COMPETITIVE ADVANTAGES OF HONG KONG - AN ELECTRICAL ENGINEERING PERSPECTIVE

The Hong Kong Institution of Engineers - Electrical Division

The 22nd Annual Symposium

19th October 2004

THE HONG KONG INSTITUTION OF ENGINEERS ELECTRICAL DIVISION

The 22nd Annual Symposium

Tuesday

19th October 2004

COMPETITIVE ADVANTAGES OF HONG KONG – 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 P.N. Ip
  Chairman, Electrical Division, The HKIE

09.05 Opening Address

- Ir James Y.C. Kwan, JP
  President, The HKIE

09.10 Keynote Speech

- Ir Prof. Felix F. Wu
  Chair Professor
  Department of Electrical and Electronic Engineering
  University of Hong Kong

1. Cutting Edge Technology

09.40 HKSTP's Infrastructure Support to Research & Development

- Ir S.W. Cheung
  Vice President
  Business Development and Technology Support
  Hong Kong Science and Technology Parks Corporation

10.00 Photonics Sensors for the Electrical Engineering Industry

- Prof. H.Y. Tam
  Professor
  Photonics Research Centre
  Department of Electrical Engineering
  The Hong Kong Polytechnic University

10.20 Discussion

10.40 Coffee Break

2. *World Class Electricity Supply*

11.10 Achieving World Class Electricity Supply - The Hongkong Electric Experience

- Ir S.T. Ip, Senior Area Engineer (Central)
- Mr K.T. Yeung, Area Engineer (Western)
  The Hongkong Electric Co. Ltd.

11.30 The Electrical Systems for TVB City

- Ir Dave K.Y. Wong, Director
- Ir Thomas K.C. Chan, Assistant Vice President
- Ir W.S. Tam, Senior Associate
- Ir Mac C.K. Mak, Senior Engineer
  Parsons Brinckerhoff (Asia) Limited, Hong Kong

11.50 Discussion

12.20 Lunch

3. *Intelligent Power*

14.10 Web-based Remote Monitoring of Electrical Supply and Distribution Systems in Buildings

- Ir C.K. Lau, Senior Building Services Engineer
- Ir Victor C.H. Yeung, Building Services Engineer
  The Government of the HKSAR

14.30 Intelligent Light Dimming and Control

- Prof. Ron S.Y. Hui, President
  e.Energy Technology Limited, Hong Kong
- Ir Dr F.C. Chan, General Manager
  CLP Engineering Ltd., Hong Kong

14.50 Discussion

15.10 Coffee Break

4. Engineering Novelties in Entertainment

15.40 The Tung Chung Cable Car – A New Icon for Hong Kong

- Ir R.F. Bayliss, Project Manager
- Ir Lawrence K.L. Chung, Manager – China Technical Support
  Mass Transit Railway Corporation, Hong Kong

16.00 An Overview on High Power LED Source for Indoor and Outdoor Architectural Lighting Applications in Harbour Lighting/Beautification Scheme

- Mr Riccardo Croce
  General Manager
  Space Cannon vH, Italy

16.20 Discussion

16.40 Summing Up

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

Closing Address

- Ir Otto L.T. Poon
  Chairman
  Energy Advisory Committee, Hong Kong

Acknowledgement

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

Speakers / Authors

Ir Otto L.T. Poon
Ir James Y.C. Kwan, JP
Ir Prof. Felix F. Wu
Ir S.W. Cheung
Prof. H.Y. Tam
Ir S.T. Ip
Mr K.T. Yeung
Ir Dave K.Y. Wong
Ir Thomas K.C. Chan
Ir W.S. Tam
Ir Mac C.K. Mak
Ir C.K. Lau
Ir Victor C.H. Yeung
Prof. Ron S.Y. Hui
Ir Dr F.C. Chan
Ir R.F. Bayliss
Ir Lawrence K.L. Chung
Mr Riccardo Croce

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22ND ANNUAL SYMPOSIUM ORGANIZING COMMITTEE

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		Ir S.K. Ho
		Ir C.L. Wong
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Paper No. 1

HKSTP's INFRASTRUCTURE SUPPORT TO RESEARCH & DEVELOPMENT

Speaker : Ir S.W. Cheung
Vice President
Business Development and Technology Support
Hong Kong Science and Technology Parks Corporation

HKSTP's INFRASTRUCTURE SUPPORT TO RESEARCH & DEVELOPMENT

Ir S.W. Cheung
Vice President
Business Development and Technology Support
Hong Kong Science and Technology Parks Corporation

Paper No. 1

ABSTRACT

The Hong Kong Science and Technology Parks Corporation (HKSTP) is a statutory body established by the Government of the Hong Kong Special Administrative Region in May 2001 to facilitate Hong Kong to become a major centre of innovation and technology, and a hub for high value-added, skill-intensive production and related services facilities in Asia. It offers a comprehensive range of services to cater for the needs of industry at various stages: offering management & technical support programmes; nurturing technology start-ups; providing advanced facilities & support services for applied R&D activities and; providing land & premises for hi-tech manufacturing. Through all activities, the Corporation fosters partnership and collaboration across industries and borders.

This paper provides an account on the roles played by and facilities of HKSTP.

1. MISSION OF HKSTP

Hong Kong Science & Technology Parks Corporation (HKSTP) exists to support this development during this important milestone of evolution success. Our key mission is to promote innovation and technology and the upgrading of Hong Kong's production and service capabilities.

Creativity is the primary force behind innovation and technology-related activities. HKSTP therefore sets out to help Hong Kong assert itself as a city of creativity and execution. We focus on creating the favorable environment in four cluster areas including electronics, I.T./Telecom, biotechnology and precision engineering, where innovative enterprises and talented people can converge to generate synergistic forces.

Providing end-to-end services differentiates HKSTP from others. HKSTP offers a comprehensive range of services to cater for the needs of industry at various stages, ranging from offering a series of management and technical support programmes through industry and university collaboration; nurturing technology start-ups through the Incu-Tech programme support; providing advanced facilities and support services in the 22-hectare state-of-the-art Science Park for applied R&D activities; providing land and premises in three Industrial Estates totaling 239 hectare for hi-tech manufacturing.

2. BUILDING QUALITY INFRASTRUCTURE CAMPUS-LIKE ENVIRONMENT

Science Park is an investment with a worth of 1.5 billion US dollars located on a 22-hectare site by the Tolo Harbour waterfront. Upon the completion of its three phases, Science Park provides a total gross floor area of 330,000 square meters to serve world-class technology firms and young, innovative start-ups in four distinct technology clusters: electronics, I.T. & telecommunications, biotechnology and precision engineering.

3. WORLD-CLASS & HIGH-TECH FACILITIES

The core building zone, which forms the backbone of the Park, provides facilities such

as business centers, conference halls, meeting and training rooms, exhibition area, restaurants, gymnasium, service apartments and car-park. Its state-of-the-art architecture has won the Innovative Design Awards in year 2001.

Science Park is well equipped with shared high-tech facilities and a team of engineers for technology support. The Technology Support Centre has passed an ISO9001: 2000 quality system certification audit by the Hong Kong Quality Assurance Agency[1], with shared facilities including IC Design Centre, IC Development Support Centre (consists of the Probe & Test Development Centre[2] and the Reliability Laboratory[3]) and Product Analysis Laboratory. HKSTP is committed to providing companies with complete security to protect their Intellectual Property by establishing special security measures to ensure total confidentiality when using the shared high-tech facilities.

4. NETWORK OF LOCAL SUPPORT & PARTNERSHIP

Representing the strong support from the government of HKSAR, HKSTP is supported by ITC[4]. Furthermore, additional local connections and networks have also been in place. Memorandum of understanding signed with the six local universities bridges the academia with commercial sector. According to the memorandum of understanding, the following will be exercised whenever feasible for provider-universities, with the aim of bringing mutual benefits to the universities, HKSTP and/or its tenants/ incubation companies: research and technology transfer programmes, R&D funding, staff appointment in the form of visiting scholars or research project associates, utilizing student internships[5], professional consultancies and facilities sharing[6] etc. Another significant alliance of resources is the close interactions with organizations such as HKIB[7] and ASTRI[8], which strive for the promotion and assistance of applied researches. All these efforts have together increased the capability of Hong Kong as-whole in the advancement to cutting-edge technology development, information and facilities.

5. A HUB FOR INNOVATION AND TECHNOLOGY IN ASIA

As the technology trends and growths evolve rapidly everyday around the world, the ease, speed and costs of accessing sources of technology information, skills, facilities and environment are vital factors towards the success of technology companies focusing in R&D activities and innovative creativities.

Hong Kong Science and Technology Parks Corporation has seen the need and given the mission to serve local start-up in becoming competitive and leading in the four industries of Electronics, I.T. & Telecommunications, Precision Engineering and Biotechnology.

Our mission is three-folds: 1) Quality infrastructure and support facilities for innovation and technology development, 2) Full-service Incubation Programme for technology start-ups, and 3) Partnership between industry and universities through joint training and research programmes.

With the quality infrastructure of Science Park, world-class and advance laboratory facilities & equipment, professional engineering staffs, network connections to local and worldwide academia & experts, continuous updates and

[1] *HKQAA certification # CC2713*

[2] *Features sophisticated automated test equipment for analog, digital, mixed signal and Radio Frequency product testing*

[3] *Accommodates various dynamic life tests and environmental stressed tests for IC products*

[4] *Innovation and Technology Commission, HKSAR*

[5] *Includes summer placements, 1-year work-study and final year project*

[6] *Includes equipment in laboratories, manufacturing plants & testing centers*

[7] *Hong Kong Institute of Biotechnology Ltd*

[8] *Hong Kong Applied Science and Technology Research Institute Co Ltd*

linkage with leading industries, Hong Kong Science & Technology Parks Corp is confident to in leveraging a wealth of industry knowledge and a considerable resource base to provide end-to-end support infrastructure for technology companies, both large and small.

Realizing technology transcends across border, HKSTP endeavors to embrace the knowledge and experiences accessible through worldwide partnerships in strive for continuous improvement to be a hub for innovation and technology in Asia.

Appendix: Facilities & Equipment of Technology Support Centre in Science Park

Probe & Test Centre

Agilent 93000 SOC tester model P600	Credence Quartet mixed signal tester
IMS Silicon Validation System Gemini	Credence ASL3000 RFIC tester
Credence ASL1000 analog tester	Kalos Engineering memory tester
Teradyne Integra J750 digital tester	Eagle ETS-300 analog tester
HI Level ETS-780 tester	Delta-Design handler
Synax SX-141 handler	MCT 4610 handler
TSK UF200AL Prober	Electroglas 2080S prober

Reliability Laboratory

Temperature and Humidity Chambers	Climatic Chambers
High Temperature Ovens	Hot Air Reflow Oven
Burn In Ovens	Vibration Simulator
Thermal Shock Chambers (Air to Air)	
HAST (Highly Accelerated Stress Test) Chambers	

Product Analysis Laboratory

Focus Ion Beam	Field emission SEM
Reactive ion etcher	Acid decapsulator
Laser cutter and probe station	Curve tracer
Atomic force microscope	Alpha-step surface profiler
Smart microscope	Optical interferometer microscope

Chip unzip (sample preparation system)
SEM with EDX and Voltage Contrast (FEI Quanta 600)
ESD and latch-up testers (KeyTek ZapMaster MK2: 512 pin HBM, MM and latch-up tester)
ESD and latch-up testers (KeyTek RCDM3: Charge Device Model tester)
Dynamic backside signal acquisition system (Optonics EmiScope II)
Scanning acoustic microscope (KSI WINSAM VARIO III 500 MHz, 0.1 micron encoder resolution)
Scanning Auger electron spectroscopy (Physical Electronics PHI 670)
TOF Secondary ion mass spectrometry (Physics Electronics TRIFT III)
X-ray photoelectron spectroscopy (Physical Electronics PHI Quantum 2000 - XPS/ESCA)
FTIR Spectrophotometer (Perkin-Elmer Spectrum One: transmission, reflectance, ATR modes)
X-ray fluorescence spectrometer (Jordan Valley EDXRF EX 6600)
Confocal microscope (Keyence VK 9510 violet laser 3D profile microscope)

RF & Analog Engineering Support Lab

RF Network Analysis Workstation

- 50GHz, 4-Port Network Analyzer Physical Layer Test System
- 6GHz Oscilloscope

RF Signal Analysis Workstation

- 3Hz - 50GHz Spectrum Analyzer (Include noise source)
- 40GHz Signal Generator
- 6GHz Vector Signal Generator (Multi-format Digital Modulation with Fading Simulation)
- Power Meter (50GHz Average)
- Pulse/Pattern Generator (3.35GHz, 2 Ch. With Noise Source)
- Wideband Receiver (36MHz Information BW, Support various format)

Communication System (Mobile Set) Workstation

- Wireless Communication Test Set (GSM, AMPS, IS-95, GPRS, EDGE, WCDMA, CDMA2000 1x/ 3x, 1xEVDO)
- Wireless Protocol Analysis Software

Communication System (BT & WLAN) Workstation

- Wireless LAN Analyzer (Physical, Datalink and MAC Layer)
- BlueTooth Communication Test Set
- Mixed Signal Oscilloscope (2+16, 100MHz BW)

Mid-band Signal Analysis Workstation

- 3-in-1 Network/Spectrum/Impedance Analyzer (10-500MHz/2-500MHz/100k-500MHz)

Power Analysis Workstation

- Mixed Signal Oscilloscope (4+16, 1GHz BW)
- DC Power Supply (Auto-series up to 200V)
- AC Power Source/Analyzer (For IEC 61000-3-2/3-3 Harmonic/Flicker Pre-Compliant Test)
- 6 Ch. Electronic Loads (6 Ch. 60V/30A, 3Ch 240V/10A)
- 60 Ch. Data-Logger (300V/1A 100MHz BW)
- Lab Automation Software

Paper No. 2

PHOTONICS SENSORS FOR THE ELECTRICAL ENGINEERING INDUSTRY

Speaker : Prof. H.Y. Tam
Professor
Photonics Research Centre
Department of Electrical Engineering
The Hong Kong Polytechnic University

PHOTONICS SENSORS FOR THE ELECTRICAL ENGINEERING INDUSTRY

Prof. H.Y. Tam
Professor
Photonics Research Centre
Department of Electrical Engineering
The Hong Kong Polytechnic University

Paper No. 2

ABSTRACT

The enormous bandwidth of hair-thin optical fibres that enables the growth of the Internet is quite well known. Perhaps, the uses of telecommunication fibres for sensing purposes are not generally known. These tiny optical fibre sensors known as "fibre Bragg grating sensors" are fabricated inside the 10 micron-core of optical fibres and up to 100 FBG sensors can be created in a single fibre. This unique feature open the opportunities for them to be used in many applications that otherwise would not have been possible. Another important advantage of this type of optical fibre sensors is their inherent immunity to electromagnetic interference that made them ideal for the electrical engineering industry where EMI is a concern for electronic sensors. The use of FBG technology in measuring the train performance parameters ranging from train loading, train speed, to counting the number of axles going in and coming out of tunnels will be presented. The principle of using FBG sensors together with laser to measure acoustic sound generated by partial discharge in transformers will be described. This talk will also show how such sensors are being used in Hong Kong's landmark, Tsing Ma Bridge for monitoring dynamic strain and temperature.

1. INTRODUCTION

Photosensitivity in fibre and the resultant index gratings were first demonstrated in 1978, by Ken Hill *et al* [1] during experiments using Ge-doped silica fibre and visible argon ion laser radiation. The grating was formed by the standing wave in the fibre and thus its reflection wavelength is close to that of the writing light. In 1989, however, Gerry Meltz *et al* [2] demonstrated a holographic technique of "side" writing Bragg gratings using UV light at 244 nm. This allows reflection gratings at virtually any wavelengths to be fabricated. A number of key technologies developed in recent years encourage the widespread use of fibre Bragg gratings (FBG).

One of the most successful applications of FBGs is perhaps as wavelength lockers for wavelength stabilization of 980 nm and 1480 nm pump lasers. Other popular applications of FBGs in optical communications include fibre grating lasers, gain flattening filters for erbium-doped fibre amplifiers and dispersion compensation.

Historically, fibre-optics sensor systems are expensive and are only employed in niche applications where conventional sensors are not suitable. However, the burst of the telecom bubble in 2001 helped to lower the cost of fibre-optics components substantially. Fibre gratings based sensor systems are now being used in large number of application areas ranging from structural monitoring of bridges, dams, railroad tracks, airplane wings to chemical sensing.

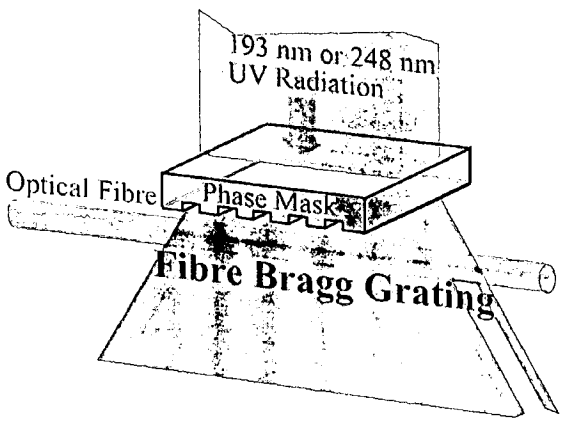
These tiny optical fibre sensors known as "fibre Bragg grating sensors" are fabricated inside the 10 micron-core of standard telecommunication optical fibres. An FBG interrogation system can handle more than 100 FBG sensors created inside a single fibre. This unique feature open the opportunities for them to be used in many applications that otherwise would not have been possible. Another important advantage of

this type of optical fibre sensors is their inherent immunity to electromagnetic interference that made them ideal for the electrical engineering industry where EMI and hazardous environment are major concerns for electronic sensors. The use of FBG technology in measuring the train performance parameters ranging from train loading, train speed, to counting the number of axles going in and coming out of tunnels will be presented in the symposium. The principle of using FBG sensors together with laser to measure acoustic sound generated by partial discharge in transformers will be described. This talk will also show how such sensors are being used in Hong Kong's landmark, Tsing Ma Bridge for monitoring dynamic strain and temperature [3].

2. FIBRE BRAGG GRATING SENSOR TECHNOLOGY

Figure 1 shows the phase mask writing technique which is widely used to fabricate FBG because it is a much simpler process than the holographic technique and can produce high performance gratings. The reflection or Bragg wavelength of the FBG formed depends on the pitch of the phase mask and the fibre itself.

Figure 1 Fabrication of FBG Inside the 9-μm Core of a Standard Telecommunication Fibre using a Phase Mask.

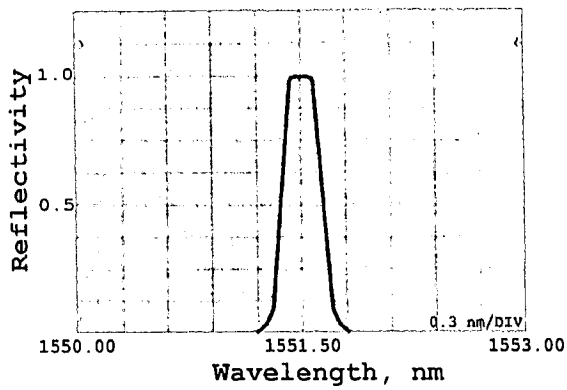


FBGs couple the forward propagating core modes to the backward modes at the wavelength, λ_B, that satisfy the resonance condition

$$\lambda_B = 2n\Lambda \qquad (1)$$

where n is the effective index of the core mode and Λ is the period. FBGs with up to ~100% reflection are routinely being fabricated. Figure 2 shows typical reflection spectrum of an FBG.

Figure 2 The Reflection Spectrum of a High Reflectance FBG Sensor



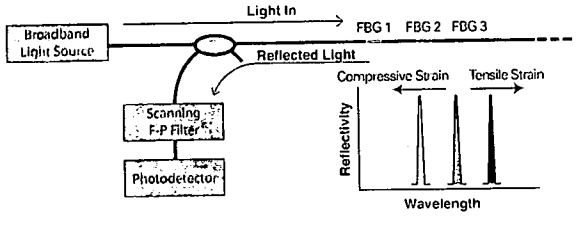
The basic principle of operation in fibre grating-based sensor systems is to measure the Bragg wavelength shift of FBGs. FBG has a very narrow reflection spectrum (~0.2 nm) and therefore many such sensors (up to 100) with different reflection wavelengths could be multiplexed on a single fibre. FBG sensors are very attractive and are being used in many applications that require many tens and even hundreds of sensors. Typical strain and temperature responses of FBG are 1 pm/$\mu\varepsilon$ and 11pm/°C, respectively, at the Bragg wavelength of 1550 nm. Since FBG sensors are sensitive to strain as well as temperature, two FBG sensors are generally required for measuring strain, with one FBG attached to the structure for strain measurement and the other FBG in close proximity for temperature compensation.

Obviously, the performance of an FBG sensor system depends very much on its capability to measure accurately the Bragg wavelength shift of FBGs with adequate resolution. In some applications, such as in the velocity measurement of train, high speed detection

may be needed. Several techniques are available in measuring the wavelength shift of FBG sensors. Since FBGs are passive devices, broadband optical light sources are required to illuminate FBG sensors. The reflected wavelength could be measured by using optical spectrum analyzers, tunable bandpass optical filters, or linear optical filters.

