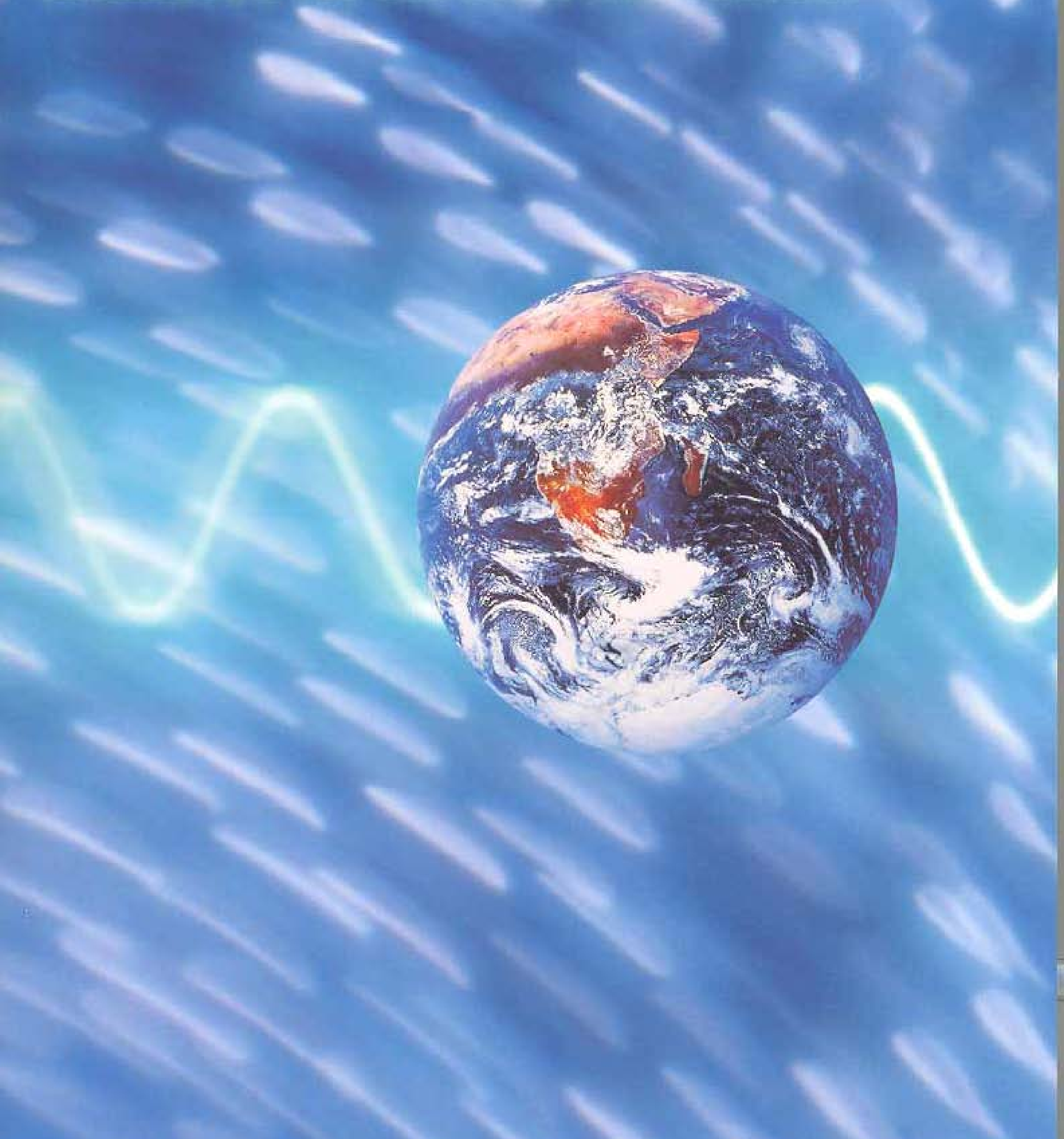
Initiatives for the New Millennium



The Hong Kong Institution of Engineers - Electrical Division

The 18th Annual Symposium, 2000

THE HONG KONG INSTITUTION OF ENGINEERS ELECTRICAL DIVISION

The Eighteenth Annual Symposium

Thursday

19th October 2000

INITIATIVES FOR THE NEW MILLENNIUM

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 Registration and Coffee

09.00 Welcome Address

- Ir Leonard C.P. Lee
  Chairman, Electrical Division, The HKIE

09.05 Opening Address

- Ir Dr John Luk
  President, The HKIE

09.10 Keynote Speech

- Ir James Blake, JP
  Senior Director - Capital Projects
  Kowloon-Canton Railway Corporation, Hong Kong

1. Projects

09.40 Electrical, Mechanical, Instrumentation and Control Systems Installed at the Stonecutters Island Sewage Treatment Works

- Mr G.K. Kukreja
  Chief E&M Engineer
- Ir Norman K.K. Siu
  Senior E&M Engineer
- Ir Dominic K.H. Ho
  Electronics Engineer
  Drainage Services Department,
  The Government of The Hong Kong SAR

10.00 Electrical Services for Data Centre and Telecommunication Gateway

- Ir Michael M.F. Waye
  Vice-President
- Ir Garrick K.P. Sze
  Assistant Vice-President
  Parsons Brinckerhoff (Asia) Ltd., Hong Kong

10.20 Discussion

10.40 Coffee Break

2. *Innovations*

11.10 **A Cryocooler Directly Cooled 6 Tesla Niobium Titanium Superconducting Magnet System**

- Mr L.Z. Lin
  Researcher
- Mr N.H. Song
  Vice Researcher
  Institute of Electrical Engineering,
  Chinese Academy of Sciences, PRC

11.30 **Enabling Broadband Network Services for Facility Management**

- Mr Kapak K.P. Leung
  Technical Director
  Hong Kong Broadband Network Ltd., Hong Kong

11.50 **Discussion**

12.15 **Lunch**

3. *Products*

14.00 **Emerging Trends in Low Voltage Surge Suppression Applications**

- Mr Nathan Tillery
  Technical Consultant
  Innovative Technology Inc., USA

14.20 **Active Filters: An Innovative and Powerful Solution to Tackle New Power Quality Challenges**

- Mr Philippe Tordoir
  Engineer
  ABB World Centre of Excellence for
  Low Voltage Network Quality, Belgium

14.40 **Discussion**

15.00 **Coffee Break**

4. Managemnet

15.30 The New Energy Management System and Distribution Management System

- Mr Paul H. Cheng
  Chief System Control Engineer
- Mr Y.T. Kam
  System Control Engineer
  The Hongkong Electric Co. Ltd., Hong Kong

15.50 Knowledge Management for Power Systems Application

- Ir Dr F.C. Chan
  Project Design Manager
- Mr C.H. Lau
  Senior Training Officer
  CLP Power Hong Kong Ltd., Hong Kong

16.10 Promotion of Energy Saving Technologies in Hong Kong

- Ir K.K. Lam
  Chief Engineer/Energy Efficiency
- Ir Martin K.T. Wu
  Building Services Engineer
  Energy Efficiency Office,
  Electrical & Mechanical Services Department
  The Government of The Hong Kong SAR

16.30 Discussion

17.00 Summing Up

- Ir S.S. Yuen
  Symposium Chairman
  Electrical Division, The HKIE

Closing Address

- Ir C.T. Leung, JP
  Director,
  Electrical & Mechanical Services Department
  The Government of The Hong Kong SAR

Acknowledgement

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Speakers / Authors

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Ir Dominic K.H. Ho
Ir Michael M.F. Waye
Ir Garrick K.P. Sze
Mr L.Z. Lin
Mr N.H. Song
Mr. Kapak K.P. Leung
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Paper No. 1

ELECTRICAL, MECHANICAL, INSTRUMENTATION AND CONTROL SYSTEMS INSTALLED AT THE STONECUTTERS ISLAND SEWAGE TREATMENT WORKS

Speakers : Mr G. K. Kukreja, Chief E&M Engineer
Ir Norman K. K. Siu, Senior E&M Engineer
Ir Dominic K. H. Ho, Electronics Engineer
Drainage Services Department
The Government of The Hong Kong SAR

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Drainage Services Department
The Government of The Hong Kong SAR

Paper No. 1

ABSTRACT

This paper describes the electrical, mechanical, instrumentation and control systems installed at Stonecutters Island Sewage Treatment Works (SCISTW). The SCISTW has been constructed under the Strategic Sewage Disposal Scheme (SSDS) Stage I to treat sewage collected from the urban area of Kowloon and Northeast Hong Kong Island with a capacity to serve a projected population of 3.5 million. Occupying only 10 hectares of reclaimed land, the SCISTW is one of the largest, in terms of capacity, and most compact treatment works of its type in the world. One of the main features of SSDS Stage I is the main pumping station at the SCISTW. Sewage collected from various catchment areas is conveyed via a 23.6km long deep tunnel conveyance system to the SCISTW, where it is pumped against a head of 37.7m to the sedimentation tanks for treatment. The pumping station consists of 8 nos. of centrifugal pumps, each capable of pumping 5.2m^3 of sewage per second and is driven by a 2.5 MW, 11kV variable speed motor. In order to monitor and control the operation of the SCISTW and all the outstations, a sophisticated, state-of-the-art computer based Distributed Control and Data Acquisition System (DCDAS) has been adopted. For completeness, a brief description on the scope of E&M engineering, technology, skill and services that have been implemented under SSDS Stage I is also included in this paper.

1. INTRODUCTION

For the urban areas around the Victoria Harbour, the practice so far has been to provide preliminary treatment to remove floatable solids and grit from sewage and then discharge it to the harbour through submarine outfalls fitted with diffusers. To address the problem of increasing water pollution in Victoria Harbour, a Strategic Sewage Disposal Scheme (SSDS) is being implemented by the Government of the Hong Kong Special Administrative Region. The SSDS is an overall sewage collection, treatment and disposal strategy for areas on both sides of Victoria Harbour. It comprises a series of deep tunnels to collect and transfer sewage from the urban areas of Kowloon and Hong Kong to a centralised treatment plant at Stonecutters Island for further treatment. The effluent is discharged through a tunneled outfall to the sea. The schematic diagram of the SSDS Stage I is shown in Fig. 1.

2. TUNNEL CONVEYANCE SYSTEM

Being one of the key elements of the SSDS, the tunnel conveyance system has been designed to intercept preliminary treated sewage from various catchment areas and convey it to Stonecutters Island for further treatment. The finished diameter of the tunnels varies from 2.2m to 3.5m with a total length of 23.6km. Up to a depth of 150m below ground, the tunnels have been bored through bedrock to give a minimum of 30m sound rock cover. Deep tunnel system has been chosen so as to avoid any interference with the utilities buried underground, e.g. the Mass Transit Railway and the foundation of buildings, as well as to minimise disruption to the traffic. At present, excavating of the tunnel conveyance system is about 95% complete and is scheduled to be commissioned in the year 2001. The layout of the Stage I tunnel is shown in Fig. 2

3. STONECUTTERS ISLAND SEWAGE TREATMENT WORKS (SCISTW)

The SCISTW was completed and put into operation in May 1997. The aerial view of the SCISTW is shown in Fig 3. It is one of the largest sewage treatment works in the world and uses chemically enhanced primary treatment (CEPT) process. It has been designed to treat a peak flow of $39.75 m^3/s$. Despite its large capacity for serving a projected population of 3.5 million people, the treatment works is accommodated within a small footprint of only 10 hectares. Through the installation of the state-of-the-art equipment and the application of land saving design features like double deck sedimentation tanks, the plant is considered to be the most compact treatment works of its type in the world. The process flow diagram of the treatment works is shown in Fig 4. The SCISTW consists of the following main facilities.

- Pumping
- Chemical Storage & Dosing
- Chemically Enhanced Primary Treatment
- Sludge Treatment
- Instrumentation and Control

4. STONECUTTERS ISLAND MAIN PUMPING STATION (SCIMPS)

4.1. GENERAL DESCRIPTION

The SCIMPS is required to lift the flows arriving from the Eastern and Western tunnels, and deliver them to the head of the treatment works. The pumping station employs a dry well, wet well arrangement which utilises a circular configuration with a divided, peripheral sump (-28.5 mpd) receiving combined flow from the two tunnels. The flow is lifted to a common discharge channel around the periphery of the pumping station at above 16.5 mpd ground level. The wet and dry wells form the substructure of the pumping station with the superstructure housing the pump motors, the system control centre for the scheme and the discharge channel. The three-dimensional layout of the SCIMPS is shown in Fig 5.

4.2. PUMPS

The SCIMPS comprises a total of 8 centrifugal pumps (6 duty and 2 standby) located in the dry well of the pumping station. Each pump is driven by a squirrel cage motor mounted at ground level and connected via vertical intermediate shafting, with thrust bearings supported at intermediate floor levels.

The pumps are designed so that there will not be any damage resulting from the stoppage of the pumps causing reverse rotation and torsional vibration due to backflow of sewage from +16.5 mpd. Non-returns valves have not been provided on the discharge pipes. However, isolating valves are provided on the discharge pipework and are kept in the open position at all times. This means that on start-up, the pump will be operating at zero static head. The isolating valves are only closed when the pump are taken out of service for maintenance.

4.3. PUMP CONTROL AND VARIABLE SPEED MOTOR

The pumps are arranged into two groups of four and each pump is driven by a 2.5 MW, 11kV motor but as there are only four variable speed drives provided, each group of 4 pumps shares two variable speed drives. This is based on the design philosophy that each pump will start on variable speed to match the incoming flow. Under normal operation two drives are used to perform soft start of the pumps and to run them with variable speed in order to maintain a constant sewage level inside the SCIMPS. If an additional pump is required for operation, one of the two variable speed pumps will be operated at fixed full speed and its drive will automatically switch to the third pump to start it on variable speed.

When three or more pumps are operating, i.e. two variable speed plus one or more at fixed full speed, and a pump is required to be stopped, one of the fixed full speed pumps will be stopped whilst the speed of the two variable speed pumps will be adjusted to ensure that the station output still matches the incoming flow. A pump curve has been selected to intersect the system curve at one pump operation. This allows the use of a maximum of only two duty variable speed drives to match the incoming flow hydraulics. The system performance curve and pump sequencing arrangement curve are shown in Fig. 6. This arrangement provides a high degree of flexibility for operation and maintenance of the pumps, motors and drives. Maximising the use of the pump at rated full speed also results in lower operating cost as variable speed drives introduce a slight drop in efficiency.

4.4. POWER SUPPLY

Two 11kV distribution main switchboards receive power from CLP by means of two 100% capacity 11kV supplies each from a different CLP Power primary substation. The switchgear associated with the two CLP Power 11kV supplies are interlocked to prevent paralleling the supplies in accordance with CLP Power practice.

There are a total number of twenty 11kV power transformers installed in SCISTW.

(a) Station Transformers

Twelve 2000 KVA, 11/0.38kV ONAN station transformers are provided for supplying low voltage to plant equipment.

(b) Supply Transformers for Pump Variable Frequency Drives

Four 3300 KVA, 11/1.2/1.2kV step-down transformers are provided for the Drive/ Variable Frequency Converters (VFC) such that each VFC is supplied from one dedicated transformer. Each transformer consists of one primary winding with nominal supply voltage of 11kV and two secondary windings with output voltage to match the nominal input voltage of the VFCs. The output from the two secondary windings of the supply transformers are displaced by 30 electrical degrees. The primary windings of the four supply transformers have been arranged with an electrical phase shift with each other to assist in cancelling out of the harmonic currents.

Paper No. 1

(c) Output Transformers for Pump Variable Frequency Drives

Four 3300 KVA, 2.4/11kV step-up transformers are provided for accepting the outputs from the VFCs such that each VFC supplies one dedicated output transformer. Each transformer consists of one primary winding with nominal voltage matching the output voltage from the VFCs and one secondary winding with nominal output voltage of 11kV.

To minimise pumping surges, the pump motors are started normally by VFC. Each pump motor supply is also provided with a bypass contactor to transfer the pump to fixed speed operating at 11kV when full speed is attained to match the inflow. Under extreme conditions, and subject to CLP Power approval, the bypass contactors can be used for direct-on-line starting. The schematic diagram is shown in Fig. 7. Any one of the VFCs 1-2 can be used to start any one of four pumps 1-4 whilst any one of the VFCs 3-4 can be used to start any one of the four pumps 5-8. This supply arrangement provides the flexibility necessary for operation and maintenance. Each pair of VFCs receives power from alternative CLP Power 11kV supply source to minimise disruption in operation of the SCIMPS in case of failure of one of the supplies.

4.5. VARIABLE FREQUENCY CONVERTER (VFC)

The VFCs consist of sophisticated instrumentations that are made up of various electronic and electrical control architecture, mechanism and devices. Each VFC employs a 12-pulse bridge rectification and 6-pulse current source inverter to realise variable speed control function. The Digital Frequency Controller of each VFC has been designed to interface meticulously with the DCDAS as well as other operational real-time signals such as phase angles and current values to achieve a reliable variable speed control system and to provide fully automatic pumping operations.

The VFCs and associated system have been arranged for automatic synchronised make-before-break transfer from variable speed to fixed speed bypass so that voltage dip limitation of CLP Power under these transfer conditions is not exceeded.

The VFCs are of water-cooled type and the heat dissipated by the VFCs to the cooling medium is removed by air-cooled type heat exchangers located outside the VFC room.

Harmonic filters are connected to each VFC supply transformer to limit the harmonic currents injected into the CLP Power system when the VFCs are in operation. The power factor correction system is configured to achieve an overall power factor ranging from 0.92 to 0.98 lagging at the SCIMPS 11kV Distribution Main Switchboard.

5. SLUDGE DEWATERING

Sludge and scum with a dry solid content of 2.5% is withdrawn from the sedimentation tanks to the sludge dewatering system for dewatering. It is dewatered, using high speed centrifuges, to a minimum dry solids content of 32% so as to make the sludge cake suitable for landfill disposal. Centrifuges were selected for the SCISTW after a comparison of this technology with other types of dewatering equipment. In order to produce 1,700 tonnes of dry sludge per day, ten centrifuges have been installed (9 duty and 1 standby). Centrifuges, each fitted with 225kW drive motor and automatically controlled D.C. backdrive, are used to achieve the high dry solids cake. The operation results confirm that the water content of the chemically settled sludge can be reduced from 97.5% to below 65% consistently. This is equal to a volume reduction of over 90%. The configuration of a centrifuge is shown in Fig 8.

6. DISTRIBUTED CONTROL AND DATA ACQUISITION SYSTEM (DCDAS)

6.1 SYSTEM OVERVIEW

The operational control of the SSDS Stage I is effected by a sophisticated microprocessor based computer system called Distributed Control And Data Acquisition System (DCDAS). The field instruments provided at various geographical positions within treatment plants will transmit monitored information on the sewage flow, system hydraulics and status of various aspects of the sewage treatment process to various SSDS control rooms. The DCDAS then goes through a decision making programme based on real-time information plus the control philosophy of each element and sends out signals to different controlling devices to regulate flow of sewage, dosage of chemicals, pumping of sludge and other operational parameters.

Wherever possible, fault tolerant approach has been employed throughout the System, which consists of a family of functional processors, input/output (I/O) modules and ring communication configuration. Redundant processors, redundant I/O modules and redundant rings have been arranged such that the failure of either one of a redundant pair shall not affect the function assigned to the pair.

Password security (through a combination of workstation hard keys and passwords) defines which users have access right to a particular function group at a particular SSDS facility.

Process database is established globally throughout the SSDS facilities, i.e. SCISTW and 9 remote stations, to provide full database functions for control, monitoring and data recording.

Graphic displays have been provided for man-machine interface. They use multiple screen panels (including graphics panels, tuning panels, trend panels and alarm panels) that can be selected, sized and positioned as desired by users. Up to 8 screen panels can be simultaneously displayed on each operator workstation in tile or cascade format.

A central control room has been provided at the SCIMPS from where each facility of the SSDS, including the remote Preliminary Treatment Works (PTWs) and Pumping Stations (P/Ss), can be monitored and controlled. In addition, all operations of individual SSDS facility can be controlled and monitored at its local workstation independently of the central control room to achieve distributed control objective.

6.2 SYSTEM PARTICULARS

The DCDAS comprises Nodes which are connected over a System Information Network that provides the means of communication throughout various SSDS facilities. The DCDAS arrangement is illustrated in Fig. 9.

(a) System Information Network (SIN)

The SIN facilitates communication functions and allows control and data signals transferring among all Nodes throughout the DCDAS at SSDS facilities. The major component of the SIN is the Infinet system which is a high-speed communication link made up of co-axial cables plus optic fibers and is configured as redundant rings running in two different physical routes to provide a high level of security to communications. The SSDS SIN is configured with one primary redundant ring at SCISTW, for interlinking SCISTW facilities, and a separate redundant ring for each of the remote P/Ss and PTWs. All of the outlying rings are interconnected by Cable and Wireless HKT to SCISTW.

(b) Node

Nodes are configured to perform all control, data collection and communications functions. Each Node is capable of operating as an independent control and data acquisition system under conditions when the SIN is inoperable.

Each Node is configured in one of the following arrangements:-

(i) Process Control Unit (PCU)

This is a system of connections, from field I/O units to redundant functional processors. Functional processors at each PCU possess the intelligence to perform control and communication tasks.

(ii) Engineer Workstation (EWS)

This workstation is a high performance, multipurpose computer based system that enables maintenance staff to configure, maintain and troubleshoot the DCDAS. The EWS software includes processor configuration utilities and console configuration utilities for the DCDAS.

(iii) Operator Workstation (OWS)

This workstation console is designed to afford ergonomic man machine interface operation and is modular in construction to allow efficient maintenance and installation. The OWS allows process monitoring and control of live system parameter from a single location through dynamic, interactive graphics. It also provides alarm management, trending, report generation, archival storage and retrieval, system status and diagnostics for DCDAS components.

(iv) Remote interface

This remote interface links outlying Infinet rings to the SCISTW Infinet ring to provide full communication between SSDS outlying facilities and the SCISTW. This enables global control and monitoring of SSDS process to be carried out from the SCISTW central control room.

(c) Functional Processor Control and I/O function

Redundant functional processors are

embedded in the Nodes at SSDS facilities to perform all logic and sequential control functions, real-time monitoring functions, workstation functions, communications functions as well as data storage functions.

Control and data acquisition programmes are stored in non-volatile random access memory (NVRAM) with power back up. They use a simplified form of programming in task-oriented module. Each of these control logic modules is composed of various function blocks, each of which comprises predefined proven process control algorithms. Control and I/O functions are capable of being programmed and edited on-line without interrupting the running process.

6.3 SYSTEM RELIABILITY

(a) In order to reduce the possibility of failures, the system incorporates proven hardware using modern solid-state techniques, packaged and protected to operate in sewage treatment works environment.

(b) To minimise the consequences of failures, the system is arranged in a distributed, fault tolerant architecture and the failure of any one of the redundant pair would not shut down normal plant operations.

(c) All I/O modules and functional processors which are redundant can be removed without the need to power-down the failed or on-line component. When a new functional processor is installed, it automatically runs power-up diagnostics, downloads the appropriate software and is brought on-line in a very short duration.

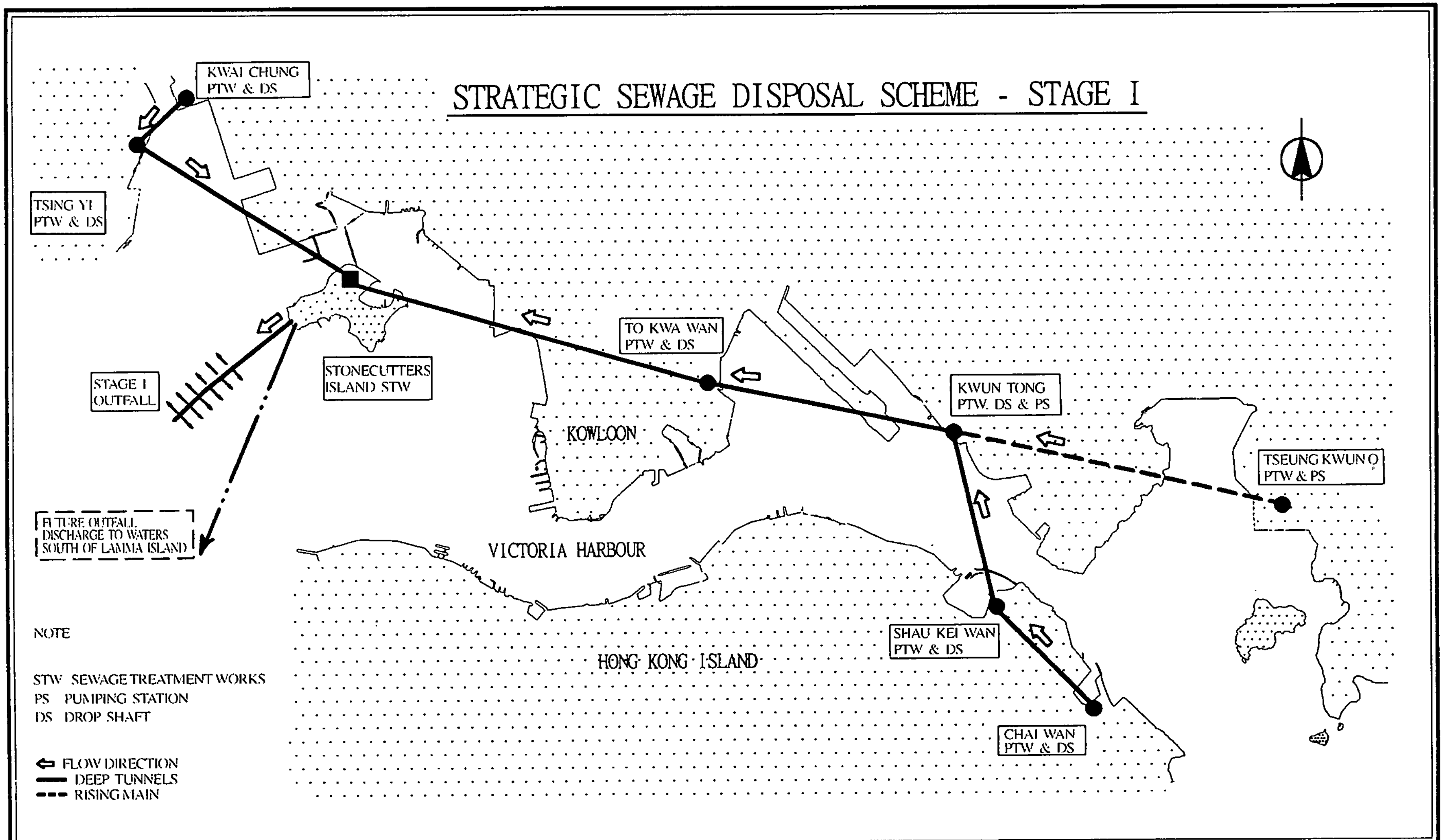
7. CONCLUDING REMARKS

The electrical, mechanical, instrumentation and control systems installed at SCISTW are without doubt, state-of-the-art equipment selected to meet with the system requirements of SSDS Stage I. Through the use of latest technologies such as VFC for controlling pump motors, centrifuge for dewatering sludge and DCDAS for overseeing SSDS Stage I communication network, we feel confident to be able to operate and maintain the world class sewage treatment system at present and in the future to serve the community of Hong Kong.

8. ACKNOWLEDGEMENT

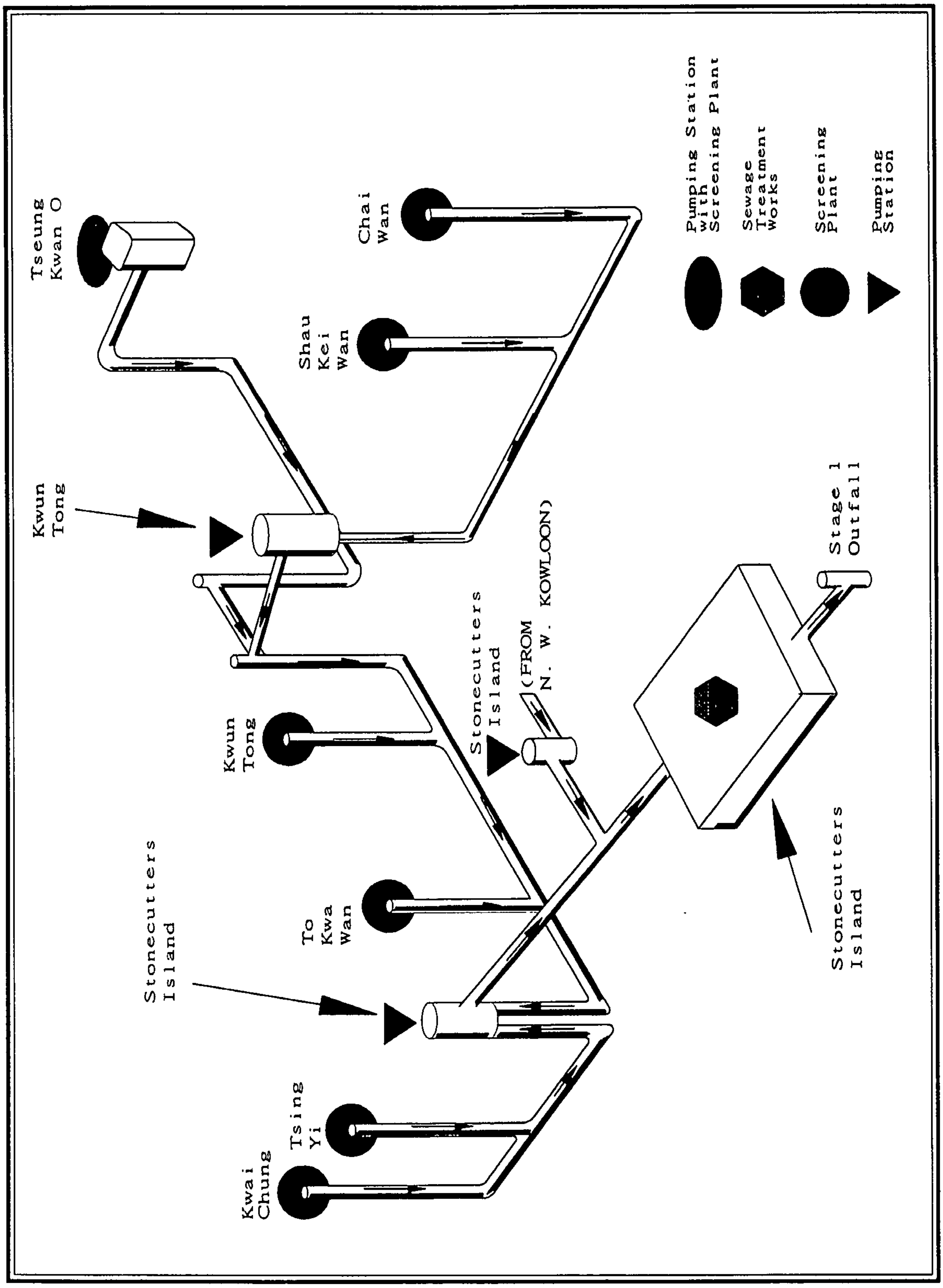
The authors would like to thank Ir John Collier, Director of Drainage Services, Government of Hong Kong Special Administrative Region, for his approval to present the paper.

