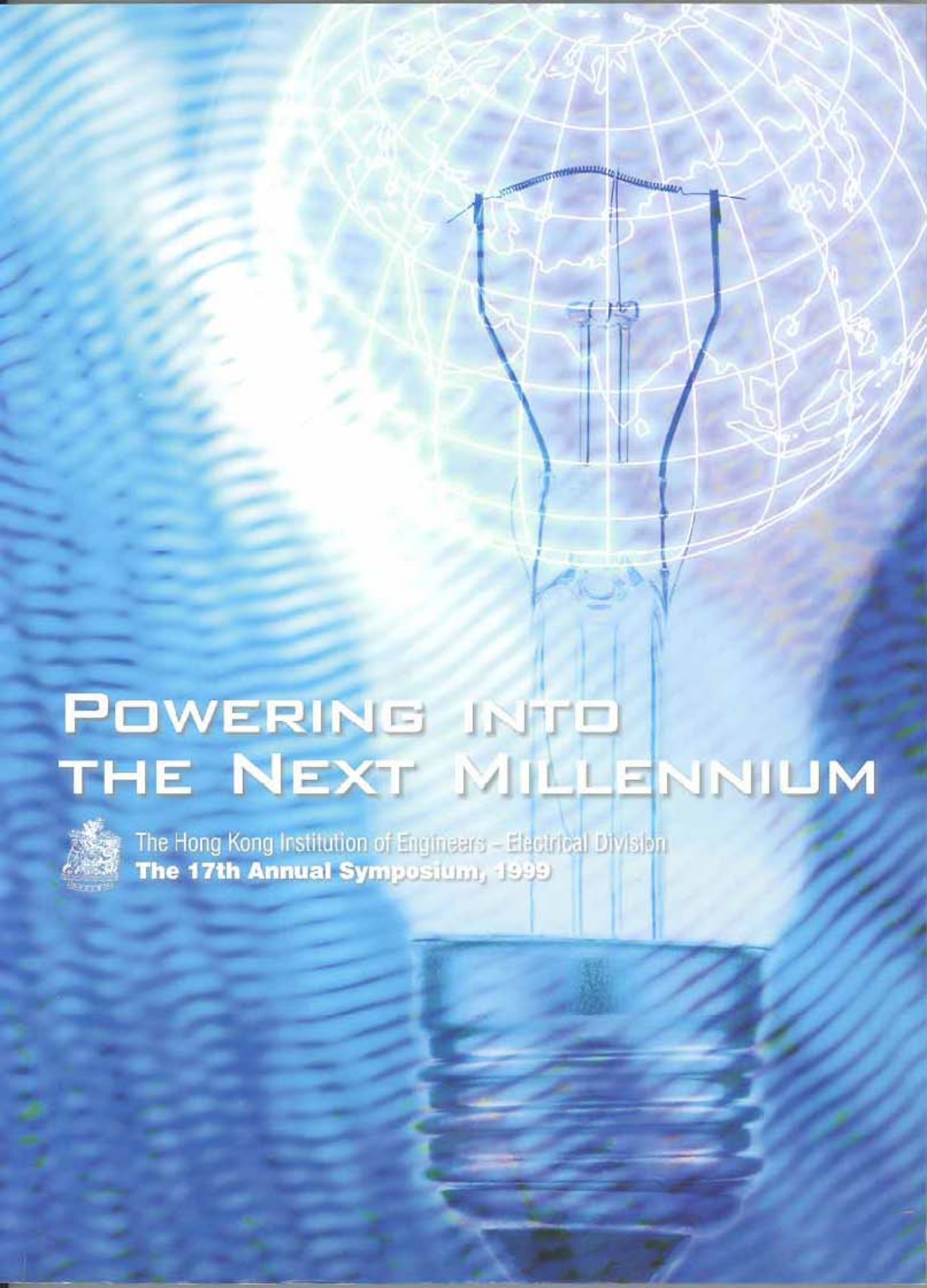

Powering into the Next Millennium

The Hong Kong Institution of Engineers – Electrical Division

The 17th Annual Symposium, 1999

THE HONG KONG INSTITUTION OF ENGINEERS ELECTRICAL DIVISION

The Seventeenth Annual Symposium

Thursday

28th October 1999

POWERING INTO THE NEXT MILLENNIUM

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 Registration and Coffee

09.00 Welcome Address
- Ir S.S. Yuen
  Chairman, Electrical Division, The HKIE

09.05 Opening Address
- Ir Prof. C.C. Chan
  President, The HKIE

09.10 Keynote Speech
- Mr Stephen S.K. Ip, JP
  Secretary for Economic Services
  Economic Services Bureau
  The Government of The Hong Kong SAR

1. Innovations

09.40 The Opportunity Information Technology Applications Hold For Hong Kong
- Mr Alexander Arena
  Group Managing Director
  Pacific Century Cyberworks Ltd., Hong Kong

10.00 Development of the Applications of Superconductivity to Electric Power Apparatuses
- Mr Shigeki Isojima
  General Manager
- Mr Takato Masuda
  Senior Engineer
- Mr Michihiko Watanabe
  Engineer
  Energy Apparatus & Systems R&D Department
  Electric Power System Technology Research Laboratories
  Sumitomo Electric Industries Ltd., Japan

10.20 Discussion

10.40 Coffee Break

2. *Projects*

11.10 Power Supply System Design for Future MTR Extensions
- Ir Samuel S.C. Chan
  Senior Engineer (Power Supply & Electrical Services)
- Ir M.K. Mak
  Engineer (Power Supply)
  Mass Transit Railway Corporation, Hong Kong

11.30 The Hong Kong International Finance Centre
- Ir Vitus W.T. Cheung
  Senior Project Manager
  Central Waterfront Property Project
  Management Co. Ltd., Hong Kong

11.50 Discussion

12.15 Lunch

3. *Power Supply*

14.00 Electricity Supply and Services in the New Millennium
- Ir P.N. Ip
  Chief Customer Services Engineer
- Ir W.M. Choi
  Senior Customer Supplies Engineer
- Ir K.T. Yeung
  Engineering Co-ordination Engineer
  The Hongkong Electric Co. Ltd., Hong Kong

14.20 Y2K Contingency Plan Development for Power Supply Reliability
- Ir Dr F.C. Chan
  Y2K Contingency Plan Manager - Supply Reliability
- Ir Victor Y.W. Lee
  Team Leader
  Y2K Contingency Plan Team - Supply Reliability
  CLP Power Hong Kong Ltd., Hong Kong

14.40 Electricity Supply Lines (Protection) Regulation
- Ir Stephen H.C. Chan
  Chief E&M Engineer
- Ir K.W. Siu
  Senior E&M Engineer
  Electrical & Mechanical Services Department
  The Government of The Hong Kong SAR

15.00 Discussion

15.20 Coffee Break

4. Applications

16.00 Development Trend of The Electronic Ballast

- Mr Sergio Corbo
  International Sales & Marketing Manager
  MagneTek Incorporation, U.S.A.

16.20 Revolution in Refuse Handing:
Automated Refuse Collection System (ARCS) for Buildings

- Ir S.C. Leung
  Senior Building Services Engineer
- Ir T.K. Ng
  Building Services Engineer
  Housing Department
  The Government of The Hong Kong SAR

16.40 Discussion

17.00 Summing Up

- Ir Vincent W.S. Tong, JP
  Symposium Chairman
  Electrical Division, The HKIE

Closing Address

- Ir Dr Raymond C.T. Ho, JP
  Member (Engineering Functional Constituency)
  Legislative Council
  The Hong Kong SAR

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Cover Design Idea of this Booklet by Mr. Alex Cheong, Analogue Group

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Paper No. 1

THE OPPORTUNITY INFORMATION TECHNOLOGY APPLICATIONS HOLD FOR HONG KONG

Speaker : Mr Alexander Arena
Group Managing Director
Pacific Century Cyberworks Ltd., Hong Kong

The material for Paper No. 1 will be presented in the Symposium

Paper No. 2

DEVELOPMENT OF THE APPLICATIONS OF SUPERCONDUCTIVITY TO ELECTRIC POWER APPARATUSES

Speakers : Mr Shigeki Isojima
General Manager
Mr Takato Masuda
Senior Engineer
Mr Michihiko Watanabe
Engineer
Energy Apparatus & Systems R&D Department
Electric Power System Technology Research Laboratories
Sumitomo Electric Industries Ltd., Japan

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Energy Apparatus & Systems R&D Department
Electric Power System Technology Research Laboratories
Sumitomo Electric Industries Ltd., Japan

Paper No. 2

ABSTRACT

Superconductivity is expected to be a technology to change electric power system drastically. Sumitomo Electric Industries, Ltd. is making great efforts to develop high temperature superconducting (HTS) wires to be used industrially, as well as to realize applications of superconductivity.

This paper first describes a study on the Superconducting Magnetic Energy Storage system (SMES). We have studied two types of magnets. One is the 400kJ class LTS (Low Temperature Superconducting) SMES for testing the power stabilization operated at liquid helium temperature and the other is the 100J class HTS SMES for confirming the possibility of applying HTS wire to SMES at liquid nitrogen temperature. Each magnet performed completely at rated operation.

Second the development of a 30m-long prototype 100MVA HTS power cable system is described. This system consists of a 30m long single phase cable, terminations, a 66kV XLPE cable for a current loop and a cooling system which circulated sub-cooled liquid nitrogen. 40kV-500A ac was successfully applied for more than 100 hours.

1. INTRODUCTION

SMES has been studied and developed for one of the power application systems using superconducting technology and is expected to be applied for energy storage, stabilization of power system, compensation for short interruption of power for electrical equipment, etc. First, the LTS SMES is described in section 2[1][2]. Next, the development of the HTS SMES is described in section 3. Recently, HTS wire operating at 77K with sufficient length and improved characteristics have been obtained [3], so we started studies on the HTS SMES to investigate whether the HTS wire is applicable to the SMES or not. The target for energy storage value was set to 100J and prototype magnet was developed [4].

Finally, the development of a HTS cable is described in section 4. HTS cable is expected to transport large electric power with a compact size because of its high critical current density [5]. Many key technologies, however, are needed and for the purpose of studying these technologies, a 30m-long 66kV-1kA HTS prototype cable was designed, developed and evaluated [6]. In this paper, the design and evaluation of the prototype cable system are described.

2. LTS SMES

2.1 MAGNET DESIGN

Fundamental specification of the test magnet was determined as shown in Table 1 in consideration of the magnet size , test scale etc.

Table 1 Design of Prototype Magnet

Energy storage	420kJ
Operating current (DC)	350A
Current density of the coil	approx. 50A/mm^2
Inductance	6.9H
Magnetic field	5T max.
Excitation ramp ratio	35A/sec(0.5T/sec)
Applied voltage	400V max.

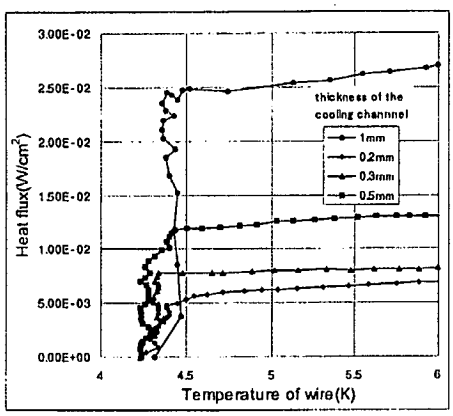
2.1.1 CONDUCTOR

When power input-output on SMES occurs, the loading current and magnetic field of the magnet are changed and an alternative current energy loss is generated (AC loss). AC loss causes a decrease in efficiency and an increase in instability of the operation. To reduce the loss of the conductor, fine diameter and short twist pitch filament was designed. In addition, high resistance material between NbTi and matrix was selected. Finally, low-AC loss superconducting wire with NbTi/Cu/CuNi monolithic construction was developed.

2.1.2 COOLING CHANNEL

A cooling channel is required to prevent a coil from the transition from superconducting to a normal state. To investigate the effect of the channel, the fundamental characteristic was tested. Fig. 1 shows the cooling characteristics of the test coil with various channel thickness. By increasing the heat flux, temperature of the conductor changed drastically. It is thought that liquid helium change from the nuclear boiling state to the film boiling state at that point.

Fig. 1 Heat Flux Test with Various Channel Thickness



Using the test result, stability of the 400kJ magnet was investigated both by the calculation and the experiment of the test coil. As a result, It was confirmed that the cooling channel must be more than 1mm.

2.1.3 HTS POWER LEAD

Next, we developed a 500A class current lead using HTS wire to reduce heat leakage from the power terminal at about 30% of Copper leads. Current leads have a temperature gradient from 4.2K to 77K in operation so the number of the layers of the HTS wire was to be optimized for minimizing the heat leakage.

Characteristics of the HTS power lead is shown in Table 2.

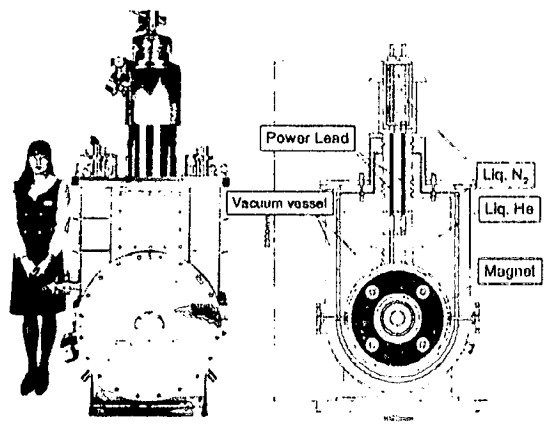
Table 2 Characteristics of the HTS Power Leads

Max. current(A)	500
Heat loss (W/leads at 350A)	0.28

2.2 FABRICATION OF THE LTS SMES

After designing the components of the magnet, 400kJ class LTS SMES was fabricated successfully as shown in Fig. 2 and the magnet operated with a rated 350A DC-current and 420kJ was stored stably.

Fig. 2 Overview of the LTS SMES

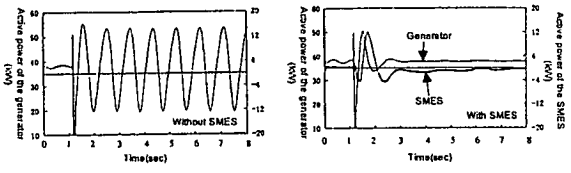


2.3 TEST RESULTS

Using the fabricated magnet with the other two

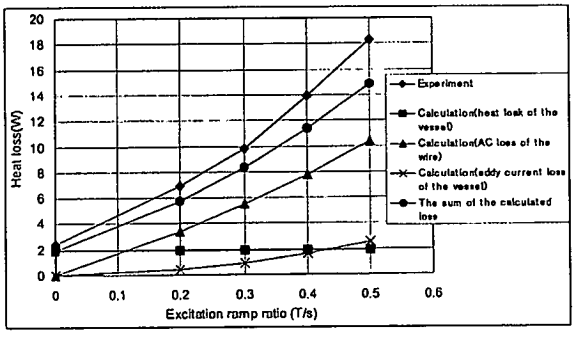
magnets, the stabilization tests were performed with a simulated power line and it was confirmed that the SMES had potential for stabilizing the fluctuation of the power system. Fig. 3 shows the results of the 3-phase short circuit test. When the SMES is active, the power fluctuation of the generator is converging within 2 seconds.

Fig. 3 3-phase Short Circuit Test



Next, the heat loss test was achieved. It operated at max. 0.5 T/s excitation ramp speed and characteristics of the heat loss versus ramp speed were observed as shown in Fig. 4. Additionally, a heat loss estimation was evaluated and the error of the calculation was obtained to be about 15 to 20% at each ramp speed.

Fig. 4 Heat Loss Test and Estimation



Finally, efficiency of power input-output on the magnet alone was calculated to be 86% at full-time operating 50A⇔330A, 0.5T/sec and cooling efficiency set to be 1/350.

3. HTS SMES

3.1 DESIGN OF THE COIL

The energy to be stored was determined to be 100J and in order to design the coil, basic characteristics, such as mechanical properties and critical current density of the high-Tc wire and cooling characteristics were measured.

3.1.1 COOLING CHANNEL

The performances of some cooling channels of the HTS SMES were also investigated. The heat flux at the transition points in each case are indicated in Table 3. It was confirmed that the heat flux at the transition point in the case of the horizontal cooling channel is about 1/20 less than the critical heat flux of atmospheric liquid nitrogen[7].

Table 3 Heat Flux at the Transition Point

Channel thickness	Horizontal direction	vertical direction
0.5mm	1.0 W/cm^2	6 W/cm^2
1.0mm	1.3 W/cm^2	10 W/cm^2

3.1.2 STABILITY OF THE COIL

We have investigated the characteristics of AC loss using a small coil with HTS wires [8]. And as a result, the maximum AC loss density of 100J SMES coil was estimated to be about 3.2 X 10^5 (W/m^3) where a maximum magnetic field of 0.4T is applied with the operating frequency of 1Hz. In this case, the heat per unit cooling area is about 0.15W/cm^2 when cooling channels with spacers of 0.5mm are made between pancakes. Therefore, the heat generated by AC loss is much less than the critical heat flux and the structure of cooling channels for 100J coil was determined to install spacers of 0.5mm thickness between pancakes.

3.1.3 DESIGN OF COIL OPERATION

The pancake shape was determined to have the inner diameter of 80mm considering the bending distortion of the wire. The outer diameter of the pancake and the number of pancakes to be stacked were determined by calculation. Finally, the design value of 100J coil shown in Table 4 was obtained.

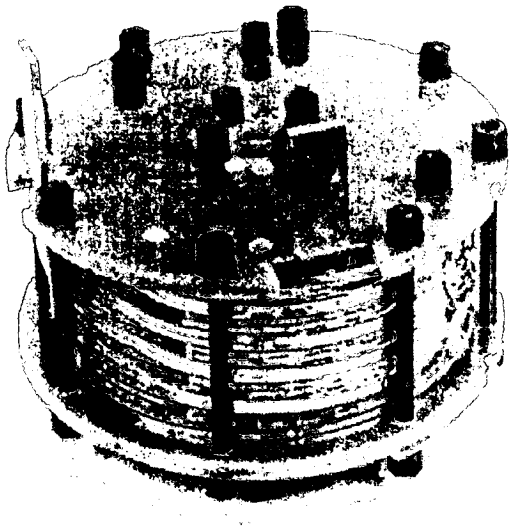
Table 4 Specification of 100J/77.3K HTS Test Coil

Wire and size (mm)	silver-sheathed Bi2223 0.25t X 3.8w 3bundle
Number of coils	10 double pancakes
Size of magnet (mm)	I.D. 80,O.D. 200, Height 93
Clear bore (mm)	42
Operating current (A)	34.2
Inductance (H)	0.171
Magnetic field (T)	Bo=00.4 Bmax=0.42
Stored energy (J)	100
Total length of wires (m)	Approx. 2,100
Total weight (kg)	Approx. 20

3.2 FABRICATION OF THE COIL

100J coil was manufactured according to the above-mentioned design. Fig. 5 shows the overview of the test coil. A 0.5 mm thick cooling channel was set between the coils to improve the cooling characteristic.

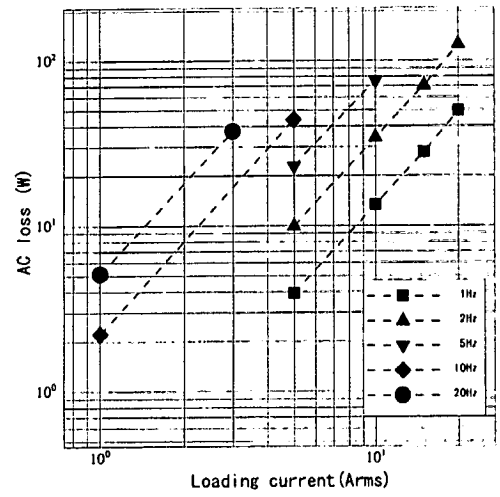
Fig. 5 Overview of Completed Coil



3.3 LOADING TEST

We conducted DC and AC current tests on the coil both at 77.3K as well as measuring the corresponding AC losses. In the DC current test at 77.3K, a holding was set to ensure the achievement of 100J energy storage at the rated current of 34.2A. The AC current was a triangle wave with peaks of 34.2A, and at each frequency of 1Hz and 2Hz, the current loading continued up to 34.2 A, demonstrating no trouble involved. The 4-terminal method was used for the measurement of an AC loss in which the current was applied at a triangle wave of the I/O current waveform during SMES operation. Fig.6 shows the measurement result concerning the AC loss at 77.3K. We measured at a frequency of up to 20Hz, and learned that the AC losses for every frequency and current value are proportional to about 2nd power of the loaded current, and are proportional to about 1st power of the operated frequency.

Fig. 6 AC Loss of 100J/77.3K HTS Test Coil



4. HTS CABLE

4.1 SPECIFICATION AND DESIGN

The cross sectional structure of the prototype cable is shown in Fig.7. The specifications of the prototype cable are shown in Table 5. The outer diameter of this cable was designed to be 130mm, applicable to existing ducts with 150mm inner diameter. The size of the cable was designed to house three cable cores together in the thermally insulated pipes.

Fig. 7 The Structure of HTS Prototype Cable

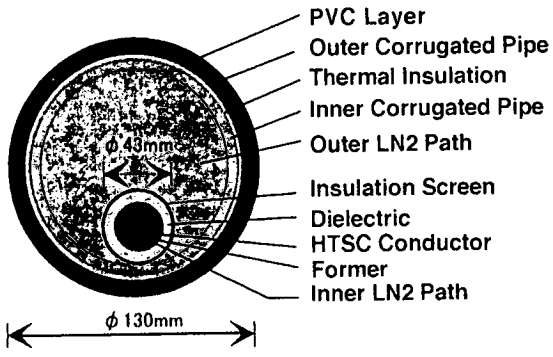


Table 5 Specification of HTS Prototype Cable

Voltage class		$66kV_{rms}$
Nominal current		$1kA_{rms}$
Number of phase		1
cable length		30m
Cooling method		circulation of sub-cooled liuquid nitrogen
Dimension	former	19.2mm O.D.
	conductor	22.8mmO.D.
	cable core	43mm O.D.
	cable	130mm O.D.
HTSC wire	materials	silver-sheathed Bi2223
	size	3.5mmw X 0.25mmt
	critical current	48A

4.1.1 CONDUCTOR

The conductor was wound with Bi2223 silver-sheathed wires spirally around a copper pipe former to make 4 layers. Each layer is insulated to cut the eddy current path between the layers [9]. The cable requires more than 1414A dc critical current, which is the peak current of 1kA ac. The conductor consists of 60 HTSC wires, taking into account the degradation of critical current by the magnetic field and mechanical stress history.

4.1.2 ELECTRIC INSULATION

The prototype cable is insulated with dielectric papers impregnated with liquid nitrogen, which is similar to the dielectric structure of oil-filled cables. The conditions of liquid nitrogen influence dielectric characteristics. Then, dielectric characteristics of the PPLP (Polypropylene Laminated Paper) impregnated with liquid nitrogen were measured using sheet samples, mini model cables and model cables. Fig.8 shows the ac and impulse breakdown stresses and Fig.9 shows partial discharge inception electrical stress (E_i) and extinction electrical stress (E_e).

