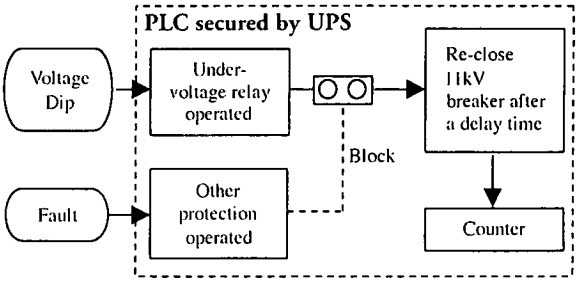
Detailed investigation revealed that a number of cranes were tripped during voltage dip incidents. Based on operation records, half of these tripped cranes were merely caused by the operation of under-voltage protection. The motor drivers for the main hoists and trolley could be reset manually but it was very time-consuming due to the location of the control circuits. An auto re-start scheme was designed and recommended to the customers. The auto re-start scheme could greatly reduce the impact arising from voltage dips. Manpower could be released to restore other affected equipments.

To reduce the impact, it is suggested to introduce auto re-closing scheme (Figure 6) to the crane's control. Some salient features of the scheme are highlighted as below:

- Auto re-close is to be initiated by under-voltage protection.
- Any other protection operated in the same event is regarded as blocking command to inhibit the re-closure.
- The re-closure of the breaker is to be performed by programmable logic controller (PLC).

The modification was implemented and the result was found successful.

Figure 6 Auto Re-close Scheme



6. CONCLUSION

A reliable and quality electricity supply is utmost important in powering the future development of Hong Kong. Even though the reliability performance matches with the high

level of standard, challenges are always here to provide better reliability and PQ.

While the customers' equipment is getting more sensitive to the power supply, an integrated approach is adopted to improve the quality of electricity from both the supply side and the demand side.

ACKOWLEDGEMENT

The authors wish to thank the Management of CLP Power for the support and permission to publish this paper.

REFERENCES

1. CLP Holdings Limited, Annual Report 2002

Paper No. 2

FIRST GAS-FIRED COMBINED CYCLE POWER PLANT FOR HONGKONG ELECTRIC

Speakers : Ir Dr C. W. Tso, Chief Mechanical Engineer
Ir Y. L. Kwan, Senior Mechanical Engineer
The Hongkong Electric Co. Ltd.

FIRST GAS-FIRED COMBINED CYCLE POWER PLANT FOR HONGKONG ELECTRIC

Ir Dr C.W. Tso, Chief Mechanical Engineer
Ir Y.L. Kwan, Senior Mechanical Engineer
The Hongkong Electric Co. Ltd.

Paper No. 2

ABSTRACT

The Hongkong Electric Company Limited (HEC) is committed not only to providing a reliable and cost effective electricity supply to its customers but also to protecting the environment of Hong Kong. To keep in pace with the development of Hong Kong in the 21st century in terms of electricity demand and better environment, HEC is developing a 1,800MW gas-fired combined cycle plant as an extension to the existing Lamma Power Station. Natural gas for the new power plant will be supplied from the regional LNG Terminal at Cheng Tou Jiao of Shenzhen via a 92km submarine pipeline.

To balance between advanced technology of high efficiency and reliability of the plant, HEC has conducted an extensive review of gas turbine technologies. This paper presents the development of the new gas-fired plant and the approach adopted by HEC in selecting the gas turbine model for its first combined cycle unit and various factors considered in optimizing the combined cycle configuration and plant layout.

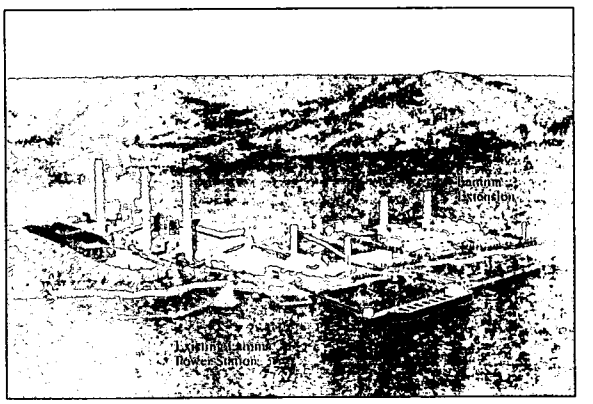
1. INTRODUCTION

The Hongkong Electric Company Limited (HEC), one of the two power utility companies in Hong Kong, is responsible for supply of electricity to Hong Kong Island and Lamma Island. HEC's coal-fired Lamma Power Station has been undergoing continual development in phases to meet the energy demand over the past two decades and now has an installed capacity of 3,420MW.

To meet the anticipated growth of electricity demand in the 21st century, HEC identified in the mid 90's the need to construct a new power plant. Following a comprehensive site search study, an extension to HEC's existing Lamma Power Station was identified as the preferred site for the new power plant (Lamma Extension). To ensure that the new generating facilities would not cause any unacceptable environmental impacts, gas-fired combined cycle plant was selected. Work on detailed Environmental Impact Assessment (EIA) study for the Lamma Extension project was commenced in 1998. Approval of EIA Reports by the Environmental Protection Department was given in May 1999 [1].

Lamma Extension is now being constructed on a piece of reclaimed land connected to the south of the existing Lamma Power Station. Six 300MW class gas-fired combined cycle gas turbine (CCGT) units will be built in phases with the first unit scheduled for commissioning in mid 2005. Fig. 1 shows the existing power station and Lamma Extension upon completion of the whole development.

Figure 1 An Artist's Impression of Lamma Extension

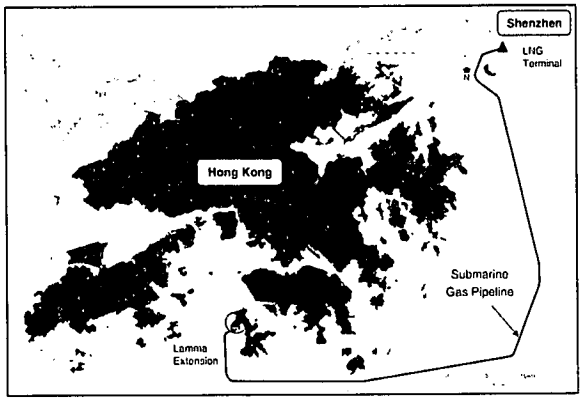


Natural gas for powering the new CCGT units will be supplied from Guangdong LNG Terminal at Cheng Tou Jiao in Shenzhen via a 92km long, 610mm dia. submarine gas

SIEMENS

pipeline buried 3m below seabed (Fig. 2). The pipeline is designed with an operating pressure of 90 kg/cm^2 to meet the operational requirements of Lamma Extension in a fully developed state.

Figure 2 Submarine Gas Pipeline Routing

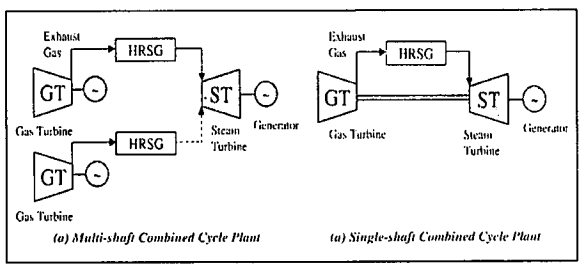


2. REVIEW OF ADVANCED GAS TURBINE TECHNOLOGIES

2.1 AN OVERVIEW

A CCGT plant combines a gas cycle and a steam cycle, and uses gas or liquid distillates as fuel to generate power. The waste heat from the gas turbine (GT) is passed through a heat recovery steam generator (HRSG) to produce steam to drive a steam turbine for secondary electricity generation. Conventionally, a combined cycle block consists of two to three gas turbines coupled with one steam turbine. However, recent trend adopts the single train concept whereby one single gas turbine is coupled to the steam turbine together with one generator on one shaft. Fig. 3 shows schematic diagram of typical CCGT plants.

Figure 3 Schematic diagram of CCGT plants



Gas turbine attains high efficiency by increasing the turbine inlet temperature (TIT) - the gas temperature at the first nozzle inlet. In the early 1980s, the first generation of gas turbines with 1,100°C TIT was applied to CCGT plant, and an overall plant efficiency in the range of 47% to 50% on a LHV basis was achieved.

Over the past two decades, with the advances in material technology, improvements in cooling systems and demand from power industry, the second generation of gas turbines, generally referred to as "F" class technology, with substantial increase in the TIT was introduced in the mid 90's. With a firing temperature of over 1300°C, the "F" class gas turbine has a higher exhaust gas temperature making it technically feasible to apply the reheat cycle, boosting up the CCGT plant efficiency to 53-55%. Today, the latest model of gas turbine with 1500°C TIT, referred to as "H" class technology, is available in the market and an overall plant efficiency of 60% has been reported.

The increased firing temperature allowed by advances in gas turbine technology has yielded not only improved efficiency, but also the output of the CCGT unit. The introduction of the "F" class gas turbine with an output of 200MW is an important step in gas turbine development. This allows the gas turbines to challenge the traditional thermal power plant prime movers to an extent not previously possible especially in terms of efficiency, output and broad application (emergency, peak, intermediate or base load).

On the other hand, due to fierce competition, turbine makers are rushing for launching innovative new turbines to the market before all technical problems have been identified and resolved. A number of serious problems were reported during initial years of operation of the "F" class gas turbines. Extensive research, re-design, testing and retrofit work had been conducted to remedy the shortcomings.

Given HEC's system is relatively small and the

new units will be HEC's core assets in electricity generation for the next 20 years, plant availability and reliability is considered of over-riding importance. In this respect, HEC has reservations to adopt the innovative new machines and would rather opt for the slightly lower efficiency but more matured and reliable design. HEC therefore embarked in 1999 on a study to obtain an insight into the latest technology development and operating experience of the "F" class gas turbine to ascertain its suitability for application in Lamma Extension.

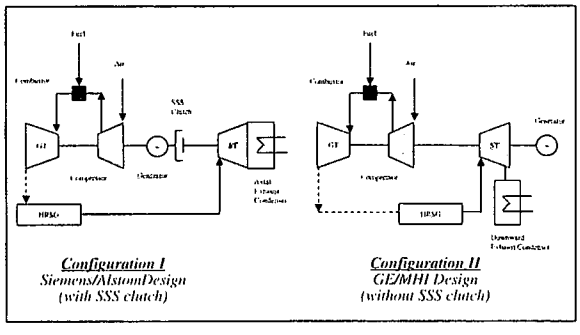
2.2 POWER TRAIN CONFIGURATION

Since the "F" class gas turbine is of 200MW range and the CCGT plant selected for Lamma Extension is of 300MW class, HEC's study was therefore focused on the single-shaft design.

The major Original Equipment Manufacturers (OEMs) that produce "F" class gas turbines for 300MW class single-shaft CCGT units are Alstom Power (Alstom), General Electric (GE), Mitsubishi Heavy Industries (MHI) and Siemens/Westinghouse (Siemens), and their respective GT models are as follows:

Manufacturers	GT Models
Alstom	GT26
GE	9FA
MHI	701F
Siemens	V94.3A

Figure 4 Single-shaft CCGT Unit Configuration



Two configurations of single-shaft combined cycle blocks adopting the "F" class gas turbines (Fig.4) are available in the market, and their main features are:

Configuration I (Siemens and Alstom)

- Presence of a Self-shifting Synchronizing (SSS) clutch between the steam turbine and generator.
- Generator is located between gas turbine and steam turbine.

Configuration II (MHI and GE)

- No SSS clutch.
- Steam turbine is located between gas turbine and generator.

Another distinctive difference between the two configurations is that Siemens and Alstom machines are floor mounted with axial flow condensers, whereas GE and MHI machines are placed on elevated foundations with downward exhaust condensers. This means that Configuration I requires a longer but lower building and Configuration II needs a shorter and taller building.

2.3 REVIEW BY ERA AND POWERGEN

In order to obtain the latest GT technologies and find out the problems of "F" class machines encountered during the initial operating years, HEC commissioned ERA Technology Ltd [2] in early 2000 to conduct a detailed assessment on each of the four "F" class GT models. The study covered development history, design features, problems encountered and improvement/modifications made, reliability, availability, output, cycle efficiency, experience on dual fuel firing, after-sales services, technical support from OEMs, etc.

In addition to information obtained from OEMs, ERA also made visits to the following combined cycle power plants in Europe to seek views from the user's perspective on the actual performance of the machines:

Paper No. 2

SIEMENS

Power Stations	Models
Enfield Energy Centre	Alstom GT 26B
Saltend Cogeneration Plant	MHI 701F2
Cottom Development Centre	Siemens V94.3A2+
Didcot B Power Station	Siemens V94.3A
Tapada De Outeiro Power Station	Siemens V94.3A1
Taranaki Power Station	Alstom GT 26A
Otahuhu Power Station	Siemens V94.3A2
Bursa Power Station	MHI 701F
Wang Noi Power Station	Thailand	MHI 701F MHI 701FA
Chiba Power Station	Japan	GE 9FA MHI 701FA
Cottam Development Centre	UK	Siemens V94.3A2
Connah's Quay Power Station	UK	GE 9FA

GT Works	Location
MHI Takasago Works	Japan
Siemens Berlin Works	Germany
GE Belfort Works	France
Alstom Baden Works	Switzerland

In order to verify the information on O&M aspects of CCGT plants, HEC further commissioned Powergen [3] in late 2000 to provide specific technical advices from the perspectives of plant operator on CCGT units. The study focused on reviewing Siemens' V94.3A1 machine at Tapada Power Station in Portugal and GE's 9FA machine at Connah's Quay Power Station in the UK with respect to major problems encountered during construction, commissioning and operation, and also modifications made by OEMs on gas turbine, steam turbine, generator and HRSG. Other issues also addressed in the study covered actual performance on dual fuel operation, unplanned outage causes, emission levels, scheduled inspection intervals, maintenance cost, spare stocking, heat rate deterioration, terms of long term services agreement, etc.

2.4 FACTS FINDING VISITS

In parallel with the consultancy studies, HEC project team made several facts finding visits to OEMs' manufacturing works and CCGT power stations in 2000 to seek further information on the capabilities of OEMs and actual performance of their machines. Observations from OEMs' manufacturing works provided an important insight into their manufacturing facilities and capability as well as availability of their manufacturing lines for meeting the delivery schedule of HEC's new unit. These visits included:

2.5 SUMMARY OF FINDINGS

The studies completed in 2000 revealed the following findings:

- Since introduction of the "F" class GT models in the mid 90's, all OEMs had made various modifications on their machines. Some of the modifications were required to address problems experienced in early models while others were for efficiency/ output enhancement.
- Different nomenclatures have been adopted by OEMs to identify their updated models. GE's F machines are labeled by F, FA, FA+, FA+ enhanced, each with its own number designation such as PG9311 with a firing temperature of 1,288°C and PG9351 with a firing temperature of 1,327°C. Siemens' initial V94.3A model is designated as V94.3A1 with a 17-stage compressor while the latest model designated as V94.3A2 adopts a 15-stage design. Similarly, MHI's latest 701F model (F3) has a higher firing temperature of 1,400°C compared with that of 1,350°C in the initial model (F1). For Alstom, "A" model was the initial configuration of GT26 which has been subsequently upgraded to the "B" rating.
- All the latest GT models have been in operation since end 1998/1999, with the exception of GT26B which has its lead unit in operation in year 2000.

- Problems identified in early models have been basically addressed in the latest models, and the operators are in general satisfied with the performance of the "F" class machines currently in operation. The latest "F" class GT models can thus be regarded as proven and reliable.
- In line with the various modification and improvement works, the OEMs have adjusted their manufacturing lines such that they can only offer their latest models to new orders.

Having taken consideration of the maturity of technology, reliability, efficiency and life cycle cost, "F" class gas turbine was adopted in HEC Tender Specification for Lamma Extension. The invited Tenderers were requested to offer their latest models of "F" class gas turbine as follows:

Tenderer	GT Model
Alstom	GT26B
GE	PG9351
MHI	701F
Siemens	V94.3A2

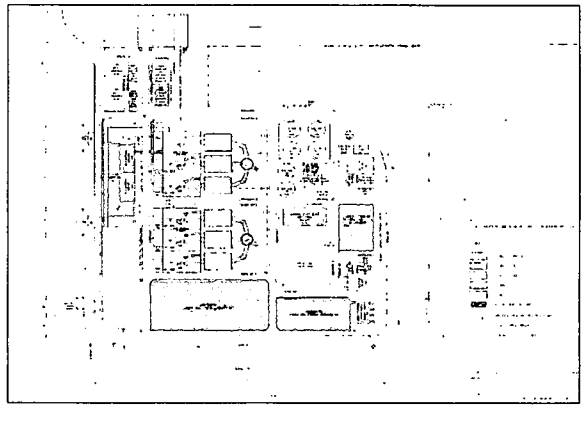
3. PLANT LAYOUT AND MAIN DESIGN FEATURES

3.1 PLANT LAYOUT

The Lamma Extension Plant is being developed in phases on a newly reclaimed land in the south of the existing power plant. Making use of the synergy benefit of co-siting with the existing Lamma Power Station, the scale and capacity of the auxiliary plants at Lamma Extension is substantially reduced. Other than generating units, the Lamma Extension Plant will have its own Gas Receiving Station and a variety of ancillary plants and buildings. To optimize the use of common facilities, most utilities are to be supplied or shared with the existing coal-fired generating units.

Construction of six CCGT units for Lamma Extension starts from north to south. The main power block is orientated in the east-west direction with the HRSG and chimney towards the east. Two 110m tall chimneys, each has three steel flues with reinforced concrete windshield on the outside, are to be constructed. A once-through cooling system is adopted. The water intake structure consisting of stop logs, bar screens, drum screens and circulating water pumps is located on the eastern side of the site, while the outfall is located on the western side in order to avoid re-circulation. The single shaft power train and electrical equipment is housed inside a Main Station Building while the HRSG is located outdoor. A master layout plan of Lamma Extension Plant is shown in Fig.5.

Figure 5 Master Layout Plan of Lamma Extension

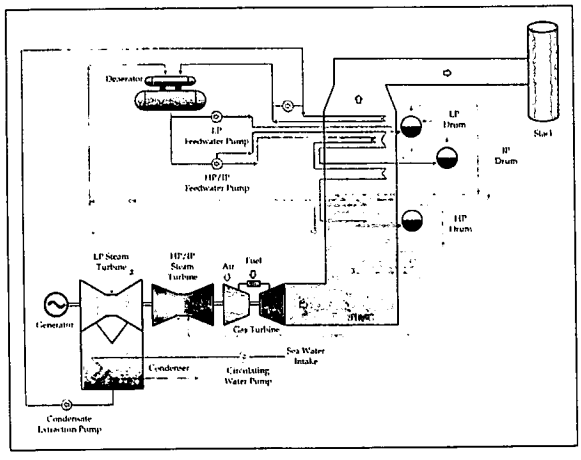


3.2 MAJOR DESIGN FEATURES

The first combined cycle unit for Lamma Extension is designed for dual-firing with natural gas as the main fuel and light gas oil for emergency backup in case of interruption of gas supply. This unit is MHI's latest model of 701F single shaft CCGT unit with a thermal efficiency of 56% (LHV). It consists of a gas turbine, heat recovery steam generator, steam turbine and generator. A simple schematic diagram and outlook of the unit are shown in Fig.6 and Fig.7 respectively.

Paper No. 2

Figure 6 Schematic Diagram



3.2.1 GAS TURBINE

The M701F gas turbine consists of a 17-stage, high efficiency axial compressor, combustion chamber equipped with 20 combustors arranged in circular array around the engine, and a 4-stage reaction type turbine. The gas turbine is directly coupled to the steam turbine at the compressor end.

The compressor has a pressure ratio of 17:1 and is equipped with a single-stage variable inlet guide vane control to improve compressor surge characteristics during start-up and part-load operating condition. The blade path is designed by using a 3-dimensional flow field analysis computer program. All compressor diaphragms are coated for corrosion protection and to improve aerodynamic performance.