Fig. 1 Schematic Diagram of the SSDS Stage I



Paper No. 1

Fig. 2 Layout of the Stage I Tunnel



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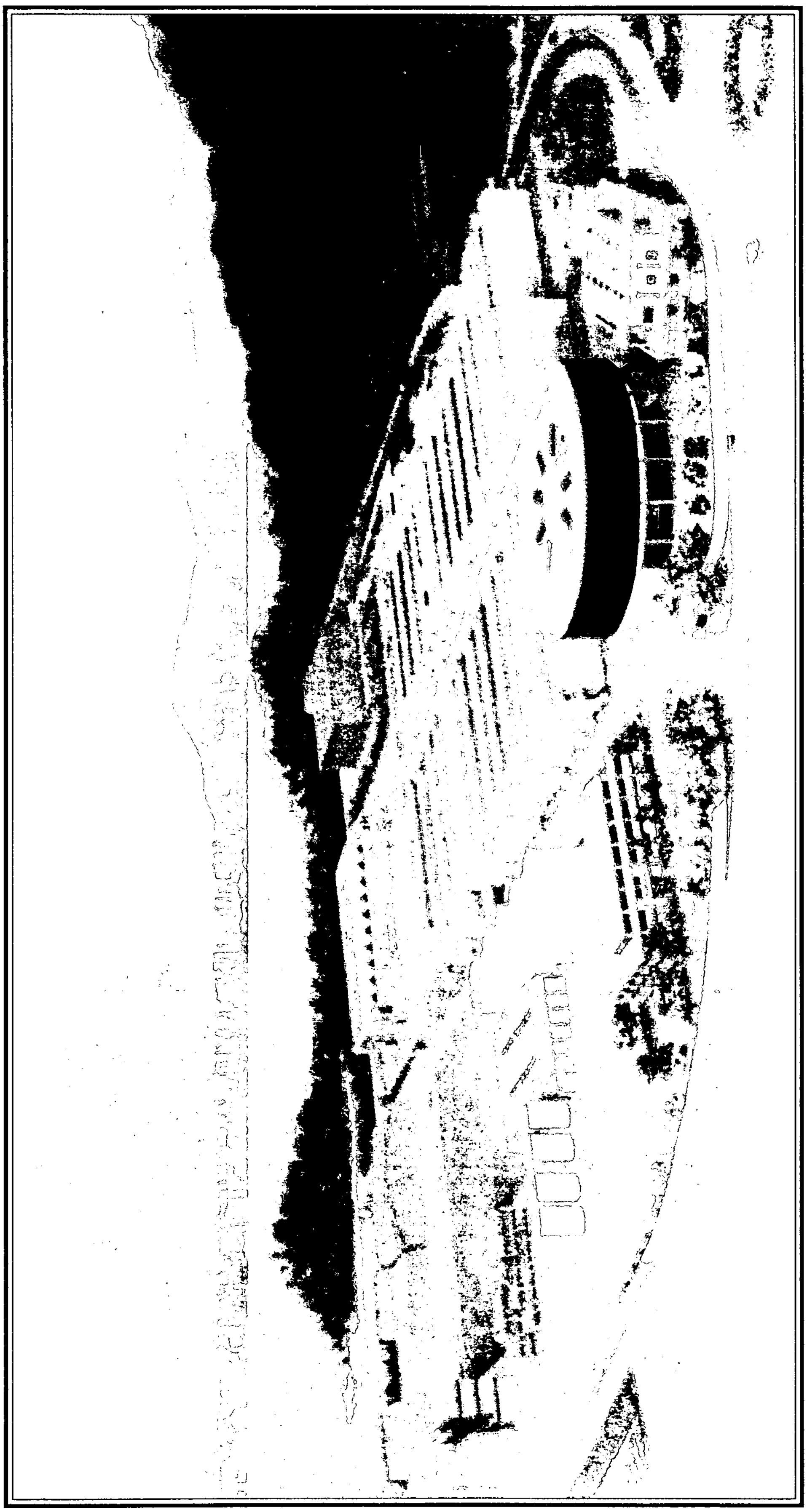


Fig. 3 Aerial View of the SCISTW

Fig. 4 Process Flow Diagram of the SCISTW

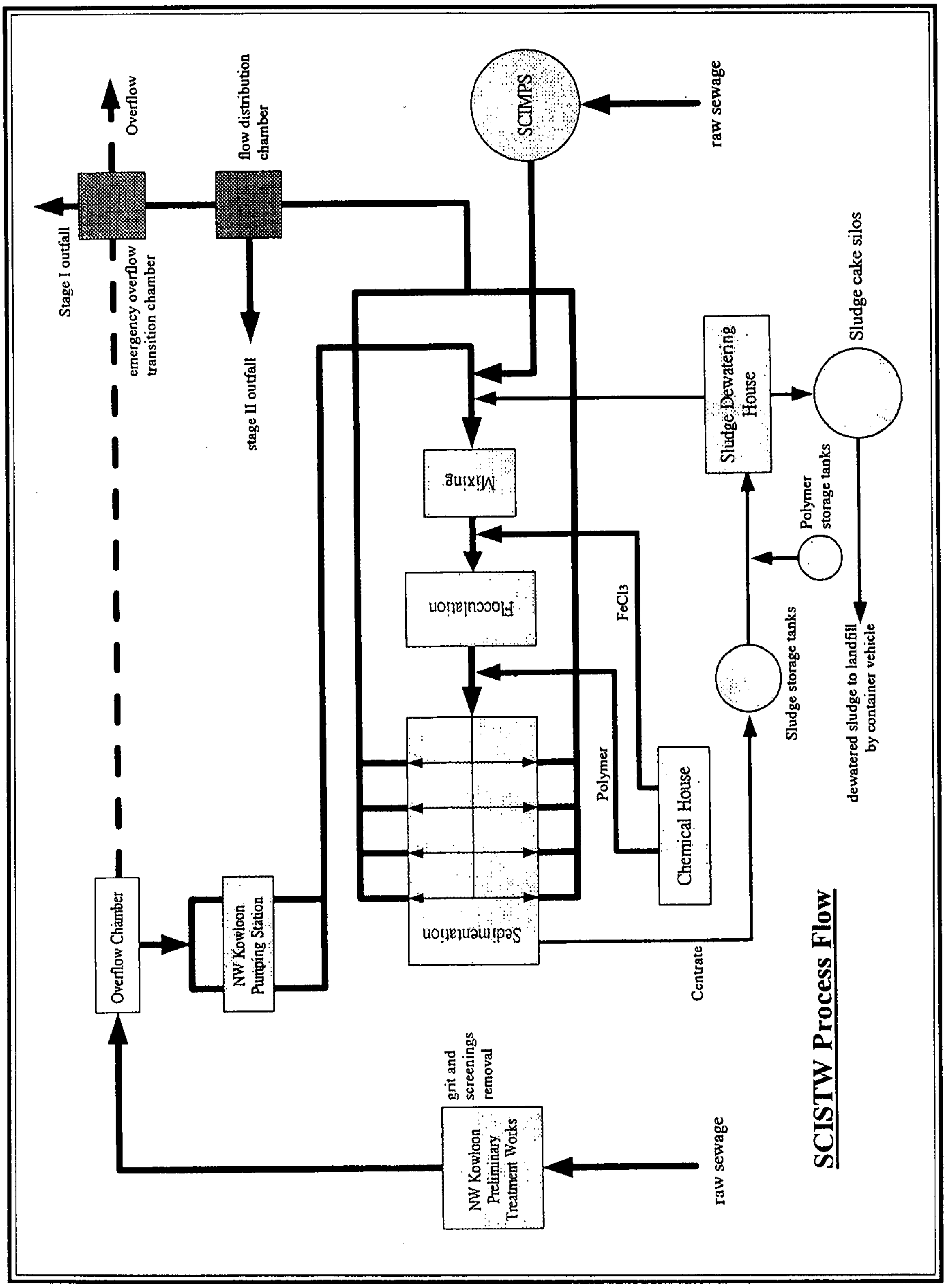


Fig. 5 Three-dimensional Layout of the SCIMPS

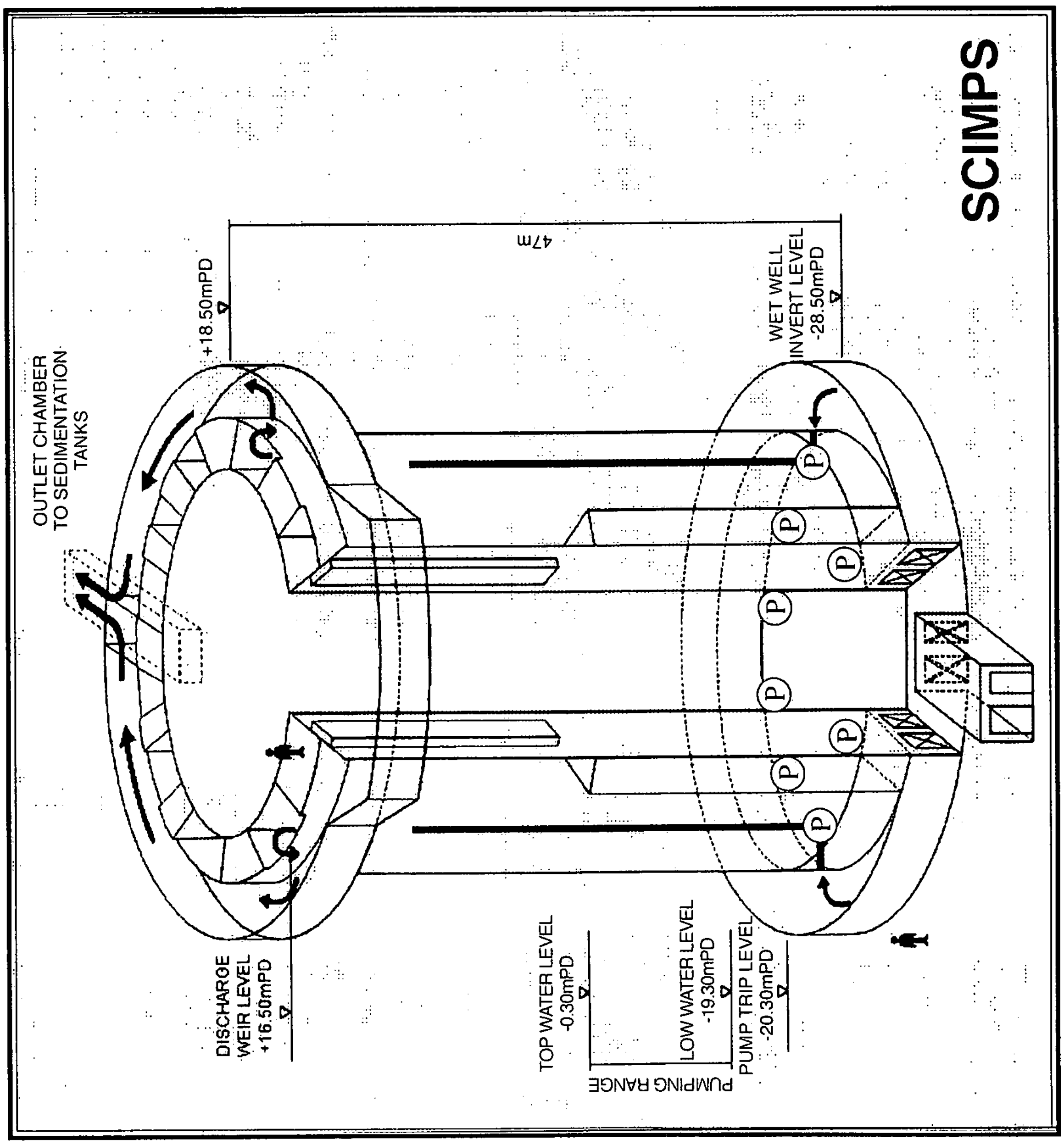


Fig. 6 System Performance Curve and Pump Sequencing Arrangement Curve for Stonecutters Island Main Pumping Station

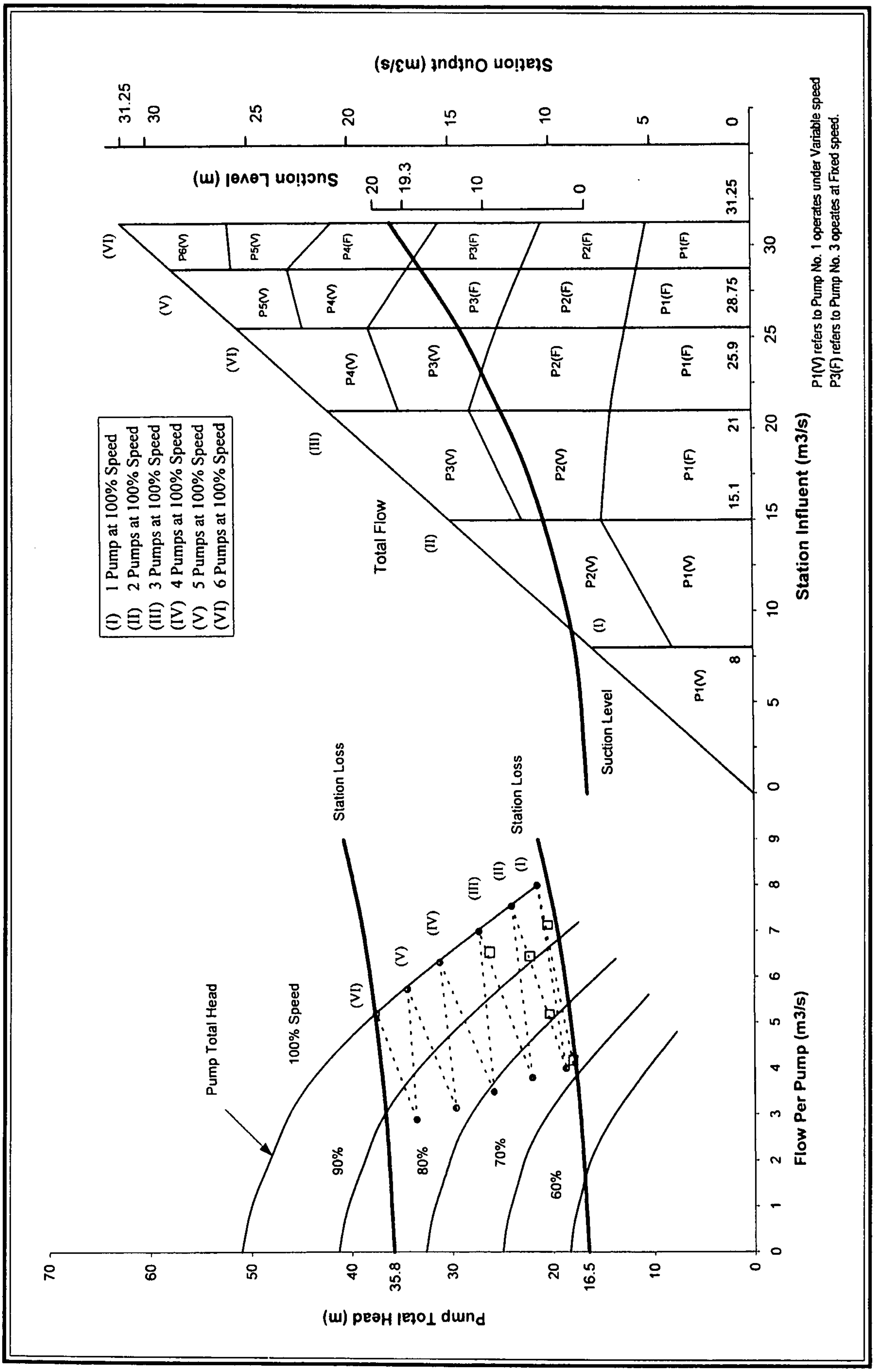


Fig. 7 Schematic Diagram of 11kV Motor Power Supply

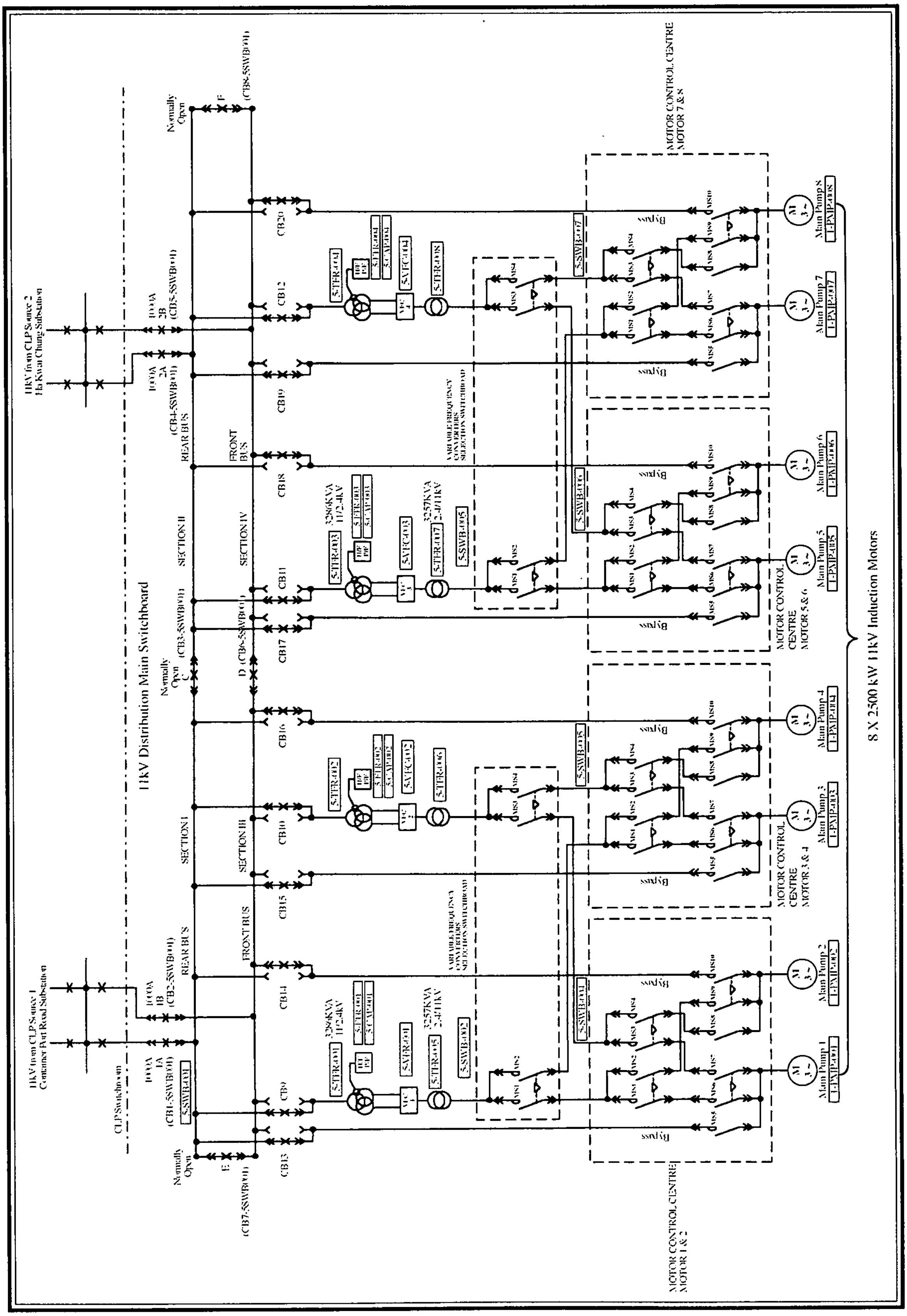


Fig. 8 Centrifuge Configuration

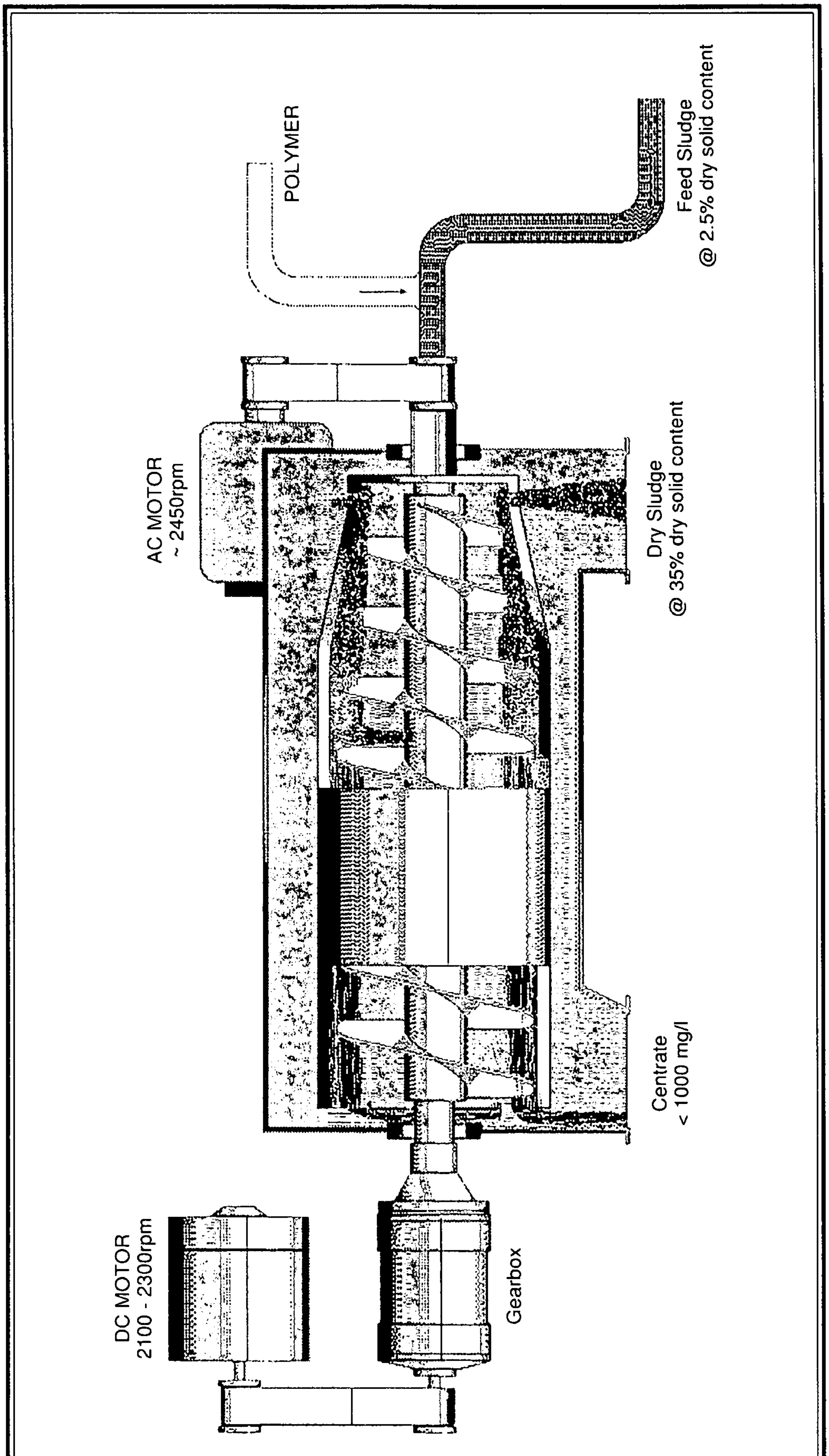
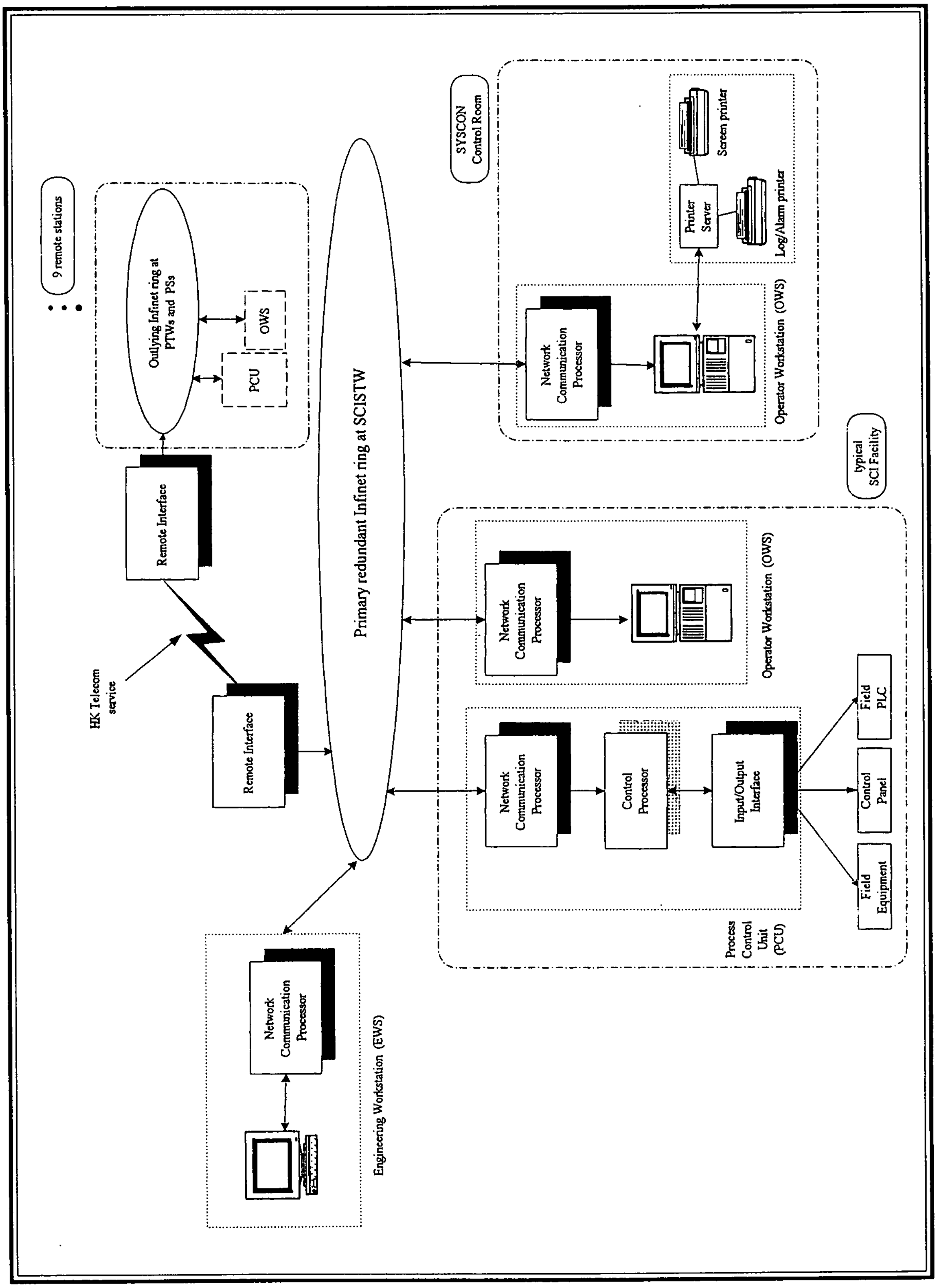


Fig. 9 DCDAS Arrangement



Paper No. 2

ELECTRICAL SERVICES FOR DATA CENTRE AND TELECOMMUNICATION GATEWAY

Speakers : Ir Michael M.F. Waye, Vice-President
Ir Garrick K.P. Sze, Assistant Vice-President
Parsons Brinckerhoff (Asia) Ltd., Hong Kong

ELECTRICAL SERVICES FOR DATA CENTRE AND TELECOMMUNICATION GATEWAY

Ir Michael M.F. Waye, Vice-President
Ir Garrick K.P. Sze, Assistant Vice-President
Parsons Brinckerhoff (Asia) Ltd., Hong Kong

Paper No. 2

ABSTRACT

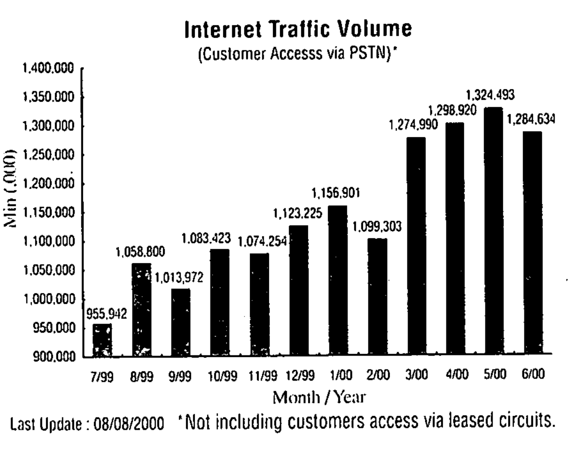
Information Technology, not only affected our lives as civilians in the society, has changed some our practices as professional engineers. With worldwide demand for IT services growing at exponential rates, electricity services must be provided of high quality and security. Also, electricity as a product must be supplied within an accelerated programme to meet the great demand. These requirement provide increasing design challenges to electrical engineers.

This paper presents essential ingredients of electrical services for data centre and telecommunication gateway for IT services. Design considerations for both functional and technical aspects will be discussed, Emphasis has been put on to special electrical services such as DC Power Plant.

1. INTRODUCTION

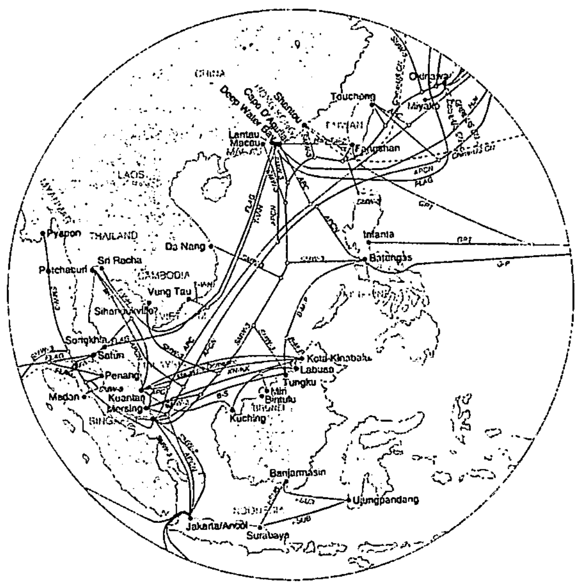
In recent years the telecommunications industry has become a booming business throughout the world, and life in the new millennium can no longer be sustained without a reliable telecommunications system. An increase in Internet Traffic of over 34% in the last 12 months is shown below in Fig.1 provided by Hong Kong Government statistics.

Fig. 1 Extract from OFTA News



Telecommunication networks are expanding rapidly throughout the world. One of the ways to achieve signal transmission is the usage of submarine optical fiber cable. The submarine cables arrive at beach manholes and run through underground ducting to the cable landing stations (CLS) which are the nodal points in the international network. The telecommunication signals will be dually multiplexed to different trunks and transmitted to local telephone networks.

Fig. 2 Submarine Cable Systems around Hong Kong



Data centre is the generic terminology for a location containing telecommunication switches, computer services, data storage facility and application software. With the rapid development of Internet services, data centres can be used for different specific functions, such as a. to e. as listed:

a. Internet services provider (ISP)

b. Internet content page provider (ICP)

c. Application services provider (ASP)

d. Business to business services provider (B2B)

e. Business to customer services provider (B2C) etc.

It is imperative that once commissioned, the telecommunication system and Internet services should be uninterruptible. For this reason, the E&M facilities in cable landing stations and data centres must be extremely reliable. Different levels of redundancy and standby installation need to be included so that the station and the telecommunications network can remain fully operative in the very worst environmental scenarios, such as a commercial power failure, typhoon, earthquake, equipment failure or maintenance outage.