Paper No. 2

Fig. 8 Relationship between Breakdown Strength of PPLP and Liquid Nitrogen Pressure

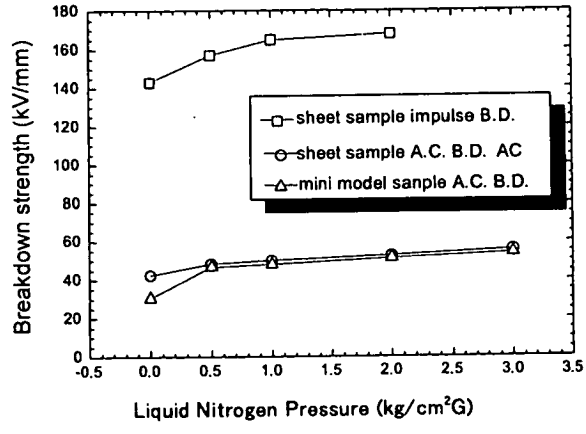
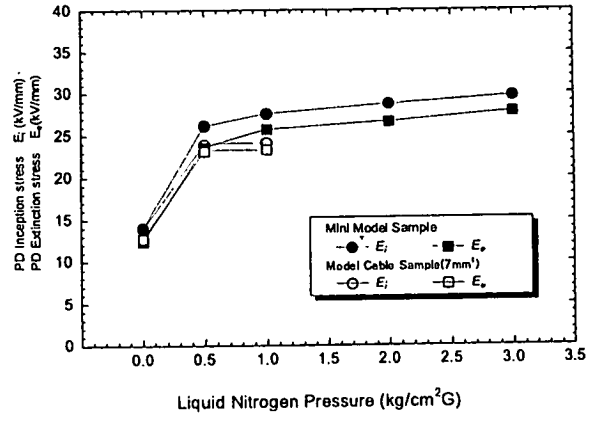


Fig. 9 Characteristics of Partial Discharge in Model Cables



These Figures show that E_i, E_e and breakdown stress increase as the pressure of the liquid nitrogen becomes higher. This tendency is thought to be the result of the decrease of bubbles, which cause partial discharge, as the pressure of liquid nitrogen increases.

The target value for electric insulation was 130kV for ac, and 385kV for impulse, which are the withstanding test voltage for 66kV class conventional oil-filled cables. The insulation thickness of the prototype cable was designed under the condition that the electrical stress of the insulation would be free from partial discharge at 130kV ac. Fig.9 shows that the E_i and E_c almost saturate over 1kg/cm²G region. Hence, the maximum stress was determined to be 20kV/mm by the Ei stress assuming that the cable is operated with more than 1kg/cm²G pressure. The insulation thickness of the 66kV prototype cable was designed to be 9mm.

4.1.3 THERMAL INSULATION

The thermal insulation consists of two coaxial stainless steel corrugated pipes and multi-layer insulation (M.L.I.) in a vacuum state. The target value for the heat leak was 1.0W/m. The thickness of the thermal insulation was designed to be 2.5mm, with the following equation.

$$W_{in} = \frac{2\pi k \Delta T}{\ln \frac{R_4}{R_3}}$$

Where W_{in} is the heat leak (1.0W/m), ΔT is the temperature difference between the room temperature and the liquid nitrogen, R_3 is the inner diameter of the outer corrugated pipe, R_4 is the outer diameter of the M.L.I., and k is the thermal conductivity of M.L.I. (3.5×10^{-5}W/m/K, measured in short samples).

4.2 LOADING TEST

A schematic diagram of the HTSC prototype cable system is shown in Fig.10. Liquid nitrogen, cooled and pressurized by the cooling system, flows into the inner liquid nitrogen path and returns through the outer liquid nitrogen path shown in Fig.7. The liquid nitrogen is sent back to the cooling system, and is cooled and pressurized again for the next cycle. The outline of the installation of the 30m HTS cable system is shown in Fig.11.

Fig. 10 Schematics Diagram of HTSC Cable System

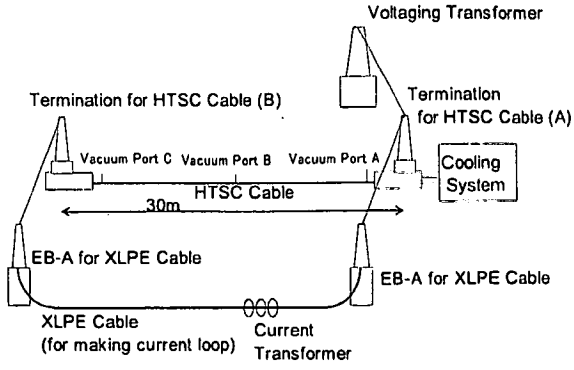
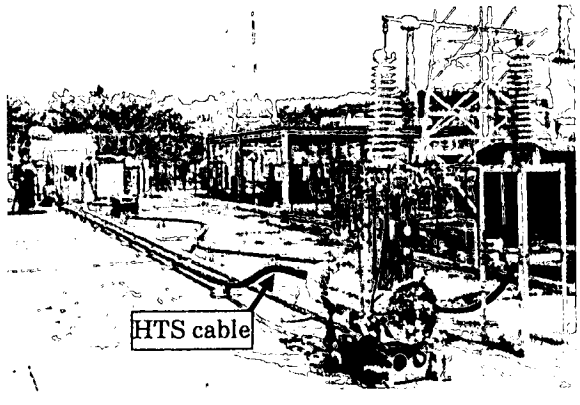


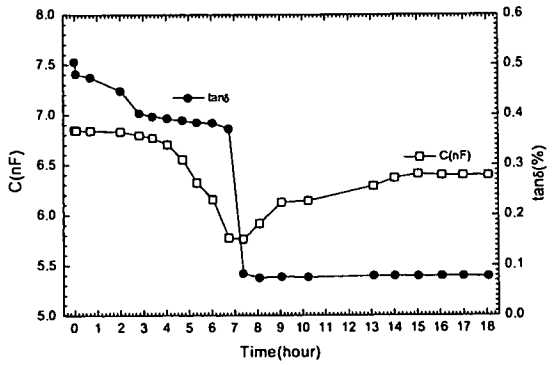
Fig.11 Outline of 30m HTS Cable System



4.2.1 COOLING TEST

The cable was cooled from room temperature to 77K using cooled nitrogen gas and liquid nitrogen. The time variation of the loss tangent (tanδ) and capacitance of the 30m long cable after the start of cooling is shown in Fig.12. It was measured at 5kV, 60Hz. Tanδ decreases dramatically at liquid nitrogen temperature in comparison with that at room temperature. About seven hours after starting the cooling, tan became constant. Capacitance shows interesting characteristics. At first, it decreases due to the temperature dependence of the ε of PPLP. Then, it increases because nitrogen gas (ε =1) between PPLP layers is replaced with liquid nitrogen (ε =1.4). After the liquid nitrogen is fully impregnated between PPLP layers, it reaches a constant value of about 6.4nF.

Fig. 12 Dielectric Loss Tangent and Capacitance of the Cable at Initial Cool Down



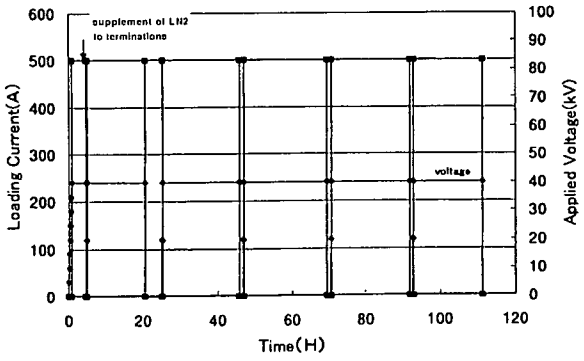
4.2.2 LOADING TEST

After being cooled down, liquid nitrogen was circulated through the cable, and the critical current was measured under the condition of 0.2kg/cm²G, 72K, sub-cooled liquid nitrogen. The critical current is measured as 1600A by the definition of $10^{-12}\,\Omega$m criterion. This value is almost equal to the design value.

The loading test was performed while keeping the same condition of the sub-cooled liquid nitrogen (0.2kg/cm²G, 72K). A 60Hz step voltage was applied at the rate of 5kV/5minutes and held at 40kV which is larger than the line to ground working voltage of a 66kV cable. After that, 1kA current was loaded for ten minutes. In these tests, there was no increase of tan δ, which indicates that partial discharge does not occur under working condition.

As the next step, 40kV-500A was applied to the prototype cable for more than 100 hours. Fig.13 shows the pattern of the voltage and current during the test. As a result, the long term loading test was successfully completed.

Fig. 13 40kV-500A Loading Pattern



5. CONCLUSION

The achievements of Superconducting technology for power application have been described.

On LTS SMES, the effect of the stabilization of a simulated power system was confirmed. Also, the estimation of the heat loss was evaluated and it was confirmed that it had good accuracy. On HTS SMES, we fabricated a test coil that uses a HTS wire, and the coil operated with DC of 34.2A and 100J was stored at 77K stably. Moreover, it successfully operated with 2Hz, triangular current of 34.2A-peak, simulating SMES operation, without a quench phenomenon.

On HTS cable, A 30m long 100MVA(66kV-1kA) HTSC prototype cable was developed and the critical current of 1600A was obtained as originally designed. At the initial loading test, the 40kV-1kA for 10 minutes was successfully applied and next 40kV-500A loading test was completed successfully with a constant tan δ and capacitance.

Toward practical use of HTS technology, improvement of current capacity of the wires, manufacturing methods, cost reduction, enhancement of reliability and stability of the system are needed for the superconducting power applications [10][11].

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Paper No. 3

POWER SUPPLY SYSTEM DESIGN FOR FUTURE MTR EXTENSIONS

Speakers : Ir Samuel S. C. Chan
Senior Engineer (Power Supply & Electrical Services)
Ir M. K. Mak
Engineer (Power Supply)
Mass Transit Railway Corporation, Hong Kong

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ABSTRACT

A number of major extensions to the existing Mass Transit Railway (MTR) are planned which will require addition of internal bulk power supply networks to meet the service requirements. Existing MTR power system design principles which had been in place for over 20 years needed review to ensure that MTR adopted the most cost-effective power system network development for its future requirements. Extensive studies using quantified reliability assessment techniques have been undertaken to review the existing design principles. As a result, new design principles and long term power system development plans are formulated for the planned MTR extensions to enhance reliability, operational flexibility and cost-effectiveness. This paper describes the new power system design principles adopted for future MTR extensions including the deletion of 11kV distribution network, the back-up philosophy and the single rectifier traction substation. A brief description on the Power Supply System for Tseung Kwan O Extension based on new design principles is also included in this paper.

Paper No. 3

1. INTRODUCTION

Apart from the Tseung Kwan O Extension (TKE), a number of major extensions are being planned or considered. These will require addition of internal bulk power supply networks and modifications to the existing MTR power supply system. If the planning of these extensions are not coordinated, incompatibilities and repetitions could occur in the power supply system design for the different extensions leading to unnecessary expenditure and constraints in the system.

MTR decided to conduct a long term staged plan study in 1996 to optimise the power supply system design for the planned MTR extensions taking into account the following uncertainties:

- Scope and phasing of future extensions.
- Load sharing requirements between the power companies (CLP and HEC).
- Services and traction power demand.

A review of the existing MTR power system design principles was deemed necessary and new design principles were required to be developed before performing the long term staged plan study. Quantified reliability, hazard and cost assessments were carried out to establish the new power system design principles taking into account the failure scenarios, equipment failure rates, extent of power interruption, restoration times and safety implications. These new design principles were applied to the long term staged plan study to formulate an optimised power system development plan integrating the planned MTR extensions.

2. THE PRESENT MTR POWER SUPPLY SYSTEM

The existing MTR power system design principles had been developed for over 20 years and were adopted for designing the power supply system [1] for the Modified Initial System (Kwun Tong to Central), Tsuen Wan Extension (Tsuen Wan to Prince Edward), Island Line (Chai Wan to Sheung Wan) and Eastern Harbour Crossing (Kwun Tong to

Quarry Bay). The design principles of the power supply system for the Lantau and Airport Railway [2] basically followed the old principles.

The major existing MTR power system design principles are summarised as follows and illustrated in Figure 1:

- Two or more infeed supplies for the MTR power supply system are obtained from both power companies, CLP and HEC.
- The high voltage (HV) power supply network comprises a 33kV transmission system and a 11kV distribution system.
- The 33kV transmission system is normally arranged in closed ring configuration and the 11kV distribution system is normally arranged in open loop configuration. Interlocking facilities are provided to prevent paralleling of any two sources of infeed supplies under all circumstances.
- Full operation service is maintained by 33kV autochangeover to the remaining healthy infeed(s) if all infeeds from either one of the power companies fail.
- Each passenger station, ancillary building and depot is provided with two 11kV supply sources derived from the two different power companies under normal operating conditions. The 415V low voltage (LV) services supply for each passenger station, ancillary building and depot is obtained from the two 11kV supply sources via 11kV/415V services transformers. Under normal conditions, the two 11kV supply sources take up approximately half of the electrical demand of the services loads. In the event of one 11kV supply source fails, the essential loads will be transferred to the remaining 11kV supply source by automatic LV changeover and shedding of non-essential loads.
- Standby generators supplying critical loads are provided at the ventilation buildings serving the immersed tubes across the harbour.
- Uninterruptible power supply (UPS) system and central battery system are provided for the computerised system and critical equipment (emergency lighting and tunnel lighting) respectively.
- The 1500V d.c. traction power supply is derived from the 33kV transmission system via the rectifier transformers and rectifier units at each traction substation. Each rectifier transformer has ±7.5° phase shift arrangement on the primary to enable an overall 24 pulse to be obtained with two rectifier transformers and rectifier units in parallel operation at each traction substation.

3. MAJOR NEW DESIGN PRINCIPLES FOR MTR HV POWER SUPPLY SYSTEM

Supply Arrangement For Infeeds

A total blackout incident happened in 1984 for one of the power companies in Hong Kong dictating the existing MTR design principle of maintaining full service operation under total supply failure from one of the power companies (either CLP or HEC). However, this high security requirement imposes substantial constraints in internal power system network optimisation for future MTR extensions.

In the detailed analysis of the system reliability levels for a typical network using the existing design principles, failure rates of the power supply equipment and infeed supply were established. Sensitivity analysis on the common mode failure for both infeed supplies derived from the same power company was included in the assessment to examine the effect on load side reliability.

The following latest developments/ improvements of the CLP and HEC networks were also considered in determining the common mode failure scenarios:

- The extra high voltage (EHV) systems at 400kV and 275kV for CLP and HEC respectively have been developed into grid and ring configurations which provide a

high level of system reliability.

- Strong interconnection between CLP and power systems in mainland China.
- Strong interconnection between CLP and HEC.
- High transient stability margins.
- Improved system damping capability.
- Spinning reserve and load shedding schemes.

The results of the analysis indicate that the configuration of the MTR internal power supply system is the major factor in affecting the system reliability and that such reliability levels are relatively insensitive to changes in the infeed supply failure rates provided that the infeeds backing up each other are independent up to EHV level.

Therefore, independent infeed supplies can be obtained from the same power company whilst still maintaining acceptable reliability levels for traction and services loads. Two or more infeed supplies from the same power company backing up each other by 33kV auto-changeover are considered adequate for supplying one or more extensions. When one infeed supply fails, all the loads will be transferred to the remaining infeed(s) by 33kV autochangeover.

The new design principle requires infeed supplies backing up each other to be independent up to EHV level and can be taken from the same power company or different power companies. This will allow more flexibility in selecting infeed supply locations close to load centres especially for an extension without a cross harbour link. The number of new infeed supplies required may also be reduced since much back-up capacity in existing infeed supplies can be released when multiple infeed supplies failure scenarios are not required to be considered.

Supply Arrangement For Services Loads

The existing design principle requires that each LV services load centre, at a station, ancillary building or depot, should be supplied from two separate HV infeed supplies, one from HEC and the other from CLP, each normally feeding half of the services loads. This arrangement requires a 11kV distribution supply network arranged in an open loop configuration as shown in Figure 1.

An alternative supply configuration as shown in Figure 2 was developed during the design principle review. In this supply configuration, the two services transformers feeding the same LV switchboard are normally fed from the same infeed supply via 33kV closed ring networks. In case the infeed supply fails, the LV services loads will be supplied from the other infeed supply via 33kV autochangeover. A reliability study using minimal cut set analysis was conducted for the existing supply configuration and the alternative supply configuration. The results of the analysis reveal that the alternative supply configuration using single voltage closed ring system has higher Mean Time Between Failure (MTBF) values with respect to total loss of LV services supplies than the existing supply configuration. The transmission losses and associated electricity cost will also be reduced significantly by adopting the single voltage closed ring system.

With this single voltage closed ring system configuration under the new design principle, the 11kV distribution network can be deleted and the LV services supplies will be directly taken from the 33kV closed ring network feeding also the traction loads. This will result in lower capital cost, lower operating costs, better maintainability, simplified design process and yet higher overall reliability. In addition, the single voltage closed ring system configuration can allow more operational flexibility to cater for uncertain load sharing requirements between CLP and HEC.

Back-up Supplies

An evaluation was conducted on the necessity of low voltage emergency supply arrangement for the computerised and critical equipment that have implication on passenger safety. The results of the evaluation are summarised as follows:

(a) Uninterruptible Power Supply System

The provision of uninterruptible power supply system is necessary to ensure that computerised equipment will not be interrupted by the transient disturbance such as voltage dip due to lightning and changeover of the power supply system. Longer back-up time is required for the UPS supplying critical equipment such as Public Address system, Radio and Data Transmission System to ensure passenger and staff safety during evacuation in the event of total loss of LV services supplies. De-centralised UPS will be adopted in supplying all the computerised systems to improve the availability and reliability as compared to the centralised UPS arrangement previously adopted.

(b) Central Battery Supply System

The provision of back-up supply for the emergency lighting and tunnel lighting is necessary to ensure passenger safety during evacuation in the event of total loss of LV services supplies. Short term interruptions will not have significant effect on the emergency lighting and therefore the Central Battery System can be used as the back-up supply source.

(c) Standby Generators

Safety analysis and cost benefit analysis were conducted to assess whether standby generators are required to provide emergency LV power supply for the critical loads (tunnel ventilation fans) at the ventilation buildings serving the immersed tube across the harbour. The results of safety analysis conclude that there are no substantial changes in risk level to passengers with or without the standby generator during emergency evacuation due to total loss of LV services and traction power supplies. The results of the cost benefit analysis show that provision of standby generators is not justified.

The provision of standby generators at the ventilation buildings serving the immersed tube will no longer be required for future extensions.

4. MAJOR NEW DESIGN PRINCIPLES FOR DC TRACTION POWER SUPPLY SYSTEM

Single Rectifier Traction Substation

The use of single rectifier traction substations (12 pulse operation) as an alternative to the existing double rectifiers traction substations (24 pulse operation) was reviewed in terms of reliability, cost benefit and harmonics considerations.

The results of reliability and cost benefit analysis reveal that the overall reliability of the traction power system are considered acceptable and there will be significant cost savings.

Harmonic study was conducted to assess the harmonic levels caused by 12 pulse rectifiers operation at the point of common coupling at the infeeds. The results of the study indicate that the total harmonic distortions are still within the limits specified by the power companies. The study also reveals that any resonance present in the internal power supply system may significantly alter the harmonic levels. The resonance condition is very sensitive to the network impedance parameters and cannot be predicated accurately during design stage. However, the newly adopted single voltage (33kV) closed ring system has operational flexibility to reconfigure the network to overcome the resonance problem that might occur.

Stray Current Corrosion Control

For the existing MTR system, the negative bar of each traction substation is connected to substation earth via drainage diode for collection of stray current. This arrangement is called diode earth system. Floating negative system, i.e. negative bar isolated from the substation earth is introduced in the Lantau and Airport Railway to further minimise the stray current. The floating negative system will be adopted for future new extensions which is in line with the latest European Standard EN50122-2.

Where the new extension is required to be connected to the existing system, further assessment will be carried out to review the arrangement of direct interconnection of a floating negative system to a diode earth system.

5. POWER SUPPLY SYSTEM FOR TSEUNG KWAN O EXTENSION

The new design principles for the HV and dc traction power supply system as described in this paper have been applied to the Power Supply System for the Tseung Kwan O Extension (TKE) to be commissioned in end 2002.

The major features of the MTR power supply system for TKE are summarised as follows:

- The infeed supplies will be obtained from HEC at QIS (adjacent to existing Quarry Bay Ventilation Building) and CLP at TIS (between Tseung Kwan O station and Hang Hau station).
- The HV power supply system comprises 33kV closed ring networks feeding traction supplies and LV services supplies.
- The LV services supplies at each passenger station, ancillary building and depot will be obtained via 33kV/415V services transformers.
- New rectifier transformer and rectifier units will feed extended portion of Kwun Tong Line (Lam Tin station to Tiu Keng Leng station) and Tseung Kwan O Line (North Point station to Po Lam/Tseung Kwan O South stations) at Tiu Keng Leng (TKL), TIS, Po Lam (POL) and the depot (TKD).
- Diode earth system will be adopted for Kwun Tong Line (extended portion) and floating negative system will be adopted for Tseung Kwan O Line.

The major new power supply equipment required for the power supply system of TKE (including future Tseung Kwan O South station) are given as follows:

- 4x60MVA 132/33kV infeed transformers provided by power companies at the two infeed substations.
- 60x1600kVA 33kV/415V services transformers at five ancillary buildings, six passenger stations and the depot.
- 7x4MW rectifier units at four new traction substations.
- 18x33kV switchboards and 7x1500V dc switchboards.
- approximate 46km of 33kV power cables and 40km of dc traction power cables.
- 33kV autochangeover and interlocking system comprising programmable logic controllers at strategic substations.

Figures 3 & 4 illustrate the HV and dc traction power supply system configurations respectively for TKE.

6. CONCLUSION

New power system design principles were established using quantified reliability assessment techniques and cost benefit analysis. The newly developed design principles allow more flexibility in power system configuration design with lower capital and operating costs whilst still maintaining acceptable reliability levels for the services and traction loads. These new design principles have been applied to the TKE and the long term staged plan study in formulating an optimised power system development plan integrating the planned MTR extensions.

ACKNOWLEDGEMENT

The authors wish to thank the MTR Corporation for their permission to publish this paper and to the design teams of the Corporation for their contribution in the power system design.

REFERENCE

(1) F.J. Murphy and P. Lawton, 'Hong Kong Mass Transit Railway Power Supply System' IEE Proceedings, Vol.133, Part C, No.7, November 1986.

(2) Patrick Cheung and Dave Wong, 'Power Supply System of the Lantau And Airport Railway' 25th Anniversary Commemorative Publication, IEEE Hong Kong Section 1996.