One of the main advantages of FBG sensor technology is that may such sensors could be created inside a single optical fibre and be interrogated by accessing just one end of the fibre. Two general approaches, namely, wavelength-division multiplexing (WDM) and time-division multiplexing (TDM), are being employed to interrogate multiple FBG sensors. WDM interrogation systems typically require highly reflective FBG sensors each operating in distinct wavelength windows. Figure 3 shows the schematic of a scanning filter FBG interrogation system based on WDM technique. Commercial FBG interrogation systems based on scanning F-P filters are available from several companies. The maximum number of FBG sensors along a single fibre that could be interrogated by a WDM interrogation unit depends on the optical bandwidth of the light source, operation range of each FBG sensors and the tuning range of the tunable filter. The typical number of FBG sensor that can be dealt with an WDM interrogation unit is about 40 and is mainly limited by the light source's optical bandwidth.

Figure 3 FBG Interrogation using a Scanning Fabry-Perot Optical Bandpass Filter



TDM systems utilize identical, low reflectivity FBGs (typically 4 % reflection) all operating in the same wavelength window. Fig. 4 shows the schematic of a TDM interrogation system where narrow optical pulses were launched into an optical fiber containing many FBGs with virtually identical Bragg wavelength. Light takes about 10 ns to propagate one round trip along 1 m of optical fiber and therefore the separation between adjacent sensors must be greater than 1 m. Individual sensors are distinguished by measuring the time of flight of signals returning to the interrogation unit. A single optical pulse consists of many wavelength components but FBG sensors reflect only the wavelength component that matches to their Bragg wavelength. Normally, the wavelength shift of the sensor is determines by using a linear optical filter which converts wavelength shift to optical power variation. However, the signal-to-noise ratio of TDM systems is lower than that of WDM systems and therefore the performance of TDM systems is generally not as good as that of WDM systems. The wavelength measurement accuracies demonstrated by WDM interrogation systems and TDM interrogation systems are typically 1 pm and 10 pm, respectively. This is equivalent to temperature and strain measurement accuracies of 0.1°C (1°C) and 1 με (10 με), respectively, for WDM (TDM) interrogation units. For comparison, the complexity of a conventional electrical sensor with its associated conditioning electronics is shown in Fig. 5. Multiplexing hundred of such sensors together can be quite a daunting task.

Figure 4 TDM Interrogation of Multiple FBG Sensors

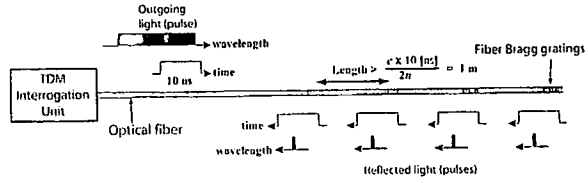
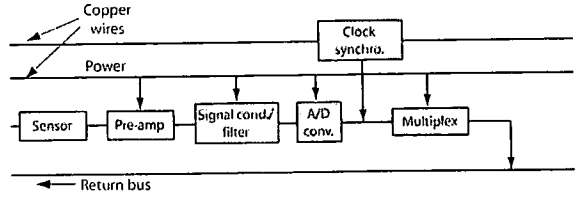


Figure 5 Conventional Electrical Sensor with its Associated Electronics



3. APPLICATIONS OF FIBRE BRAGG GRATING SENSORS

The applications of FBG sensors are growing rapidly because of their many advantages, such as immune to EMI, remote sensing, insensitive to signal intensity fluctuation, very small size and ease of multiplexing many sensors on a single fibre. Some examples of FBG sensor applications are described in the following sections.

3.1 NON-CONTACT TORSION MEASUREMENT ON ROTATING SHAFT

The torsion in a rotating shaft can be measured using two FBG sensors arranged as shown in Fig. 6 (a) and (b) [4]. The FBG sensors were mounted at 45° with respect to the axial direction of the shaft and at 90° to each other to measure pure tensile and pure compression strain. An interesting feature about this measurement technique is that the optical signal from the sensors is coupled to the measure system via a pair of collimating lenses separated by an air gap, allowing non-contact measurement. Light was launched to the FBG sensors via ports 1 & 2 of the optical circulator and the reflected light was routed from ports 2 & 3 to the interrogation unit. The tensile and compression experienced by the shaft are determined by the change in wavelength separation between the two FBG sensors and thus the fluctuation of the optical intensity does not affect the measurement results. Temperature of the shaft can also be determined by the wavelength shift of the FBG sensors.

Figure 6(a) Optical Set-up for Non-contact Torsion Measurement.

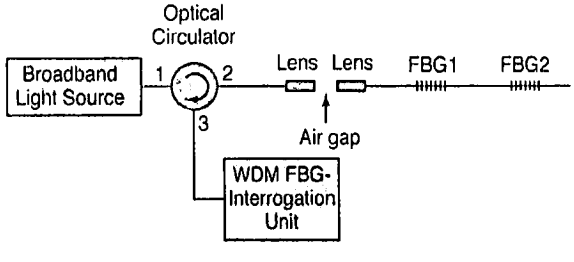


Figure 6(b) Mechanical Experimental Set-up. Inset shows the Mounting of the FBG Sensors on a Rotating Shaft

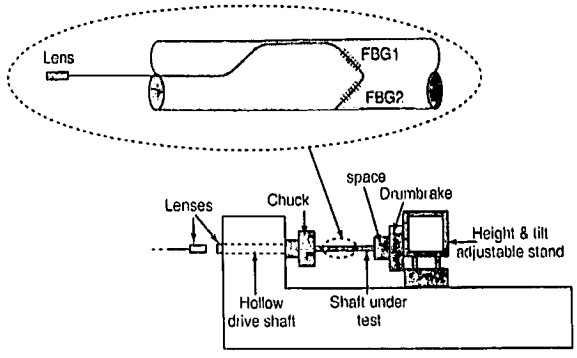


Figure 6(c) Experimental and Theoretical Results of the Non-contact Torsion Measurement

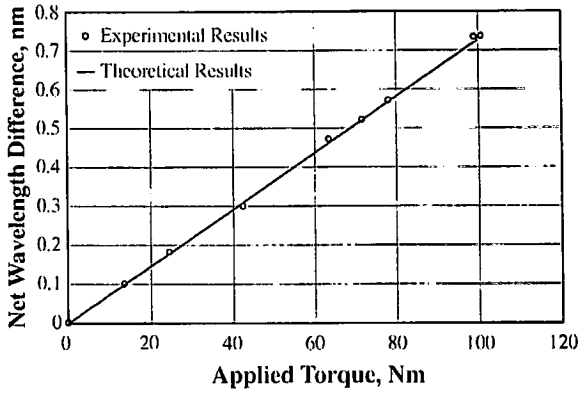


Figure 6 (c) shows the measurement results of the experiment and they are in excellent agreement with the predicted results.

3.2 ACOUSTIC WAVE MEASUREMENT USING FBG SENSORS

FBG sensor has been successfully utilized to measure acoustic pressure in water [5]. The experimental set-up for the measurement of acoustic pressure is shown in Fig. 7 (a). A narrow linewidth semiconductor laser is tuned such that its emission wavelength is positioned to the slope of the transmission spectrum of the FBG sensor, as shown in Fig. 7 (b). When the FBG is subjected to acoustic pressure, it's spectrum shifts and consequently changes the reflected power as well as transmitted power of the FBG. As shown in Fig. 7 (b), when the spectrum shifted from the solid spectrum to the dashed spectrum, the level of light transmission reduced from A to B.

Figure 7(a) Experimental Set-up for the Detection of Acoustic Pressure using FBG Sensors

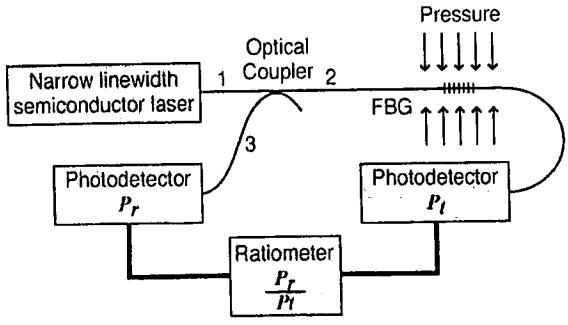


Figure 7(b) Transmission Spectra of FBG Sensor when Subjected to Acoustic Pressure

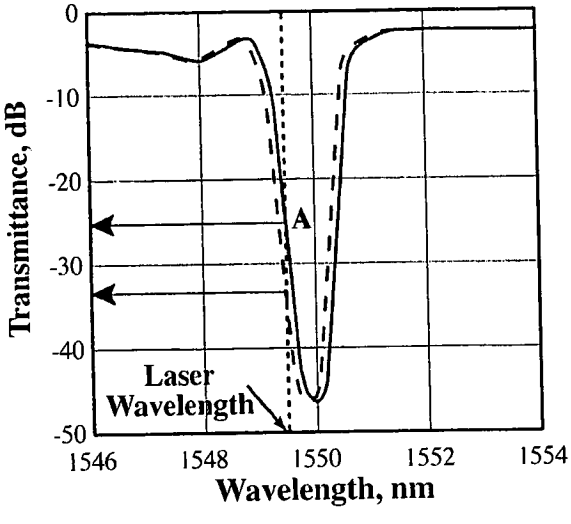


Figure 7(c) Sound Pressure Dependence of FBG Sensor

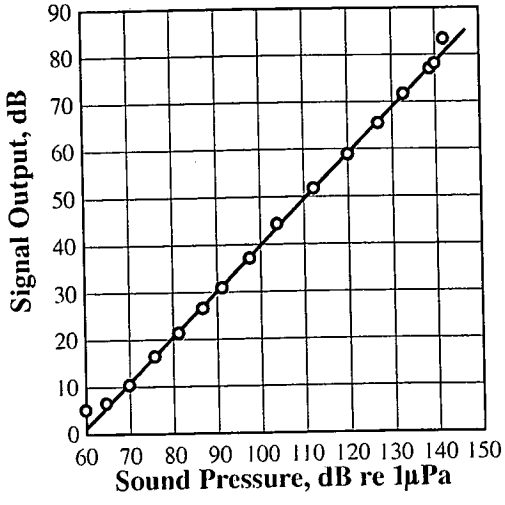


Figure 7(d) Frequency Dependence of FBG Sensor

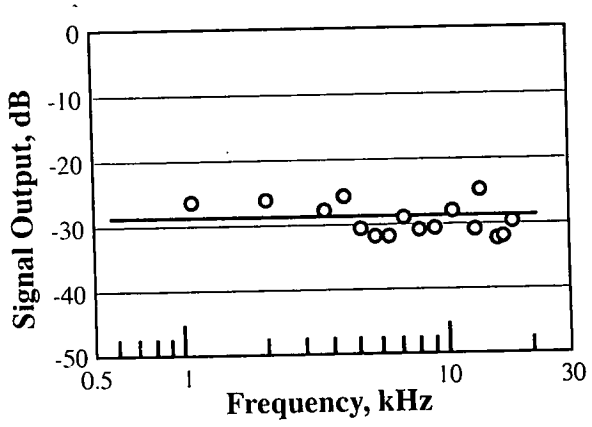


Fig. 7 (c) shows the measured results on the dependence of the ac component of the reflected optical power on the applied sound pressure in water. The dynamic range is more than 70 dB. Dependence of the FBG sensor on acoustic frequency is shown in Fig. 7 (d). The frequency response of the FBG sensor is flat over the frequency range. The maximum frequency of 18 kHz was limited by the experiment. However, the FBG sensor is expected to operate over a wide range of acoustic frequency. One of the potential applications of FBG acoustic sensor is in the detection of partial discharge in high-power oil-filled transformers.

3.3 ULTRASONIC HYDROPHONE BASED ON FBG LASER SENSOR

A novel fiber-optic hydrophone that uses a dual polarization distributed Bragg reflector (DBR) fiber laser as sensing element was invented and demonstrated at the Photonics Research Centre of The Hong Kong Polytechnic University [6]. The operation principle is based on the modulation of the birefringence of the fiber laser by high-frequency ultrasound. By measuring the amplitude and frequency of the sidebands as well as the polarization beat frequency of the output of the fiber laser using a photodetector and a rf spectrum analyzer, the amplitude and frequency of the acoustic pressure, and temperature can be determined simultaneously. The DBR fiber laser hydrophone has a linear response to acoustic pressure and can detect acoustic frequency up

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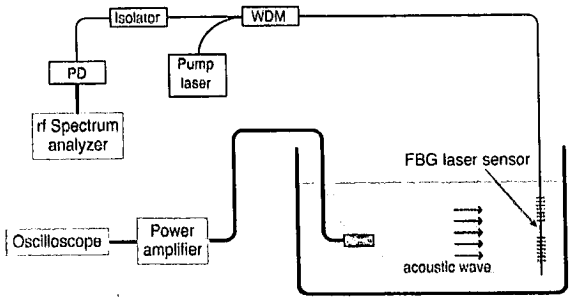
to at least 40 MHz. Fig. 8 shows the experimental setup. The fibre grating laser-based sensor is excited by a pump laser, and the output of the laser sensor is measured with a photdetector connected to an rf spectrum analyzer.

Figure 8 Schematic Diagram of the Experimental Setup. WDM: Wavelength Division Multiplexer; PD: Photodetector



The DBR fiber laser consists of a pair of wavelength-matched Bragg gratings written in an active fiber with appropriate separation. It operates in two orthogonal eigen-polarization modes due to the fiber birefringence introduced during fiber fabrication and grating inscription. The frequency difference between the two modes is given by

$$\Delta\nu = \frac{B\nu}{n} \qquad (2)$$

where ν is the lasing frequency, B and n are the birefringence and refractive index of the optical fiber, respectively. The polarization beat frequency, Δν, of the laser can be measured with a photodetector and a rf spectrum analyzer. When the DBR fiber laser is subjected to an acoustic field, the acoustic pressure changes the fiber refractive index owing to the photoelastic effect. For acoustic wavelength much larger than the fiber diameter, the induced index change is isotropic, whereas for acoustic wavelength comparable with or much smaller than the fiber diameter, the acoustic pressure induces different index changes along and perpendicular to the direction of the acoustic wave and therefore changes the fiber birefringence. In the case that a high frequency (>1 MHz) plane ultrasonic wave is incident normally upon a fiber, the induced change in birefringence is given by

$$\Delta B = k p_a \sin\omega_a t \cos 2\theta \qquad (3)$$

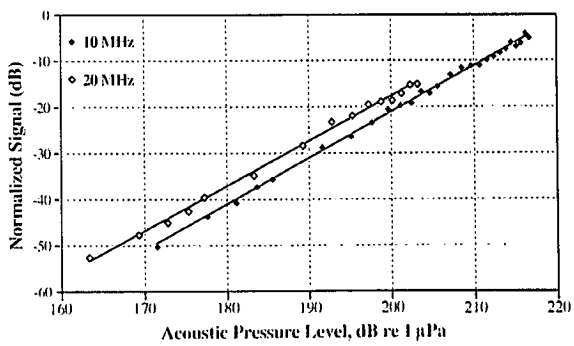
where k is a constant depending on the acoustic frequency, and the photoelastic coefficients and refractive index (seen by the ultrasonic wave) of the optical fiber. p_a and ω_a are the amplitude and angular frequency of the acoustic pressure, respectively. θ is the angle between the polarization axis of the fiber and the propagation direction of the acoustic wave. Hence ultrasound results in frequency modulation of the beat carrier produced by the fiber laser. By measurement of the frequency and the amplitudes, relative to the carrier, of the upper and lower sideband components, the angular frequency and the amplitude of the acoustic pressure can be determined simultaneously. In most practical situations the acoustic pressure along the fiber is not uniform. Provided that the fiber is parallel to the acoustic wavefront (i.e. the line of constant phase), the induced beat frequency change is given by

$$\delta\Delta\nu = \Delta\nu \frac{k\int_0^L p_a dl}{BL}\cos 2\theta \sin\omega_a t \qquad (4)$$

where L is the cavity length of the DBR fiber laser. Therefore, the readout of the sensor is the line integral of the acoustic pressure amplitude across the laser cavity.

Fig. 9 shows the experimental results of the fibre grating laser-based ultrasound sensor for measuring 10 MHz and 20 MHz ultrasonic signals.

Figure 9 Normalized Magnitude of the First Order Sideband versus Ultrasound Pressure Measured with a Commercial PVDF Membrane Hydrophone



A linear relationship between the measured magnitude (normalized with the carrier magnitude) of the first-order sideband and the ultrasound pressure was obtained.

3.4 FBG SENSORS FOR RAILWAY APPLICATIONS

The applications of FBG sensors in railway networks are enormous. Examples include axle counting, on-line measurement of train speed, train weight estimation, wheel imbalance weighting, train identification, detection of untoward activities, etc. FBG sensor system is best suited for railway monitoring due to its many unique features that are not found in electrical monitoring systems. These include EMI immunity, long distance remote sensing, and wavelength-encoded signal. The unique wavelength-encoded sensing information of FBG sensors means that variation of signal amplitude is not important since amplitude changes would not affect the measurement results because wavelength is an absolute parameter. This means that signal amplitude changes due to changes in transmission line loss would not affect the integrity of the sensing signal and thus offers maximum signal security and reliability to railway network. Preliminary experimental investigation of FBG sensors in KCRC station demonstrate the huge potential of FBG sensing system in locating train position, measuring train speed, estimating train weight, and measuring wheel imbalance. Fig. 10 shows some of the on going projects being conducted at the Photonics Research Centre of The Hong Kong Polytechnic University.

Figure 10 Applications of FBG Sensors in Railway Engineering

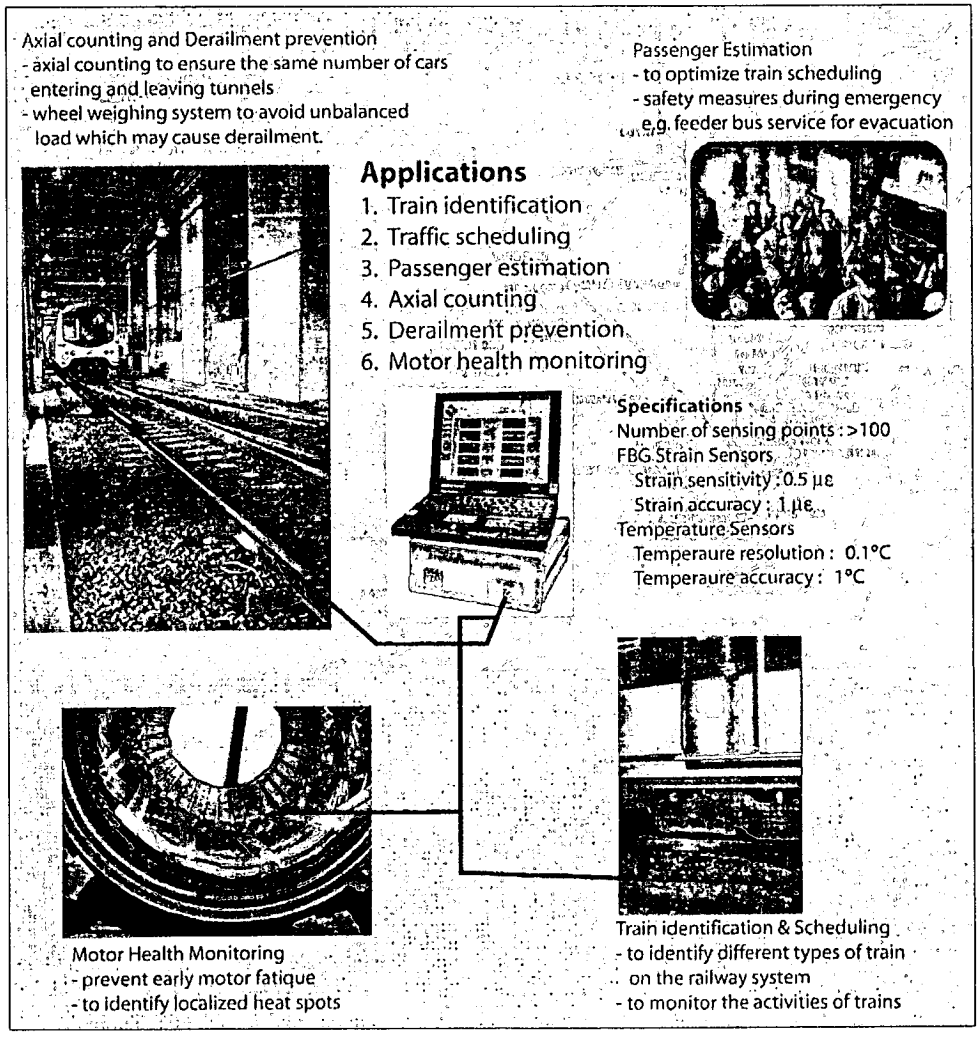


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Figure 11 Experimental Results of FBG Sensor for Train Speed Measurement. Inset shows the Rail Track with FBG Sensor

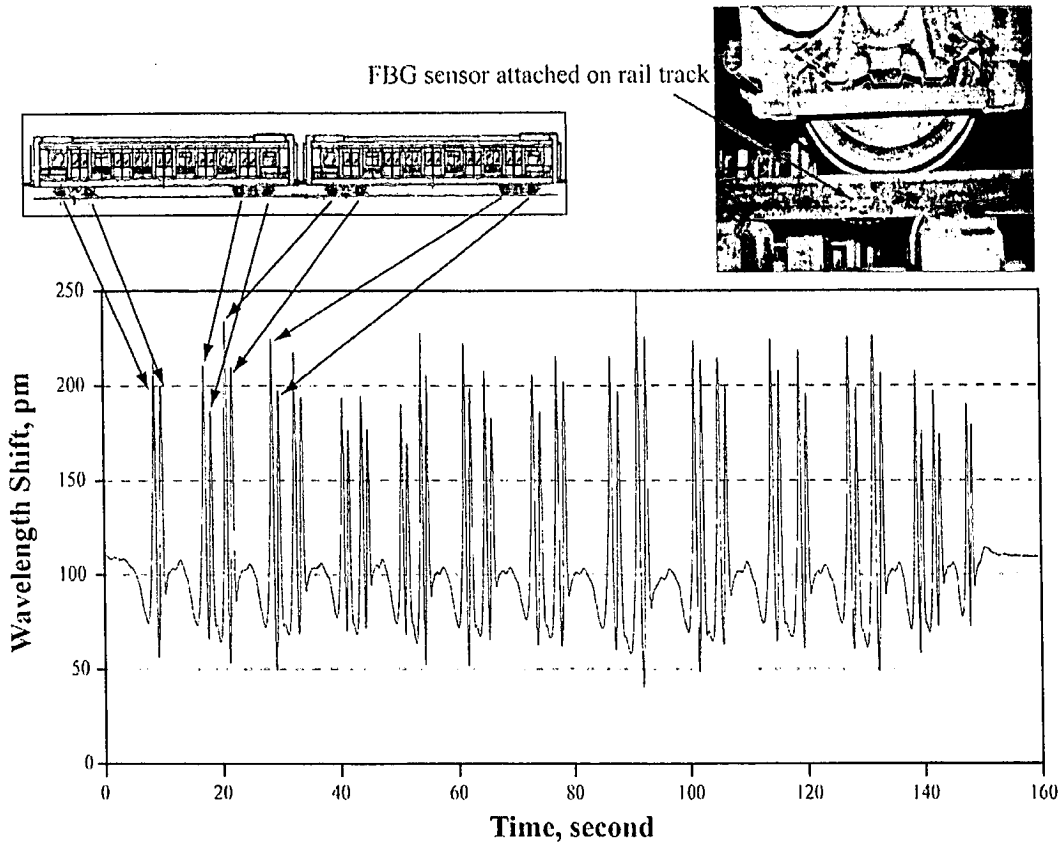


Fig. 11 shows the measured result of an FBG installed on a KCRC rail track. Each individual wheel passing through the FBG sensor is clearly identifiable. Since the distances between the wheels are known, train speed can be easily computed by using just one FBG sensors. Alternatively, two FBG sensors installed on rail track, separated by a known distance can also be used to measure train speed. The wavelength shift, i.e. the amplitude of the peaks shown in Fig.11 is related to the force applied to the sensor by the wheel passing over it.