2. GENERAL PLANNING OF CABLE LANDING STATIONS AND DATA CENTRES

2.1 GENERAL CONSIDERATIONS

Cable landing stations and data centres are different facilities for telecommunication systems. In a cable landing station, telecommunications equipment converts the signal from different gateways and various bandwidths to highly compressed Dense Wavelength Division Multiplex (DWDM) and transmits through the submarine optical fibre cable. In a data centre, telecommunications directs telecommunication traffic to various designations or to the content library located in the data centre. Telecommunication equipment located in these facilities is therefore entirely different. However, there are commonalties in the philosophy of electrical power provisioning for these types of facilities.

2.2 FUNCTIONAL REQUIREMENTS

From a functional consideration, both facilities are required to house a considerable quantity of telecommunications equipment, which once installed, will operate 24 hours a day and for 7 days a week. The cable landing station is likely to be required to operate constantly for 25 years. For a data centre; Internet users throughout the world will require the services at all times, and consequently, the design of these facilities to provide operability, maintainability and expandability are of major concern. Extremely high security systems will need to be provided and the building services will need to be monitored internationally by a 24hour operator-manned International Network Operation Centre.

The provision of a reliable and quality electrical power supply are of vital importance in the supply of these services. It may be difficult to conceive of a design with dual power supply, back up generators, UPSs and DC Power Plants. If we consider electricity as the "food" of telecommunication facilities, we can understand why we need different "food" stored in the building. An adequate redundancy needs to be built into the electrical power supply system to ensure a continuous supply of telecommunication services.

2.3 RELIABILITY, MAINTAINABILITY AND EXPANDABILITY

Electrical systems that are provided in these facilities require to support the operation for 25 years or more: exceeding the life span of most electrical equipment, and therefore requires consideration of specific means in providing overhaul and replacement of such equipment.

Telecommunications equipment may grow in exponential order, and consequently the facilities will need to be designed with capability to expand from 2 times to 10 times of their original capacity. Despite the ongoing upgrade and maintenance activities, these telecommunication facilities will always be maintained at an extremely high level of security. Precision system engineering and long term planning are essential.

Since the Cable landing stations and data centres are used to perform important electronic activities, 5 'R'eliability elements are considered vital, namely:

- Reliable AC and DC power supply
- Reliable air-conditioning for equipment cooling

- Reliable security control
- Reliable protection against fire
- Reliable protection against water flooding

2.4 HIGH CONCENTRATION OF POWER

Within the facilities the equipment rooms have a large quantity of telecommunications equipment stacked up in racks and the heat dissipation from this equipment has to be removed by air-conditioning. When we add the equipment load with the required air conditioning load, the overall power density is extremely high with the designed power density of data centres of up to 2,000VA/sq.m not being uncommon. Given the invention of smaller computer chips with increased processing power, there is a tendency to use more power in these facilities, especially in data centres where new computers are standard.

2.5 COMPACTED CONSTRUCTION PROGRAMME

To cope with the ever-increasing demand in telecommunications, the rapid change of technology and international competition, cable landing stations, data centres and gateways will need to be constructed within a very short time frame, with no room for error. Although the installed capacity of a data centre can easily exceed an airport, the construction programme of data centre can be one fifth of that of the airport.

3. SYSTEM AVAILABILITY

Complete electrical services required providing extremely high system availability with every component of the system needing to be reviewed to ensure that no single point failure occurs. The following measures should be considered in the design of any high availability network.

A. Dual paths - The network should provide two parallel distribution paths to the equipment.

B. Dual location - Elements of the network should be in two different locations to provide higher availability. For cable routing, they should be physically separated from the redundant route and for equipment; a duplicate room should be provided so that failure of one equipment will not affect the equipment in the alternate room.

C. Equipment redundancy - Essential elements of the network should operate in redundancy mode so that standby equipment can kick into the network when the duty equipment fails or is under maintenance. Full equipment redundancy of N + N and single equipment redundancy of N + 1 should be considered. (See Table 1)

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Table 1 Typical Redundancy in Cable Landing Stations and Data Centres

Item	System element	Redundancy
1.	Telecommunication cable containment	Dual path and route diversity
2.	Utility supply cable	Dual path and route diversity
3.	Main Switchboard	Sectionalized busbar
4.	Submain cables	Dual path and route diversity
5.	DC Power Plant System	Equipment redundancy
6.	Batteries for DC Power Plant System	Equipment redundancy
7.	Rectifiers	Equipment redundancy
8.	Emergency Generator	Equipment redundancy
9.	Uninterruptible Power Supply System	Equipment redundancy
10.	Batteries for UPS	Equipment redundancy
11.	Distribution board	Equipment redundancy
12.	Final sub-circuit	Dual path and route diversity
13.	DC Power Plant room	Dual location
14.	UPS room	Dual location

4. TELECOMMUNICATION EQUIPMENT AND DC POWER SUPPLY

4.1 GENERAL REQUIREMENTS FOR A DC POWER PLANT

All telecom equipment needs an electricity supply to work, and with many governments demanding the continuous operation of telecom systems - even during an AC mains failure - DC has become the main source of power for telecom equipment. In the modern telecommunication networks, 48V DC and 24V DC are the most popular working voltage levels, despite other voltage systems using 60V or 110V.

The basic requirement of the DC power supply system (DCPSS) is to feed power to the telecom equipment. Thus it has to meet the following requirements:

a. It will be uninterruptible

b. It will keep the output voltage within given limits

c. It will not cause electromagnetic interference to the telecommunications equipment.

4.2 PLANNING OF DC POWER SUPPLY SYSTEM

4.2.1 System Selection

To optimize between cost and reliability, different distribution and redundancy arrangements are made to meet the client's requirements, namely:

Single plant power supply, Single distribution system -

Only one DCPSS plant and one distribution system is installed to supply power to the telecommunications equipment. However, whilst this scheme provides the lowest installation cost it has the lowest reliability.

Single plant power supply, Dual distribution system -

Two distribution systems are installed to increase reliability in the case of power cable or circuit breaker fault in the system.

Single plant power supply, Dual battery string system -

Dual battery string is provided for increased reliability in the case of failure in a battery string.

Dual plant power supply, Dual battery string and Dual distribution system -

The most reliable system architecture has power supply plant, distribution and battery provided in redundant mode. This ensures no single point of failure is found in the system.

The actual space taken up by a DCPSS will mainly depend on the level of redundancy required.

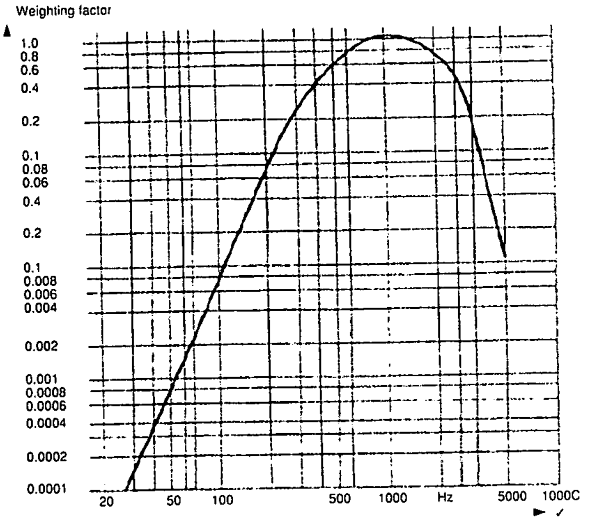
4.2.2 Rectifier Selection

Rectifier is the heart of the DCPSS. It is usually manufactured in a modular form, which makes the maintenance easy. N+1 redundancy is normally used. When one rectifier module is out of order, the system still can provide enough power to the load and the failed rectifier can be replaced very easily by hot plug in a spare rectifier module into the plant.

Switch mode rectifier is used for telecommunication load to ensure more dedicated control for the load and the input source can be done. Also constant power output characteristic is used to provide a better performance of the rectifier to the load.

The output of the DC rectifiers should be free of ripple if possible. However, there is always a superimposed AC voltage will gets into the circuits of the telecommunication system. The electrical noise should not exceed the tolerable value according to ITU-T (CCITT) A - weighted curve.

Fig. 3 CCITT A-Weighted Curve



4.2.3 Battery

A. Selection of battery type

Apart from rectifiers, batteries are also an integral part of the DCPSS, and the appropriate type and capacity of battery is very important for a reliable DC system. Stationary batteries consist of two types, namely alkaline batteries and lead acid batteries, with alkaline batteries offering good performance at low temperatures and providing deep discharge characteristics. However, they are more expensive and have limited ampere-hour capacity as compared with lead acid batteries, and subsequently are seldom used for data centres and telecommunication gateways. As a result subsequent discussion will be concentrated on lead acid batteries.

B. Lead acid batteries

Lead acid batteries contain diluted sulphuric acid with positive and negative plates; with various types of plates having been designed to suit different capacities. Tubular plates, rod plates and large surface area plates are used in the design of batteries with different maximum ampere-hour, internal resistance and discharge characteristics, namely:

- Rod plates are designed to provide capacity to 2,000 Ah.
- Large surface area plates are designed to provide capacity to 2,800 Ah.
- Tubular plates are designed to provide capacity to 12,000 Ah.

Three types of vent plugs are available for lead acid batteries: Gas drying plugs used in Freely Vented Lead Acid batteries (FV), Ceramic plugs used as flame traps to prevent the ignition of gases inside the batteries, and Recombination plugs used as regulating plugs, which convert gas back to water. They are called Valve Regulated Lead Acid (VRLA) batteries. British Standard BS 6290 stipulated the requirements for the batteries, and these batteries are the most commonly used in the telecommunications industry. They have the following advantages over the FV batteries:

a. Low hydrogen gas release and low explosion risk
b. No water refill is needed and does not leak.
c. Maintenance-free
d. Simple ventilation provision
e. Compact in size
f. Will not leak acid to the battery room which would create corrosion

However, there are some disadvantages of VRLA batteries.

a. Lower reliability
b. Higher cost
c. Shorter lifetime
d. Risk of thermal runaway
e. Fewer charging/discharging cycles
f. Sensitive to incorrectly charged voltage
g. Sensitive to overcharging

C. Discharge characteristics

The discharge characteristic of batteries is not linear, with typical curves being shown in Fig. 4. Depending on the total discharge time, the capacity can range from 80% to 100% of capacity for 3 to 10 hours' discharge.

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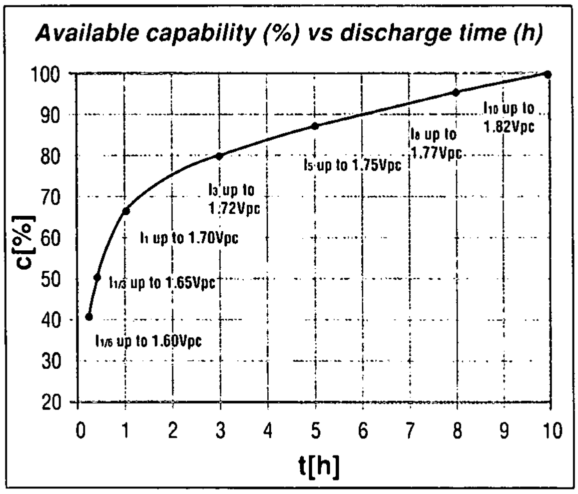
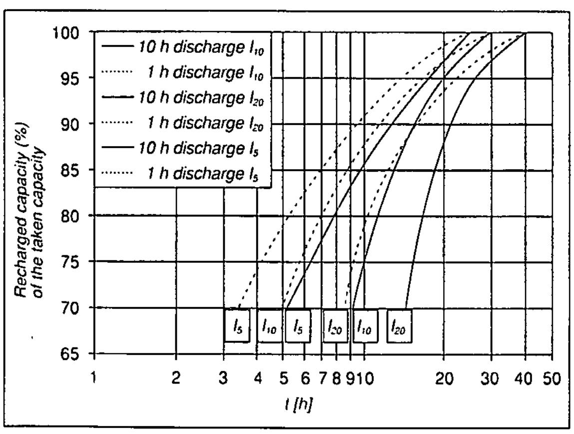
Fig. 4 Available Capability as Function of Discharge Time



D. Charging characteristics

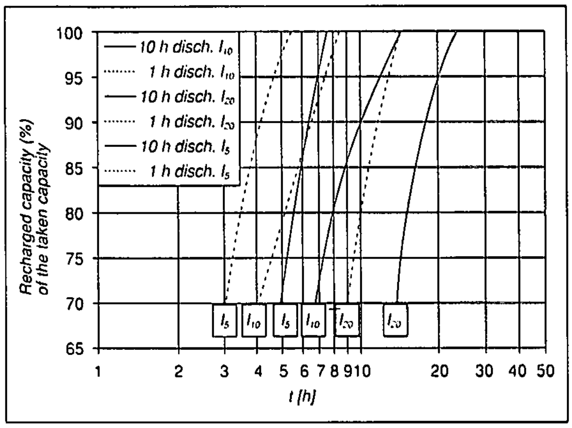
In order to recharge fully discharged batteries within the shortest possible time, a high current is injected into the batteries. Under float charge conditions, the injected voltage will be approx. 2.25V per cell and the recharging time for nominal usage is around 24 hours. The recharge times based on different discharged conditions are shown in Fig. 5.

Fig. 5 Recharging Time under Float Charge Conditions



In order to complete recharge of batteries faster, a boost charge of 2.35V per cell can be applied, with the recharge time for nominal usage being approximately 10 hours. The recharge times based on different discharged conditions are shown in Fig. 6.

Fig. 6 Recharging Time under Boost Charge Conditions



However, the voltage must be limited so that the current charging will not be so fast as to create gas at the battery plates, which will stop future charging of batteries. The maximum charging voltage for lead acid batteries is between 2.37V to 2.4V.

The other considerations will be the voltage level from the equipment. During the boost charge period, the equipment might suffer over voltage; boost charge voltage should therefore be selected to match the voltage characteristics of the telecommunication equipment.

E. Battery capacity and service life

The capacity and life of batteries is stated by the manufacturer based on a temperature of 20°C; as a lower temperature will lower the capacity of the battery. However, the service life will be longer than the stated life. Likewise, at higher temperatures, the capacity will be increased and the service life will become shorter than the stated life. BS 6290 provides an estimation of service life with the operating temperature as shown in Fig. 7.

cables throughout the entire data centre.

6.4.2 Video wall

With several monitoring and control systems in the data centre or CLS, it could prove to be beneficial to have a large video wall to display the status of various systems. This video wall could also be a convenient showcase to the guests of the data centre or CLS.

6.4.3 Receipt of material and testing laboratory

Traditionally, a data centre may start with partial installation, with telecommunication equipment delivered and installed in several phases. It could be ideal to have a small laboratory as part of the data centre to test the newly received materials before allowing them to be connected to the telecommunications network.

7. CONCLUSION

The Cyber World of the Internet has changed the way we live and the way we work. The following noticeable changes are happening in our industry:

7.1 CONSTRUCTION SPEED OF A PROJECT

For a conventional electrical design project, it takes a few months to design and over a year to build the system. A project with an installation capacity of 6 MVA will take about two to three years to complete. In terms of electrical services for the telecommunication and Internet industry, the normal design and construction time frame is approximately 6 to 12 months. With additional construction management effort, some projects can be completed in 4 months. The compression of design and construction of electrical systems has ultimately changed our design approach.

7.2 ELECTRICITY AS A PRODUCTION MATERIAL

Electricity in the construction industry has always been a support to the operation of buildings, railways, highways and other facilities. For the telecommunication and Internet industry, electricity is part of the end product we need to deliver to the user. Without the electrons, we cannot provide the information from one end user to the other. The reliability and availability of electricity is crucial for the Internet to operate, and equally as crucial consumers require electricity to be available 24 hours a day and for 7 days a week, with suspension of services for maintenance being simply not acceptable.

7.3 GLOBALIZATION

The Internet and telecommunications bring people closer together than ever before. It is not uncommon to have more than one telephone line per family. With the proliferation of Personal Communication Systems, the mobile telephone number becomes an important tool; similar to an identity card. Such globalization requires design standards in all parts of the world to match the highest standard as required by the industry. As an example, design standards in the United States will need to be implemented in Hong Kong, Taiwan and Singapore, etc. Design standards in Japan will need to be implemented in Korea, and Engineers in Hong Kong and the region will play an important role in facilitating this globalization process.

Parsons Brinckerhoff as a global company is glad to actively participate in facilitating the changes required in the world with regard to IT and Telecommunications. With offices in North America, Europe and Asia, we have been and are at present commissioned to work on cable landing stations and data centres on all seven continents. We also appreciate the fact that the Hong Kong Institution of Engineers has accepted our paper, allowing us to share our experiences with our fellow engineers. We consider this a great opportunity for us to increase our knowledge in this area and thus help to position Hong Kong Engineers amongst the top professionals in the world. The electricity supply to telecommunication facilities is a vast topic which requires more time than we have time for here and we apologize that we are unable to cover all design aspects here to-day.

ACKNOWLEDGEMENT

We take this opportunity to acknowledge Emerson for providing us with their product information for us to incorporate into this paper. We apologize that due to a confidentiality agreement between PB and our client, we cannot release the project information in its entirety.

Paper No. 3

A CRYOCOOLER DIRECTLY COOLED 6 TESLA NIOBIUM TITANIUM SUPERCONDUCTING MAGNET SYSTEM

Speakers : Mr L. Z. Lin, Researcher
Mr N. H. Song, Vice Researcher
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Chinese Academy of Sciences, PRC

A CRYOCOOLER DIRECTLY COOLED 6 TESLA NIOBIUM TITANIUM SUPERCONDUCTING MAGNET SYSTEM

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Paper No. 3

ABSTRACT

A 6 Tesla Niobium Titanium magnet system directly cooled by a 4K Gifford-McMahon cryocooler was made. The magnet, with an inner diameter of 60 mm, outer diameter of 100mm, height of 172mm, achieves a central field of 6 T at a current of 118A. Powdered Aluminum Nitride was mixed in the impregnation epoxy to increase the epoxy thermal conductivity. The details of the system and test results are presented.

NOMENCLATURE

B magnetic field

I current

I_c critical current

T temperature

1. INTRODUCTION

Recently, Gifford-McMahon(GM) cryocooler cooled superconducting magnet systems are being developed quite rapidly in some countries [1]-[6]. The qualities of easy operation and compactness are important factors for the final choice of the end users. This kind of superconducting magnet system will be an aid to its usage in China where the problems in cryogenic engineering associated with liquid helium impedes the utilization of superconducting magnet systems.

In this paper we describe the design and the test results of a cryocooler cooled 6 T superconducting magnet system, and the application of cryocooler cooled magnet systems.

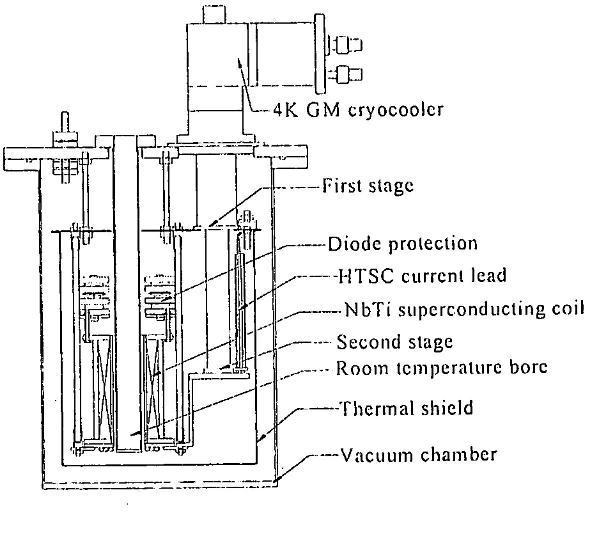
This work was supported by the National Center for R&D on Superconductivity of China.

2. DESIGN AND CONSTRUCTION

2.1 COMPONENTS OF SYSTEM

Our magnet system consists of a 6 T NbTi superconducting coil, protection diodes for the coil, high temperature superconducting (HTS) current leads, 4K GM Cryocooler, thermal radiation shield, vacuum chamber, power source and measurement equipment. The parts in the vacuum chamber (components at low temperature) are shown in Fig. 1.

Fig. 1 Cross Section of the Magnet System



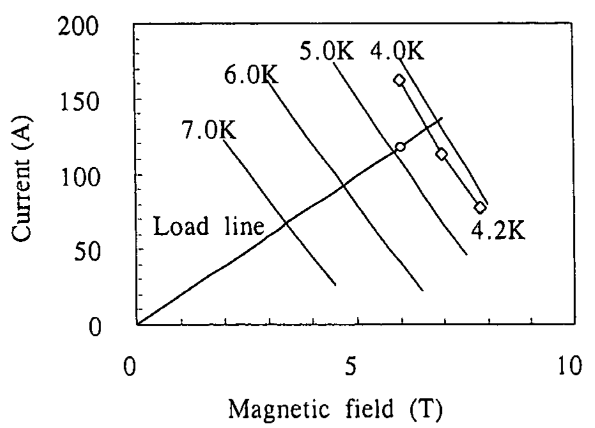
2.2 NbTi COIL SPECIFICATIONS

The coil, 60 mm inner diameter, 100 mm outer diameter and height of 172 mm, is designed to generate 6 T center field at the normal operating current of 118 A. The calculated field uniformity of 10 mm diameter sphere at the center is better than 0.1%.

Multifilamentary NbTi superconducting wire is used in the coil winding. The wire parameters are 0.65 mm diameter, 18 µm filament diameter, 1.5:1 Cu/NbTi volume ratio and a composition of Nb-50.0wt%Ti. A weight of 5 kg of NbTi wire is used in the coil. Total inductance is 1.52 H.

The field dependence of the critical currents at various temperatures is obtained by using the reduced critical state method [7]. Figure 2 shows critical current (I_c) versus magnetic field (B) curves estimated at every 1.0 K step from 4.0 to 7.0 K including the measured data at 4.22 K. The load line of the coil is also shown in Fig. 2. The critical temperature of the NbTi coil is estimated at 4.9K for a 6 T central field.

Fig. 2 Critical Current versus Magnetic Field at Various Temperatures for NbTi Wire and the Load Line



2.3 COIL FABRICATION AND COOLING STRUCTURE

The coil was wound on a bronze mandrel and flanges with the wet method using epoxy. The epoxy was mixed with aluminum nitride (AlN) powders to increase the epoxy thermal conductivity. The coil is covered with a pair of split cylindrical copper plates and radially compressed by the outer stainless steel binding wire to keep the thermal contact to the coil winding. The coil is cooled by thermal conduction through the copper outer cylinders [8,9].

The coil was tested in a liquid helium bath for training. The highest quench current 132 A (6.75 T) reached almost 100% of the critical current of the NbTi wire measured from the short sample test.

2.4 COIL PROTECTION

A diode shunt circuit is mounted at the 4 K stage to protect the coil. The stored energy of the coil is 10.8 kJ at 6 T. When a coil quench occurs, the stored energy is absorbed adiabatically by the magnet mass and the protection diodes only. In order to protect the coil should the high temperature superconducting current leads burn out, we choose to install the diodes at the 4 K second stage instead of the first stage at which the cooling power is larger. This is a correct decision because we experienced HTS current lead burn out once during the experiments.

2.5 4K-GM CRYOCOOLER

The cryocooler is a double stage 4K Gifford McMahon cryocooler bought from Sumitomo Heavy Industries, Ltd. The cooling capacity of the first stage of the cryocooler is 1 W at 4.2 K and the second stage 31 W at 40 K.

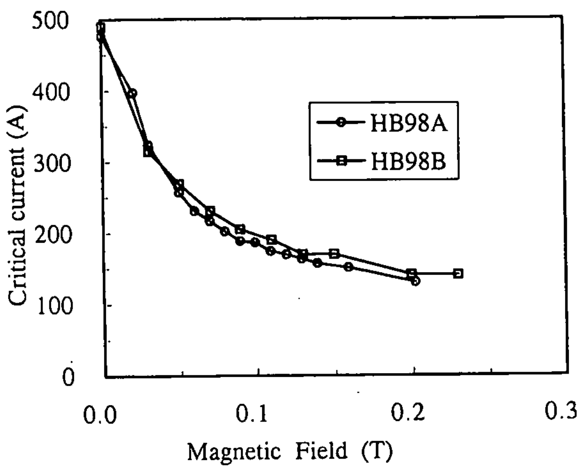
2.6 HTS CURRENT LEADS

$Bi_2Sr_2Ca_2Cu_3O_{10}$ oxide superconducting current leads are used for reducing the heat leakage into the 4 K stage.

Fig. 3 shows the field dependence of the critical current of the leads at liquid nitrogen temperature. The current leads maintain the superconductivity at the operating current of 118A and a temperature of 40K. The estimated heat loads from 60K to 5K for a pair of leads is about 0.182W.

All current leads are thermally anchored through aluminum nitride insulation spacers at each cooling stage. AlN is a good electrical insulator; meanwhile it presents a high thermal conductivity larger than that for copper.

Fig. 3 Field Dependence of the Critical Current of the HTS Current Leads at Liquid Nitrogen Temperature

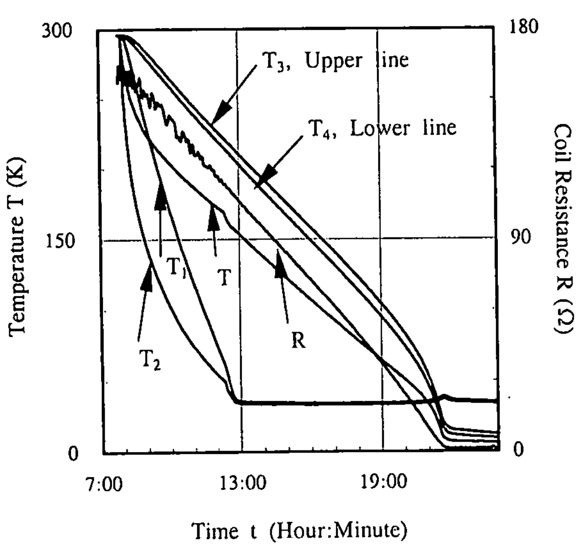


3. EXPERIMENTAL RESULTS

3.1 INITIAL COOL DOWN

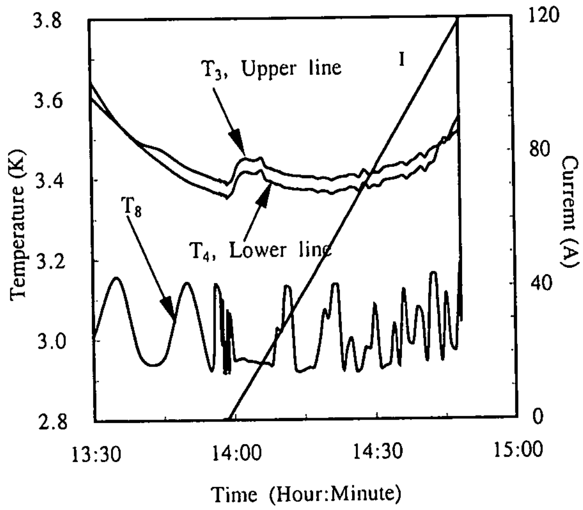
Fig. 4 shows the temperature during cool down. T_2 is the temperature of the first stage, T_8 the second stages, T_3 top of the NbTi coil, T_4 bottom of the coil, T_1 top of the shield.

Fig. 4 Temperatures of the System Cool Down



The coil was cooled down to 3.6 K in about 21 hours. The stable temperature of the second stage is 3.1 K, the first stage 33 K. Fig. 5 shows the temperature of the coil, second stage and ramping current of one of the excitations. The coil quenched after maintaining at a current of 118 A (field of 6 T). The coil temperature rose up to 19 K after quench and was cooled down to stable temperature of 3.6 K again after about 2 hours.

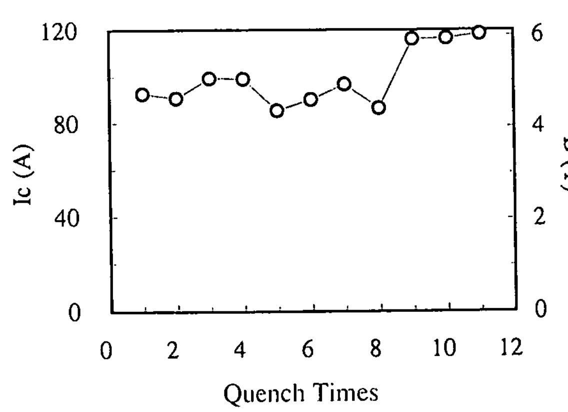
Fig. 5 The Temperatures of the Magnet, Second Stage and Ramping Current of One of the Excitations



3.2 MAGNET PERFORMANCE

The magnet was excited to quench for more than ten times. The magnetic field reached 6 T at a quench current of 118 A, as shown in Fig. 6. We have operated the magnet at several stable field levels of 3.5 T, 4.0T, 4.5 T and 5.0 T.

Fig. 6 Quench Fields of the Cryocooler Cooled Magnet System



4. APPLICATIONS AND FUTURE PROJECTS

During the last 20 years superconducting magnets have been finding an increased number of industrial and semi-industrial applications. Now mechanically driven coolers using rare earth regenerator materials make it possible to dispense with liquid helium as a refrigerant and operate superconductors without difficulties those liquid refrigerants present [10]. The superconducting magnet systems directly cooled by cryocoolers have been developed and in usage in recent years in several countries.

In Japan, A 10 T NbTi/Nb_3Sn system was made in 1996 [11]. In the meantime, Another 10 T NbTi/Nb_3Sn system with changeable bore direction (both vertical and horizontal), the fully advantages of the cryocooler cooled superconducting magnet systems, was made [12]. Recently, a 15 T cryocooled Nb_3Sn superconducting magnet with a 52 mm room temperature bore was finished [13].

A cryogen-free open superconducting magnet for interventional Magnetic Resonance Imaging (MRI) application was made in GE, USA and has been in clinical use at hospital [14]. And in 1997, they developed a cryogen-free 0.5 Tesla MRI magnet for head imaging [15]. A lightweight rugged cryocooler cooled superconducting magnet system for minesweeper applications was built by U.S Navy [16].

Oxford Instruments company has designed a cryocooler cooled 6 Tesla NbTi magnet to replaces an earlier conventional superconducting magnet in a High Gradient Magnetic Separator system and is now in full operation [10].

The most promising usage of the cryocooler in magnet systems is the cryocooler cooled high Tc Bi2223 superconducting magnet systems operated at 20 K temperature levels. The Jc-B properties of Bi2223 tapes were drastically improved at less than 20 K and stability is also significantly improved. Cooling efficiency of 20 K refrigerator is 5 times higher than that of 4 K refrigerator, therefore it is economical and reliable.

Sumitomo Electric Industries, Ltd., fabricated two types of cryocooler cooled high Tc superconducting magnets; 4-Tesla and 7-Tesla types [17]. The 7-Tesla type magnet could be excited at a rate of 2 Tesla per minute. In Japan, a 1 MJ cryocooler cooled high Tc superconducting magnet for Si single-crystal growth applications were progressing [18].

In America, three large cryocooler cooled high temperature superconducting coils were made in the 15 kV class Fault Current Limiter, which were the world's largest Bi2223 high Tc coils ever built [19]. Superconducting Fault Current Limiters (SFCL), unlike reactors or high-impedance transformers, normally operate with low impedance in the electrical system. In the event of a fault, the limiter inserts impedance into the circuit and limits the fault current. With current limiters, the utility can provide a low-impedance, stiff system with a low fault current level. The usage of HTS materials in SFCL systems will reduce the operational cost and increase the stability and safety of the systems compared with using the low temperature superconducting materials. Several utilities and electrical manufacturers around the world are pursuing developments of SFCL, and commercial equipment is expected to be available in a few years.