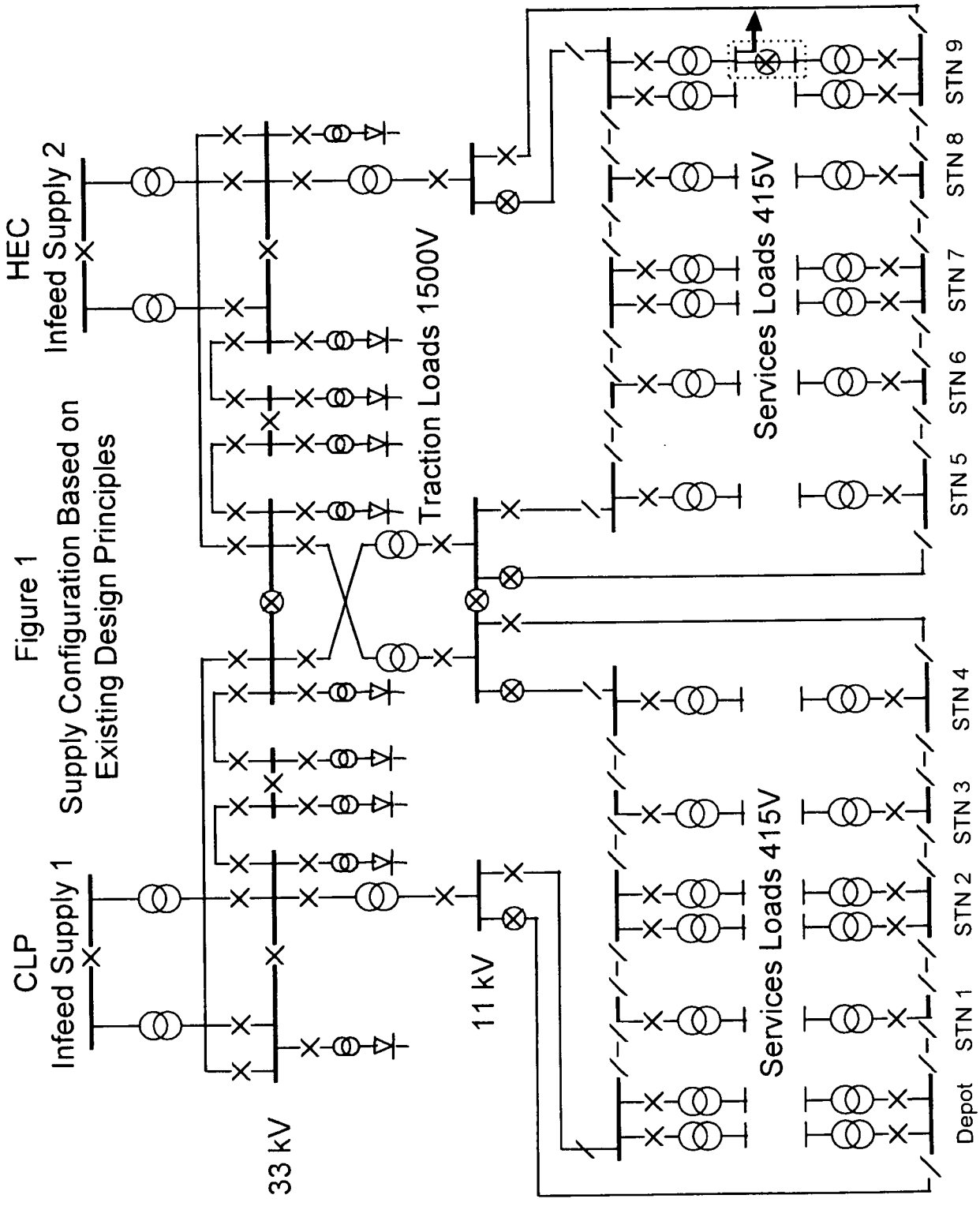

Figure 1
Supply Configuration Based on Existing Design Principles

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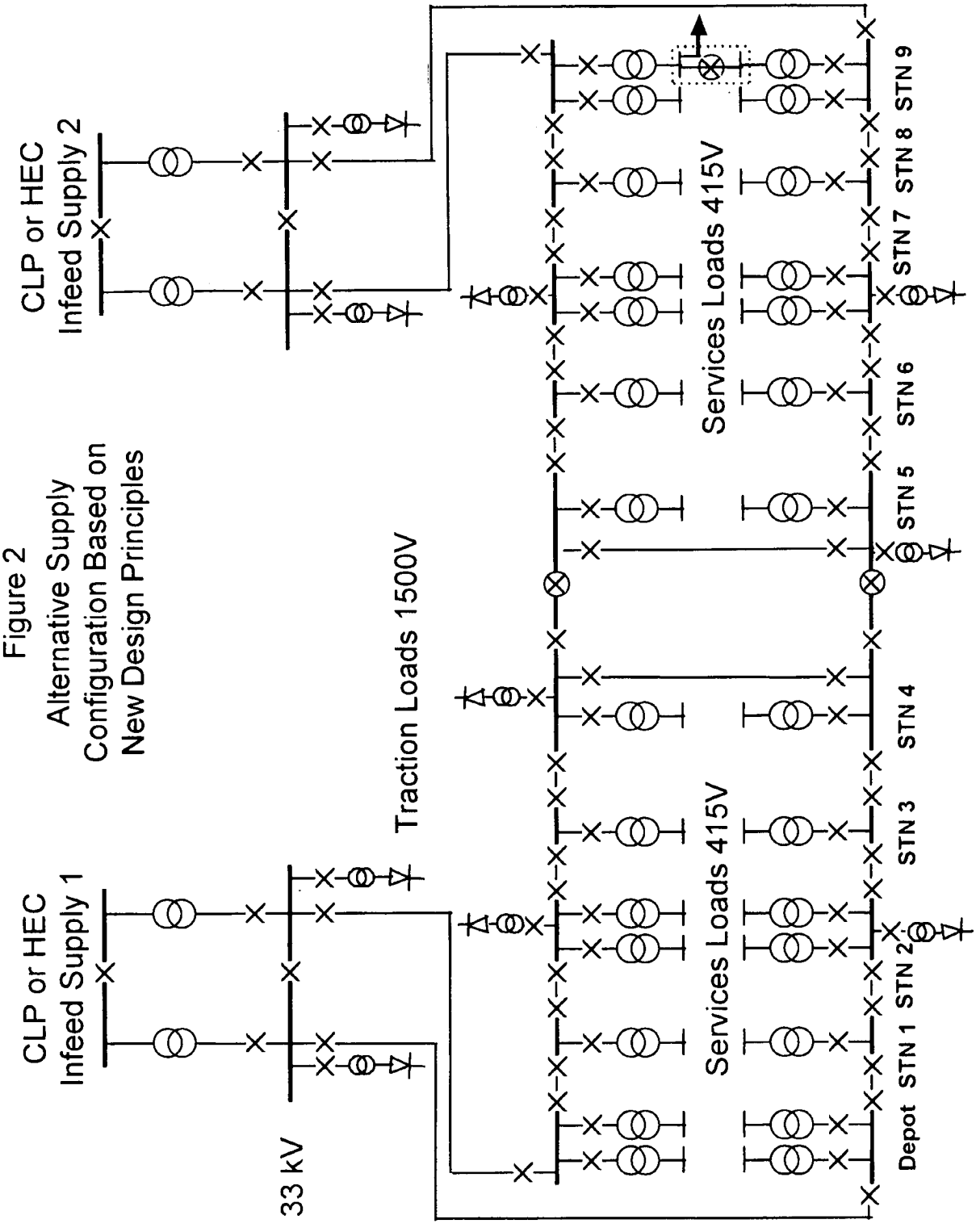

Figure 2
Alternative Supply
Configuration Based on
New Design Principles

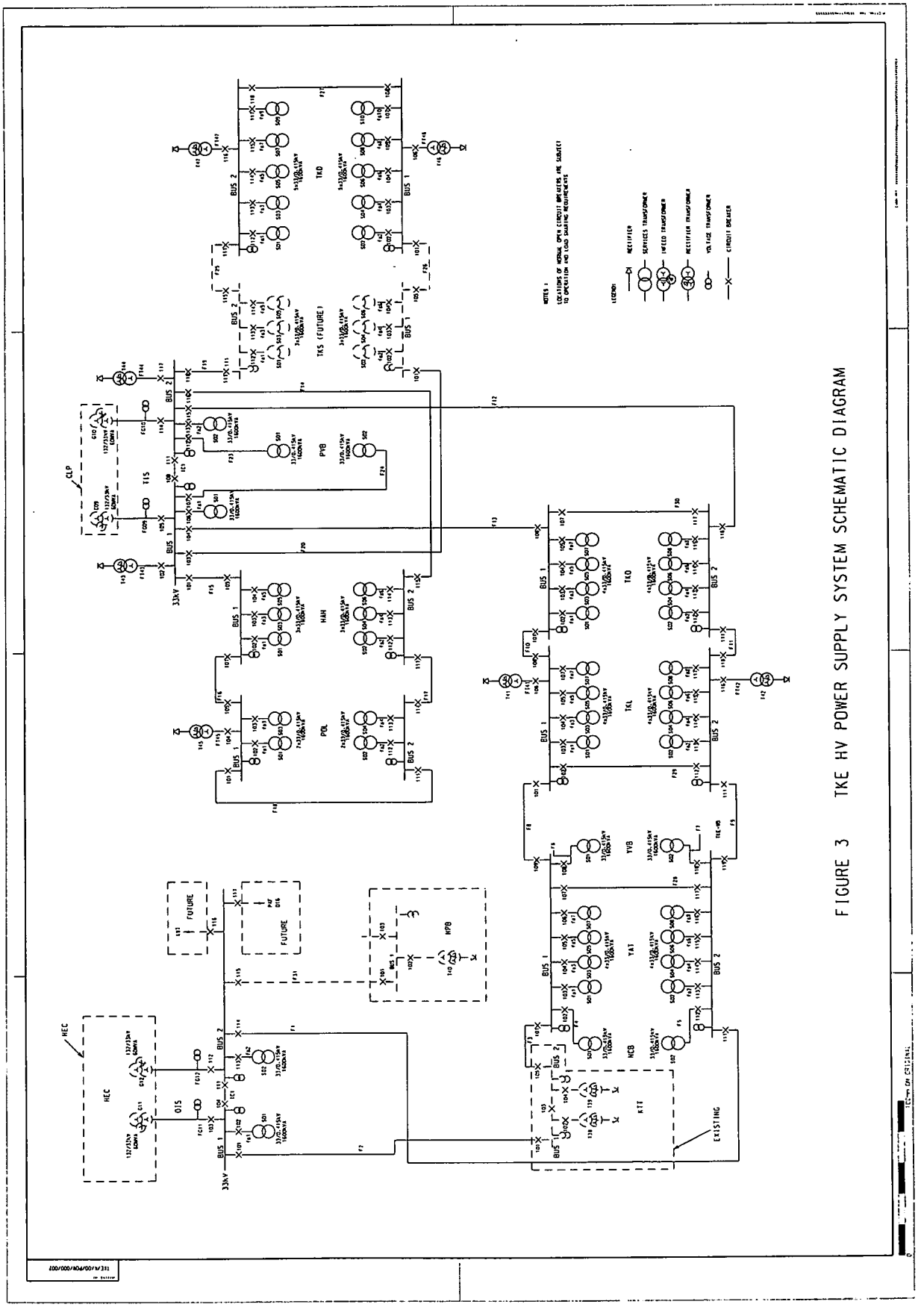

FIGURE 3 TKE HV POWER SUPPLY SYSTEM SCHEMATIC DIAGRAM

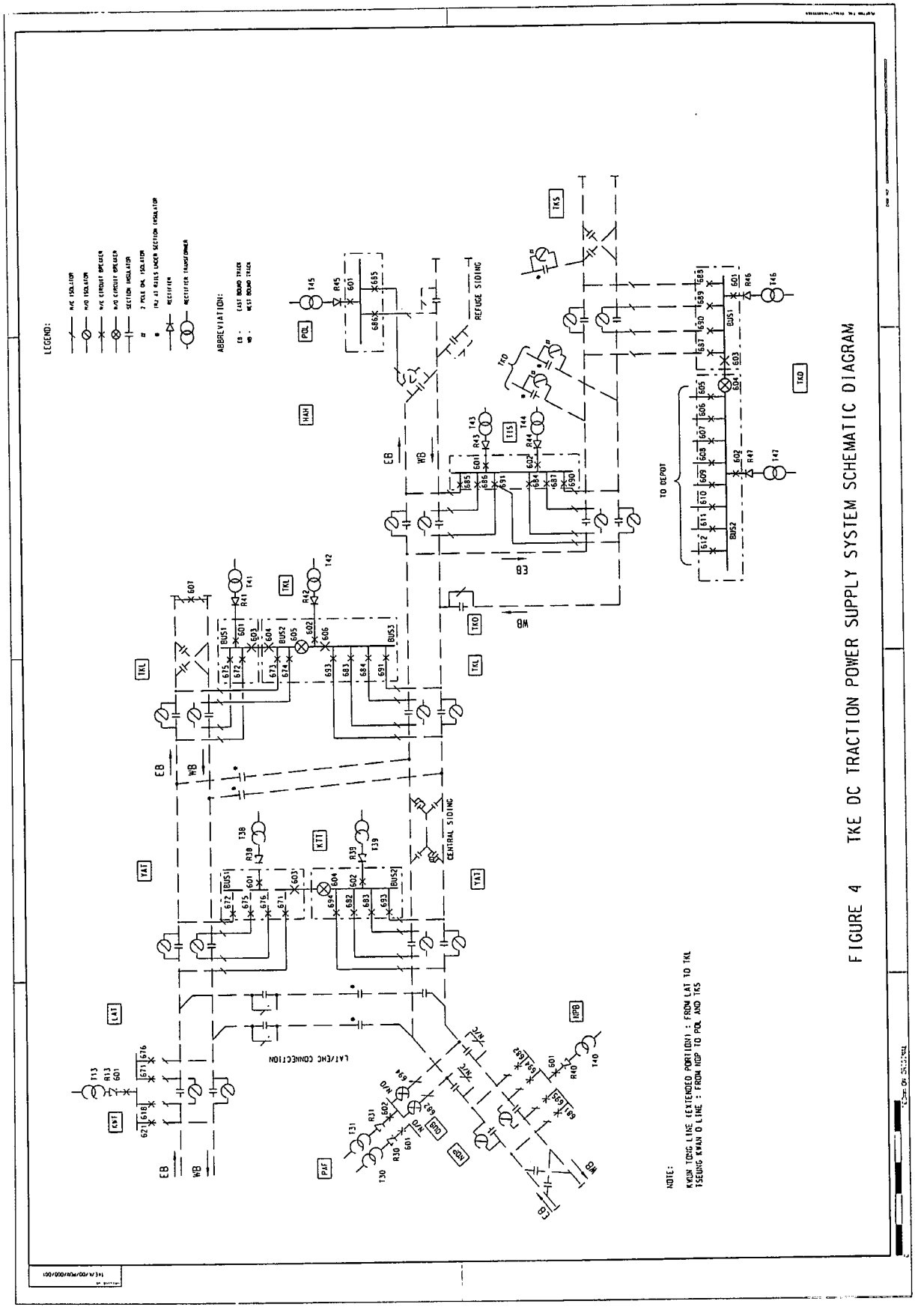

FIGURE 4 TKE DC TRACTION POWER SUPPLY SYSTEM SCHEMATIC DIAGRAM

Paper No. 4

THE HONG KONG INTERNATIONAL FINANCE CENTRE

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Senior Project Manager
Central Waterfront Property Project
Management Co. Ltd., Hong Kong

THE HONG KONG INTERNATIONAL FINANCE CENTRE

Ir Vitus W.T. Cheung
Senior Project Manager
Central Waterfront Property Project
Management Co. Ltd., Hong Kong

ABSTRACT

International Finance Centre is a premier large scale property development located on top of the Airport Express Line (HK) Station comprising

- 4.5 million sq. ft GFA
- Two office towers
- Two hotel towers
- 3 levels of leisuretainment centre
- 6 levels of basement carparks

The first phase of the development, including One IFC (a 38-storey grade A office building), was completed in December 1998.

The buildings were designed to possess not only electronic intelligence, but also interactive capacities to accommodate tenant's ever changing demand from time to time.

The paper discusses briefly how the building services (including Electrical and Information Technology) systems are designed in close integration with the architectural and structural design to give timeless quality to the buildings. The discussion is focused on One International Finance Centre for the sake of easy reference.

1. INTRODUCTION

IFC is a super-grade A mixed property development located directly on top of the AEL (HK) Station. It is the hub of all transportation like MTRC, taxi, bus, pedestrian footbridges, ferries and AEL.

The premier location of IFC at the Central District waterfront enables all the buildings in the development enjoying both panoramic sea view and convenient connection with the other prominent developments around.

In view of the above factors, IFC is a perfect place to be the centre of financial activities. The development, especially the two office buildings, were therefore designed in a manner to meet the expectation of financial institutes, bankers and investment companies.

Before carrying out the design, visits to both local and overseas financial offices were conducted extensively to formulate the design brief.

It was found that different companies have substantial deviation in policies and market share. Yet, they do have common technical requirements as listed below :

- Rectangular floor plate; span best between 13 to 14m; headroom best to be 2.7m for office and 3.3m for dealing area.
- High structural load area (e.g. 10kPa) for filing room, safe, vault or equipment room.
- Flexible design of building services to allow frequent change of the open plan office and dealing area layout or even expansion of the premises.
- Extra high demand on both capacity and reliability of power supply, cooling capacity and telecommunication infrastructure.
- Requirement of pre-action sprinkler and total gas-flooding system for the data CENTRE.
- Comprehensive building security control and facility management.
- Concern on energy efficiency, environmental issues, electromagnetic interference and fung-shui issues.

2. DESIGN SOLUTION

Architectural

- Change circular floor plate to square with equal size corner offices opportunity at the 4 corners.
- Introduce high headroom floors (3.3m) for dealing use.
- Provide multiple main switch rooms, dual TBE rooms, dual power/telecom riser ducts, dual dedicated riser ducts for tenants.
- Introduce more plant floors and provide UPS rooms at plant floors for tenants.
- Introduce hotel-feel warm tone interior design.
- Include fung shui concept into the building design.
- Modular 1500x1500 ceiling panels and 600x600 raised floor design. 150mm raised floor for office and 300mm raised floor for dealing areas.
- Double glazed (10/12/10mm) curtain wall to reduce both noise and heat transfer.
- Electromagnetic shielding to all electrical equipment rooms located immediately adjacent to office areas.
- Building Control CENTRE located at 2/F with direct access from the main lift lobby. CENTRE is 24-hours manned.

Building Services

- Electrical
  - CIBSE Cat 1/Cat 2 lighting with electronic ballast to eliminate eye strains, noisy operation and harmonic content.
  - Dual feed 11kV supply from HEC.
  - Totally separated Tenant supply from the Landlord supply to avoid harmonic distortion damages.
  - 11kV landlord supply to increase the flexibility and reliability.
  - 60VA/m^2 supply density to office and 120VA/m^2 supply density to dealing floors.
  - Separate Landlord and tenant generators. Tenant generators to back up tenant's own essential equipment and the essential chillers. 60kVA/floor design loading.
  - Clean telecommunication earth risers, dedicated for large tenants and communal for small tenants.
  - True dual physically separated telecom riser trunking for the FTNS cables. Dedicated conduits for large tenants.
  - Dual power supply riser busducts for each floor.
  - 20% standby transformer capacity.
- HVAC
  - 2 AHU's per floor with main air duct interconnected.
  - 30% standby chiller capacity to allow reliable chilled water supply and possible dedicated chiller to large tenant.
  - High essential chiller capacity, 50RT per floor design loading.
  - Fully distributed intelligent BMS, each VAV box can be controlled individually. BMS talks to other system like Fire Services, security, etc. via high level interface using BACNET protocol.
  - Low OTTV of 16W/m^2 as compared to the Buildings Regulation of 35W/m^2.
  - Sea water cooling for podium area to save energy and minimize heat rejection to the atmosphere.
  - High fresh air intake rate, 1 to 1.5 l/s per sq.m to eliminate rich building syndrome. Facilities like high efficiency filter and access panels in air ducts also allowed.
  - Design temperature in 23°C, 50% RH nominal.
  - Strict noise and vibration control.
  - CO/NO_2 detectors at carpark levels for air quality control.

- Fire Services
  - Pre-action sprinkler for large tenants.
- Security
  - All M/E major plant room and riser ducts are fully under 24-hour surveillance.
  - Access control system for passenger lift (after office hours) and critical plant rooms.
- Building Management System (BMS)
  - Full integration with all services with control/supervision at the Building Control Centre.
- Information Technology
  - Dual FTNS cable riser, cat 3/cat 5. About 500 pair copper and 12 core fibre-optic per floor.
  - Building backbone :
    - 24 core single mode/multi-mode fibre-optic floor
    - 100 pair cat 5 copper per floor
  - Audio-visual directory display and Financial information at the main lobby and passenger lifts.
- Others
  - Electromagnetic interference shield to all major plant rooms and sensitive areas, limiting residual magnetic field in tenant area to be below 10mG.
  - Fung Shui features at G/F and 3/F lobbies.
  - Comprehensive preventive maintenance schedules for generators, chillers, etc.
  - Comprehensive operation and maintenance plan to regularly monitor harmonic content, supply loading and space temperature.
  - Advance set up of facility management team.
  - Thorough commissioning of all major systems prior to building OP and handover to the tenants.
- Year 2000 Compliance

  Year 2000 Compliacne in full compliance with DISC PD2000-1:1998 A definition of Year 2000 conformity Requirements as prepared by British Standards Institution committee BDD/1/3 and issued by the British Standards Institution, as fully verified on all building system.

  Year 2000 conformity is interpreted to be neither performance nor functionality is affected by dates prior to, during and after the year 2000.

  In particular :

  - No value for current date will cause any interruption in operation.
  - Date-based functionality must behave consistently for dates prior to, during and after year 2000.
  - In all interfaces and data storage, the century in any date must be specified either explicitly or by unambiguous algorithms or inferencing rules.
  - Year 2000 must be recognised as a leap year.

    The Terminal Compliance Dates is taken as : 1st January 2050.

    Compliance Dates for which specific tests have been performed to demonstrate full compliance with the above definition are :

    Date Test 1 : 31st December 1998 to 1st January 1999

    Date Test 2 : 31st December 1999 to 1st January 2000

    Date Test 3 : 28th February 2000 to 29th February 2000

    Date Test 4 : 29th February 2000 to 1st March 2000

    Date Test 5 : 31st December 2000 to 1st January 2001

    Date Test 6 : 31st December 2001 to 1st January 2050

Paper No. 4

The systems to be investigated were determined by a process of reviewing all contract specifications, drawings and information from contractors and conducting visual site inspections. All systems have potential Year 2000 compliance issues were identified and appropriate assurances and information sought from contractors. All systems having potential Year 2000 compliance issues were tested by the appropriate contractors and confirming tests were witnessed.

Suggested actions to the Landlord's Building Emergency Plan aimed at minimising any potential disruptions caused by date related systems failures were also made.

3. RESULT

Total success in meeting tenant's requirement. By August 1999, One IFC is more than 85% committed.