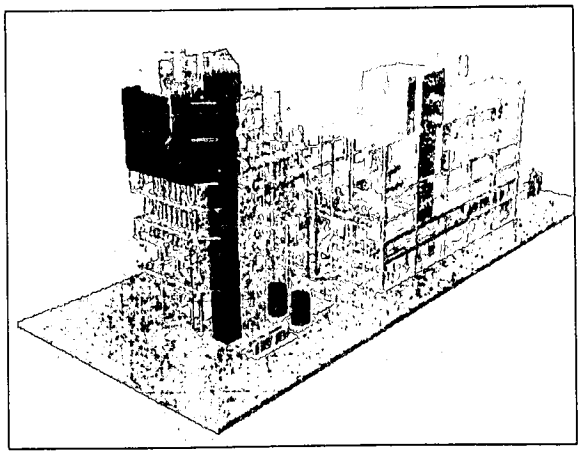
The M701F combustion system is of dual-fuel design capable of burning natural gas and light gas oil. Dry Low NO_x (DLN) combustors are provided for natural gas firing to achieve high plant efficiency. The DLN combustor can limit NO_x emission down to 25 ppm while operating at a firing temperature of 1400°C. The hybrid combustor is equipped with a bypass valve which directs a portion of the compressor delivery air into the transition piece to enhance flame stability during start-up and to maintain the desired fuel/air ratio during normal operation.

The turbine vanes and blades are made of Ni base/Co base alloy. The first two stages are coated with thermal barrier coating to reduce the metal temperature. The cooling system for the turbine section consists of a rotor cooling circuit and four stationary cooling circuits. Rotor cooling air is provided by compressor discharge air extracted from the combustor shell. Direct compressor discharge air is used to cool the row 1 vane. Compressor bleed air from HP and IP LP stages is used to provide cooling air to turbine blade ring cavities at stages 2 and 3 respectively. Bleed air from LP is directed to Stage 4 for inter-stage cooling.

3.2.2 HRSG

The HRSG is of vertical gas flow, triple pressure, reheat and natural circulation design without supplementary firing. The HRSG connects directly to the gas turbine exhaust with no by-pass stack. The HRSG is of full modular design comprising 15 shop-fabricated tube block modules and 16 casing modules so as to minimize the high pressure welding work at site and to shorten the construction period. The exhaust gas temperature from the gas turbine is of 600°C at rated condition on gas-firing, and the waste heat is used to produce high pressure steam at 540°C and reheat steam at 569°C to drive a three-stage pressure steam turbine-generator.

Figure 7 Outlook of Lamma L9 Combined Cycle Unit



3.2.3 STEAM TURBINE/GENERATOR

The steam turbine is of a 2-cylinder, tandem

compound double exhaust, condensing reheat type which consists of a combined high pressure and intermediate pressure turbine and a double-flow low pressure turbine with downward exhaust. A 100% capacity rating HP/IP/LP steam bypass system is provided for startup as well as effective unit loading control during emergency conditions. The generator directly coupled to the steam turbine is of hydrogen-cooled design with static excitation. A static starting system consisting of static frequency converter, transformer and change-over dis-connector is provided for startup of the gas turbine.

3.2.4 DISTRIBUTED CONTROL SYSTEM (DCS)

The DCS is designed for fully automatic unit startup/shutdown, loading control and emergency handling under different modes. The DCS is configured with redundancy to eliminate the possibility of plant shutdown due to single component failure. Geographically and functionally distributed DCS optical fibre network and remote I/O system are adopted to minimize the amount of field cables. Besides, local instruments in hazardous areas are designed to explosion-proof or intrinsically-safe in compliance with natural gas operation requirements.

4. CONCLUDING REMARKS

Following an extensive study on combined cycle power plant technology, HEC has come up with the conclusion that the latest "F" class gas turbine technologies is proven and reliable. The adoption of the "F" class gas turbine has reflected the prudent and expedient approach taken by HEC to get the maximum benefit of economies of scale and high efficiency while ensuring high reliability for the first combined cycle unit of Lamma Extension.

The introduction of natural gas and adoption of advanced combined cycle technology for Lamma Extension will make HEC's generation system a more efficient, reliable and environmentally friendly one in the near future. This demonstrates HEC's commitment to supply clean and reliable energy to meet the expectations of the community.

ACKNOWLEDGEMENT

This paper is published with the kind permission of The Hongkong Electric Company Limited.

Paper No. 2

REFERENCES

1. ERM, 1999, *"Environmental Impact Assessment of a 1,800MW Gas-Fired Power Station at Lamma Extension - Executive Summary"*, February 1999, Environment Resource Management Ltd, Hong Kong
2. ERA Technology, 2001 *"Review of Combined Cycle Technologies for Lamma Power Station - Final Report"*, January 2001
3. Powergen, 2001 *"Lamma Power Station Extension CCGT O&M Review - Final Report"*, May 2001

SIEMENS

Paper No. 3

ELECTRICAL SERVICES DESIGN IN THE NEW 88-STOREY TWO INTERNATIONAL FINANCE CENTRE

Speakers : Ir Joseph C.M. Leung, Director
Ir Albert W.K. To, Technical Director
Ir P. K. Yip, Senior Associate
J. Roger Preston Ltd., Hong Kong

ELECTRICAL SERVICES DESIGN IN THE NEW 88-STOREY TWO INTERNATIONAL FINANCE CENTRE

Ir Joseph C.M. Leung, Director
Ir Albert W.K. To, Technical Director
Ir P.K. Yip, Senior Associate
J. Roger Preston Ltd., Hong Kong

Paper No. 3

ABSTRACT

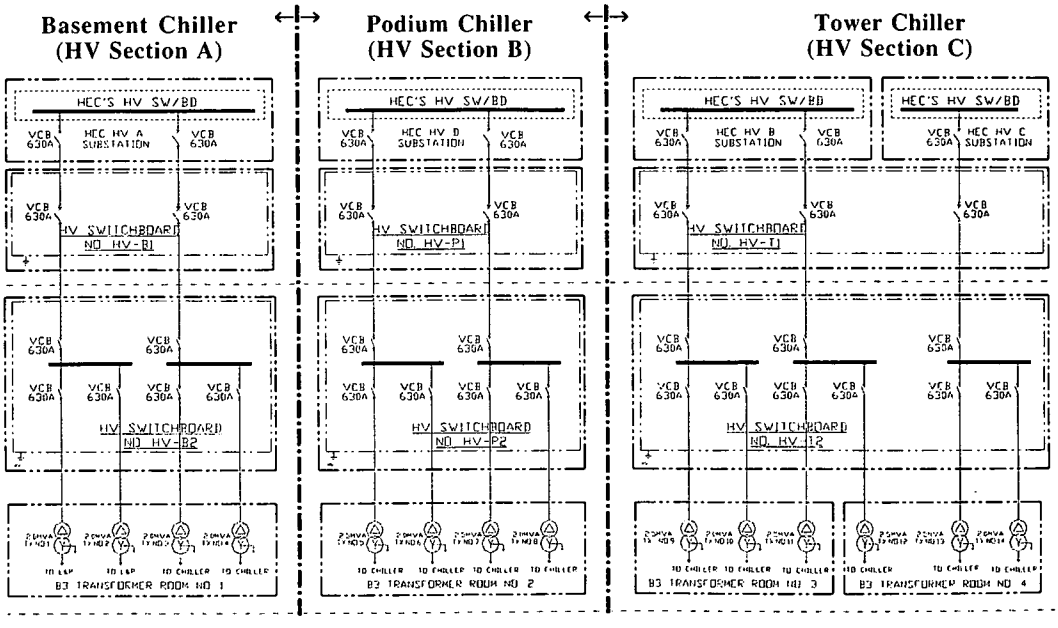
The skyline of central district area has been re-drawn by the completion of an 88-storey skyscraper called Two IFC which stands at 420m off the ground and the third tallest building in the world as at June 2003. Two IFC is a grade A office building with a total gross floor area (GFA) of more than 180,000m^2 and an estimated working population of 15,000 person. The tower is divided into 7 lift zones with twin sky lobbies and 4 mechanical floors to service each individual zones of the building in the most economical and energy saving manner.

The electrical design represents a challenge to all engineers not only because of its shear height but the complexity, security and reliability of the electrical and mechanical systems which are designed to serve those world class grade A tenants locally, as well as the multi-national financial institutions.

1. INTRODUCTION

The central seawater cool chiller plant (~20,000 refrigeration tons) serving the whole of northern site is located in basement level. As this is the major load center, HV supply (11kV) is employed and fed from the power company's HV supply network and terminated at the consumer side HV panels. 7 nos. of 11kV radial feed HV feeders running along the dedicated riser duct are provided to serve the HV distribution panels in basement (Fig. 1). The reason of choosing the HV scheme is due to the economical reason as well as the voltage dip caused by the starting of seawater cooling chillers. A total of 8 nos. of 2MVA and 6 nos. of 2.5MVA package type cast resin transformers were used in Basement Levels (total 80,000m^2 of construction floor area) to serve general lightings, power and carpark / smoke extraction ventilation system.

Figure 1 Simplified HV Schematic for Basement Chillers, Lighting, Power and Ventilation

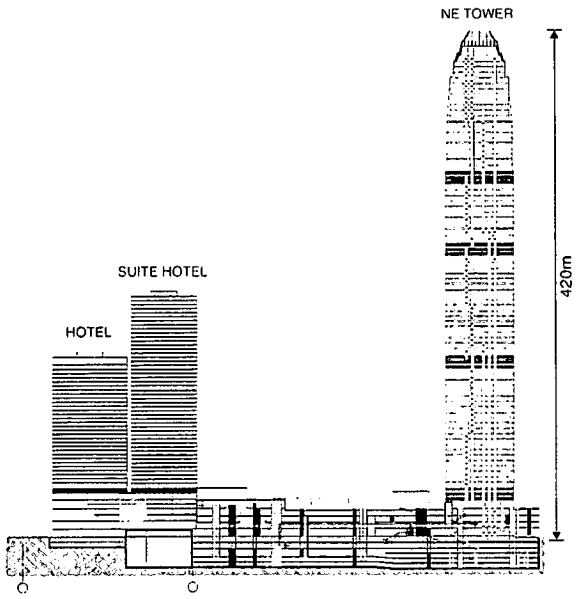


SIEMENS

2. ABOVE-GROUND TRANSFORMER SUBSTATION

Due to the shear height of Two IFC, above ground substations are definitely required in all the mechanical floors to contain voltage drop and to efficient deploy of energy to various loads centres. In order to comply with Power Company's requirement with respect to the delivery of transformer, a 4,000 kg service lift is required to accommodate the selected size of 1,050kVA transformer which are used throughout the building. The service lift car cage and its shape is specially designed which can facilitate transportation of transformer as well as bulky furniture for tenants up and down the tower. A total of 16 above-ground substations accommodating a total of 46 nos. of 1,050kVA transformer with installed capacity of 48MVA are provided. Each transformer loading is pre-calculated to cater for any incidental taking off-line of one of the transformers within the same substation, while still maintaining continuity of normal power supply to tenant.

Figure 2 Sectional View of Two IFC



3. SERVICING STRATEGY

Reliability of power supply system is of paramount important to ensure the normal operation of the building. A number of measures have been adopted as follows:

- HV dual supply : Currently, the Power Company is feeding their power supply from their separate sub-stations, including Connaught Road zone substation, Rumsey Street zone substation, and Tamar zone substation to ensure dual HV infeed are maintained at all time.
- Dual HV riser : Power Company's 11kV cables are running in two independent risers rising through the core of the building to eliminate the possibility of total blackout in case of fire or accident happened in one of the risers.
- Dual tenant riser : Each tenant floor will be served by dual riser LV busduct system feeding from different transformers sources. In case of power failure, it would be possible to changeover the tenant loads to other healthy risers.
- Reduced loading capacity : Each transformer shall be loaded to only up to ~ 60% (approx.) of rated capacity of the transformer. This would allow additional loading transfer from other tenant riser in case of emergency situation.
- Within the building core, dry and wet services are planned to divorce from each other thus minimizing risk of flooding impact. Leakage alarm devices are installed at strategic locations to report leakage via BMS for immediate response by the building operator.

4. EMERGENCY POWER SUPPLY (BUILDING SYSTEMS AND TENANT'S BACKUP SUPPLY)

Two categories of emergency generators are provided, namely the FSI generator and non-FSI generator (including Tenant's backup supply).

a. FSI Generator (Refer to Fig. 3 and Table 1)
In order to maintain the integrity and full backup for the fire services installation (FSI), it was decided in the early design

stage that all FSI equipment should be served by its dedicated FSI generators. All FSI generators are connected to a centralized fuel supply system which consists of 2 x 20,000 litre bulk fuel tank at G/F, upfeed pumps in fuel tank room; intermediate transfer tanks are provided on mechanical floors with transfer pumps to transfer fuel to the higher zones. Leakage detectors are installed at strategic location along the entire vertical riser whilst the horizontal fuel pipes are enclosed in separate compartment of appropriate fire rating filled with sand. A total of 4 nos. FSI generators are installed with installed capacity of 6.2 MVA. The FSI generators serve :-

- Sprinkler system and detection system
- Hose reel / Hydrant system
- Drencher system
- Staircase pressurization system
- Essential lighting which are also backed up by battery with charger
- All Firemen's lifts

Figure 3 Simplified Fuel Supply Schematic

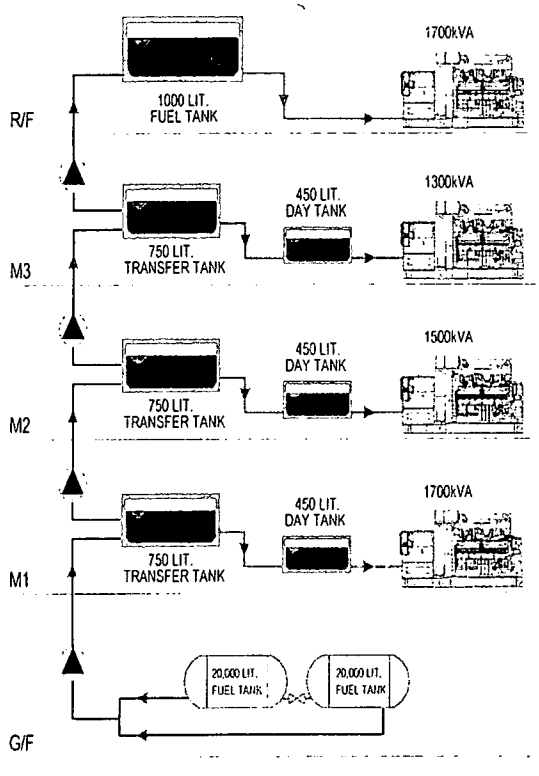


Table 1 Genset Installed

	Basement / Podium	Tower
G/F	2 x 1,800 kVA (F) 1 x 2,000 kVA (F)	
3/F	1 x 800 kVA (F) 1 x 1,500 kVA (F)	
1st Mechanical Floor		1 x 1,700 kVA (F) 1 x 1,500 kVA (T) 1 x 1,300 kVA (T) 1 x 800 kVA (T)
2nd Mechanical Floor		1 x 1,500 kVA (F) 3 x 1,500 kVA (T)
3rd Mechanical Floor		1 x 1,300 kVA (F) 1 x 1,500 kVA (T) 1 x 1,700 kVA (T)
Roof		1 x 1,700 kVA (F) 1 x 1,300 kVA (T) 2 x 1,800 kVA (T)
Upper Roof		1 x 1,300 kVA (T) 1 x 1,500 kVA (T)

(T) Tenant genset **(F) FSI genset**

b. Non-FSI generator (Refer to Table 1)

As Two IFC is also targeted to serve financial institutions who will demand a highly reliable power supply system. In this respect, non-FSI generators are provided within building to cater for:-

- All essential air-cooled chillers in mechanical floors are backup by generators. This will ensure that critical computer equipment (such as tenant's on-site data center, UPS, CRAC, TBE room, etc) is backed up 100% with chilled water supply even for the very remote case of the failure of power supply for seawater cooled chiller in basement.
- At least one of the lifts in each zone, including the shuttle lifts for sky lobbies, are backed up by generators for tenants emergency operation.
- Base building critical equipment are also backed up by generators. This includes the security system, CCTV system, carpark control systems, emergency broadcast and the building automation system.

Paper No. 3

SIEMENS

5. POWER QUALITY MONITORING

The tremendous increase in the use of information technology has dramatically increased the importance to monitor the quality of power supply system throughout the building. Traditionally, power quality could be measured by a standalone type harmonic analyzer which can only measure data for a short duration of time on a need basis. Such approach will be expensive and ineffective. It is therefore the Two IFC has adopted a state-of-the-art fully computerised power analyzer system which can monitor the power quality on real time basis continuously for almost all major loads and circuits. This would also facilitate the building management personnel to conduct regular critique of energy consumption and implement measures to conserve energy with a handy energy audit data bank created at wish.

All power analyzers are connected to a dedicated fast Ethernet network which in turn connects to building automation system via DDE link for effective cross-transfer of useful energy trail audit data enabling building operation monitored and controlled at its peak efficiency. The following parameters are measured:-

- Current, voltage, frequency, power factor
- KVA, kVAr, maximum demand, kWh
- Harmonic content up to 15th order

Graphical image to display min/max, trending, histogram of harmonic, waveform, surge, etc are tailored made for ease of use as reporting log sheets by the building manager. There are more than 500 nos. of power analyzers with 22 nos. of DDE servers linking the power analyzer and building automation system to achieve the energy performance and auditing objectives.

Figure 4 Typical Starting Current of Double Deck Lift Machinery

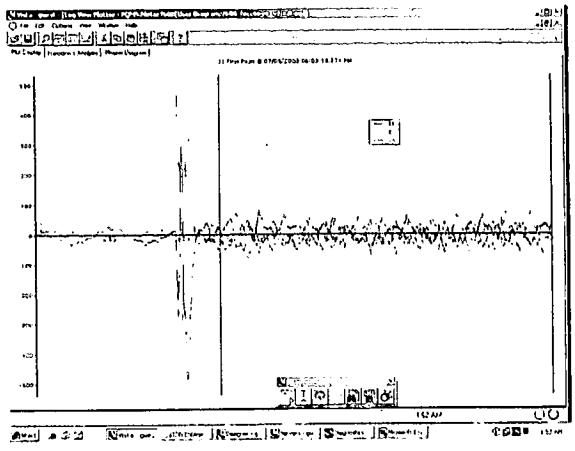
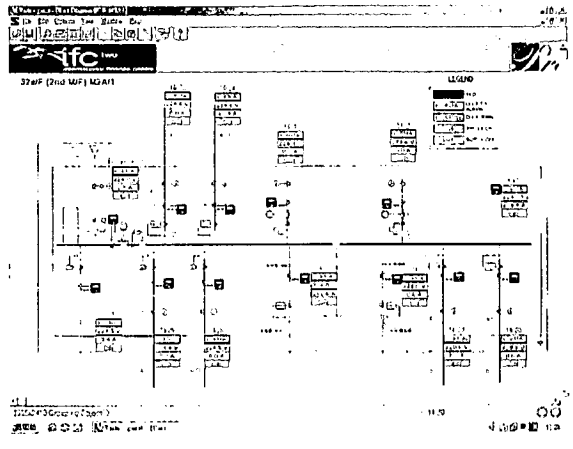


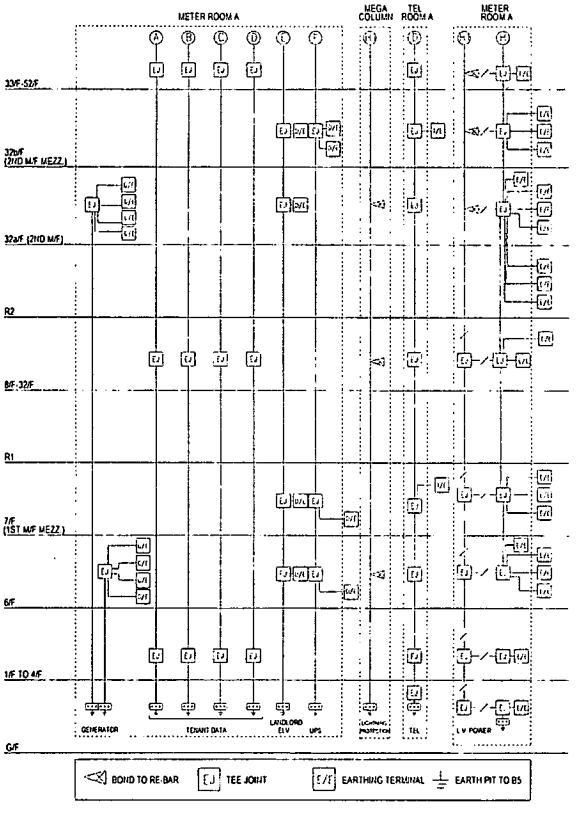
Figure 5 Power Analyzer - Electrical Schematic Display



6. LIGHTNING PROTECTION SYSTEM

Considering the great height of this building and its geographical location, it is expected that Two IFC will be subject to a relative high frequency of lightning strike. On top of the building is a passive type early streamer arrester which will be able to protection the utmost part of the building. The early streamer is then connected to a number of dedicated re-bar down conductors embedded inside the mega columns evenly spread around the building perimeter. A counter is also installed to monitor and record the number of lightning strike year round.

