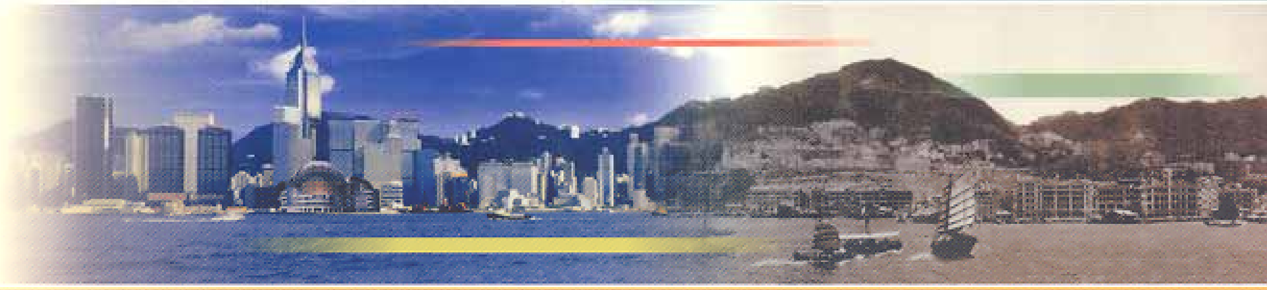

Achievement and Development - 50 Years Plus

The Hong Kong Institution of Engineers - Electrical Division
The Fifteenth Annual Symposium, 1997

THE HONG KONG
INSTITUTION OF ENGINEERS
ELECTRICAL DIVISION

The Fifteenth Annual Symposium

Tuesday

28th October 1997

ACHIEVEMENT AND DEVELOPMENT
50 YEARS PLUS

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 **Registration and Coffee**

09.00 **Welcome Address**
– Ir Wong Wai Ho
Chairman, Electrical Division, The HKIE

09.05 **Opening Address**
– Ir Prof. C.C. Chan
Senior Vice President, The HKIE

09.10 **Keynote Speech**
– Ir Prof. Charles K. Kao
Chairman
Energy Advisory Committee, Hong Kong

1. Electric Power

09.40 **The Design, Operations and Maintenance of Guangzhou Pumped Storage Power Station**
– Mr Basil S.P. Yeung
First Deputy Station Manager
Mr Anthony N.L. Leung
Contracts & Tech. Services Engineer
Mr Edmond K.W. Chan
Electrical Maintenance Engineer
Guangzhou Pumped Storage Power Station
China Light & Power Co. Ltd.

10.00 **Transmission and Distribution of Electricity in Hongkong Electric - Past, Present and Future**
– Ir Chan Loong
Chief Construction and Maintenance Engineer
Ir Chan Ping Kee
Senior Protection Engineer
The Hongkong Electric Co. Ltd.

10.20 **Discussion**

10.50 **Coffee Break**

2. Large Projects

11.20 Steam, Diesel and Electric - 50 Years of Development in Kowloon - Canton Railway

- Ir Lee Kang Kuen
  Director East Rail
  Kowloon - Canton Railway Corporation

11.40 Power Supply System for the Yangpu Economic Zone, Hainan Island

- Ir Dave K.Y. Wong, Director & Vice President
  Ir Eric C.H. Chui, Assistant Vice President
  Ir Thomas K.C. Chan, Senior Associate
  Parsons Brinckerhoff (Asia) Ltd.

12.00 Discussion

12.30 Lunch

3. Products and Legislation

14.00 The Advantage of Employing Microprocessors for Motor Soft Starters

- Mr Bernard Hall
  Export Manager
  Mr Nick Allen
  Technical Manager
  GEC Alsthom T&D Low Voltage Equipment Ltd.

14.20 Advanced Technology of Power System Engineering in Japan

- Mr Hiromichi Kinoshita
  Chief Engineer
  Power System Engineering Department
  Beijing Office
  Mitsubishi Electric (Hong Kong) Ltd.