After the first successful fabrication of a 6 T NbTi superconducting magnet directly cooled by cryocooler, we have a plan to build a 7 T NbTi magnet system of this type with a warm bore of 5 cm. And our laboratory is applying for fund for a 10 T cryocooler cooled NbTi/Nb3Sn superconducting magnet system with a 10 cm warm bore diameter. All of these magnet systems are composed of standard solenoid type superconducting magnets with a warm bore and for general-purpose usages. For example, the systems could be used in material properties measurements under magnetic fields.

In the next few years, we will apply the conduction cooling techniques to Superconducting Fault Current Limiter (SFCL) systems. We are engaged in a research project to establish a 10 kV class SFCL system using HTS tapes.

5. CONCLUSION

A cryocooler cooled NbTi superconducting magnet was designed and constructed. The coil was cooled down to 3.6 K in about 21 hours. A central field of 6 T was obtained. This was the first successful cryogen free superconducting magnet system in China. We will continue the research of conduction cooling techniques and their application in superconducting power systems.

6. ACKNOWLEDGMENT

The authors would like to thank the help and technical assistance from the colleagues of Cryogenic Laboratory, CAS, and of Northwest Institute for Nonferrous Metal Research.

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Paper No. 4

ENABLING BROADBAND NETWORK SERVICES FOR FACILITY MANAGEMENT

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ENABLING BROADBAND NETWORK SERVICES FOR FACILITY MANAGEMENT

Mr Kapak K.P. Leung, Technical Director
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Paper No. 4

ABSTRACT

Telecommunication continues to be one of the most fascinating industries in Hong Kong, with fundamental changes taking place simultaneously in technology and human behavior. These changes are reshaping the way we live and work, opening up many new growth opportunities.

The advanced telecommunication technology makes dreams into reality in the new millenium. This paper, of the theme "Electrical Initiative for the new Millenium, Engineering for the future", will mainly concentrate on the area of how the broadband infrastructure change the mode of facility management, housing management and related fields.

Excessive traffic volume of information consisting data, figure, and even visual image carry on everyday, a well-established wireless telecommunication network is definitely significant. By utilizing the efficient broadband network, different kinds of building facility monitoring elements and services would then be adequately facilitated. For example, security guard service can well be benefited. A wireless telecommunications network built within a housing estate would eliminate the lead time of data transmission cost by using the existing fixed network, when a security guard scanned the pre-set code in a designated area and uploaded the information to the centralized database promptly without delay.

Increasing demand on bandwidth also imposed pressure on the capacity of the existing network infrastructure. Again, wireless telecommunications networks acts as a viable and instant relieve to such situation.

In a densely populated and fast paced city like Hong Kong, wireless network, a state-of-the-art technology, would definitely bring in a brand new experience on our daily lives.

1. INTRODUCTION

Human being different from all other creatures being that we have language and this enable us to exchange information near and far. This includes both verbal and text communication. In order to overcome geographical limitation, many communication means had been invented, from ancient smoke signaling to express mail. However, all these means involve putting the content on a physically media and carrying it from the originator to the receiver. Until people are able to transmit information over a copper wire, telecommunication was born. This had a fundamental break through of changing the content into electrical signal and transmit in the speed of light. By building large telecommunication network, distance between people is diminishing, information becomes instant. Geographical as well as cultural barriers break down.

2. HOW POWERFUL IS THE BROADBAND NETWORK?

Broadband is now going to become an indispensable part of our daily life. It makes our life easier and more productive. With a Broadband Infrastructure, many part of our daily life all come together - on our PC screen. Turning what used to be trips to clicks. Enriching your working life with more quality time.

From Housing Management perspective, how the colleagues can be benefited from this Broadband Network? How can the network smoothen the communication among various local office and the headquarter? How to enhance the efficiency of information flow among huge number of colleagues involved? The answers can be found in the following section.

3. HISTORY

Until 15 years ago, instant telecommunication had been perceived as verbal conversation with each telephone call occupying a dedicated switching circuit. This circuit is only available to the respective parties during the course of conversation. Although digitized and compressed voice appeared to perform miracle on circuit efficiency, it is still expensive and inefficient in comparison to digital data communication.

Remember that facsimile was such an impressive means for transmitting text information. Looking carefully, one would discover how much silence in a voice telephone conversation and blanks in a facsimile document. This silence and blanks transmission on a circuit switch connection is a total waste. "Silence is golden" only for the telephone company collecting the phone bill. This is made possible by converting the voice and image into digitized data and transmitted through broadband network. Remember we were able to watch the Olympic games on TV in 1996 and now on the Internet.

With information other than voice transmitted between parties, data connection was required. Circuit capacity for data connections had been increased exponentially and surpassed voice circuit capacity in mid 1998. It is projected that data circuit bandwidth requirement will be doubled every year for the next five years. Beyond that, it is only wild guess.

With the increasing demand for the bandwidth requirement, a Broadband Network infrastructure is a must in the trend. By taking advantage of a broadband network, virtual private network can be created between offices. This will ensure all parties involved are sharing up-to-date information instantaneously. Deploying such network using incumbent network service provider will have huge cost implication, but can be economically provided by wireless broadband network operators. All individual site office can be linked up and also can be connected with the Headquarter. In handling such a huge number of populations in Hong Kong, vast amount of document and information needed to be shared and communicated between many offices.

4. TECHNOLOGIES

There are several alternative mechanisms for the delivery of high-band-width services to consumers ranging from Digital Subscriber Line (DSL), Hybrid Fibre Coax cable networks satellite and fixed Wireless system. The most common so far is DSL and fixed Wireless system of which the technology is approved by OFTA earlier this year.

Digital Subscriber Line - DSL is the generic name for a range of new modem technologies that provide high-speed data transmission over telephone lines. This is achieved by exploiting the additional usable spectrum on the copper line not required for telephony. DSL comes in a number of variations, and XDSL is often used to denote the generic rather than any specific form of DSL. Asymmetrical digital subscriber line (ADSL) is by far the most common form of DSL. It is called asymmetric because it offers a different transmission rate for each direction. More bandwidth is allocated for transmissions towards the user (downstream) than away from the user (upstream). ADSL support downstream transmission rate of 1Mbit/s to 9Mbit/s and upstream transmission rate of up to 640 Kbit/s. This compares with the maximum 56K speeds for analogue modems.

On the other hand, Broadband wireless (is quickly emerging as a strong network access alternative for the delivery of data, Internet, voice, video and multimedia applications to business and residential customers. Ease and speed of deployment, minimal disruption to community and environment, and lower infrastructure and real estate requirements offer a strong and flexible alternative that will help accelerate service delivery to new markets.

5. APPLICATION

Broadband wireless access, combines with an integrated multi-service network architecture, enables the simultaneous transmission for a broad range of traffic types. Service providers can consolidate multiple services. Create dynamic bandwidth, and support guaranteed quality of service levels. In additional, broadband wireless access can also extend the reach of advanced and value-added services such as virtual private networks, encryption, tele-conferencing, and voice over IP, distance learning, and telemedicine.

For example, an estate Intranet web application can be developed for the residents within the estate. This will come together with the estate management office to bring in all kind of innovative estate management service to residents. Estate information is right at their fingertips. Residents for instance can now pay their management fees, receive notices from the management office, or even reserve club facilities such as tennis court at touch of a button. The management office can also broadcast memo/notice and any emergency announcements to residents online any time during the day or night, send information request by email to the management office, make maintenance request to the management.

In terms of varieties of access, technologies really have gone round a full circle. Communication originated from verbal to text writing thousands of years ago, then this is "simplified" to telegraph Moss code and keyboard type writing. Now, we are back to voice commanding and jot character recognition. When data communication first started, expensive dedicated data link was the only means to link up terminal devices, then came dial up modem which makes data access affordable with the compromise on performance. Today, we have high bandwidth packet switching broadband access at consumer pricing. Also wireless access with mobility is dawning. Powerful electronics enables seamless multi-mode transmission switching without interruption.

For example, Broadband Network service can also be applied in estate security. The CCTV system will be linked with the estate Intranet and the management office and/or the residents can see the place in the estate web site. Besides, management house invests a lot in terms of time and money in taking these items into their daily management work.

Recently, many estate install many video camera within the estate for monitoring the critical area, e.g., in the lift, in the carpark, and install the device in making sure the security staff they employed patrolling the designated area. It seems sufficient but not efficient.

With Broadband Network infrastructure, the video cameras would it be for surveillance or security purposes proved to be more powerful than before. Video images can be transmitted off site, stored in electronic media in digital form and can be randomly retrieved by all interested parties on web.

Besides, estate security officers currently going for patrolling has to sign log books at various checkpoints. With Broadband Network, the officer is just carrying a mobile positioning device similar to a cellular phone operating in the 3G network and incorporating the data backhaulling by broadband network. Their patrolling tracks and time stamp can be recorded and archived. Even better, with the advancing of electronic components, their whole patrolling process can be recorded on real-time video for immediate support or future investigation.

On top of all the content that one wants to put on the network, there is also machine to machine communication that is working silently at the background of that is necessary to ensure a smooth and orderly manner within the network. All these were done by some network designers on agreed boundaries to save us all the hassles and we can whole heartly take it for granted. This can be extended to building facilities automated management and monitoring which results in much efficient response and improves service quality without extra man power.

This can be applied on the building monitoring and automation. For example, in building complex as large as Housing Authority estates, there is a lot of building facilities. From as simple as a water pump to emergency power generator and intelligent elevator optimization. All these facilities require machines communicating with each other as well as being monitored and reporting fault to the monitoring center. With all this information connected by the broadband network, monitoring center can discover problems instantly and respond before residents call in for trouble to improve service quality.

6. CONCLUSION

With the increasing amount of information being exchanged, bandwidth demand had surpassed infrastructure growth. Wireless telecommunication networks have become a viable and instant relieve to such demand. This is more evident in dense cities such as Hong Kong. Since air is free, the amount of information one can put on a wireless link is only limited by modulation techniques. Again this can easily be realized by the advancement of semiconductor technology. Broadband networks enable vast amount of personal information being exchanged within short time interval.

Considering the amount of information we can exchange within our live time as compared to our previous generation, can we not say that we have lived longer?

Life is limited, live it......?

Paper No. 5

EMERGING TRENDS IN LOW VOLTAGE SURGE SUPPRESSION APPLICATIONS

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EMERGING TRENDS IN LOW VOLTAGE SURGE SUPPRESSION APPLICATIONS

Mr Nathan Tillery, Technical Consultant
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Paper No. 5

ABSTRACT

There are two major problem areas in power quality that affect the proper operation of today's sensitive microprocessor controlled machinery, voltage surges and voltage dips. This paper discusses the need for externally provided transient voltage Surge Protection Devices (SPD) as a method to insure the smooth and trouble free operation of today's microprocessor controlled equipment as well as other sensitive low voltage electronic equipment. While most project design engineers today recognize the need for installing SPD devices at the service entrance, little thought is usually given to the downstream distribution system within a facility, and the transient voltages that are generated by the facilities normal electrical operation.

NOMENCLATURE

AVR Automatic Voltage Regulator
MLV Measured Limiting Voltage
MOV Metal Oxide Varistor
SAD Silicon Avalanche Diode
SPD Surge Protection Device
SWT Sine Wave Tracking
TVSS Transient Voltage Surge Suppressor
UPS Uninterruptible Power Supply

1. HOW TRANSIENT VOLTAGES ORIGINATE

Unwanted transient voltages occur any time there is the disturbance of a normal flow of electricity in a circuit. Common causes are the mechanical switching on or off of electric or electronic equipment, the operation of power factor correction capacitor banks, normal operation of manufacturing and production machinery, and the untimely release of energy from inductors and capacitors used in equipment during power interruptions, among others.

Transients come from two different directions or sources: (1) External sources such as lightning, power utility operations, industrial accidents, neighboring facilities, and (2) Internal sources on the customer side of the meter. Statistically, as reported in General Electrics' "Current Scene" magazine about 80% are from internal sources, while 20% come from external sources. External sources tend to be more impulse type, or single, high energy unidirectional "pulses" while internal sources tend to be more oscillatory or ringing in nature, often bouncing back and forth between transformers, inductive loads and capacitors within the customer distribution system. Existing facilities, when faced with "unexplained" equipment malfunction or operational difficulties traditionally turn to "known solutions" which upon examination do not actually offer much protection from transients. Voltage dips may also present a formidable problem which may require more specialized equipment than the "normal" solutions.

2. WHAT ARE THE COMMON SOLUTIONS GENERALLY EMPLOYED?

Common externally provided solutions usually include one or more of the following:

(1) Medium energy shunt type SPD's at the service entrance

(2) The addition of Uninterruptible Power Supplies as a "filter"

(3) The use of power conditioners or Automatic Voltage Regulators

However, these solutions almost always are applied in the belief that transients and dips only come from some upstream source such as the power utility, and are filtered out at the service entrance, UPS, or AVR. Closer examination of the performance of these equipments will show that most often, their use as a "filter, regulator, or conditioner" is perhaps true for events happening at the millisecond range and above, but not for transient events that are in the microsecond or nanosecond time periods. In fact, since it can be shown that 80% of transient disturbances are generated by the customer's load equipment and its operation, and is probably happening on the load side of these common solutions, one must also be looking at the upward flow of this transient energy from the loads towards the source. Most commercial UPS systems do not work well if at all when subjected to continuous sub-cycle power dips of 50% to 80% of nominal.

Of course, it is true that virtually every manufacturer of electronic equipment has included some form of internal circuit protection in the form of inexpensive solid state devices, generally MOV or SAD components mounted inside the customer equipment in power supplies or on printed circuit boards. This became necessary as early electronic equipment was quite easily damaged as it moved from the research and development labs into the "real world". There are in fact, so many of these devices installed and working today that power quality studies done in customer premises can no longer give a clear picture of transient activity due to the many hundreds if not thousands of these devices in a typical factory. With these multitudes of devices already installed, then why should we be concerned with adding even more external SPD devices to an electrical system? Because electronic and microprocessor controlled equipment still suffers from "unexplained" malfunctions and improper operation, and there are several basic problems in relying on this "built in" protection

3. WHAT IS THE PROBLEM WITH THIS INTERNALLY PROVIDED COMMON SOLUTION?

First, they employ "threshold" type MOV suppression circuits which only react to impulse type transients, not the oscillating kinds, so up to 80% of all transient activity is not probably not adequately addressed.

Secondly, these MOV devices are usually mounted on the same circuit board of the circuit they are protecting. Since there is a known reaction time, often nanoseconds or less, there is still a possibility that transient activity can still damage other circuit components before the on board device operates.

Thirdly, if the on board device becomes degraded or damaged due to transient activity which is inevitable, the customer is still faced with equipment downtime and repair, just to repair the SPD devices.

These MOV solutions are quite inexpensive and usually engineered to be effective for only a limited range of abnormal conditions and a limited time period (warranty). Problems outside this range (which varies from equipment to equipment) are expected to be handled by external solutions. Since MOV devices are only going to react to impulse transients above a preset threshold, generally twice the expected RMS normal operating voltage, there is still a lot of transient activity that is going to get past.

Only SWT type SPD circuits are going to be able to address transient activity that falls below the normal threshold device turn on point. But, the cost of a SWT circuit to be provided internally is economically hard to justify for an equipment manufacturer. And, of course, the spare parts and repair business can be quite lucrative for many equipment manufacturers or suppliers.

The use of sine wave tracking circuits employ very high quality capacitors in a "hybrid" circuit to begin to address transient activity deviating more than 2-3 Volts RMS from the normal give superior results in reducing internally generated ringing transients.

4. PROPER CONTROL OF TRANSIENT SURGE VOLTAGES

Complete alleviation of transient surges requires the addition of externally connected Surge Protection Devices (SPD) in a network approach. Larger energy threshold type devices at service entrances, medium energy threshold type devices at the main distribution panels to eliminate transients generated by motors, air conditioners, and lighting systems, and SPD's with SWT ability to handle ringing or oscillating transients at the final service panels feeding sensitive loads.

The IEEE Emerald Book (IEEE Std 1100-1999 page 337) makes specific recommendations as to the need for a minimum of two levels of suppression from the service entrance to the protected loads.

SPD's are generally "rated" by their Peak Surge Current capability, generally in the 10's to 100's of thousands of amps per phase or mode. It is interesting to note that the Peak Surge Current rating is a measurement of the internal capability of the SPD to conduct a high current under certain short test conditions, While this is certainly acceptable as a method to specify what size units should be placed at what locations, it is not an indication of how good the SPD is actually going to perform in limiting the transients going to a load. In simple terms, simply specifying that a SPD with 100kA peak surge current shall be added to the service entrance panel is not enough, it is possible to do this without protecting the customer loads from transients. The most important characteristic of a SPD should be the Measured Limiting Voltage, or the residual voltage that will not be "trapped" by the device under normal installed conditions.

SPD equipment can be connected to load circuit in two ways, parallel and series. Parallel SPD devices do not conduct load current, instead, they remain "on standby" only reacting to transients as their respective threshold of sensitivity is reached.

Parallel devices can contain either threshold circuitry or a combination of threshold and SWT circuitry. In the implementation of parallel type devices, SPD size, circuit design, and installation play the key role in actual performance. Because of the nature of fast rise time current pulses in impulse transients, there is going to be a voltage drop across the wires from the load circuit being protected and the actual SPD components. This serves to "de-rate" the actual voltage limiting performance of the device. Worse, due to a lack of reporting and testing standards, it is very difficult to assess from a SPD specification sheet what the actual MLV will be for any particular device even under "laboratory" conditions. The voltage drop across the connecting wires can be calculated to be about 10 Volts per inch (consider the complete return path distance) on a typical 8 x 20 µSec impulse wave.

In practical terms, simply moving the SPD device back 6 extra inches from the load circuit connection can let an additional 120 Volts past the device during operation while an impulse transient happens. So, it is possible if not easy to render a parallel device completely ineffective by poor design, i.e. a large cabinet enclosure for the SPD or by poor installation in the field.

Parallel devices can be quite economical as one device can conceivably protect many pieces of equipment. They must include an approved disconnect method to remove them from the load circuit in the event of a failure. Typical MLV performance should limit transients to less than double the typical operating voltage for impulse transients and less than the threshold of disturbance (around 100 Volts) for ringing transients.

Series connected SPD's conduct load current, so it is possible to also include some inductive filtering, SWT circuitry, as well as the standard threshold components. So it can be said that series SPD devices will always perform better than their parallel counterparts because of a fixed lead length installation and additional components that can be provided. Series units are generally limited to single phase, lower current applications. Since virtually all sensitive electronic and microprocessor equipment is low current, single phase, this make series models very attractive for the last layer of protection in a multi-layered approach. If upstream parallel SPD equipment is properly installed, one should not need to be concerned with the failure of the downstream series devices which might remove power to the protected load should they fail.

When evaluating series devices, what is important is to study the relative MLV performance for ring wave type transients of lower energy. Typical performance should limit ringing transients to less than 100 Volts to be considered effective. The real test of a SWT circuit is to use a measurement at 180° on the sine wave and see if the STW circuit can limit the peak of the transient to below the peak of the sine wave. Independent evaluation of several "advertised" SWT models have shown no better performance than could be expected with a threshold circuit. There are however, models that can actually perform quite well in eliminating both impulse and ringing transients in one design, both parallel and series types.

5. SPD EQUIPMENT DOES NOT ADDRESS POWER DIPS

In heavier industrial locations, power dips may cause a number of unexplained malfunctions of sensitive equipment that may mimic the effect of surges. Many operations now use solid state switching for even heavy loads, and the resultant dips and spikes that occur may cause the misoperation of circuits that are using "zero crossing" techniques. The problem is that the dips or surges may cause false zero crossing points that are out of sync with the power supply. Ferroresonant transformers may be necessary to control this type of activity.

6. WHAT ADDITIONAL FEATURES MAY BE DESIRABLE IN A SPD?

In evaluating the purpose for an SPD, it becomes quickly evident that the only purpose of the device is to limit potentially disturbing or damaging transient voltages from affecting system loads. Therefore, any extra features that go beyond this should have questionable benefit. For example, surge counters and additional circuitry diagnostics. Surge counters were developed as a marketing "toy" to make it easy for non-technical managers to recognize the need for SPD equipment. Having once established that an electrical system does have transients present, the additional data of knowing how many occur becomes redundant if steps are taken to adequately and permanently limit them. Unfortunately, many end users may be more affected by the "bells and whistles" than they are by the real purpose of the device, but one needs to simply ask, how much better will the SPD devices operate (in limiting transients) by having this additional feature? After all, SPD equipment should be "install it and forget it" in nature and the novelty of a surge counter quickly grows thin.

It may be desirable to remotely monitor the SPD to insure that it is "on line" and functional, especially in locations that are remote, hard to monitor visually or unmanned.

7. CONCLUSION

As markets mature, more and more manufacturer's jump in on the bandwagon to provide equipment to a consumer market. One result is a proliferation of "look alike" or "act alike" products. Engineers and users should look for certificates like Underwriters Laboratories, to insure that they are getting

SPD equipment that has been subjected to rigorous failure testing. SPD equipment is designed to deal with abnormal electrical conditions. These abnormal conditions can be dangerous to both life and property. SPD failures have been reported to be catastrophic if not life threatening in nature. Locally produced copies of well established products do not offer the margin of safety that should be required, no matter what the financial savings.

When evaluating external SPD requirements, consider every piece of equipment in a customer location as to both its susceptibility to damage from surges, as well as it's ability to generate or even amplify surge internal activity.

More and more standards are being devised by both the IEEE and the IEC in relation to the application and use of SPD equipment and manufacture. Recently, the emphasis is shifting to more failure mode testing and demands that manufacturer's SPD devices that fail do not show any evidence of catastrophic failure beyond some simple indicator, that is, no deformation, heat, smoke or fire.

There are also movements to specify the use of individual fusing on each MOV within an SPD. There are still large gaps between the different standardization bodies in this regard, but one can expect a merging of standards as time goes forth.

IEEE C62.41 - 1991 Paragraph 2.2.7 "The cost of surge protection can be small, compared to overall system cost and benefits in performance. Therefore, added quality and performance in surge protection may be chosen as a conservative engineering approach to compensate for unknown variables in the other parameters. This approach can provide excellent performance in the best interest of the user, while not significantly affecting overall system cost."

Paper No. 6

ACTIVE FILTERS: AN INNOVATIVE AND POWERFUL SOLUTION TO TACKLE NEW POWER QUALITY CHALLENGES

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ACTIVE FILTERS: AN INNOVATIVE AND POWERFUL SOLUTION TO TACKLE NEW POWER QUALITY CHALLENGES

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ABSTRACT

The issue of harmonics has since a long time played a special role in the quest for good power quality. However, with the intensive use of non-linear loads in modern electrical installation and the advent of electricity markets deregulation, filtering the harmonics from the power systems is taking a new dimension. Innovative filtering solutions, better adapted to this new environment, are needed.

The latest power electronics technology has allowed the development of such a revolutionary solution: the active filter.

After presenting the traditional approach to the issue of harmonics and the solutions of today, this paper describes the need for a new and better technology for harmonic filtering. It then shows the level of performance that can be obtained with active filters using PWM switching technology together with modern IGBT's and Digital Signal Processors and how well it is adapted to tomorrow's power quality challenges.

Potential further evolution of this technology is also discussed.

Practical applications of this solution to residential and commercial buildings are finally presented.

1. INTRODUCTION

The issue of harmonics has since a long time played a special role in the quest for good power quality. Practical and efficient means to eliminate harmonics have been lacking and the engineer has been left with the sometimes almost mystical behavior of the common solution: the installation of a tuned passive filter.

Good technical solutions may be obtained by passive filters when dimensioned correctly, but a few characteristic weaknesses of the concept of passive filters do often cause trouble in practice; either immediately or after some time. The key weakness of the passive filter is that its function is dependent upon the network where it is installed and then also dependent upon changes in this network.

Since some time it has been possible to deal with harmonics in a fundamentally new way through active filtering technology. Better and more cost-efficient power semiconductors, especially IGBT's, have permitted this, but equally important has been the plunge in the cost of performing advanced calculations implementing complex control algorithms in real-time.

The need for a new and better technology for harmonic filtering is described in this paper and it is shown how this need is satisfied by active filtering. General characteristics of active filters are described and cases are discussed where the advantages of active filtering is illustrated.

We will deal with applications for low voltage networks in the present text, but much of the content may be generalized to networks at higher voltage levels than the here typical 380 to 690 Volts.

2. HARMONICS AND THE SOLUTIONS OF TODAY

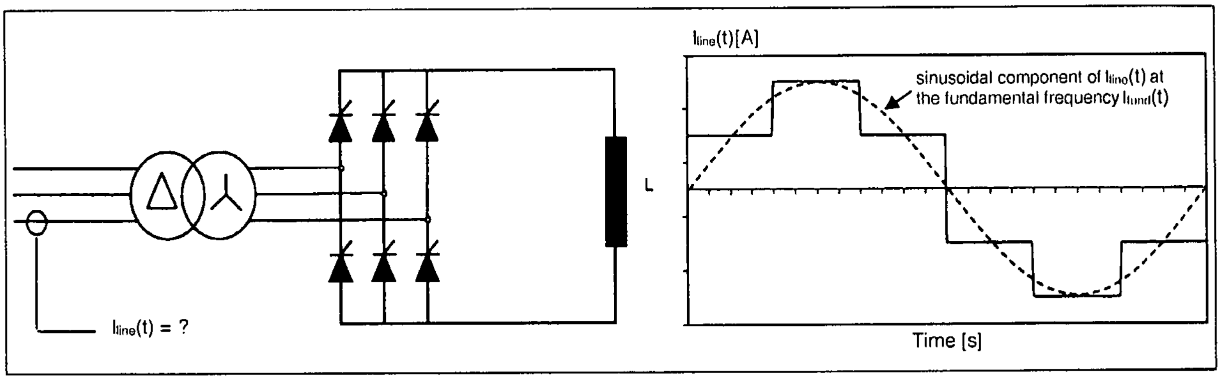
2.1. ORIGIN AND CONSEQUENCES OF HARMONICS

Power system generators normally produce a clean sinusoidal waveform at their terminals. However, more and more types of loads absorb non-sinusoidal current from the power system. A typical distorted current ($I_{line}(t)$) drawn by a six-pulse thyristor bridge is shown in Figure 1.

of the harmonic components is expressed as a percentage of the magnitude of the fundamental component. The horizontal axis shows generally the harmonic order, which is given by the ratio of the harmonic frequency over the fundamental frequency.

Loads causing current waveform deviation from the clean sinusoidal case, i.e. loads generating harmonics, are named 'non-linear' loads: there is no linear relationship between the current response to a voltage source.

Fig. 1 Non-sinusoidal Current Drawn by a Six-pulse Thyristor Bridge



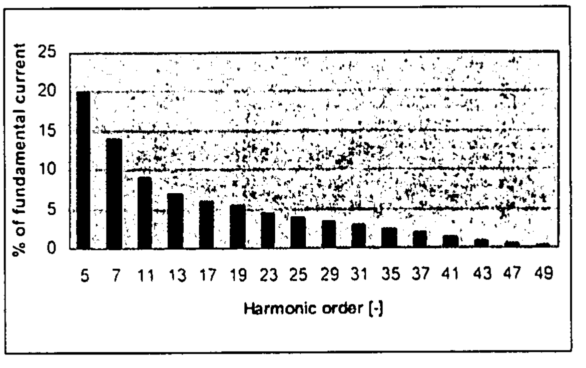
The strongly distorted current $I_{line}(t)$ may in fact be seen as the combination of sinusoidal current components, known as 'harmonics', superposed to the sinusoidal current waveform $I_{fund}(t)$ at the fundamental frequency.

Those harmonics exist at frequencies which are integer multiples of the fundamental frequency.

Instead of representing the distortion effect of the load by the resulting current waveform, it is considered that the load draws from the power system generator a clean sinusoidal current at the fundamental frequency and injects harmonic components into the supply system.

It is common to represent the harmonics injected by a load by means of the current spectrum. This spectrum shows for each harmonic frequency the magnitude of the corresponding harmonic component present in the current analysed. Possibly, the magnitude

Fig. 2 Example of Harmonic Current Spectrum



Typical non-linear loads are:

- Power electronic equipment: AC or DC drives, UPS's, welders, PC's, printers, lifts or air-conditioners with drives. In general, the semiconductor switches in this equipment conduct only during a fraction of the fundamental period. This is how such equipment can obtain their main properties regarding energy saving, dynamic performance and flexibility of control.

However, as a result a discontinuous current containing a considerable amount of distortion is drawn from the supply.

- Various types of lighting.

Harmonic pollution causes a number of problems. A first effect is the increase of the RMS-value and the peak-value of the distorted waveform. This is illustrated in Figure 3 that shows the increase of these values as more harmonic components are added to an initially undistorted waveform. The RMS-value and the peak-value of the undistorted waveform are defined as 100 %. The peaks of the fundamental component and the distortion components are assumed to be aligned. It may be seen that the distorted waveform, which contains harmonics up to the 49th harmonic, has a peak value that is twice the value of the undistorted waveform and a RMS-value that is 10 % higher.

electronic equipment may be damaged. Equipment, which uses the supply voltage as a reference may not be able to synchronise properly and either applies wrong firing, pulses to switching elements or switch off. Interference with electronic communications equipment may occur.

Distorted networks may also cause generators to malfunction.

Overall it may be concluded that an excessive amount of harmonics leads to malfunctions and premature ageing of the electrical installation.

2.2 THE SOLUTIONS OF TODAY

Traditionally the issue of harmonics has been treated as a local issue for each installation and the need for a solution was only evaluated on the basis of qualitative measures such as the

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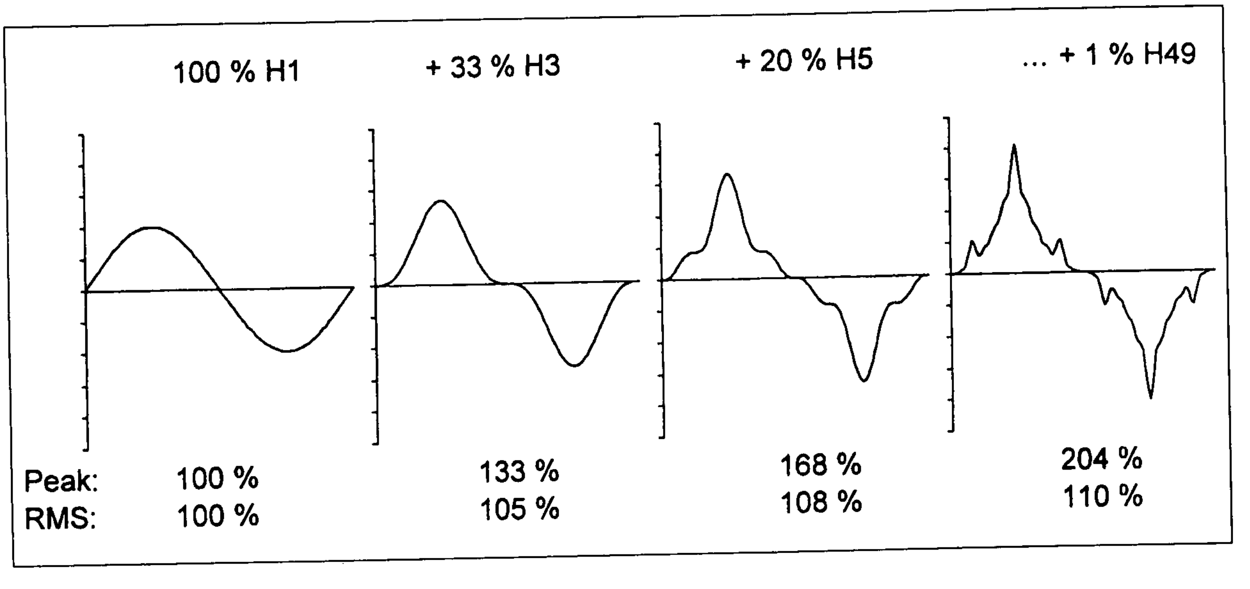
Fig. 3 Evolution of the Increase in Peak-value and the RMS-value of a Waveform as More Harmonic Components are Added



The increase in RMS-value leads to increased heating of the electrical equipment. Furthermore, circuit breakers may trip due to higher thermal or instantaneous levels. Also, fuses may blow and capacitors may be damaged. Energy meters may give faulty readings. The winding and iron losses of motors increase and they may experience perturbing torques on the shaft. Sensitive

appearance or expected appearance of operational problems.