Figure 6 Simplified Earthing Schematic for Electrical, Tenant, Lightning, Telephone, Clean and Generator System

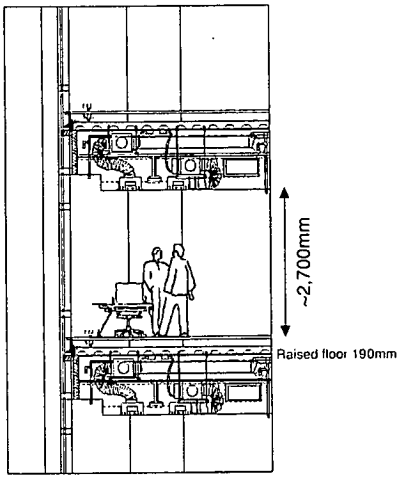


The entire curtain wall system is also designed to be electrically continuous and hence act as a faraday cage. The curtain wall is bonded to the dedicated re-bar embedded in each of the mega column at every three floors intervals to protect building from the attack of side-flashing. The re-bar as mentioned above is then connected to Basement earth pit systems used as a low impedance path for effective and fast discharge of the lightning energy.

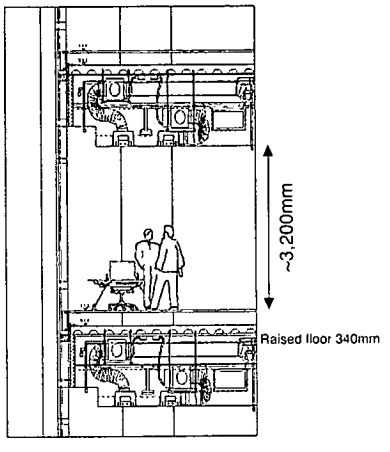
7. LIGHTING DESIGN

The design is based on then the LG3 issued by the CIBSE. In general, the lighting level is designed at average 500 lux on desk level with uniformity better than 0.75. Category 1 louvre is used all for 22 nos. of trading floors and Category 2 louvre is provided for the remaining 45 nos. of typical office floors. Integrated air handling fluorescent panel complete with double parabolic and low brightness diffuser using T8 tube and high efficiency electronic ballast are used throughout the office area.

Figure 7 Typical Lightning Design



Typical Floor



Trading Floor

8. CONCLUSION

The design of Two IFC was very much tenant and market driven with extensive consultation of targeted tenants at the outset of the design. A highly reliable electrical supply system with sufficient spare capacity and flexibility for growth and future move and change is provided in order to ensure that this building will stand for the challenge. No doubt, Two IFC and the rest of development will surely be a distinctive benchmark in Hong Kong and overseas, providing a landmark and a destination that Hong Kong will be proud of for years to come.

Paper No. 3

SIEMENS

Paper No. 4

HONG KONG INTERNATIONAL AIRPORT – HUB FOR THE REGION, GATEWAY OF CHINA

Speaker : Ir Y.F. Wong
Head of Technical Services and Procurement
Airport Authority, Hong Kong

HONG KONG INTERNATIONAL AIRPORT – HUB FOR THE REGION, GATEWAY OF CHINA

Ir Y.F. Wong
Head of Technical Services and Procurement
Airport Authority, Hong Kong

ABSTRACT

Hong Kong International Airport is one of the world's busiest international airports - a hub for the region and the gateway of China. More than 65 airlines operate over 3,900 flights a week from HKIA to more than 130 destinations worldwide. More than 33 million passengers and over 2.1 million tones of cargo passed through HKIA named World's Best Airport for 2001 and 2002 by Skytrax Research, a UK based aviation research company. We were also voted Cargo Airport of the year 2002 by Air Cargo News.

This paper highlights the special features of the HKIA systems in ensuring the safe and reliable operation of the airport at both the Airfield and the Passenger Terminal Building, being the largest building in Hong Kong. In addition, the approach in maintaining the high availability of these system will also be described including the Reliability Centered Maintenance for some critical airport operation systems.

1. INTRODUCTION

Hong Kong International Airport is one of the world's busiest international airports - a hub for the region and the gateway of China. More than 65 airlines operate over 3,900 flights a week from HKIA to more than 130 destinations worldwide. More than 33 million passengers and over 2.1 million tones of cargo passed through HKIA named World's Best Airport for 2001, 2002 and 2003 by Skytrax Research, a UK based aviation research company. We were also voted Cargo Airport of the year 2002 and 2003 by Air Cargo News.

This paper highlights the special features of the HKIA systems in ensuring the safe and reliable operation of the airport at both the Airfield and the Passenger Terminal Building, being the largest building in Hong Kong. In addition, the approach in maintaining the high availability of these system will also be described including the Reliability Centered Maintenance for some critical airport operation systems.

Paper No. 4

2. PLANNING AND GROWTH OF HONG KONG INTERNATIONAL AIRPORT

2.1 OUR NETWORK EXPANDS

Hong Kong International Airport works with over 65 airlines in providing passenger services to over 130 destinations. Half of world population is within 5 hours flying time from Hong Kong International airport. We welcomed more than 10 new airline partners during last year. Our new partners bring more frequent flights as well as new destinations, and both of these elements are key to our development as a regional and international hub.

The Airport Authority Hong Kong will ensure facilities are adequate to support further increases in runway capacity, the current average of air movement has gone up to 49 movements per hours during peak hours.

2.2 CARGO AND LOGISTICS

Strong growth of 20% in cargo was achieved during last year with throughput reaching 2.55 million tonnes. Express cargo growth was particularly strong at 24%, and is expected to continue to grow at a faster pace than cargo. Hong Kong International Airport retained the position which it has held since 1996 as the

world's busiest international cargo airport. This largely reflects the role of Hong Kong International Airport in the flow of manufactured goods from the fast growing industrial powerhouse of the Pearl River Delta.

We will continue to study capacity issue arising from the rapid growth of air cargo. In particular, it will be looking at further increasing the number of cargo stands which was already increased from 13 to 21 in December 2001. A new Express Cargo Terminal is scheduled to commence operation in 2004. These facilities will also entrench Hong Kong International Airport's position as the air cargo and logistics superhub of the region.

2.3 INTEGRATION WITH THE PEARL RIVER DELTA

Integration of Hong Kong International Airport with the Pearl River Delta is being driven through co-operation and partnership with the other airports of the Delta region. Such integration is being built through intensive development of multi-modal transport for both passengers and cargo.

For passenger, we have opened a new coach station for Mainland passengers coming to Hong Kong International Airport and a cross-boundary ferry terminal is due to open this summer. For cargo, barriers to access to Hong Kong International Airport are being dismantled through facilities such as our Marine Cargo Terminal and the direct sealed truck services between Hong Kong International Airport and Mainland cities offered by both Hong Kong Air Cargo Terminals Limited and Asia Airfreight Terminals Limited.

3. AIRPORT FACILITIES

In order to accommodate the growth in passenger, cargo and aircraft movements, we have to equip, maintain and improve airport facilities to provide a safe and reliable services to our customers. Some special facilities installed in Hong Kong International Airport are highlighted and discussed in the following sections.

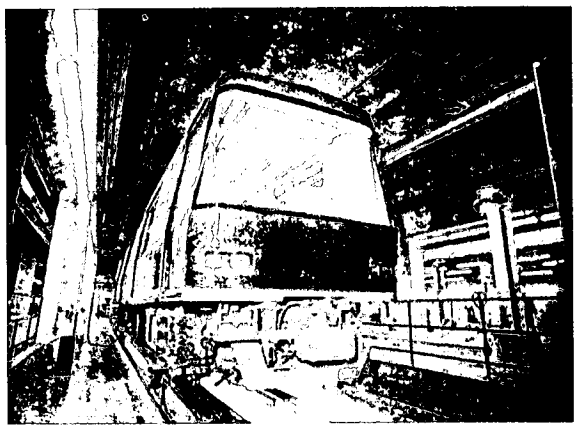
3.1 AUTOMATED PEOPLE MOVER

The mission of the Automated People Mover (APM) installed in the Hong Kong International Airport is to provide convenient and timely connectivity for all primary passenger routes within the terminal and airside gate facilities. The APM system is comprised of vehicles, guideway equipment, switches, propulsion power distribution, UPSs, automated train controls, communications equipment, platform screen doors, station dynamic signs and maintenance depot facility.

3.1.1 SYSTEM CAPACITY

The APM system consists of 8 nos. of vehicle cars and each car's capacity is 76 passengers. The train is of fixed two-car formation and able to couple another tain into four-car formation. The maximum passenger capacity of existing system is 5186 passenger/hours and expects to be increased to 9749 passenger/hours after adding 10 nos. of car to the system

Figure 1 Automated People Mover



3.1.2 AUTOMATIC TRAIN CONTROL SYSTEM

The APM vehicle operate fully automatically under the control and supervision of existing Automatic Train Control (ATC) system.

The existing ATC system employed a fixed block signalling system. There are three functional level as follows:

Automatic Train Protection (ATP)
Automatic Train Operation (ATO)
Automatic Train Supervision (ATS)

3.1.3 MANUAL CONTROL

In additional to the ATC system, the APM vehicle can operate under manual control. Under manual mode, the control of the vehicle starting, maximum acceleration, emergency braking, detection and annunciation of vehicle malfunctions, door operations and reverser operations shall remain operational.

3.1.4 AUTOMATIC TRAIN PROTECTION / TRAIN DETECTION (ATP/TD)

The ATP system functions are achieved by the use of fail-safe equipment and circuits. The ATP system include the following functions:

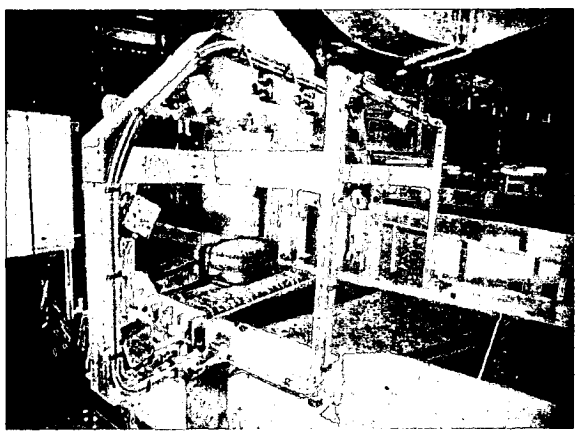
- Overspeed protection
- Reverser control

The Train Detection (TD) system is provided based on the check-in/check-out principle. This consists in providing wayside track circuit loops coil for each block section. The rubber tyred vehicles are detected by means of receiving oscillated signals from TD antennas located at the front and rear of each vehicle.

3.2 BAGGAGE HANDLING SYSTEM

The Baggage Handling System at Hong Kong International Airport is a centralised, highly automated system, controlled by computers and incorporating a high level of security. It supports a common use "free" check-in opeartion and incorporates a centralised 100% hold baggage security screening system.

Figure 2 Baggage Handling System



3.2.1 CHECK IN

When a passenger arrives at the check-in counter in the Departure Hall on level 7 of the Terminal Building to check in hold baggage, the airline staff will print a baggage tag with IATA standard bar-code which contain information about the passenger and the flight. The Baggage Handling System (BHS) interfaces with the Common User Terminal Equipment (CUTE) system of airlines to obtain the Baggage Source Messages (BSMs). The BHS processes the BSMs and use them to track the bags all the way to their intended destination. The check-in hall is comprised of 288 check-in positions. These can serve approximately 110 bags per minute.

Paper No. 4

3.2.2 IN TOWN CHECK IN

Check-in can also be done at the In-Town Check-in (ITCI) desks at the two Airport Express Line (AEL) stations- Kowloon Station and Hong Kong Station. These bags will then be transported to the Airport on the AEL. On arrival at the Airport, the bags will be unloaded from the AEL containers in a dedicated "de-stuffing" hall located in the basement of the Ground Transport Centre (GTC), located east of the Passenger Terminal Building. From here conveyors transport the baggage through a connecting tunnel to Terminal Building's baggage hall, where these conveyors merge with the delivery conveyors from the Terminal Building's check-in facilities, and injected into sortation system.

3.2.3 TILT-TRAY SORTERS

Bags are tracked on the converyors in the Baggage Handling Hall on level 3 of the Terminal Building. Automatic bar code scanners on the conveyors read the bar code tag to get the flight information for sortation. As all baggage is mixed up and fed into the system when check-in, the sorters are used to sort the baggage by flight. The sortation system employs sorters in two stages, namely primary sorter and secondary sorters. Each primary sorters is connected to every secondary sorter via inter-sorter lines. i.e. a total of 16 inter-sorter lines. On each inter-sorter line, there is a

high speed X-ray machine with automatic explosive detection capabilities. The automated sortation system will direct the bag to the appropriate sortation make-up flight spur, known as flight laterals. At these laterals, ramp operators will transfer the baggage into aircraft containers. Any of the common user check-in desks is able to serve any of flight laterals, and hence route baggage to any departing aircraft ("free" check-in operation).

3.2.4 CONTROL SYSTEMS

The BHS is controlled from the centrally located main control room, which is manned 24 hours a day. The control workstations, PLCs and data servers are linked together in one fully redundant data network built on network switches and hubs. Two main sub-systems for the control and operation of Baggage Handling system are the Management Information and Control System (MICS) and the Sort Allocation Computer (SAC).

3.2.5 MANAGEMENT INFORMATION AND CONTROL SYSTEM (MICS)

It is the top-level computer system with screens allowing staff to monitor the status of all conveyor belts and sorters from baggage control room. The MICS interfaces with the conveyors PLCs. Fault and status messages from PLC include started, off, not in automatic mode, bag jam, die-back or emergency stop will be reported to the MICS. Any faults developed in the electro-mechanical components of the BHS would immedistely displayed on the monitor screens in the baggage control room to alert the system operator.

3.2.6 SORT ALLOCATION COMPUTER (SAC)

The SAC controls the logistical part of the sortation process in the BHS. The SAC translates the 10-digit bar code read by the automated code reader onto a destination. The SAC forms a link between the airport computers (i.e. CUTE of airline departure control system, flight information and display system (FIDS)), the early bag storage conveyors and tilt-tray sorter control system.

The SAC is built on a Unix platform with an Oracle database and is accessed from the operator workstation.

3.2.7 HIGHLIGHTS OF SYSTEM

<u>System Processing Capacity</u>

Check-in collector conveyor processing rate: 20bags/min
Total System Capacity: 19,200 bags/hour

<u>Check-in System Data</u>

No. of check-in positions: 288
No. of OOG check-in positions: 16

<u>Tilt-Tray Sorter</u>

No. of Sorter : 4 (2 primary 2 secondary)

<u>Early Bag Storage</u>

No. of storage lanes : 100
No. of baggage storage position : 4000

<u>Control System</u>

No. of servers : 8
No. of workstation : 13
No. of Sorter Controller : 16 (fully redundant backup for 8 nos. of sorters)

3.3 AIRFIELD GROUND LIGHTING SYSTEM

The Hong Kong International Airport was first opened with single runway in July 1998. The Airfield Ground Lighting (AGL) system is required to provide visual guidance to pilots when approaching to land and during take-off at airport. The AGL system provides a fully automatic operation and reliable performance to meet the ICAO requirements for Precision Approach Runway Category II (CAT II). In July 1999, the second runway located at north side of Chep Lap Kok island was also put into services. An individual and separate AGL system is provided for the second runway.

The Airfield Ground Lighting system consists of the following lighting facilities :-

a. Stop bar
b. Taxiway centreline
c. Runway centreline
d. Taxiway edge

e. Approach strobe
f. Threshold etc.

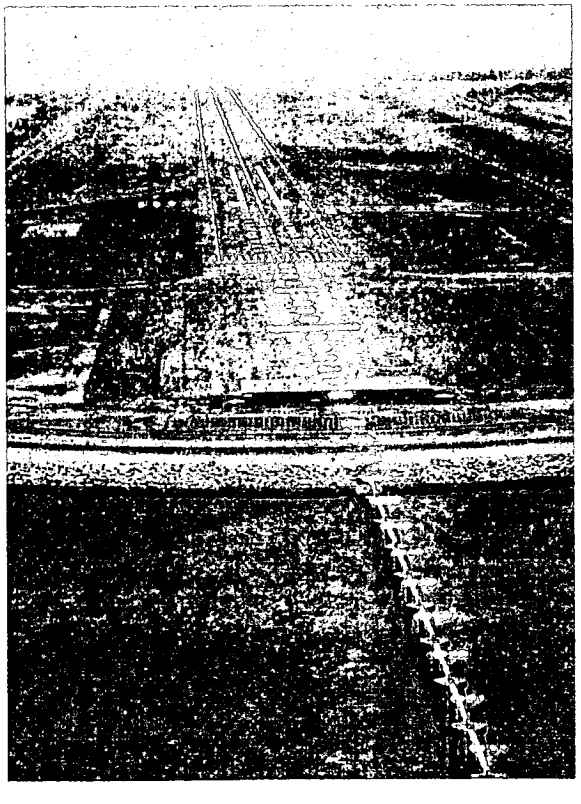
These lighting facilities are controlled and managed by several systems, such as AGLCMS (Airfield Ground Lighting Control and Monitoring System), ASPS (Airfield Smart Power System) and other detection systems.

Most of the airfield ground lighting circuits are controlled using CCR (Constant Current Regulator) and CU (Concentrator Unit), except for the Approach Strobe lights that are directly controlled by PLC digital outputs.

CCR provides a regulated constant current output i.e. constant lighting intensity independent of variations in supply voltage and output circuit loading within the range and controls the level of intensity of the lamps within its circuit. If a CCR is fitted with a CS (circuit selector), several circuits can be individually controlled by the CCR.

Individual selection of a set of lamps is made possible by means of the ASPS.

Figure 3 Airfield Ground Lighting System



3.3.1 CONTROL AND MONITORING SYSTEMS

Fig shows the system architecture of the AGLCMS, it is made up of several independent networks under the following two main categories:-

a. The fixed communication networks
b. The device networks

The fixed communication network is made up of redundancy fibre optic network and FCS (Fixed Communication System Rack Interface Unit) allowing the connection of the sub-networks. In case of a failure on the fixed communication network, the FCS located in the Vaults will ensure local communication between the PLCs.

The user workstations (located at the ATC Tower, the Maintenance Base, the Central Control Centre and the AGL Vaults) and PLCs of the system linked together by this communication network. This is used to transfer data between the PLCs and the workstations using TCP/IP protocol.

There are several separate device networks which are used by the PLCs to communicate with the remote I/O, sensors and devies.

(i) Interbus network

This network is used to communicate between the PLCs and the CCRs. In each Vault, there are two Interbus neworks, one between each of PLCs and the CCRs of a Vault to provide redundancy.

(ii) Allen-Bradley DH+ network

This is used for the communication between the PLCs and the CUs. for the control of the ASP devices. The network links the two CUs and the two PLCs per Vault.

3.3.2 MAJOR COMPONENT

The CCR is a Thyristor Constant Current Regulator for airport lighting systems. It is designed with an analogue feedback loop, controlling the current by phase controlled thyristors coupled back to back.

The overall control and monitoring, as well as interfacing, is performed by a 40MHz processor with operating program stored in non volatile memory, securing automatic start up when powered.

Remote control of CCR is performed via serial bus (Interbus) interface and local control by means of one rotating switch with Remote, Off and Local 1,3,5 or 7 intensity-steps.

The CCR provides the open circuit "Io" and over current "Im" protections while a general alarm "GA" will indicate all other faults of CCR.

4. MAINTENANCE BUSINESS MODEL FOR AIRPORT FACILITIES

It is a large different to manage and maintenance of airport comparing with other buildings and plants. As mentioned in the previous sections, the airport consists of some special systems and facilities which shall be looked after by multi-discipline professionals with specialist knowledge. However, to operate maintenance as a business, there are other key elements that must be considered. Businesses have customers, business plans, performance indicators and performance reviews for continuous improvement.