14.40 Electricity Safety Legislation - Past, Present, and Vision of the Future

- Ir Uy Tat Ping
  Chief Electrical and Mechanical Engineer
  Lai Hon Chung
  Senior Electrical and Mechanical Engineer
  Electrical and Mechanical Services Department
  Hong Kong Government

15.00 **Discussion**

15.30 **Coffee Break**

4. Economics and Education

16.00 **Energy Labelling on Electrical Products**
- Mr Li Kai Ming
  Deputy Chief Executive
  Consumer Council

16.20 **The Role of Engineers and the Challenges of Electrical Engineering Education**
- Ir Prof. C.C. Chan
  Head
  Department of Electrical & Electronic Engineering
  The University of Hong Kong

16.40 **Discussion**

17.10 **Summing Up**
- Ir Simon S.M. Kum
  Symposium Chairman
  Electrical Division, The HKIE

17.20 **Closing Address**
- Ir Dr Raymond C.T. Ho, JP
  Chairman
  Association of Engineers in Society

18.00 **Cocktail Reception**

19.00 **Dinner Party to Celebrate the 50th Anniversary of The HKIE**

19.30 **Speech by Mr Jan Lee, Chief Economist, Hongkong Bank on 'World Stock and Currency Markets'**

20.30 **Souvenir Presentation to Sponsors**

22.30 **End of Dinner Party**

Acknowledgement

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Speakers / Authors

Ir Prof. Charles K. Kao
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Paper No. 1
(Keynote Speech)

50 YEARS OF DEVELOPMENT IN ENERGY FOR HONG KONG

Speaker : Professor Charles K. Kao
Chairman
Energy Advisory Committee
Hong Kong

50 YEARS OF DEVELOPMENT IN ENERGY FOR HONG KONG
(Keynote Speech)

Professor Charles K. Kao
Chairman
Energy Advisory Committee
Hong Kong

Paper No. 1

Mr. Chairman, distinguished guests, ladies and gentlemen,

As the invited speaker, it gives me great pleasure to speak at this occasion of the 15th Symposium by the Electrical Division of the Hong Kong Institution of Engineers which is also the celebration of the 50th anniversary of the Institution.

First may I extend my hearty congratulations to HKIE for contributing to the great achievements for the community in the past 50 years in the pursuit of engineering excellence of its members. Their professionalism is present in all sectors of our economy. The theme of your symposium this year, 'Achievement and Development 50 Years Plus', clearly indicates the ongoing direction this dynamic institution will undertake into the future.

To complement your theme today, I have chosen to speak on the past 50 years of energy in Hong Kong, a topic which I hope is particularly fitting for today's symposium. I have been involved more closely in this subject since serving as the Chairman of the Energy Advisory Committee when it was established in July 1996.

First of all I would ask you to try to cast your mind back to the past 50 years of achievements and the development of energy, especially here in Hong Kong. Judging from the youthful faces of the participants present in the audience, perhaps I am making an impossible request! Anyway, please allow me to picture this for you; the beginning of the 50 year period was influenced by the first post-war years of World War II which were characterised by the heroic efforts of the government and by the electric and towngas companies in reactivating the pre-war electricity and towngas supplies to meet the needs of a recovering post-war Hong Kong economy. To illustrate these early years, I would like to draw on the relevant parts from an interesting book by Austin Coates "A mountain of lights" in which he described the peak demand for Hongkong Electric Co. (HEC) in 1945 was around 7.8 MW and how this rose rapidly to around 30MW by 1949.

The early 1950's saw a spurt in the growth of electricity requirements for the budding industrial sector especially in Kowloon and the New Territories. Additionally, the use of air-conditioning in offices as well as in the residential sector had gradually increased during these years. The growth of peak demand could be illustrated by the corresponding figures for HEC from around 45MW in 1952 to about 100MW by 1960 and those for China Light and Power (CLP) were 45MW in 1952 growing to 145MW by 1960. In the same period the towngas requirements only grew moderately and LPG was introduced into Hong Kong in 1956. There was such a rapid expansion of electricity requirements, which coupled with some opposition from the community on electricity prices increases by the electric companies, that in 1957 the government deemed it necessary to establish an Electricity Supply Companies Commission. The first Electricity Commission was appointed by the government in 1959. The findings of the commission called for government's participation in the ownership of the two companies. An outcome of this was the signing of the first Scheme of Control Agreement between the government and CLP in 1964 that initially lasted 15 years to 1978. From 1979, HEC also entered into a Scheme of Control Agreement with the government. These 15-year Schemes of Control agreements between government and the two companies have since been re-negotiated and the current ones will last until 2008.

During the 1960's and early 1970's, the growth in Hong Kong's economy fueled the growth of the electricity requirements which were met through oil-fired generation. Gas requirements were met by LPG and from towngas generated from fuel oil. The peak load from 1960 to 1973 for HEC grew over 3 times from around 100MW to about 420MW and that for CLP grew over 5.5 times from 145MW to around 960MW.