3.5 MONITORING OF TSING MA BRIDGE USING FBG TEMPERATURE AND STRAIN SENSORS

Sensors for strain measurement are indispensable for structure monitoring. Fiber Bragg Grating (FBG) technology are found to be suitable for strain sensing and have a number of advantages compared to conventional strain gauges. Recently, we carried out a field trial with a FBG sensor array system on the world's longest span suspension bridge carrying both trains and regular road traffic (The Tsing Ma Bridge in Hong Kong). The experiment was carried out with a high-speed dense-channel demultiplexing/ interrogation system for FBG sensor arrays (DC to ~20 kHz for all channels simultaneously). More than 40 FBG sensors divided into 3 arrays were installed on different parts of the bridge (suspension cable, rocker and frame section), as shown in Fig. 12. The goal of this field trial is to monitor the strain of the different parts of the bridge under railway load and highway load. Various measurements were performed including an overnight measurement of about 20 hours with a sampling frequency of about 500 Hz. The measurement results reveal the presence of significant higher frequency components in the FBG sensor signal during train passages. The results of the FBG sensor also compared with existing strain gauges. Although the sensors are not located at exactly the same location, great resemblance has been found.

Figure 12 Forty FBG Sensors are installed on the Tsing Ma Bridge to Measure Temperature and Strain at (1) Truss Girders, (2) Rocker Bearing, and (3) Hanger Cable. (4) is the FBG Interrogation System Developed by the Photonics Research Centre of The Hong Kong Polytechnic University.

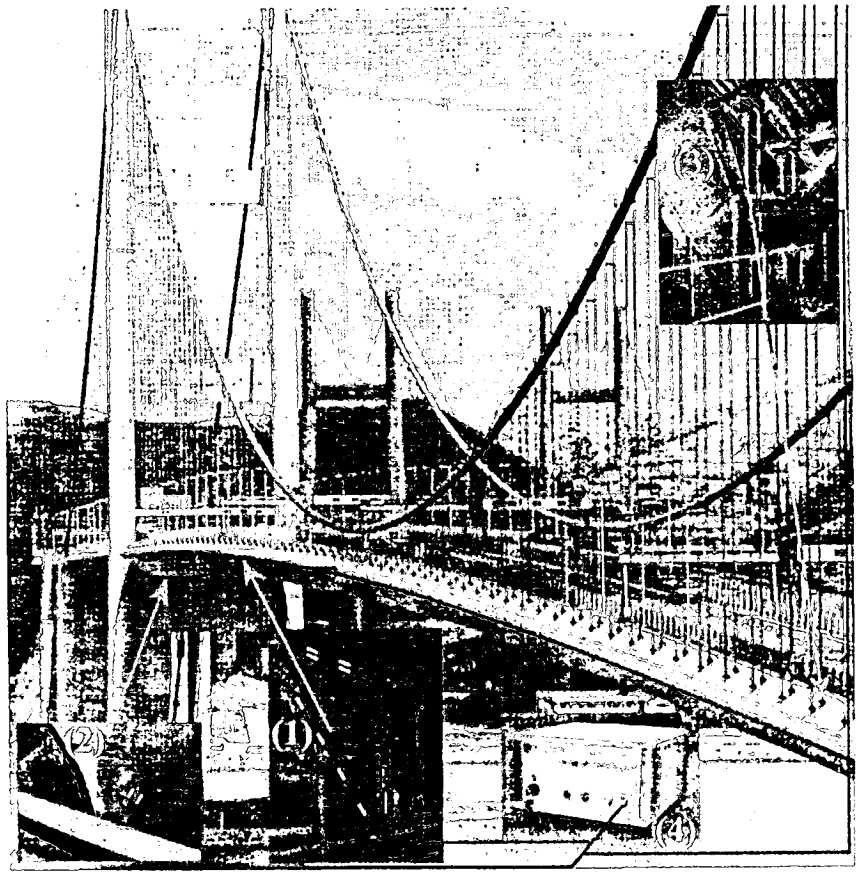
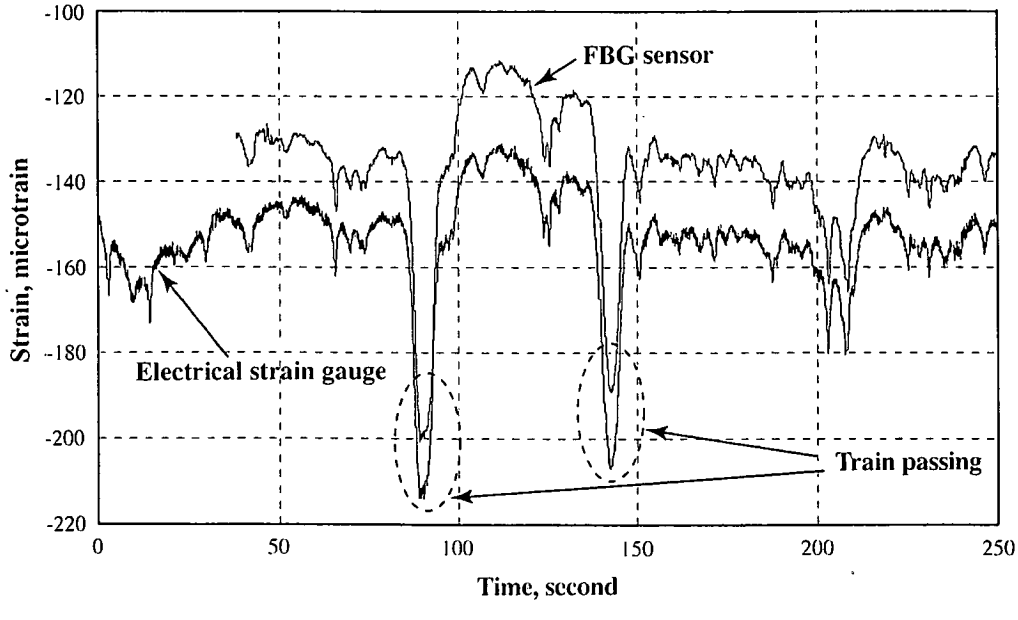


Figure 13 Comparison Between FBG Strain sensor (Upper Trace) and Strain Gauge (Lower Trace) installed on Frame of Section 23 of Tsing Ma Bridge.



In Fig. 13, the signal of a FBG is compared with the signal of the corresponding strain gauge. The sampling time of the FBG sensor is 0.0528ms. A moving average filter of 10 points is applied to the data of the FBG sensor and the detection bandwidth of the FBG sensor is reduced to about 2 kHz. The FBG sensor signal has also an arbitrary offset for display purpose. Although the sensors are not located at exactly the same location, great resemblance has been found.

4. SUMMARY

In summary, we have described the fibre Bragg grating sensors technology and some of their many applications in electrical engineering. The advantages of FBG sensors such as immunity to EMI, remote sensing and multiplexing capabilities, are particularly useful to the electrical engineering industry. Examples of their uses in the measurement of pure tensile and compression strains in rotating shaft, detection of acoustic waves up to 40 MHz frequency, train speed measurement and the measurements of temperature and strain on various sections of TsingMa Bridge are briefly explained. The potential application of FBG sensors is huge and it is expected to grow even more rapidly in the coming years.

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Paper No. 3

ACHIEVING WORLD CLASS ELECTRICITY SUPPLY – THE HONGKONG ELECTRIC EXPERIENCE

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ACHIEVING WORLD CLASS ELECTRICITY SUPPLY – THE HONGKONG ELECTRIC EXPERIENCE

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ABSTRACT

Reliable and sufficient electricity supply is essential for the prosperity and success of a world-class city like Hong Kong. Being one of the two electricity suppliers in Hong Kong, the Hongkong Electric (HEC) has been supplying electricity to Hong Kong Island, where the major financial, economical and cultural centres located, for over 110 years. For the past 8 consecutive years, HEC has achieved an electricity reliability of 99.999%, which is one of the best in the world.

This paper describes the various aspects that HEC has considered, from equipment and network design, asset management to knowledge management, in order to achieve such reliability rating.

1. INTRODUCTION

The Hongkong Electric Co., Ltd. is a vertically integrated power company. The electricity generated in Lamma Power Station is transmitted at very high voltages to the load centres in Hong Kong Island where the power is then distributed to the customers at lower voltages. To achieve a high overall supply reliability rating, not only every major equipment along the generation, transmission and distribution chain must be reliable but also the transmission and distribution network should also be designed to take into account of and be capable to handle all reasonably foreseeable contingencies in the system.

Reliability considerations should be applied system-wide in every aspect of asset management which include the construction, operation and maintenance of transmission and distribution equipment and network. Asset management should also contain mechanism to continuously and consistently capture and analyze internal performance data and external incidents regularly, critically and structurally. This will enable derivation and implementation of improvement plans to up keep the performance of the system in anticipation of its aging, new failure modes and customer expectations.

Apart from the above, knowledge management also plays an important role to ensure the reliability of the system over a long period of time. Through systematic development, assessment and skill enhancement programs, engineers responsible for the operation, construction and maintenance of the system would not only acquire the necessary knowledge and skill to perform their daily tasks competently but also to identify potential pitfalls in the system before significant defect evolved.

In the following sections, the above aspects for transmission and distribution system will be elaborated in greater details.

2. NETWORK DESIGN

2.1 TRANSMISSION NETWORK

In the past century, the transmission system of HEC had undergone several major changes. Some of the changes were load driven while others were reliability related. In the post war era, the transmission voltages were only 6.6kV and 22kV. Afterwards, 33kV and 66kV were introduced in 1958 and 1964 respectively. In 1971, 132kV transmission system was first introduced followed by 275kV in 1982. The transmission network gradually evolved from

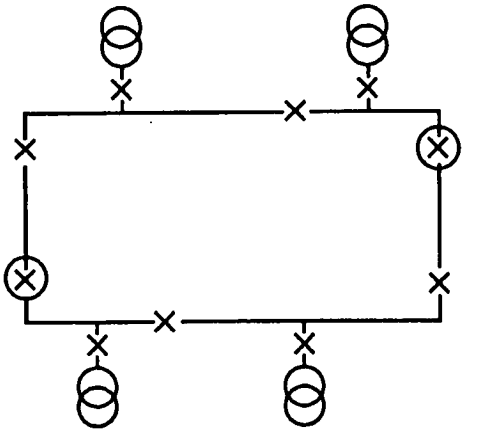
the post war radial system to a highly interconnected mesh system at 275kV and 132kV level of today as system demand increased by 13 folds in the past 40 years.

The transmission networks in HEC are designed to meet n-1 criteria. The networks are highly interconnected to provide the necessary redundancy in case of contingencies. Different busbar configurations, including single busbar, double busbar, mesh and 1-1/2 breakers have been used at different time and locations. System behaviours for different types of fault under different busbar and network configuration were reviewed regularly. This in turn would enable contingency plans to be drawn up accordingly.

Apart from network topology, key factor which contributes to high transmission reliability is the extensive use of underground transmission system. Our 275kV system is 100% underground while over 90% of the 132kV system is underground. This has made our system highly immune to the effect of adverse weather, typhoon and lightning strikes, which is particularly important in subtropical area like Hong Kong. To further minimize the impact of external interference, due consideration had been taken into account in planning of cable routes. Dedicated cable tunnels were built to avoid external interference. Parallel circuits would be laid in different routes as far as practicable to avoid simultaneous loss of multiple circuits in case of external damage.

Power transmitted at high voltages will be stepped down to lower voltages for distribution in zone substations. Each zone substation would normally be equipped with 4x40MVA or 4x60MVA zone transformers from the 275kV or 132kV network. The low voltage side of the transformers are connected to 4 single busbars, which are connected in mesh configuration. Under normal configuration, the transformers would be operated in pair and tripping of any transformer or its supply circuit would not result in any supply interruption. Following the tripping of one of the four zone transformers, the zone substation busbar would automatically be reconfigured to share the load among the remaining 3 transformers. This immunity to loss of supply to our customer due to transmission fault contributes significantly to the overall reliability rating. The typical zone substation 11kV busbar arrangement is shown in Figure 1.

Figure 1 Typical Z/S 11kV Busbar Arrangement



Initially single bus-section switches were installed in zone substation to connect two busbar sections. Fault on this bus-section switch, though remote, could cause simultaneous black out of the two adjacent busbars, affecting a considerable area of supply. New designs eliminate this weakness by using cable interconnectors between bsubars to further enhance reliability.

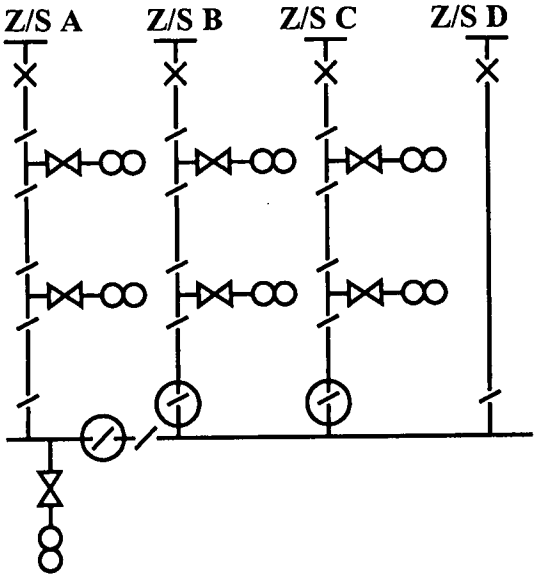
2.2 MV DISTRIBUTION NETWORK

6.6kV distribution was first introduced in HEC in 1946 as the MV distribution network. 11kV was then introduced in 1961 to phase out the 6.6 kV distribution to meet the increasing demand in electricity. At present, 11kV is still the major distribution voltage in HEC.

The HEC MV distribution system is 100% underground which is immune from adverse weather conditions. The configuration of 11kV distribution system is in the form of open ring with ring main unit installed along each feeder. Normally 4 radial feeders are connected together to form a feeder group. 3 feeders would be loaded to its rated capacity while one

lightly loaded feeder would serve as the backfeed source. The feeders forming the group would be fed from different zone substations or busbars to improve supply security. The typical 11kV feeder group is shown in Figure 2.

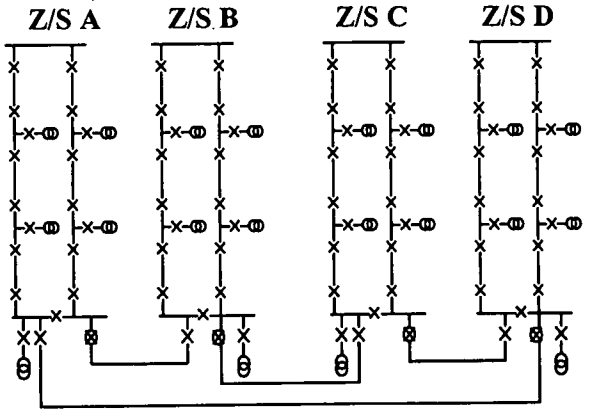
Figure 2 Typical 11kV Network



The 11kV network is secure, simple, flexible and yet has reasonable feeder utilization ratio. Each distribution substation would be connected to 2 sources. Should the main source fail, the backfeed source could be switched in to maintain the supply. However, the open ring configuration has the drawback that all customers of the feeder would suffer from supply interruption if any fault occurs in the feeder until the backfeed source was switched in. To enable fast restoration of supply on 11kV network, HEC had commissioned its distribution automation project in 1981 and today have achieved 100% remote control and supervision in all distribution substations. Fault detection and isolation can then be done remotely and promptly. The average restoration time achieved in 2003 is less than 3 minutes.

To meet the ever-increasing demand of electricity supply, reliability and power quality and to overcome the problem of mutual heating among cables installed underground, HEC had introduced its 22kV closed ring distribution network for new development areas to supplement its 11kV network in 2003.

Figure 3 Typical 22kV Network



The 22kV network operates in the form of close ring and a maximum of 4 rings are interconnected to form a group. This topology would achieve continuity of supply in case of any single cable fault. The typical 22kV distribution network is shown in Figure 3.

2.3 LV DISTRIBUTION NETWORK

Reliability of LV distribution system is also critical as any failure would have prolonged impact to the customer concerned.

LV distribution network consists mainly of underground cable and a small portion of insulated overhead line in rural areas. To improve the supply reliability under adverse weather condition, HEC had started its overhead line refurbishment projects some ten years ago. Aerial bundled cables with galvanized steel poles and hardware were introduced to replace the painted steel poles and the older 4/5 wires overhead line system. In addition, undergrounding of the LV overhead line in selected areas were also carried out with encouraging results.

Much effort had also been spent to improve the LV network which was originally designed in a radial feed manner. To improve the network integrity and backfeed capability, turn in-out arrangement for main cable had been adopted

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to replace the tee off services arrangement in the 1980's. Through strategic network reinforcement, over 50% of the LV feeders are now connected to more than one supply source to provide some form of backfeed in case of LV cable failure. New equipment design, such as in/out link type cutout and LV switchable ring main unit etc. are progressively introduced to effectively implement such interconnected LV system.

3. ASSET MANAGEMENT

3.1 ASSET DESIGN

Whenever major equipment is planned to introduce in the system, a design review committee comprising members of various stakeholders will be formed to critically assess the technical specification of the equipment. Opinions from operational staff on the operation and maintenance aspects would be sought and incorporated into the technical specification where appropriate. Emphasis would be placed to ensure only proven technology from stable and reputable suppliers are selected. Technical visits to other users to collect first hand information regarding the performance and reliability of the equipment will be conducted if necessary. Pre-tender factory visit to assess the quality and capability of the potential suppliers will also be conducted by the design review committee if appropriate.

Pre-qualification site trial may be conducted to short-listed suppliers. Operational feedback would also be sought during the site trial. For some critical equipment, full scale mock up long-term energisation test may be conducted before large scale implementation of the equipment in the system. All the above steps are taken to ensure only the most suitable and reliable equipment will be introduced in the system.

3.2 ASSET MANUFACTURING AND CONSTRUCTION

Stringent production control is required to ensure the equipment are manufactured to meet the high reliability standards at all time. Factory quality audit would be conducted by the design review committee to check the quality procedures and quality records. In addition, discussion with all levels of manufacturing personnel will also be conducted to reinforce the reliability awareness of the one producing equipment for us.