4.1 CUSTOMERS

In the airport maintenance business, the most important task is to discover a need or requirement of customer (airlines, passenger and our airport tenants) that we can satisfy. We create a culture of "serve the customer". In order to help our maintenance personnel making the paradigm shift, we provide some education and training to them to create the "serve the customer" mindset.

4.2 MAINTENANCE BUSINESS PLAN

Once the customer need is identified, we could develop a maintenance business plan which keep the maintenance teams focused on what is important for improving system performance, defining what should be accomplished, when it should be accomplished, and how it is to be accomplished.

In the plan, we set goals for the different types of systems and facilitates and determine the strategies for each goal. Two major maintenance performances are defined:

- maintenance costs
- equipment reliability.

4.3 GOALS & STRATEGIES

Reliability is the key for the airport business. We need to be proactive because we cannot afford to wait for something to breakdown. Our goal is make sure it doesn't happen.

Usually there is more than one way to achieve a goal. The key is to choose the best strategy which wisely be thoroughly understanding the customer needs and the maintenance team's capabilities.

The goals and strategies must be adjusted based on the customer's business climate.

4.4 KEY PERFORMANCE INDICATORS (KPI)

Within the maintenance business plan, Key Performance Indicator (KPI's) are necessary to track maintenance performance. The improvement strategies being implemented must be measured and correlated to the goal. This is one of more important of all of the steps required. We need to be able to define the KPI's that we will need to monitor in order to reach our goals. The necessity for tracking KPI other than just equipment reliability and budget performance is to pinpoint areas responsible for negative treads (leading indicators). So that we may able to easily pinpoint the root causes of systems failures in the future.

The following is a list of some of key performance indicators used in the airport facilities maintenance.

Table 1 Key Performance Indicatior

Key Performance Indicatior	
Reliability/ Availibility • **MTBF** • **MTTR** • **MTBR** **Preventive Maintenance** • **PPM labours** • **PPM Wos**	**Materials Management** • **Stores Services Level** **Work Process Productivity** • **Maintenance costs divided by net asset value**

4.5 PREVENTIVE MAINTENANCE RATIOS

Many plants measure maintenance effectiveness by calculating the percentage of preventive and predictive activities to the total amount of maintenance activities. World-class plants have a preventive and predictive maintenance (PPM) ratio of 80 to 85 percent.

In some instances, preventive and predictive tasks are divided into separate classifications. While this provides better detail, either method is effective when used properly.

The PPM ratio assumes that all preventive and predictive maintenance tasks are valid and provide measurable benefits. Historically, this is not true. In a typical plant, 33 to 42 percent of preventive tasks do not meet this criterion. This is especially true of lubrication, inspections, calibrations and adjustments, which comprise the majority of preventive maintenance tasks.

Making the PPM ratio a valid measurement requires eliminating unnecessary tasks, verifying task frequencies and providing sufficient detail and enforcement to ensure universal application and adherence to best practices.

This method also ranks tasks or activities equally in terms of effectiveness. Preventive and predictive tasks should be weighted to account for the criticality of equipment and reliability issues. This will ensure that critical tasks are preformed in a complete and timely manner.

4.6 PLANNING RATIO

The planning ratio is the number of planned activities as a percentage of total work activities. Many plants have adopted it to quantify and track maintenance effectiveness. However, defining the term "planned" can be problematic.

To be effective, this criterion should define activities as planned tasks only if they are "fully" planned. By that I mean that tasks are well defined, work proceeds in a logical sequence, materials, tools and permits are available, and proper labor hours and skills are allocated.

The three primary reasons for unplanned maintenance tasks are:

- Emergency or breakdown work.
- Call-outs or add-on work.
- Planner fails to plan a task.

Emergencies and breakdowns are a frequent cause of unplanned work. However, with an effective preventive and predictive maintenance program and management's support, they can be controlled, and will become less of a factor as maintenance effectiveness improves.

Call-outs during normal production hours and add-ons during maintenance outages also contribute to unplanned maintenance work. The planning function has no control over these activities. Including them into the planning ratio may lead to incorrect conclusions.

The third cause is within the control of the planning function and is a valid measure of planning effectiveness.

However, one way to resolve these issues is to track each as a sub-set of the planning ratio.

4.7 MAINTENANCE BUDGET RATIO

This is the maintenance budget as a percentage of the facility replacement or insured asset value. It implies that maintenance budgets will be based on the facility's replacement or

insured asset value. In world-class plants, the maintenance budget is based on the preventive and predictive maintenance tasks required to maintain plant production systems properly. Proper tasks and intervals obtain optimum life cycle cost without sacrificing reliability.

Many plants track maintenance costs as a percentage of replacement or asset value. However, it's difficult to determine the real replacement or asset value is for a particular plant. When attempting to compare multiple plants, it's imperative to standardize calculation methods.

The cost of world-case maintenance is between 1.5 and 2.0 percent of replacement value. This benchmark budget includes all maintenance costs (direct labor, material, overhead, fringe benefits, clerical and supervisory personnel, etc.). This range is based on the average labor and material costs required to perform preventive/predictive maintenance tasks properly. It includes allowances for periodic rebuilds and equipment replacement.

4.8 MAINTENANCE INVENTORY VALUE

This is the total inventory value as a percentage of the facility's replacement or insured asset value. Most world-class plants include this, or a similar KPI, as part of their materials management evaluation and tracking program. The difficulty with this KPI is a universal definition of replacement value.

Issues that affect the validity of this performance indicator include unofficial inventories, in-process repairs, vendor-stocked inventories and other hidden storerooms which may represent millions of dollars, but don't exist "officially."

Effective maintenance organization make it an objective to minimize the number of MRO items and the quantities held in inventory. It's not uncommon for stockrooms to house significant quantities of obsolete and damaged materials. In many cases, inventories can be reduced by 30 to 50 percent without degrading plant reliability.

These are only a few of the KPIs used to quantify maintenance effectiveness. When used properly, they provide an accurate indication of performance. When used improperly, they can hide serious deficiencies. The former is a necessary requirement of continuous improvement. The latter is a sure way to assure that nothing will ever change

4.9 RELIABILITY CENTERED MAINTENANCE (RCM)

Maintenance program design, implementation and continued optimization is the cornerstone of plant performance. Success in this area can be measured by total maintenance cost and overall equipment availability and performance. RCM is a method used for optimising maintenance strategies through reduction of maintenance cost and improving plant availability. The strategies are based on a systematic evaluation of failure modes and production loss and asset cost. By combining RCM with risk analysis, our RCM process can be focused around safety- and environmental critical systems.

With RCM, maintenance is scheduled based on actual equipment reliability and performance data rather than arbitrarily established time-based intervals. In addition, RCM seeks to prioritize equipment based on failure consequences and incorporate condition-based and predictive along with run-to-failure data.

Application to AGL

The RCM Program is an extension to the Failure Modes, Effects and Criticality Analysis (FMECA) and Fault Tree Analysis (FTA) which are used to identify the potential failures in the system. The entire program would be divided into 4 stages.

a. Stage 1 - Scope Definition

   This early phase of the project is seen as crucial in order for all parties to come to a solid base of understanding covering all aspects of the program. It will be necessary to review and assimilate all available technical and operational information. The working team will need access to all

available technical documentation and will also schedule meetings with all key stakeholders. It is expected that this will include representatives from the vendors, the maintenance contractors, the airport management, technical and operations staff plus other users of the system.

A tailored RCM decision logic and terminology will be well defined for the analysis by the end of this stage. The RCM maintenance planning framework and scope will also be developed. Since RCM analysis software package will be required for the analysis during and also after the implementation of the program, the existing maintenance management system 'EMPAC' will be reviewed with respect to its capabilities against the RCM software.

b. Stage II - Maintenance Task Definition

This is seen as a key phase since, by the end of which, the complete AGLS will have been subjected to RCM analysis and the required maintenance tasks, inspections and tests will have been defined in detail. In this stage, the RCM candidates will be sorted and they will be subjected to full RCM analysis, as tailored during Stage I. The preventive maintenance and condition monitoring tasks will also be identified by the end of the analysis. It is important to recognize the resources required to perform each task, which includes cost, labour, equipment, spare parts etc. They will be well defined in this stage of work. The maintenance plan will be drafted, which includes the tasks required for each types of equipment being analyzed but excluding the schedules. The complete analysis will be based on the information on the equipment from the previous FMECA and the data will be transferred to the RCM software. In parallel with the analysis, training sessions will be held to train the frontline staff in the RCM analysis technique.

c. Stage III - Maintenance Scheduling

The phase 3 of the project will integrate preventive maintenance work practices and condition monitoring inspections/tests with the operational requirements and constraints of the HKIA. It will be necessary to conduct work sessions with technical and operational staff and airport management. The objective will be to identify suitable maintenance windows, when the scheduled tasks may be performed without impact on the operational safety or availability of the airport.

During this stage, very close co-operation with the operational staff of the Civil Aviation Department will be maintained to ensure that the maintenance windows are accurately identified and exploited. The frontline staff will be involved to assist with the estimates of the duration of the tasks that have to be performed during these maintenance windows. The approach will be to use shorter rather than longer intervals to accomplish this, as longer interval will have detrimental effects on safety, availability and costs. The frontline staff will also participate in the determination and possible changes in the resources required for the tasks.

By the end of this stage, a list of maintenance windows, describing the time of day, week, month and year, as well as the duration (available time) of each will be well defined. The appropriate maintenance tasks and inspections allocated to each window will also be identified. A complete maintenance plan will be compiled and ready for implementation.

d. Stage IV - Maintenance Plan Implementation

The focus of this activity will be on implementing the process of efficient maintenance scheduling, covering as many of the maintenance tasks. For each repair and maintenance tasks analyzed, the type of equipment best suited for the repair, maintenance and inspections tasks will be identified. This is a preparatory work for a more rigorous and ongoing Condition Based Maintenance System. The process of detailing procedures for repair/maintenance tasks and inspection and test result sheets will be commenced. Training will be

developed and conducted on new tasks and tests. The scheduled tasks and inspections/ tests will be incorporated into the Maintenance Management System as tailored in Stage I of the program.

4.10 SUPPLY CHAIN OPTIMIZATION

We apply the supply chain strategy in maintenance contract management to maximize the added value of the suppliers. We re-package the maintenance works to best meet the market supplier capability with an aim to increase the competition and reduce the dependency to one maintenance contractor.

We continue to develop the knowledge based of our in-house maintenance team; therefore, we arrive at a position to be technically independent of external contractors. Our in-house maintenance team now is in full control of all critical airport systems.

5. CONCLUSION

Three airport special systems- Automated People Mover (APM), Baggage Handling System (BHS) and Airfield Ground Lighting (AGL) have been discussed in this paper. Such excellent systems and efficient operations are vital at the airport but they are not enough. To make Hong Kong International Airport the best in the world, we have to continue improve and maintain these facilities to ensure the safe and reliable operation of the Airport. With the introduction of the Reliability Centered Maintenance program, the maintenance cost is reduced and the reliability of the whole system is improved.

REFERENCES

1. Moubray J M (1988). "Developments in Reliability-centered Maintenance". The Factory Efficiency & Maintenance Show and Conference, NEC, Birmingham, UK; 27 - 30 September 1988.
2. Moubray J M (1988). "Maintenance Management - The Third Generation". The 9th European Maintenance Congress, Helsinki, Finland; 24 - 27 May 1988
3. Asia Pacific Airport Consultant (2001). "A Strategic Overview of Major Airport Development, Contract 173 - The SOMAD Study"

Paper No. 5

RENEWABLE ENERGY DEVELOPMENT IN HONG KONG

Speakers : Ir Dr K.M. Leung, Chief Engineer
Ir Dr Y.F. Kwok, Building Services Engineer
Energy Efficiency Office
Electrical & Mechanical Services Department
The Government of the HKSAR

RENEWABLE ENERGY DEVELOPMENT IN HONG KONG

Ir Dr K.M. Leung, Chief Engineer
Ir Dr Y.F. Kwok, Building Services Engineer
Energy Efficiency Office
Electrical & Mechanical Services Department
The Government of the HKSAR

ABSTRACT

Hong Kong does not have any indigenous energy resources. As a net energy importer, Hong Kong is potentially susceptible to fluctuation in the oil and gas prices or any stoppage in energy supply line.

To improve the sustainability of our energy sector, the Electrical and Mechanical Services Department commissioned a two-stage consultancy study in November 2000 to investigate the feasibility of wide-scale application of renewable energy (RE) technologies in Hong Kong. The study evaluated the potential of various forms of RE technologies for wide-scale local use, and related legal, institutional and promotional issues. It also made recommendations for formulating an implementation strategy.

Upon reviewing current technological trends and applications, and taking into account Hong Kong's local characteristics, RE technologies that are considered potentially feasible for wide-scale application in Hong Kong include:-

a. Solar power;
b. Wind power; and
c. Energy from waste.

Public consultation on the findings and recommendations made in the study was also conducted from February till April 2003, and the results indicated that the public are more receptive to RE than the Government has envisaged.

In addition, among other RE projects, this paper also briefly describes a design and build project involving the installation of a 55kW building integrated photovoltaic system in the Wanchai Tower. This was the largest RE pilot project in Hong Kong by the time it was built. It covers a total area of 500 m^2 PV panels.

1. INTRODUCTION

Hong Kong has no indigenous energy resources. Being a net energy importer, Hong Kong is potentially susceptible to changes in the global energy market. Against this background, our energy strategy is to serve reliable and safe energy supplies at reasonable prices to sustain our economic and social development.

Paper No. 5

As Hong Kong does not have any fossil fuel reserves, all our primary energy needs are met by imports from the Mainland, Singapore and other overseas countries. Despite the increase in energy efficiency by 15% over the past decade, the local energy consumption over the same period has registered an increase of 22% as a result of the continuous growth in population and the economy.

The burning of fossil fuels gives rise to greenhouse gas emissions and air pollution. The most significant greenhouse gas is carbon dioxide. The carbon dioxide emission [1] from electricity generation in Hong Kong for the year 2000 was around 20 million tonnes. If the growth in energy consumption continues, the emission of carbon dioxide for the year 2010 will be over 27 million tonnes, an increase of 35% over the 2000 level.

Introducing more RE sources may help contain fossil fuel use, thereby reducing purchase of fuels and greenhouse gas emissions.

2. RE PROJECTS IN HONG KONG TODAY

2.1 BIPV INSTALLATION AT WANCHAI TOWER

A 55 kW Building Integrated Photovoltaic (BIPV) system was commissioned through a design and build contract at Wanchai Tower, which is a high-rise government office building located in a busy commercial area. The installation works commenced in late April 2002 and was completed in end 2002. The performance of the BIPV system is now under close monitoring by EMSD until mid 2004.

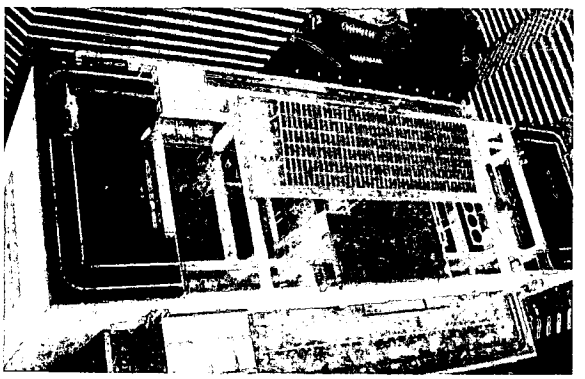
There are 3 types of PV sub-systems installed at Wanchai Tower, which cover a total area of 500 m^2 with a peak power output of 55 kW and they are:

a. rack type on the roof top,
b. sunshade type from 1st to 12th floors, and
c. skylight type at the front entrance hall.

2.1.1 RACK TYPE

The "Rack" type sub-system is installed on the rooftop of the building (Figure 1). Over 160 m^2 of poly-crystalline silicon PV panels with a peak power of 20 kW are installed. The PV panels are tilted optimally at 10° to the horizontal plane after considering the shading effect due to adjacent buildings. Each PV panel is rated at 80 W (peak) with an open circuit voltage of 21.5 V and a short circuit current of 5.3 A. A computer software called "Array Shading Evaluation Tool" together with the fisheye photographic technique are used for the shading analysis.

Figure 1 Rack Sub-system



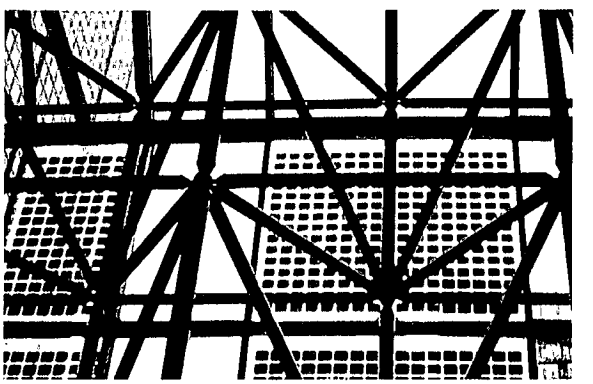
2.1.2 SUNSHADE TYPE

Figure 2 Sunshade Sub-system - Interior View

The second sub-system is called the "Sunshade Screen" sub-system comprising double-glazed panels completed with integrated mono-crystalline PV cells. Each panel is rated at 76.8 W (peak) and with an open circuit voltage and short circuit current of 19.8 V & 5.46 A respectively. They are externally mounted on the building facade to provide shading for the upper portion of all south-facing windows from 1st to 12th floors of the building (Figure 2). The total area of installed panels is about 230 m^2 and the installed peak power is 25 kW. By using the sunshade type PV panels, the solar heat gain into the building through the windows is effectively reduced.

2.1.3 SKYLIGHT TYPE

Figure 3 Skylight Sub-system - Interior View

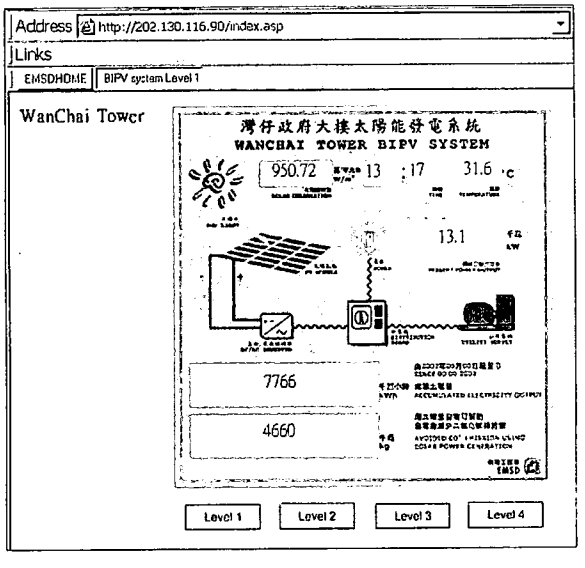


The third sub-system is the "Skylight" sub-system comprising PV panels similar to that of the Sunshade type but are much larger. The

panels are used to replace some of the vertically mounted glass-infill of the existing glass atrium at the southbound front entrance hall. About 100 m^2 of PV panels, each rated at 288 W (peak) with an open circuit voltage and short circuit current of 74.4 V & 5.46 A, are installed with a peak power slightly over 10 kW (Figure 3).

2.1.4 MONITORING SYSTEM

Figure 4 BIPV Website for Public



There is a one-year monitoring and evaluation period to assess the performance and reliability of this BIPV pilot project. A sophisticated and on-line computerized monitoring system has been installed in order to closely monitor the performance of the BIPV. Key monitoring parameters include solar radiation, wind speed, PV panel temperature, power output, cumulative energy output, power quality etc.

In addition, an information display panel has been installed at the building main entrance to disclose real time operational data to the general public. The data include solar irradiance, power output, cumulative energy generated and CO_2 avoided by the BIPV system. The information, which is also accessible through Internet (Figure 4) at the Internet Protocol address of "202.130.116.90", will help the general public understand the concept of PV technology.

2.1.5 DESIGN PERFORMANCE

The design performance of the BIPV system was calculated basing on the solar irradiance recorded at King's Park in 1999 by the Hong Kong Observatory. The expected annual energy yield for the whole system is around 30,000 kWh.

2.2 OTHER SOLAR PROJECTS IN HONG KONG

Besides the BIPV at the Wanchai Tower, there are various photovoltaic (PV) systems already installed in Hong Kong. One of the most well-known projects is the Science Park PV project (Figure 5) currently under construction, the Phase I system includes 138 kW photovoltaic panels. Whilst, the Phase II PV system will have an additional generation capacity of about 60 kW.