Also, the only solution so far has been the installation of passive filters.

When harmonic levels are not too high it is feasible to achieve sufficient filtering by so-called de-tuned power factor correction banks, equipment principally intended to provide reactive power. Whenever feasible this solution is both cost-efficient and reliable.

When harmonic levels are too high for a de-tuned solution, then fine-tuned filters have been used and sometimes in combination with high-pass filters. The principle is very simple. Harmonic currents generated by, for example, a frequency converter is shunted by a filter-link designed to have a low impedance at a given frequency compared to the rest of the network. The impedance of the filter is given by its series connected capacitor- and reactor-components. More complex combinations of capacitive, inductive and resistive components used for filters for higher voltages are not common for low voltage applications.

Figure 4 illustrates schematically the described function with a harmonic generator, an impedance representing all other loads, a filter and a network. The equivalent circuit seen from the harmonic generator modeled as a harmonic current generator is shown in Figure 5. Here is included a medium voltage network in the model and some voltage distortion is included as a harmonic voltage generator.

Fig. 4 Passive Filtering of Harmonics

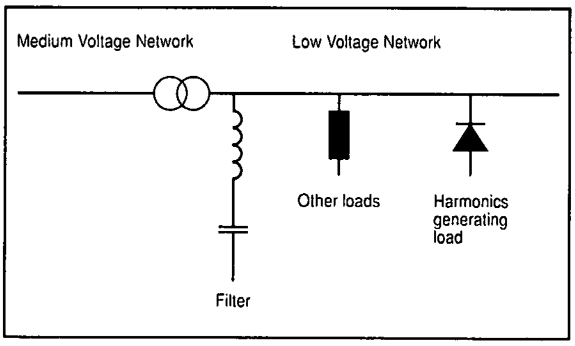
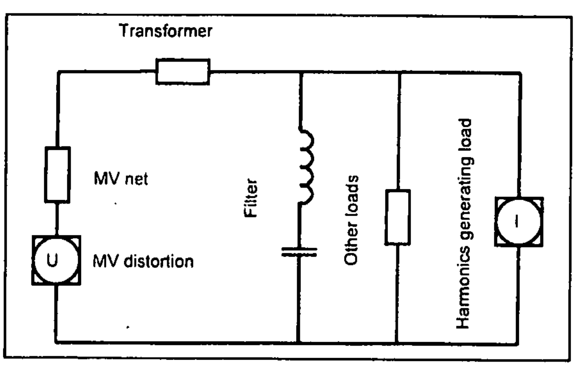


Fig. 5 Equivalent Circuit for Passive Harmonic



By studying Figures 4 and 5 we may immediately draw a few conclusions:

1. A filter branch may only filter one harmonic component. A separate filter branch is required for each harmonic that needs to be filtered.
2. The degree of filtering is given by its impedance in relation to all other impedances in the network. The degree of filtering will therefore vary together with the variations of the network impedance.
3. The harmonic current absorbed by the filter is not controlled, but is the result of the impedances, the generated harmonic current and any harmonic distortion originating from the feeding network.

Less obvious from a rapid study of these figures, although quite typical is that the filter generates reactive power.

In practice all this means that the network characteristics need to be well known to allow for a correct dimensioning of the passive filter. More important: all later changes in the network result in changes in the behavior of the filter. A new converter, a new neighboring factory or changes in the utility network may all be sufficient to overload the filter.

As long as such changes are known it is in principle possible to modify the filter for the new situation, but in practice this is usually difficult.

3. NEW NEEDS FOR HARMONIC FILTERING

Recent developments in electric power systems have accentuated the weaknesses of passive filters and led to new harmonic filtering requirements.

Previously, the reactive power generation of the passive filter was not really any disadvantage, since the need for filtering was always accompanied by a need for reactive power compensation. Nowadays this is not always true. Common AC motor drives are today built with diode front-ends and consume only small amounts of reactive power. Trying to filter the harmonics with reactive power generating passive filters then rapidly leads to overcompensation

But the link between reactive power generation and filtering is already in the general case somewhat of a control problem, since their relation vary in dynamic duty. If filters are switched based on reactive power demand, then the harmonics may overload the filter. If the switching strategy is based on harmonic loading, then the reactive power compensation may become incorrect.

Concerned by the slow but continuous annual growth of network harmonics level (this could reach 150% of the IEC voltage planning level by 2010 [1]), Utilities are taking specific actions to counteract this trend. Standards limiting harmonic current injection in public networks exist in many countries and their application is becoming more common and stricter.

The harmonics issue has become more than a local issue for each installation and is important in the relations between the power consumer and the supplier. Absolute levels of harmonic injection imposed by the supplier confronts the customer and user to a new situation where the absolute degree of filtering becomes more important than previously when more qualitative measures such as the lack of operational problems could be used.

Deregulation of electricity markets is also fostering this evolution.

In terms of harmonic filter performance, this new environment has creates new needs, that could be translated as follows:

1. Not possible to overload
2. Easy to extend and modify
3. Degree of filtering independent of the network
4. No link between filtering and reactive power generation
5. Adjustable degree of filtering
6. Choice of which harmonic components to filter

The needs define an ideal filter and the passive filter is once forever not suitable to fulfil the requirements.

However, we will see that the active filter comes very close to this ideal filter.

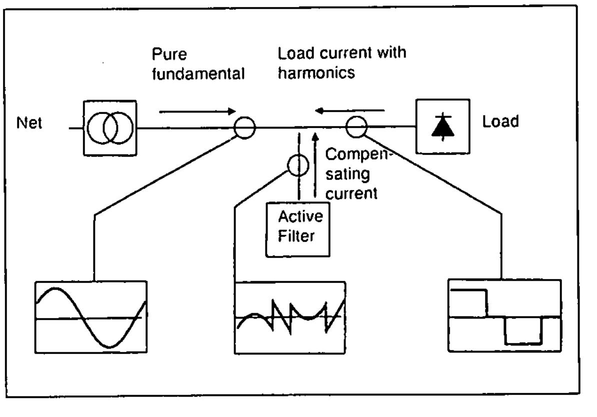
4. AN INNOVATIVE AND POWERFUL SOLUTION: THE ACTIVE FILTER

4.1 HOW THE ACTIVE FILTER WORKS

The principle of the active filter is fundamentally different from the passive filter. We have seen that the passive filter is not controlled and that the filtering is a result of the impedance characteristics. The active filter does instead measure the harmonic currents and generates actively a harmonic current spectrum in opposite phase to the measured distorting harmonic current. The original harmonics are thereby cancelled.

The principle is shown in Figure 6.

Fig. 6 The Principle of the Active Filter



The control of the active filter in combination with the active generation of the compensating harmonic currents allows for a concept that may not be overloaded. Harmonic currents

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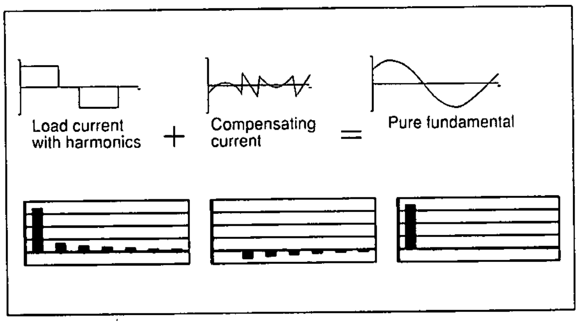
exceeding the capacity of the filter will remain on the network, but the filter will operate and eliminate all harmonic current up to its capacity.

The principle of the active filter showing currents and spectra is clarified in Figure 7.

Fig. 7 Active Filter Principle Illustrated in the Time and Frequency Domains



To control the active filter the choice stands between open loop and closed loop current control. Figure 8 shows open loop current control. The harmonic currents are measured on the load side of the active filter that computes the required compensating current and injects it into the network.

Closed loop current control is shown in Figure 9. In this topology the resulting current to the network is measured and the active filter operates by injecting a compensating current minimizing this resulting current.

The open loop control system is easier to implement, but performs with less efficiency in spite of requiring higher-class current sensors. In addition to being more precise, the closed loop control system also allows for a direct control of the degree of filtering.

An active filter may also be controlled to an ideal voltage, but this strategy is more suitable for applications at higher voltage levels under the responsibility of the network operator than for the individual client. With current control, filtering of the local load or a part of the network is achieved. Voltage control deals with the whole network and the filter power has to be sized accordingly.

Fig. 8 Open Loop Current Control

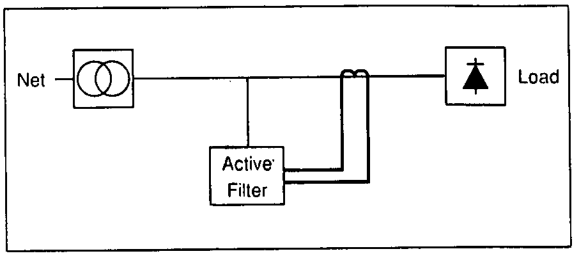
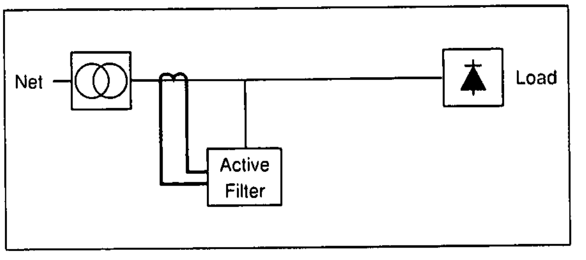


Fig. 9 Closed Loop Current Control



4.2 THE COMPENSATING CURRENT GENERATOR

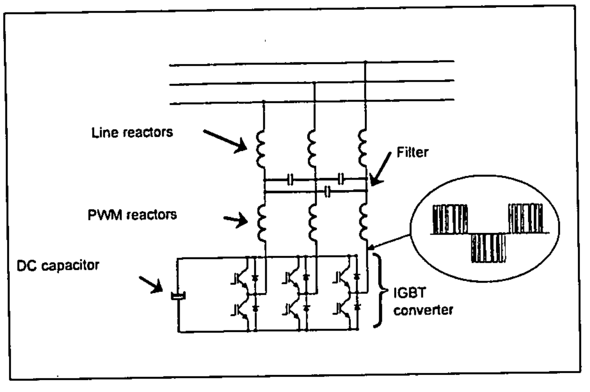
The current generator and the control system are the two most important parts of an active filter. Different current generator topologies are possible and power semi-conductors such as MOSFET's and GTO's might be considered, but today the practical solution is always IGBT's for the discussed application.

The compensating current is in a first step created by a three-phase IGBT bridge that is able to generate any given voltage waveform with PWM (Pulse Width Modulation) technology. The IGBT bridge uses a DC voltage source realized in the form of a DC capacitor. The generated voltage is coupled to the network via reactors and a small filter circuit. A good approximation to the desired ideal current generator is achieved.

Figure 10 shows the main parts of this power circuit. It should be noted that the IGBT converter charges the DC capacitors simultaneously with its generation of the compensating current to the network. There is therefore no need for a separate power supply to charge the DC capacitor.

The capacity and performance of the active filter is determined by the choice of components and the execution of the power circuit. A higher switching frequency gives as an example the possibility to filter harmonics of higher orders.

Fig. 10 The Power Circuit of an Active Filter



4.3 THE CONTROL SYSTEM

An active filter may be controlled by a relatively simple analog or digitally analog simulated control algorithm. The measured distorted input signal may be compared to a reference signal with the difference signal used to control the power circuit.

It becomes, however, rapidly evident that the potential of active filtering can only be exploited to a very small extent with such simple control. Even such a basic function as overload control can not be handled well with analog control.

To fully exploit the potential of an active filter we need a digital measurement and control system that is fast enough to operate in true real time. We need to be able to track the individual harmonics and control the compensating current according to the requirements of the plant and this with full control at every instant in time. To achieve this, we need advanced Digital Signal Processors, DSP's.

With sufficient computational power it is possible to achieve performance and programmability in tune with the requirements of the individual application. Degree of filtering, choice of harmonics to filter, optional reactive power compensation are all examples of such programmable parameters.

Detailed knowledge about the network is not required to install an active filter and special engineering is not required either. A standard product is selected and is then easily programmed for the application.

Changes in the network or the addition of new loads will not cause failure of the well-designed active filter. It may be designed to function to its full capacity without being overloaded.

The functionalities of filtering and reactive power compensation are separated and independent. Only the size and total capacity of the active filter limits it.

When we compare our wish-list for the ideal filter with the actually available performance of an active filter we see that we come very close.

4.4 FUTURE DEVELOPMENTS

The explosion of the telecommunication industry is one of the key factors sustaining the continuous and rapid development of DSP technology. The active filter will directly benefit from those developments: increased calculation power and flexibility for even better performances and lower costs.

The considerable amount of investment in power electronics research will also further enhance the performances of the active filter. It will remain at the cutting edge of available technology.

But communication capability of the active filter is the area where most changes are expected to come.

On the short-term first, modern telecommunications tools will be integrated in the control system of the active filter and will allow a close monitoring of the unit by the service supplier, wherever it is located.

On-line programming, troubleshooting or performance assessment will become new service standards.

On the long term then, the revolution under way in the electricity generation business will lead to the emergence of 'micropower': the generation of electricity by small-scale fuel cells and gas turbines ([2], [3]).

Associated with information technology, those microgenerators will be able to monitor themselves, communicate with each other and they will constitute microgrids.

A new type of energy suppliers will appear: virtual utilities ([2], [4]). Those firms, by managing several microgenerators of different types and by integrating power quality equipment, will offer greater system reliability, lower operating costs, reduced environmental impact and improved overall business.

The active filter, with enhanced communication capabilities, will perfectly fit in this new framework.

Fig. 11 Electrical Diagram

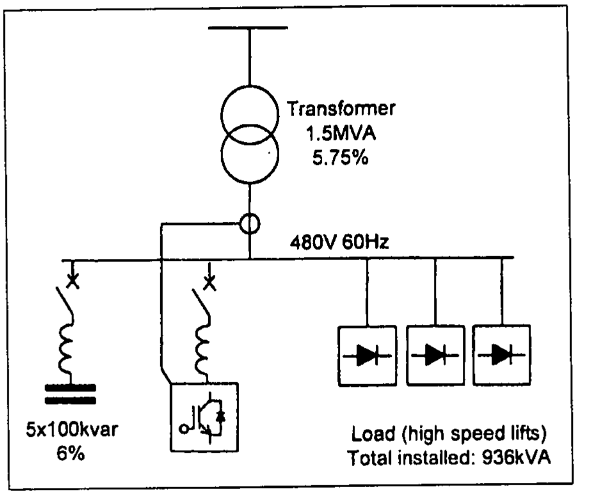


Fig. 12 Current Harmonic Spectrum

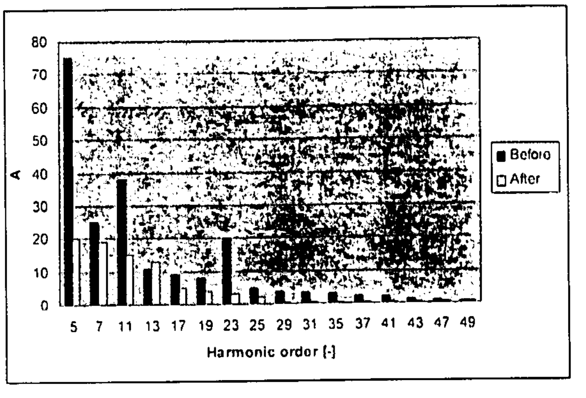


Figure 12 represents the harmonic spectrum before and after filtering. The efficiency and capability of filtering several harmonics simultaneously is demonstrated.

This example also shows the ability of the filter to follow dynamic loads.

5. PRACTICAL APPLICATIONS

5.1 COMMERCIAL BUILDING APPLICATION

In this first example, the application is a business center building of 41 floors. The high-speed lifts of the building are controlled by AC drives injecting a fairly big amount of harmonics in the network. The electrical diagram of the installation is shown in Figure 11.

An active filter, with closed loop control, was connected to the system.

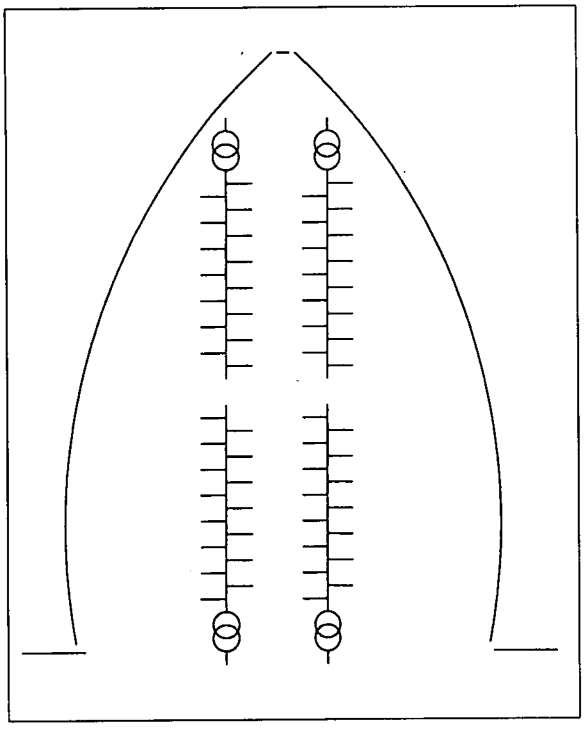
5.2 RESIDENTIAL APPLICATION

The second presented application takes place in a hotel building, one of the most luxurious and exclusive in the world.

All suites of this engineering marvel make extensive use of latest available technology to ensure the best possible level of service and comfort to their guests.

From the electrical point of view, the huge air-conditioning system, lifts and escalators are equipped with Variable Speed Drives and the whole suites lighting system only relies on dimmers.

Fig. 13 Representation of the Distribution Network



Power Quality, and in particular Harmonics, became then a major challenge in the design of the building: without adequate solution, the system would just no be able to be started.

The loads of the building are fed by 8 transformers located in the basement and upper floor.

A total of about 3 MVA of dimmers and 1.5 MVA of lifts and escalators are installed. Drives for the air-conditioning reach another 3 MVA.

A partial representation of the distribution network is given in Figure 13. Each transformer feeds a main busbar riser, which in turn feeds distribution boards located on the different levels.

Active filters have been installed on all transformers and have insured the proper operation of the whole system.

The harmonic spectrum, both current and voltage are given hereafter. The ability of the filter to filter several harmonics simultaneously results in a voltage THD reduction from 14% to less than 4%.

Fig.14 Harmonic Current Spectrum

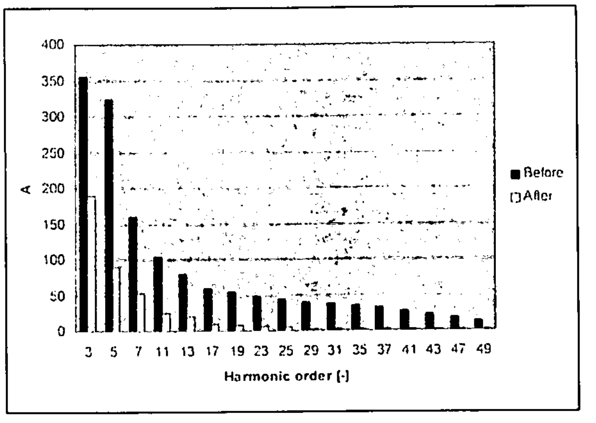
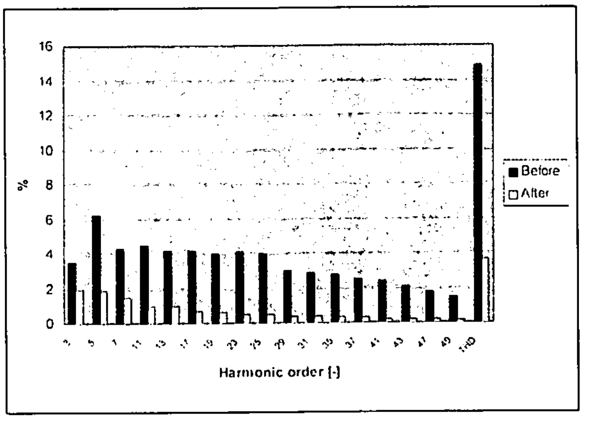


Fig.15 Harmonic Voltage Spectrum



6. CONCLUSION

After a brief introduction to the origin and consequences of harmonics on power systems, the traditional approach of the harmonic issue and the passive filter concept have been presented. The weaknesses of this solution have been enlightened, in particular the risk of overloading and the lack of controlled filtering and flexibility.

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With the evolution of power systems and the deregulation of electricity markets, harmonics filtering is taking a new dimension. On the basis of the requirements of this new environment, the characteristics of an ideal filter have been developed.

The innovative and powerful technology of active filters has then been studied and it has been demonstrated that they come particularly close to the ideal filter.

They are not only well adapted to new power quality challenges but offer a remarkable potential for longer-term developments. Combined with sophisticated telecommunication technology, active filters will play a major role in the electric revolution under way.

Finally some applications of the active filter to residential and commercial buildings have demonstrated the theory in practice.

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Paper No. 7

THE NEW ENERGY MANAGEMENT SYSTEM AND DISTRIBUTION MANAGEMENT SYSTEM

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ABSTRACT

The Hongkong Electric Co., Ltd. (HEC) commissioned its third generation Energy Management System (EMS) and Distribution Management System (DMS) in July 1999 to replace its previous SCADA and Distribution Computer systems commissioned in 1985. The previous systems were of the traditional dual-computer configuration and both had reached their capacity limits due to the rapid growth of HEC's power system and increased requirement in automation.

The new systems incorporate distributed open system architecture and many state of the art technologies in their design. This paper presents an overview of the two systems, the MMI conceived, the functionality of the systems with particular reference to the new and improved features.

1. INTRODUCTION

HEC supplies electricity to over 519,000 customers in Hong Kong and Lamma Island. Electric power generated in Lamma power station is transmitted to Hong Kong island by submarine circuits and distributed to customers via a number of switching stations, zone substations and over 3,300 distribution substations. Hongkong Electric is interconnected with CLP Power Hong Kong Ltd. since 1981.

HEC commissioned its new Siemens EMPOWER Spectrum EMS and DMS in July 1999 to replace its previous Hitachi SCADA and Distribution Computer Systems which had reached their capacity limits. The design of the new systems takes into accounts of operational needs and places special attention to human factors. The new EMS and DMS employ a Siemens EMPOWER Spectrum system with distributed open system architecture.

2. SYSTEM CONFIGURATION

The Siemens EMPOWER Spectrum incorporates a client/server open system architecture on a variety of industrial standard components, such as:

- Workstation with RISC technology
- POSIX-compliant UNIX operating system
- Ethernet LAN
- TCP/IP network communication
- X window system
- OSF/Motif full graphic user interface
- Relational Data Base Management (Oracle)

High computer performance is achieved by distributing the system tasks over multiple servers, allowing programs to operate in parallel to a large extent. Distributed Databases is also one of the major Spectrum feature. Spectrum uses multiple distributed databases to provide scalability to the system, and each component (relation) of these databases will be properly distributed to the appropriate servers according to their server type when they are being initialised.

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Fig. 1 System Overview

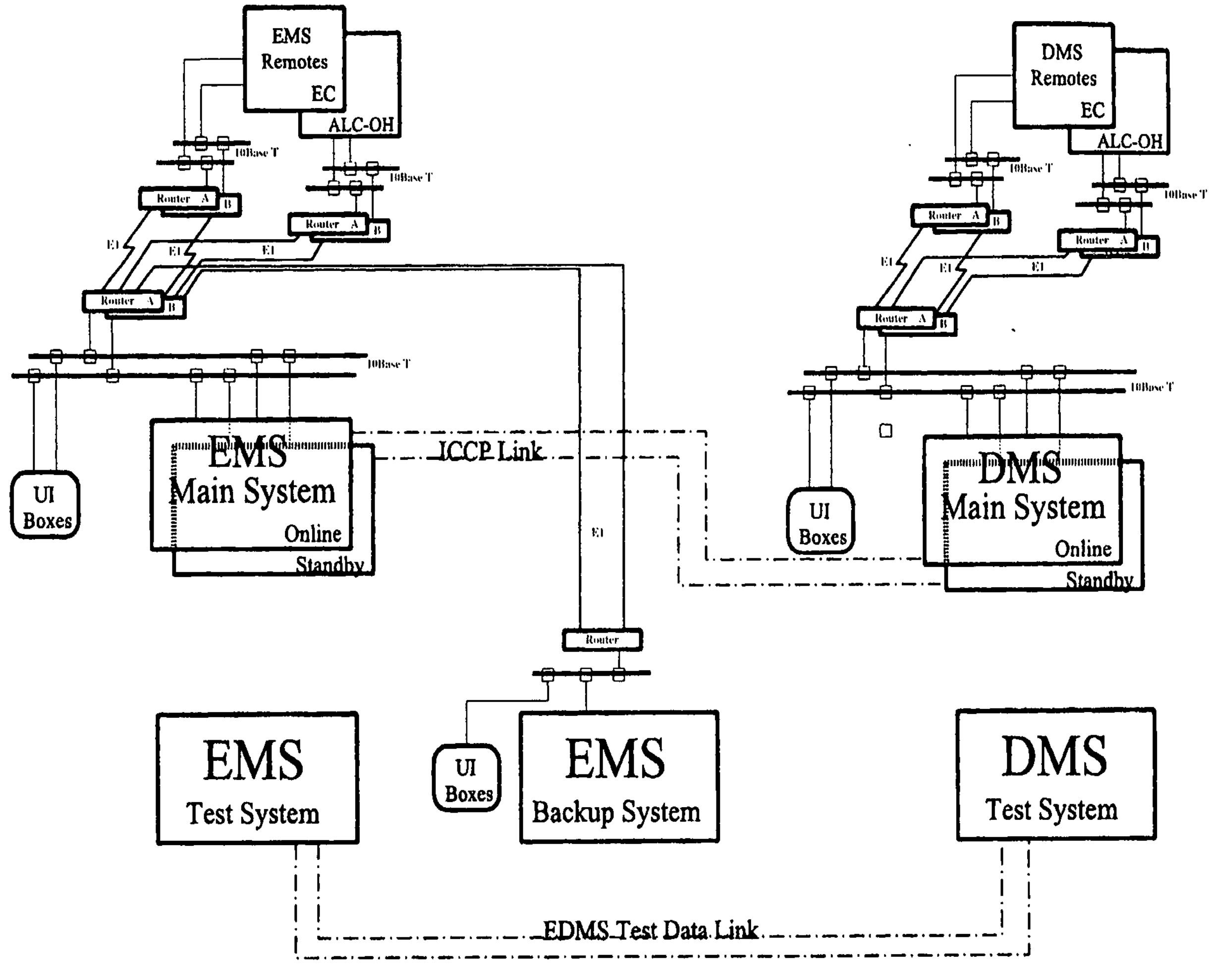

Figure 1 shows the installed system overview of the HEC EMS and DMS.

The design of the system is to provide 100% redundancy for both hardware and software, such that system availability is not affected by a single equipment failure. To meet this demand of high availability, all servers are connected via a Dual Ethernet Local Area Network (LANs) service, together with the Computer Network Management function, the status of all active processes is monitored and automatic failover to standby/spare LAN or servers would be triggered whenever necessary.

The following table provides a breakdown of the hardware system configuration.

Table 1 Hardware System Configuration

Server Type	Redundancy Method	Server Function
ADM	Spare	Data, graphics, database, and system administration. Programs maintenance and distribution.
COM	Hot-standby	Communication of all SCADA functionality.
RTDS	Share	Scanning, acquisition, and processing of RTUs data.
NAES	Spare	EMS Network Analysis Applications, both real time & study mode, and Expert System Applications.
GCS	Spare	Generation Control and Scheduling Applications
UCS	Hot-standby	Utility Communications (ICCP)
DMS	Spare	DMS Network Analysis Applications, both real time & study mode, and Expert System Applications.
MMI	Other MMIs	Man Machine Interface

The Spectrum system uses three modes of redundancy methods, they are:

1. The Spare mode of redundancy which triggers an event of failover when the primary server fails.
2. The Hot-standby mode of redundancy which ensures uninterrupted server operation. The hot-standby server is configured to run identical processes in parallel with its primary server. If the primary server fails, the hot-standby server will immediately be switched into the role of the server that failed.
3. The Share mode of redundancy, just like division of labour, allows functionality to be shared among partner servers. If one server fails, there is no failover, the loading of the failed server will be picked up by the other healthy servers.

All critical servers use either the hot-standby or share redundancy mode.

There is a test system installed for software and hardware testing. Listening service of real time telemetry system is set up for the test system such that close to real time testing condition can be simulated. The test system database is subjected to periodic synchronization from the main system.

3. SUBSYSTEM DESCRIPTION

The Subsystem configurations of EMS and DMS are almost identical except for the application subsystem and some external interface links. The following is a brief description of the subsystems.

3.1 ADMINISTRATION SUBSYSTEM

This consists of the ADM servers. It covers the following functions:

- Historical and future data
- RDBMS
- Database master and job management

EMS provides the following additional functions:

- Load forecast
- Interchange transaction scheduler
- Outage scheduler

3.2 DATA ACQUISITION SUBSYSTEM

This consists of the RTDS and COM servers. This subsystem handles all the real time functions including:

- RTU data acquisition
- Time/Frequency interface
- SCADA data processing
- Alarm processing
- Topology calculation and network colouring
- User interface to status and analogue data
- Logging
- Supervisory control

EMS provides the following additional functions:

- Load frequency control and economic dispatch
- Reserve monitoring
- Production cost monitoring
- Local fast I/O interface

3.3 APPLICATION SUBSYSTEM

In EMS, it consists of the NA and GCS servers and provides the following functions:

- Real time sequence control
- Model update
- State estimation
- Network parameter adaptation
- Security analysis
- Voltage scheduler
- Power flow

- Bus load forecast
- Unit commitment
- Transaction evaluation

In DMS, it consists of the DMS server and provides the following functions:

- Power flow
- Short circuit calculation
- Outage management analysis
- Fault location
- Switch order generation
- Parallel switching study

3.4 COMMUNICATION SUBSYSTEM

This consists of the UCS servers and provides ICCP and external interface links.