In addition to factory quality audit, critical items such as cable, joints, terminations etc., will be subjected to sample inward quality inspection to ensure quality compliance. Such quality inspections are normally carried out by internal resources. The whole batch of goods would be quarantined should any deviation from the specification or abnormality be found. Rectification must be carried out by the supplier before the goods could be released for use, otherwise the whole batch would be rejected. The inward quality inspection is found to be a very effective tool in spotting out manufacturing defect, transportation and kitting problems etc. commonly associated with distribution equipment and is a important step in quality control. Repeated rejection would be investigated and re-audit on the supplier's QA/QC system would be carried out if deem necessary.

Apart from design and manufacturing, site construction of asset is also under strict control. Only qualified installers are allowed to carry out the specific kind of installation work. Training of qualified installers would include workshop training as well as on site assessment. Only those installers acquired the necessary skill and pass both the workshop and on site assessment would be allowed to carry out the construction work. Refresher course would be arranged regularly to up keep the trade skill of installers. Proper technical manual are made available to the installers and forms are designed to guide the supervisors and installers to ensure the equipment are constructed to the required standard.

3.3 ASSET OPERATIONS, MAINTENANCE AND REFURBISHMENT

Clear demarcations of plant ownership are defined within HEC. The plant owner shall be

responsible for the routine operation, maintenance and housekeeping of the plant. The plant owner would work closely with the plant designer to monitor the performance of their plant and derive refurbishment / improvement plans if required.

Maintenance policies are derived by the plant owner with the advices from the plant designer and suppliers, taking into account of their own operating experiences and specific local conditions. Suitable maintenance methodologies including preventive, predictive and detective maintenance would be adopted depending on the type and relative reliability importance of the asset and its position in the system.

In-house developed computerized maintenance scheduling system integrated into the asset database and work management system is established to keep track of the maintenance activities of the plant.

In addition to maintenance scheduling, a computerized system is also developed in-house to keep track of the performance of the plant. Any abnormality found would be recorded in the system. The plant owner should then investigate and rectify the defect. The essence of the computerized system is to capture each defect occurrence and every defect, no matter how minute, must be handled and recorded in a close loop manner. Based on the data captured, the plant owner could carry out statistical analysis on the performance of his plant and appropriate improvement plan be derived. Improvement recommendations could either be repairing, replacement or refurbishment depending on the cost and reliability impact analysis and the technical constraints faced.

To ensure the T&D system would function satisfactorily under foreseeable contingencies, the plant owner should also conduct failure consequence analysis and derive suitable contingency plans for his own plants. The plans would be reviewed and drills would be conducted regularly to ensure all parties involved are conversant with the plans.

4. RELIABILITY MANAGEMENT

4.1 STEERING ORGANIZATION AND FEEDBACK MECHANISM

Reliability of the T&D system is managed through a 3-tier steering and review structure. The top tier is the reliability directive from the management. The second tier is a high level working committee comprising of members from management, system control and various plant owners to formulate reliability policies and plans. The third tier is the working level tier which comprises of various regular technical and reliability meetings on transmission and distribution system. In addition, a comprehensive reliability review on every operational aspects of the T&D system will be conducted by the plant owner to critically review the performance of the system, from major equipment to auxiliaries. Such review will be carried out periodically and recommendations are classified into different priorities for implementation. Through this 3-tier system, which embraces both the top-down and bottom-up approaches, the concept of reliability could be disseminated to each level of the company. In addition to regular meeting, adhoc meeting/committee in response to a specific reliability issue may also be set up as and when required.

The concern of reliability is not only confined to within HEC. Regular QA/QC meeting with major suppliers on the quality issues will also be conducted to review the quality and reliability issues related to their equipment. This arrangement will eliminate any gap between HEC and its major suppliers on the quality and reliability standard.

4.2 KNOWLEDGE MANAGEMENT

A stable and competent workforce is essential to maintain the reliability of the system. HEC has an established in-house training and development plans for engineering staff. Technical expertise would be passed on to young engineers through on job training and job rotation. Succession plans are worked out to identify and develop key personnel for asset development and management. A stable

workforce is therefore one of the key success factors in reliability achievement.

To assess and classify the technical competency of the operating staff, HEC operates a comprehensive authorization and accreditation system. Only those staff authorized to a particular voltage level could carry out works and test on the equipment of that or lower voltage classes.

HEC also believes retaining the critical skill level of their installer is important to ensure consistency of workmanship and hence the reliability of the system. Many of the critical tasks such as transmission and distribution cable jointing, GIS erection etc., would be done by in-house resources as far as practicable. An accreditation system is in place to train the installer and to assess their trade skill. Manufacturer training on specialized skill will also be arranged to keep up the skill with the latest equipment development.

Other than the above, regular in-house seminars and training courses will be organized as part of the competency development training of the engineering staff and installers. The training activities are overseen by a Training Review Committee to ensure in-house training resources are deployed effectively and the training needs with emphasis on reliability are met.

5. CONCLUSION

There are many factors affecting the reliability of supply to our customers. Many of these factors are inter-related and considering the reliability of each individual element alone may not be able to yield the desired result. HEC has taken a holistic approach which embraces aspects of the design, manufacturing, asset management, reliability reviews and knowledge management to achieve a high supply reliability rating.

This approach has enabled HEC to achieve an electricity supply reliability of 99.999% for the past 8 consecutive years, which we consider a valuable asset to a world-class city like Hong Kong.

ACKNOWLEDGEMENT

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Paper No. 4

THE ELECTRICAL SYSTEMS FOR TVB CITY

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Ir W.S. Tam, Senior Associate
Ir Mac C.K. Mak, Senior Engineer
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THE ELECTRICAL SYSTEMS FOR TVB CITY

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Ir Thomas K.C. Chan, Assistant Vice President
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ABSTRACT

A competitive and modern city is certainly one that allows efficient flow of information within the city itself, and across its border to its neighbourhood regions. Watching TV programmes is a routine and an essential part of our daily life, especially in Hong Kong where the TV programmes offer the latest information and the most convenient and economical means of entertainment. The rate of dissemination of information is considered the highest amongst other modes of mass media. Also, it can reach a large number of audiences in different parts of the world at the same time.

TV broadcasters are continuously pursuing new technologies for higher quality programme production and transmission. The ability to provide consistently high quality and efficient programmes broadcasting and transmission is critical to attract advertisement sponsorship for maintaining company sustainability and growth. To achieve this end, quality electrical systems including a quality power supply system, a strategic TV broadcasting and transmission network and a powerful information technology (IT) infrastructure backbone system have become a necessity for producing quality programmes and broadcasting these programmes to the public.

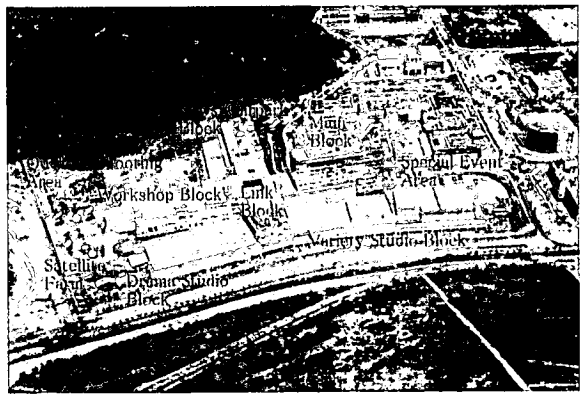
The aim of this paper is to discuss the design of various electrical systems to satisfy the above requirements for a TV production and broadcasting company in Hong Kong.

1. INTRODUCTION

The project of TKO TVB City (**Figure 1**), developed by Television Broadcasts Limited (TVB), has been completed and was put in operation in year 2003. This development is situated on a 93,200m² site at Tseung Kwan O Industrial Estate of Hong Kong. It consists of the following main buildings, an outdoor shooting area and one satellite antennae farm:

- Main Block
- Variety Studio Block
- Drama Studio Block
- News and Carpark Block
- Workshop Block
- Link Block

Figure 1 TVB City



At project design stage, it was anticipated that a large number of sophisticated electronic equipment and telecommunication and transmission systems would be introduced for TVB's programme production and TV broadcasting. These electronic equipment would be very sensitive to power quality such as power fluctuation; voltage dip; transient; surge; harmonic; noise etc. Therefore, power supply to this equipment must be of high quality.

Furthermore, TVB is one of the leading TV broadcasting companies in Hong Kong and its digital TV broadcasting system requires a

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powerful transmission and communication network. A strategic network for TV broadcasting and transmission, voice, signal and data communication is provided for its TV programme broadcasting and transmission.

2. POWER SUPPLY SYSTEM

Power supply to TVB City is demanding. The source of power supply must be secure and reliable particularly for live TV programme broadcasting, when any power interruption cannot be tolerated, even for less than one second. The power supply must also be stable and of high quality so that the quality of TV programme can be guaranteed.

Tseung Kwan O Industrial Estate is a newly developed territorial area. The 11 kV power supply from power company (CLP Power) to TVB City is fed from a single primary substation. Dual feed power supply, with a total power capacity of 16.5 MVA, from two substations to TVB City at the time of the project completion is not possible under the current CLP Power's power distribution network.

The power supply system is therefore backed up by an emergency generating plant with total power capacity of 7 MVA which is over 40% of the total normal power supply. The emergency generating plant can support TVB's normal operation even in the event of mains power failure.

In addition, the use of uninterruptible power supply (UPS) system as part of power supply system can provide higher quality of power supply which minimise power disturbances such as voltage sag, over-voltage, frequency variation, harmonic, HF noise, flicker, etc.

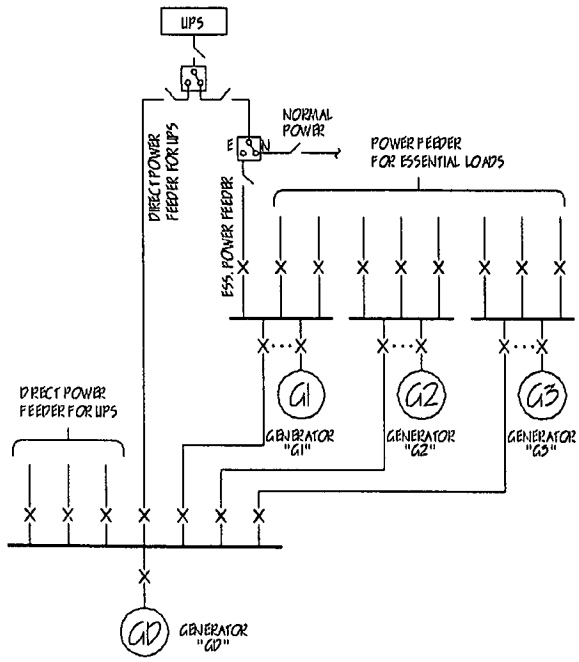
2.1 HIGH SECURE AND RELIABLE EMERGENCY POWER

The emergency generating plant (**Figure 2**) is formed by five diesel emergency generating sets with a total power capacity of 7 MVA. Besides an individual 1,250 kVA diesel generating set which is provided for fire services installation, there are 2 tiers of emergency generator system serving as a secondary power supply for backing up for all crucial and essential equipment and systems.

The first tier of generator system is formed by three diesel generators namely G1, G2 and G3 rated at 1,250 kVA, 1,600 kVA and 1,250 kVA respectively. The generators G1 and G2 back up all the most critical equipment such as TV broadcasting equipment, computer servers, telecommunication equipment, studio lighting and essential building services installations including operation lighting, air conditioning system, etc. The generator G3 backs up other essential building services installations such as passenger lifts, the remaining air conditioning system, etc.

The second tier of generator system consists of a 2,000 kVA generator numbered GD which further supports all essential loads originally backed up by either G1, G2 or G3, or selected loads of these three generators in case either one, two or all these three generators fail to start or operate when required.

Figure 2 Emergency Generating Plant



Resumption of emergency power supply to city power mains may cause momentary power break to the power supply system when the

system switches back from the standby power to the city power mains restored from failure. However, this momentary power break, no matter how short, is also undesirable for TVB's operation particularly when there is a live TV programme broadcasting. Hence, an anti-restoration control is tailor-made for the emergency generator system to prevent automatic switching of the power supply system when the mains power supply is restored. The city power mains resumption is only by manual control and under a managed manner at an agreed and appropriate moment.

Despite of the provision of a high secure power supply system, a contingency plan on the power supply system is designed and provided for TVB City for backing up some critical TV broadcasting equipment. The contingency plan caters for the scenario when city power mains and the entire emergency generating plant fail simultaneously. Provisions are made in the main low voltage switchboard for coupling with different power ratings mobile generators.

2.2 QUALITY POWER

A large amount of electronic equipment is used for TV broadcasting and programmes production processing. The intensive use of these electronic equipment requires a high quality power supply system because these electronic equipment are susceptible to power fluctuation, voltage dip, transient, surge, harmonic, noise, etc.

The following mitigation measures have been adopted in TVB City to provide a quality power supply system for these sensitive electronic equipment:

- Active Harmonic Filters
- Transient Voltage Surge Suppressors
- Technical Earthing System
- Isolation Transformers

In addition, Balanced Power Supply System (which has been installed for similar project, another movies production building in Hong Kong), is also an effective means of mitigation measure.

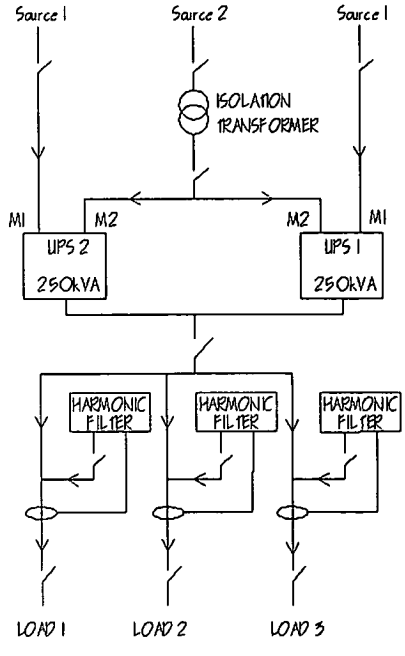
2.3 ACTIVE HARMONIC FILTER

In addition to some electrical installations such as transformers; switchboards; circuit breakers; isolators; motor starters; UPS; cables; discharge lighting; computers; etc, the electronic equipment will also generate a substantial amount of harmonic pollution to the power supply system. Most of the TV broadcasting and recording equipment are built-in with switch-mode power supply circuits of which the rectifiers and inverters will undoubtedly draw non-sinusoidal current from the power source. As a result, current and voltage harmonic distortion is formed. Such harmonic distortion will generate high neutral current, high neutral to ground voltage, zero-crossing error, etc.

The harmonic current will not only create serious and unexpected problems such as the failure of electrical equipment; overheating of electrical equipment and cables; nuisance tripping of switchgear or circuit protection device; etc, it will also create the problem of disturbance to other sensitive electronic equipment.

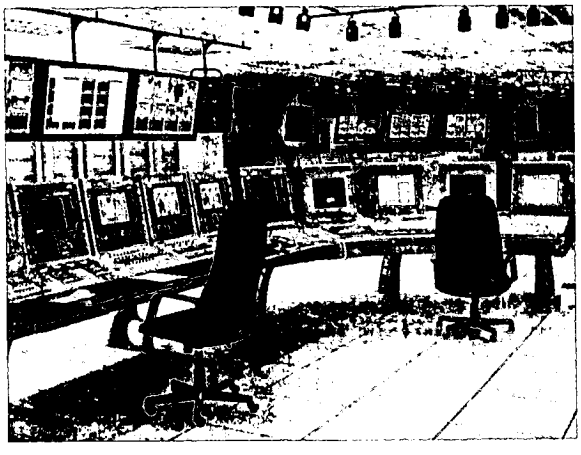
There are 5 sets of active harmonic filter installed for TVB City in total. The operation principle of an active harmonic filter is a harmonic generator that injects back the 180° out of phase harmonic current to cancel the harmonic current generated by the power supply system.

Figure 3 Active Harmonic Filter



Taking an example of three sets active harmonic filter (**Figure 3**) installed for the electronic equipment in the Master Control Room (the heart of TVB City for TV programme broadcasting) (**Figure 4**), the average total harmonic distortion (THD) is significantly reduced from 49% to 14% after installation of active harmonic filters.

Figure 4 Master Control Room



2.4 TRANSIENT VOLTAGE SURGE SUPPRESSOR (TVSS)

Provision of transient voltage surge protection for all TV broadcasting equipment is essential because all these electronic equipment are sensitive and susceptible to transient surge and all-round operation of broadcasting may be interrupted otherwise.

Surge voltages and currents in power supply system may be originated from two major sources: lightning and switching. The lightning surge includes direct strike, resistive coupling and inductive coupling to power line or telephone line while the switching surge includes capacitor switching, heavy current switching and high inductive load switching.

The use of TVSS is to suppress the voltage transient due to lightning or switching surge. Two TVSS have been installed and used for the protection of electrical equipment in TVB City, one installed in the main LV switchboard and the other adjacent to the protection-intended equipment. The design of TVSS for surge protection is in a two layered-configuration (**Figures 5a and 5b**) from the services entrance in accordance with IEEE Std: C62.41.

Figure 5a Two Layered TVSS Configuration Type A

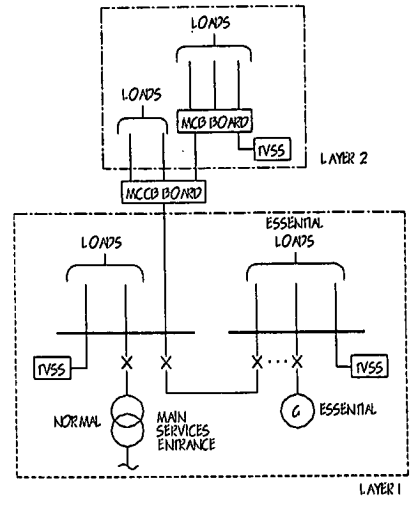
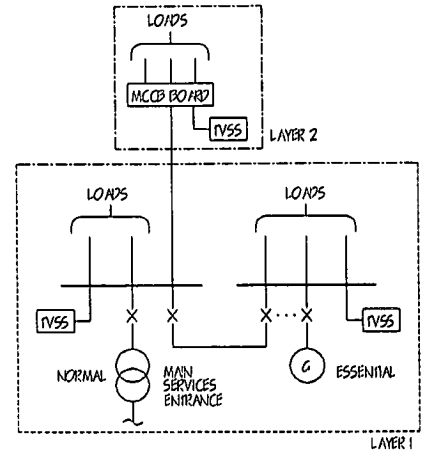


Figure 5b Two Layered TVSS Configuration Type B



2.5 TECHNICAL EARTHING SYSTEM

The noise generated by an electrical equipment may have impact on a delicate electronic equipment's operation if they are both connected to a common earth. Noise from one equipment may be transmitted into sensitive signal circuit of other equipment via the equipotential bonding conductor. To avoid such situation, a separate technical earthing system has been adopted for the TVB's broadcasting equipment including satellite equipment and dishes.

The technical earthing system protects electronic equipment by providing a clean earthing with a low impedance path to ground so that noise signal from sources of disturbance will go to ground via the technical earthing instead of going to other electronic equipment via the equipotential bonding conductor.

The technical earthing system is separated from the building earthing systems for electrical system, emergency generator system, lightning protection system and extra low voltage (ELV) systems.

How the technical earthing system can be fully and electrically separated from the building earthing system became a challenging task to achieve. To ensure that it is fully and electrically separated, the following methods have been adopted:

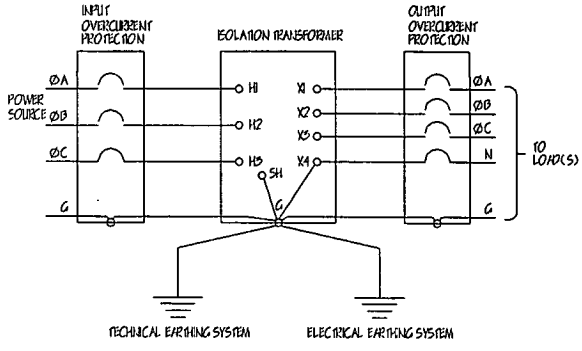
- The technical earthing system is physically separated from the electrical earth system. Besides separate technical earth pits are provided, PVC sheathed copper earthing tapes have been used for connecting the earth electrode in the earth pits and the earth terminals in the equipment room. Clips and saddles for fixing the copper tapes are made of non-metallic material.
- The technical earthing is star-point connected so that only one point of the system is connected to ground.

2.6 ISOLATION TRANSFORMER

The use of isolation transformer is to electrically isolate the power source from the loads, to filter the common mode noise, to suppress the high energy transients or spikes and to provide an isolated ground reference for sensitive electronic equipment.

250kVA isolation transformers (**Figure 6**) have been installed for the electronic equipment in the Master Control Room. Care has been taken when the isolation transformers were selected since the isolation transformers supply power to the non-linear loads. Harmonic load currents will cause additional heating on the transformer winding and hence derate the isolation transformers. In order not to deteriorate the transformer and affect the power supply stability, K-Factor has been considered. K-Factor is a weighting of the harmonic load currents according to their effects on the transformer heating, as derived from ANSI/IEEE C57.110.