One IFC enables total flexibility for the tenants with two tools :

- Interactive intelligence
- "FIRST" class building services :
  - Flexibility
  - Intelligence
  - Reliability
  - Security
  - Technology

ABBREVIATIONS

BMS – Building Management System

FTNS – Fixed Telecommunication Network Services

GFA – Gross Floor Area as defined in the Building Ordinance

IT – Information Technology

AEL – Airport Express Line

HEC – Hong Kong Electrical Co Ltd

AHU – Air Handling Units

VAV – Variable Air Volume

RT – Refrigeration Tonnage

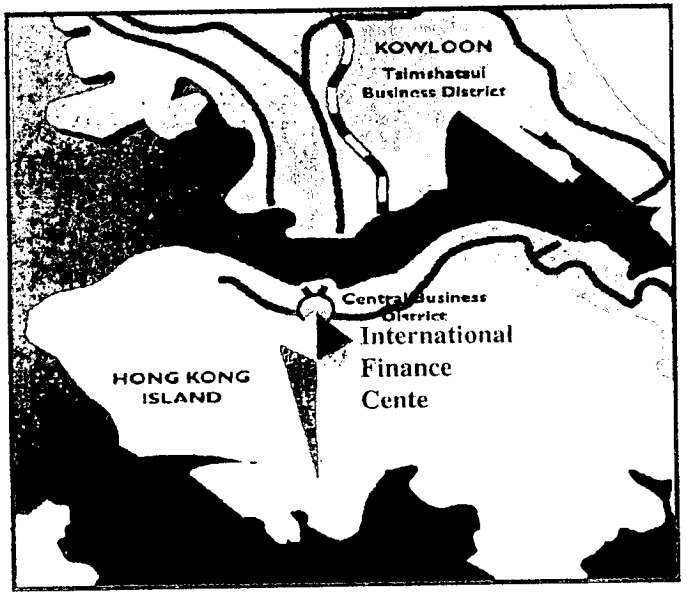
BACNET – Building Automation Control Network

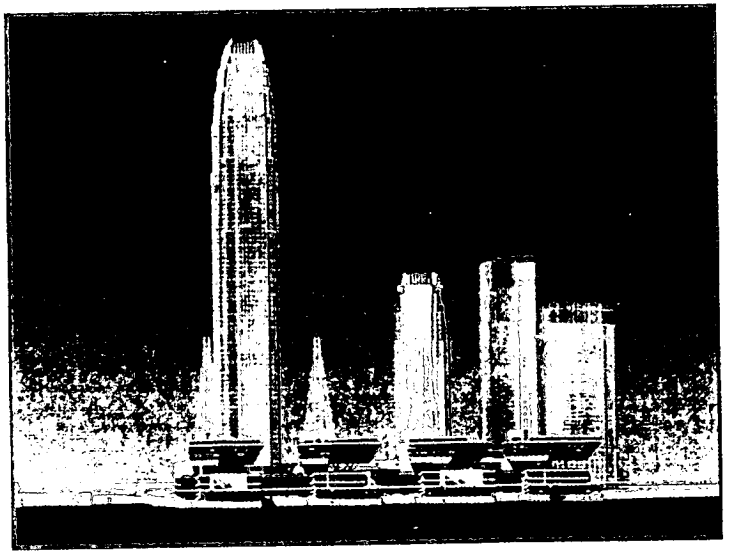
APPENDICES

- Design Schematics for Building System
- Graphical information about International Finance Centre

INTERNATIONAL FINANCE CENTRE

Supreme Location





International Finance Centre

DEVELOPMENT MIX

- MTRC Airport Railway (AEL & LAL Line)

  Hong Kong Station
- Two Office Towers

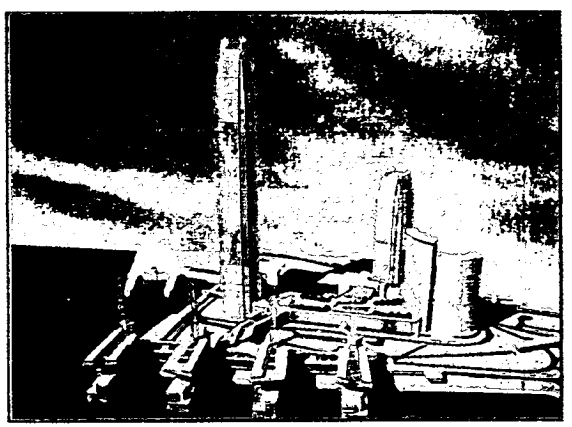
  GFA = 2 800 000 sq ft
- Retail Podium

  GFA = 800 000 sq ft
- 5-Star Hotel / Suite Hotel

  GFA = 1 100 000 sq ft
- Carpark

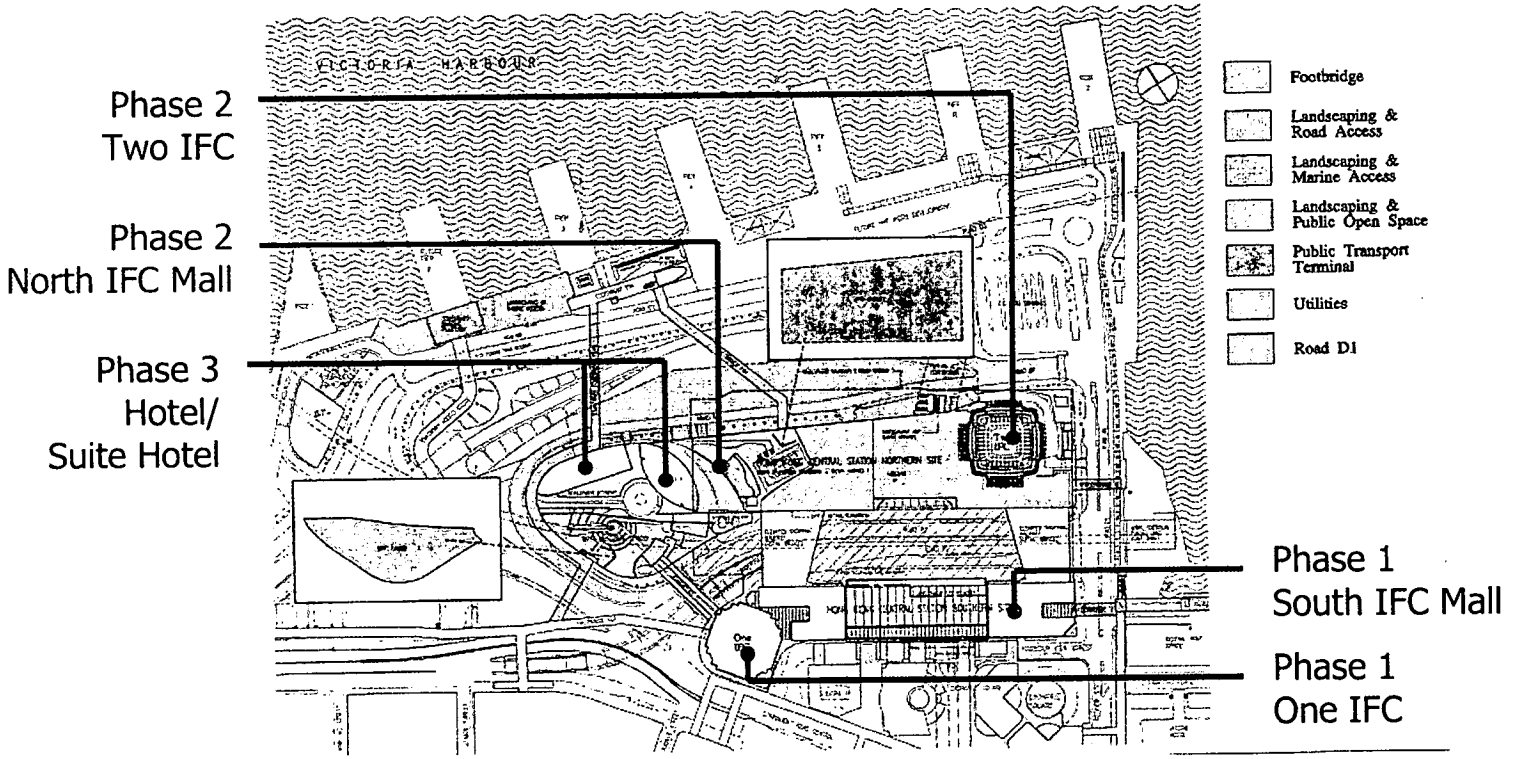
  1 800 parking stalls
- Landscape Garden

  110 000 sq ft



International Finance Centre

DEVELOPMENT PHASING PLAN

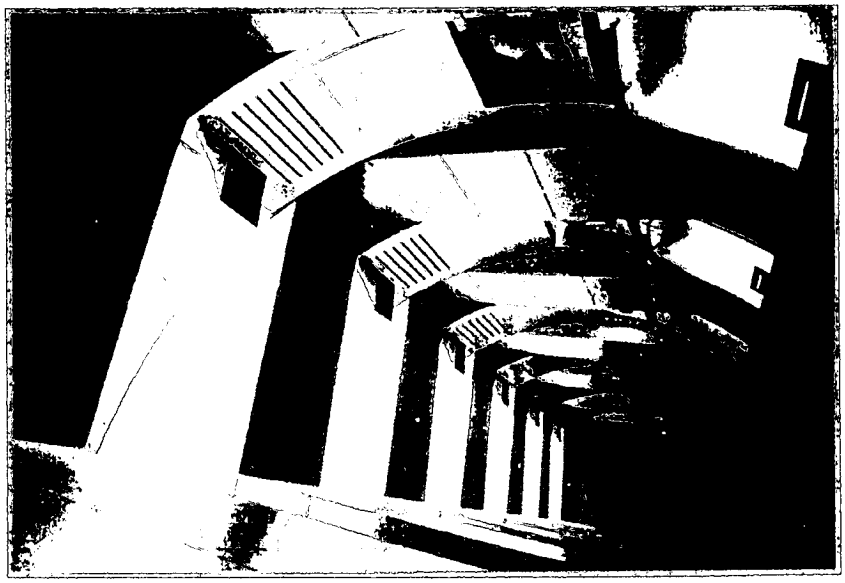


International Finance Centre

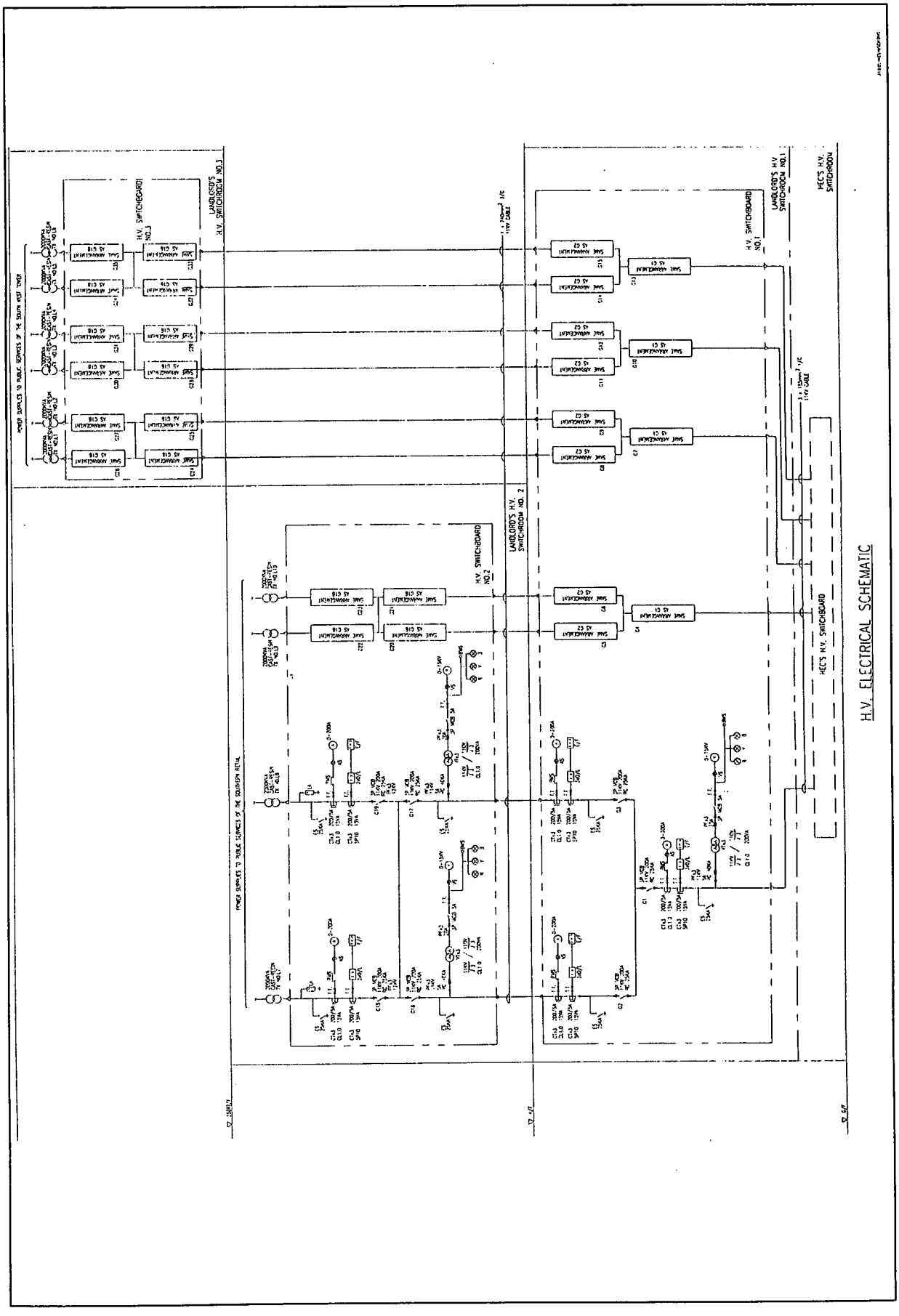
Paper No. 4

ONE IFC

- Building Control Centre



International Finance Centre



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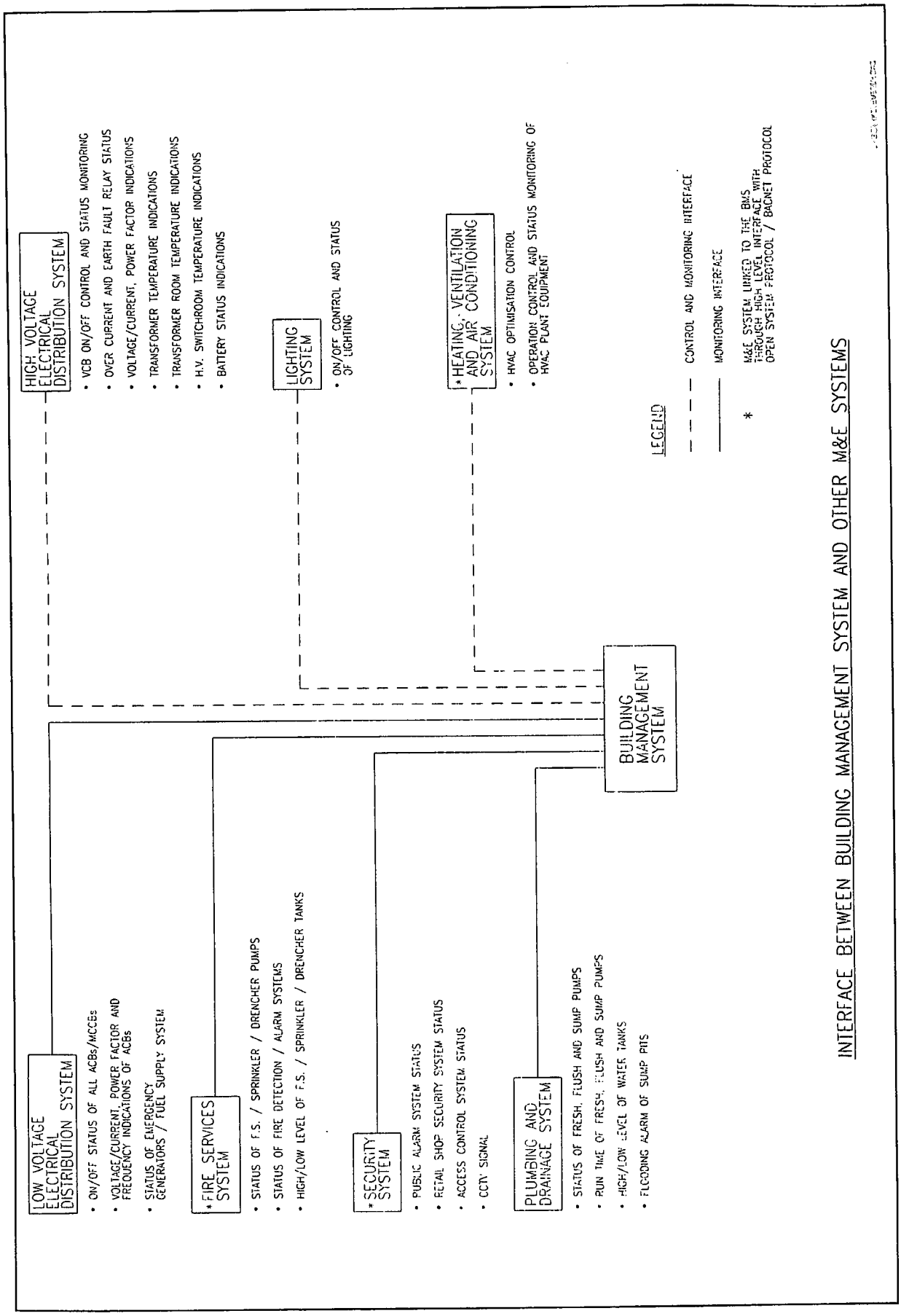
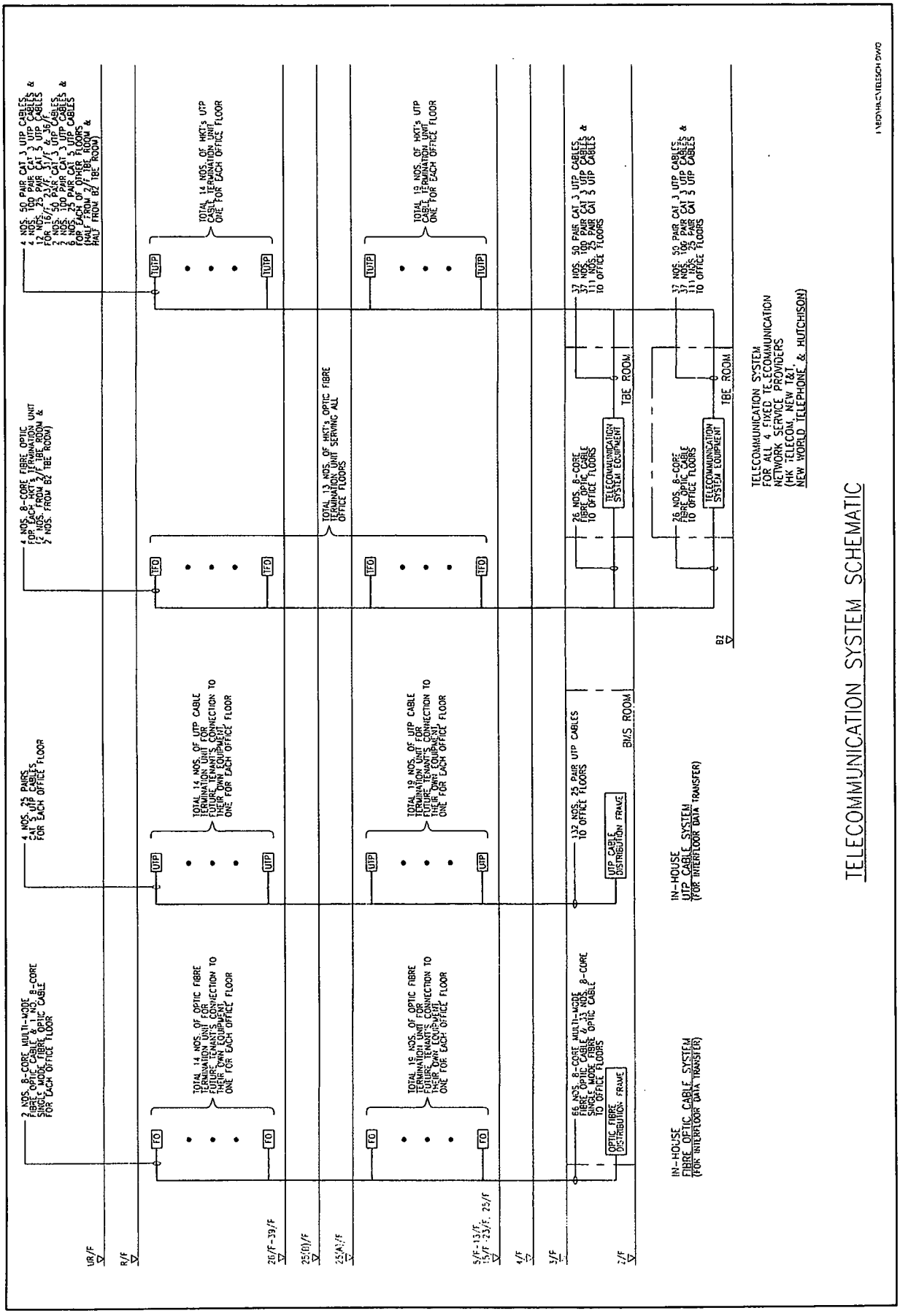


INTERFACE BETWEEN BUILDING MANAGEMENT SYSTEM AND OTHER M&E SYSTEMS



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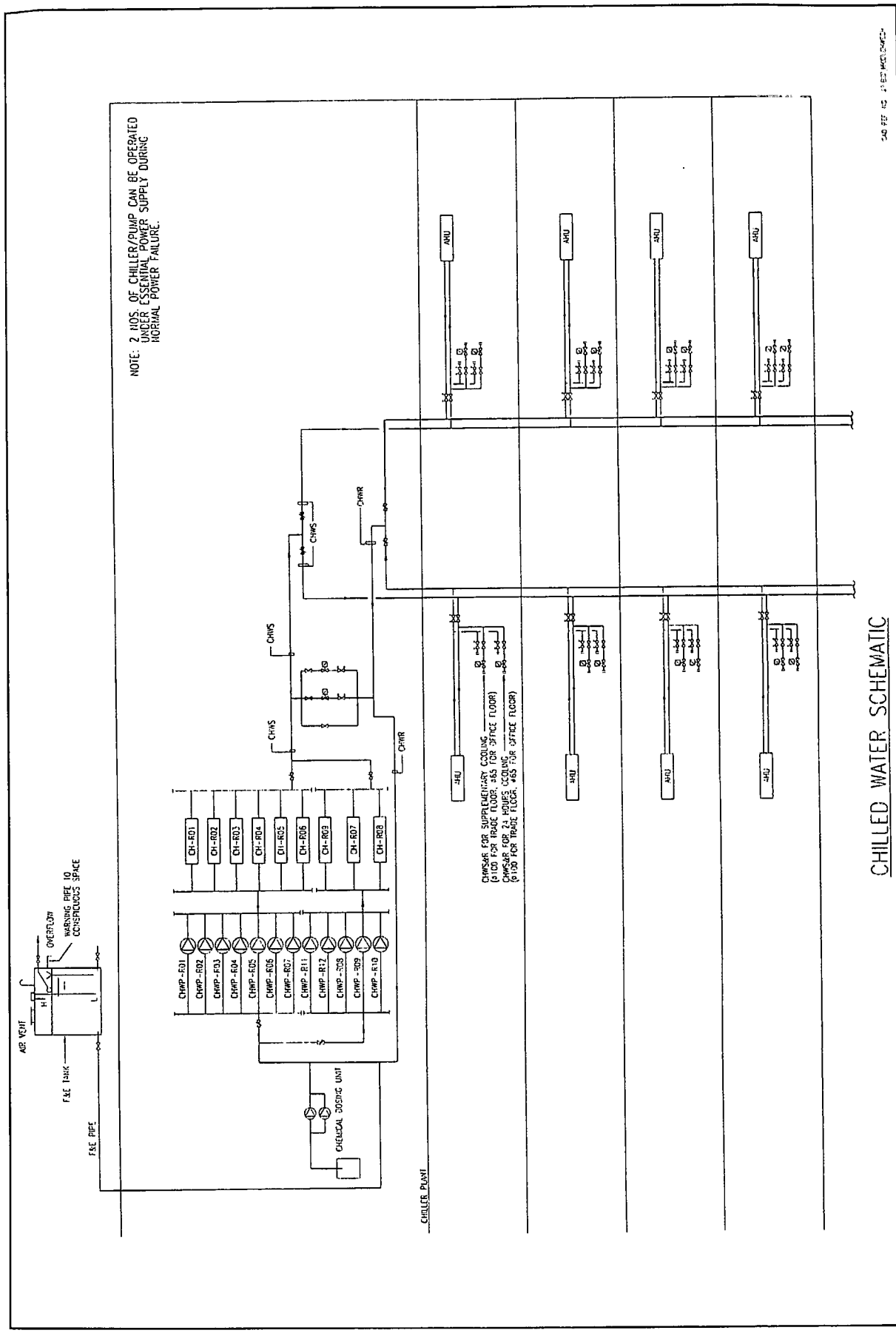
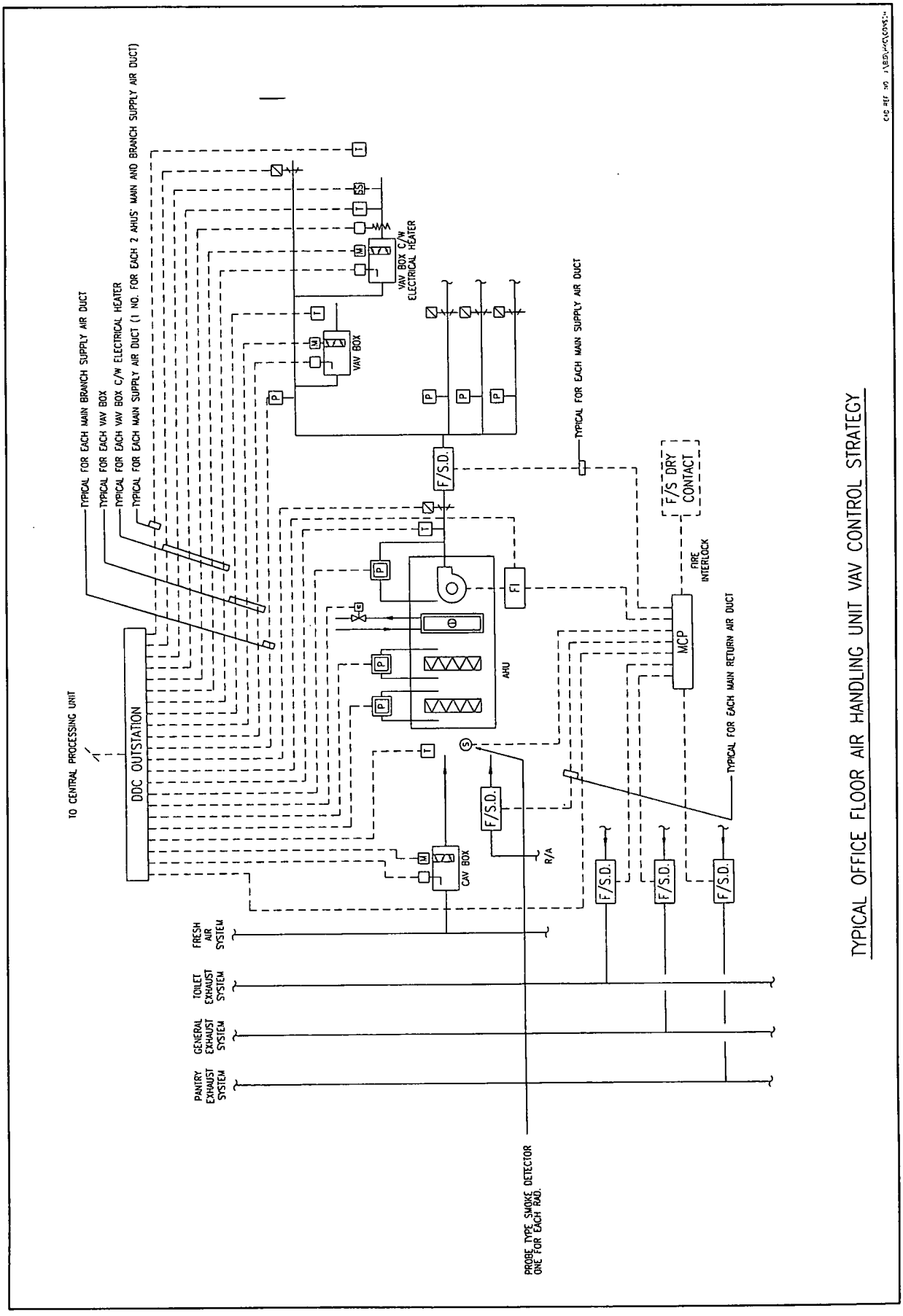