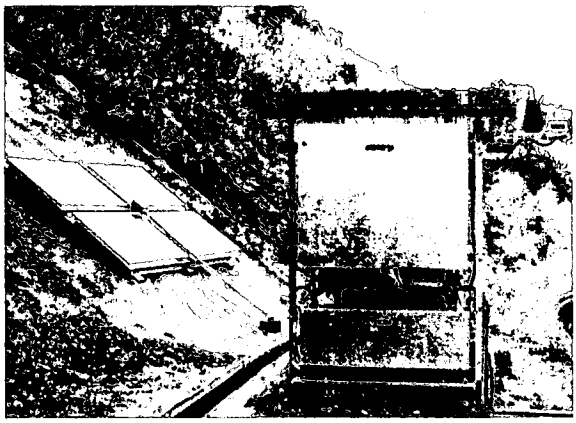
Figure 5 BIPV of Science Park

Another innovative PV project worth mentioning is an automatic slope irrigation system (Figure 6) built at Kat Shut Wan Government Explosives Depot. The integrated system, which comprises an array of photovoltaic modules, a charger, an inverter and backup battery, and an irrigation system with pumps, water storage tank, piping and sprinklers, automatically abstracts water from a nearby stream course sump pit and irrigates vegetation on a man-made slope at the Depot. This system was commissioned in July 2003.

At the moment, the total electricity generation capacity of all installed PV systems in Hong Kong is around 247 kW, whilst that for solar

water heating systems is about 586 kW.

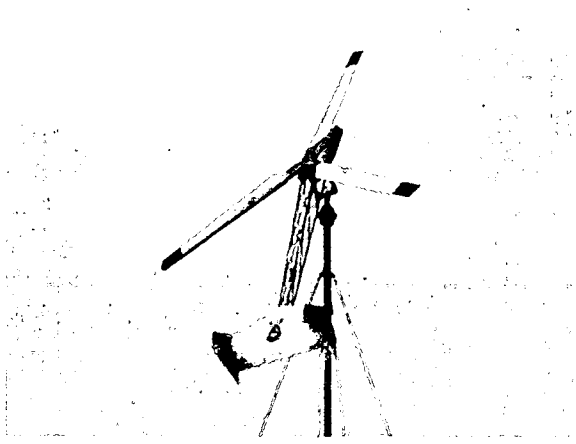
Figure 6 Automatic Slope Irrigation System



2.3 WIND TURBINE PROJECTS

Wind turbines installed in Hong Kong so far are mainly for experimental or research purpose. Currently, the largest wind turbine is a single 2.5kW machine (Figure 7) installed at Shek Kwu Chau Drug Rehabilitation Centre by CLP Research Institute. The turbine operates in parallel with a 3.3kW PV installation forming a non-grid connected hybrid RE system.

Figure 7 Wind Turbine at Shek Kwu Chau



There are also some small wind turbines installed by the Hong Kong Observatory for weather monitoring stations at remote areas. They are mostly hybrid systems integrated with photovoltaic and are not connected up to the grid. These turbines are rated between 140 W to 500 W.

3. CONSULTANCY STUDY

In view of the worldwide growing demand for cleaner energy and reduction of greenhouse gas emissions from power plants, a consultancy study was commissioned by EMSD to investigate the viability of using RE technologies in Hong Kong and to make recommendations for formulation of an implementation strategy. The study commenced in November 2000 for completion in 2004.

The study evaluated the potential of various forms of renewable energy for wide-scale local use, and the related legal, institutional and promotional issues. The Study Report [2] was published in February 2003.

Upon reviewing the current technological trends and applications, and taking into account Hong Kong's local characteristics, RE that are considered potentially feasible for wide-scale application in Hong Kong include:

a. solar power,

b. wind power, and

c. energy from waste

Whilst, other resources of RE including biomass energy, geothermal energy, hydro power and tidal and wave power have limited potential for development in Hong Kong.

3.1 SOLAR ENERGY POTENTIAL IN HK

Solar energy resource in Hong Kong is regarded mildly rich. Hong Kong has an "annual average global horizontal solar irradiance" of 1,290 kWh/m^2. If all 1,098 km^2 land areas of Hong Kong are covered up with photovoltaic (PV) collectors, about 133 TWh of electricity (approximately 4 times the total electricity consumption in Hong Kong in 2002) will be generated annually.

According to the consultancy study [2], PV systems are mainly divided into 2 categories:

a. building integrated photovoltaic (BIPV) system,

b. non-BIPV system.

The BIPV type is usually mounted on the rooftop, facade and external walls of a building, while the non-BIPV type is built along highway noise barrier, slopes and so on.

The consultancy study revealed that the potential of solar energy in Hong Kong is 5,944 GWh/year which is equivalent to around 16% of the 2002 electricity consumption in Hong Kong. This was derived by assuming that all feasible land areas for solar energy application were covered up by both BIPV and non-BIPV systems. The overall conversion efficiency of PV system was conservatively assumed as 9.3%. The shares of energy potential for BIPV and non-BIPV are 5,383 and 561 GWh/year respectively.

In the study, solar heating has also been reviewed and is considered suitable for site-specific applications, such as hotels, hospitals, etc., and its potential in Hong Kong is regarded insignificant.

3.2 WIND ENERGY POTENTIAL IN HONG KONG

Wind farms can be classified principally into land based wind farms and marine based wind farms. Large-scale wind turbines are usually rated over 1 MW with a "hub height" of 50 to 70 m and the total height (including the blade) of over 100 m. Marine-based wind farms can be either near-shore or offshore.

The wind energy potentials in Hong Kong are estimated at 2,630 GWh/year for land-based rural wind farms, 3,000 GWh/year for small urban wind turbines and 8,058 GWh/year for near-shore wind farms.

3.3 POSSIBLE LOCATIONS OF WIND FARMS

Hong Kong does not have any sizeable wind turbines installed yet, mainly because of the social, visual impacts and financial considerations.

Also, high wind resource areas in Hong Kong are mainly located at mountain tops on the eastern side of Hong Kong and most of the offshore marine areas. However, most of these mountain top areas are within country parks, which may not be suitable for building wind farms.

More promising locations for wind farms appear to be outlying islands and off-shore marine areas, even though electricity generation and transmission costs are higher.

3.4 GENERATION COSTS

"Levelised Cost of Electricity" (LCE) is a term commonly used to compare the cost of alternative power generation systems. LCE adopts a life-cycle costing approach and uses net present value calculations (for the capital cost and operation and maintenance costs) as a means of comparing the average unit cost of electricity generated. The study revealed that LCE for PV power is between HK$2.2 to HK$4.1 per kWh, whilst that for rural wind farm is between HK$0.20 to HK$0.35 per kWh. The LCE for conventional fossil fuel power generation is between HK$0.2 to HK$0.4.

3.5 SUMMARY OF BARRIERS TO RE DEVELOPMENT

Major issues that may hinder wide-scale development of RE in Hong Kong include :

(a) Availability of suitable sites for large-scale RE projects;
(b) Concerns over the visual and noise impact of RE systems (for example wind turbines);
(c) Relatively higher cost of RE; and
(d) Access to the existing electricity grids by third party RE producers.

3.6 PROPOSED RE TARGETS

After seriously considering all the constraints

including Hong Kong's geographical limitations, legislation and institutional restrictions, commercial viability and social acceptability, the RE targets for Hong Kong were initially proposed as 1% in 2012, 2% in 2017 and 3% in 2022, taking 1999 as the base year.

3.7 PUBLIC CONSULTATION

Subsequent to releasing the Study Report to the public, a two-month public consultation exercise was then conducted from 7 February to 6 April 2003 during which members of the public and relevant stakeholders were invited to offer their views on the study.

28 submissions were received from all walks of life including the following groups:

(a) Green Groups and Non-governmental Organisations;
(b) Professional Institutions and Trade Organisations;
(c) Political Parties;
(d) Power Utilities;
(e) Business Interests;
(f) Consulting Companies; and
(g) Individuals.

Public support is the most critical factor for the successful development of RE. According to the views collected [3], most respondents considered the targets recommended conservative. This may indicate that the public are more receptive to RE than the consultant has envisaged. In this context, the proposed RE targets are currently under review to meet the latest aspiration of the public subsequent to the public consultation exercise.

4. WIND MEASUREMENT

Following a site survey and environmental impact assessment study, two outlying island sites, one on Po Toi and the other on Lamma, had been chosen for wind power monitoring and measurement stations by a power company. The data collection for a period of 12 months has been completed. The collected data, including wind speed and directions, will be used to build up a wind atlas for assessment of wind energy potential in the southern part of Hong Kong.

In addition, the Government also intends to perform a wind monitoring and measurement programme. By installing wind monitoring equipment at potential sites for measuring their site specific wind characteristics, more accurate assessment of the electricity output can be provided for paving future wind farm development on these sites. The measurement will last for 12 months to obtain the year-round characteristics.

Outlying islands, country park areas and buildings are sites under consideration and the potential sites identified for the programme are at eastern Hong Kong. Land sites and potential outlying islands include:

(a) Town Island;
(b) Tin Ha Shan;
(c) Pottinger Peak;
(d) Tit Cham Chau
(e) Tai Leng Tung; and
(f) Government Logistics Centre.
(g) Po Toi Cluster (Po Toi, Beaufort and Sung Kong);
(h) Tung Lung Cluster (Tung Lung Chau); and
(i) Kau Sai Cluster (Kau Sai Chau, Jin Island, Bluff Island and Basalt Island)

Figure 8 Locations of Potential Land Sites

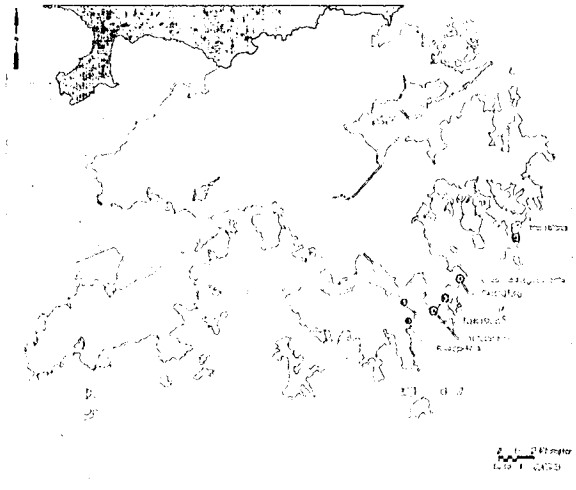
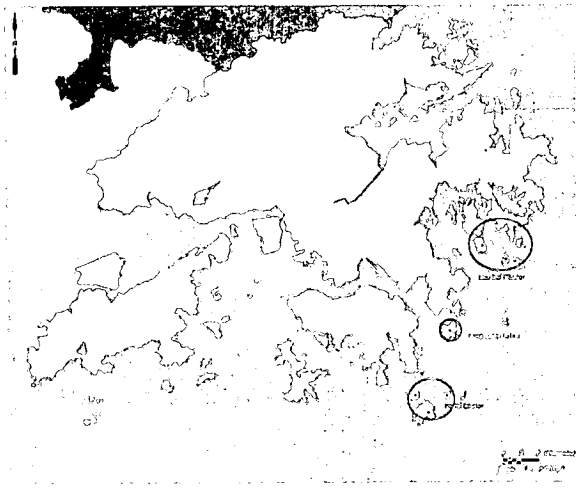


Figure 9 Locations of Potential Outlying Islands



Figures 8 and 9 are maps showing the locations of all these potential land sites and outlying islands.

5. CONCLUSION

The public consultation exercise on the findings and recommendations of the Stage 1 Study on potential applications of renewable energy in Hong Kong has recently been concluded. We note that most respondents considered the targets recommended by our consultant conservative (i.e. 1% in 2012, 2% in 2017 and 3% in 2022). Therefore, we will review the RE targets proposed by the consultant with a view to meeting the latest aspiration of the community.

In parallel, EMSD has installed Building Integrated Photovoltaic Panels at Wanchai Tower as a pilot project to measure its performance under local weather conditions. The data will be useful for us to accurately assess the potential of solar energy technology in Hong Kong.

With the BIPV system installed at Wanchai Tower, about 18 tonnes of greenhouse gas (CO_2), 30 kg of NO_x and 45 kg of SO_2 pollutant emissions can be eliminated annually.

REFERENCE

1. Greenhouse Gas Emission Control Study, EPD, HKSAR, 2001.
2. The Stage I study report on the potential applications of renewable energy in Hong Kong. EMSD, Nov 2002.

   "http://www.emsd.gov.hk/emsd/e_download/wnew/stage1_report.pdf"
3. Public Consultation on Stage I Study Findings - Summary of Comments Received, EMSD, May 2003.
   "http://www.emsd.gov.hk/emsd/e_download/wnew/RE_PC_Report_Eng.pdf"

Paper No. 6

APPLICATION OF NANOTECHNOLOGY IN ELECTRO-MECHANICAL INTERFACE

Speakers: Prof. P. Sheng, Professor and Head of Department
Dr Weijia Wen, Assistant Professor
Department of Physics and Institute of Nano Science and Technology
Hong Kong University of Science and Technology

APPLICATION OF NANOTECHNOLOGY IN ELECTRO-MECHANICAL INTERFACE

Prof. P. Sheng, Professor and Head of Department
Dr Weijia Wen, Assistant Professor
Department of Physics and Institute of Nano Science and Technology
Hong Kong University of Science and Technology

ABSTRACT

Electrorheology (ER) denotes the control of material's flow properties (rheology) through electric field. For certain ER fluids the application of a strong field (>1000V/mm) can lead to an anisotropic solid, with a yield stress characterizing its strength. We have fabricated nanoparticles colloidal systems, consisting of coated nanoparticles ~50-70 nm in diameter suspended in silicone oil, that exhibit electrically controllable liquid-solid transitions in which the solid state can reach a yield strength of 130 kPa, an order of magnitude larger than that achievable by conventional electrorheological (ER) fluids. The giant electrorheological (GER) effect breaks the theoretical upper bound on ER static yield stress that is based on the general assumption of linear dielectric response of the component materials, and displays near-linear variation of the static yield stress versus the electric field, in contrast to the quadratic variation usually observed. Our GER colloids display low current density over a wide temperature range of 10-120°C. As the change of the rheological properties is usually accomplished under 10 ms and reversible, the GER colloids can function as an interface which translates electrical signals into mechanical signals, opening the possibility of actively controllable clutches, dampers, valves, locks, etc. Finite element numerical simulations, based on the model of saturation surface polarization in the elastic contact regions of neighboring particles, yield predictions in excellent agreement with the experiment.

* Work done in collaboration with Weijia Wen, Xianxiang Huang, and Shihe Yang

1. INTRODUCTION

In this paper, an unconventional topic is introduced for the electrical engineering community – the material effect which can serve as the interface between electrical and mechanical signals – and the role of nanoscience and nanotechnology which makes it practical.

In today's world, there are two very large technology universes – the electrical universe and the mechanical universe. Interfaces between the two are generally in the form of switches that can turn on and off the electrical power to the mechanical systems. That is a rather crude and rudimentary type of interface. Imagine a material whose mechanical property can be "instantaneously" changed, reversibly, through electrical means. Such a material effect would go to the heart of the electrical-mechanical interface, and can open up countless potential applications.

Paper No. 6

Electrorheology (ER) denotes the control of material's mechanical / flow properties (rheology) through electric field [1-10]. It is an effect that has been known for sixty years. An ER fluid generally consists of fine solid particles suspended in some insulating fluid, e.g. silicone oil. Application of an electrical field to the ER suspension can increase the viscosity of the fluid. For certain ER fluids the application of a strong field (>1000V/mm) can lead to an anisotropic solid, with a yield stress characterizing its strength. The ER effect remained a scientific curiosity until the late 1980's and early 1990's, when almost every major automotive company had a group working on the ER fluids, in anticipation of their widespread penetration into all forms of mechanical devices, in the role of an interface to electrical signals so that the devices could be made actively controllable. As shown by the

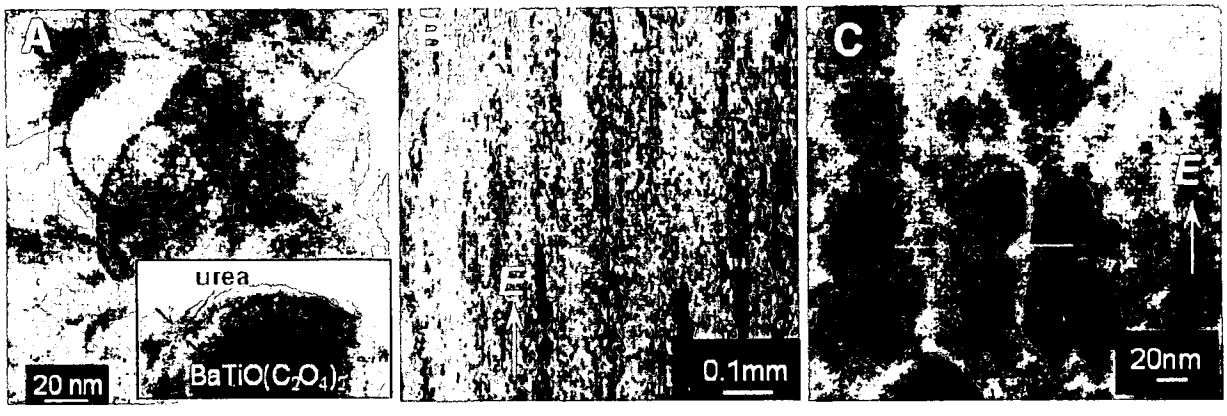
numerous popular articles on the subject at the time [11-13], underlying the high expectations was a firm belief that the most important characteristic of the ER fluids – yield stress – will improve with time so that 25-50 kPa can be realized in the near future. However, with the passage of time this expectation failed to materialize. After many years of development the commercially available ER fluids have a yield stress mostly on the order of 5-10 kPa (hard tofu, or beancurd). As a result, the fervor that existed in the ER field cooled down considerably in recent years.

We have fabricated suspensions of nanoparticles, consisting of coated nanoparticles ~50-70 nm in diameter dispersed in silicone oil, that exhibit electrically controllable liquid-solid transitions in which the solid state can reach a yield strength of 130 kPa, an order of magnitude larger than that achievable by conventional electrorheological (ER) fluids. The giant electrorheological (GER) effect [14] breaks the theoretical upper bound on ER static yield stress that is derived on the general assumption of linear dielectric response of the component materials [15], and displays near-linear variation of the static yield stress versus the electric field, in contrast to the quadratic variation usually observed [9,10, 16-19]. Except close to the breakdown at ~5500V/mm, our GER colloids display low current density over a wide temperature range of 10-120°C. As the change of the rheological properties is usually accomplished under 10 ms and reversible, the GER colloids can potentially function as an interface which translates electrical signals into mechanical signals, opening the possibility of actively controllable clutches, dampers, valves, locks, etc [20]. By coupling a sensor to such actively controllable mechanical devices, one obtains "smart" mechanical gadgets which can respond quickly to environmental variations.

The reason that one has to appeal to nanoscience in order to greatly enhance the ER effect can be understood qualitatively as follows.

Comparing the gravitational attraction between two electrons with their electrical interaction, we can immediately deduce that the electrical force is 10^{42} times stronger than the gravitational force. But in our everyday life the reverse seems to be the case: We feel only our weight due to gravitation, but can hardly feel any strong electrical forces. The reason is, of course, that the positive and negative charges in our universe are finely balanced and their electrical forces nearly cancelled. Fortunately, the cancellation is not complete due to quantum mechanics and entropy. What this incomplete cancellation means is that the electrical forces are extremely weak at distances larger than the atomic / molecular dimensions, i.e., nanometers, but can be very strong at the nanoscale. Hence to harness the large electrical forces, we fabricate nanoparticles and enclose them with another coating material, such as urea. Such particles (suspended in silicone oil) and their behavior under an electric field are shown in Figs. 1(A)-1(C). The existence of nanoscale interfaces can modify the material characteristic of the coating, so that the molecular dipoles are utilized in the resulting GER effect. Finite element numerical simulations, based on the model of saturation surface polarization in the elastic contact regions of neighboring coated particles, yield predictions in excellent agreement with the experiment [14]. This is shown in Fig. 2. The conduction current density in polar ER fluids, shown in the inset to Fig. 2, is attributed to the thermal generation of charge carriers when ions, possibly originating from the molecular dipoles, are activated over the Coulomb barrier from the counter ions. A signature of such activation is the lowering of the Coulomb barrier as $\sqrt{E}$ [21,22]. In inset to Fig. 2 we show that $\lambda n J \propto \sqrt{E}$, confirming this physical picture.