User Interface Subsystem

This consists of the UI servers and supports full graphic displays and system service interface.

4. IMPROVED FEATURES AND NEW FEATURES

Many new features and improvement to existing features are introduced in the new EMS and DMS. The following is a description of the major ones:

4.1 OPEN SYSTEM ARCHITECTURE

The previous system were closed and proprietary systems which did not allow extension and upgrading unless the original supplier designed and produced enhancement parts of larger capacities. This would be more time consuming and expensive compared with upgrading a system of open system architecture design.

4.2 MULTIPORT RTUS WITH MULTIPLE COMMUNICATION ROUTES

The communication routes run along different physical paths connecting different ports of the RTUs to the EMS and DMS (main systems) located in the main Control Centre and those (backup systems) in the Backup Control Centre. This separate physical path configuration enhances the security of the routes. In addition, by selecting the ports connecting to the main systems or the ports connecting to the backup systems to be the control master through a RTU manipulating MMI, control changeover between the main and the backup systems is easy and efficient.

4.3 FULL GRAPHIC USER INTERFACE, AUTOMATIC TOPOLOGY CALCULATION AND NETWORK COLOURING

The systems support full graphic user interface (GUI). It continuously monitors the state of the switches and breakers captured by the Data Acquisition Subsystem and the tagging applied by the operator. From these information, it automatically computes and assigns states (voltage level, dead or earth) to the network topology elements and presents it to the operators via different network colouring. For example, orange for 275kV voltage level, cyan for 132kV, green for dead equipment and greyish green for earthed up apparatus. This gives the operator a very easily comprehensible network presentation and improves operating accuracy and efficiency.

4.4 DISTURBANCE DATA COLLECTION

This feature allows automatic data collection for various pre-defined system disturbance for post fault analysis as well as scenario re-creation in the Operator Training Simulator (not yet commissioned), thus providing hands-on training of realistic system disturbance for all operators.

4.5 PRE-SWITCHING AND TAGGING INTERLOCK CHECKS

The support staff create and maintain switching and interlock logic tables which are stored in the systems. Logic checks can be defined as 'worldwide' for all equipment in the power system, or as 'local' for a group of equipment, or as 'specific' for any particular apparatus.

When the operator initiates a switching or tagging operation, the logic check automatically kicks off. It then alerts the operator of any violation such as making dead an equipment, energising an earthed up apparatus etc. Thus supply security and safety is much enhanced.

4.6 MESSAGE RESTORATION

This feature allows and/or-not filtering capability. With this feature, system and operating messages of particular interest in a certain time interval can be retrieved by specifying the necessary text input. Obviously this is a valuable tool for any type of investigation.

4.7 VISUAL DISPLAY SYSTEM

There are two visual display systems in the main Control Centre, one for the EMS and one for the DMS. The display systems are in fact arrays of rear-project visual display units. The operators can select via the wallboard handling MMI different displays to be projected in the display systems. These displays give the operator an overview of the power system. Pre-defined displays will also be projected automatically in the display systems under system disturbances.

4.8 MULTIPLE DATABASE JOBS

Several database change jobs can be prepared at the same time and then activated individually. This capability allows database change job to be prepared in advance by planning staff and only activated when the corresponding network is changed. This feature minimizes the network discrepancies without the need of extra manpower.

4.9 GROUP SWITCHING

This is a specifically designed module. It allows the operator to do switching of a pre-defined group of switches with one control action via a group switching MMI. There are about 20 switches which need routine switching on and off once every day. This feature reduces manual handling and human errors.

4.10 UNDERFREQUENCY LOADSHED SUMMARY AND RESTORATION

This module relates any underfrequency stage relay operation alarm with the corresponding Zone Substation tripping and compares the identity of the breakers tripped with the breaker database of that particular underfrequency stage. All breakers not belonging to that stage but tripped will be reported in the abnormal trip summary. All breakers which tripped correctly will be automatically closed to restore load when system condition allows the operator to activate the automatic load restoration function via the load restoration MMI for that particular stage. Therefore the operator doesn't need to close the breakers one by one manually. This enables an efficient load restoration process after an underfrequency loadshedding incident.

4.11 SOPHISTICATED NETWORK APPLICATION

The Network Application subsystem consists of various sub-functions including Real Time Sequence, Model Update, State Estimation, Network Parameter Adaptation, Network Sensitivity, Security Analysis, Voltage Scheduler, Fault Calculation and Dispatcher Power Flow. Every sub-function requires a lot of calculation. However, with the high performance servers, Real Time Sequence which is configured as a sequence from model update through to security analysis can be completed in less than 2 minutes. Now it is configured to run at 15 minutes interval because of the quasi-static nature of the power system although it can be run more frequently.

Moreover, the Network Application subsystem supports multi-user environment. Different users can have simultaneous access to the function to create and save study cases.

5. CONCLUSIONS

The new EMS and DMS of The Hongkong Electric Company Limited incorporate many state-of-the art technologies. They use a client/server distributed open system architecture.

High performance is achieved by distributing system tasks over multiple servers. The systems provide 100% redundancy for both hardware and software. The hot stand-by mode of redundancy ensures uninterrupted server operation and therefore a high system availability is achieved.

Besides the high performance and availability, the systems are also characterised by their new features and the improvement based on the existing functions.

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Paper No. 8

KNOWLEDGE MANAGEMENT FOR POWER SYSTEMS APPLICATION

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ABSTRACT

In the present world of knowledge-based economy, presentation of the right data for timely decision is a key success factor to cope with dynamic and complex changes. The purpose of the Knowledge Management (KM) is to help organization better create new knowledge assets, leverage existing knowledge assets, manage the development and profitable exploitation of its knowledge assets.

The paper describes the knowledge development process from awareness to implementation. Some specific applications in power systems will also be highlighted. These include, for example, enhancing productivity through efficient occupational knowledge transfer, mitigation of operations risks through incident recall and decision system. In CLP Power, the existing Operation Integrity Management System can be utilised as the framework for KM development. The three basic components for KM: People, Content and Technology are further examined in this paper. Knowledge Management is a new discipline of enabling individuals, teams and entire organizations to collectively and systematically create, share and apply knowledge, to better achieve the business objectives.

1. INTRODUCTION

Knowledge Management (KM) is defined as processes to create, capture and leverage knowledge so as to enhance company value and improve performance. The purpose of KM is to enable companies to capture, apply and create value from their employee's creativity and expertise. In short, it allows people to use knowledge of others by collaboration and experience sharing through specific knowledge infrastructure. KM allows the corporate intelligence to grow as knowledge, which is constantly created and renewed, is essential for companies to survive and succeed in today's highly competitive business environment. Knowledge grows when it is shared and knowledge deteriorates when it is not used.

In the last decade, companies applied various management tools to improve their business performance. These management tools included: Business Process Re-engineering (BPR), Total Quality Management (TQM), Scenario Planning and Knowledge Management.

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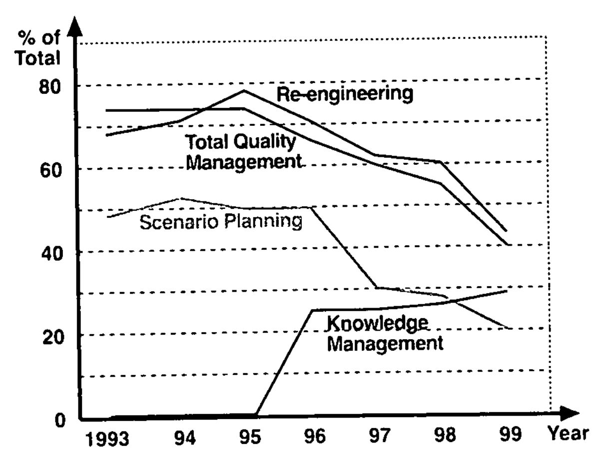
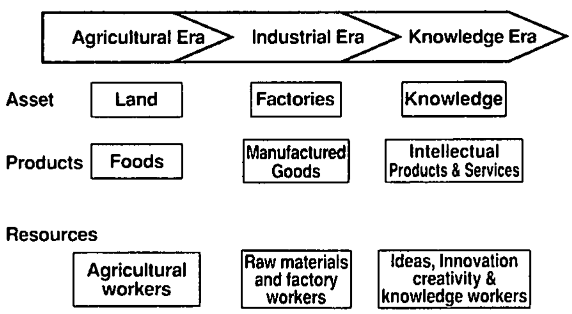
Fig. 1 Management Tools adopted by North American companies



As shown in Fig. 1 for a group of companies in North American, BPR and TQM bloomed in early nineties and have slowed down in the past few years. On the other hand, KM has increased during the past few years and some companies have also adopted in a high profile with senior executive posts created to take charge of KM development and implementation. It is interesting to note that even some companies not taking KM initiatives explicitly, systematic information sharing approach has been placed as a high priority.

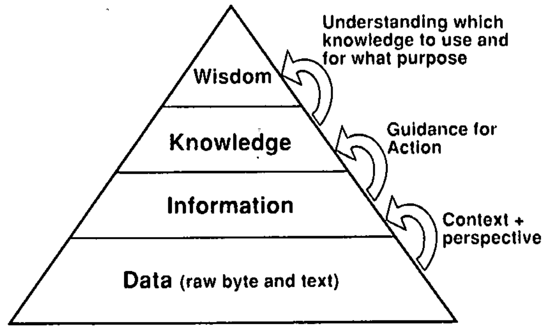
In today's knowledge based economy, knowledge is an important asset and a high portion of the work force in the society is under the category of knowledge workers. In fact, the knowledge era has arrived as compared with the previous agricultural or industrial eras as shown in Fig. 2. The agricultural workers produce foods and factory workers produce manufactured goods. The assets associated are land and factories respectively. In the knowledge era, the knowledge workers produce intellectual products and services with knowledge as the major asset. To a large extent, the knowledge asset is intangible. The main resources available in knowledge era include ideas, innovations, and creativity of knowledge workers.

Fig. 2 Development to Knowledge Era from Agricultural or Industrial Eras



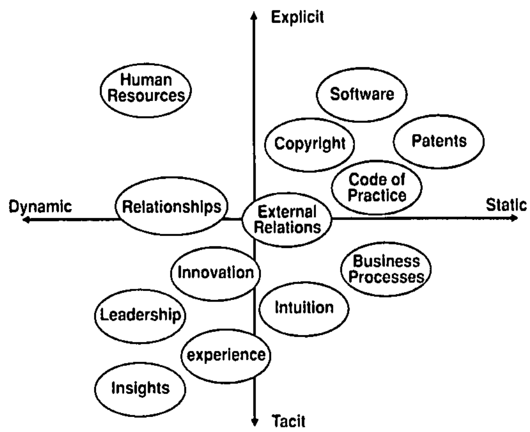
From the hierarchical structure point of view of knowledge, it can be divided into four levels: Data, Information, Knowledge and Wisdom as shown in Fig.3. Data is the raw form of facts. After manipulating, it is transformed as information. Based on the information, guidance for action and hence capabilities can be developed to formulate knowledge. Understanding which knowledge to use and for what purpose is the wisdom.

Fig. 3 Hierarchy of Knowledge



2. APPROACHES IN KM

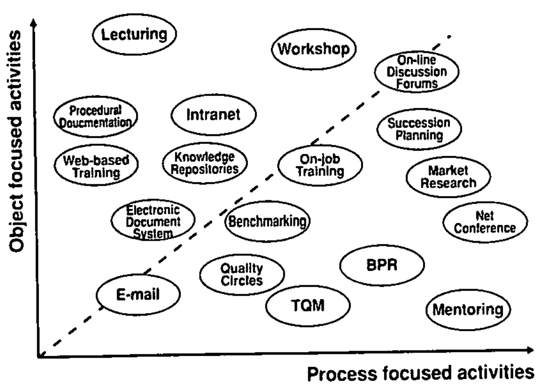
Fig. 4 Explicit and Tacit Knowledge



Knowledge can broadly be classified into two types: explicit and tacit. Explicit knowledge that can be easily codified and conveyed to others includes for instance, documentation files, database and drawings. On the other hand, personal knowledge embedded in individual experiences is difficult to capture, for example, experience and know-how based on instincts, insights. Hence, tacit knowledge depends on tapping from insights, intuitions and ideals of employees, which is indispensable for continuous innovation.

There are two major approaches to KM, namely the Object Focused Approach and the Process Focused Approach. The Object Focused Approach treats knowledge as an object that can be translated, documented, stored, retrieved and shared. The benefits from this object approach are efficiency, standardisation and tighter control on information. Information Technology (IT) can be extensively applied to this approach to enhance the effectiveness of the KM process. On the other hand, the Process Focused Approach treats KM as system, culture and environment which can facilitate knowledge growth. Major benefits are realised through innovation, market development and business competitiveness. Self-assessment of knowledge asset processed by the company; external and customer assessment through benchmarking and survey are phenomenal in this approach. Both the object and process approaches in KM can be implemented with or without sophisticated information technology systems, but such IT systems can often enhance the power and efficiency of the KM.

Fig. 5 Object and Process Focused Activities



3. FROM DATA, INFORMATION TO KNOWLEDGE

3.1 PROTECTION REMOTE INFORMATION AND DATA EVALUATION SYSTEM

One major application of the object focused KM system is to extract useful information from a large quantity of raw data, and transformation of useful information to knowledge and decision making tools. Example of this can be illustrated by the Protection Remote Information and Data Evaluation System (PRIDES) adopted by CLP Power for the analysis of power system disturbances. Enormous amount of data are generated by the various fault monitoring and protection devices in the power system during a system fault condition. Interpretation of the data and coming up with an operation decision associated with protection system is a task demanding a high interpretation skills based on past experiences of a Protection Engineer.

The PRIDES is developed to provide centralised control and information retrieval of the remote system monitoring devices. The PRIDES includes a process control server (PRIDES Server) and number of application programs. These applications are all built on the Intranet platform and they can be easily accessed through common Internet Browser programs.

Sequence of Events (SOE) Recording is a time-tagged event-logging device. It can record the events that have occurred in a substation. Subsequent to a system disturbance or fault, the operation of a high speed protection relay and the subsequent operation of circuit breaker operation are recorded. The SOE is a useful information to re-construct the sequence of a system disturbance or fault, and through this information, any deficiency in the protection system can be identify to determine if the operation of the protection relays is correct.

Digital Fault Recorder (DFR) is a device installed in a substation, connected with current and voltage signals from respective circuits, to capture the current and voltage transients under system disturbance. The captured waveforms from a DFR can help to determine the nature of a system disturbance.

If the sequence of descriptions indicates that there is an operation of main protection with a circuit breaker open event, the program will issue command to associated remote substations for retrieving disturbance fault recorder chart automatically. The retrieved recorder chart and the associated SOE descriptions will be automatically sent to the "Fault Analysis Result" page for reference.

Adoption of a set of alarm processing, fault diagnosis and operations decision systems make the laborious task much more manageable. Through the company intranet system, the information and operations decision can be used by the protection engineer and retrieved by other staff who need to act in the process.

A typical output report is shown in Fig. 6. This is a typical application from data acquisition to decision supports.

Fig. 6 Typical Output from the Analysis

Priority : Medium
Date : 2 February, 2000
Time : 02:20hr
Circuit : Black Point – Castle Peak No. 1
Protection Operated : Current Differential protection and Distance Protection

Fault clearance time : 102mS
Faulty phase : Red-Yellow.
Auto-reclose successful : YES
Distance-to-faulty calculation : 2.2km from Black Point Side
Fault summary : System fault correctly cleared

3.2 DISTRIBUTION MANAGEMENT SYSTEM FOR FAULT LOCATION, ISOLATION AND SERVICES RESTORATION

CLP Power has implemented a large-scale Distribution Management System (DMS) which will have 6000 RTUs installed in customer substations with one of the major purposes to reduce customer minute loss (CML) due to unplanned system outages. A software function for fault location, isolation and service restoration is developed. The objectives of this function are as follows:

- Locate a fault based on information from fault detectors and switch status changes
- Determine the sequence of actions to optimally isolate the fault by using remotely controlled devices (such as pole-mounted switches)
- Determine the switching order for transferring the non-faulted sections to other supply sources

The function executes after a change in connectivity which results in a loss of service to the customers. When there is a fault, it will automatically generate the recommended sequence of actions for the operator to isolate the fault and to restore loads.

This process is a kind of knowledge-based system where the decision can be explicitly stated in term of rules. In fact, in the initial stage of DMS operation, the above function will be in an advisory mode. When more experience is gained, and hence the knowledge derived, the function will be fully automatic.

4. EXTERNALISATION OF TACIT KNOWLEDGE

One major challenge in KM is how tacit knowledge can be extracted from human beings, and be made readily transferable to another person. This is not an easy task, and few IT systems can help. Special intellectual skills and methods on top of any IT are needed to capture tacit knowledge.

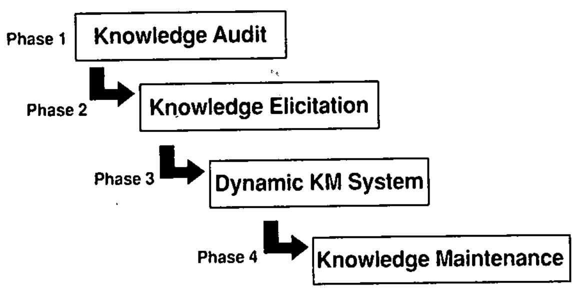
Retirement, turnover, downsizing, and re-engineering initiatives might lead to possible loss of the most valuable asset of an organisation - key individuals. These staff carry expertise, judgement, and knowledge. The risk of loosing the essential know-how can be mitigated through systematic retention and sharing of knowledge within in the organisation. Furthermore, tapping the tacit (their insights, intuitions and ideas) is often highly subjective and some time might be difficult to verify.

A solution can be done by modelling of tacit knowledge of key individual to knowledge objects, which can be stored and shared through a dynamic IT infrastructure. The solution is said to support the development of learning culture, and a knowledge based organisation.

4.1 FOUR PHASES OF DEVELOPMENT

The four phases of development consist of knowledge audit, knowledge elicitation, dynamic KM system and knowledge maintenance as shown in Fig.7

Fig. 7 Knowledge Management Process



a. **Knowledge Audit**

In this initial phase, analysis of key processes, evaluation of knowledge reliance against procedural reliance, profiling of knowledge holders and sources, selection of strategy to prevent loss of knowledge are the steps to be taken.

b. **Knowledge Elicitation**

After the key processes and personnel are identified, the knowledge holders are interviewed through a systematic structure and the results are put into a set of transcripts. These transcripts are further verified before inputting into a KM system.

c. **Dynamic KM System**

The KM system is mainly an IT system enabling specific knowledge archive to be stored and shared. It should also be able to support intelligent decision process. Such IT tools include Intranet, Web-based Learning and Expert discussion forums. In order to have efficient and effective information and knowledge dissemination, some form of Electronic Document System should also be implemented.

The knowledge archives can be implemented on a PC based 'web browser' providing Intranet based access to the knowledge.

d. **Knowledge maintenance**

In the final phase of knowledge system implementation, it is essential to establish knowledge base culture so as to maintain existing knowledge and to expand to new knowledge.

5. KNOWLEDGE MANAGEMENT APPLICATIONS IN POWER SYSTEMS

The following are two examples on knowledge management implementation in power systems in CLP Power.

5.1 OCCUPATIONAL COMPETENCE

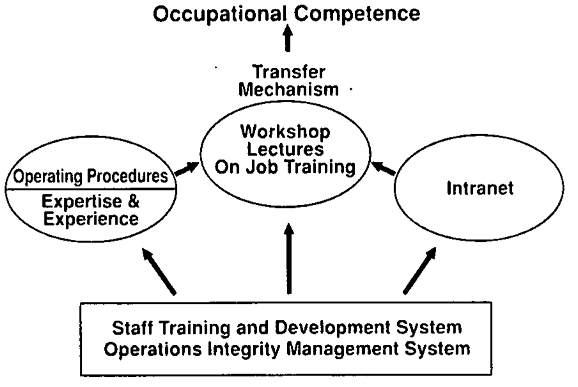
The most frequently applied KM activities are those needed to support basic occupational competence for staff working in the power systems. These activities included training, competence assessment; certification, refresher training and associated subsystems such as training need matrix, training record, authorisation procedures and qualified trainer registration etc.

Knowledge database is needed to be maintained on occupational competence which included operations procedures, engineering instructions, working instructions, safety rules etc. Making these pieces of information explicit, accessible by staff, and up to date are important for power system operation integrity.

To supplement the explicit knowledge, means for tacit knowledge elicitation has to be formulated. The tacit knowledge can be initially developed as a paper based document and later is enhanced by the adoption of IT tools. Through IT tools such as electronic document management system, intranet, efficient knowledge archives can be built to facilitate knowledge sharing. These knowledge archives also serve as a just-in-time learning tools for the power systems personnel.

In Engineering Projects Design, the design work activities involve multidiscipline covering civil, structural, building services, switchgear, transformers, overhead lines and cables. Engineers with wide experience and technology skills are required in order to deliver an effective and optimal design to world class standard for implementation. One way to enhance such design is by the application of KM.

Fig. 8 Occupational Competence



Before the KM system is implemented, all design team staff were briefed with the purpose and functioning of such system, the importance in sharing existing knowledge and gaining new knowledge to meet required business needs. An openness and mutual trust environment is the pre-requisite of building KM system. A Design KM team is also formed to act as a centre of excellence.

The KM implementation adopted in the Project Design starts with knowledge audit. All key elements for design are identified. All design team members are encouraged to submit 'Transcripts' based on their areas of expertise and experiences. These transcripts are reviewed and verified at regular interval by the Design KM team. Once the transcript is verified with key words identified, it will be stored into the KM database. The KM database has a search engine enabling future knowledge retrieval.

Their transcripts can also be considered as a system approach to problem solving as they contain knowledge form past experiences, from best practices of others. Since it can be easily put in the Intranet, knowledge can be quickly, efficiently and effectively shared throughout the organisation.

The basic tool to achieve occupational competence is through the use of Intranet and the basic transfer mechanism is through the workshop, lectures and on-job training based on the operating procedures (explicit knowledge) and the elicited knowledge from expertise and experiences as illustrated in Fig. 8.

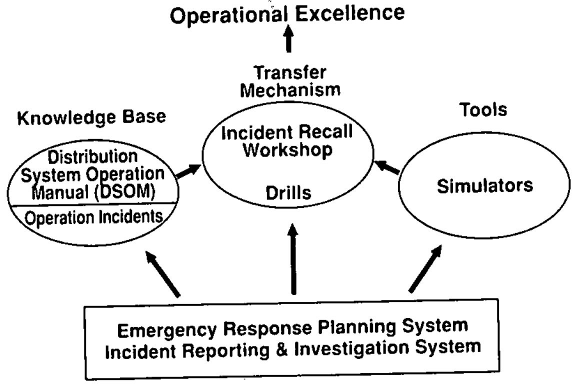
5.2 OPERATIONAL EXCELLENCE

Fully explicit knowledge archive system is ideal, but explicit knowledge system is often incomplete. This is typical for system operation decisions in complex operation processes involving external factors. Example of these situations may range from best / optimal supply restoration procedures after power system fault to crisis situation when an area brown out is associated with personnel injury and sensitive customers. Time and resources are just never sufficient to build an ideal knowledge archive system to cover all scenarios.

Experience, or tacit knowledge processed by individual staff often determines how well the incidents can be handled. This tacit knowledge can actually represented by the individual's ability to refer to and make use of the known explicit knowledge. For example, circuit parameters, safety rules, customer contact, utilities contact, internal resources mobilisation information and mass media handling skills.

The KM system provides supports which include learning from incidents, or explicit engineering instructions written as a result of past incidents. Sufficient cases are accumulated to enable system operations manuals to be built. An example of this is the development of a Distribution System Operations Manual (DSOM) by a task group consisting of project leader and the Operation Quality Improvement Team. The objective of the group was to develop a set of unambiguous operation procedures for various parts and situations in the distribution system. The operation experiences of all the distribution operations staff were elicited in the process. Apart from the day-to-day operations, this information included legal requirements, procedural changes, staff's difficulties in following ad-hoc instruction and new procedures arising form operations incidents. Regular meetings were held among task group members for drafting the DSOM and a schedule prioritising the required procedures to be developed. The developed DSOM can be assessed through Intranet.

Fig. 9 Operational Excellence



Since knowledge if not utilised will deteriorate, the KM system therefore can help to provide KM refreshment and to enhance the operation staff by knowledge verification. The basic tool to achieve operational excellence is through the model as indicated in Fig. 9 where training simulators for system operation is used for system operation knowledge refreshment and verification. At regular intervals, the system operation staff must go through such training and knowledge verification process in order to upkeep the required standard of the system operation staff.

Furthermore, operation decision knowledge can be shared through incident recall sessions, quality circles and crisis management drills. Incident recalls may be for ad-hoc incidence, as well as a more structured approach like the DSOM example above. Crisis management drills can be of various scales. Supply restoration drills for major customers, typhoon drills, crisis involving cross-departmental resources and media handling efforts are some of the examples.

6. KEY FACTORS FOR KM IMPLEMENTATION

To develop a KM Strategy, it is essential to know where you are and where you want to go. KM initiatives need to tie in specific business objectives. This may start from knowing the knowledge risks through self-assessment or more formal knowledge audits.

There are two approaches to knowledge measurement, taking stock of knowledge assets and measurement of the effectiveness of these knowledge assets. In the " Stock-taking" approach, the number of qualified or key knowledge holders in the company, and other knowledge stock as indicated in the Explicit/ Tacit knowledge grid in Fig. 4 can be measured. In the "Effectiveness" measurement approach, the value of knowledge of a company and its management is measured by, the difference in its market value and its book value.

Knowledge is practically tied in with every business process, and as different organisation has its own business strategies, KM implementation for one organisation is likely to distinct from another. Since one size does not fit all, there is no single KM solution for all organisations. However, there are factors which are critical to success for KM implementation. Without these, sharing of knowledge cannot be succeeded. In developing the KM strategy for implementation, the three key factors in KM: People, Content and Technology must be addressed.

6.1 PEOPLE

If knowledge sharing is important for the success of a business, it should make sense if systems should be built to support and encourage sharing of knowledge. These systems included common language for knowledge sharing, freedom to create and access knowledge, and incentive for sharing knowledge. These ideas are quite straightforward but the implementation is not, in particular, incentive for sharing knowledge. In today's competitive business environment, issues like downsizing, business process reengineering, internal competition, job security can all be obstacles to knowledge sharing. Company who breaks through these barriers provides incentive by linking knowledge sharing activities directly or indirectly with the companies' reward system. For example, Federal Express operates a pay-for-knowledge programme, at Ernst & Young, part of each consultant's compensation is based on knowledge sharing activities, at Lotus Development, 25 % of a customer-support worker's performance assessment is related to knowledge sharing.

In the KM implementation, it is therefore essential to recognise the sharing of knowledge and to promote a learning organisation culture throughout the company.

6.2 CONTENT

Data, information and knowledge are important to the business. The cognitive knowledge (know-what), the advanced skill (know-how), the system understanding (know-why) and self-motivated creativity (care-why) are the levels of knowledge content that an organisation must recognise to determine its leverage point. In mapping the content with staff, it is therefore important to identify who own the knowledge and who use it. For example, in Engineering Projects, 80% of the project values are determined at the project design stage and hence the required knowledge of Project Design is a good starting point for implementing knowledge management.

6.3 TECHNOLOGY

Technology is an enabler to capture, store and deliver knowledge. With the recent development in web-based, object oriented and data network technologies, it is possible to build a knowledge system infrastructure so that data-mining and visualisation are possible once the knowledge is put into the database. The web-based learning (e-training) is developed to enable flexible learning and subsequent assessment. For example, Learning Modules on operational knowledge and Distribution System Operation Manual procedures are designed so that participants can individually learned and assessed.

7. CONCLUSION

Knowledge Management is a new discipline. It enables individuals, teams and entire organizations to collectively and systematically create, share and apply knowledge, and to better achieve the business objectives.

Most organisations have knowledge sharing activities, but few of their management can specify their position in knowledge management. The demarcation of this passive approach in KM and the more proactive approach for those who have explicit knowledge management initiatives probably start from measurement.

This paper has outlined the basic concept in knowledge management, the applications of data, information collection to form knowledge, the approach to externalise tacit knowledge and key components in KM implementation. A number of examples are given with particular reference to power systems application. Knowledge Management definitely enhances organisational values and brings success to achieve business objectives.

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Paper No. 9

PROMOTION OF ENERGY SAVING TECHNOLOGIES IN HONG KONG

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PROMOTION OF ENERGY SAVING TECHNOLOGIES IN HONG KONG

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ABSTRACT

Hong Kong is a leading commercial and financial centre in Asia and the energy consumption is increasing substantially every year over the past ten years. The electricity consumption in the commercial sector is increasing at about 7% per annum and is the fastest growing sector. The Energy Efficiency Office of Electrical and Mechanical Services Department is actively exploring means to reduce energy consumption and a series of initiatives are being implemented to achieve the goal. One of the initiatives is to investigate advance and innovative energy saving technologies with a view to promote the wider use of these technologies in Government buildings. The investigation covers equipment for lighting, air conditioning, lifts and escalators. The paper will present a report of the current status of our findings and our future research interests in lighting. Case study reports of successful lighting technologies that have been widely accepted by design engineers and building operators will be presented in more details.

1. INTRODUCTION

In 1995, the Secretary for the Treasury approved under delegated authority a non-recurrent commitment of $6 million for EMSD to carry out a 3-year Pilot Energy Management Opportunities (EMO) Implementation Programme (the Phase I Programme). The objective of this Programme was to examine the cost effectiveness of various advanced energy-efficient building services technologies under local conditions.

The Phase I Programme was completed in early 1999 and the report was published in the EMSD's Homepage in July 1999. The Phase I programme had successfully introduced energy efficient equipment, such as electronic ballasts, variable speed drives, high efficient motors, etc. to Hong Kong. These energy efficient products are now widely used in offices and commercial buildings and have also been included in the recently launched Demand Side Management (DSM) programme operated by the two power companies in Hong Kong. Application guidelines and information pamphlets for promulgating the use of electronic ballasts and variable speed drives have also been published and details can also be found in the EMSD Homepage.

The two-year $6M Phase II Programme had also been approved and started in May 1999 to further study the application of innovative energy efficient equipment in Government buildings. The site investigation and equipment research commenced in June 1999. As far as office lighting is concerned, we have carried out pilot projects including the installations of dimmable electronic ballasts, T-5 fluorescent luminaries and intelligent lighting control at 27/F, Arsenal House, the new Environment & Food Bureau (EFB) offices in Citibank Plaza and 35/F, Queensway Government Offices (QGO). This paper will mainly focus on the findings from these pilot lighting projects using T5 lamps and intelligent lighting control.