NOTE: 2 NOS. OF CHILLER/PUMP CAN BE OPERATED UNDER ESSENTIAL POWER SUPPLY DURING NORMAL POWER FAILURE.
CHILLED WATER SCHEMATIC
CHILLER PLANT
CHWS
CHWR
AHU
CH-R01
CH-R02
CH-R03
CH-R04
CH-R05
CH-R06
CH-R07
CH-R08
CHWP-R01
CHWP-R02
CHWP-R03
CHWP-R04
CHWP-R05
CHWP-R06
CHWP-R07
CHWP-R11
CHWP-R12
CHWP-R08
CHWP-R09
CHWP-R10
CHEMICAL DOSING UNIT
CHWSAR FOR SUPPLEMENTARY COOLING (9100 FOR ROOC FLOOR, 463 FOR OFFICE FLOOR)
CHWSAR FOR 24 HOURS COOLING (9100 FOR ROOC FLOOR, 463 FOR OFFICE FLOOR)
AIR VENT
OVERFLOW
WARNING PIPE TO CONSPICUOUS SPACE
FAE TANK
FAE PIPE



Paper No. 4

OFFICE AIR HANDLING UNIT VAV CONTROL

THE OFFICE FLOOR AIR HANDLING UNITS WILL BE DDC CONTROLLED AND HAVE THE FOLLOWING FUNCTIONS

A. AIR HANDLING UNIT

1. CONTROL
   - ON/OFF CONTROL AND STATUS MONITORING
   - SUPPLY AIR TEMPERATURE RESET CONTROL
   - CHILLED WATER VALVE
   - FAN SPEED
2. MONITORING
   - TRIP ALARM
   - FILTER DIRTY ALARM
   - FIRE ALARM
   - EMERGENCY STOP
   - HIGH SPACE TEMPERATURE ALARM
   - SUPPLY AIR TEMPERATURE MONITORING
   - RETURN AIR TEMPERATURE
   - AIR FLOW
   - CHILLED WATER VALVE
   - FAN SPEED
   - COOLING LOAD
   - CHILLED WATER ENTERING TEMPERATURE
   - CHILLED WATER LEAVING TEMPERATURE
   - CHILLED WATER VALVE POSITION
   - SYSTEM AIR PRESSURE

B. VAV BOX (COOLING ONLY)

1. CONTROL
   - DAMPER ON/OFF CONTROL AND STATUS MONITORING
   - DAMPER POSITION
   - TEMPERATURE SETTING
2. MONITORING
   - SPACE TEMPERATURE
   - AIR FLOW
   - DAMPER POSITION

C. VAV BOX W/ELECTRIC HEATER

1. CONTROL
   - DAMPER ON/OFF CONTROL AND STATUS MONITORING
   - DAMPER POSITION
   - TEMPERATURE SETTING
2. MONITORING
   - ELECTRIC HEATER TRIP
   - SPACE TEMPERATURE
   - AIR FLOW
   - DAMPER POSITION

Paper No. 5

ELECTRICITY SUPPLY AND SERVICES IN THE NEW MILLENNIUM

Speakers : Ir P.N. Ip
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Ir W.M. Choi
Senior Customer Supplies Engineer
Ir K.T. Yeung
Engineering Co-ordination Engineer
The Hongkong Electric Co. Ltd., Hong Kong

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The Hongkong Electric Co. Ltd., Hong Kong

ABSTRACT

The Hongkong Electric Co., Ltd. began supplying electricity in Hong Kong in 1890. During these hundred and nine years of operation, tremendous changes have taken place and many new concepts and technologies were introduced in the course of time to improve electricity supply and services.

The new Millennium is set to witness more changes in the electricity supply industry. On one hand, with the increasing sophistication of the society and the increasing reliance on electricity for business and social life, customer expectations on supply reliability and service standards are constantly rising. On the other hand, the rapid development in communication and information technologies is certain to impact, in a significant way, on the operations of the electricity supply companies in future and gives rise to many opportunities for business transformation. This paper recapitulates the developments in the electricity supply industry and attempts to gaze the path of changes in electricity supply and services as we migrate into the new Millennium.

1. ELECTRICITY SUPPLY

1.1 TRANSMISSION SYSTEM

The transmission system has gone through major transformation since World War II. From simple radial network operated at 6.6kV in 1946, the transmission system of HEC has grown to 66kV, 132kV and 275kV networks, to meet the increasing electricity demand of Hong Kong Island. In this period, the transmission capacity has been increased by more than 160 folds. The design of today's transmission system ensures the reliability of electricity supply in the event of any conceivable fault in the transmission system.

Paper No. 5

On the equipment side, new technologies and computer aided design and simulation have made the transmission equipment more reliable, more compact, safer and less maintenance intensive. Oil insulated switchgear which used to dominate in the past has been by and large phased out. Power transformers and transmission cables have also seen the similar developments. 132kV XLPE cable was first introduced in HEC in 1987 inside substation and later on was employed for two other transmission circuits in 1992. It is expected that XLPE cable will gain more popularity in future especially under controlled installation conditions because of its low fire risk and less maintenance required than oil filled cables. Similarly, gas insulated transformers which started to emerge in the late 1970's offer some distinct advantages over oil filled transformers. Gas transformers are non flammable, compact and easy to install and maintain. They are expected to find increasing use in cities where fire risk is of major concern.

With these technologies in place, new primary substations can be designed to be completely oil free. This allows greater flexibility in the selection of new substation sites in crowded cities. With the non flammable property of the substation equipment, it can be expected that before long underground primary substations or substation-cum-commercial developments

may appear in Hong Kong to economize on the use of land in developed areas.

In recent years, increasing attention has been paid to environmental considerations in the design of new transmission circuits. In view of visual impact and the disadvantage of sterilizing land use, the prospect of constructing new overhead transmission lines in Hong Kong will be very limited. Instead new transmission circuits will increasingly take the form of cable transmission. Where justifiable, cable tunnels may be considered for large scale cabling work to avoid interruption to traffic and annoyance to the public.

1.2 DISTRIBUTION SYSTEM

In the MV distribution system, gas circuit breakers and vacuum switches have replaced the oil circuit breakers in the market since late 1970's. Looking into the future, advancement in the MV switchgear technology will be focused on longer design life, reduced maintenance and higher reliability. Much effort will be spent in evaluating the long term compatibility of materials. As we see it now, vacuum circuit breakers will continue to be the most popular type of circuit breakers used in MV distribution systems but more new developments could take place in the insulating media of MV switchgear - either compressed air or nitrogen gas could be considered apart from SF6 gas. Switchgear with gas insulated busbars or solid insulated screened busbars could become more popular in view of its immunity to the environment and higher reliability. With the primary parts effectively sealed from the environmental effects and the use of high grade lubricants on the more robust design of the operating mechanism in future, maintenance intervals can be substantially extended without affecting reliability, which will further cut cost and improve availability.

However, much of the developments in MV distribution, in the foreseeable future, will be in distribution automation. HEC is an early starter in distribution automation. In 1982, we started to implement automation for distribution substations. Today all HEC distribution substations are remote controllable through the distribution SCADA system. With the advancements in computer and communication technologies, we could expect a more widespread application of distribution automation among the utilities in future, which together with automatic meter reading, will provide holistic system data for operation, planning, and customer services.

1.3 PROTECTION AND COMMUNICATION SYSTEMS

The protection system has also experienced a period of metamorphosis in the last two decades. Fuses and electromechanical relays were used in the past. In 1971, solid state relays were first introduced in HEC and numerical relays in 1989. Electromechanical relays and HRC fuses are still used today in view of their proven performance and low cost but they are limited to simple applications only. Numerical relays are now increasingly applied in transmission protection. Modern numerical relays have many advanced features and technical advantages over conventional relays - for example, continuous self monitoring and self diagnostic features, sophisticated relay characteristics, fast protection time, ability to capture system fault information, remote communication with PC and SCADA, built-in control and metering functions etc. In addition, the characteristics of numerical relays could be modelled through computer such that the behaviour of the relays could be studied thoroughly before putting into service. All these features will greatly improve the functionality, quality and reliability of the protection system. It is anticipated that the application of numerical relays will not only be limited to transmission applications but will gradually be extended to MV distribution system in future.

Before 1981, the communication system in HEC consisted of only metallic pilot and telephone cables for in-house telephone and protection systems. To satisfy the increasing needs of Company's operations for high quality and reliable communication, digital microwave radio link was commissioned in HEC in 1981. Optical fibre communication system was later introduced in 1987. Nowadays, optical fibre

communication system has formed the backbone of the Company's communication system to support operations and to meet the increasing needs for data and graphical transmission of the Company. One potential development in power system communication could be in the use of the distribution power lines for carrying information signals for control, metering and other purposes. However, the capacity of power lines, especially underground power cables, to carry information signals is limited by the narrow available bandwidth and noise. At this point in time, the application of distribution line carrier system is confined to low volume traffic like remote meter reading and status point control only. Considerable research is being carried out overseas to overcome these limitations. It is too early to predict what prospects will eventually be borne out from these researches.

1.4 METERING

Metering is another area in the power supply industry where major transformations are in store. In the past, tariff meters were mostly electromechanical in construction and performed the very basic function of registering electricity consumption. Nowadays, metering goes far beyond the simple task of registering consumption. Firstly, with the increasing use of time-of-use tariff for demand management, and the progress in the micro-processor technology, programmable meters which have more intelligent functions have come on to the market. These meters typically have programmable time bands for multi-rate tariff and are built-in with other load management and auxiliary functions including load profile, communication port/optical coupler for automatic meter reading and data retrieval, as well as other self diagnostic capabilities. Certain power line monitoring functions such as loss of supply, harmonics and voltage profiles could also be recorded for retrieval on request. Secondly, automatic meter reading has been made economically viable with the rapid development in communication technologies. Automatic meter reading has the advantage of being able to provide real time information about electricity consumption which is useful for load management and real time pricing of electricity tariff. Today automatic meter reading is provided primarily for the large customers only. However with the cost of automatic meter reading equipment continuing to come down, further expansion of automatic meter reading in future is something that can only be expected. In HEC, automatic meter reading has been provided to about 90 large customers since 1995. Plan is in hand to further expand the automatic meter reading system to other maximum demand customers.

2. CUSTOMER SERVICES

While much engineering developments have taken place in electricity supply, at the same time, the electricity supply companies have spared no efforts to upgrade their customer services to keep up with the needs and expectations of customers which increase with the progress of the society. Today, public utility companies are expected to be speedy in response and courteous in service delivery and to provide services which are convenient to acquire. It is expected that in future customer service will further elevate to the higher level such that the emphasis will be laid upon more personalised and caring services (in spite of being in a mass market) and multiplicity of access through a variety of communication means, such as e-Commerce.

2.1 CALL CENTRE OPERATION

In the old days, customers often have to pay a visit to the electricity supply companies in person when they apply for electricity supply etc. Today most of the electricity account services can be provided "one stop" simply by phone. Phone processing of electricity account matters does provide unparalleled convenience to customers; however it brings to fore the importance of call centres to utility operations nowadays. Call Centre management has been playing a key role in customer services in electricity supply companies. Modern call centres have computer telephony integration which provides advanced call handling features such as call line identification, screen pop,

automatic caller record and skill based call routing capability etc. which improve productivity and enhance customer services. Automated telephone services through interactive voice response systems which have become popular since early 1970's effectively break the time zone of telephone enquiry services to truly round-the-clock at a very low cost. As we enter the cyber age in the new Millennium, e-Commerce is expected to proliferate with the result that today's call centres would probably have to transform to web-based communication/processing centres capable of supporting diverse methods of interacting with customers through telephone, voice over Internet, e-mails, etc.

2.2 E-COMMERCE

The age of e-Commerce has dawned. e-Commerce is certain to revamp in many ways the conventional methods of doing business and delivering services to customers. Today many on-line services are already provided on Internet. These services range from on-line application of electricity accounts to real time access to customer account information. Internet payment for electricity bills will be available before long. For large customers provided with automatic meter reading, timely load profile information is also available at the click of a few keyboard strokes.

The advantage of e-Commerce is obvious. It facilitates customers round-the-clock access to services at a low cost. It also provides a more private and interactive mode of operation with all the conveniences of self services, which appeal to many people. With more and more real time applications developed on the Internet, the service of a live agent would become less essential for many operations. The home computer would resemble the desktop platform of an agent of the Company and customers are capable of operating their accounts in a private manner. This brings both convenience to customers and helps to improve productivity of the electricity supply companies. Further operational gains could be realised by integrating automatic meter reading and distribution automation with e-Commerce in the next stage of development.

The successful implementation of e-Commerce is contingent upon the support of a powerful and state-of-the-art Customer Information System. To keep up with the pace of development in e-Commerce, it is envisaged that electricity supply companies will in no time have to upgrade their Customer Information Systems in preparation of the onset of the e-Commerce era.

3. CONCLUSION

The above describes some of the changes in the electricity supply industry that can be expected to evolve in the new Millennium. The fundamental factors which drive these changes are supply reliability, customer services and productivity. The enablers for many of these changes will come from communication and computer technologies which are destined to affect significantly the operations of the electricity supply companies in the years to come. While supply reliability will continue to bear heavily upon the performance of the electricity supply companies, the success of the electricity supply companies will depend very much on how they can capitalise on the new technologies to upgrade their customer services and to improve productivity. No doubt the new Millennium will present many challenges and abundant opportunities to the forward-looking electricity supply companies.

Paper No. 6

Y2K CONTINGENCY PLAN DEVELOPMENT FOR POWER SUPPLY RELIABILITY

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Y2K CONTINGENCY PLAN DEVELOPMENT FOR POWER SUPPLY RELIABILITY

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ABSTRACT

This paper describes the development of a Y2K contingency plan to ensure the supply reliability during the rollover of the Y2K dates. The approach taken by CLP Power starts with brainstorming sessions aimed at identifying all potential failure events. For each individual event, a risk assessment is carried out based on the likelihood and consequence of happening. Following this, a framework is drawn up to investigate the impact of sequential or coincident events. A specific strategy and plan to deal with each Y2K rollover date is then prepared and the plan is further supported by required operational arrangements. With 100% Y2K ready and with all required contingency plans in place, CLP Power are confident to ensure continuing and reliable supply to customers before, during and after the rollover al all Y2K critical dates.

1. INTRODUCTION

1.1 GENERAL

The Year 2000 (Y2K) problem, as it has come to be known, will become talk of the town as the new millennium approaches. Y2K is the computer programming shortcut that uses a 2-digit year field, coding the Year 2000 as "00." This may confuse computers and computer-operated equipment to interpret as 1900 and hence cause them to malfunction when their clocks turn over to 1 January 2000.

The worldwide attention is focused on major infrastructure: the telephone system, the airlines, banking, and electric power, because every home and business depends on them. Electric utilities, like many other industries and government agencies, cannot satisfy their operating commitments without computer hardware and software. The exact severity and extent of Y2K problems is complicated by many factors:

- a large and diverse software inventory,
- numerous embedded systems that may be difficult to inventory and test,
- the potential for operability issues or disruption of business operations,
- the need to obtain information from vendors,
- limited time to identify and correct the problem,
- significant staff requirements, and
- the need to co-ordinate with customers, suppliers, and other interconnected entities.

As the major electricity supply utility in The Hong Kong Special Administrative Region (HKSAR), CLP Power face similar significant and complex task in solving the Y2K problem. In May 1996, CLP Power commenced a comprehensive company-wide Y2K Programme to tackle the Y2K issues in both the hardware and software that operate the power system facilities and in the embedded systems. At the end of 1998, a Y2K Contingency Plan Team on Supply Reliability was set up to

ensure electricity supply continuity. The Team was also responsible for the development and implementation of a comprehensive plan to ensure power supply reliability in rollover during the Y2K critical dates.

1.2 DEFINITIONS

(a) Critical Y2K Sensitive Dates

The following dates are identified to be of critical:

Level	Dates
Level 1	31 Dec 1999 rollover to 1 Jan 2000
Level 2	28 Feb 2000 rollover to 29 Feb/1 Mar 2000
	8 Sep 1999 rollover to 9 Sep 1999
Level 3	21 Aug 1999 rollover to 22 Aug 1999
	8 Apr 1999 rollover to 9 Apr 1999
	31 Dec 1998 rollover to 1 Jan 1999

The date for the New Year Eve rollover is the most critical one. Other dates associated with End-of-File nature are 9 Sep (Tetra-9) and 9 Apr 1999. Apart from the Leap Year date, the date associated with the week counter reset of the Global Positioning Systems (GPS) is also included in the Y2K sensitive dates.

(b) Year 2000 Compliance

Year 2000 compliance (also known as conformity) shall mean that neither performance nor functionality is affected by dates prior to, during and after the year 2000. The following 4 rules are applied:

- No value for current date will cause any interruption in operation.
- Date-based functionality must behave consistently for dates prior to, during and after Year 2000.
- In all interfaces and data storage, the century in any date must be specified either explicitly or by unambiguous algorithms or inferencing rules.
- Year 2000 must be recognized as a leap year.

The definition can be found in the document BSI/DISC PD2000-1:1998.

(c) Year 2000 Readiness

Year 2000 readiness is defined as "compliant enough" to ensure that a business can continue in operation. More exactly, a system is Y2K ready if:

- It has no date function, or
- It is date-compliant, or
- For non-compliance, users of the system have made adequate plans to manage the consequences of non-compliance.

The definition of "Y2K Ready" can be found in The Institution of Electrical Engineers' "The Millennium Problem in Embedded Systems" as given in the homepage at http://www.iee.org.uk/2000risk/w-128.htm.

(d) Risk Periods

The duration of the risk is classified into four periods:

Rollover - within ±0.5 hour during the rollover,
Short term - within 2 hours after the rollover,
Medium term - within 24 hours after the rollover, and
Long term - within one month after the rollover.

(e) Mission Critical Systems

The definition of HKSAR on mission-critical systems refers to those computers and embedded systems whose proper functioning is related to public health safety, the provision of critical services to the public, or payment and revenue collection.

When this is translated to the context of public utilities, CLP Power adopt that systems related to ensure supply reliability are Mission Critical systems. These include the following elements:

- Safety of public and employees.
- Keeping the lights on - reliability.

In developing the Y2K Contingency Plan, CLP Power have placed their main focus on both 'Safety' and 'Reliability' for their critical mission - supply continuity.

2. NATURE OF THE Y2K PROBLEM IN ELECTRICITY GENERATION AND DELIVERY

Maintaining a reliable supply of electricity during the Y2K transition is not an insurmountable task. The following critical areas may pose a possible threat to power generation and delivery:

- **Power generation** – Generating units must be able to operate through critical Y2K periods without inadvertently tripping. The threat is the most severe one in power plant with digital control systems (DCSs). Numerous control and protection systems within these DCS use time-dependent algorithms that may result in unit trips. Most older plants operating with analog controls will be less problematic. Digital controllers built into station equipment, protection relays, and communications also may pose a threat.
- **Energy management systems** – Control computer systems within the electric control centres worldwide use complex algorithms to operate transmission facilities and control generating units. Many of these control centre software applications contain built-in time clocks used to run various power system monitoring, dispatch, and control functions. Many energy management systems are dependent on time signal emissions from GPS Satellites, which reference the number of weeks and seconds since 00:00:00 UTC January 6, 1980. Hence precautionary measures must be taken associated with systems using GPS clock.
- **Telecommunications** – Electric supply and delivery systems are highly dependent on microwave, telephone, and VHF radio communications. The dependency of the electric supply on facilities leased from telephone companies and commercial communications network service providers is a crucial factor. With telecommunications being the 'Nervous' system of the electrical networks, risk assessment and strengthening the existing telecommunication method and media are therefore essential.
- **Substation controls and system protection** – Throughout the electric transmission and distribution system, there are substations that contain control equipment such as circuit breakers, disconnect switches, and transformers. Remote terminal units (RTUs) in substations serve as the communications hubs for the substations, allowing them to communicate with the control centres. Substations also contain most of the transmission and distribution system protection relays, which serve to operate circuit breakers to quickly isolate the equipment should an electrical fault occur on a line, transformer, or other piece of equipment. Many devices and relays in a substation are electromechanical (not digitally controlled), but a portion of these devices may be digital. The greatest threat here is a common mode failure in which all the relays of a certain model fail simultaneously, resulting in a large number of coincident transmission facility outages.
- **Transmission & Distribution systems** – Distribution systems deliver electricity from the transmission network to customers. Because there is a lot of commonality in the types of substation equipment in distribution as compared to transmission, transmission and distribution substations are aggregated as one area. Distribution systems have additional equipment outside substations (for example along a distribution feeder) that may have electronic controls. Examples include reclosers (relays that open and close a feeder in rapid succession to allow a fault to clear), capacitors, voltage regulators, and special monitoring devices.

The general approach to tackle the Y2K issues can be classified into the following phases:

- Identify from the inventory on those components and systems that are date-sensitive.
- Perform required risk assessment on these components and systems.
- Carry out test to find out their readiness.

- Correct those that are not Y2K ready.
- Develop required contingency plan.

In CLP Power, there are 1516 systems, all mission-critical systems inclusive, declared to be 100% Y2K ready on 22 June 1999. Systems contingency plans were prepared to outline the contingent measures in case of these systems fail. In order to ensure that no missing components and systems, a process approach is also adopted so that the asset-based inventory can be compared with the process-based inventory. Only one non-Y2K sensitive item was found missing in this inventory comparison.

3. PURPOSES AND NEEDS FOR CONTINGENCY PLAN

The followings are the reasoning behind for preparing a contingency plan:

- Software defect repairs and updates are never 100% efficient.
- Risk of failure is not limited to our internal systems, an outside service may be the weakest link.
- Demonstration of 'Due Diligence' - reduce litigation risk for supply failure due to Y2K issue.
- Increased government concern & public attention.