Then came the first oil shock of 1973/74 in which the price of oil shot up from less than US$5 per barrel to over US$12 per barrel. The government responded to the consequent rise in energy prices for Hong Kong consumers and to the almost sole dependence on oil by initiating drives in energy conservation, focusing on the security of fuel supply and by meeting the energy needs from divergent fuel sources. During the remaining years of 1970's, great efforts were made by all concerned to ensure Hong Kong could have adequate energy to propel her economy. From the early 1970's towngas was produced using naphtha and the maximum daily demand had grown to over 3 times in the period 1970 to 1981, from about 3.5 TJ to around 15.5 TJ. (1 TJ = 278 MWh)

This situation continued until 1979 when the second oil price increase hit Hong Kong. This time the oil prices shot up from around US$16 per barrel in early 1979 to hit around US$40 by end 1980. The need to switch from oil-fired generation to coal-fired generation was compelling and in 1982 more efficient coal-fired generation plants at Lamma Island and Castle Peak came on line. In 1981 the government also released the findings on gas safety and the ensuing demand from developers for piped towngas contributed to the growth of towngas requirements from 1981 onwards. During the period from 1982 to 1996 the maximum daily demand rose over 3 times from around 18 TJ to 78.6 TJ.

Commencing from the winter of 1985/86 a sudden drop in the oil prices, from about US$27 per barrel to under US$15 which eventually stabilised to under US$20, sent Hong Kong's price of energy downwards for three years from 1986 to 1988.

In the past decade from 1988 to the present, Hong Kong had continually diversified her fuel sources first through the import of electricity from nuclear generation plant from 1993 and then from natural gas fired combined cycle plants in 1996. In the area of energy policy, the government first set up the Energy Efficiency Advisory Committee (EEAC) in April 1991 to advise government on the energy efficiency and conservation initiatives suitable for implementation in Hong Kong. In August 1994, the Energy Efficiency Office was established in the Electrical & Mechanical Services Department to accelerate the development and implementation of the various energy efficiency and conservation initiatives arising from the EEAC as well as to provide technical support to the policy bureaux of the Government Secretariat in utility monitoring, energy efficiency and conservation matters.

In 1996, in response to the Consumer Council's report on assessing competition in the domestic water heating and cooking fuel market, the government set up the Energy Advisory Committee in July 1996 to advise the government on energy policy matters concerning energy supply, demand, energy efficiency and conservation, and any other related matters referred to it by the government. I have the great honour to serve that Committee as its Chairman and we have considered many topical issues in our deliberations in the past year, including matters concerning the electric and towngas companies, energy efficiency and conservation programmes, developments and other issues which will affect the many facets concerning how our energy needs could be met both now and for the future.

So in concluding my talk on the past 50 years in energy for Hong Kong, I hope that it will rekindle your interest in this vital subject. I would encourage you to be involved in discussions whenever and wherever you have the opportunity to address the many aspects in which energy issues may contribute to a sustainable development of our economy.

Thank you for your attention and I hope you will all find much to interest you in the wealth of subjects to be presented today by the many distinguished speakers. These should indeed show the way forward for HKIE's 50 years plus.

Paper No. 2

THE DESIGN, OPERATIONS AND MAINTENANCE OF GUANGZHOU PUMPED STORAGE POWER STATION

Speakers : Basil S. P. Yeung
First Deputy Station Manager
Anthony N. L. Leung
Contracts & Tech. Services Engineer
Edmond K. W. Chan
Electrical Maintenance Engineer
Guangzhou Pumped Storage Power Station
China Light & Power Co., Ltd.

THE DESIGN, OPERATIONS AND MAINTENANCE OF GUANGZHOU PUMPED STORAGE POWER STATION

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Guangzhou Pumped Storage Power Station
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Paper No. 2

ABSTRACT

Guangzhou Pumped Storage Power Station (GPSPS) consists of two phases, with capacity 4 x 300 MW + 4 x 300 MW. Phase I has been operating since 1994. By end 1999, when all phase II units are commissioned, GPSPS will be the largest pumped storage power station in Asia. CLP has purchased the right to use of 50% of capacity of Phase I. This paper presents the design features of the phase I plant, the functions of GPSPS in the Guangdong and Hong Kong network; how the station is jointly and remotely operated by both CLP and Guangdong Dispatch Centres; the management systems which are evolved from PRC, French and Hong Kong experience and culture; and the operations and maintenance experience of this PRC/French designed power station.