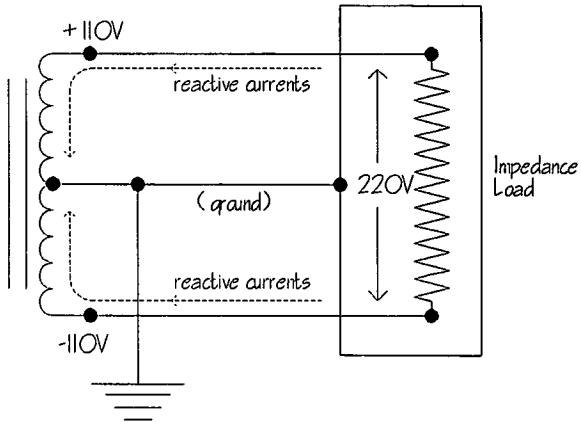
Figure 6 Isolation Transformer



2.7 BALANCED POWER SUPPLY

Although balance power supply system has not been adopted in TVB City, this system has been installed in other movies production building, Movie City in Hong Kong.

Figure 7 Balanced Power Supply Unit



3x25kVA, 3x120kVA, 9x180kVA and 3x200kVA balance power supply system are installed. The application of balanced power supply unit (**Figure 7**) is to eliminate the hum generated from the electrical system. The balanced AC supply is 220V that has been split evenly across two AC mains. One phase is +110V while the other is -110V. The AC mains are always 180° out of phase across the load

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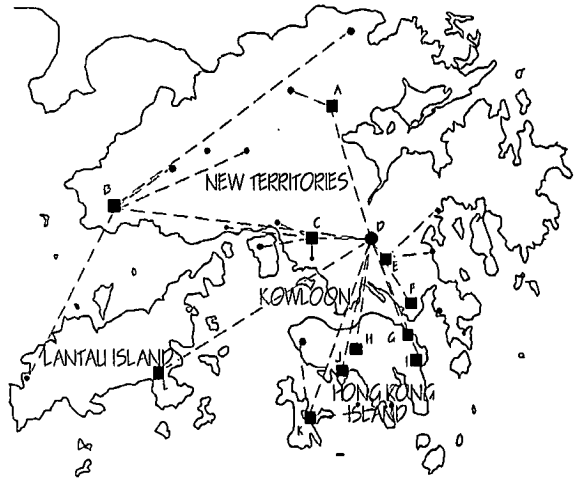
and sum to 220V. However, the ground wire is not connected to the neutral of the AC transformer as usual but located at the centre tap of secondary coil of the transformer. Such earthing arrangement will eliminate the reactive current in the ground as a source of interference in sensitive signal circuits.

Since the reactive current is 180° out of phase to each other as is the source voltage across the mains and it travels back to the centre tap of the transformer. The 180° out of phase reactive current will eventually cancel each other.

Figure 8 DTT Broadcasting Network in Hong Kong



A – Cloudy Hill
B – Castle Peak
C – Golden Hill
D – Temple Hill
E – Kowloon Peak
F – Chi Keng Wan Shan
G – Sai Wan Shan
H – Mt. Nicholson
I – Pottinger Peak
J – Brick Hill
K – Lamma Island
L – Hill 275

Transport stream will be transmitted via fibreline network from Temple Hill which is the TVB's main transmitter station to 11 hilltop transposer stations (Slave Single Frequency Network Stations). Minimum of two fibrelines are installed for linking Temple Hill to each slave transposer station. The maximum transmission rate for transport stream is 45 Mbps which is much faster than the traditional analogue transmission network of 20 Mbps.

3. TV BROADCASTING AND IT INFRASTRUCTURE NETWORK

Supplementary to the secure, reliable and quality power supply system, a strategic TV broadcasting and IT infrastructure network is also provided for supporting TVB's digital TV programme production; broadcasting and transmission. It provides a quality and high speed means for TV programme broadcasting as well as voice, signal and data transmission.

The TV broadcasting and transmission and IT infrastructure network not only covers all buildings in TVB City with a total site area of 93,200m², it also links up a number of transmission hilltop sites, and dedicated offices and buildings located in different areas in Hong Kong via optical fibre cable network.

3.1 TV BROADCASTING AND TRANSMISSION NETWORK

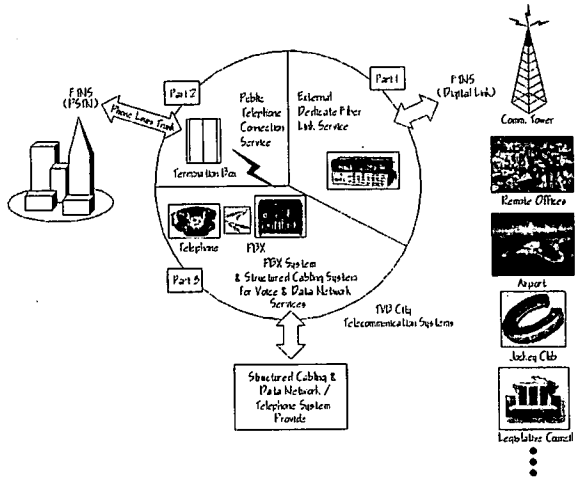
The network for TV broadcasting and transmission supports TVB's Digital Terrestrial Television (DTT) Broadcasting Network (**Figure 8**). External optical fibre links have been provided and connected between TVB City and a number of hilltop and rooftop transmission sites that are orientated at difference locations in Hong Kong.

3.2 VOICE, SIGNAL AND DATA COMMUNICATION SYSTEM

The IT infrastructure network provides TVB with a voice, signal and data communication system with a multi-product and multi-vendor

environment. Telecommunication equipment and cabling installation are intended to serve the commercial enterprises. The structural cabling system is capable of supporting the diverse telecommunication needs of building occupants. Its performance and technical criteria are suitable for various types of cabling and connecting hardware and for different cabling system design and installation.

Figure 9 TVB's Telecommunication System



The IT infrastructure network for TVB's telecommunication system (**Figure 9**) is divided into 3 parts:

- Public Telephone Connection Services from Fixed Telecommunication Network Services (FTNS) to TVB City PABX rooms.
- PABX system, structural cabling system and voice and data network services.
- External / dedicated optical fibre links.

3.3 PUBLIC TELEPHONE CONNECTION SERVICES

Telephone incoming cables to two PABX rooms of TVB City are fed from telephone company's two different telephone cable exchanges. The telephone service is very secure. When one group of telephone cables is broken down or one telephone exchange is out of service, the telephone system will remain in service through other group of telephone cables of the other telephone cable exchange.

3.4 PABX SYSTEM & STRUCTURAL CABLING SYSTEM

3.4.1 PABX SYSTEM

Five sets of PABX system are installed in five separate buildings and these five sets of PABX system are interconnected to form a complete PABX system. The initial capacity of the PABX system is about 3,000 extensions. The system is expandable to user's need in the future.

3.4.2 THE STRUCTURAL CABLING SYSTEM

The structural cabling system is formed by combination of optical fibre cables and Unshielded Twisted Pairs (UTP) Cat. 6 cables. Optical fibre cables are used for interconnection for all buildings and satellite farms while UTP cables are used for vertical and horizontal cabling run within each individual building.

The design and installation of structural cabling system are based on ANSI/TIA/EIA 568 [Telecommunications Building Wiring Standard]; UTP Category 6 Standards.

The EIA/TIA Standards defines a generic cabling system which is application dependent and supports assorted cabling components. It provides a flexible cabling structure such that changes are both straightforward and easy to implement.

3.4.3 EXTERNAL / DEDICATED FIBRE LINKS

External/dedicated audio and video fibre links are connected between TVB City and different buildings in Hong Kong via the telephone company's cabling network. The buildings include Government offices, Chek Lap Kok Airport, Registration Council, Happy Valley Jockey Club, etc. Live broadcasting in these buildings can be performed via the means of these external / dedicated fibre links.

4. CONCLUSIONS

Electrical systems are essential in that they are supporting the smooth running of all business, financial and industrial activities. Stable and quality power supply systems, coupled with powerful TV broadcasting and transmission and IT technologies, are no doubt prerequisite to a city's competitiveness. At an individual level, these systems and technologies have enriched one's daily life, to a certain extent. For instance, TV broadcasting programmes have become a major entertainment for many of us and it is appreciated that there is an ever ending demand for better audio and visual effects of the programmes. Without a quality power supply system, powerful TV broadcasting and transmission and IT infrastructure network, TV broadcasting business will not be able to sustain. All in all, investment in quality electrical systems is a must to increase a city's competitiveness.

ACKNOWLEDGEMENT

The authors would like to express their sincere thanks to the Television Broadcasts Limited (TVB) and Parsons Brinckerhoff (Asia) Limited for the permission to publish this paper.

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Paper No. 5

WEB-BASED REMOTE MONITORING OF ELECTRICAL SUPPLY AND DISTRIBUTION SYSTEMS IN BUILDINGS

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Ir Victor C.H. Yeung, Building Services Engineer
The Government of the HKSAR

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The Government of the HKSAR

ABSTRACT

This paper describes the pilot scheme of a web-based remote monitoring system for monitoring the electrical supply and distribution systems in government buildings. This monitoring system is implemented using power analyzers together with a management unit to process and transfer data through broadband Internet connections. The management unit will periodically acquire data from different measuring points of the electrical system. These data will be transferred through the Internet connection to a central repository location currently located in APB Centre, Hunghom, where the corresponding management PC is situated. These monitoring data are then regularly replicated and stored to another web-servers so that they can be further processed. One of the most promising initiatives of this remote monitoring system (RMS) is the centralized monitoring and logging system for all electricity consumption data from different government buildings. With this monitoring system, those valuable data such as the consumption profile, harmonic content, power factor, etc would be continuously recorded and could be easily retrieved for further analysis and investigation. To enhance the security for Internet transfer, virtual private network (VPN) hardware routers are employed to encrypt and decrypt the data when they are being transferred through the Internet.

It is hoped that the implementation of the system will bring about more efficient and effective operation and maintenance of the electrical installations in government buildings. The reliability of electrical supply will also be improved through better predictive maintenance and more effective monitoring on the performance and status of the electrical system.

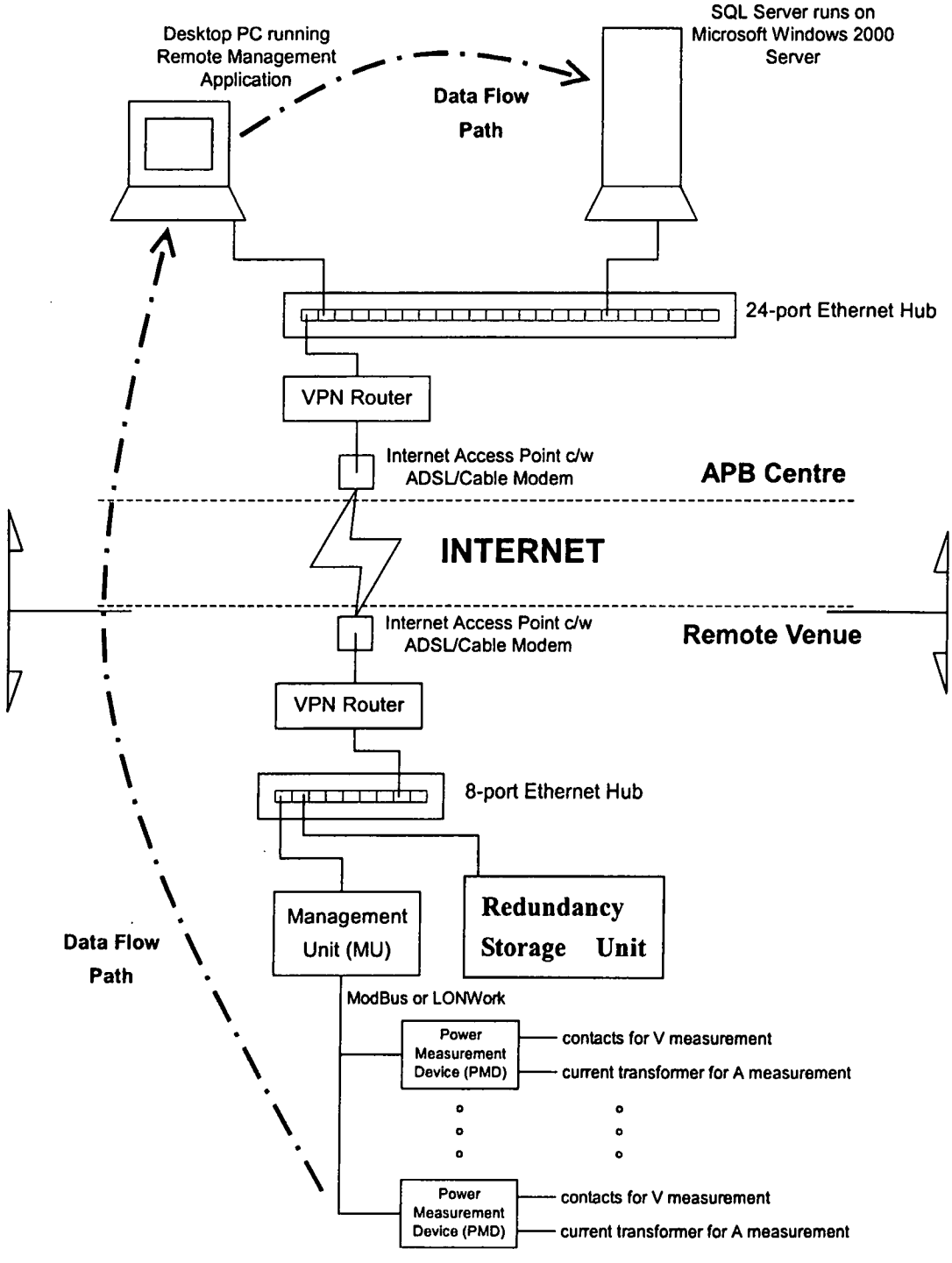
1. INTRODUCTION

Traditional power data indication system for the electrical installation has been widely used for monitoring purpose by operation and maintenance staff. In such system, those manual monitoring devices such as the dial-type voltage, current and power meters are usually installed at the locations where the operator can monitor for any abnormal conditions. Operation staff would record the readings from these indicators manually and periodically. However, the quality of record is low and is difficult to be traced. It is also impossible to search the recorded data for any desired information. In addition, venues without resident operation staff would have no records of the electrical information. Recently, the fast development of Internet has provided an intermediate transmission medium to support remote monitoring of the data in an electrical distribution system. [1]

A pilot scheme has been undertaken by Government to study the implementation of an electrical data logging system. In this scheme, a number of web-based remote monitoring and logging installations each serving as an information network have been installed and developed. Each installation comprises of three major components, namely, data logging devices, information transfer system and historical database. These systems are connected to the Internet through broadband services by local service provider, and provide multiple remote monitoring functions such as live inspection of operating status of electricity consumption, monitoring of power quality and

supervision of operating conditions of protective devices. The system configuration is as Figure 1. Compared with traditional monitoring systems, the Internet-based monitoring systems have some obvious advantages. The digital data can be recorded and stored, and it is also possible for non-linear search of useful data in an efficient and effective way. The recorded data would be valuable information for energy audit or evaluation of energy consumption profile for identifying the energy saving opportunities and for better planning of the maintenance schedule.

Figure 1 Schematic Diagram of the Centralized Monitoring System



The focus of the study is on the assessment of the performance and effectiveness of such power monitoring system by application of evaluation technique. One of the most important issues is on monitoring the system state, which constitutes the starting point of the models and algorithms for analysis. [2–6]

2. METHODOLOGY

2.1 DESCRIPTION OF SYSTEM COMPONENTS

2.1.1 POWER MEASUREMENT DEVICE (PMD)

Many parameters from the electric networks are nowadays required to be measured and analysed. A complete analysis is that which permits an on-site visualization of the measured parameters as well as a further detailed management and analysis of logged data by means of the appropriate software in any desktop personal computer. The PMD could measure, calculate and display main electrical parameters including the active power, power factor, current, line/phase voltage, indicative reactive power, capacitive reactive power, harmonic distortion and frequency in any three-phase power system in either balanced or imbalanced conditions. [7, 8 & 9]

2.1.2 POWER QUALITY MEASUREMENT DEVICE (PQMD)

When power measurement is required at key distribution points or for some sensitive loads, the PQMD could offer unmatched value and functionality. The PQMD features a large graphical display completed with high accuracy measurements, 1/2 cycle setpoint response, power quality analysis, energy and demand tracking, providing historical trending, and control capabilities. The PQMD could summarize power quality measurements into simple pass indicators. Such monitoring is in compliance with international standards such as EN5016, IEC 61000-4-7 (harmonics), and IEC 61000-4-15 (flicker). The device could measure power quality including instantaneous 3-phase voltage, current, frequency, power factor, energy, harmonics, individual & total harmonic distortion up to the 127th, transient detection, etc. The unique dynamic-ranging inputs maintain avenue accuracy at the regular measurement range while simultaneously capturing large-scale disturbances. It could also discover the sources of power quality events, harmonics, voltage sags, analyze problems and avoid interruptions. The PQMD could set up alarms to warn any pending problems. [7, 8 & 9]

2.1.3 VPN BROADBAND INTERNET SERVICE

The Virtual Private Network (VPN) consists of a pair of VPN router which provides tunnelling and encryption with IPSec completed with firewall function, stateful packet inspection, packet filtering and ICSA certification. The Internet service includes the provision of a 24-hours service broadband Internet connection. The broadband service is to provide minimum 512kbps upload/download speed with fix Internet IP address and always on connection.

2.1.4 MANAGEMENT UNIT (MU)

The management unit is an integral part of the data logging system. It is a high performance, modular Direct Digital Control (DDC) supervisory field panel. The field panel operates stand-alone or networked to perform complex control, monitoring and energy management functions using a high level processor. The MU also provides central monitoring and control for distributed network devices and other building services systems (e.g. chiller, boiler, fire services, security and lighting) if necessary. The MU is designed to be capable for connecting up to 100 modular field panels and peer-to-peer communication using industry standard 10/100 Base-T TCP/IP

network. The MU has an integration platform for communication and interoperability with other systems and devices. For complete facility management, a built-in energy management application and DDC programs are also available in MU. In order to communicate with other BS systems/ equipment, the MU shall be completed with LONWork and ModBus connections. [10]

The MU composes of an open processor which provides a microprocessor-based multi-tasking platform for program execution and communications with other field panels, Floor Level Network (FLN) devices, point modules and third-party equipment. The MU is also capable for integration with the Structured Query Language (SQL) server via VPN through the Internet connection. It provides on site access by operator devices such as a CRT terminal or laptop PC. The program and database information stored in the RAM memory of MU is battery-backed. This eliminates the need for running time-consuming program and database re-entry in the event of an extended power failure. The Point Termination Modules (PTM) are available for analog and digital input or output. The PTM consists of two pieces: the electronic point module and termination block which provides the wire connections. [10]

The MUs are high performance controllers with complete flexibility to allow us to customize each control panel with the exact hardware and program for any application. For monitoring applications, the control panel can be customized with the exact number and type of analog or digital inputs to match the sensor devices. Each MU could be capable of communicating with multiple systems to receive data from other building systems. This powerful flexibility provides an unlimited number of configuration possibilities. In case of stand-alone configuration, the MU could fulfill all requirements of a Building Management System supervisory network coordinator, managing operation schedules, alarms, dialing out to other building systems, printers and communication with connected devices. [10]

2.1.5 STRUCTURE OF DATABASE FOR MEASURING PARAMETERS FROM REMOTE SITE

The instantaneous (real-time) measurements such as the true RMS value per phase of voltage, current, power demand, kVAR, kVA, power factor, frequency, harmonic distortion and any voltage or current imbalance phenomenon reading from PMDs or PQMDs will be temporarily stored in the built-in memory of MU, which is capable for holding data from 1,000 measuring points for 10 days in 10 minutes capturing intervals. By adopting the technology of virtual private network on Internet, these stored information would then be transferred back to the central server at APB Center through a desktop personal computer with the remote management application provided from the service vendor. A set of Redundancy Storage Unit (RSU) having the same specification of MU is served as a backup unit to take up the duty of data storage should the MU failed to operate. Firstly, the raw data in the desktop PC at APB Center will be arranged to match with the pre-set format and categorized according to their building number, point type and point schedule. The scheduled electrical data will be stored in the SQL Server for further analysis.

2.2 DESCRIPTION OF OPERATION SOFTWARE

2.2.1 REMOTE MANAGEMENT APPLICATION

The remote management application software is a standard protocol of software tool that allows facility systems from different manufacturers to communicate key information with each other. We have to understand that no single "tool" could meet all clients' unique needs. In the controller level, we have specified that the application software should support all of the protocols as discussed

including Modbus, LonWorks, BACnet as well as vendor-specific protocols in order to utilize the best tool for the job. To communicate with other Building Automation System, the application software should be capable for data communication over TCP/IP or Web access. [11]

2.2.2 WEB SERVER BASE SOFTWARE

By running this software, the desktop PC would become a powerful workstation. It provides a graphical approach to monitor a number of buildings from an easy-to-use interface and also for facility-wide information sharing. With this station, we can:

- graphically monitor BS equipment operation environment,
- collect, view and analyze trend information,
- connect to SQL Server using the networking feature,
- make management decisions with information and reporting capabilities,
- share trend data with Microsoft Excel, and
- help to store and retrieve long-term information.

2.2.3 SQL SERVER RUNS ON MICROSOFT WINDOWS 2000

The SQL Server not only serves to backup the scheduled energy data retrieved from the desktop PC but also be able to perform multi-tasking simultaneously. To have a unique data processing system for information taken from different vendors, an application software has been tailored-made for running on Windows 2000 working platform in SQL Server to conduct following functions: [11]

- Analyze trends of electricity consumption

  It provides trending capabilities that allow the operator to easily monitor and store a record of point data values over an extended period of time. Trending is especially useful in monitoring critical points of interest such as kWh or Amp.