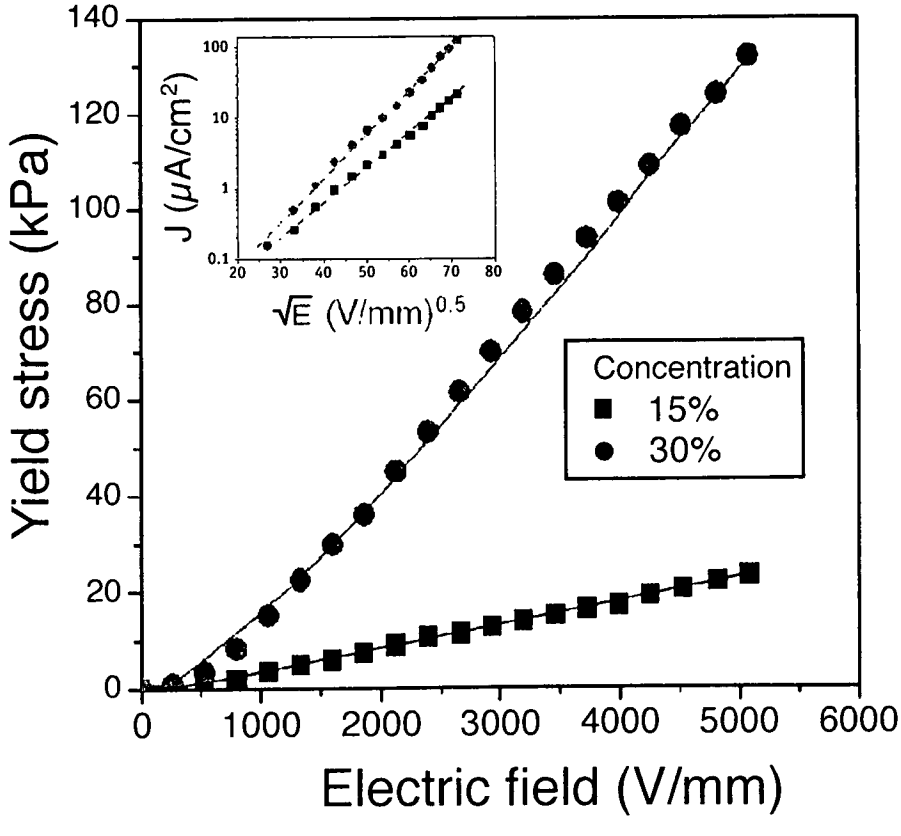
Figure 1 Images of Nanoparticles in GER Suspensions



Images of nanoparticles in GER suspensions. (A) TEM image of coated nanoparticles. Urea coatings are clearly seen. (B) Optical microscope image of a sample prepared in epoxy, solidified under an applied field of 2000 V/mm. Aligned columns along the field direction are visible. These columns are responsible for the solid-like yield stress (the breaking stress under shear) of the GER suspensions. (C) TEM image of a section of the column shown in (B). The arrows indicate one of the flattened interfaces. The aligned dipolar layers at the interfaces account for the GER effect.

Paper No. 6

Figure 2 Static Yield Stress Variation



Static yield stress variation plotted as a function of applied electric field for two solid concentrations. Symbols denote experiment; solid lines are theory. Inset: logarithm of the current density J plotted as a function of $\sqrt{E}$. The dashed straight lines serve to delineate the $\lambda nJ \propto \sqrt{E}$ relationship, indicating the mechanism of activation over the Coulomb barrier.

REFERENCES

1. Whittle, M. & Bullough, W. A., The structure of smart fluids, *Nature* **358**, 373-373 (1992).
2. Halsey, T. C., Electrorheological fluids, *Science* **258**, 761-766 (1992).
3. Clercx, H. & Bossis, G., Many-body electrostatic interaction in electrorheological fluids, *Phys. Rev. E* **48**, 2721-2738 (1993).
4. Tao, R. & Sun, J. M., 3-dimensional structure of induced electrorheological solid, *Phys. Rev. Lett.* **67**, 398-401 (1991).
5. Gamota, D. R. & Filisko, F. E., Linear and nonlinear mechanical-properties of electrorheological materials, *Int. J. Mod Phys B* **6**, 2595-2607 (1992).
6. Chen, Y., Sprecher, A. F. & Conrad, H., Electrostatic particle-particle interaction in electrorheological fluids, *J. Appl. Phys.* **70**, 6796-6803 (1991).
7. Davis, L. C., Ground-state of an electrorheological fluid, *Phys. Rev. A*, **46**, R719-721 (1992).
8. Martin, J. E., Odinek, J., Halsey, T. C. & Kamien, R., Structure and dynamics of electrorheological fluids, *Phys. Rev. E* **57**, 756-775 (1998).
9. Anderson, R. A., Effects of finite conductivity in electrorheological fluids, in *Electrorheological Fluids*, edited by Tao, R. (World Scientific, Singapore, 1992), p. 81-90.
10. Davis, L. C., Polarization forces and conductivity effects in electrorheological fluids, *J. Appl. Phys.* **74**, 1334-1340 (1992).
11. Mel Mandell, *High Technology Business*, July-August 1989, p. 20.
12. Hugh Aldersey-Williams, *New Scientist*, 17 March, 1990, p.37.
13. W. A. Bullough, *IEE Review*, October 1992, p. 328.
14. Weijia Wen, Xianxiang Huang, Shihe Yang, Kunquan Lu, Ping Sheng, *Nature Materials*, to appear.
15. Ma, H., Wen, W., Tam, W. Y. & Sheng, P., Dielectric electrorheological fluids: theory and experiment, *Adv. in Phys.* **52**, 343-383 (2003).
16. Garino, T., Adolf, D. & Hance, B., The effects of solvent and particle dielectric constants on the electrorheological properties of water-free ER fluids, in *Electrorheological Fluids*, edited by Tao, R. (World Scientific, Singapore, 1992), p. 167-174.
17. Randall, C. A., McCauley, D. E., Bowen, C. P., Shrout, T. R. & Messing, G. L., High dielectric constant particulate materials for electrorheological fluids, in *Electrorheological Fluids*, edited by Tao, R. & Roy, G. D. (World Scientific, Singapore, 1994), p. 60-66.
18. Liang, R. & Xu, Y, Some new evidence on electro-rheological mechanisms, in *Electrorheological Fluids*, edited by Tao, R. & Roy, G. D. (World Scientific, Singapore, 1994), p. 233-250.
19. Randall, C. A., Bowen, C. P., Shrout, T. R., Messing, G. L. & Newnham, R. E., Dielectrophoretic assembly: a novel concept in advanced composite fabrication, in *Electrorheological Fluids*, edited by Tao, R. & Roy, G. D. (World Scientific, Singapore, 1994), p. 516-525.
20. Examples can be found in *Electrorheological Fluids and Magnetrorheological Suspensions*, Proceedings of the Eighth International Conference, edited by Bossis, G. (World Scientific, Singapore, 2002).
21. Neugebauer, C. A. & Webb, M. B., Electrical conduction mechanism in ultrathin, evaporated metal films, *J. Appl. Phys.* **33**, 74-82 (1962).
22. Hill, R. M., Electrical conduction in ultra thin metal films I. Theoretical, *Proc. Roy. Soc.* **A309**, 377-395 (1969).

Paper No. 7

SEMICONDUCTING NANOWIRES AND DEVICE APPLICATIONS

Speaker : Dr C.S. Lee
Associate Professor
Department of Physics and Materials Science
City University of Hong Kong

SEMICONDUCTING NANOWIRES AND DEVICE APPLICATIONS

Dr C.S. Lee
Associate Professor
Department of Physics and Materials Science
City University of Hong Kong

ABSTRACT

An oxide assisted (OA) method has been developed to synthesize high quality silicon nanowires in bulk quantities [1,2]. It was found that the OA method can be easily extended to synthesize nanowires of other semiconductors including Ge [3], SiC [4,5], ZnO [6,7], ZnS [8,9], GaN [10,11], GaP [12], GaAs [13], etc. The synthesized nanowires were characterized with various techniques including different electron microscopies, vibrational spectroscopies, diffraction techniques etc. In particular, electronic properties and surface atomic structures of silicon nanowires of different diameters were measured with scanning tunneling microscopy [14]. It was found that the crystal structure and atomic arrangement of the silicon crystal are well preserved even when the diameter is as small as one nanometer. On the other hand, electronic properties of the silicon nanowires change tremendously as the diameter decreases. Obvious band gap widening was observed in nanowires with diameter smaller than 7nm. This is the first direct evidence of quantum size effect on band gap of semiconductor nanowires. Potential applications of nanowires as electronic, sensor [15], laser [16], catalytic materials are also discussed.

REFERENCE

1. N. Wang, Tang YH, Zhang YF, Lee CS, Bello I, Lee ST, Si nanowires grown from silicon oxide, Chem. *Phys. Lett.* **299** 237 (1999)
2. S.T. Lee, Y.F. Zhang, N. Wang, Y.H. Tang, I. Bello, C.S. Lee, Y.W. Chung, Semiconductor nanowires from oxides, *J. Mater. Res.* **14** 4503 (1999)
3. Y.F. Zhang, Y.H. Tang, N. Wang, C.S. Lee, I. Bello, S.T. Lee ST, Germanium nanowires sheathed with an oxide layer, *Phys. Rev. B* **61** 4518 (2000)
4. X.T. Zhou, N. Wang, H.L. Lai, H.Y. Peng, I. Bello, N.B. Wong, C.S. Lee, S.T. Lee, beta-SiC nanorods synthesized by hot filament chemical vapor deposition, *Appl. Phys. Lett.* **74** 3942 (1999)
5. H.L. Lai, N.B. Wong, X.T. Zhou, H.Y. Peng, F. C.K. Au, N. Wang, I. Bello, C.S. Lee, S.T. Lee, X.F. Duan, Straight beta-SiC nanorods synthesized by using C-Si-SiO_2, *Appl. Phys. Lett.* **76** 294 (2000)
6. J.Q. Hu, Q. Li, N.B. Wong, C.S. Lee, S.T. Lee, Synthesis of uniform hexagonal prismatic ZnO whiskers, *Chem. Mater.* **14** 1216 (2002)
7. J.Q. Hu, X.L. Ma, Z.Y. Xie, N.B. Wong, C.S. Lee, S.T. Lee, Characterization of zinc oxide crystal whiskers grown by thermal evaporation, *Chem. Phys. Lett.* **344** 97 (2001)
8. Y. Jiang, X.M. Meng, J. Liu, Z.R. Hong, C.S. Lee, S.T. Lee, ZnS nanowires with wurtzite polytype modulated structure, *Adv. Mater.* **15** 1195 (2003)
9. Y. Jiang, X.M. Meng, J. Liu, Z.Y. Xie, C.S. Lee, S.T. Lee, Hydrogen-assisted thermal evaporation synthesis of ZnS nanoribbons on a large scale, *Adv. Mater.* **15** 323 (2003)
10. W.S. Shi , Y.F. Zheng, N. Wang, C.S. Lee, S.T. Lee, Microstructures of gallium nitride nanowires synthesized by oxide-assisted method, *Chem. Phys. Lett.* **345** 377 (2001)
11. H.Y. Peng, X.T. Zhou, N. Wang, Y.F. Zheng, L. S. Liao, W.S. Shi, C.S. Lee, S.T. Lee, Bulk-quantity GaN nanowires synthesized from hot filament chemical vapor deposition, *Chem. Phys. Lett.* **327** 263 (2000)
12. W.S. Shi, Y.F. Zheng, N. Wang, C.S. Lee, S.T. Lee, Synthesis and microstructure of gallium phosphide nanowires, *J. Vac. Sci. & Tech. B* **19** 1115 (2001)

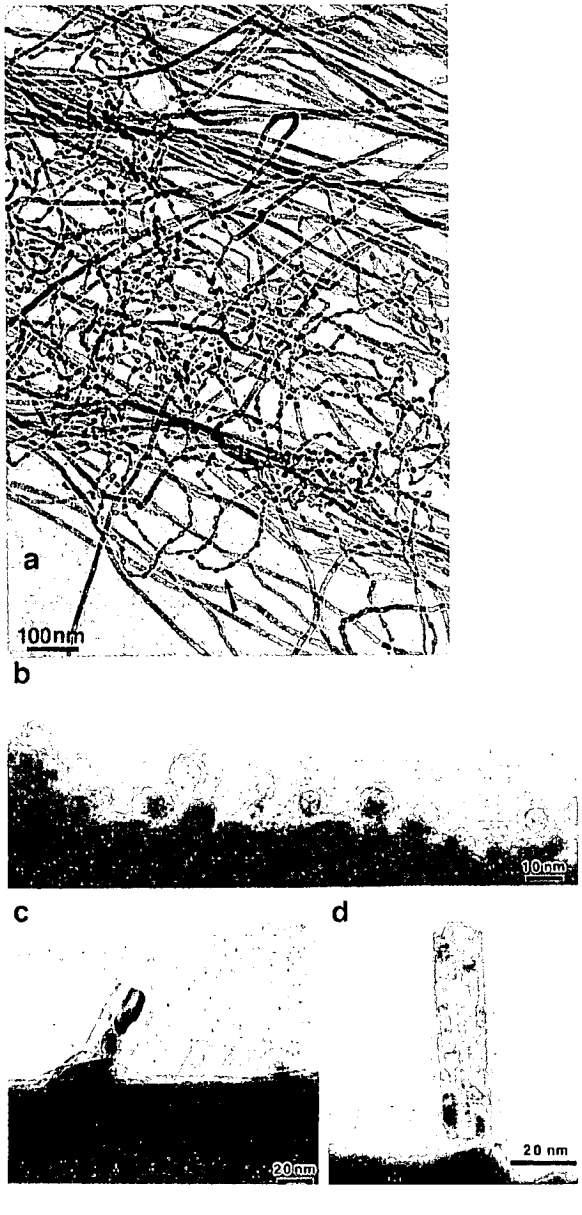
13. W.S. Shi, Y.F. Zheng, N. Wang, C.S. Lee, S.T. Lee, Oxide-assisted growth and optical characterization of gallium-arsenide nanowires, *Appl. Phys. Lett.* **78** 3304 (2001)

14. D.D.D. Ma, C.S. Lee, F.C.K. Au, S.Y. Tong, S.T. Lee, Small-diameter silicon nanowire surfaces, *Science* **299** 1874 (2003)

15. X.T. Xhou, J.Q. Hu, C.P. Li, D.D.D. Ma, C.S. Lee, S.T. Lee, Silicon nanowires as chemical sensors, *Chem. Phys. Lett.* **369** 220 (2003)

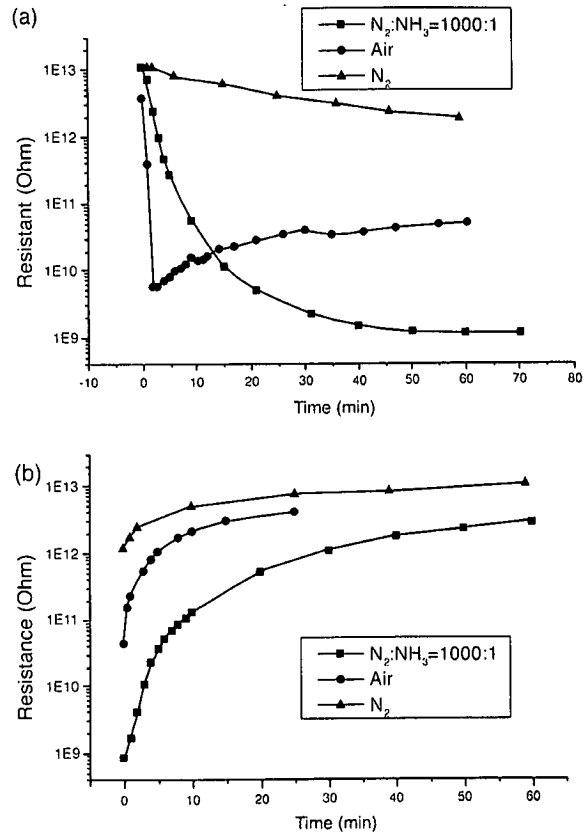
16. C.H. Liu, J.A. Zapien, Y. Yao, X.M. Meng, C.S. Lee, S.S. Fan, Y. Lifshitz, S.T. Lee, High-density, ordered ultraviolet light-emitting ZnO nanowire arrays, *Adv. Mater.* **15** 838 (2003)

Figure 1 Images of Si Nanowires



(a) TEM images showing the morphology of Si nanowires synthesized by the evaporation method. (b)-(d) Nucleation stage of the Si nanowires.

Figure 2 Electrical Responses of Si Nanowire Bundle



Electrical responses of the Si nanowire bundle of to N_2, a mixture of N_2 & NH_3 (NH_3 concentration: 1000 ppm), and air with a relative humidity of 60%; (a) when the gases were introduced into the chamber and (b) when the gases were pumped away.

Paper No. 8

A WEB-BASED MULTI-LINGUAL TEACHING AND LEARNING METHOD FOR ELECTRICAL ENGINEERING

Speaker: Dr Eric K.W. Cheng
Associate Professor
Department of Electrical Engineering
Hong Kong Polytechnic University

A WEB-BASED MULTI-LINGUAL TEACHING AND LEARNING METHOD FOR ELECTRICAL ENGINEERING

Dr Eric K.W. Cheng
Associate Professor
Department of Electrical Engineering
Hong Kong Polytechnic University

ABSTRACT

This paper is to introduce a new method of the teaching that is integrated with web-based software for teaching engineering subjects. The software is not only integrated with html web-based lectures, but also with web-based exercises, translation, oral-form of web-based lecture, web-based seminar, multilingual translation and dictionary. The software is very user-friendly and the users including both the teachers and students are not required to have any previous knowledge in web programming. A large database is implemented inn the software to provide multilingual function. Trial on students has found that the software is very useful for engineering teaching and significant improvement has been found on students.

1. INTRODUCTION

With the rapid development in the internet and the web-based technology, the use of new medium of teaching is now a very popular method to deliver a lecture [1]. The advantages of using Internet to enhance teaching and learning are certain. A good method of teaching and learning not only depends on the Internet, but it is also required to make an effective method to deliver the subject to users. Teaching of engineering subject is more difficult than the non-engineering one because the engineering teaching involves mathematics, computer programming and hardware examples. Therefore a careful design of the web-based software is needed.

A Web-based teaching and learning package is not only to convert the materials into html. It requires a cleverer way to present the materials so that it helps students to understand better. That is why nowadays the problem-based and output-based learning become a fashion to design the teaching materials into a suitable form of web-based teaching [2]. Problem-based learning (PBL) is to give a problem to students and allow them to search for the answer. During the course of working out the answer, students can develop the skill to learn by themselves. Research has found that students can learn better and have shown significant improvement [3]. There are many different methods of PBL that can be used for general teaching, however, in the application of a web-based delivery, the method can be limited and the PBL with web-based exercise has been found to be quite successful [4].

On the other hand, the Asian students receive difficulty in learning engineering especially the language hinders their learning an engineering subjects. Today engineering subjects are mostly developed in the West and therefore many of the explanations and materials are often found in English rather than Chinese. The jargons used in the subjects are also quite different from the conventional English. Therefore a suitable web-based tool is needed to help engineering student in this aspect.

In order for a web-based package to be user-friendly, it is necessary to integrate with a number of tools including the chat-room, news, etc. It should also provide an environment such that professors can program their materials easily without any knowledge of web-programming. Therefore our web-based programming has developed a list of tools and uploading procedures. A teacher can follow a set of the steps and their materials can be programmed into the web-based software easily.

WebCT [5] is a popular multilingual software package for teaching. It has also been adopted by many universities and it also has multifunction features that allow professors and students to use. However, the software is not orientated to Chinese language.

In this paper, each of the tools will be explained and their significant contributions in the teaching and learning are described. By going through the paper, you will then experience the new-method of teaching based on a web-based method. The software has been tried in electrical engineering teaching for a year. Students' improvement after using the software has been observed.

The web-site is named as the eelearning because it is initially used for electrical engineering teaching and it is also using electronic engineering means to deliver the learning method. The URL of the software is: http://eelearning.ee.polyu.edu.hk.