Because of the nature of the electric utility industry, emergency response is an inherent part of daily operations. Many systems and procedures are already in place to deal with emergencies as they occur. However, the Y2K issue still presents an increased risk of simultaneous loss of systems and facilities that support the electrical grid. This increased risk warrants additional preparations and contingency planning by the industry to maintain adequate reliability. The following points depict the salient features of a Y2K Contingency Plan versus traditional contingency plans:

- Extent not predicable.
- Common-mode malfunction may render 'redundancy' helpless.
- Multiple, Widespread, Simultaneous Initiators.
- Affect operability.
- Potential data corruption.
- Unprecedented, no previous models or best practices.

All these attributes of the Y2K contingency plan, the last point in particular, make the plan development a very challenging project.

4. DEVELOPMENT OF Y2K CONTINGENCY PLAN

CLP Power adopt a "defense-in-depth" concept and assumes that although one has taken all reasonable and necessary preventive steps, there can never be one hundred percent assurance that major system failures cannot cause a catastrophic outcome. Instead, multiple defense barriers are established to reduce the risk of catastrophic results and to mitigate the severity of any such events.

The steps for 'Defense in Depth' are:

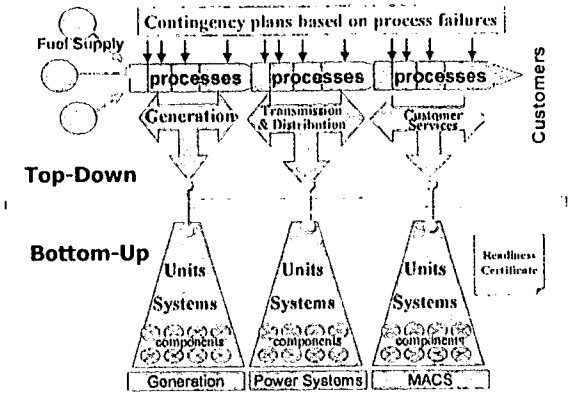
1. Information and fix knowledge sharing for known Y2K problems between all stakeholders (including interconnection parties).
2. Identify worst case conditions.
3. Prepare for the worst.
4. Operate systems in a precautionary posture during critical Y2K transition periods.

The following outlines the development of Y2K Contingency Plan for Supply Reliability.

4.1 PROCESS APPROACH

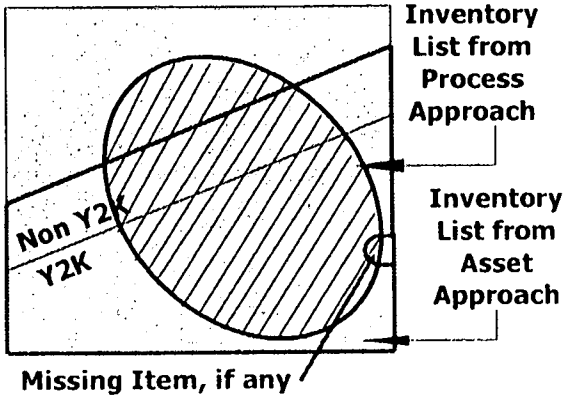
While the CLP Power's Y2K Programme follows the asset inventory-based approach to check each individual components and systems, the Team adopts a complementary end-to-end process-based approach.

Fig. 1 Asset-Based Inventory Vs Process Based Inventory



In the component or system inventory checking which is on individual basis, it is referred to as bottom-up approach. On the other hand, the process approach examines the supply process, viewed from generation, transmission & distribution to deliver electricity to the customers. From such process approach, which can be called a top-down approach, an inventory list can also be generated.

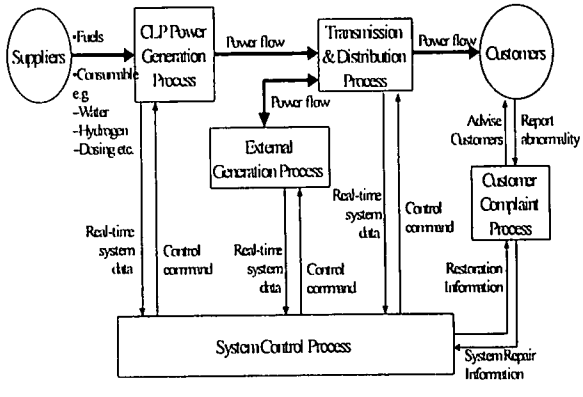
Fig. 2 Matching of Asset-Based Inventory Vs Process Based Inventory



The breakdown of the process or sub-process is detailed to a level where the inventory components can be found inside that process, i.e. they can be linked across. After the process is mapped out, the owner of the process confirms and signs off the process. With both the inventory and process consideration, there should be no gap or missing item being overlooked. As shown in Figure 2, the process approach therefore offers a complementary check on what has been carried out on items under the Y2K programme.

CLP Power provide electricity to the Kowloon Peninsula, the New Territories, and most of the outlying islands of Hong Kong. CLP Power's transmission network is also interconnected with Guangdong Power Holding Company (GPHC) in the PRC, and the Hongkong Electric Company (HEC). Figure 3 illustrates the main process of the CLP Power Electricity Supply System.

Fig. 3 The Overall Main Electricity Supply Processes



Basically there are two main line processes in a power system, namely the 'Generation Process' and the 'Transmission and Distribution Process'.

Generation Process can be further divided into "local" and "external". The "local" power stations, which include the Black Point Power Station, the Castle Peak Power Stations (A & B), and the Penny's Bay Power Station, generate a portion of the electric power required to meet customer demand. The company also acquires "external" electricity supply from the joint venture power stations in Guangdong Province, which include the Guangdong Nuclear Power Station (GNPS) in Daya Bay and the Guangdong Pumped Storage Power Station (GPSPS) in Conghua. Under emergency situation, the company can obtain electricity supply from GPHC and HEC.

Transmission and Distribution Process is a delivery process. The transmission network

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(operated at 400kV, 132kV and 66kV) acts as the 'highway' to transmit electric power from the power stations to the distribution system (operated at 33kV, 11kV and below), which then delivers the electricity supply to customers.

In order to ensure proper and reliable delivery of electricity to our customers, the following feedback and control processes are adopted to supplement the main electricity supply process. Two additional processes are required, i.e. The 'System Control Process' and the 'Customer Compliant Process' for the supply of electricity to our customers.

System Control Process utilises sophisticated computers to provide centralised real-time monitoring of power system operations, retain historical data, and allow for the manual and automatic control of field equipment. The control system presents the electric system data to operations personnel via a graphical user interface. Based on the data gathered, the operators may initiate control signals to various control points in the power system. The control system may also automatically initiate control command to the field equipment, such as control of generating unit output. The system control centre also deals with the emergency handling of the power system and acts as the co-ordination centre of all interconnecting partners.

Customer Complaint Process handles all customer complaints of supply interruption and emergency. It is comprised of the call taking in Customer Telephone Services Centre and the call processing before passing to the System Control's Emergency Dispatch Unit.

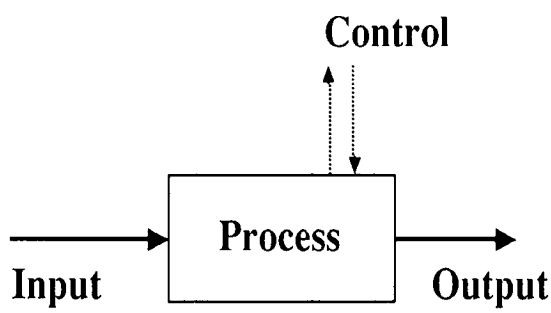
In order to support the above processes, there are three basic auxiliary processes: namely, the Protection System Process, the Telecommunication Process and the Data Acquisition Process.

4.2 STEPS TAKEN FOR RISK CONSIDERATION

The process approach as described in the last section is adopted and the following steps are therefore taken in failure event generation and the development of contingency plan.

- Process maps signed off
- Brainstorming failure events
- Events categorising and linking
- Risk analysis
- Worst scenario identification
- Disaster detection & recovery
- Contingency plan

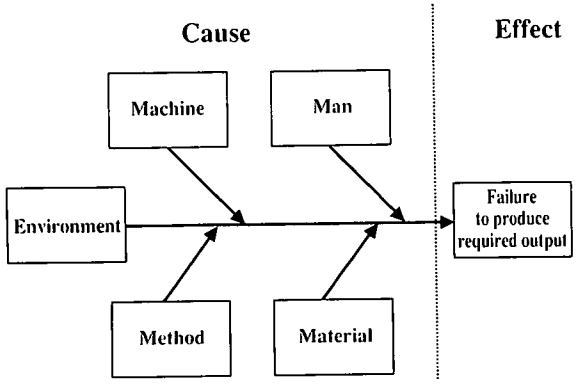
Fig. 4 The Process



A process can be defined as a collection of activities which take one or more inputs and create outputs. Some control decisions can be exercised as shown in Fig. 4. Hence, based on the process map, the failure events where no output is produced can be postulated and identified for further risk analysis.

In order to brainstorm the possible failures associated with a process, a cause-effect technique is adopted. Hence, for a process which fails to produce the required output, a number of categories are considered. These include 'Man', 'Machine', 'Material', 'Method' and 'Environment' as shown in Fig. 5. Under each of this category, all causes which lead to output failures are listed out. The output from this brainstorming would be a list of possible failure events which will then be further assessed. This technique is applied in the internal workshop on Supply Reliability - Y2K Contingency Plan.

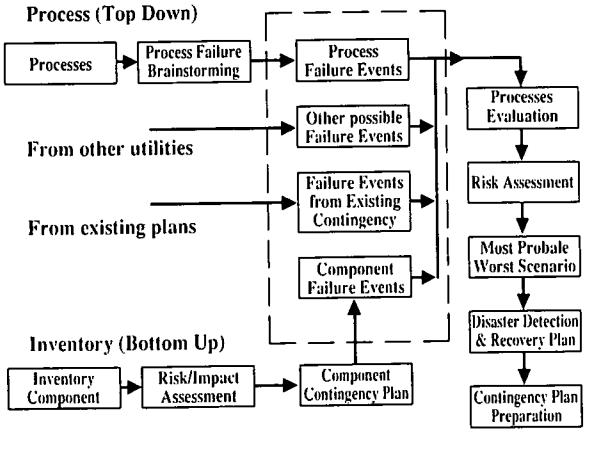
Fig. 5 Cause - Effect Approach



4.3 Y2K WORKSHOP

A Y2K workshop on Supply Reliability was organised to provide a collective input from over 60 line managers in CLP Power. Through a well structured brainstorming sessions, the critical failure events are generated. Fig. 6 was the approach adopted in the workshop.

Fig. 6 Generating Critical Failure Events



The failure events are built up basically from three sources. The first source is the relevant findings by other utilities solicited in external seminars and through searching Internet web sites. The second source based on the known failures from the existing contingency plans. The third source based on the critical failure events identified with extreme or high risk in the process-based approach.

In the workshop where brainstorming technique was adopted, initially over 500 failure events - including those highly unlikely to happen, were generated by the workshop participants. After combination, a total of 211 failure events were generated. Through linking and categorising of these 211 failure events, the nine groups in the workshop developed 63 scenarios.

Subsequent to the workshop, to ensure there was no missing part, the Y2K Contingency Plan Team conducted a thorough examination on all these failure events and the scenarios produced in the workshop. Reference was also made to the findings of external utilities. After this re-examination and grouping, the number of worse case scenarios in the list is now 37. Some scenarios were removed as judged professionally to be not directly related.

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4.4 RISK ASSESSMENT

In the risk assessment, the failure events that have been generated in the previous sections would be assessed according to the procedure as outlined in the Australian Standard AS4360. The likelihood of the failure events to occur and the magnitude of their consequences are assessed. Likelihood and consequences are combined to produce a level of risk.

To assess and analyze the likelihood and consequences, the judgement would base on the following information from the line staff, past records, relevant experience, industry practice and experience, relevant published literature, specialist and expert judgement. A qualitative analysis is adopted. Qualitative analysis uses word form or descriptive scales to describe the likelihood of each event arising and its consequences. These scales can be adopted or adjusted to suit the circumstances and different descriptions may be used for different risks.

Likelihood and Consequence

The qualitative measures of likelihood are shown in the following table:

Level	Descriptor	Description
A	**Almost certain**	The event is expected to occur in most circumstances
B	**Likely**	The event will probably occur in most circumstances
C	**Moderate**	The event should occur at some time
D	**Unlikely**	The event could occur at some time
E	**Rare**	The event may occur only in exceptional circumstances

The qualitative measures of consequence or impact are shown in the following table:

Level	Descriptor	Description
1	Insignificant	No injuries, low financial loss
2	Minor	First aid treatment, on-site release immediately contained, medium financial loss
3	Moderate	Medical treatment required, on-site release contained with outsideassistance, high financial loss
4	Major	Extensive injuries, loss of production capability, off-site release with no detrimental effects, major financial loss
5	Catastrophic	Death, toxic release off-site with detrimental effect, huge financial loss

Risk Classifications

		Consequences				
		1	2	3	4	5
Likelihood	A	H	H	Ex	Ex	Ex
	B	M	H	H	Ex	Ex
	C	L	M	H	Ex	Ex
	D	L	L	M	H	Ex
	E	L	L	M	H	H

Legend:
Ex = Extreme Risk; H = High Risk;
M = Moderate Risk; L = Low Risk

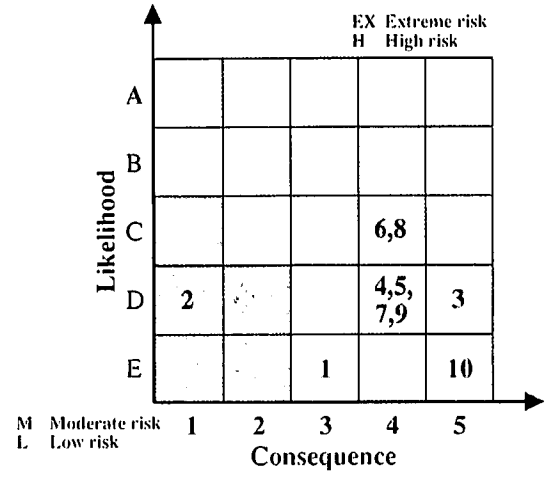
4.5 FINDING OF CRITICAL FAILURE EVENTS

After a series of activities such as internal workshop, internet search, information exchange with other utilities, and research on company's major incident; a list of critical events pertinent to CLP Power's situation was identified as follows, in ascending order of impact.

1. Failure of Protection System for Plant
2. Failure of Customer Telephone Centre
3. Loss of Supply to CLP Power's critical locations
4. Loss of Energy Management System (EMS)
5. Loss of Telecommunication
6. Loss of generation in External System
7. Loss of Load
8. Failure of major Power Station
9. Major System Disturbance
10. System Blackout

The worst case scenario is the combination of events 4, 5 and 10. The risk matrix of these failure events is shown in Fig 7. Each of this event is covered by the respective process or system contingency plans.

Fig. 7 Risk Matrix for Critical Failure Events for New Year Eve (NYE) Rollover



4.6 RISK MITIGATION

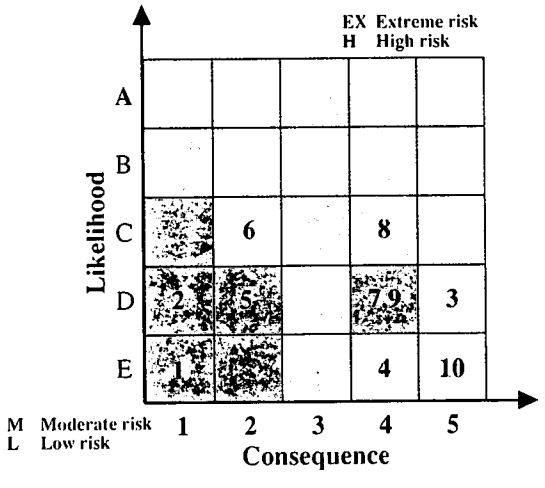
Windowing (clock roll backward or forward) is a common technique used to fix computers vulnerable to Year 2000 problems. Basically, programmers instruct software to interpret the year based on a future date, or "pivot year." For example, a software program with a pivot year

of 30 will interpret the years 00 through 29 as 21st century dates, and interpret years 30 through 99 as during the 1900s.

CLP Power considered 'clock roll backward' is not a perfect desirable choice and should only be arranged with an explicit purpose. It may put some constraint in operation, such as conversion table to lookup. Consequently it may possible delay in alarm interpretation. Due care should be exercised to set it back to normal after certain date.

The purpose of the risk mitigation in the context of Y2K Contingency Plan is either to reduce the likelihood of occurrence of the failure events or the impact to the power system should they occur, or both ideally.

Fig. 8 Risk Matrix after Mitigation for NYE Rollover



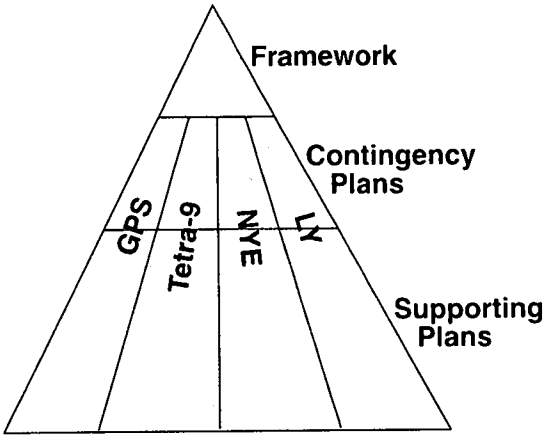
As shown in Fig.8, some of the failure events have moved toward the lower left corner. However, for some of the failure events, it is not possible to reduce the probability of failure or the failure impact.

5. CONTINGENCY PLAN PREPARATION

5.1 STRUCTURE OF THE PLAN

The Contingency Plan on Power Supply Reliability is a three-tier structure contingency plan. Fig. 9 shows this contingency plan structure which consists of framework, contingency plans and supporting plans. It will cover four Y2K critical dates - 22 Aug 1999 (GPS), 8/9 Sep 1999 (Tetra-9), 31 Dec 1999/1 Jan 2000 (NYE) and 28-29 Feb/1 Mar 2000 (LY).

Fig. 9 Three-tier Structure Contingency Plan



The development of the framework is to have all failure events be systematically brainstormed and categorised. The events include the normal failures, and Y2K direct and indirect failures. A risk assessment based on Standards Australia AS 4360 was adopted to evaluate the risk level. Based on the scenarios, a "Defence-in-depth" approach is developed. Therefore, the framework provides solution to all types of failure events.

The contingency plans aims to deal with the worst scenarios including the extreme worst case where total system blackout and credible worst case consisting of multiple failure like partial loss of generation, partial loss of communication and partial loss of EMS. It addresses the manning considerations, system operational arrangement, load forecast, planting scheduling and interconnection operation.

The supporting plans aims to support the contingency plans. The plan will focus on the pre-contingency arrangement, triggering of the emergency actions and the post-contingency arrangement upon relevant addition information and situation changes.

To enable the rollover to be smoothly and successfully as well as to maintain high standard of power supply reliability as usual, an effective training plan is of paramount importance. The training plan will specify the training requirement and strategy as well as the drill / dress rehearsal.

The CLP Power Y2K Contingency Plan also made provision to link up with the sector-wide plan prepared by the SAR government to ensure public order of the community.

During the Y2K rollover, Electrial & Machanical Services Department (EMSD, regulator of power utilities) of HKSAR will set up an Emergency Centre at their Headquarters. EMSD will have communication link directly linked to the Centre Government Office. (CGO).

During the rollover, both CLP Power and HEC will send report to EMSD at an interval of one-hour starting from 5pm on 31 Dec 99. From 11:30pm to 1:00am, the interval will be reduced to 15 minutes. Report on loss of on-line generators, loss of load in a district area and down to a single building (if possible) will be reported immediately.

To strengthen the communication to the centre, a trunked mobile radio from each supply utility will be given to the EMSD centre. On top of that a direct hotline will be considered to be established from the respective System Control Centre to the EMSD centre using internal CLP Power / HEC telecommunication network.

5.2 GENERAL STRATEGIES

The general strategies to be applied to deal with the failure scenarios include:

- Increased staffing during the Y2K critical periods,
- Staff be conversant with emergency procedures,
- Minimise scheduled maintenance,
- Black start generation ready and available,
- Reliable communications with sufficient backup,
- Transmission System intact,
- Fuel supplies available for back up generation,
- Increase operating reserve requirement,
- Evenly spreading of spinning reserves,
- Communication of the Contingency Plan.

These strategies are very similar to most of the leading utilities worldwide.

5.3 THE FRAMEWORK

The 'Framework' describes the rationale of the contingency plan development, and adopts a comprehensive approach to analyse all the failure events. The contingency plan for individual rollover dates describes the best contingent action to counteract the worst case scenarios, pertinent to the prevail conditions. The supporting plan of individual rollover dates elaborates the detail arrangement for effective implementation of the plans. The training plan deals mainly with human resources. The plan can never be successfully implemented without a team of skilful staff.

5.4 PROACTIVE AND REACTIVE ARRANGEMENT FOR NYE ROLLOVER

Of the entire contingency plan, the most critical one is the New Year Eve rollover plan. The following sections describe the contingency arrangement for the NYE plan.

5.4.1 Proactive Arrangement

These are the pre-contingency operation arrangement to be set up before the New Year Eve rollover. The duration of the risk is classified into four periods:

To prepare for the long-term contingency, the following action for supply chain management must be completed before the rollover:

- The equipment of the natural gas supplier for Black Point Power Station should be Y2K ready before rollover.
- CLP Power's critical suppliers must be closely monitored to ensure that have contingency plan in place so that their product and services, including essential

spares, fossil fuel, station consumables and water supply, can be delivered after the rollover.

- Sufficient stock level of the station consumables should be kept.

For medium-term contingency, selected Customer Services Centres will be put into operation if a prolonged failure of external communication (Cable & Wireless, Hong Kong Telecom's public telephone system) occurs longer than 8 hours. The staff in these Customer Services Centres will be equipped with Trunk Mobile Radios as communication means.

Because of the geographical difference, New Zealand and Australia (East Coast) will have a time of 4 hrs and 2 hrs ahead of HKSAR respectively. Contacts have been established to utilities in these two countries to obtain their experience in rollover one hour before rollover takes place in HKSAR.

Referring to section 4.6, one item for further consideration is setting the clock forward or backward. Such preparation to avoid the rollover of Y2K is considered as a final means when all other possible contingencies are less effective. The reason behind is that by forward/backward the clock, it introduces operational constraints as when a normal alarm is generated; it needs to have a table look up method to identify the actual date/time hence resulting in a slower response.

Manpower mobilisation

In addition to the routine shift operation teams, several teams and centres will be set up as appropriate to provide high-level management direction and communication to different stakeholders.

Furthermore, manpower level will be strengthened at the following locations during rollover for the short-term period:

- Back up Control Centre will be manned during the rollover.
- Appropriate staff will be located at selected critical substations. If needed, they should be able to operate the equipment manually or provide status verification if EMS fails.

Power Systems

The following arrangement will be set up before the NYE rollover:

- The load forecast during the NYE rollover is 2200MW. Load forecast will be a very difficult task, due consideration will be given to possible unusual load pattern in load estimation.
- Generation will be spread among different types of units as well as different types of fuel.
- Spinning reserve will be around six times of the normal requirement.
- Two Guangdong Pumped Storage Power Station units will be operated as interruptible motor load.
- CLP Power will take less generation from Guangdong Nuclear Power Station.
- Castle Peak generating units will be operated with mixed fuel of oil and coal.
- In CLP Power, all critical circuits and generating units will be returned to services before 28 December 1999.
- Suspending all maintenance work activities to allow redundancy and flexibility to react.
- All power system stabilisers installed on generators have to be put in service.
- The circuits that employ digital relay protection will be switched out during rollover, as far as possible.
- To avoid excessive overvoltage in case of a load rejection, a normal system voltage profile should be maintained. At least two 132kV shunt reactors should be kept open standby to control system over-voltage if required.

For the interconnection with other parties, the following are adopted:

- No 'risk of trip' test on generators will be scheduled during rollover.
- All interconnectors will be inspected before 28 December 1999. No outage on these

interconnectors will be planned during the rollover.