- Alarm management

  It allows operators to troubleshoot alarms as they give off without disturbing the current task and to troubleshoot only the alarms that are relevant to the jobs or locations.

- Creating graphics

  It provides a graphical approach to display the captured data on Windows platform. The operator could readily observe the changes of parameters so as to take prompt action in rectifying the abnormal operation.

- Information storage and retrieval

  It allows the storage of pre-scheduled data and reports onto a variety of media types. Information could be collected network-wide and stored on a single device thus enhancing cost effectiveness for the storage of long-term information data.

Paper No. 5

3. EXPERIENCES LEARNED FROM CASE STUDY

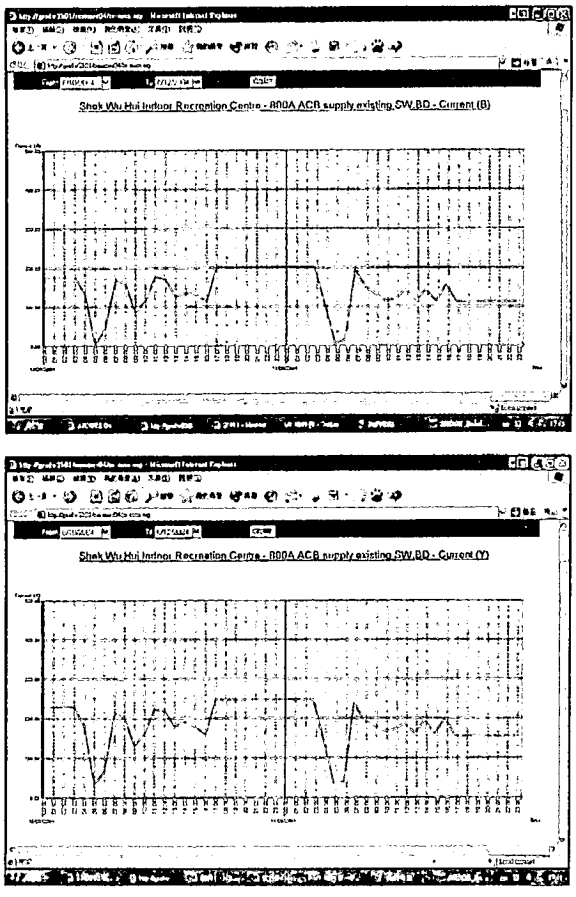
Some examples of data analysis from the pilot study are presented below:-

3.1 CASE 1

According to the information extracted from the historical database, the yellow phase nominal current of the 800A Air Circuit Breaker of Indoor Recreation Centre has only reached ¼ of its full load capacity in some instances. However, there was 20 % higher current in the yellow phase compared with the currents in the blue phase and this phenomenon has been maintained for about ten hours causing imbalance loading problem. This phenomenon may be caused by the large electrical equipment inappropriately connected to the yellow phase. The imbalance three phase load may cause electric potential to be built up at the neutral point which may endanger the safety of the operator or maintenance staff. Also, the designer of improvement work for existing electrical network may find difficulty in assessing the available spare capacity if three

phase imbalances occurred in the circuit. From our observation, three phase imbalance condition is commonly found in electrical installations installed more than ten years ago. This may be due to the inappropriate connection of additional electrical loads. To tackle this problem, we could re-arrange the load distribution by using the data captured by the remote monitoring system to come up with a balance load distribution among the three phases as far as possible. The remote monitoring system offers a real-time supervision platform to monitor the nominal current passing through each protective device and provides opportunity for system operator to analyze the current profile by making reference to the historical data in the database. Please refer to Appendix for findings of this case in Screen 1.

Screen 1 Currents in Y & B Phases of the 800A Air Circuit Breaker of an Indoor Recreation Centre for Case 1



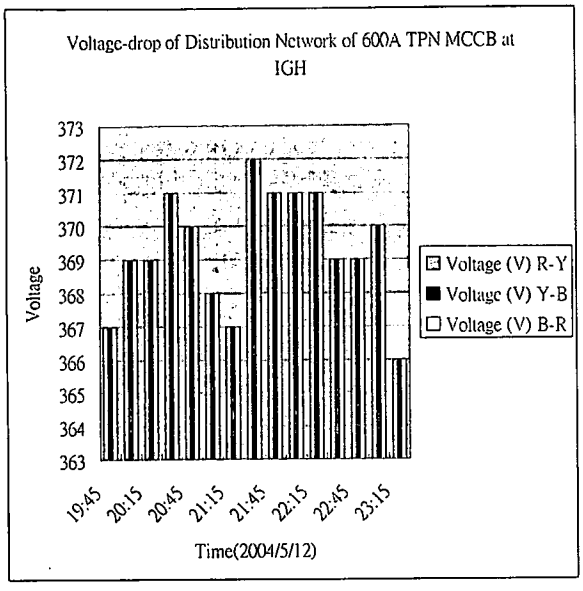
3.2 CASE 2

According to the usual practice, the voltage difference in the distribution network measured between the final circuit and the incomer should not exceed 4%. The undesirable voltage drop will cause electrical equipment to draw on more current in order to perform the required work. According to the data captured from a 600A TP&N MCCB of an Indoor Game Hall (IGH), we observed the line to line voltage is more than four percent below the supply voltage of the power company measured at the incomer point. Furthermore, the power factor was found low. The operating power factor of electrical equipment should at no time be permitted to fall below a minimum of 0.85 lagging. The low power factor would reduce the operational efficiency of electrical equipment. Since the data was measured from load side, the cause of under-voltage should be due to the problem from distribution network. To resolve this voltage drop problem, we could liaise with the maintenance parties to trace out the causes of the problem and making use of the information from database to verify and analyse the problem. Also, we need to find out if installation of power factor correction equipment is necessary to order maintain the power factor to not less than the permitted value. Please refer Appendix for findings of this case in Table 1 and Chart 1.

Table 1 Data Logging Extracted from 600A TP&N MCCB of IGH for Case 2

Date	Time	Power Factor	Voltage R-Y	Voltage Y-B	Voltage B-R
2004/5/12	19:45	0.85	367	367	367
2004/5/12	20:00	0.81	369	369	369
2004/5/12	20:15	0.79	369	369	369
2004/5/12	20:30	0.79	371	371	371
2004/5/12	20:45	0.78	370	370	370
2004/5/12	21:00	0.78	368	368	368
2004/5/12	21:15	0.78	367	367	367
2004/5/12	21:30	0.78	372	372	372
2004/5/12	21:45	0.78	371	371	371
2004/5/12	22:00	0.78	371	371	371
2004/5/12	22:15	0.78	371	371	371
2004/5/12	22:30	0.80	369	369	369
2004/5/12	22:45	0.78	369	369	369
2004/5/12	23:00	0.78	370	370	370
2004/5/12	23:15	0.78	366	366	366

Chart 1 Voltage-drop of Power Distribution Network Extracted from a 600A TP&N MCCB in an IGH for Case 2

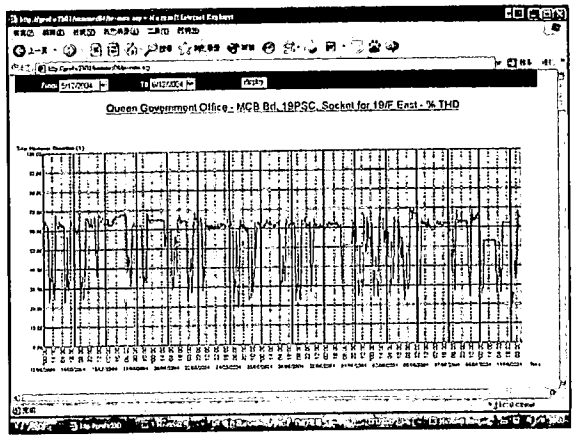


3.3 CASE 3

Harmonic distortion is a dominant factor affecting the power quality of an electrical system. The total harmonic distortion (THD) of current for any circuit should not exceed the appropriate values as in the Code of Practice for Energy Efficiency of Electrical Installations. The problems associated with the presence of harmonics on power distribution systems are not just the power quality problems but also affect the energy efficiency of the system. Typical problems include overheating transformers, motors, phase and neutral conductors creating unacceptable neutral-to-earth voltage, voltage distortion, electromagnetic interference, capacitor bank failure, etc. Many of the problems are related to the proliferation of non-liner loads such as variable speed motor drives, rectifiers for direct-current power supplies, electronic ballasts in energy efficient lighting and switch-mode supplies in computers and other electronic office equipment.

According to the data retrieving from the database as shown on Screen 2, the total harmonic distortion recorded is as high as 70% for a 30A MCB for the socket outlet at Queensway Government Offices. To tackle this problem, the quantity and nature of those known non-linear equipment connected to the circuit should be studied and harmonic filters may needed to be installed to mitigate the problem. Please refer to Appendix for findings of this case in Screen 2.

Screen 2 Data Logging Extracted from a 30A MCB in Queensway Government Offices for Case 3



3.4 CASE 4

Apart from those typical operation parameters like the voltage, current, power factor, harmonic distortion, etc., some other important information including the deformation of sinusoidal current/voltage wave form, the dropout of power supply within/over a definite period of time, the event of transient and the error of frequency could be easily recorded by the Power Quality Measurement Device. A screen showing the records of abnormal events of power supply for a MCB at 19/F East of QGO is extracted as shown on Screen 3 in Appendix. Also, the duration of these abnormal conditions have been captured and will be used as an evidence to explain the cause of equipment breakdown. For some delicate equipment, any changes on the conditions of the power source may cause unaffordable system breakdown. If this is the case, the system designer should ensure the quality of power by adopting a UPS and a reliable power monitoring system c/w alarms to protect the equipment.

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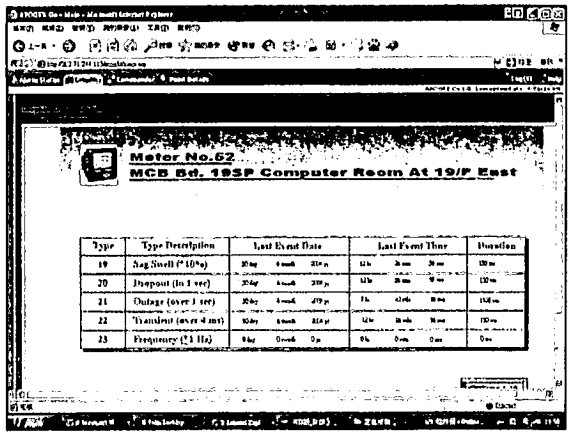
Screen 3 Data Logging of Abnormal Events of a MCB Board for a Computer Room in Queensway Government Offices for Case 4



4. CONCLUSIONS

In this paper, the methodology and the architecture of a Web-based Remote Monitoring System for monitoring electrical installation has been described and the experiences learned from the case studies of the pilot scheme have been discussed. By adopting this monitoring system, the most valuable energy consumption data or the operation characteristics of electrical installations could be recorded for further analysis. The monitoring system can be further extended and developed to monitor data of other engineering systems such as HVAC and fire services installations. It is hoped that a central control centre would be set up in future for monitoring all engineering services installations in all major government buildings.

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Paper No. 6

INTELLIGENT LIGHT DIMMING AND CONTROL

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INTELLIGENT LIGHT DIMMING AND CONTROL

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ABSTRACT

The increasingly obvious effects of global warming and the diminishing reserve of fossil fuel resources are alarming signs for society to rethink the way energy is used. This paper presents a new energy-saving technology and performance enhancement for public road lighting systems. This patent-pending dimming technology and its approach to intelligent light dimming and control system are described. With the new dimming technology with digital control and interface, it is possible to extend the lighting system to include other value added facilities, including alarm handling and remote control. Hence an integrated remote monitoring and control on public road lighting can be effectively achieved. This paper provides information on site trials results and derived benefits for its application to public road lighting systems.

1. INTRODUCTION

The heat wave in Europe in the summer of 2003 led to an estimate of 3000 to 10,000 deaths in France alone [1]. As the global heat wave continues in 2004, the Shanghai Municipal Government has set new regulation in July 2004 that all decorative public lighting systems in the city square and along the Shanghai Bund would have to be turned off in the evening whenever the temperature rises above 35°C [2]. Heat waves result in increasing use of air-conditioners and thus electrical energy usage and fossil fuel consumption. Consequently, the vicious cycle of greenhouse gases emission and global warming continues. Hong Kong is not immune from global warming. The Hong Kong Observatory reported in July 2004 that the sea level in the Victoria Harbour has risen by 0.12m over the last 50 years, at an average rate of 2.3mm per year [3]. Hong Kong also recorded the hottest day of 1st July in 2004. As the effects of global warming become increasingly alarming, it is necessary to rethink the way energy is used. Wise use of energy is therefore essential. In this study, focus is made on a new environmental-friendly, energy-saving dimming technology for public road lighting systems.

Lots of research efforts have been devoted to energy efficient lighting systems in the last decade. Among them, discharge lamps such as high-intensity-discharge (HID) and fluorescent lamps are popular choices because of their high efficacy (lumen per watt). Traditional incandescent lamps have an efficacy of typically 8-11 lumen/Watt and fluorescent lamps have typical efficacies of 60-100 lumen/Watt. In general, HID lamps have typical efficacy of 100-200 lumen/Watt and lifetime of 10,000-24,000 hours. These attractive features of HID lamps make them the natural choices for public road lighting applications. Together with highly reliable magnetic ballasts, HID lamps are commonly used in public road lighting market.

With recent rapid advancements in power electronics, new dimming concepts and technologies for electronic lighting systems have emerged. Most of these dimming methods have been adopted in modern electronic ballasts for both high-pressure and fluorescent lamps. Electronic ballasts for HID ballasts have also attracted much attention, but their wide spread applications have been severely hampered by the acoustic resonance problems in HID lamps when operated at high frequency. Despite the fact that some efforts have been devoted to the use of dimmable electronic ballasts for public road lighting

systems, the high initial equipment replacement cost is a one major hindrance to their application. More importantly, the use of individual dimmable electronic ballasts in each lamp-post in a large lighting network could be a maintenance nightmare for road lighting organizations.

In addition to a brief review on the state of the art lighting technology, this paper describes some results of this collaboration. The system features of a new dimming control system suitable for public road lighting application and the results of a trial test of this patent-pending dimming system are reported. Various cost and environmental benefits, such as energy saving and reduction of greenhouse gases, arising from this new dimming system are addressed.

2. NEEDS FOR DIMMING CONTROL FOR PUBLIC AND ROAD LIGHTING SYSTEMS

For public road lighting applications, road safety, lighting pollution and energy consumption are important issues to be considered. In many existing public road lighting systems, energy saving can be achieved by turning off a fraction of the total number of lamps in a road lighting network. For example, one out of every two or three lamps can be turned off in a lighting network. While this approach can save energy, the uneven light distribution is a concern for public road lighting. Two major road safety studies in 1972 [4] and 1994 [5] have indicated that lit roads are safer than unlit roads. At the same time, there are rising concerns in the USA, Europe and China on the over use of high brightness in road lighting that may lead to road safety problem, energy wastage [6,7,8] and light pollution [9,10]. Light pollution is believed to have adverse impacts on health and environment such as the sleep disorders and abnormal hormonal changes of human beings, plant and wildlife disturbance. It is estimated that over 100 million migrating birds died of crashing into lit buildings each year in the USA [11]. Many US companies now support the campaign of switching off the lights in tall office buildings. For public road lighting systems, most authorities require lighting throughout the night while allowing a brightness reduction in road lighting in order to save energy and reduce light pollution [6].

The Dutch government has been actively pursuing a policy on energy conservation and environmental protection [9]. In the late 1990, the Dutch Ministry of Transport has tested a road lighting dimming system on a 14 km six-lane highway [6]. Under this test, 100% normal lighting level was used for high traffic density and 20% level was used for low traffic at night. The study found that the 20% lighting level was sufficient for light traffic at night and did not have any negative consequences. In 2002, a road safety research on M65 Motorway in England conducted by University of Manchester Institute of Science and Technology (UMIST) [7] concluded that the flicker effect of passing under a series of overhead light of high brightness at speed is uncomfortable and possibly dangerous. The report also concluded that driving is more comfortable under light traffic conditions when the lighting level is reduced. Therefore, dimming of road lighting has the potential of both energy saving and road safety.

3. DIMMING APPROACH AND CONTROL STRATEGY

Dimming technology for large public road lighting systems should preferably satisfy the following criteria:

(a) High energy efficiency (>95%) with significant energy saving

(b) Smooth and continuous dimming range (say, from 100% to 50% of lamp power)

(c) Environmental friendly – with minimum generated toxic components and preferably using recyclable materials.

(d) Minimum equipment replacement cost

(e) No major change in existing infrastructure and no major re-wiring task

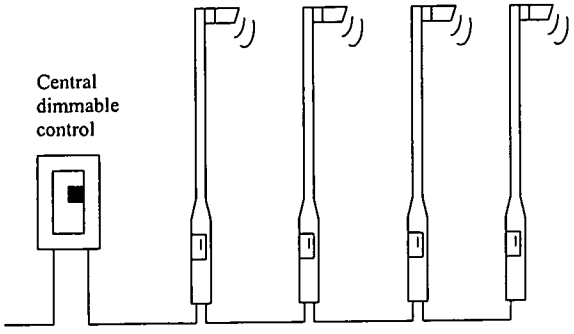
(f) Extremely reliable – Failure of public road lighting system is not acceptable for safety reason. The lighting system must function normally even if the dimming system fails.

(g) Long ballast lifetime (>10 years without replacement)

(h) Good immunity against severe weather such as wide temperature variation and lightning.

(i) Centralized group control with flexibility of either hard-wired or wireless communications.

Figure 1 Schematic of a Centrally Controlled Dimmable Public Road Lighting System



Based on the criteria laid down previously, one can review existing dimming methods so as to determine the optimal dimming approach for public road lighting systems. The general schematic of a centrally controlled dimmable road lighting systems is shown in Fig.1. The control device is working on a single phase principle. Dimmable Road Lighting Systems have been tested in the last decade in Europe. Existing methods can be broadly classified into (1) ***electromagnetic*** and (2) ***electronic*** dimming approaches.

(1) ***Electromagnetic*** approach refers to the use of "autotransformer" to adjust the a.c. voltage that powers a chain of magnetic-ballast-driven HID lamps housed in the lamp posts. This method has the following features;

Advantages

(i) There is no need to replace existing highly reliable magnetic ballasts (with typical lifetime exceeding 10 years)

(ii) Laminated steel material of magnetic ballasts is recyclable .

(iii) No major change in existing power supply infrastructure is required.

(iv) Stepper motor is usually used to adjust the autotransformer in order to vary the a.c. voltage supplied to the lighting system. One dimming module is sufficient for a series of lamps.

(v) Tolerance against extreme weather conditions and lightning is good.

(vi) Over-voltage of HID lamps due to poor regulation of ac mains can be avoided.

Disadvantages

(i) A.C. voltage variation (dimming range) is limited by the thermal limitation of autotransformer.

(ii) Autotransformer is relatively bulky and lossy.

(2) ***Electronic*** approach refers to the use of a dimmable electronic ballast in each lamp-post and the use of a central dimming control system to control all the lamps in the network. This method has the following features:

Advantages

(i) Dimmable electronic ballasts allow a wider dimming range than autotransformer.

(ii) Over-voltage of HID lamps due to poor regulation of a.c. mains can be avoided.

Disadvantages

(i) All existing magnetic ballasts are to be replaced by electronic ballasts.

(ii) Electronic ballasts are more expensive and less reliable than magnetic ones, leading to a higher installation cost and possibly reduced reliability. Typical lifetime of electronic ballasts is limited to 3-5 years due to the limited lifetime of the electrolytic capacitors.

(iii) Customized wired or wireless central dimming control compatible with the electronic ballasts is needed for uniform dimming control.

(iv) Most of the materials of electronic ballasts are not recyclable. Their relatively short lifetime could be an environmental concern as some electronic components contain toxic materials.

(v) Tolerance against extreme weather conditions and lightning is relatively poor.

(vi) For public road lighting applications in large cities (say with over 100,000 lamp-posts), 1% failure rate means over 1,000 lamps. So the use of one dimmable electronic ballast in each lamp-post could be a maintenance nightmare.

As can be seen from previous discussion, the electromagnetic and electronic approaches have their advantages and disadvantages. In terms of reliability, cost, lifetime, maintenance, immunity against severe weather conditions and recyclability, existing magnetic ballasts used in public road lighting systems are much better than electronic ballasts. Electronic ballasts offer a slightly better energy efficiency, but are inferior in many other aspects. As maintenance cost is a significant cost component in a large road lighting system, high reliability and long lifetime of magnetic are particularly attractive.

In the lamp control aspect, there are two approaches: namely the Group Approach and the Individual Approach. For the Group Approach like the electromagnetic ballasts using autotransformer, a number of lamps are grouped and controlled at the outlet units using autotransformer. Such Group Approach can maximize the degree of control and simplify the control and management effort to a manageable size. For the Individual Approach, every individual lamp will be equipped with the required communication interface and associated control electronics. The advantage, of course, is that each lamp can have different control profile. However, the public road lights along a road are not required to have different lighting profiles for lamps adjacent to each other. Hence, the Individual Approach must be carefully considered with consideration to the subsequent maintenance efforts (for both preventive and corrective maintenance.) With over 120,000 light poles installed in the public road lighting system in Hong Kong, the optimal approach for an effective lighting management is the application by Group Approach.