2. PILOT EMO PROJECTS FOR LIGHTING

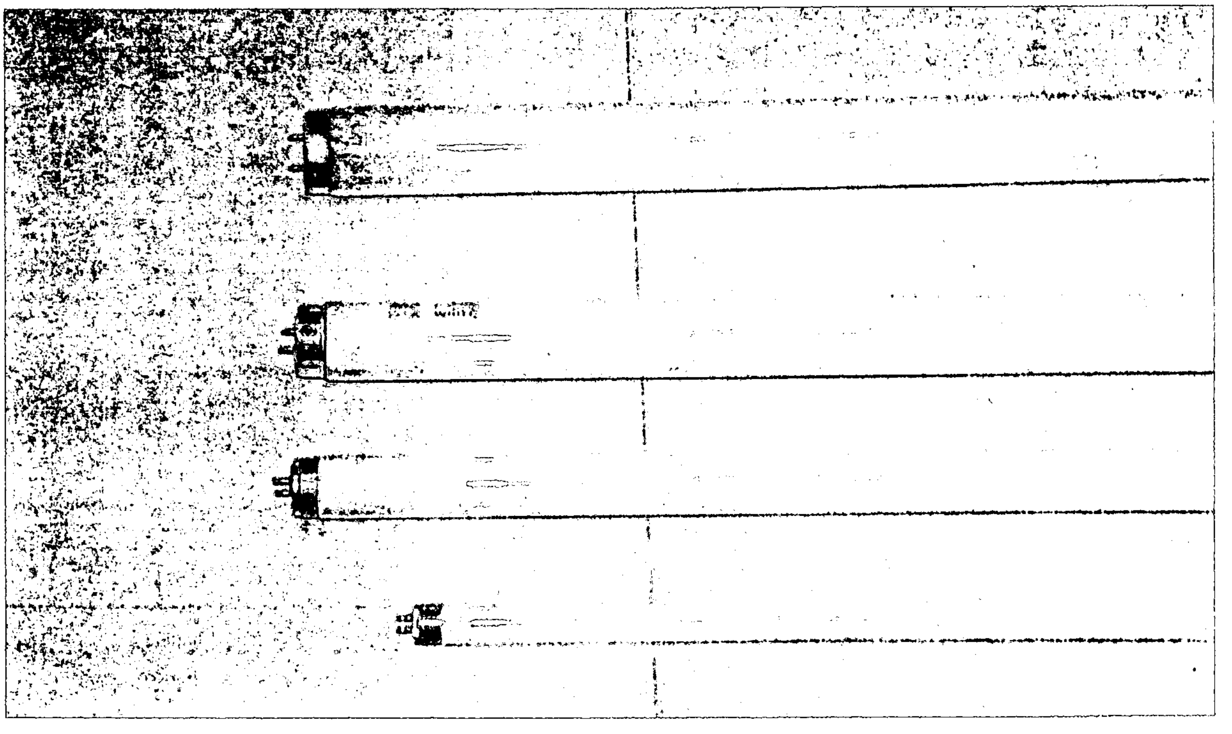
Lighting consumes about 20-40% of the energy consumed in Hong Kong office buildings. There are many opportunities for energy savings in lighting, such as:

- the use of more efficient lamp/ballast systems;
- the use of more efficient luminaire reflector/louver systems;
- the installation of dimming or on/off control systems for the maximum utilization of available daylight; and
- the use of occupancy detectors to switch off or dim down the lamps in unoccupied zones.

As far as energy efficiency lamp is concerned, a new generation of T5 fluorescent lamp with a diameter of 16mm (5/8") and G5 base has recently been introduced into Hong Kong. T5 lamps have been available with outputs of 4W, 6W, 8W and 13W for over 30 years. However, these lamp types were mainly used for furniture, signage and table lighting in the past.

A few year ago, however, new T5 lamps with higher wattage were developed, which, owing to their superior luminous efficiency outputs (efficacy about 100 lm/W), represent serious competition for the classical T12 or T8 fluorescent lamps. The standard wattage of the new T5 lamps is 14W, 21W, 28W and 35W. Enhanced economy is achieved by high frequency operation with electronic ballasts, which are specified in principle for these new lamp types. Owing to their slim shape, the new T5 lamps permit innovation in luminaire design as a further reduction in luminaire casing dimensions. In addition, the lamp length of all T5 lamp types is 50mm shorter than their T12/T8 counterparts and T5 luminaires could then be dimensioned to enable them to fit exactly into the usual metric grid (600mm and 1200mm) of suspended ceilings.

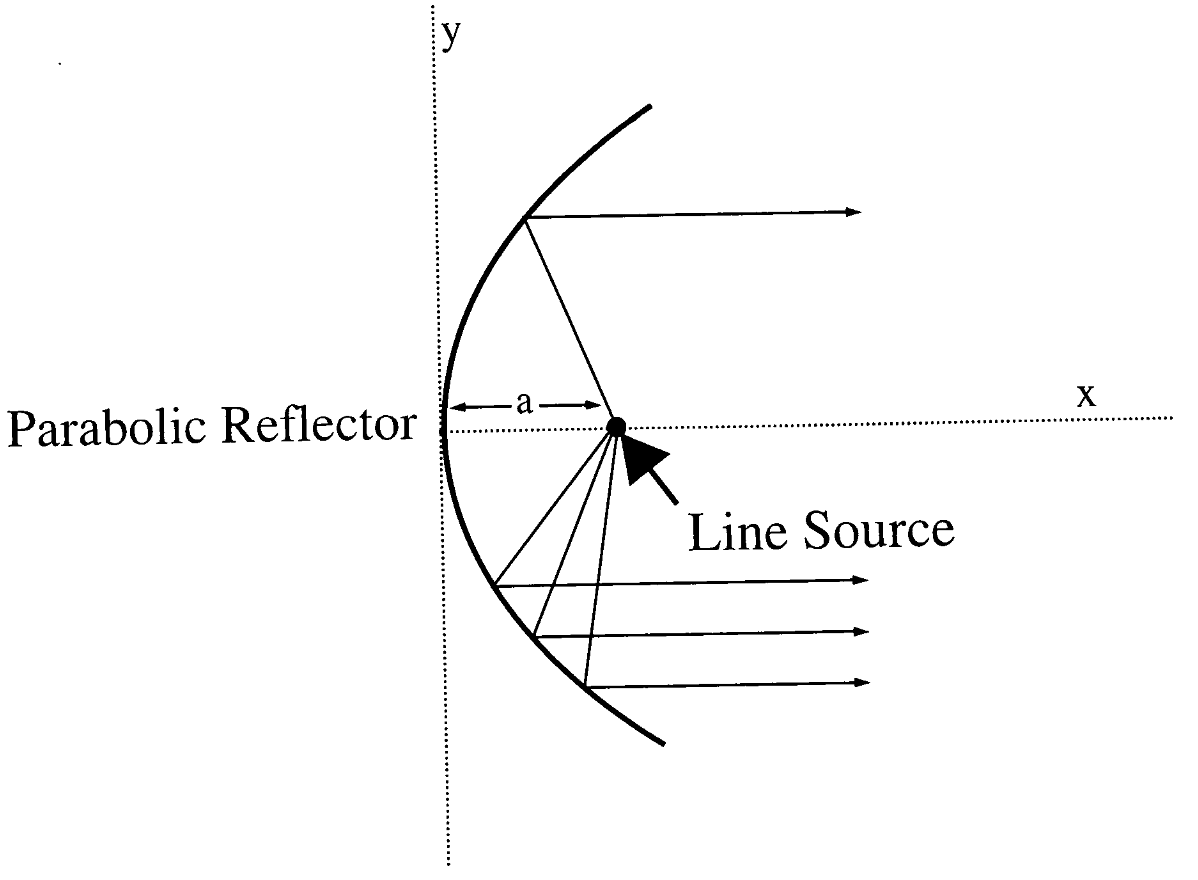
Fig. 1 Relative Size of T12,T10, T8 & T5 Lamps



An important element in the design of luminaire is optical control. The purpose of optical design is to redirect the light from a bare source to the area where it is needed, to reduce the light in those zones where it may cause glare, and to provide a housing that is pleasing in appearance while, if necessary, protecting the lamp. Opal diffusers, prismatic controllers and parabolic specular reflectors are the most common types of optical control used in fluorescent luminaires.

For fluorescent luminaires with T5 lamps, the most effective means of optical control is parabolic reflection. The parabola is the most commonly used reflector contour: it is defined by the equation $y^2 = 4ax$ where a is the shortest distance of the focal point to the reflector. The most important optical property of the parabolic reflector is that if a line source is placed at its focus a parallel beam of light is obtained. Fig. 2 shows the beams of reflected light produced by a line source at focus of the parabolic reflector. In practice the ideal line source is difficult to obtain from fluorescent tube and the shape of the distribution curve depends on the size of the source in relation to the focal length and mouth width of the reflector. As the diameter of T5 tube is much smaller than its T8 and T12 counterparts, and is more closer to a line source, optical control of luminaires with T5 lamps and parabolic reflector can be more precise and efficient.

Fig. 2 Parallel Beam Produced by Line source at Focus of Parabola



The latest development of digital technology in electronic ballast and lighting sensors design has also made the control and dimming of fluorescent lighting more easily. Intelligent lighting control with integrated sensor to detect daylight and occupancy is also available to enhance further energy saving in T5 lighting system.

Several pilot projects in office lighting using the above-mentioned technologies have been tried out recently in some Government buildings. Details of these pilot projects are described as follows.

3. T5 LUMINAIRES RETROFIT AT ARSENAL HOUSE

The pilot project included the replacement of the existing 320 sets 3 x 18W T8 600mm x

600mm recessed modular fluorescent luminaires in the office areas on 27/F, Arsenal House, with new 3 x 14W T5 600mm x 600mm recessed modular fluorescent luminaries, complete with electronic ballasts (1 for 3 lamps type) and parabolic reflectors designed to CIBSE LG3, Cat. II. The lighting layout of the floor and the new luminaire used are shown in Fig.3 and 4 below.

Fig. 3 Lighting Layout at 27/F, Arsenal House

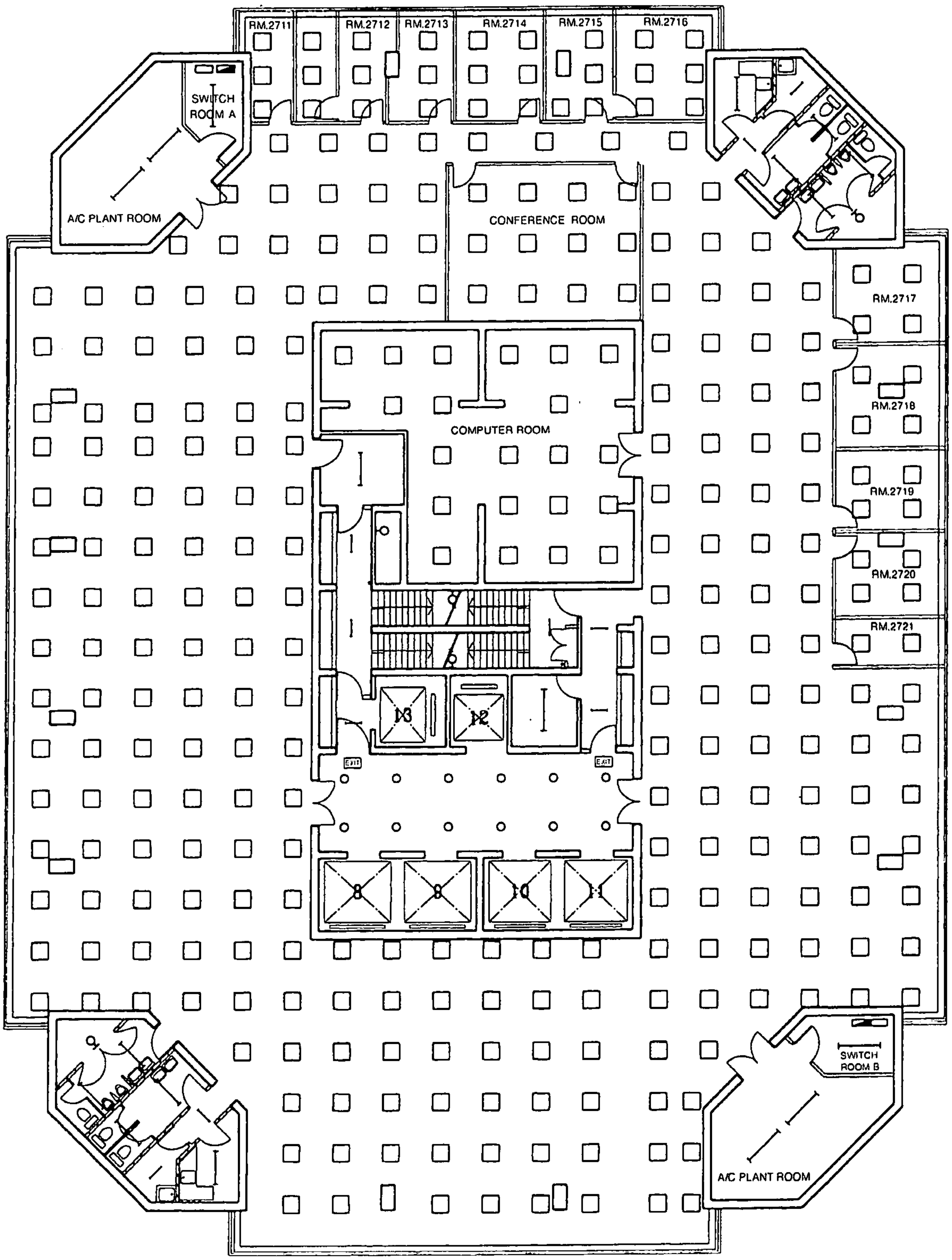


Fig. 4 New 3 x 14W T5 Luminaire used at Arsenal House

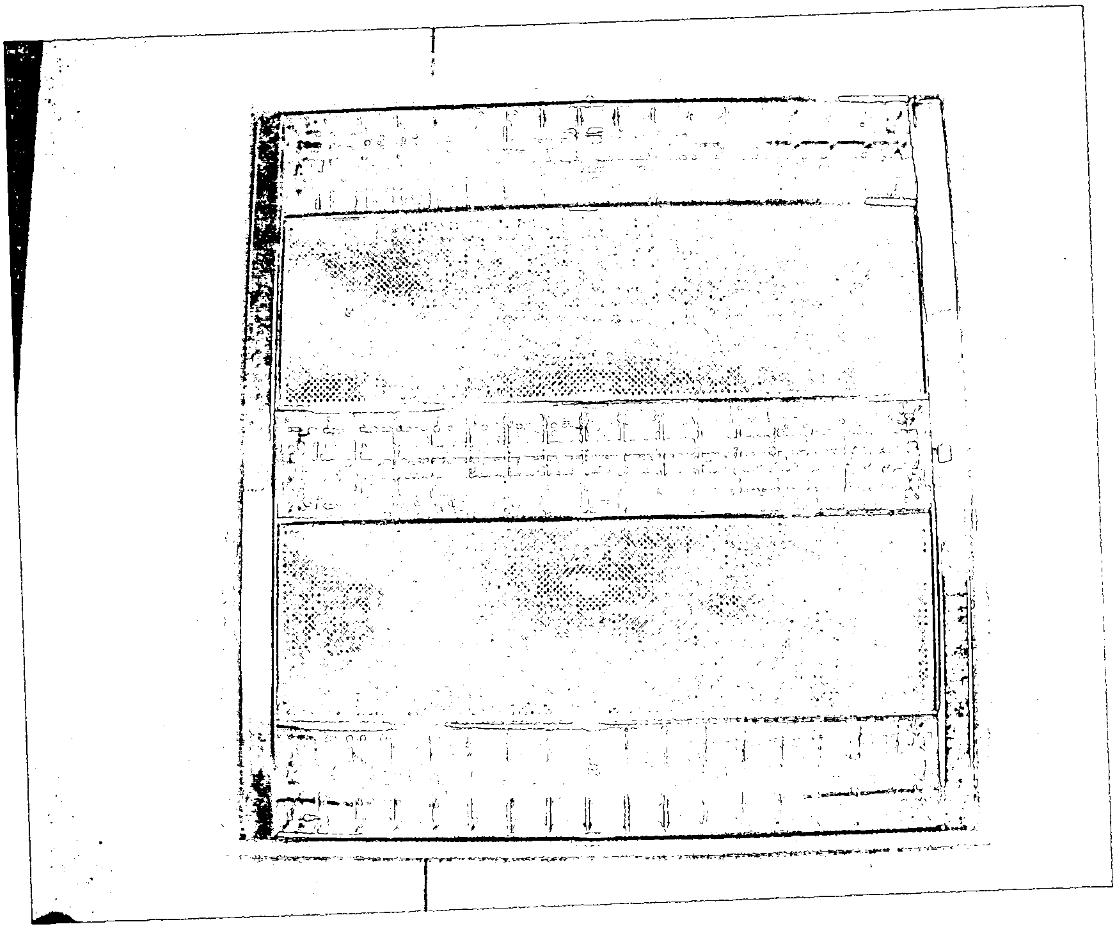


Table 1 and Fig. 5 below show the test data of the existing 3 x 18W T8 luminaire removed from site.

Table 1 Electrical Parameters of the Old 3x18W T8 Luminaire

			Voltage	Current
Frequency	49.99	RMS	223.4	0.754
Power		Peak	312.7	1.095
W	90	DC Offset	0.2	-0.02
VA	168	Crest	1.4	1.45
var	142	THD Rms	2.23	8.80
Peak W	244	THD Fund	2.23	8.84
Phase	58°lag	HRMS	5.0	0.66
Total PF	0.53	KFactor		1.51
DPF	0.53			

Fig. 5 Current Waveform and Harmonic Content of the Old 3 x 18W T8 Luminaire

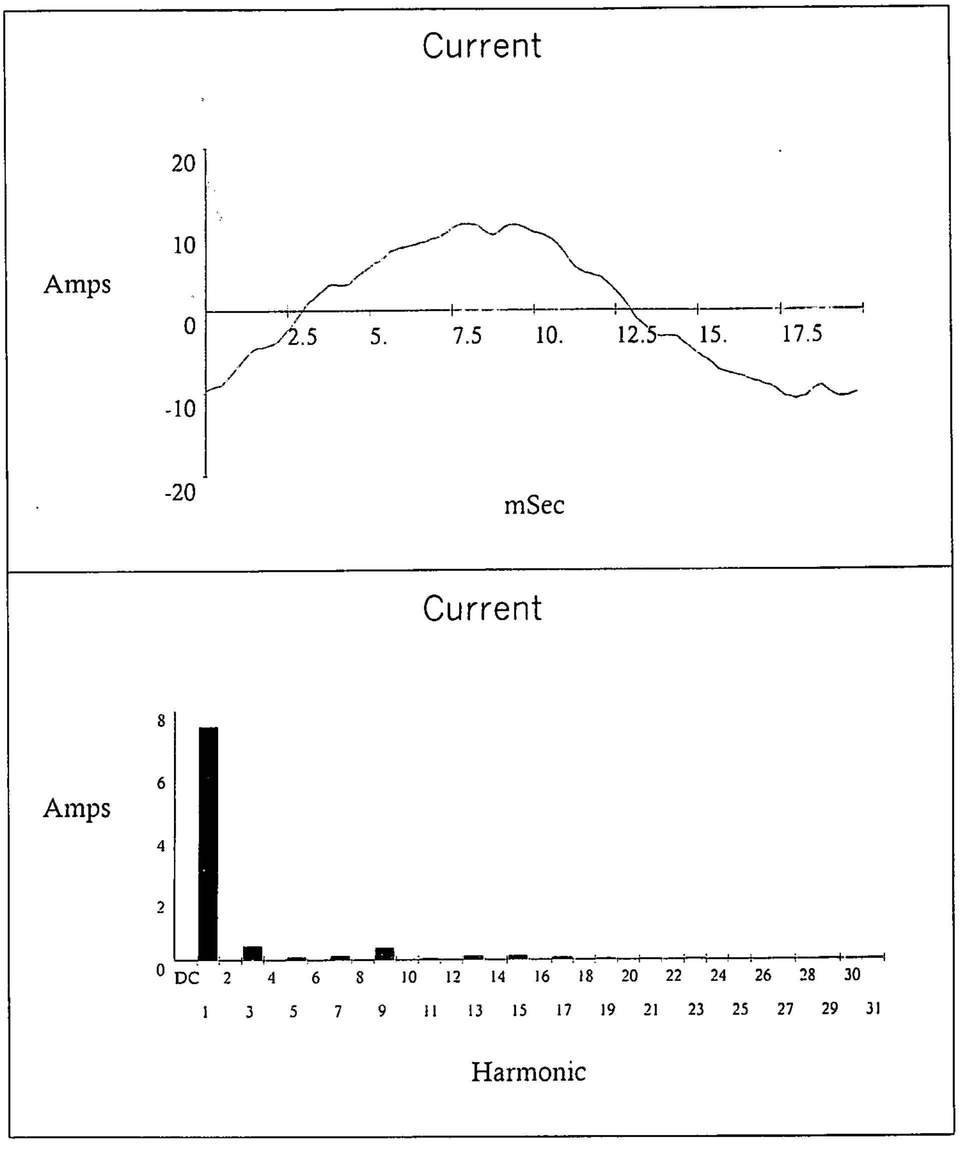
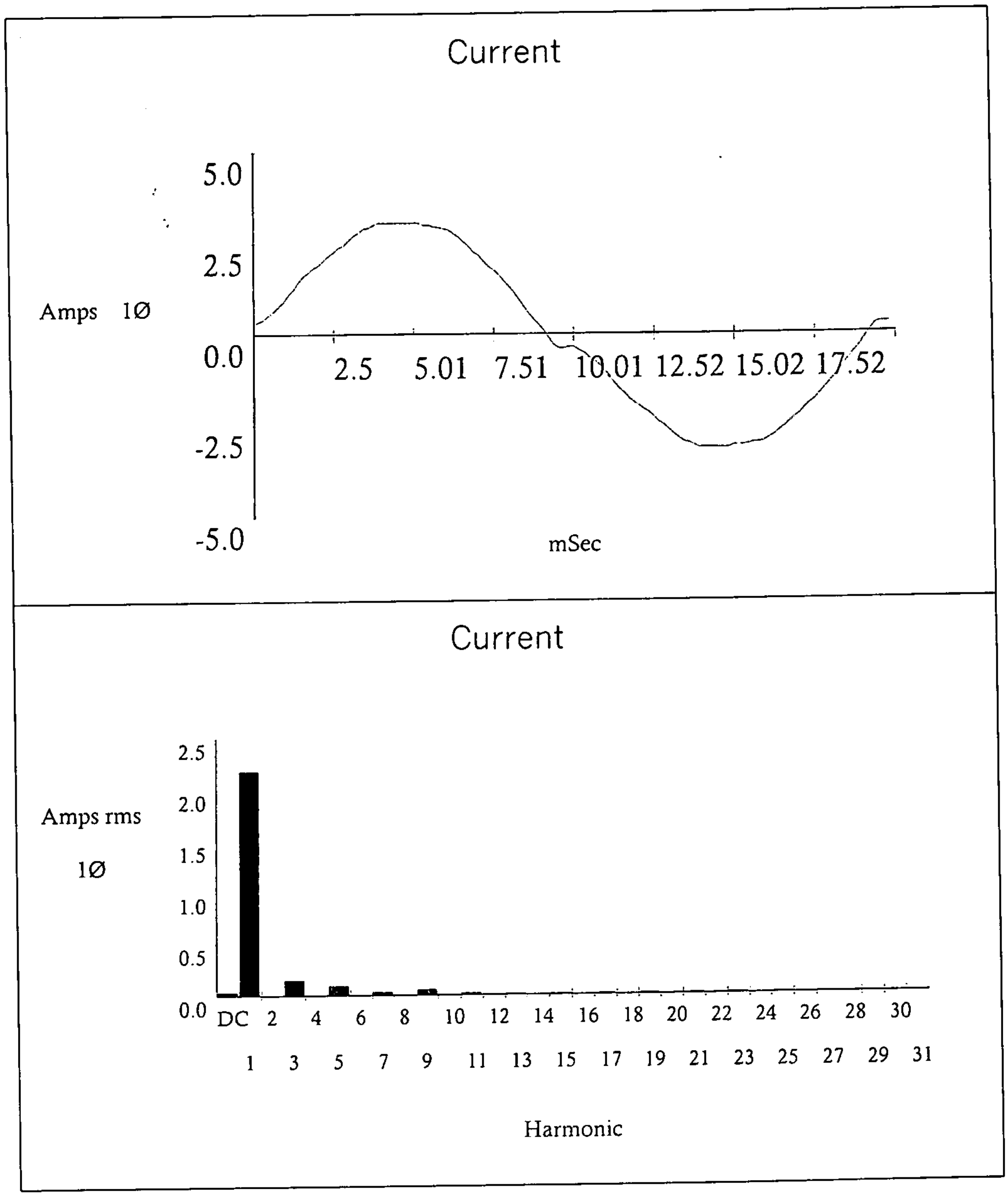


Table 2 and Fig. 6 show the test data of the new 3x14W T5 luminaire used in the project.

Table 2 Electrical Parameters of the New T5 Luminaire

			Voltage	Current
Frequency	49.94	RMS	221.8	0.22
Power		Peak	308.5	0.316
W	48	DC Offset	0.0	-0.03
VA	49	Crest	1.39	1.44
var	7	THD Rms	2.30	8.60
Peak W	98	THD Fund	2.30	8.63
Phase	8° lead	HRMS	5.1	0.19
Total PF	0.99	KFactor		1.19
DPF	0.99			

Fig. 6 Current Waveform and Harmonic Content of the New 3 x 14W T5 Luminaire



Measurement on site before the lighting retrofit indicated that the floor had a total lighting load of 28kW and an average daily energy consumption of 470kWh. Each of the existing 3x18W T8 luminaire consumed 90W at a power factor of 0.53. The low power factor was mainly due to the under designed of the capacitors inside the luminaire (only one 5.5 uF capacitor was used for the whole luminaire). Table 3 below summarises the performance of the new T5 lighting installation as compared with the old lighting system.

Table 3 Summary Table for the Lighting Retrofit at 27/F Arsenal House

	Existing T8 Lighting System	New T5 Lighting System	% Difference
Active Power (kW)	28 kW	16 kW	- 42%
Power Factor.	0.53	0.99	+ 87%
T.H.D.	11%	8.6%	- 21.8%
Apparent Power (kVA)	52.8 kVA	16.2 kVA	- 69%
Reactive Power (kvar)	23.7 kvar	2.3 kvar	- 90%
Average Illuminance	450 lux	600 lux	+33%
Lighting Power Density	30 W/m²	18 W/m²	-40%

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Based on the information above, the following observations could be drawn for this pilot T5 lighting retrofit project:

- The average daily lighting energy consumption measured on site before retrofit was 470 kWh. The average measured daily lighting energy consumption after retrofit was 270 kWh. An annual energy saving of 55,000 kWh is anticipated per floor.
- The power factor of the lighting circuits was greatly improved from 0.53 to 0.99, resulting in lower circuit current, less reactive power, smaller distribution loss and possible saving in demand charge.
- The reduction in reactive power of the lighting load in this floor is 21.4 kvar. The reduction of reactive power for the whole building will be 642 kvar if all 30 stories of offices/workshops are retrofitted with new T5 luminaires. This would eliminate the requirement to add extra capacitor banks at the main distribution board for power factor correction.
- The average lighting power density before retrofit was 30 W/m^2, which exceeds the maximum 25 W/m^2 as stipulated in the Lighting Code. The new lighting power density after retrofit was 18 W/m^2.
- There was also a slight reduction in Total Harmonic Distortion (THD) of current, causing fewer problems to the power quality of the building.
- Due to improvement in the design of parabolic reflector and the more linear T5 light source, the utilisation factors of the new luminaire is higher. The average illuminance measured after retrofit was 600 lux, which was 33% brighter than the original lighting installation. However, the office ceiling appeared darker than before because of the Cat II luminaire designed for use in computer floor.

4. T5 LUMINAIRES RETROFIT AT NEW EFB OFFICES

As part of the Phase II EMO Implementation Programme, the new offices of Environmental and Food Bureau (EFB) in Citibank Plaza have been selected to try out the latest T5 fluorescent lighting technology in their lighting installations. The adoption of the new generation of T5 fluorescent lamps together with appropriate T5 electronic ballasts in the specially designed air-handling fluorescent luminaries have provided many energy efficiency features. The new lighting installations increased illumination at the working plane from 500 lux to 700 lux and at the same time consumed 38% less energy than their T8 counterparts with conventional lamps and electromagnetic ballasts. Intelligent lighting control has also been included in some offices along the perimeter with digital control technology for dimming and occupancy sensing.

The scope of work includes the following:

- Retrofitting of about 600 sets of 2 x 28W T5 air-handling luminaries (designed to CIBSE LG3, Cat. II) with electronic ballasts for office lighting.
- Installation of 70 sets of T5 batten luminaries for indirect ceiling and cabinet lighting
- Installation of 50 sets of compact fluorescent downlighters with electronic ballasts in meeting rooms
- Installation of intelligent lighting control systems at five senior staff offices

Tests were carried out on the existing 2x36W T8 luminaire removed from site. The luminaire was controlled by conventional ballasts and electronic starters with 8 uF power factor correction capacitor. The test results are indicated in Table 4 and Fig. 7 below.

Fig. 7 Current Waveform of the Existing Luminaire

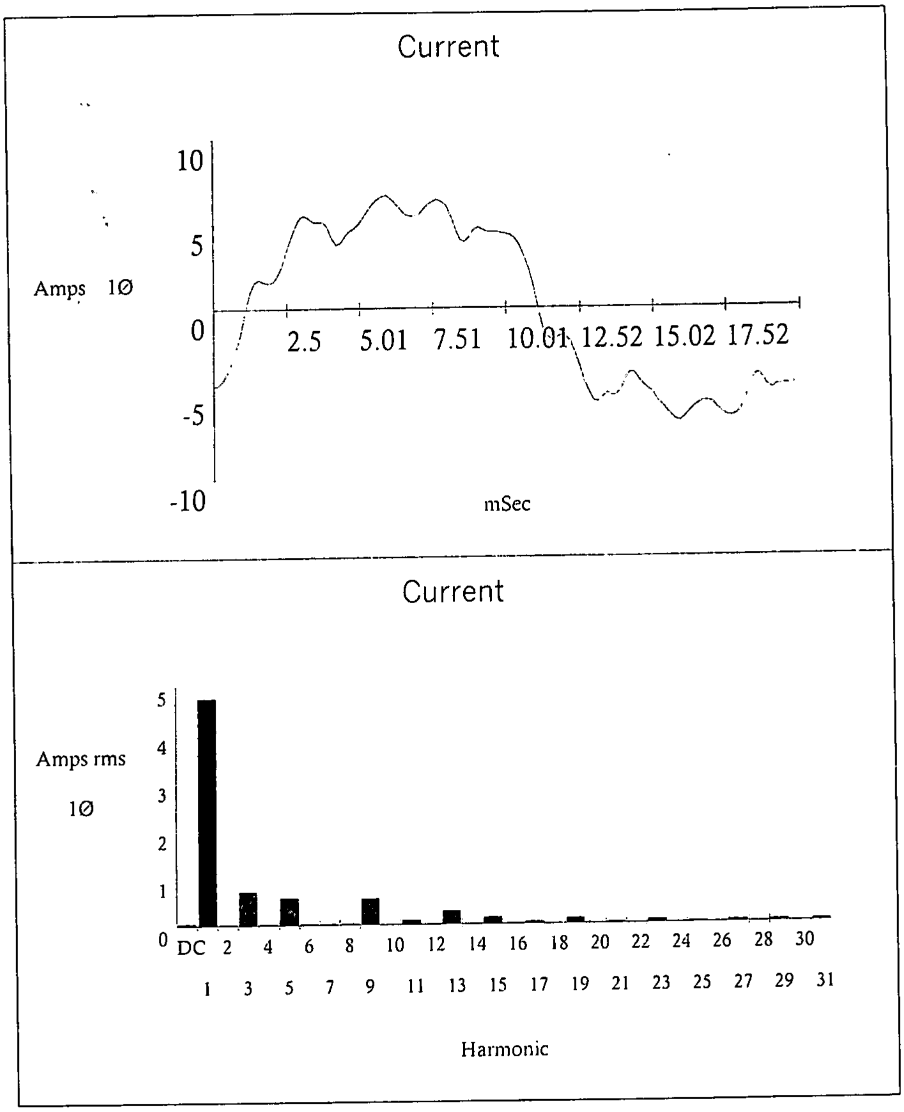

Table 4 Test Results of the Old Luminaire

			Voltage	Current
Frequency	49.94	RMS	225.6	0.488
Power		Peak	314.0	0.686
W	98	DC Offset	0.0	-0.03
VA	110	Crest	1.39	1.41
var	46	THD Rms	2.67	22.46
Peak W	213	THD Fund	2.67	23.04
Phase	25°lag	HRMS	6.0	1.10
Total PF	0.89	KFactor		3.53
DPF	0.90			

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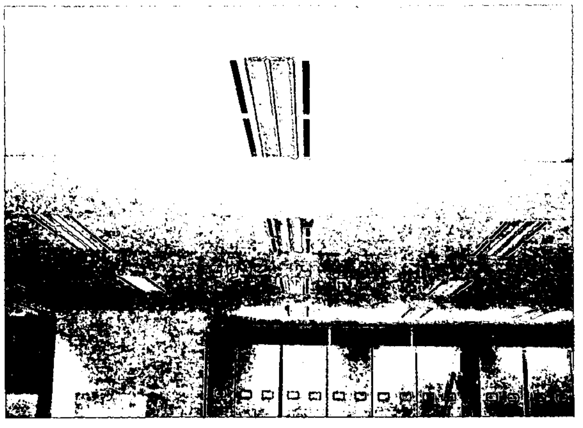
Fig. 8 New 2x28W T5 Luminaires installed at EFB Offices



The new 2 x 28W T5 luminaire complete with a single electronic ballast had also been tested.