- CLP Power, GPHC and HEC will increase spinning reserve extensively during the rollover period.
- No power interchange will be planned and the power transfer on interconnectors will be kept to minimum.
- Guangdong Nuclear Power Station Unit N2 will be out of service for refuelling. Generation output of Unit N1 will be reduced from 980MW to 760MW before the rollover.
- To reduce the impact of losing an entire power station, the maximum generation of any single power station within the interconnected network will be restricted below 760MW. This is the recommendation following a frequency excursion study.

Communication Systems

In order to minimise the possible interruption in communications, both the normal and emergency back-up Trunk Mobile Radios (TMR) will be run in parallel before and during the rollover period. Furthermore, eleven TMRs on vehicles will be modified to serve as repeater sites for the emergency TMR backup system. Additional hotlines using 'clean connections' will be installed between operating centres. Satellite phones will be made available at strategic locations.

5.4.2 Reactive contingent actions

These are the proper actions to counteract failure events to contain the impact to minimum:

Loss of Supply to CLP Power's Critical Locations

Most of the locations with fixed standby generators are installed with automatic changeover switch. Upon loss of incoming supply, the standby generator will be automatically run up and the essential supply will be automatically changed over to the standby generator. Otherwise, the changeover will have to be done manually upon receipt of supply failure alarm.

Loss of EMS

Failure of EMS is readily observable by System Control staff. The following table describes the action and triggering of contingency plans as required for:

Component failure	Action	Remarks
Main computer	Trigger the appropriate component contingency plans	Switch to Backup Control System
Both main computer & Backup Control System		Common mode failure
Remote Terminal Units		Partial failure likely
Telecom network		Partial failure likely

Loss of communication

Telecommunication staff will monitor the telecommunication network closely at 30 minutes before and after rollover. They will conduct functional check on all the telecom equipment after rollover. If any abnormality is detected, contingency plan will be triggered accordingly.

System Blackout / Major System Disturbance

These will be evident by the EMS alarms, voltage depression, sharp frequency change, and customer complaints. In the absence of EMS information, power flow and frequency information can be obtained from power station staff, interconnection partners, and staff on standby in substations. Contingency plans for major system disturbance or system black start will be triggered by the System Control staff.

The contingency actions following major system disturbance will focus on mitigating damages by controlling the spread of supply interruption and restore system to normal as quickly as possible, and preventing the situation to worsen leading to major system breakdown. The main issue will be the collection of information for diagnosing the cause of the disturbance. A distinct feature of possible Y2K attack is the simultaneous occurrences of multiple disturbances, which make the fault analysis even more difficult.

Means to control generation surplus (due to load rejection) and generation deficiency are

described in more details in the associated operational procedures already established. To avoid system disturbance to spread, depending on the source of instability, manual decoupling of the tie lines may be warranted.

5.4.3 Post Contingency

If the rollover is peaceful, the following post contingency actions will be implemented as to resume the system back to normal operating state:

- Telecommunication staff will confirm to System Control all CLP Power's telecom equipment units are in normal state before disbandment.
- A unified machine off-bar plan to co-ordinate with interconnection parties on the sequence of taking unit off-bar after the rollover risk, to avoid sharp frequency change, will be implemented.
- The circuits employing digital relays with sensitive date elements will be tested before restoring to service.
- Generation will return to normal operating mode in an orderly manner coordinated among all interconnection parties.
- Switch the Black Point unit on oil fired back to gas fired.
- Castle Peak units oil support will not be required.
- Before shutting down the Castle Peak 'B' units, as a positive measure to test the machine start-up capability, another Castle Peak B unit which is on standby mode will be started and connected to the power system first soon after the rollover.
- Guangdong Power Pumped Storage Power Station units on pump mode will be operated to suit system requirement.
- Guangdong Nuclear Power Station Unit N1 may be restored to full output to suit requirement.
- Rollover status of major customers will be checked.
- Rollover status of major vendors will be checked.

6. IMPLEMENTATION & COMMUNICATION

Since the Y2K attack is obvious and its impact is unpredictable, resources have been allocated to check, test, replace and verify the inventory so as to ensure the systems are Y2K ready. As a responsible utility, contingency plans as well as supporting plans for various Y2K critical dates are all well established by June 1999 in order to maintain the electricity supply reliability to our customers.

However, the smoothness of the implementation of the contingency and supporting plans depend on the understanding and support of our management and our fellow colleague. Hence, communication sessions, training and drills dedicated to them regarding details of the contingency and supporting plans are of paramount importance.

Beside the internal communication sessions, training and drills; being the act of a good corporate citizen, CLP Power should also communicate with our customers to enable them to have a better understanding of the development and a brief summary of the contingency plan. Last but not least, educating our customers to behave in a co-operative manner during the rollover period, which is crucial to the system stability, is also a major objective of the communication sessions.

6.1 DRILLS/DRESS REHEARSAL

The objectives of the drill/dress rehearsal are as follows:

- To test the effectiveness of the various desktop contingency plans.
- To check the responses of the operational staff and the co-ordination of various operational parties so as to reinforce the training, if so required.
- To uncover and identify the potential problems in any aspect, if any, for the review and /or revision of the respective contingency plans.
- To enable all the operational staff to familiarise and response to the worse case scenario through the selected stimulation.

The following drills are scheduled:

- Partial loss of telecommunication.
- Full dress rehearsal on 9 September 1999.
- Loss of EMS, frequency control and tie-line flow control by power station staff.
- Load restoration after under-frequency load shed.
- Transfer to back up control computer.

6.2 COMMUNICATION STRATEGY

As a responsible utility, CLP Power should communicate to all stakeholders on the company's comprehensive approach on the Y2K issue. The company aims at providing as much open and factual information as possible, in a pro-active approach, on the efforts of CLP Power exercised. This can help the public to gain confidence and abundant all ineffective contingency measures.

Objective

The objectives of the communication sessions are as follows:

- To enable all staff and the general public to have a better understanding of the Y2K impact to the supply reliability and our strategy in developing the respective contingency and supporting plans.
- To educate the general public to behave in a co-operative manner during the rollover period.
- To enhance company image as a responsible utility and good corporation citizen.

Internal Communication

- Team briefing and in-house publication are effective means to promote Y2K awareness of the employees. Regular update will be issued to each employee.
- Communicate with the responsible Departments to demonstrate how the contingency plan works.
- Presentation in internal seminars. Self-assessment survey that provides some details can be done with internal staff as to get feedback.

External Communications

- To enhance the confidence to the general public and improve our company image, we shall communicate the contingency plan and our due diligence approach to the general public so as to demonstrate CLP Power as a responsible, co-operative Company.
- To make use of CLP Power Internet site and 'bill insert' as channels of delivery. Regular updates or 'news print' to be incorporated.
- To communicate the contingency plan to our inter-connection partners, i.e. HEC, GPSPS, GNPS and GPHC, and to exchange information mutually and regularly.
- To communicate the contingency plan to the relevant Government parties.
- To make the contingency plan more creditable, presentation to professional institution and Universities, is recommended. Various comments from different point of view can be sought.
- To reply written enquiry from customers in an open manner, information to be updated regularly.

Responsive communication

- Participate in local media interviews.
- Basic training to Customer Services staff and Account Managers to enable them to answer question related to Contingency Plan. For in depth enquiry should be referred to the Y2K Contingency Plan Team.
- To response to the customer request, presentation to major customers is also important. Public body such as Local Customer Advisory Committee (LCAC) should also be included.

Key messages to deliver

- CLP Power started early, making good progress to schedule.
- Comprehensive program, with emphasis on defense- in-depth approach.
- 100% Y2K Ready.
- Our service reliability is above 99.99%.

- CLP Power do not expect service disruptions.
- CLP Power have comprehensive contingency plans in place today and for the Year 2000.

6.3 TRAINING

Rapid technological development in computer technology has made the power industry very dependent on computer and process control. Reinforcement in training is the best way to make power engineers to be conversant with manual control procedures, in the case of Y2K attack to control computers.

The objectives of the training are as follows:

- To ensure all duty operational staffs are fully conversant with their roles in the rollover.
- To strengthen the familiarisation of the Black Start Procedures for the duty system control staff and the duty shift staff of the Power Stations.
- To enable the duty system control staff to familiarise with the operation of the system in "island" and various tie-line modes.
- To refresh the duty System Control staff in calculating the "Area Control Error" manually for generation despatch.
- To reinforce all operational staff to communicate clearly and precisely even in the occurrence of worst case scenario with limited voice communication channels available.
- To enable the duty System Control staff and their counterparts of interconnection partners to familiarise with the operation of the satellite phone.
- To enable all operational staff to familiarise with the reporting procedures during the rollover.
- To enable the transmission and distribution staff to familiarise with the manual operation of all the power equipment.

7. EXTERNAL AUDIT

Despite the regular check by the Internal Audit Department on the Y2K asset based inventory identification process and the required remediation work, CLP Power have chosen to conduct an independent audit. The scope of work of external audit included the following:

(a) to check on CLP Power general Y2K preparedness

(b) to evaluate and validate the Y2K Contingency Plan for Supply Reliability.

An international consultant, which has already undertaken Y2K audits of over 20 corporations in electricity supply industry covering generation, transmission & distribution and retail of power, was employed to conduct the external audit in July 1999. The audit was carried out for a period of four weeks with audit report submitted in mid August 1999.

Paper No. 6

The auditor report confirmed that the statement made by CLP Power on '100% Y2K Readiness' is valid. The following summary is the audit findings extracted from the audit report:

"The level and detail of CLP Power's Y2K project including contingency plans and testing work done to date shows that CLP Power are in a position to effectively deal with any Y2K issues that may arise. The threat to supply reliability has been dramatically reduced through the project.

It is evident from the level of documentation and awareness within CLP Power that an extensive program has been undertaken. In the audit team's opinion, the statement of 100% Y2K readiness is valid. When compared to similar Y2K Programs within the power industry, CLP Power are well advanced. ... The overall or integral Y2K contingency plan development process is one of the best seen by the auditors."

8. CONCLUSION

The development of 'Supply Reliability - Y2K

Contingency Plan' is an unprecedented task. As there is no 'proven model' available until the Y2K critical dates have passed over; the Team has taken a 'Defense-in-depth' concept including an exhaustive search and information collection in relation to Y2K both internally and externally. The scale and dimension of possible system or component failures are identified and plans are thus formulated to counteract the Y2K attack.

CLP Power are having the following favourable factors:

- A team of good staff dedicated to power supply industry.
- Well prepared, handle the Y2K issue in a professional, serious and meticulous manner.
- Relative strong power system network.
- Possession of privately owned telecommunication network, thus fewer dependants on external voice and data communication services.
- Hong Kong will be at light load-demand period during Y2K rollover.
- No extreme weather.
- Good and wide mix of generation from different kind of fuel and technologies.
- Pumped Storage units provide rapid disconnectable load.

Finally, by preparing and implementing the above described contingency plans, CLP Power are confident to ensure continuing and reliable supply to customers before, during and after the rollover of all Y2K critical dates. Even in the unlikely event of a Y2K-related incident affecting any part of our supply chain, CLP Power's contingency plans are in place to ensure that resources are available to maintain supply reliability.

REFERENCES

(1) Expert sources used in the CLP Power Y2K Readiness Programme:

NERC - North America Electric Reliability Council

EEI - Edison Electric Institute

EPRI - Electric Power Research Institute

NRC - Nuclear Regulatory Commission

BSI - British Standards Institute

IEE - Institution of Electrical Engineers, UK

IEEE - Institute of Electrical & Electronic Engineers, USA

(2) Standards Australia AS4360 Risk Management

(3) Various standing instructions and procedures of CLP Power

(4) Materials from the following Y2K Seminar / Workshop/Symposium participated:

- Y2K Contingency Planning for Utilities Singapore. 25-26 Mar 1999
- Y2K Technical Forum on Y2K Industrial Process, HKIE. 9 Mar 1999
- Y2K Readiness of Hong Kong, HK, 21 Jan 1999
- Y2K Contingency Planning for Utilities, Houston, Texas, US. 16-18 Nov 1998
- Y2K Contingency Plan Workshop by ERPI, HK 28-30 Jul 99.

Paper No. 7

ELECTRICITY SUPPLY LINES (PROTECTION) REGULATION

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ELECTRICITY SUPPLY LINES (PROTECTION) REGULATION

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ABSTRACT

The Government will introduce a new legislation, namely the Electricity Supply Lines (Protection) Regulation (ESLPR) to deter third parties from damaging the underground electricity cables and overhead electricity lines. The objective of the proposed legislation is to regulate works in the vicinity of underground electricity cables and overhead electricity lines owned by the electricity supplier with a view to preventing electrical accident and power interruption.

The existing Electricity Ordinance (Cap. 406) has no provisions to protect electricity supply lines from damage arising out of works. The current voluntary practice in the trade is proved to be inadequate on its own to prevent such damage incidents which very often cause electrical accidents and power interruptions. Legislative measures are therefore required to prevent the occurrence of such incidents. The Director of Electrical & Mechanical Services (DEMS) will be empowered under the ESLPR to approve "Competent person" for cable locating work, to inspect works in the vicinity of an electricity supply line and to require that remedial measures be taken against any contravention of the Regulation. The standard practices with detailed technical guidelines and working procedures will be prescribed in a Code of Practice issued by DEMS which is intended to be used by all those who have responsibilities to comply with the requirements stipulated under the ESLPR.

1. INTRODUCTION

Electricity supply lines (i.e. underground electricity cables or overhead electricity lines) transmit and distribute electricity throughout Hong Kong. If a live electricity supply line is severed or damaged during works, there may be an explosion and site workers and others in the vicinity may be exposed to the danger of an electric shock or burns. In addition, the electricity supply may be interrupted, causing considerable inconvenience to the public.

The Electricity Ordinance (Cap. 406) has no provisions to protect electricity supply lines from damage arising out of works. Prevention of such damage currently depends upon voluntary practice in the trade to seek information from the power companies on electricity supply lines in their works site, using a cable locator to locate the underground electricity cables and adopt safe working procedures. However, this practice is proved to be inadequate on its own to prevent such damage and electrical accidents and thereby jeopardise safety and the continuity of electricity supply. Since 1994, the number of incidents involving damage to electricity supply lines by works contractors has averaged about 700 a year. These incidents had resulted in four fatalities and over 90 injuries and thousands of power interruption over the last five years. Careless use of the excavator, pneumatic drill, crane or hoist by works contractors is the primary cause of such incidents. Legislative measures are therefore considered necessary to prevent the occurrence of such incidents.

2. THE LEGISLATIVE PROPOSAL

In the interests of safety and reliability of

electricity supply, it is proposed that :-

(a) amendment shall be made to the Electricity Ordinance (Cap. 406) to include provisions of measures to ensure that activities performed in the vicinity of electricity supply lines owned by electricity suppliers do not prejudice safety or the continuity of the electricity supply;

(b) regulations to be made requiring that activities performed in the vicinity of electricity supply lines owned by electricity suppliers are performed in a manner that minimises causing electrical accidents or interruption to electricity supply;

(c) the contravention of the requirements of the regulation is liable on conviction to a fine and imprisonment; and

(d) the Director of Electrical and Mechanical Services should be empowered under the regulation to approve "Competent person" for cable locating work, to inspect works in the vicinity of an electricity supply line and to require that remedial measures be taken against any contravention of the regulation as he considers necessary.

A Bill to amend the Electricity Ordinance for introducing the new legislation was submitted to the Legislative Council in January 1999. If enacted, the Bill will be followed by a new regulation, namely the Electricity Supply Lines (Protection) Regulation (ESLPR). There are two principal requirements under the ESLPR. First, it prohibits the carrying out of certain works in the vicinity of an underground electricity cable or overhead electricity line unless all reasonable steps have been taken to ascertain the existence of the cable or line together with certain information relating to it. In the case of an underground electricity cable, reasonable steps shall not be regarded as having been taken unless a competent person has undertaken an investigation for the purpose of ascertaining the existence within the proposed works sites or its vicinity of any underground electricity cable and its alignment and depth and has provided a written report of his findings as to those matters. Secondly, the Regulation requires that in the carrying out of the works all reasonable measures shall be taken to prevent the occurrence of an electrical accident or an interruption to the supply of electricity arising from those works.

3. REMEDIAL NOTICE

The ESLPR will empower the Director to serve on a person whom he believes to be contravening the Regulation a remedial notice directing the person to remedy that contravention within a period specified in the notice. It also enables the Director, in the interest of safety , to intervene where there is a failure to comply with a remedial notice by prohibiting further works on the site or by remedying the contravention himself if necessary.

4. CODE OF PRACTICE

The new Regulation will be supplemented by a Code of Practice (COP) issued by the Electrical and Mechanical Services Department. The COP which prescribes the standard practices with detailed technical guidelines and working procedures has been drawn up in consultation with the parties concerned and will be made available before the new Regulation comes into effect. This COP is intended to be used by all those who have responsibilities to comply with the requirements stipulated in the ESLPR, including employers, employees, site contractors, electricity suppliers and those concerned with planning, organising and supervising work near electricity supply lines.

It will be a defence to a charge of failure to take reasonable steps to ascertain the alignment or other relevant particulars of an electricity supply line, or of failure to take reasonable measures to prevent the occurrence of an electrical accident or interruption to the electricity supply, for a person to show that he has complied with the relevant provisions of the COP.

The COP serves to provide detailed guidelines

on how the statutory requirements of the ESLPR can be met, it will prescribe the safe system of work for working near underground electricity cables and overhead electricity lines as outlined in paragraphs below :-

4.1 SAFE SYSTEM OF WORK - UNDERGROUND ELECTRICITY CABLES

(a) For underground electricity cables, the safe system of work comprises of taking reasonable steps in respect of obtaining plans for the cables, locating the alignment and depth of the cables and using trial holes to confirm their positions and also taking reasonable measures to avoid damaging the cable in the course of works by adopting the safe working practices. For most of the works, these four key elements must be employed when working near underground electricity cables. Having established the alignment and depth of the cable, excavation or other works involving ground penetration may begin. Special care must be taken when digging, especially using mechanical excavators or hand held power tools, above or close to the cable alignment to avoid damaging the cable.

(b) Site contractors are required to, or to cause to, engage or employ a Competent Person, who is a holder of a valid certificate of approval issued by the Director of Electrical and Mechanical Services for conducting underground cable locating work, to pinpoint as accurately as possible any cables located within the proposed works site or its vicinity before excavation takes place by using suitable non-destructive cable locating devices. In the interest of regulating the quality of work performed by the Competent Persons, the Director is empowered to suspend or revoke the certificate of approval granted to a Competent Person. The potential applicants for the Competent Person shall be required to satisfy the necessary training and experience requirements in order to obtain the certificate of approval from the Director.

The Kowloon Bay Training Centre of Construction Industry Training Authority (CITA) currently offers a 2-day training course on a regular basis for those who wish to acquire the skill in locating underground electricity cables with a view to qualifying as a Competent Person. Details on the course dates, fees, enrolment requirements and other information may be obtained from CITA's Training Centre at Kowloon Bay.

4.2 SAFE WORKING PROCEDURES - OVERHEAD ELECTRICITY LINES

For overhead electricity lines, the safe working procedures include taking reasonable steps to ascertain the alignment, ground clearance and voltage of the overhead lines through prior planning and consultation with the electricity supplier and taking reasonable measures by following the safe working practices in the course of works. In avoiding danger, the first step will involve planning by finding out whether there is any overhead line within or in the vicinity of the works site, or across any route to it and obtaining the necessary information on the overhead line from the electricity supplier. Based on the information provided, the electricity supplier is to be consulted to assess the minimum safe working distance between the overhead line and any object which may be operating within or near the works site through conducting a site meeting with the electricity supplier. Once the overhead line information required for the works in its vicinity is known and the relevant electricity supplier has been consulted regarding the proposed work plan, works including the use of various heavy machinery may begin after taking reasonable measures to avoid causing an electrical accident and adopting the safe working practices in the course of works.

5. WAY FORWARD

The proposed legislation is being scrutinised by the LegCo Bills Committee on Electricity (Amendment) Bill 1999. Upon enactment of the new legislation, there will be a grace period

for the trade to become acquainted with the requirements of the new legislation and COP. In the meantime, the COP is being finalised by EMSD taking into account the comments received from various organisations including the Government departments, utlilities, professional and trade organisations as a result of consultation exercise conducted in 1999.

6. CONCLUSION

EMSD will be charged with the responsibility of enforcing the ESLPR. While the ESLPR had gone through the consultation process during the drafting stages, its successful implementation in future depends greatly on the cooperation of the works contractors, trade associations and electricity suppliers concerned. It is also crucial for the contractors and workers concerned to develop a safety culture based on the established Code of Practice for compliance with the new Regulation in order to achieve its objective to prevent electrical accident and power interruption caused by inadvertent damage to the electricity supply lines.

Paper No. 8

DEVELOPMENT TREND OF THE ELECTRONIC BALLAST

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ABSTRACT

We are living through one of the most exciting periods in history, where market globalization is leading to continuous technology improvements. This paper presents a brief review of how these changes are affecting the electronic power ballast industry.

Index Terms — Electronic power ballast, magnetic components, ballast packaging, global ballast market, ballast regulatory standards.

1. INTRODUCTION

TRADITIONAL BUSINESS environment was characterized by long periods of stability followed by short periods of industry-wrenching change. In recent times, availability of low cost materials and large use of information technology are becoming engines of continuous change. Individual mobility is increasing our attitude to take risks, which will result in an even greater pace of change.

"The tools of the industrial age extended the capabilities of our muscles, while the tools of the information age extend the capabilities of our mind" [1].

2. BUSINESS RULES FOR NEW TECHNOLOGY

In a number of occasions the lighting industry has been addressed as a commodity industry. This was mainly due to the identification of basic electric illumination as one of the necessary needs of today's life.

Recent and continuing studies are proving that a properly designed lighting system, tailored to the type of application, can bring a number of benefits including, but not limited to, reduced energy consumption, reduced lighting pollution, increased safety due to more even light distribution, reduced light stress on the human body and overall sensation of more pleasant environment.

The concept of better lighting as benefit to the customer is now highly regarded by lighting manufacturers.

To serve this renovated need the lighting industry is changing its role from supplier of basic lighting to supplier of systems and services.

The "voice of the customers" [2] initiative, largely embraced by several leading companies, translates in custom applications and continuous innovations. This requires better features and reliability, faster product introduction, shorter product cycle and lower cost.

The electronic power ballast is certainly playing a leading role as gear for the lighting system, continuously subjected to innovation.

The incessant introduction of new technologies and components guarantees high flexibility and leading innovation in designing new electronic power ballasts.

In an era of industry consolidation flexibility is increasingly becoming a fundamental marketing tool in addressing both global and local market needs.

Today, global ballast technology platforms can

be quickly reconfigured to serve new customers in different markets.

3. GLOBAL BALLAST MARKET EVOLUTION

The estimated world ballast market in 1998 was 309 million units.

North America and Europe played a leading role, respectively with 115 and 130 million units, while Asia and Latin America followed with 49 and 15 million units [3]. Electronic ballasts were widely diffused in North America where they accounted for 30% of the volume. The rest of the world was mainly an electromagnetic ballast market with volume shares above 90%.

We can forecast that in 2010 the market will be grown by more than 50% to 480 million units globally.

The highest growth regions, Asia and Latin America, will be characterized by a triplication of the market volume when compared with 1998 (150 and 45 million units). North America and Europe, being mature markets in terms of quantity, will have a slower growth pace (+21% and +10%, or 140 and 145 million units in 2010). Electronic ballasts will certainly lead the growth, reaching a share of 71% of the global market. Due to regulation changes Europe will be characterized by the most dramatic shift towards electronic ballast, which will reach a share of 79% in 2010, growing from 8% in 1998.

4. EVOLUTION DRIVERS

It is estimated that electricity generation accounts for 35% of total primary energy use and about 30% of man-made CO_2 emission in the atmosphere [4]. Lighting systems consume about 25% of the total energy in the world [5]. Several organizations are currently planning and introducing new regulations with the aim to reduce global waste and pollution.

The lighting industry, highly sensitive to this issue, is responding by introducing lighter and more efficient products.