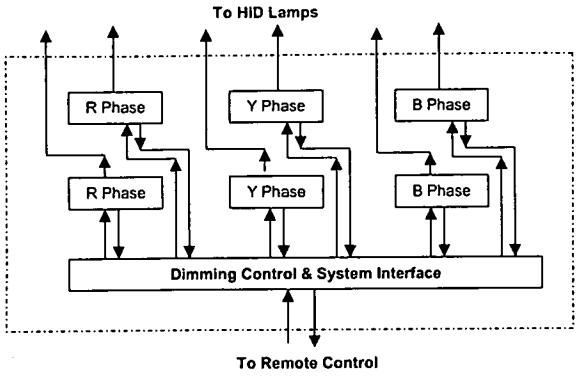
4. NEW DIMMING TECHNOLOGY FOR PUBLIC ROAD LIGHTING SYSTEMS

An ideal dimming technology for public road lighting systems should have the advantages of both electromagnetic and electronic approaches. In this section, we describe a new dimmable Public Road Lighting System. The proposed dimming system has the same infrastructure as described in Fig.2. The dimmable Intelligent Control Unit controls a network of ballast-lamp units in the lamp-posts. This new dimmable system retains most of the advantageous features of previous methods. However, it can achieve a very high energy efficiency (up to 97%) and has a non-intrusive feature over existing road lighting infrastructure. Non-intrusiveness refers to the fact that even if the dimming unit fails to operate normally, the lighting system will still function at full power without dimming ability. No major infrastructural change is required.

4.1 FUNCTIONAL BLOCK DIAGRAM OF THE DIMMABLE INTELLIGENT CONTROL UNIT

Fig.2 shows the overall block diagram of the road lighting Intelligent Control Unit. The dimming control in the unit generates the required voltage and current to control the brightness of the HID lamps. It can decode the required dimming level and the on/off control message. The system interface can be connected to a central location so that the required control signal can be received and executed.

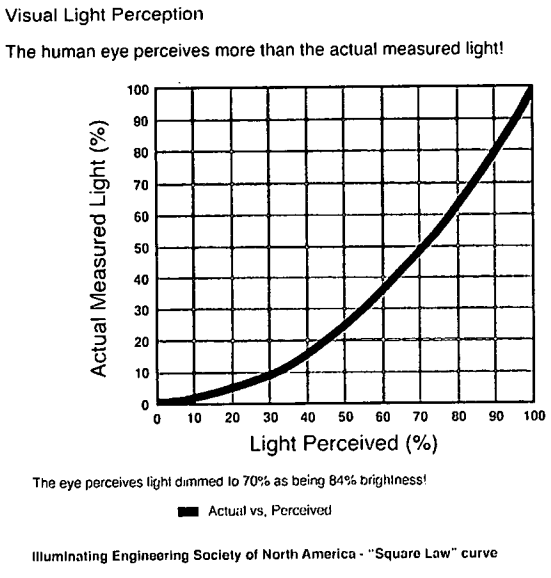
Figure 2 Intelligent Control Unit for Road Lighting Monitoring and Control



4.2 HUMAN LIGHT PERCEPTION VERSUS ACTUAL LIGHT

Obtained from the Illuminating Engineering Society in the USA, Fig.3 shows the relationship between the actual measured light and human light perception. It is important to note that such relation is not linear. Instead, it obeys the "square law". The significance of this relationship is that human eyes perceive less reduction of light than the actual light reduction. For example, Fig.3 shows that a 20% actual light reduction corresponds to only 10% drop in human light perception, and a 50% of actual light reduction is equivalent to only 30% drop in human light perception. This medical information can be taken advantage of in a dimmable public road lighting control.

Figure 3 Relationship between Human Light Perception and Actual Measured Light (IES Webpage)



4.3 FUNCTIONS OF THE NEW DIGITAL DIMMING SYSTEMS

The functions of the new digital dimmable Intelligent Control Unit are summarized as follows:

- It can provide dimming functions for all types of discharge lamps.
- Typical dimming range exceeds at least 50% of lamp power.
- It is a centralized dimming system for a network of ballast-lamp units.
- Major re-wiring of existing infrastructure is not required.
- It has a non-intrusive feature to ensure system reliability.
- It offers over-voltage protection, resulting in longer lifetime of lamps.
- It can be extended to include wired or wireless communication for control, fault identification and remote metering purposes.
- It can achieve real energy saving with a high energy efficiency up to 97%.

Pape No. 6

4.4 SITE TEST OF THE INTELLIGENT CONTROL UNIT FOR ROAD LIGHTING

A prototype of this new dimming controller was successfully tested in February 2004. Tests were conducted to evaluate the dimming performance of an approximately 1kW public road lighting system from 100% to about 45% of the full power.

Table 1 Test Results of the Intelligent Control Unit for Road Lighting

Dimming Range (System Input Power)	100 % - 45 % of Full System Power
Total Power Loss in Dimming System	1.7 % - 2.8 % of Full System Power
Power Saving Capability	Up to 55 % of Full System Power
Dimming Range of Actual Light	100% - 25%
Dimming Range of Human Perceived Light	100% - 50 %
HID Lamp Arc Stability	Whole Dimming Range Under Test

It is important to note that high energy efficiency can be achieved with this new dimming unit near full power operation of the

lighting system. The total power loss in the dimming controller is very small (less than 3% of full system power) and does not change significantly throughout the dimming range. This high energy efficiency is essential to a genuinely energy saving dimming system.

4.5 DIMMING PROFILES AND ENERGY SAVING

Existing public road lighting systems have not equipped with dimming function. While energy can be saved by turning off some of the lamps (e.g. one every three lamps) in the network, uneven light distribution could be a safety hazard. In order to meet the safety, energy saving and avoidance of light pollution, the ideal scenario is to achieve even light distribution through the use of an energy-efficient dimmable road lighting system.

Fig.3 show an important fact that a 10% reduction of actual light is equivalent to only 5% drop in human light reduction. This means that existing public road lighting system can be dimmed by 10% in terms of total power without being noticed by most road users. Both the Dutch and UMIST research results have confirmed that a reduction of lighting level is beneficial late at night when the traffic density is low. These findings enable us to propose a dimming profile that can meet all the requirements.

The patent-pending dimming technology can dim the lamp power of some HID lamps such as high-pressure sodium lamps from 100% down to about 20%. For Metal-halide lamp, the lamp power can be reduced to about 45% of the full lamp power. In practice, there should be a balance between energy saving and illumination requirements.

Fig.4a shows one example of a dimming profile for road lighting system. It is assumed that the public road lighting system is used from 6pm to 6am each day. From 6pm to midnight, a reduction of 10% power is proposed because most users cannot even detect such small reduction in luminous flux. Since the traffic density from midnight to 5am is low, a 40% reduction of power (with 65% of human perceived light level) can be acceptable for road safety, driver comfort and reduction of light pollution. If such dimming profile is adopted, an overall energy saving of 22.5% can be achieved.

As previous results in Europe confirm that low lighting setting is acceptable at night when traffic is not heavy. A second dimming profile with more energy saving is shown in Fig.4b. A 20% of power reduction in total power during the peak hours (6pm to midnight) of the evening causes a drop of only 13% of human perceived light. This could be a good solution in urban area where the neon lights of the advertising signs play a significant part in light complement. From midnight to 5am, the dimming level of the lamp power can be lowered to 50%. This dimming profile leads to an overall energy saving of 32.5%.

Figure 4a A Dimming Profile with 22.5% Energy Saving

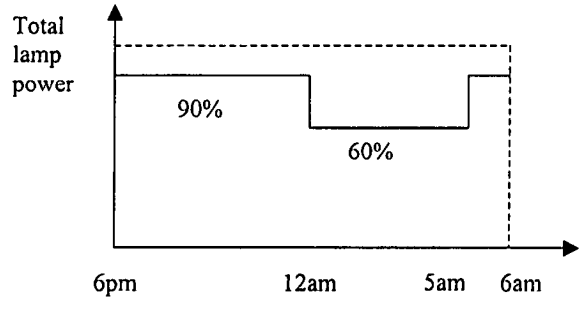
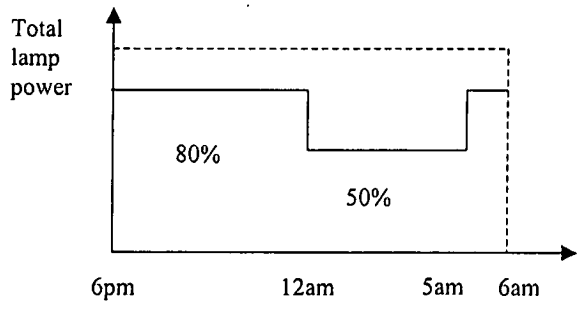


Figure 4b A Dimming Profile with 32.5% Energy Saving



5. CENTRALIZED MONITORING AND CONTROL

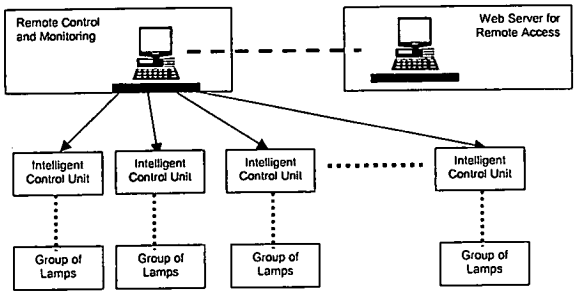
In this Section, the centralized monitoring and

control hierarchy for public road lighting systems is described.

5.1 BASIC CONCEPT

As explained in Section 3 that individual control of each lamp is impractical and hence the overall lighting control by Group Approach is designed and is achieved via each dimmable Intelligent Control Unit. As shown in Figure 3, each Intelligent Control Unit typically monitors and controls around 60 lamps and it is considered as the most optimal solution for monitoring and control of the public road lighting systems. A Web Server is provided to enable remote access. It is also essential that the system should be simple, reliable, secure and user friendly.

Figure 5 Centralized Monitoring and Control



Appropriate lighting profile is downloaded to each set of Intelligent Control Unit on site and all the profiles can be stored in the central database. It also has the capability to change lighting profile of each individual control unit at remote end, keep time stamp for the events occurred. The monitor and control functions include but not limited to the following:

1. Lamp ON/OFF control
2. Lamp dimming control according to required dimming profile
3. Alarm alert when lamp is faulty
4. Self supervision by the control watchdog
5. Recording of essential data for a pre-determined time window

5.2 GRAPHICAL DISPLAY

For a high reliability control system, the control function must be equipped with 'Select, Check Back and Execute' features.[12] In the graphical single line diagram, appropriate colours and symbols are provided to enable the following status be viewed : On, Off, Faulty and Selected. In term of general functionalities, it can be classified as Selected, Obsolete, Alarm, Warning, Manual and Control Blocked.

The database of the central control must also be inter-linked with the existing Public Lighting Digital Data (PLDD) and Public Lighting Information System (PLIS), to enable lighting details, controller details, maintenance history and graphic cable circuit information be fully integrated. This integrated data base approach will provide operational history, for better planning of maintenance and energy management.

5.3 COMMUNICATION CONSIDERATIONS

Paper No. 6

There are various means possible to connect the central system to each of the Intelligent Control Unit. It can be done via wireless, powerline carrier, fibre-optics and cable sheath. The communication means can be designed to meet specific location requirement. For the choice of communication protocols, standard and open type is preferred, for example, the use IEC60875, DNP3.0, TCP/IP.

6. POTENTIAL BENEFITS TO HONG KONG

Hong Kong has about 120,000 lamp-posts and accordingly it is estimated to use 100,000 GWh per year and produce 73,000 kilotonnes of CO_2 emission (assuming 0.731 kg of CO_2 per kWh [13]).

Assuming a typical reduction of 30% of the total power, the following potential benefits can be achieved.

6.1 ENVIRONMENTAL AND HEALTH BENEFITS

- Reduction of 22,000 kilotonnes of CO_2 emission each year.

- Reduction of other greenhouse gases such as SO_2 and acid rain.
- Reduction of coal or energy consumption and their corresponding pollutants.
- Less coal ash production.
- Reduction of cases of Asthma and Respiratory illness.
- Reduction of light pollution. Less sleep disorder cases and smaller impact on wild life.

6.2 FINANCIAL BENEFITS

- Financial benefits from energy so saved
- Improved lifetime of HID lamps due to the reduction of lamp power.
- Less replacement cost of HID lamps.
- Reduction of scouting manpower for monitoring and maintaining the public road lighting system because of the central control system.

6.3 PERFORMANCE AND MAINTENANCE BENEFITS

- New dimming system allows existing public road lighting system to become dimmable.
- New central control for the dimmable system makes maintenance and monitoring of road lighting systems user-friendly.
- Quick response to any faults due to intelligent control and sensing.

7. CONCLUSION

An intelligent approach to public road lighting management system, consisting of dimming, monitoring and control function is described in this paper. The breakthrough in dimming technology has enabled the development of a complete public road lighting management system. From various research studies, it is clear that the advantage of dimming can enhance road safety, apart from the advantage of energy saving and reduction of light pollution.

Site test results have confirmed that the dimming system can achieve high efficiency exceeding 95%. Other benefits include various enhancements in safety, health, environment and quality. This patent-pending dimming technology has been practically proven. It offers a environmentally friendly and energy saving solution to public road lighting systems of modern cities. It could bring about reduced light pollution, effective use of energy, road safety, and a better environment.

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Paper No. 7

THE TUNG CHUNG CABLE CAR – A NEW ICON FOR HONG KONG

Speakers : Ir R.F. Bayliss, Project Manager
Ir Lawrence K.L. Chung, Manager – China Technical Support
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THE TUNG CHUNG CABLE CAR – A NEW ICON FOR HONG KONG

Ir R.F. Bayliss, Project Manager
Ir Lawrence K.L. Chung, Manager – China Technical Support
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ABSTRACT

In July 2002, MTR Corporation was selected by the Hong Kong Government as the franchisee for the design, construction and operation of the Tung Chung Cable Car Project, a new tourism attraction, which will provide a unique cultural and environmental tourism experience for local and overseas visitors.

The Project comprises two key elements - a 5.7 km cableway linking terminals at the Tung Chung new town and Ngong Ping, home of the "Big Buddha", and a village containing cultural attractions, restaurants and retail, adjacent to the Ngong Ping Terminal.

The 20 minute cable car journey will provide panoramic views over the North Lantau Country Park, the South China Sea, Hong Kong International Airport and surrounding areas, culminating in a spectacular view of the Big Buddha while approaching Ngong Ping.

The paper describes the project and in particular the cable car system, the first of its type in Hong Kong. It explains some of the key challenges faced by the project and the initiatives adopted to deal with these.

1. INTRODUCTION

Ngong Ping, home of the Big Buddha statue (the biggest seated bronze Buddha in the world) and the Po Lin Monastery, is an important tourism destination in Hong Kong with approximately 1 million visitors each year, despite suffering from poor transport connections. During the 1990's studies were carried out on the development of a cable car link between the Tung Chung new town and Ngong Ping as part of the Government's initiative to develop Lantau as a tourism destination.

After a competitive bid process, in July 2002 MTRC and the Government of the Hong Kong SAR entered into a Provisional Agreement in respect of the Tung Chung Cable Car Project. During this period Government enacted the Tung Chung Cable Car Ordinance and the Corporation carried out and obtained approval of, an environmental impact assessment and a scheme design.

In November 2003 The Corporation and Government signed a Project Agreement for the cable car and terminals and a Private Treaty Grant for a themed village adjacent to the Ngong Ping Terminal. The franchise commenced on 24th December 2003 and will last for 30 years, after which the cable car system will be transferred free to Government. Construction is due to last for 26 months, with opening planned in early 2006. The capital cost of the project is approximately HK$950M.

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2. PROJECT DESCRIPTION

The Cable Car Project is fundamentally a tourist attraction, intended to offer a quality tourism/leisure experience for Hong Kong residents and international visitors. Projections indicate that in 2006 some 1.5 million tourists and Hong Kong residents will ride the cable car system. The facility consists of the following features:

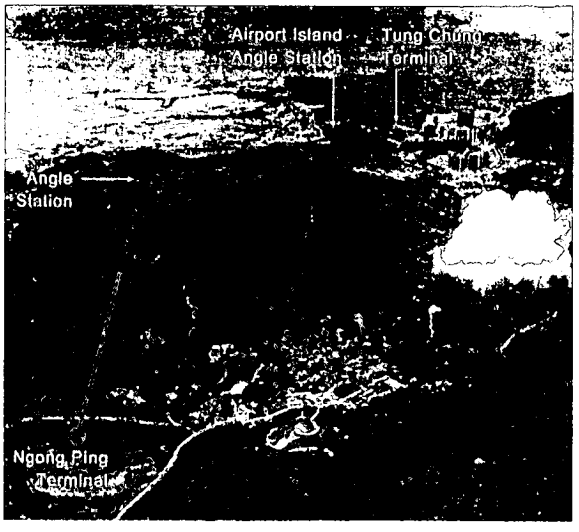
- A terminal at Tung Chung New Town, adjacent to the MTR Station, and a passenger transport interchange.
- A cable car system which commences at the

Tung Chung Terminal and runs approximately 5.7 km via a turning station on Airport Island and another turning station to the west of Nei Lak Shan in the North Lantau Country Park to a second terminal at Ngong Ping. There will be no provision for disembarkation or embarkation at the angle stations other than for emergency situations. See Figure 1 for cable car alignment.

- A cable car terminal at Ngong Ping.
- A cultural village ("The Village") adjacent to the cable car terminal at Ngong Ping. The Village is intended to provide an oriental themed village environment connecting the Ngong Ping Terminal to the Po Lin Monastery and the statue of Buddha.

Whilst the cable car system is a major component of the project, passenger transportation is secondary to the provision of the leisure/tourism experience.

Figure 1 Cable Car Alignment



To facilitate the development of Ngong Ping, Government has also entrusted other works to MTRC:

- A new Public Transport Interchange, adjacent to The Village.
- Landscaping, roadworks and water supply and sewerage works to develop the area at the foot of the Buddha Statue into a pedestrianised piazza area.

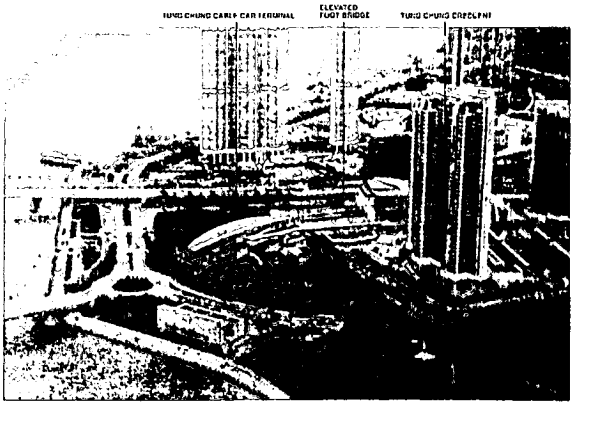
3. THE TERMINALS

The Tung Chung terminal provides the start of the experience. Designed as an open air building with natural ventilation, provision will be made for ticketing, visitor queuing, tourism merchandising and presentation of the experience ahead. Below platform level a whole floor will accommodate cabin storage and cleaning, with offices and plant rooms located on the ground floor, alongside the transport interchange. The structure is of relatively simple reinforced construction set on a piled foundation, with architectural finishes consistent with the modern urban environment.

Ngong Ping Terminal provides the arrival point from which visitors will enter The Village and visit the Big Buddha and Po Lin Monastery. The open air terminal building accommodates ticketing, visitor queuing, tourism merchandising, limited cabin storage / maintenance facilities and the management offices for The Village. The structure is of simple reinforced construction, set on pad foundations with architectural finishes consistent with the rural environment.

At present the foundations to both terminals are complete and the building structures are in progress.

Figure 2 Perspective of Tung Chung Terminal



4. THE CABLE CAR SYSTEM

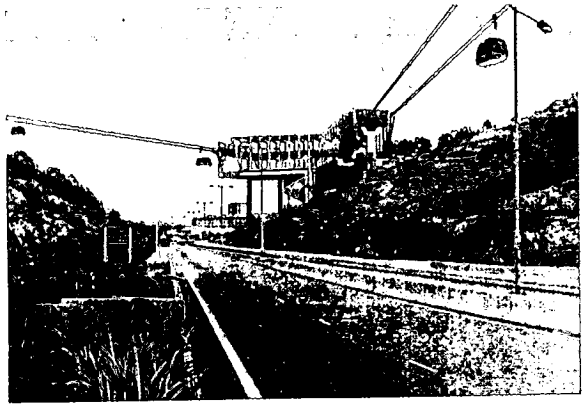
After considering alternative options of monocable, 3-S and Funitel systems, a detachable bicable circulating cable car system was selected, based on its capacity, cost and environmental impact.

The ropeway system will be circular, operating continuously in an anti-clockwise direction. Cabins will safely detach from the circulating rope to permit safe embarkation and disembarkation of passengers at 0.25 metres per second at terminals while maintaining a full line speed of up to 7 metres per second.