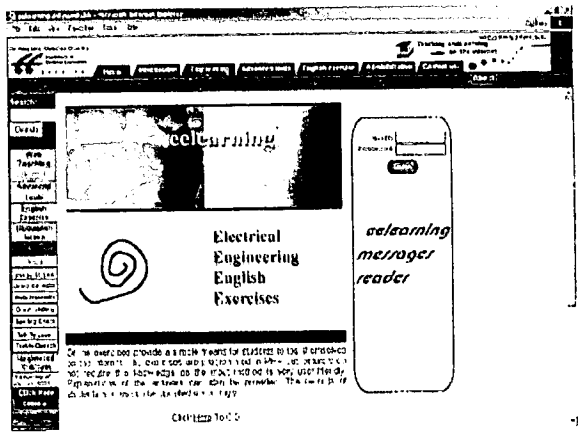
2 BASIC STRUCTURE OF THE SOFTWARE

2.1 BASIC WEB PAGES

A basic platform for the web-based teaching software is to convert the materials into html and to be presented in the web. Therefore a number of methods that a document can be converted to it including the Frontpage, Composer, Dreamweaver, etc. Of course a web-based material must have animation so that some difficult theories can be explained in a suitable format with movement. It also arouses the interest of students. Sometimes, certain materials cannot be programmed with animation, only some changes in colour of the diagram may also help.

Fig 1 is a typical title page for the web-site. From there, a number of functions can be started. The left-hand side is the function icon. Users can click on the icon to access different functions. The function can also be accessed from the top bar. As the lecture notes have a copyright protected, therefore a login and password control is built in. The passwords are controlled by the system administrator and can be applied through the subject lecturer.

Figure 1 Title Page of the Web-site



The basic teaching materials can be accessed easily by the web-teaching icon. There are many subjects that can be reached in the web-based. Users can also select the subject that they want to view by sending requests to their professors or the system administrator. Fig 2 shows the content pages of a web-site where a number of chapters are shown. Some flashes are included the page. Each of the content names can also be given out in oral form so that can arouse the interest of users. Fig 3 shows an example of the web-based lecturer note. The lecture note in html is quite standard, but the pictures are programmed with some animations so as to arouse the interest and improve the learning. The layout of this particular web-page looks like usual web site; the right hand column is a hyperlink bar which gives fast access to a section of the lecture note.

Figure 2 A Content Page for the Web-based Lecture

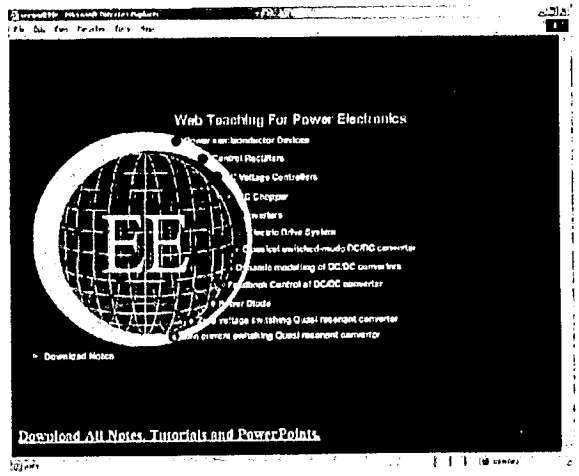
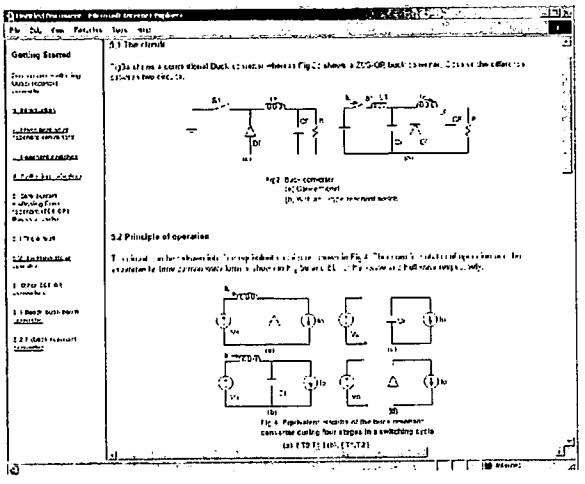


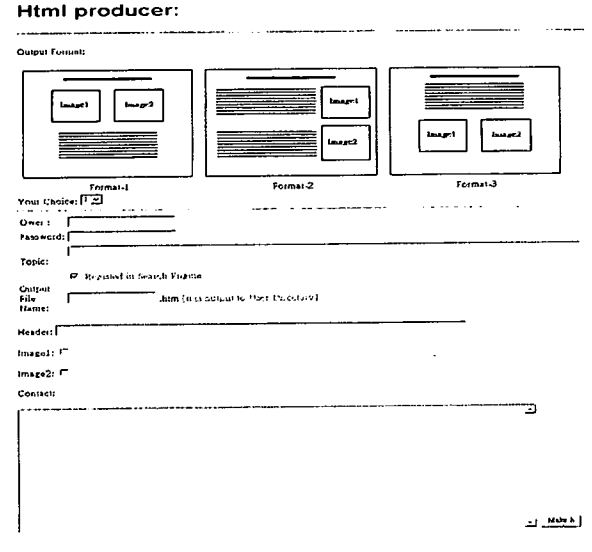
Figure 3 An Example of Web-based Lecture Notes



2.2 HTML PRODUCER

The HTML Producer helps the administrators (professors) to manage their own web teaching material without prior knowledge of html or other web-packages. It is only accessible by administrators. The web-page is protected by password access. The function of HTML Producer includes: Upload lecture notes, Post the News on the web and create the HTML notes by the HTML Producer. The procedure is very simple as just by filling in the fields as shown in Fig.1. The HTML Producer provides three HTML layout formats for selection. Professors just provides the Output file name, Header and the text content to the server then it can automatically produce the HTML format.

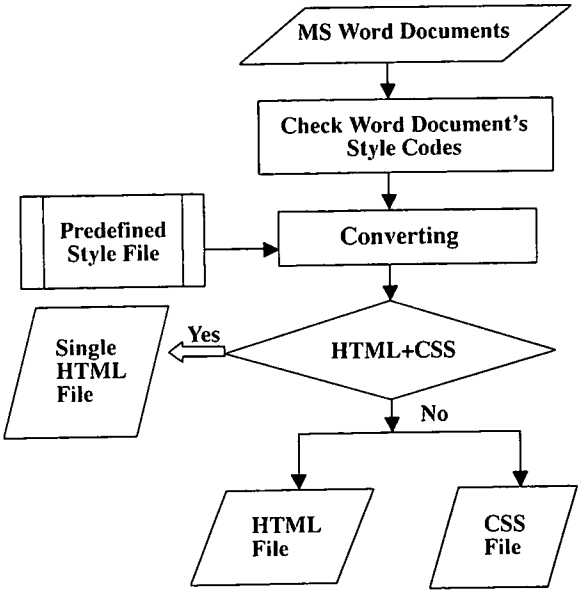
Figure 4 HTML Producer



2.3 WORD TO HTML CONVERTER

Although the standard word package can convert from Word to html, its conversion is usually not beautiful as the converted page is not the same as the Word and the spacing is changed. A converter for conversion from Word to HTML4.0 format, is developed for the package. Many professors have adopted Word as their teaching presentation format for delivering lectures in traditional class long time ago while HTML is now a standard multimedia presentation format of the WWW. There are many differences between the two formats as a simple built-in converter usually does not work properly. The conversion can also be refined by changing the style file and therefore the conversion can enable a uniform output in respect of different Word styles. This will give a more unified output in the web site.

Figure 5 Flow Chart of the Word to HTML Converter



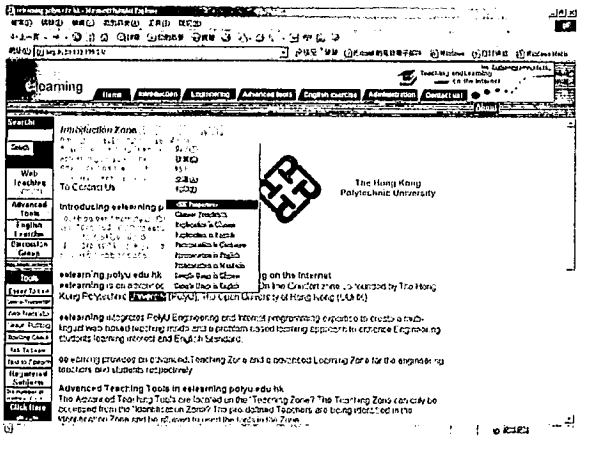
3. MULTILINGUAL WEB-TRANSLATOR

3.1 MULTIFUNCTIONAL TRANSLATOR

Asian students have a language barrier that slows down their learning. It is inconvenient for them to look up the dictionary when they are reading lecture notes. Although there are

many web-based dictionary websites, they still they have to open another browser to do that. In addition, all the dictionary sites give a long list of words that are confusing to students as they do not know which the most suitable meaning for the context is. It therefore stimulates us to develop the web-based translator. Basically a plug-in is installed in the internet explorer so that when the right hand click of the mouse is pressed, an extended menu is popped up as shown in Fig 6. The menu allows users to obtain additional information of a word. The function includes: Chinese translation, explanation in Chinese, English, Pronunciations in English, Cantonese and Mandarin, Sample usages in Chinese and English. The special feature is that the translation or explanation is orientated to engineering and in most cases; the explanation is configured to the electrical engineering and other engineering. Therefore only limited explanation is displayed. Students will not find that the translated word or explanation are too many and confusing. The pronunciation is given in three dialects so that it is especially useful for teaching in Hong Kong. The above information is stored in a database so that it allows future extension to cover other language and additional features can be added.

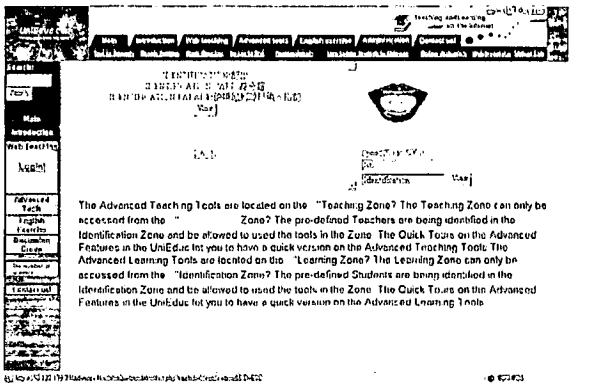
Figure 6 Web-based Translator



3.2 SCAN TRANSLATOR

The scan feature is particularly useful for a quick conversion into the Chinese meaning without complicated operation. When the function is energized, the essay is input from users and then processed by CGI engine. The engine matches word by word from essay and produces Hyperlink for each word. Finally, the user can read the essay and word's meaning together. The voice is available when the user installs Speech SDK Engine which is the mouth engine for pronunciation. The Chinese translated version will then be displayed when the mouse is placed on an English word. Fig 7 shows an example of the function.

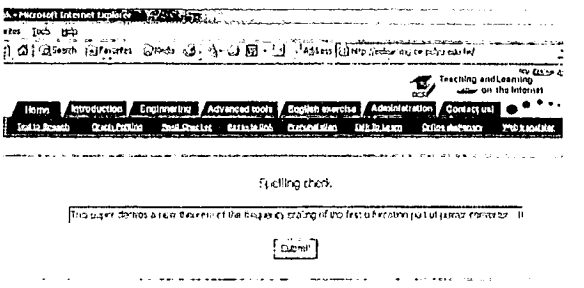
Figure 7 Scan Translator



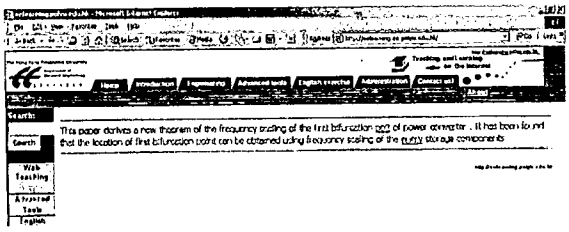
4. SPELLING CHECKING

Spelling checking is very common feature of many typesetting packages. The special feature of ours is that it orientates to engineering word. Therefore all the special engineering jargons can be checked again the database. Fig 8 shows the display of the menu of the web page. Fig 8a is the input page where a sentence or phases can be input to the field. After submitted to the server, the wrong spellings are shown by the server as in Fig 8b.

Figure 8 Web-page for Spelling Check



(a) Input page



(b) Return page

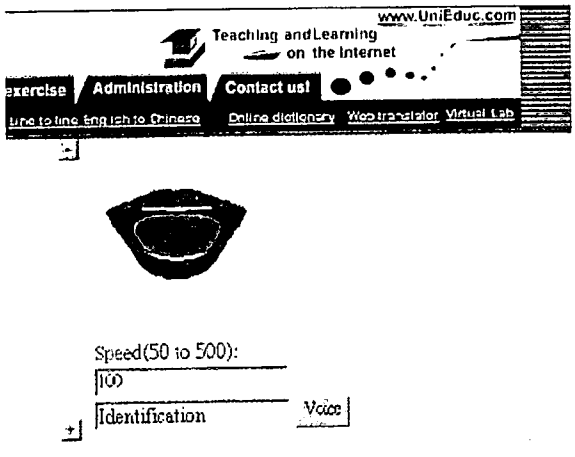
5. VOICE FUNCTION

The voice function can be divided into the on-line pronunciation, oral web and voice controlled.

5.1 PRONUNCIATION

A mouth engine is programmed that gives pronunciation of any word you enter. The speed of the sound can also be controlled and the corresponding movement of the mouth is also shown. It gives an interactive manner for users to follow a pronunciation. Fig 9 shows the page of the mouth pronunicator.

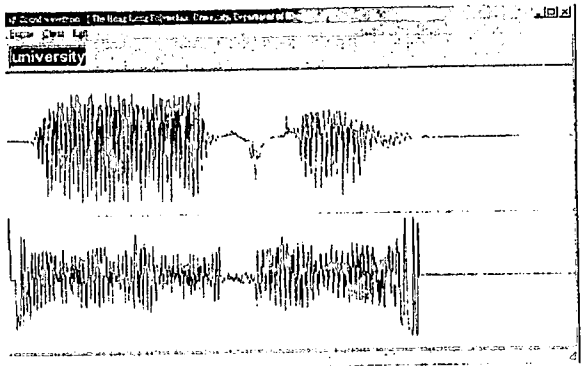
Figure 9 On-line Pronunciation Engine



5.2 PRONUNCIATION TRAINING

A browser can be involved to compare the waveforms between the database and that a student pronounces. Fig 10 shows the two waveforms that the students can be seen on the browser. Users can speak any word to the voice input of his computer and the corresponding waveform is the displayed. He can also follow the standard voice from the pronunciation database for training.

Figure 10 Waveform Recorder to Compare Your Voice with Standard

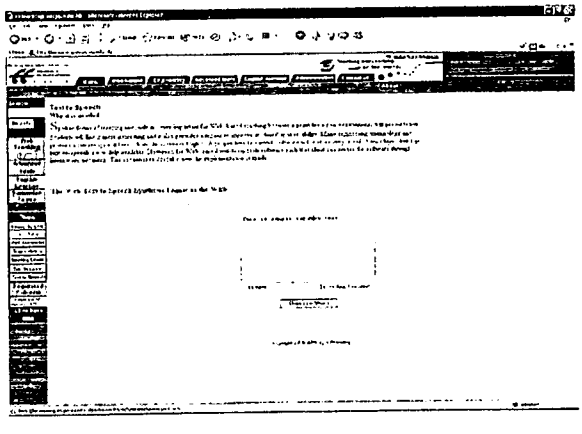


5.3 TEXT-TO-SPEECH

In order to arouse the interest of the users, a text-to-speech function is developed for the software. Any text can be converted into the spoken form and produced by the software. Fig 11 shows the web-page of the section. Any text can be placed in the box as shown and the wave file can then be generated.

Therefore the function can also be useful for someone learning a lecture without watching. It is also useful for disable person.

Figure 11 A Text-to-speech Web Page

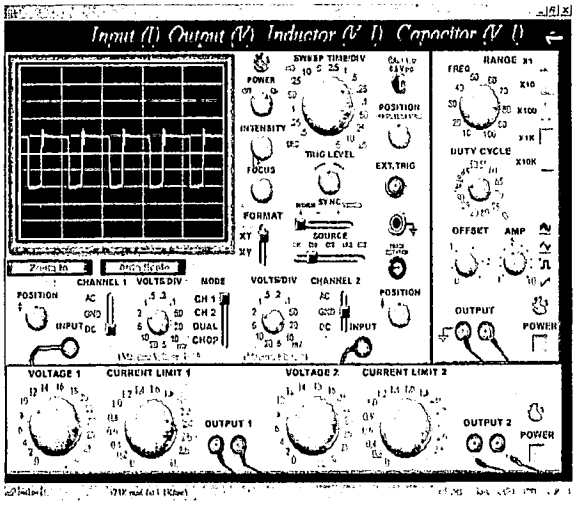


6. VIRTUAL LABORATORY

The most important part for an engineering teaching-and- learning is the experiment. Conventional laboratory is conducted in a physical laboratory. With the development in the web-facility, the remote controlled experiment has been developed. It is based on LabView [6] and all the instruments are

connected using GPIB. The experiment is actually existed in the laboratory and is controlled by LabView and the measurement and the input parameters are also controlled by LabView. A camera is also installed to give students a more realistic feeling of the experiment. The main advantage is that it can eliminate the danger during the hardware experiment as all the procedures and safety issues have been taken precaution. The saving in time and space can make more users to use the equipment in 24 hours a day and all years. Fig 12 shows the interfacing panel of the web pages. The control panels of the signal generator, power supply and oscilloscope are shown and can be adjusted from the browser. The measured waveforms are displayed in an oscilloscope manner.

Figure 12 User Interface of the Virtual Lab (Using LabVIEW Imports Picture as Oscilloscope's Display)



7. WEB-BASED EXERCISES

Part of the engineering teaching and learning is through practicing. An automatic exercise package has been developed that also has various forms of the web-based exercises. It includes the fill-in-the-blank, multiple choices and True-and-false. All the questions and answers are uploaded into a database. The software packages involved are JSP and paradox. The professors do not require to have any previous knowledge in database and html.

Fig 13 shows the web-page of the web-based exercise. The explanation of the answer is also available. Fig 14 shows the web-page for the explanation after the students has submitted the answer to the server.

Figure 13 Web-based Multiple-choice Exercise

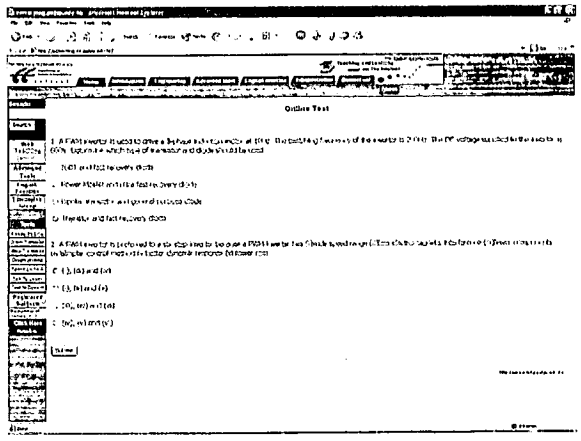
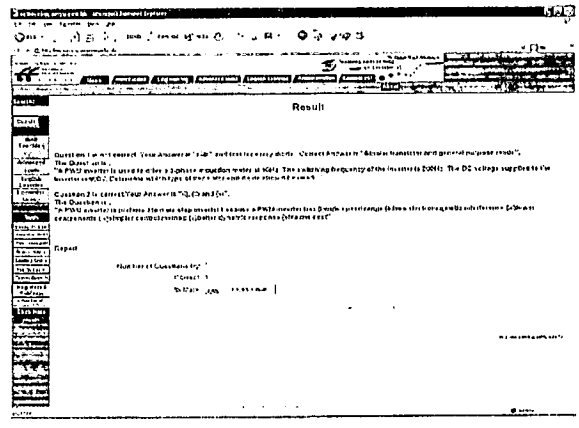


Figure 14 Explanation Page of the Submitted Answer



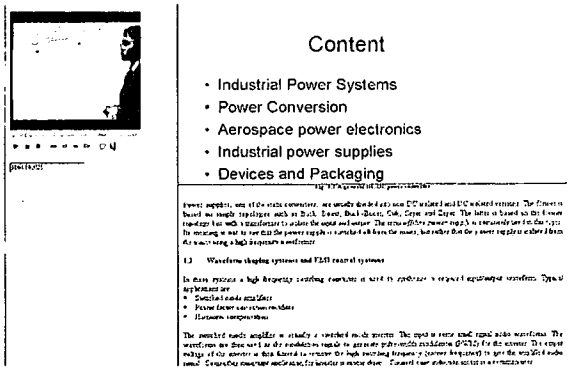
8. WEB-BASED SEMINAR

Webinar means WEB-base semINAR that is used to provide a platform for lecturers to create a web-based presentation or lecture. The professors need not to have knowledge about the web-design and web programming; they can through webinar to create their seminar.