The test results are shown in Table 5 and Fig. 9 below.

Table 5 Test Results of the New Luminaire

			Voltage	Current
Frequency	50.13	RMS	225.8	0.284
Power		Peak	316.0	0.434
W	60	DC Offset	-0.1	-0.03
VA	64	Crest	1.4	1.53
var	20	THD Rms	2.71	13.70
Peak W	134	THD Fund	2.71	13.83
Phase	18°lead	HRMS	6.1	0.19
Total PF	0.95	KFactor		1.52
DPF	0.95			

Fig. 9 Current Waveform of the New 1 x 28W T5 Luminaire

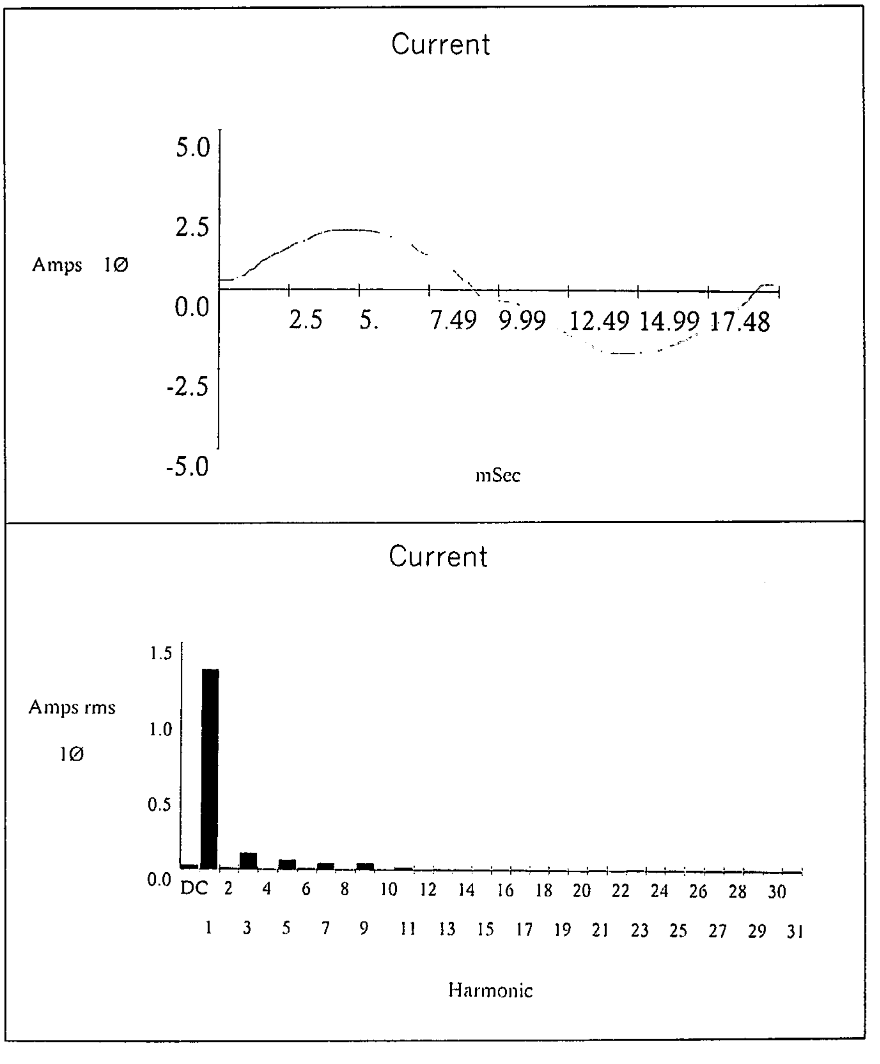


Table 6 Comparison between the Existing and New Luminaires

	Original 2x36W T8 Luminaire	New 2x28W T5 Luminaire	% Difference
Test Voltage	225.6V	225.8V	--
Current	0.488A	0.284A	- 42%
P (W)	98W	60W	-39%
S (VA)	110VA	64VA	-42%
Q (var)	46var	20var	-57%
Total PF	0.89	0.95	+7%
DPF	0.9	0.95	+7%
THD Fund	23.04%	13.83%	-40%

Table 7 Summary Table for the Lighting Retrofit at the New EFB Offices

	Existing T8 Lighting System	New T5 Lighting System	% Difference
Active Power (kW)	34 kW	23 kW	- 32%
Power Factor.	0.89	0.99	+ 11%
T.H.D.	23%	10%	- 56%
Apparent Power (kVA)	38 kVA	23 kVA	- 39%
Reactive Power (kvar)	17 kvar	3.2 kvar	- 81%
Average Illuminance	500 lux	700 lux	+40%
Lighting Power Density	27 W/m^2	17 W/m^2	-37%

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The major energy efficient and environmental features of the newly refurbished offices are highlighted as follows:

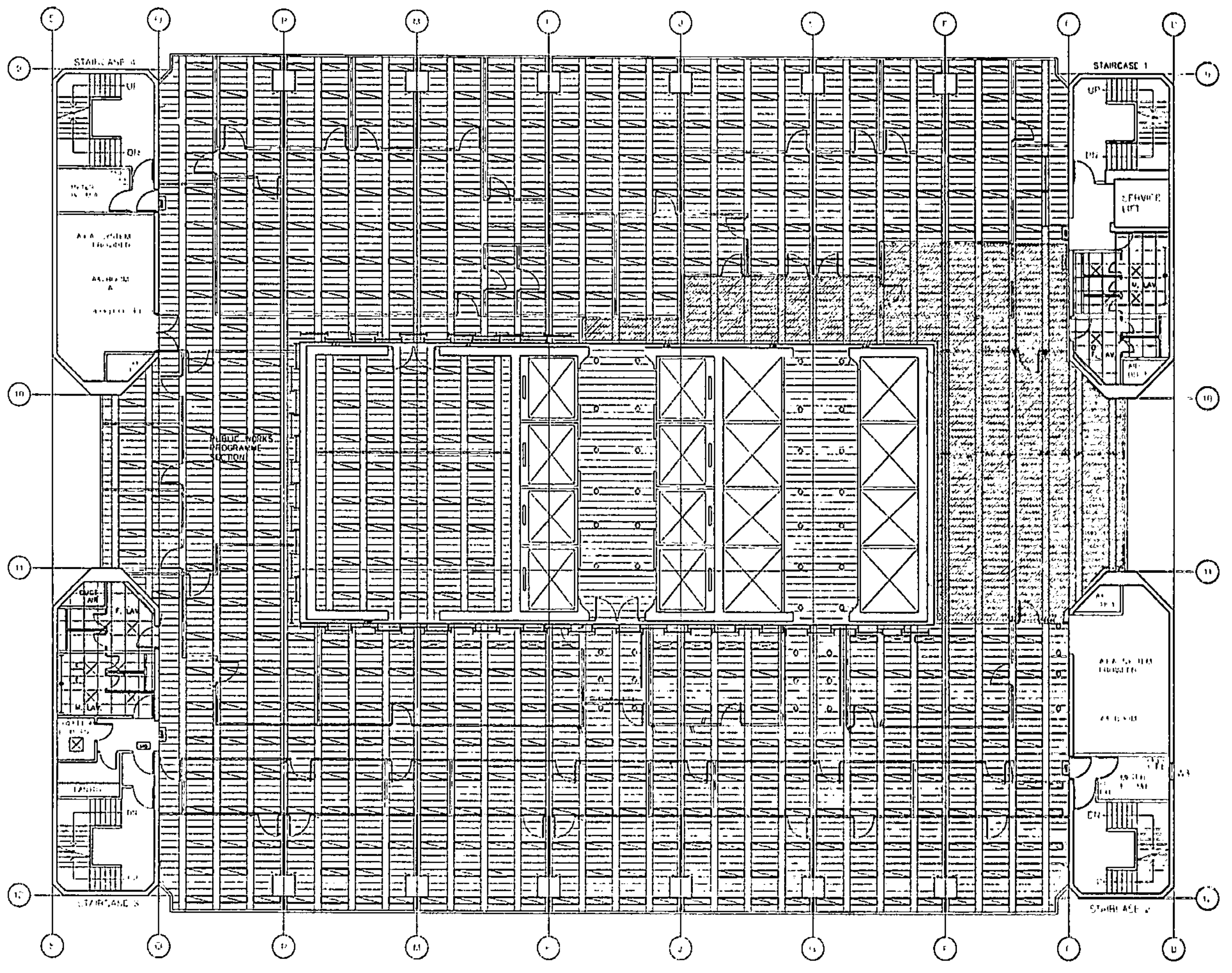
- Original circuit power per luminaire (based on 2x36W T8 with conventional ballasts) is 98W
- New circuit power with 1 electronic ballast driving 2 T5 28W lamps is 60W
- Reduction in lighting circuit power per luminaire is 38W (-39%)
- Annual energy saving per luminaire based on 3000 hours/year and $0.9/kWh will be HK$103
- Additional material cost for T5 luminaire is about HK$200. Simple payback is approximately 2 years.
- The average lifetime of T5 lamps is 15,000 hours (almost double the standard T8 lamps of 8,000 hours)
- Average measured illumination level is 700 lux (+40% as compared with the original 500 lux lighting scheme)
- The new T5 lamps use less glass, less mercury and less packaging materials (disposal and recycling costs are reduced)
- The new T5 luminaires were designed more efficiently and use less metal for their casing and reflectors
- Anticipated energy consumption if the original T8 lighting systems were used would be 175,740 kWh
- Average monthly lighting energy

consumption measured on site was 9,080 kWh and the anticipated annual lighting energy consumption would be 108,960 kWh

- Anticipated annual energy saving of T5 lighting system in EFB would be 66,780 kWh (about HK$60,000 @ $0.9/kWh)

5. T5 LUMINAIRES RETROFIT AND INTELLIGENT LIGHTING CONTROL AT QGO

Fig. 10 Lighting Layout at 35/F, QGO



A typical floor of QGO has an office area of 1390 m^2 and is illuminated by about 500 recessed single-lamp 300x1200 mm luminaires. The existing 1x36W T8 luminaires was controlled by conventional electromagnetic ballast and starter switch with 4 uF power factor correction capacitor. Before the retrofit, the average illuminance on working plane was about 460 lux with an installed lighting power density of about 22 W/m^2.

This pilot project was a complete replacement of the original luminaires with new T5 luminaires designed to CIBSE LG3, Cat. II. Each new luminaire was fitted with a digital dimmable ballast, a 28W T5 fluorescent lamp and anodised aluminium reflectors and louvers. The layout of luminaires was basically unchanged except in parts of the floor at which minor modification works were carried out during the retrofit period. A total of 500 new luminaires have been installed. The new lamps are T5 28W (colour temperature 4000°K) and the new ballasts are 1x28W digital dimmable ballasts. These 500 luminaires were divided into about 150 groups, each group consisting of two to four luminaires. The luminaires in the open-plan area and in large rooms are arranged in groups of 4. The luminaires in a group are linked to an integrated sensor, which detects illuminance, occupant presence and the signal from a remote control. The sensor utilises the new digital technology called 'Special Mode Advanced Regulating Technology (SMART)'. Fig. 11 shows part of the ceiling with retrofitted luminaires and SMART sensors.

Fig. 11 T5 28W Luminaire Installed at 35/F, QGO

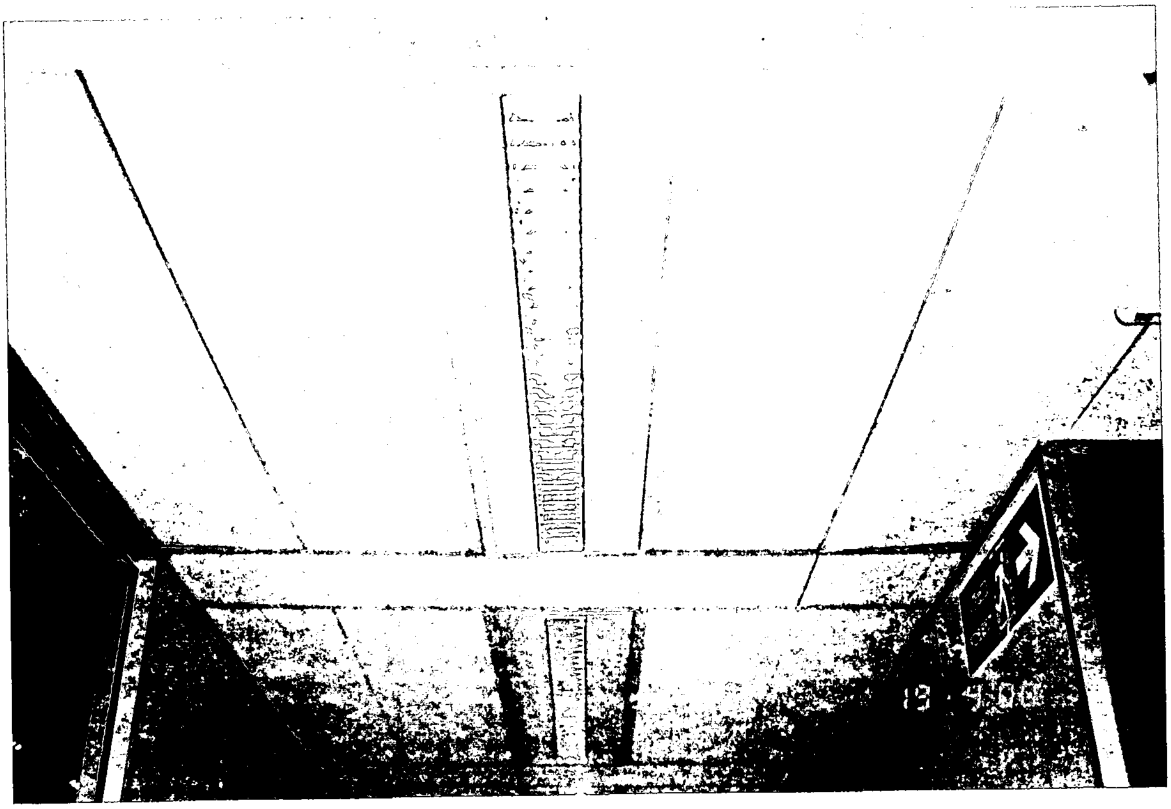
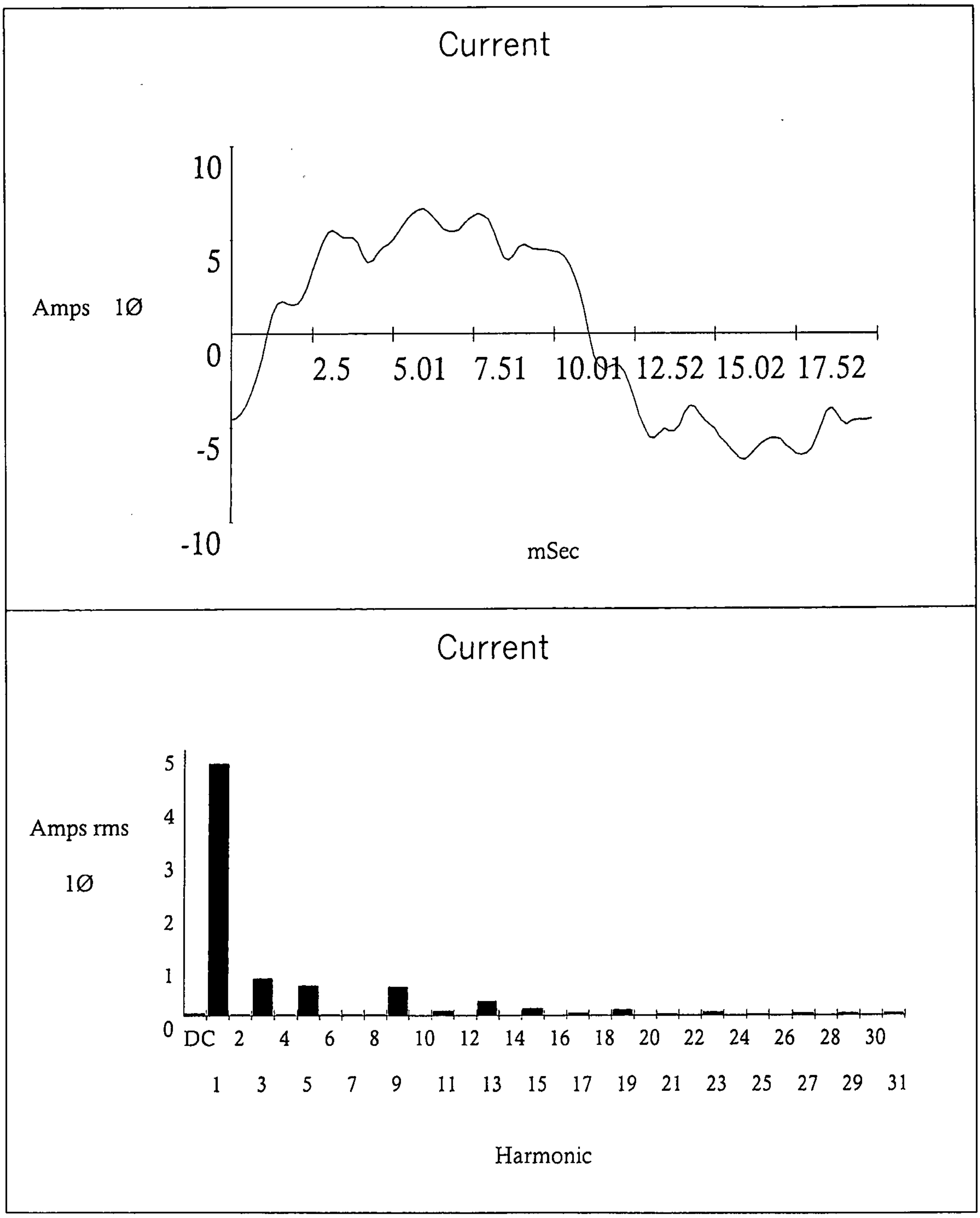


Table 8 Test Results of the Existing 1x36W T8 Luminaire

			Voltage	Current
Frequency	49.94	RMS	225.6	0.244
Power		Peak	314.0	0.343
W	49	DC Offset	0.0	-0.03
VA	55	Crest	1.39	1.41
var	23	THD Rms	2.67	22.46
Peak W	107	THD Fund	2.67	23.04
Phase	25°lag	HRMS	6.0	1.10
Total PF	0.89	KFactor		3.53
DPF	0.90			

Fig. 12 Current Waveform of the Existing Luminaire



The electronic ballast has a dimming range from 1% to 100%. It can be switched on or off via the mains or with digital control signal. It provides constant light output independent of fluctuating supply voltage. It is capable of disturbance free precise control with a digital signal and has an integrated SMART interface. It also provides safe shutdown of defective lamps and lamps at end of life without allowing these lamps to flicker.

Fig. 13 Current Waveform of the New 1x28W T5 Luminaire

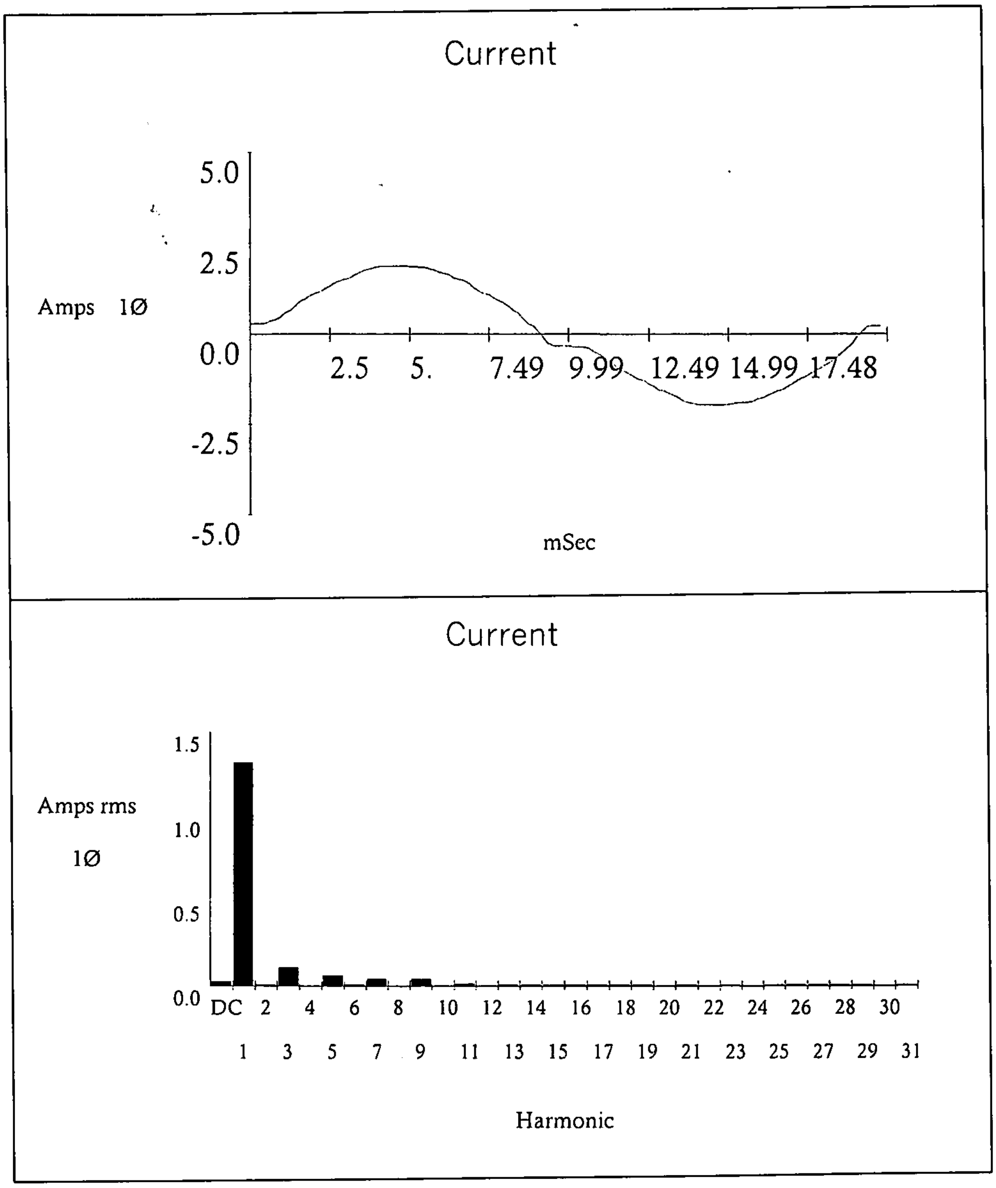


Table 9 Test Results of the New 1x28W T5 Luminaire c/w Digital Dimmable Ballast at Full Power Output

			Voltage	Current
Frequency	50.13	RMS	225.8	0.142
Power		Peak	316.0	0.217
W	30	DC Offset	-0.1	-0.03
VA	32	Crest	1.4	1.53
Var	10	THD Rms	2.71	13.70
Peak W	67	THD Fund	2.71	13.83
Phase	18°lead	HRMS	6.1	0.19
Total PF	0.95	KFactor		1.52
DPF	0.95			

Table 10 Comparison Between the Existing and New Luminaires

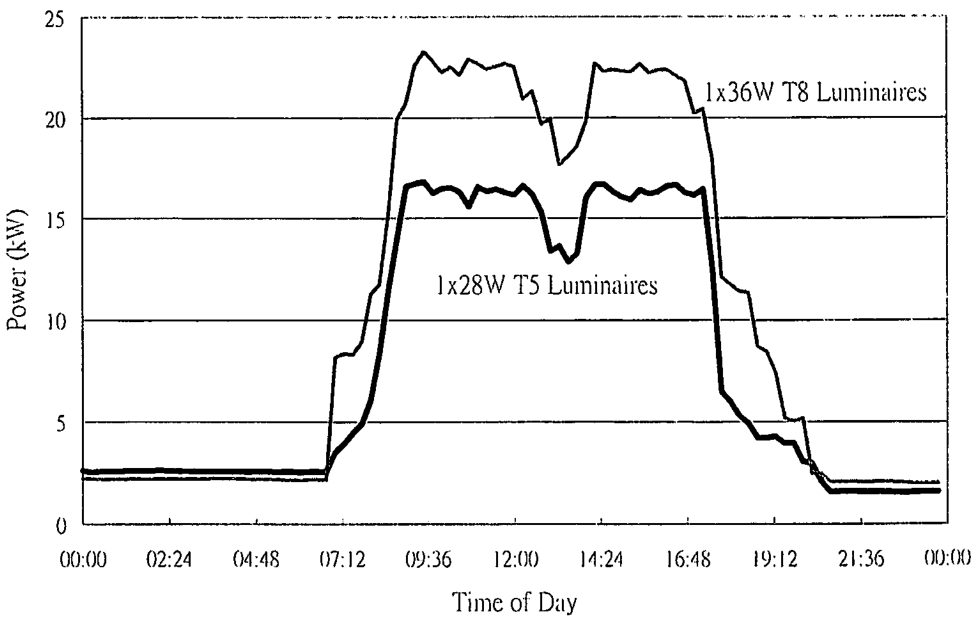
	Original 1x36W T8 Luminaire	New 1x28W T5 Luminaire	% Difference
Test Voltage	225.6V	225.8V	--
Current	0.244A	0.142A	- 42%
P (W)	49W	30W	-39%
S (VA)	55VA	32VA	-42%
Q (var)	23var	10var	-57%
Total PF	0.89	0.95	+7%
DPF	0.9	0.95	+7%
THD Fund	23.04%	13.83%	-40%

The sensor is a constant light system with integrated light level detection, presence detection and infra-red remote control. With a SMART programmer, the following operating parameters can be programmed: light level (1-100% or max), time delay (30s-60min or continuous), PIR activation (active or inactive or off), bright-out (yes or no), state if vacant (off or dimmed to low level), state at power up (on or off), 10% start (on or off), hold override (on or off). An infra-red remote controller can also be used to turn the lights on or off, or dim the lamps up or down manually and temporarily overridden the automatic functions.

The luminaire box consists of a white power coated metal casing with a 30-cell aluminum louver/reflector for optical control of the light so that the luminaire belongs to category 2 luminaire as defined in CIBSE LG3 (CIBSE 1993).

Data measured by the energy meter were analysed to give daily profiles of lighting power consumption. The power profiles for all working days in the two months before and the two months after the retrofit were reviewed. The lighting power profiles for two typical (cloudy) working days, one before the retrofit and one after the retrofit, are plotted in Fig. 14.

Fig. 14 Typical Daily Load Profile before and after the Retrofit at 35/F, QGO



The figure shows clearly that there is an average 6.5 kW reduction in lighting power after the retrofit Calculation from the daily consumption values shows a 35% energy saving. It can be noted that there was still significant power consumption with about one quarter of the lamps still on between 6:00 pm and 8:00 pm in a typical working day before the retrofit. This after-office-hour power consumption happened on all working days during the two-month period before retrofit. Review of the power consumption data for the two-month period after the retrofit shows that there was only little power consumption with occasional peaks after office hours. This indicates that there is occasional occupancy after office hours but, before the retrofit, about one quarter of the lamps were left on after office hours until very late at about 8:00 pm when the last occupant left the floor or when a guard or caretaker switches all lamps off. After the retrofit, the occupancy sensing function of the control gear switches off lamps in zones where there is no occupant. If one worker stays at the office until very late, then only one or two groups of lamps in the area covered by the sensor range will be on. This occupancy detection was normally set between 5 and 10 minutes and contributes significantly to energy savings in this floor.

Table 11 below summarises this pilot project using T5 lamps, dimmable electronics ballasts and intelligent lighting control.

Table 11 Summary Table for the Lighting Retrofit at 35/F, QGO

	Existing T8 Lighting System	New T5 Lighting System	% Difference
Active Power (kW)	24 kW	16 kW (Max.)	- 33%
Power Factor.	0.89	0.95	+ 6.7%
T.H.D.	23%	14%	- 39%
Apparent Power (kVA)	27 kVA	17 kVA	- 37%
Reactive Power (kvar)	12 kvar	5 kvar	- 58%
Average Illuminance	460 lux	730 lux	+59%
Lighting Power Density	22 W/m^2	13 W/m^2 (Max.)	-41%

The test results found in this pilot project revealed that, other than those similar advantages found in the previous two projects, the intelligent lighting control would also enhance further energy saving when the rooms are well lit by daylight or areas are not occupied during the office hours. The new lighting system would also be able to provide flexibility in setting the illuminance required to suit individual need for various tasks and functions.

6. CONCLUSION

It could be seen from the encouraging results above that office lighting using T5 lamps and luminaries has proved to be more energy efficient and has performance improvement in other electrical parameters, such as power factor, total harmonic distortion, etc. Although the testing of reliability and performance of the new T5 lighting is still ongoing, we have confidence that the T5 lamps and luminaries will be the future norm for office and commercial lighting. Because of their low brightness design to CIBSE LG3, Cat. II (for use in room with visual display units or computer monitors), the luminaires we used for the above pilot lighting installations appeared to have a darker ceiling but have lower glare.

There are many opportunities for reducing losses and consumption of electricity in buildings. It is the aim of the Government to improve, in long term, the use of energy in buildings through energy efficiency and conservation measures. Other than office lighting, we have also carried out energy efficient pilot projects in other areas, such as air conditioning, lifts and escalators, power quality improvement, etc. Reports for these pilot projects will be prepared in separate issues.

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