The pressure to make the electronic solution a valid alternative to the magnetic ballast is bringing to the market new electronic gears with fewer and cheaper components, able to comply with the most stringent proposed regulations.

A detailed analysis reveals that overall ballast cost is currently decreasing by 3 to 6% per year. This trend is reducing the EL/EM cost ratio, thus making the electronic ballast more attractive. The value of energy saved repays the cost of the ballast, resulting in shorter payback time. Consequently, electronic ballasts are becoming the choice of specifiers not only for new constructions, but also for energy efficient and cost saving retrofit solutions.

5. REFINING EXISTING TECHNOLOGY

Taking into account the evolution drivers described above we can estimate that most of the new ballast development will be concentrated on refining existing technologies and reducing their costs.

Program or warm start ballast, characterized by a long preheat (~1.0 sec) that will preserve the lamp cathode with gentle strike, will become extensively available. Three and four lamp ballasts will dominate the multi lamp fixtures market.

Packaging will be brought to the next level where surface mounted devices, smaller standard components and magnetics will help to reduce size, losses and cost.

Further size and losses reduction will be achieved, at a cost, in high end products, by utilizing film printed circuit boards, low profile magnetics, planar magnetics and, possibly, piezoelectric ceramic devices.

6. REGULATORY STANDARDS

One of the advantages of globalization is the convergence of regulatory standards. The two major players for ballasts are IEC and ANSI.

IEC compliance is compulsory in the European Union and in most of Eastern Europe. Japan migrated towards IEC-J in 1998, while China and other Asian countries are developing standards based on IEC. Most of South America is not regulated at this time, but IEC products are required for high-end applications.

ANSI is sponsored by NAFTA countries (Canada, United States, and Mexico) and is accepted in 120V Central American countries. It also has a strong influence in countries characterized by large U.S. investments, such as Brazil and the Philippines.

It is expected that ANSI and IEC will eventually be unified generating a desirable global standard. Progressive migration talks have been characterized by optimistic results.

7. CONCLUSIONS

This paper illustrates the likely development of electronic power ballasts. The trend has been explained by analyzing how, taking into account the global business environment, the new and existing technologies are generating products able to satisfy both customer requirements and regulations.

An analysis of the ballast industry drivers has been utilized as tool to develop a projected picture of the global ballast market in year 2010.

New and unexpected elements, such as new standards, industry consolidation or newly formed economic regions, can strongly influence these results.

However, the ballast industry appears to be mature and prepared to react efficiently to challenging stimuli.

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Paper No. 9

REVOLUTION IN REFUSE HANDLING: AUTOMATED REFUSE COLLECTION SYSTEM (ARCS) FOR BUILDINGS

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ABSTRACT

Refuse disposal and collection, being indispensable activities in our daily life, are always associated with odour nuisance and hygiene problems. Automated refuse collection system (ARCS) provides the solution by collecting and handling refuse in a totally concealed manner. This paper will firstly introduce the development of ARCS in high-rise domestic buildings in Hong Kong. It will then explain how the design and contractual arrangements are coordinated and managed to meet conflicting requirements in engineering and building designs, environmental aspirations, building residents' culture and behaviour in refuse disposal; and to ensure proper operation and maintenance of the system. Finally the paper will explore the potential for further development and the future of ARCS, and discuss the profound implications that ARCS may have in changing the way we handle refuse in the 21st Century.

1. INTRODUCTION

People and building generate refuse everyday. The traditional ways of collecting refuse in buildings are to dispose and store refuse at refuse rooms or collection sheds. The collected refuse is then removed by refuse trucks on a daily basis. Such ways of storing and collecting refuse unavoidably result in odour nuisance and hygiene problems.

ARCS provides a revolutionary way to collect and handle refuse in a totally concealed manner in and outside buildings. Refuse, after being dumped into disposal inlets, is automatically sucked under vacuum and transported through underground ducting to a central collection station, where it is separated from the transportation air stream, compacted into special containers and then removed by collection trucks for disposal.

ARCS is a pneumatic refuse transportation system that consists of the following major components -

(a) air extraction facility at top of refuse chute,

(b) gravity refuse chutes,

(c) indoor refuse disposal inlets,

(d) refuse storage & discharge facilities at the bottom of gravity refuse chutes,

(e) outdoor refuse disposal inlet, storage & discharge facilities,

(f) refuse transportation ductworks,

(g) refuse separator,

(h) refuse compactor,

(i) refuse containers,

(j) dust filtering facility,

(k) air blowers, and

(l) de-odorizing facility.

The schematics of a typical ARCS is shown in Figure 1.

The essence of ARCS is to have refuse handled in a totally concealed manner once dumped into the system. Odour is prevented from leaking into the surroundings through openings such as disposal inlets and air inlets by

maintaining a negative pressure inside the gravity refuse chute through the roof extraction fan. While odour carried by the refuse transportation air stream will be removed by the use of activated carbon filter or water scrubber before being discharged to the atmosphere. Foul liquid associated with the process will be collected in the containers and disposed together with the refuse. Filtering facility is provided to remove dust particles from the refuse transportation air stream after leaving the refuse separator to prevent clogging the downstream equipment and contaminating the environment.

Although ARCSs in hospitals, offices, hotels and condominiums have been developed and used in Europe, North America and Japan for more than 20 years. Hong Kong pioneers its application in high-rise and densely populated domestic buildings where the residents have different refuse disposal behaviour and pattern.

Two pilot ARCS installations of Swedish and U.S. design respectively were completed and put into operation by the Housing Department since 1995. The systems have been performing satisfactorily and residents' response are positive. The Housing Authority (HA) thus decided in 1998 that ARCS would be a standard provision for all public housing estates completed in or after 2001.

2. HIGHLIGHT OF DESIGN ENHANCEMENT

Given the hot climate in Hong Kong during summer time, the high liquid content of household refuse and the large number of flat units in each building in public housing estates, design of the ARCS has been enhanced to cater for the unique Hong Kong situation basing on the experiences gained from the two pilot projects.

Refuse Storage Capacity for Each Building

The number of flat units in a single building within a public housing estate ranges from several hundreds to over a thousand. The amount of refuse disposed during peak hours, e.g. after-dinner time, will be rather substantial. Since ARCS can only collect refuse from buildings one at a time, sufficient storage must be provided for each building to receive refuse dumped into the disposal inlets while the system is collecting refuse from other buildings.

Refuse disposal pattern of public housing residents have been studied and the storage capacity in each building is specified to be not less than any of the values calculated in accordance with the following formulae or 500 litre whichever is the greater -

(a) PRDR x NDFU x SCT

(b) (DRO x NDFU) / (NAS x NOH)

where PRDR : Peak Refuse Disposal Rate

NDFU : No. of Domestic Flat Unit in the building

SCT : System Cycle Time

DRO : Domestic Refuse Output

NAS : No. of Allowable Starts per hour for the air blower set

NOH : No. of Operation Hour per day

The "system cycle time" is the total time (in minutes) required for collecting sequentially refuse in the storage facilities of all the buildings connected to the ARCS plus the time required for collecting refuse in the outdoor disposal inlet which is farthest away from the central refuse collection station.

In the case of public housing estates, the various parameters are taken as -

PRDR : 0.11 litre/flat/min

DRO : 15 litre/flat/day

NOH : 16 for operation between 0700 and 2300

The values of other parameters will depend on the building & estate configuration, system design and type of equipment provided.

Provision of the calculated capacity for refuse storage will allow residents to dump refuse into

the ARCS at any time except when the accumulated refuse in a building is being sucked into the transportation ductworks and the refuse disposal inlets are locked up automatically. However, such operation only lasts for a few seconds.

Loosening Up of Refuse Agglomerate in Storage Facility

Due to the high moisture content of household refuse collected, refuse agglomerate is likely to be formed inside storage facilities at the bottom of gravity refuse chutes. Subsidiary air inlet(s) are introduced at appropriate location(s) of each storage facility to facilitate loosening up of refuse agglomerate formed and transport of refuse in order to prevent system blockage. However, the inlet(s) will only be opened during collection of refuse by the central plant and remain air tight at all other times to prevent odour from leaking out of the system.

Apart from the provision of air inlet(s), mechanical devices such as augers may have to be used in large capacity storage facilities in order to loosen the accumulated refuse agglomerates.

Selection of De-odorizing Facility

Refuse is moved inside transportation ductworks at a speed of 20 to 30 m/s. The amount of heat generated during the collection process is quite substantial. Given the high ambient air temperature (usually above 30°C) in Hong Kong during summer time, temperature of the refuse transportation air will be raised to a level that will adversely affect the performance of de-odorizing media such as activated carbon. The use of activated carbon filter for odour removal is therefore not as effective in Northern Europe or Japan where the ambient air temperature is usually lower than that in Hong Kong.

To overcome the problem, refuse transportation air has to be cooled down before passing through the activated carbon filters or the filter media have to be replaced more frequently. Additional energy will be consumed if cooling facility has to be provided while it is very costly to replace the activated carbon filters frequently. Water scrubber with appropriate chemical dosing has therefore been specified instead to achieve the odour removal purpose given the successful application for removing odour from the exhaust of scalding areas in HongKong's wet markets.

On the other hand, activated carbon filter is still chosen for the air extraction facility at the top of refuse chute since the extracted air temperature will remain at a level which will not adversely affect the performance of the de-odorizing media.

3. RECYCLABLE WASTES COLLECTION

As an initiative towards protecting the environment, possibility of handling recyclable wastes by the ARCS has been explored at the outset of the design and specification process.

Automatic optical sorting of coloured refuse bags for different waste types in the central collection plant is simply not feasible since refuse bags are unlikely to remain intact after falling from a great height in high-rise buildings. On the other hand, use of multiple refuse disposal inlets together with multiple vertical gravity chutes and separate storage facilities at the bottom for handling different types of wastes will result in a much larger service core and a corresponding reduction in the habitable space. The arrangement is considered not acceptable as this will adversely affect the housing production.

Instead, recyclable waste collection bins will be placed in public areas inside each building for the disposal of papers, aluminium cans and plastic bottles respectively by the residents and to be removed regularly for recycling. The recyclable wastes are relatively clean and should not produce any objectionable smell when in storage. Provision has also been allowed in the ARCS such that recyclable wastes can be collected through the system by allocating specific time slots for the handling of

different waste types if so desired.

4. PLANNING CONSIDERATION

To optimize the initial and recurrent costs, ARCS will only be installed in HA estates with 2,400 domestic flats or more. However, there are also topographic factors that need to be addressed before adopting the system.

One topographic factor is the availability of land space in a site to accommodate and provide access to the central refuse collection station. Typical footprint of a self-contained free standing central station for up to 4,550 domestic flats is approximately 13.5m x 26.5m. Although acoustic treatment, dust filtering and de-odorizing facilities are provided in the station, it is advisable to have it located away from residential blocks to minimize the psychological and environmental impacts. Central refuse collection station should also be located close to the load centre so as to minimize the travel distance of refuse in the collection process and thus enhance the operation efficiency. Consideration can also be given to locate the station underground in the lack of suitable ground space.

Space for accommodating the large diameter (500mm in the case of HA estates) underground refuse transportation ducting is another concern as the ducting will certainly take up some space that is normally allocated for other underground utility services.

On the other hand, sites with extensive rock platforms will give rise to a high initial cost in the formation of trench for accommodating the underground refuse ducting; while sloped platforms or platforms with significant level difference will pose difficulty to the refuse transportation process since the permissible duct gradients are 20° maximum uphill and preferably 30° to 40° downhill.

5. OPERATION & MAINTENANCE

Design and specification of the ARCS and other associated works have been developed in such way as to ensure the maintainability and smooth operation of the system under all conceivable circumstances. It is expected that residents may take some time to adapt to the new way of refuse handling. However, special consideration in the planning and design of ARCS will speed up the transformation process.

Self-Disposal Approach

One of the objectives to provide ARCS in public housing estates is to facilitate self-disposal of refuse by the residents themselves. Designs in respect of the disposal environment and ARCS/ user interface are carefully thought out to ensure the acceptability of the system to users.

A clean, well ventilated and well illuminated refuse room that will not deter users from entering it is the pre-requisite to the success of the self-disposal approach. A see-through glass panel on the refuse room door also helps to give users a sense of security and prevent possible crime inside.

As a means of user interface, a flush mounted panel with red, amber and green LED lights and low volume dual pitch buzzer is integrated with the self-closing and volume-controlling type disposal inlet to indicate the status of the ARCS with regard to its availability for refuse disposal. The arrangement is to inform both the visually impaired and the normal residents whether they can dump refuse into the system on entering the refuse room and to avoid frustration in case of lock-off of the disposal inlet. It is also intended that the indication lights and buzzer can be used in future for showing other system status such as designated time for accepting recyclable wastes, etc.

Contingency Arrangement

As refuse will be dumped by residents into the

ARCS at any time of the day, contingency measures must be available for manual handling of refuse in the event of system breakdown or blockage. A diversion device, which can be manually operated to divert falling refuse towards an emergency outlet for connection to conventional refuse collection bins, is provided at the bottom of the gravity refuse chute or the refuse storage facility. Residents can continue to dump their refuse through the disposal inlets regardless of whether the system is down or not.

Outdoor Refuse Disposal Inlets

So far we have only mentioned the collection of household refuse within buildings. For refuse collected from external public areas, they can be dumped into an outdoor disposal inlet provided in the vicinity of every two buildings.

To facilitate the disposal of larger quantity of refuse in each operation, the inlet opening size is much larger than that of the indoor disposal inlet. Special safety features are therefore incorporated to prevent accidental falling of children into the inlet.

Electric lock provided for inlet door is of the key operated type and will remain in the locked position in the event of power interruption. The disposal inlet will queue up for refuse collection or initiate immediate collection by the central plant only upon closing of the inlet door and removal of the key. An electrical interlocking device is also provided for proving the closed and locked position of the inlet door before collection action is initiated.

If an inlet door is forced open without the use of the correct key, an alarm signal will be initiated at the control and monitoring station of the central refuse collection plant together with the location of the disposal inlet indicated. The inlet will be excluded from any refuse collection cycle until the alarm signal is manually reset by authorized personnel at the station.

In case the cleansing contractor has forgotten to lock up an inlet door or has left it open for longer than a preset time period, an alarm signal together with the location of the inlet will also be shown at the control and monitoring station to remind the plant attendant to inspect the inlet and take appropriate action.

Junk Collection

Since the ARCS only caters for the collection and disposal of smaller items of household refuse, junks such as discarded furniture, home appliances, etc. will have to be handled separately. Junk collection points are still required at strategic locations when ARCS is provided.

Specific Contractual Arrangement

The adoption of ARCS in new HA developments will gradually create a demand for ARCS operation and maintenance personnel. It is therefore stipulated in the ARCS contracts that arrangement has to be made to provide training to operation/ maintenance personnel (who may be staff members of other ARCS operation/ maintenance contractors) nominated by the HA for acquiring full knowledge and appreciation of all aspects of the day to day operation, breakdown and routine maintenance, and fault diagnosis of the ARCS installation. ARCS suppliers are also required to provide technical supports and supply proprietary spare parts to contractor(s) hired by the HA for operation/ maintenance of ARCS.

6. FUTURE DEVELOPMENT

The design and specification of ARCS to cater for specific local conditions and to attain a more effective performance will be under continual development as more and more experiences are gained from the operation and maintenance of ARCS in high-rise domestic buildings. Wider application of ARCS in Hong Kong should also be explored in order to improve the overall living environment.

Design and Specification Development

The proprietary nature of ARCS and the

different design approaches and parameters used by suppliers render it difficult to establish a specification for individual components. Instead, a performance based approach is used resulting in less control on the equipment specification.

Upon gaining more experiences from local installations, appropriate specifications for individual components can be developed to ensure the quality, reliability and maintainability of the ARCS. Furthermore, through the collection of various operation parameters of the systems installed, a database of daily system refuse output, individual building refuse disposal pattern, plant energy consumption, nature and frequency of faults, etc. can be built up and used for detailed analyses so as to further refine and optimize the system design.

Integration of Different ARCSs

The size and scale of an HA residential development can be up to ten thousand flats which are usually constructed under different phases over a number of years. In the present situation, a single contractor needs to be employed for the design, supply and installation of the ARCS for all phases of a development since systems provided by different manufacturers may not be compatible with each other.

The drawback is that only those phases that will be developed within more or less the same period can be served by the same ARCS and a separate system will be required for subsequent phases of development. Such limitation not only complicates the contractual arrangement but also undermines the feasibility of adopting ARCS if the number of flat units involved cannot reach the threshold figure of 2,400. The benefit of economy of scale in terms of construction and operation costs will also be lost.

However, the development of a more or less unified design and specification as mentioned before will, in the end, enable the interfacing and integration of ARCSs provided by different manufacturers. Different portions of an ARCS can then be supplied and installed by different contractors.

Extended Application

Although refuse collection trucks will still be used for removing refuse containers from individual central collection plants to refuse transfer stations or landfill sites, the use of ARCS eliminates the need for them to stay in an estate for a prolonged period to collect refuse bin by bin with its engine left running during the time of collection. The staying time is considerably shortened since a refuse container can be rolled onto a collection truck in less than five minutes. Moreover, refuse are compacted two to three times into the containers so that the number and frequency of collection trucks to be deployed will also be reduced.

Adopting ARCS within an estate development results in a better living environment for the residents and reduces the number of refuse collection trucks running on roads. If ARCS can be extended to cover both residential and non-residential buildings in a large district and integrated with either a refuse transfer station or incineration plant, the number of refuse collection trucks running on roads and hence the amount of unwanted vehicle emission can be further reduced.

In fact, there are examples in Japan that ARCS is adopted on a district-wide basis when a new area is planned and developed. Combustible wastes are collected and incinerated in the central collection plant while incombustible wastes collected separately are disposed to landfill sites.

7. CONCLUSION

The use of ARCS for high-rise residential buildings is a new, revolutionary and promising approach in Hong Kong. In fact, we have an advantage of lower per capita cost in adopting ARCS for refuse handling on both district-wide and individual development basis due to the high

population density here in Hong Kong.

Through the use of ARCS, the objectionable nature of traditional refuse handling work can be totally eliminated. The unpleasant scenario of messy and smelly refuse collection/storage areas in and outside buildings will become a thing of the past in HongKong's public housing development. Meanwhile, reduction in unwanted emission from refuse collection trucks due to the shorter staying time inside housing estates and the less number of trucks that will be required to run on roads helps to alleviate part of the ailing air quality problem in Hong Kong. The effect will even be better if application of ARCS can be extended to a district-wide basis. Eventually, the use of ARCS will bring about a clean, sanitary and better living environment in each and every public housing estates in the 21st Century.

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- Study of Household Refuse Disposal in Public Housing Estate by the Hong Kong Technical College (May 1998)

Fig. 1 - Schematics of a Typical ARCS

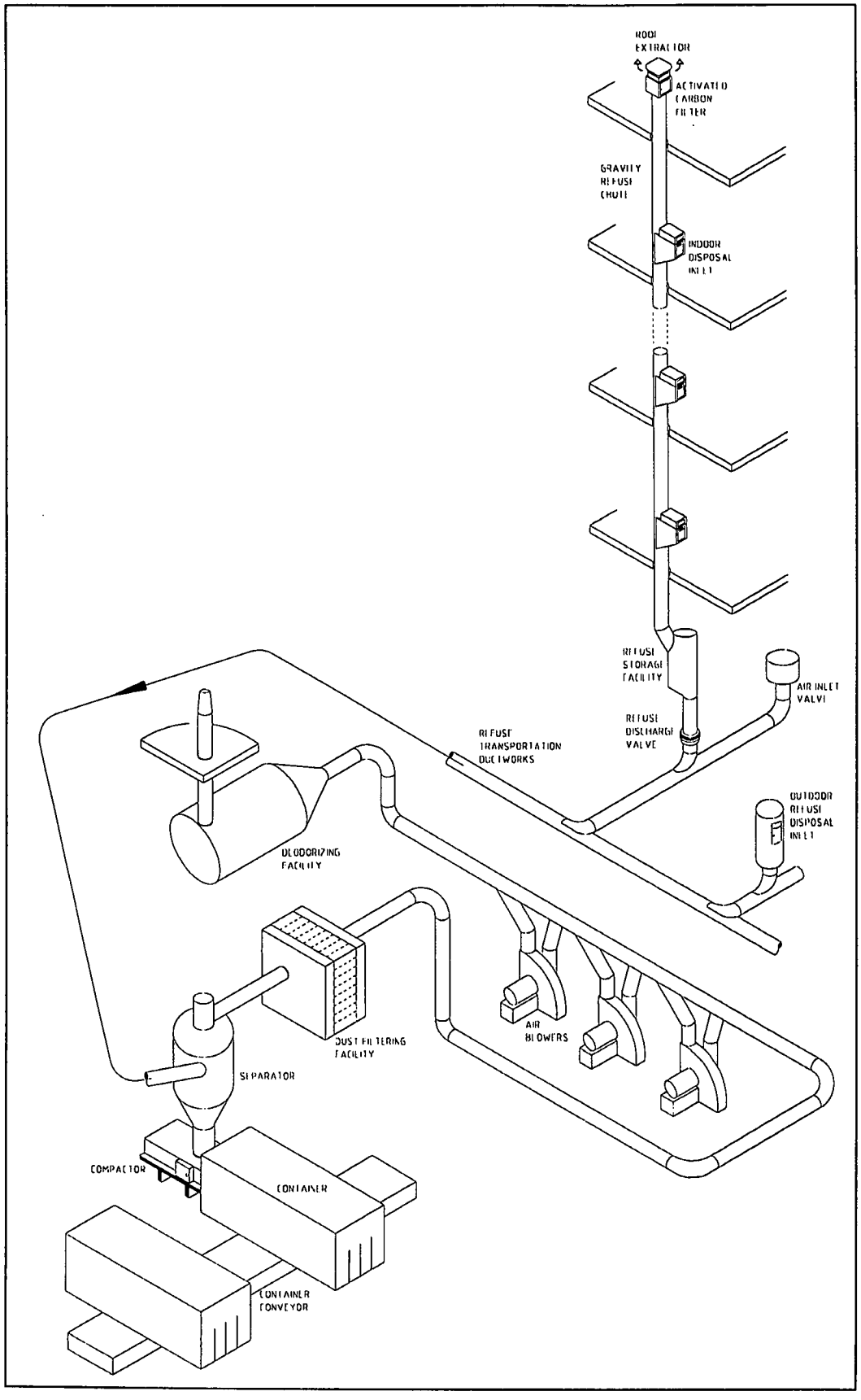

Fig. 2 - Refuse Storage & Discharge Facilities at the Bottom of Gravity Refuse Chute

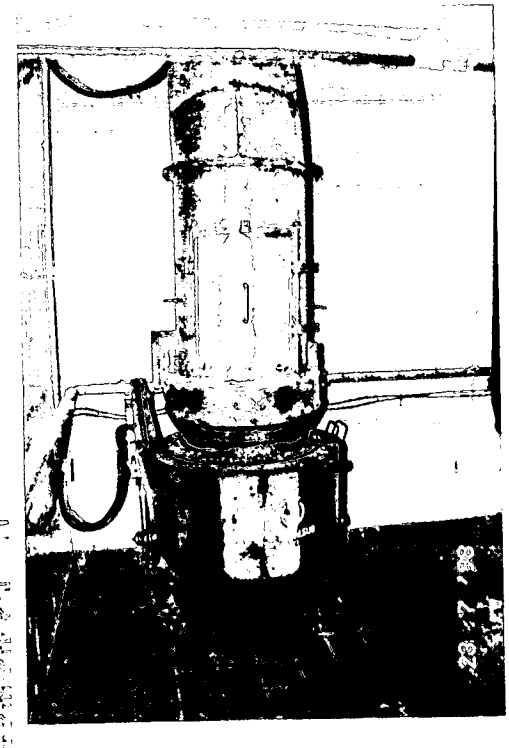

Fig. 3 - Refuse Container being Rolled onto a Collection Truck from the Central Refuse Collection Station

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Fig. 4 - Interior View of the Central Refuse Collection Station after one of the Refuse Containers is Removed