Recently Hong Kong has been badly affected by Atypical Pneumonia. It makes the schools and universities in Hong Kong suspense for several weeks. So the webinar can help the

teachers and students as it provides a communication media that can give continuous teaching and learning through the web as it is in a classroom. Another point is that if students miss one of lectures, they can use webinar to study the corresponding lecture at home or any place through a computer and Internet. Fig 15 shows the Webinar page of the software. The left-had-side is the video that shows the lecture. The right-hand-side is divided into the power point (at the top) and the detailed lecture notes at the bottom for reference.

Figure 15 The Webinar Page

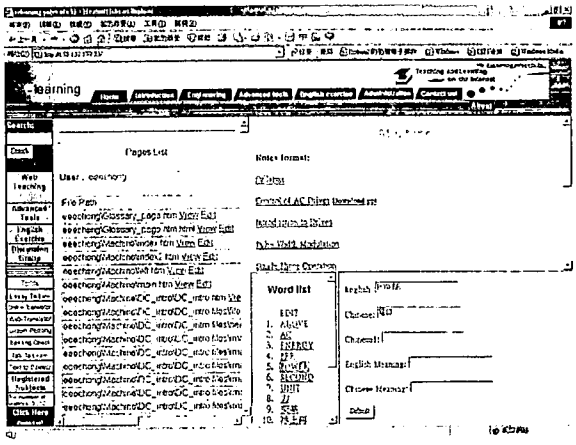


9. GLOSSARY

Glossary input page is an interface for professor to input the detail of the word which the professor wants to describe any particular engineering jargon. The main advantage is that the student can understand more detail about the word during revision and learning from the Web. After professors have made notes as html files and still they want to add the additional description for the word, this page can help them to do it without changing the original html page.

In the glossary input page, the left hand side is the directory that displays the file path for editing and the history. The right hand sides are divided into two parts. The top is to display the web page. The bottom is the area for input and editing that the professor wants additional description of the word.

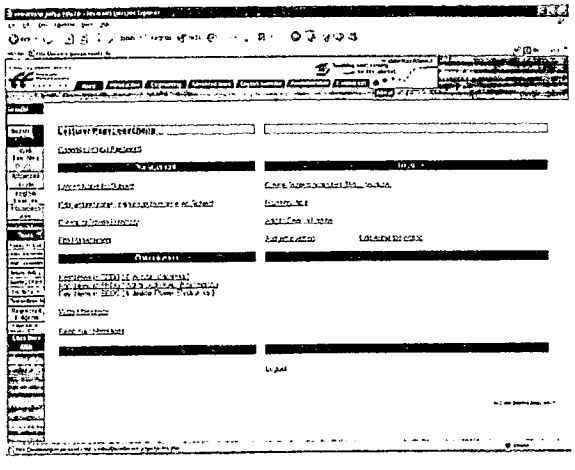
Figure 16 Glossary Input Pages



10. WEB-SITE MANAGEMENT

The management of the web-sites is simple and also very user friendly. Professors can upload the lecturer notes and program the above said functions. He/She can also manage his/her lecture documents, access the search engine, create subjects, manage the exercise, conduct web-based examination, etc. Fig 17 shows the management web-site.

Figure 17 Management Web-site of the Software



11. CONCLUSION AND DISCUSSION

A software package is developed especially for

engineering students. The software aims to assist the teaching and learning of engineering subjects and also improve the language skill of the students who are Chinese origin but their learning medium is English. The paper discusses this new software in brief. The software developed consists of many functions to help both students and professors. The software provides basic web-based lecture materials and animations. It also provides a scan-dictionary. Its function is much better than web-based dictionary. It can give pronunciation in English, Mandarin and Cantonese; explanation in English and Chinese. The database consists over 60,0000 words which cover general English and Engineering jargons. The software also provides chat room, diary, student monitoring system and engineering graphic tools. It also consists of search engine, html generator and spell-checking and oral form of lectures. Html generator is very useful for converting some text into html for the posting in a web-page in a customized format. The student monitoring system is especially useful to look at the diary of the students and understand their learning progress, so that the teacher can offer help to some weak students.

The software is written by a number of computing languages. It is initially used for electrical engineering in the universities. The software can also be used in many other disciplines because the format is very general and user friendly. The questionnaires collected from the students also confirm that the developed software is very useful for the teaching and learning. This software is now being used in the Hong Kong Polytechnic University. The URL of the web-site is located in: http://eelearning.ee.polyu.edu.hk.

ACKNOWLEDGEMENT

The author grateful acknowledge the financial support of the OPD and L&T committee of the Hong Kong Polytechnic University and the UGC of Hong Kong.

REFERENCES

1. Cheng K.W.E., Cheung T.K., "Development of a multilingual web-based teaching and learning software for engineering students", Special issue of Call Asia/Information Technology &Universities in Asia 2002.
2. Cheng K.W.E. and Lu Y., "Development of an electronic book for Power Electronics, Machine and Drives based on the multilingual and Problem-Based Learning Techniques", EPE-PEMC, 2002.
3. K.W.E.Cheng, "Exploring problem based learning techniques in electromagnetic computation, Compumag'2001, Evian, France, Vol. 4, pp. 116-117.
4. K.W.E. Cheng and S.C. Cheung , "Examination of PBL and Web-based Exercises in English Language Improvement for Engineering Students". Asia-Pacific Conference on PBL2001, Dec 2001, pp. 49-56.
5. www.webct.com
6. www.ni.com/labview

Paper No. 9

HONG KONG DISNEYLAND – ENGINEERING CHALLENGES IN PROVIDING WORLD CLASS FAMILY ENTERTAINMENT

Speaker : Mr Tommy J. Jones
Technical Director
Walt Disney Imagineering, USA

HONG KONG DISNEYLAND – ENGINEERING CHALLENGES IN PROVIDING WORLD CLASS FAMILY ENTERTAINMENT

Mr Tommy J. Jones
Technical Director
Walt Disney Imagineering, USA

ABSTRACT

Engineering is a difficult, challenging, but ultimately rewarding activity. When the engineering is "Imagineering", it is an even more challenging and rewarding activity. The reward is the development of world class family entertainment that is limited only by the imagination. It is that limit, or lack thereof, that increases the challenges. The challenges, both technical development and operational, stem from setting and maintaining a high standard of quality. This standard of quality is expected internally and most importantly from our guests. In this paper, I will discuss a systems view of the engineering challenges we face in creating the magic.

1. INTRODUCTION

Disney will celebrate its 50 years of magic in 2005. Throughout these 50 years, we have strived to deliver memorable family vacations for our guests. Walt Disney Imagineering is the portion of Disney challenged with the design, development, and production of theme parks and resorts.

Disney is embarking on the development of its 11th theme park and its first resort in China. Though lots of experience has been gained in the development of the previous parks and resorts, each development has its own unique challenges. The common challenge is converting guest perceptions and behaviors into quantifiable requirements that can be implemented in a cost effective manner. The unique challenges are most directly related to the locale. The local resort environment must reflect the cultural demographics and behaviors in addition to the local regulatory requirements. Demographics and local regulatory requirements are constantly evolving throughout the development cycle. Systems engineering or systems thinking plays a large role in being responsive to these changes while creating the magic for our guests.

2. SYSTEMS ENGINEERING

A definition taken from Merriam Dictionary defines a system as "a regularly interacting or interdependent group of items forming a unified whole". In early days of technology and industry, man made systems were very simple. In today's high tech, highly industrialized world, systems have become so complex that it can be hard to distinguish between the system and the subsystems. A theme park/resort presents the ultimate systems challenge. A theme park/resort system can be classified as an open system. Open systems have a dynamic interaction with their environment and are ever-changing until they reach a steady state. For HKDL, our system, according to the definition, is the regular interaction of our resort elements and the guests. If our system is developed properly, the system's steady state is aptly characterized as "The Happiest Place on Earth".

Systems Engineering is defined as both an engineering discipline and a set of methods. . Having been a practionier of Systems Engineering in several industries, it is clear that there isn't a unified definition or application. The application of the disciplines and methods has varied based on the individuals or product market. In large aerospace and defense projects with long design cycles (> 10 years) and long service lives (> 20 years), both the

Pape
No. 9

engineering discipline and methods are employed. The long design cycle, stringent performance requirements, and service life drive the level of process rigor. As the product design cycle shortens and the product market is more competitive, the process for Systems Engineering becomes less structured and is assumed to be more of a product development team characteristic. This less structured approach uses the methods of Systems Engineering and relies more on Systems Thinking. (Salter 2001).

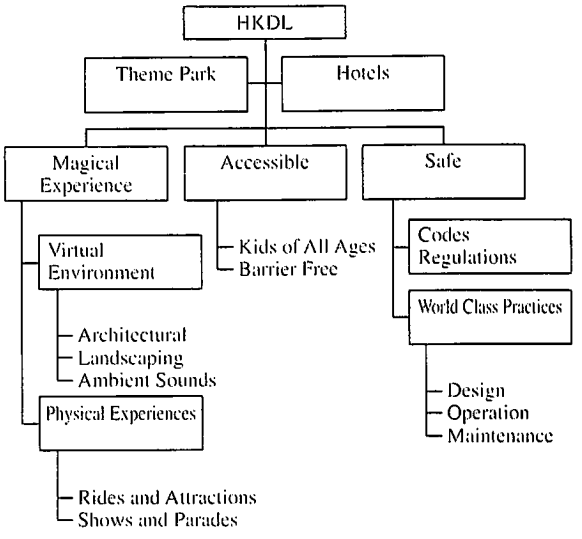
Conceptually, systems engineering of product development is very straightforward. Define quantitative, measurable requirements that can be produced for a given budget and schedule. So imagine the challenges that exist when the primary requirement is to create a "magical experience". As part of this requirement add a commitment to life cycle requirements such as safety, accessibility, and maintainability for "one off" designs. This combination of soft (quantified through interaction or feedback, i.e., magical experience), emerging (safety, accessibility, regulatory), and hard (quantifiable) requirements creates an interesting challenge. Cost and schedule, two key performance requirements, constrain the ability to iterate for optimal solutions. These business constraints in turn drive the use of systems thinking and systems methods such as requirements decomposition, requirements management, and risk assessment.

3. REQUIREMENTS DECOMPOSITION

3.1 HKDL'S "MAGICAL EXPERIENCE"

A simplistic decomposition of the Hong Kong Disney Land's (HKDL) "magical experience" is provided in Figure 1. Disneyland, Walt Disney World, and EPCOT (Experimental Prototype City Of Tomorrow) are synomous with virtual environments. Unlike the virtual reality that is mostly associated with computer simulation, the Disney experience immerses the guest in a "physical" virtual reality". By providing the requisite amount of detail to the architecture, landscaping, and ambient environment, the guests can be emotionally transported to a different time or place.

Figure 1 Requirements Decomposition for "HKDL's Magical Experience"



Once the guests are transported emotionally, the incorporation of physical experiences can be used extend the emotional experience. Steam trains and antique cars reinforce the period and theme of Main Street. In a similar sense, rafts and jungle boats are integral to the sense of adventure that exists in Adventureland. By combining these physical conveyance means with period architecture, sights, and sounds, the foundation for a magical experience has been created.

The concept of integrating these physical and emotional elements is not unique to Disney. However, the history of taking a vision of the possibilities and making it a reality is unique to Disney. This requires the designers and engineers to design "with the end objective in mind" at all times. Designing and producing with the end objective in mind requires a "top down" assessment of the system. This view from the systems level allows assessment of the interaction between elements (physical instantiations and guests). This systems view relies and integrates the expertise of the creative design and engineering talents and the operational talents to balance the system implementation.

3.2 ACCESSIBILITY

The next key aspect of the decomposition is accessibility. An experience that can be shared by families that cross several generations is truly magical. Families that cross generations (grandchildren to grandparents) tend to have baby carriages and wheelchairs. Additionally Disney has strived to make its environment accessible and enjoyable by guests with varying disabilities. The overall accessibility, or barrier free, design approach addresses hearing, vision, and mobility impairment. Because the requirement for a family experience is primary, design consideration for these guests has been evolving internally well in advance of many of today's regulatory requirements.

Implementation of barrier free designs imposes requirements on all aspects of the physical and operational design. As an example, the architectural elements integrate physical elements to assist with lighting levels, hearing assistance systems, and graphical signage. Ride designs evaluate the effectiveness of egress and restraints. Creative designers develop means to integrate the functional accessibility requirements so that they "blend" into the overall storyline of the design. This is just a sample of the issues that must be addressed to make accessibility designs effective.

3.3 SAFETY

The last element of the decomposition, Safety, is the most critical. Safety is the result of proper implementation of design codes and standards, well trained operators, and diligent maintenance. However, safety is an elusive ever changing characteristic. In the theme park open system where guests are considered an integral element, the guest behavior and interaction can ultimately determine the safe state.

Emerging regulatory requirements and changing guest behavior/demographics have intensified a difficult design problem. . This is further complicated by the uniqueness of some of our products. For example, when you create the experience of a malfunctioning elevator, commercial elevator design and operation requirements don't readily apply. Creation of a safe product requires intimate knowledge of the components being integrated, the local regulatory codes and continual assessment of how guests and cast members interact with the end product.

In this area, we extract from the cumulative knowledge gained during the 50 years of creating magical and safe experiences. It is still a difficult challenge, but one that we assess daily to ensure it is met.

3.4 REQUIREMENTS CLARITY

Clarity of the requirements creates the biggest challenge for cost effective timely product development. There are numerous examples in the literature of methods to achieve clarity. This characteristic is complex and for products described as "magical", requirements clarity can be quite elusive.

To further demonstrate the flow down of the requirements decomposition, a functional description of the attraction may be as follows:

"Guests in "rockets" travel out into "space" for a high-speed journey through meteor showers and other inter-galactic events, dipping and rising and experiencing high-speed turns, and then finally return to the Space Port".

The functional description above must be transformed from colorful words and phrases into physical subsystems for the guest's experience. In Table 1, a simple relationship between key words in the verbal description is shown.

Table 1 Example of Transformation from Functional Description to Physical Elements

Characteristic	Physical Representation
Rocket	Vehicle Body Design
Space	Dark Facility
High Speed	Propulsion (gravity or powered)
Dipping and Rising	Track Profile
Meteor Showers	Lighting Effects Sound Effects
Intergalactic Events	Lighting Effects Show Sets

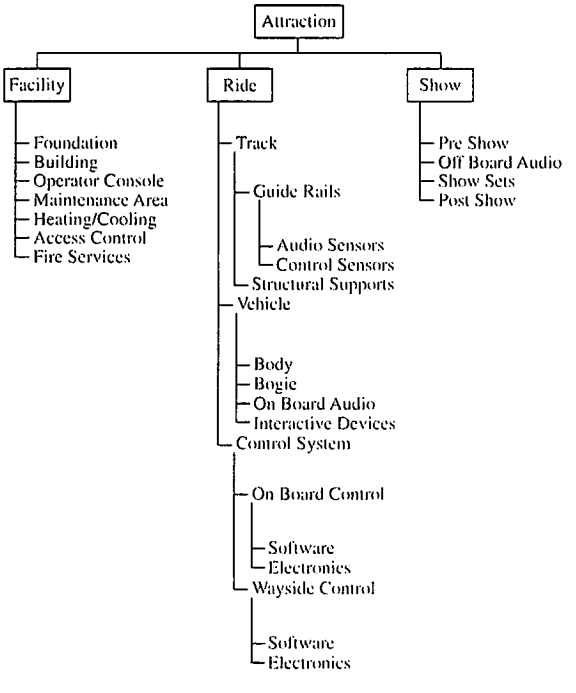
Definition of the problem is essential to providing an engineering solution. Once "soft" requirements are documented, the design and engineering iterates using drawings, sketches, mockups and other means to clarify the requirements.

For highly technical products, airplanes, bridges, skyscraper office buildings, the requirements, are easier to clarify and manage. The ease of clarification is due to dominance of "hard" performance requirements such as speed, occupancy, and weight. In those applications, the development challenge can be driven primarily by the current state of technology. For theme parks and resorts, the scope complexity is tremendously different because of the preeminence of "soft" requirements , .i.e., "the magical experience", emerging requirements (safety and accessibility), and the current state of technology.

3.5 PHYSICAL DECOMPOSITION

Once functional characteristics are mapped into the physical space, physical subsystems can be more finely decomposed into elements. It is at this point that the engineering takes a more familiar form. An example of a physical decomposition for an attraction is illustrated in Figure 2. It is at this point that the track designer or audio specialists can really do what they do best. This graphical schematic of the overall attraction provides a simple means to understand the interaction of major subsystems.

Figure 2 Attraction Decomposition Example



Having this vision of the interaction between the subsystems and how they are expected to work as a whole allows design teams to quickly assess impact of changes as the design/ requirements mature.

3.6 DESIGN OPTIMIZATION – TOP DOWN, BOTTOM UP

During product development, there is a continuing quest for design optimization. This theoretical state gives the sense that the design meets the requirements without wasted time or money. The time or money measure is often equated to design margin. The primary competing thoughts of design optimization are "top down vs. bottom up". Top down approaches work best for highly structured products and organizations. The subsystems are forced to meet the requirements of the overall objective. For Bottom Up designs, the subsystems are the focus and selective integration decisions lead to a desired top level objective.

The previous sections described uses of traditional tools and methods for systems engineering, from a top down perspective. Unfortunately very few product development teams follow that sequence or structure. Requirements decomposition, functional to physical mapping, and system decomposition may occur from either direction. As is often the case, a product exists that is looking for a solution. In the case of starting with a product looking for a solution (bottom up), the requirements evolve on the basis of utilizing key characteristics of the subsystem. At the end, if all works well, it is difficult to tell where the design team started. The final product and the documentation may give the impression that the team used a structured logical systematic approach. For those who subscribe to the notion that the "end justifies the means",

the process follows the product.

For creatively driven products, neither model fits extremely well. Both models require a certain level of quantifiable assessment at each measurement point. So, the magical experience as a top level requirement provides the ultimate challenge for design optimization and validation. That challenge of validating the top level requirement is the system risk.

4. REQUIREMENT RISK

The prevalence and fluidity of soft requirements in theme park development pushes the limits of risk management. One popular risk management statement is "No invention on the critical path!" But for a product that its very nature is invention or relies on the guest validation, the system risk can be immeasurable.

The complexity of assessing the risk is a product of differentiating between system and subsystem risk. In a conceptual sense, it is easy for a subsystem designer (track) to identify technical risk. However, as you move through the system hierarchy, how does that subsystem risk manifest itself in the delivery of the "magical experience"? In the example of this paper, the track is integral to creating the rising and falling effect by creating changes in gravitational forces on the guest. While modifications for physical subsystem risks can be made to address the near term technical risk, the ultimate validation remains open until experienced by the guest.

Assessing the system risk involves use of scale physical models, assessment of historical guest preferences and surveys of future guests. This continual concern for the system risk and need to ensure that the big idea comes to life drives the process. It creates a dynamic environment where methods of systems engineering and system thinking must be used by nature and not by rule. The innate approach, which organizationally may be described as an adhocracy, is in itself an additional risk. But the reward is the creation of a "magical experience".

5. CONCLUSION

Product development is the successful integration of design, engineering, and production. Design is limited only by the imagination. To be truly innovative, design must challenge the laws of physics and sometimes re-write the rules of engineering. However, the innovative design that initially is created on paper must eventually be produced, operated, maintained, and entertain our guests. Methods of systems thinking, collaboration, and interdisciplinary teams, must be an inherent part of the development process for products driven by soft and emerging requirements.

REFERENCES

Salter, Kenneth, "Systems Engineering and Theme Park Development". Proceedings of the Twelfth International Symposium of the INCOSE, 2001.

Blanchard, B., Fabrycky, Hooks, I., "Systems Engineering and Analysis" Prentice Hall Inc. 3rd Edition