The speed of cabins passing through the angle stations will be reduced to ensure passenger comfort during turning of the cabins through the angle. This is done by detaching the cabins from the rope, transferring them around the turn on a separate wheeled system and then attaching them to the rope again.

The ropeway will be driven by two physically separate drive units, both located at the Airport Island Angle Station. The two units, one driving the section between Tung Chung Terminal and Airport Island, the other driving the section between Airport Island and Ngong Ping, will be synchronized to operate the ropeway as a single system. Overall control of the ropeway will be from the Airport Island Angle Station.

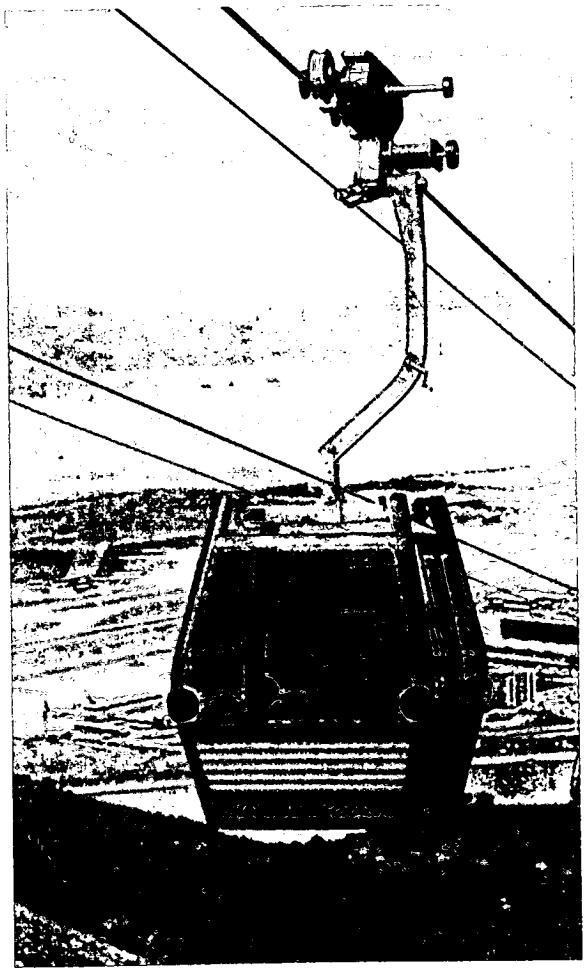
Figure 3 View of Airport Island Angle Station



The ropeway will be capable of operation under most reasonable circumstances. In excessive wind speeds or in the event of lightning, the ropeway will be emptied of passengers at a safe speed and operation ceased.

Cabins will have a carrying capacity of 17 – 10 seated and 7 standing, for peak times. They will be stored at Tung Chung Terminal each night. Cycling cabins on and off the rope will be fully automatic and parking cabins in the storage area will be semi-automatic.

Figure 4 Cable Car Cabin



Cabins will be naturally ventilated using louvred vents, windows and air scoops and they will be equipped with emergency support facilities.

Further key technical details of the cable car system are set out in Table 1.

Table 1 Cable Car System Characteristics

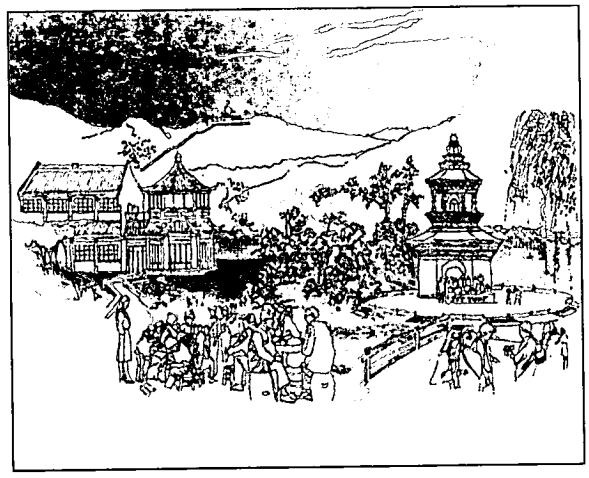
Item	Description	
1	System type	Detachable Bicable Circulating System (2S)
2	System capacity	3500 passengers per hour
3	Route length	Section 1: 610m Section 2 : 5193m Total : 5811m
4	Total no. of cabins	112
5	Cabin spacing on line	Distance 122.4m Interval 17.5 sec.
6	Capacity per cabin	17 Persons (total), 10 seated and 7 standing (wheelchair user allowed)
7	Rated passenger load	75 kg/person
8	Rope speed	0 – 7.0 m/s
9	Station speed	0.15 – 0.25 m/s (for passenger loading / unloading)
10	Angle station speed	0.4 – 1.0 m/s (for transit of cabins)
11	No. of line towers	1 tower at Tung Chung 2 towers on Airport Island 5 towers in North Lantau Country Park } Total 8 towers
12	Cabin storage area capacity	At Tung Chung all cabins can be stored (total 112 cabins) At Ngong Ping approx. 8 cabins can be stored if required
13	Cabin ventilation	Natural ventilation, in-cab temperature only slightly exceeding ambient
14	Cabin communication	In-cab broadcasting system
15	Track rope	70mm diameter fully locked
16	Track rope anchoring	Tung Chung Terminal, anchored on drums Airport Island Station, anchored on drums Tower 3, clamped to prevent movements of the rope Nei Lak Shan Angle Station, tower 5 side, anchored on drums Ngong Ping Terminal, anchored on drums
17	Diameter of anchor drums	About 4.6m
18	Track rope security factor	At least 3. 3 against actual breaking load
19	Haul rope tension system	Section 1 tensioning device at Tung Chung Terminal Section 2 tensioning device at Ngong Ping Terminal
20	Gearboxes	2 for section 1 drive and 2 for section 2 drive
21	Motors	2 for section 1 drive and 4 for section 2 drive
22	Nominal power of 1 motor	About 420 kW

5. THE VILLAGE

The Village is specially designed to complement the existing attractions at Ngong Ping and the cable car ride. Providing entertainment, food and beverages and retail opportunities, The Village will include a town square, a Buddhist Interpretive Centre, a Tree Theatre, a Country Market, an iconic tea house and a contemplative garden. Design of The Village and its themed streetscape has involved the input of specialist consultants from the entertainment industry, in coordination with local architects. Extensive market research and testing has been carried out to ensure the content of the village and it's attractions meet the requirements of the tourism market, which is rapidly changing with the recent influx of

visitors from the mainland. The buildings will be typical reinforced concrete structures with an architectural styling based on simple Chinese village architecture. The appearance will be compatible with the existing characteristics of the area. A focal point will be provided by a Bodhi Tree, which whilst artificial will replicate a mature natural tree. Facilities will also be provided for street theatre to entertain visitors.

Figure 5 Perspective of The Village



Progress to date has involved the permanent diversion of the existing Tung Chung Stream using environmentally friendly rock filled wire baskets (gabions) as opposed to concrete lining in the new stream course. Site formation works are complete and construction of the buildings has commenced.

6. THE ENVIRONMENT

Safeguarding the environment and its natural beauty has consistently been a key criteria of the project. From the outset, the project team has been cognizant of the special environment associated with the area and has worked to develop the Project with as little environmental impact as possible. Every aspect of the environment has been carefully addressed with a view to keeping any possible environmental impact to a minimum. The selection of the cable car system technology and its alignment is a direct result of this approach, minimizing the number of tower structures and ensuring they will not damage the local ecological system.

A comprehensive environmental impact assessment has been carried out and all personnel involved with the project undergo environmental training prior to commencing work on site. Prior to work commencing in the North Lantau Country Park ecological surveys were carried out and flora and fauna translocated.

7. STAKEHOLDERS AND SUSTAINABILITY

Stakeholder Management was identified from a very early stage in the project life cycle to be a key issue for the project. There are many stakeholders with varying degrees of interest in the Project - the Tourism industry, Government departments, Green Groups, Religious Groups, Ngong Ping and Tung Chung Residents to name but a few. The project team has developed a stakeholder management plan which monitors the relationships with each of the stakeholders to ensure that appropriate communication and consultation takes place with all of them.

The principal of Sustainability features strongly, both in the positioning of the Tung Chung Cable Car as a tourism experience, and in the manner in which the project is being designed and constructed. In support of this approach, MTRC asked Hong Kong University to establish and chair an independent Sustainability Advisory Board. This Board, which involves a range of project stakeholders, advises on sustainability issues and has developed a set of sustainability performance indicators, against which the project is measured. The remit of the Board is not only limited to the Tung Chung Cable Car Project itself, but also considers the wider development of Ngong Ping and surrounding areas. Membership includes Government Departments, Green Groups, the Bus Operator, Tourism Operators, Religious parties and the Cable Car Project Team. Meetings are held quarterly. This is a world class, innovative and unique approach in Hong Kong.

8. OPERATIONS

Contrary to MTRC's normal practice of operating their own facilities, they have appointed Skyrail-ITM (Hongkong) Ltd as operator for this project. Skyrail-ITM (Hongkong) Ltd was established from the success of Skyrail, owner and manager of one of Australia's best tourism attractions, a 7.5km rainforest cable-way experience in Cairns, North Queensland, Australia. Skyrail has won many awards, including Australia's Best Tourist Attraction (twice) and the British Airways' Tourism for tomorrow Award.

Skyrail is currently establishing an operating team for the project. Operational procedures are being developed to cater for all eventualities, with a focus on safety and passenger comfort and convenience. Provisions will be included to cater for the mobility impaired. Extensive redundancy has been built into the design of the system to minimize the need for emergency evacuation. In the event evacuation is however required, proven techniques, developed elsewhere, will use a combination of vertical and horizontal rescue, depending on the location of the particular cabins.

9. THE PROJECT TEAM

To meet the needs of the project, a team consisting of both international and domestic partners has been formed to provide the necessary design, construction and consulting services. Project management is by MTRC's own in house Project Division and a strong partnering ethos has been developed, which includes a Project Charter, signed by all those involved. Table 2 sets out the key players and the contractual vehicles under which their services have been procured.

10. CONCLUSIONS

With a focus on providing a quality experience for both Hong Kong residents and international tourists, the Tung Chung Cable Car Project combines architecture sympathetic to its surroundings with the sophisticated engineering of a modern cable car system. The 5.8km bicable system will provide a comfortable 20 minute journey with extensive redundancy and safety back-up. It will be the first such system in Hong Kong.

Project delivery is by a team of international and domestic partners, each experts in their own field, project managed by MTR Corporation, the Project Owner. When it opens in early 2006, the Tung Chung Cable Car project will provide a new icon for Hong Kong, not only on account of the product offering, but also on account of its approach to delivery.

ACKNOWLEDGEMENTS

Development, design and construction of the Tung Chung Cable car is being undertaken by an

Table 2 Project Suppliers

Party	Role	Contracting mechanism
Skyrail-ITM	Tourism and Cableway adviser	Time charge
Mott Connell Ltd	Environmental Consultant	Lump sum
Leitner GmbH	Aerial Ropeway Contractor	Lump Sum
Aedas Ltd	Lead Design Consultant	Time charge with pain share/gain share
Maeda Corporation	Building and Civils Contractor	Target cost with pain share/gain share
JCP SE Asia Ltd	Partnering Consultant	Schedule of rates
Edwards Technologies	Specialist Attraction design and procurement	Project management fee and procurement budget

international team of partners, project managed of MTRC. As with every project, many people, not only from this team, have played their part in getting the project from its original concept to the current stage. The authors acknowledge the significant contribution of all who have contributed to the project in the pursuit a creating another icon for Hong Kong.

The authors are grateful to the MTR Corporation for permission to publish this paper.

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Paper No. 8

AN OVERVIEW ON HIGH POWER LED SOURCE FOR INDOOR AND OUTDOOR ARCHITECTURAL LIGHTING APPLICATIONS IN HARBOUR LIGHTING/BEAUTIFICATION SCHEME

Speaker: Mr Riccardo Croce
General Manager
Space Cannon vH, Italy

AN OVERVIEW ON HIGH POWER LED SOURCE FOR INDOOR AND OUTDOOR ARCHITECTURAL LIGHTING APPLICATIONS IN HARBOUR LIGHTING/BEAUTIFICATION SCHEME

Mr Riccardo Croce
General Manager
Space Cannon vH, Italy

ABSTRACT

This paper attempts to introduce the main technical features and relative advantages of the High Power LED sources in architectural lighting applications in world class cities, as well as attempts to clarify, from a luminaire manufacturing point of view, the advantages and the main problems encountered on the application of the High Power LED.

1. INTRODUCTION

Since introduced in early sixties to the marketplace, a lot of research and development has been carried out on Light Emitting Diode (LED). For decades, these components have been commonly utilised as indicators or signals, for example showing whether the mobile phone or the computer monitor is on or off. This conception is not limited to mass at large, but also to some of us engaging in engineering career.

These same components have now been developed into High Power Light Emitting Diodes, generating between 10 to 50 lumens per LED, depending on the colour spectrum with refreshed and wider range of applications.

Newly found applications of these new electronic components are replacing and will continue to replace many different applications traditionally covered by lamps. The advantages and the challenges on using these new technologies compared to well known conventional lamps may be seen in various different areas like **longer life; lower maintenance; safety; higher efficiency** and in particular as a product aimed to abate to the new rules of a modern and more **sustainable world**.

We can safely state that the advent of this and its introduction to the market of this "solid state lamp" may be equivalent to the Thomas Edison's 20W incandescent light bulb invented more than a century ago.

2. ADVANTAGES

The main advantages on using these High power solid state components compared to the well known conventional lighting source like incandescent, halogen or fluorescent are the following:

- Longer life
- Lower maintenance cost
- Vivid saturated colours
- No heat or UV in the light beam
- Direct light for increased lighting system efficiency
- Design flexibility

2.1 LONGER LIFE

High Power LED contains solid state technology without moving parts, nor fragile glass environments, nor mercury, nor toxic gas and filament. Unlike typical conventional light sources, LED is not subject to sudden failure or burn out. There is no point in time at which the light sources ceases to function; instead, LED will only slowly degrade in performance over time.

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This latest product, for example, is capable to deliver an average of 70% of initial intensity after 50,000 hours of operation. In an application where the light source would be used for 12 hours per day and 365 days per year, this would result in a system lifetime of over 11 years with only 30% degradation from initial luminous output with no anticipated catastrophic failures.

2.2 LOWER MAINTENANCE COST

Since LED based light sources can last at least 10 times longer than a conventional light source, there is no need to consider constant lamp replacement, reducing or even eliminating ongoing maintenance costs and periodic relamping expenses. To this end, LED is an excellent product for those regulated and critical lighting applications that would require scheduled and periodic lamp bulb replacement.

Further unlike the conventional sources that would fail as a total burn out at the end of the useful life, LED remains lit. Hence, the need to employ standby team for emergency services in securing unfailing light source in safety critical applications is much lessened.

LED provides even greater advantage in applications of remote locations, as such building facades and roof top features, where routine maintenance and replacement would be difficult. Dramatic reduction, let alone elimination, of the frequency of required maintenance can save a lot of money on maintenance call.

2.3 VIVID SATURATED COLOURS

Various shades of red, green, blue and other colours can be generated directly from LED. There is no need of additional filters to produce coloured light, resulting in deep and saturated colours without wastage. As an added advantage LED is fully dimmable to ensure minimum changes on the characteristics of the hue and tone.

2.4 NO HEAT OR UV IN THE LIGHT BEAM

The conventional light sources, once powered, emit both visible light and invisible radiation. The emitted radiation can be of very short wavelength, known as ultraviolet, or long wavelength, known as infrared. The ultraviolet light can damage other materials by causing colour changes and eventually breaking the materials down. The infrared light produces heat damaging displayed objects and increasing air-conditioning costs at the detriment of environmental comfort. High Power LED only generates light in the visible range. There are no ultraviolet or infrared radiation emitted.

Eliminating these harmful and non-useful components of the spectrum could result in a light beam that will not degrade illuminated objects while providing a cool beam with high efficacy.

2.5 DIRECT LIGHT FOR INCREASED LIGHTING SYSTEM EFFICIENCY

The light emitted from LED is directional. On the contrary, conventional lighting sources such as incandescent, halogen or fluorescent are typically omni-directional, emitting lights in all directions.

To fully utilise the light aiming onto the object that needs to be illuminated, light that is not directed toward the desired location must be redirected, often using secondary optics. However, each and every time a light beam is reflected it loses some of its intensity, resulting in a fixture loss.

Typical fixture losses can range from 40 to 60%, meaning that in some cases less than half of the light generated by the source is directed in the desired direction. The unidirectional nature of LED can boost fixture efficiencies of 80 to 90%, requiring less total lumens to provide the same level of illuminance.

When considering LED as a light source it is important to consider all factors in determining

the appropriate solutions. For example, if a 500 lumens source in a fixture with 50% efficiency is replaced with a LED based source with 85% efficiency, it can be seen less than 300 lumens will be required from a LED source for an equivalent illuminance.

A fringe, yet important, benefit from the directionality of light emitted from the LED solution is the reduction of light pollution.

2.6 DESIGN FLEXIBILITY

The smaller dimensions of High Power LED in comparison to that of the conventional lighting source provide the lighting designers with more options and choices. For instance, instead of taking a single high power and bright source and mounting it in a reflector optic to distribute light, LED can enable an alternative lighting concept where the light source can be provided by multiple points of light, distributed across a surface or placed in multiple planes.

3. BRIEF CONSIDERATION FROM THE LUMINAIRE MANUFACTURER

To optimise the unique and advantageous features offered by High Power LED, it is fundamental that particular attention from the luminaire manufacturer is required. In fact, special care must be placed on choosing the powering components and the thermal dissipation device. In addition the design of the luminaire should address the following two main points:

- thermal management
- electrical requirement

The product High Power LED basically falls in the power semiconductor component category of which part of the electrical energy supplied would be converted into heat. Obviously good thermal management is of crucial importance. It follows to materialise the advantages of the High Power LED previously presented and in particular to ensure the fruit of long life and colour stability, it is fundamental that it is treated similarly as an electronic power component device.

Needless to say, the correct thermal dissipation assessment is fundamental to guarantee a proper component life and light output characteristics of the entire luminaire design performance. In fact, a long operation life of 100,000 hours may be reached only through good thermal dissipation design of the component itself.

Another important feature is the electrical circuit design. The powering systems for High power LED are current dependent devices. Therefore, current limiting devices are required in the power supply circuitry. Even in this case, in order to guarantee the semiconductor a proper life, proper design of the driving circuit is required.

Having presented the main and most important advantages related to the LED components, we have to emphasize that these benefits could only be fully explored provided that the luminaire manufacturer adopts proper design of effective heat dissipation. As well as to take proper precaution on components selection and strict control in assembly of the High Power LED and other powering related components in the lighting fixtures.

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4. THE APPLICATION IN THE HONG KONG HARBOUR LIGHTING BEAUTIFICATION SCHEME

As from January 17th, 2004, the scheme "Symphony of Light" had bought vigour and life to the harbour and skyline of Hong Kong in a blaze of colours and sound each night. Over 18 buildings were lit with two of them took on the technology offered by the **High Power LED**. They are the Convention and Exhibition Centre and the City Hall. The design approach are breifly discuues as follows.

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4.1 THE CONVENTION AND EXHIBITION CENTRE

The Hong Kong Convention and Exhibition Centre is a prominent building on the Hong Kong harbour front and provides more than 63,000 square meters of convention and exhibition space. Being one of the largest curved roof structures in the world and together with many curving surfaces, its facade shape constantly changes. Hence it would required a very special lighting project approach.

This building is at present lit using three different kind of lighting sources: high pressure Xenon lamps, metal halide lamps and high power LED.

The lighting of the vertical surface of the multiple balconies at the front of the building employed some 300 meters of LED Bar. Each individual length of LED Bar can be uniquely controlled through a DMX input signal allowing such effects as changing and rolling colours to be created in this part of the design.

It can definitely be stated that the Hong Kong convention and exhibition centre is the first lighting project worldwide combining these three lighting technologies together.

4.2 THE CITY HALL

In comparison to the other buildings situated along the Hong Kong harbour, this building is relatively small. In addition to it being taking out a very prominent seafront sight line at the very edge of all busy ferries traffic, it is for decades, a significant architectural structure to the people of Hong Kong, bearing many fond and nostalgic moments. In 2002 it celebrated 40 years as the first cultural complex ever built for the community.

This building is now lit with over 250 meters of RGB LED Bars, with individual DMX control. There are approximately 90 windows in total and all of them have their own individually controlled length of LED Bar. A row of LED bar was also installed across the top window line as well as along the staircase of each floor.

The City Hall, now accenting the already spectacular seafront of the world most famous harbour, is a good example that the use of High Power LED together with the flexible physical configuration of the luminaries can provide the lighting designers a wide variety of possibilities to express their creativity.

5. CONCLUSION

The architectural lighting of a world city is playing a vital role in the sentiment of the people that are "living" in the city, let alone bring afresh attraction to tourists. This new technology, combined with long life energy efficiency and high light output is providing a greater flexibility in the lighting design so much so that the application of the High Power LED must be an alternative if not a trendy solution to future lighting challenges.

ACKNOWLEDGEMENT

A very special thanks is extended to Lumileds. For the preparation of this paper, reference material has been taken from Lumileds Application brief.

Figure 1 City Hall with High Power LED Lighting

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