NOMENCLATURE

IOMC	Interconnection Operation and Management Committee
JMC	Joint Management Committee
GIS	Gas Insulated Switchgear
REMS	Remote Energy Management System
GPHC	Guangdong Electric Power Holding Company
MOEP	Ministry of Electric Power
EEL	Exxon Energy Limited
CLP	China Light & Power Company, Limited
PSDC	Hong Kong Pumped Storage Development Company, Limited
CFRD	Concrete Face Rockfilled Dam
RCCD	Roller Compacted Concrete Dam
CB	Circuit Breaker
COC	Chief of Consignment
CD	CLP System Control
GD	GPHC Dispatching Centre
CR	GPSPS Central Control Room
LC	Local Control Panel

1. INTRODUCTION

The Guangzhou Pumped Storage Power Station (GPSPS) is situated at Conghua, about 130 km away from Guangzhou. It comprises Phases I and II, each of which equipped with four 300 MW pumped storage units making GPSPS the world's largest pumped storage power station when fully commissioned. The electrical and mechanical equipment of Phase I and II are imported from France and Germany respectively, while the civil design, construction and plant erection are taken up by PRC contractors. PSDC (joint investment by EEL and CLP) has purchased the right to use 50% of the Phase I capacity, with CLP seconding staff to participate in the station management and production. GPHC and CLP thus share the right to dispatch the Phase I pumped storage units.

Such arrangement has created a unique opportunity for the establishment of a multi-cultural management system to effect a highly efficient power station with a slim organisation, while making significant contributions to the stability of both the GPHC and CLP grids through simultaneous remote control from both Dispatching Centres.

2. DESIGN

After extensive survey and study, GPSPS was able to identify the current site with excellent geographic and geological conditions which enabled the completion of the project with an underground powerhouse at very low civil work construction and maintenance costs. Major civil structures comprise the upper and lower reservoir dams, underground powerhouse 70 m below lower reservoir level, underground transformer hall, and tunnels connecting the reservoirs and the plant. Two natural valleys enabled the formation of two adequate sized reservoir by building two relatively small dams. Excellent geological conditions and stringent erection requirements made it possible to build underground caverns and tunnels with extremely small leakage rates of 0.32 l/s and 0.22 l/s respectively, much lower than most similar power stations.

Table 1. Major Civil Structure Characteristics

Upper reservoir CFRD: height	68 m
length	318.5 m
Lower reservoir RCCD: height	43.5 m
length	153.1 m
Powerhouse size (W x H x L)	21 x 44.5 x 146.5 m
Powerhouse submergence	70 m
Reservoir total capacity	24,000,000 m3
Reservoir live capacity	17,000,000 m3

The reversible pump-turbine units are of state-of-the-art design with high parameters, operating at 500 rpm and maximum head of 535 m. The runner is of vertical, reversible, single stage Francis type. Due to its high specific speed of 35.88 when compared with 429 rpm option, the runner weight is reduced by 40% and the cost by 30%. The maximum turbine efficiency achieved is 93.1%, 1.2% higher than the prototype model runner.

Table 2. Pump/Turbine Characteristics

Parameters	Maximum	Minimum
Generating mode		
Gross head (m)	541.80	509.60
Static head (m)	537.18	496.02
Turbine flow (m3/s)	62.88	68.73
Rated power (MW)	306.00	306.00
Maximum output (MW)	347.70	
Pumping mode		
Pump head (m)	550.01	514.14
Discharge (m3/s)	52.75	60.03
Pumping input (MW)	310.70	326.08
Rated speed (rpm)	500	
Max. runaway speed (rpm)	700	
Axial hydraulic thrust (kN)	2100	

The generator-motor is of semi-umbrella type with capacity of 333 MVA. Each stator frame is in four segments for site assembly. Rotor is also site stacked. Its structural design was optimised for easy erection and commissioning at a three month interval. Units can be started in pump mode either by a Static Frequency Converter or back-to-back starting. The generator output is transferred to the main transformer via three 18 kV isolated phase busbar system with a 3-phase SF6 generator CB and 5 phase reversing isolators in between. The main transformer has a capacity of 340 MVA and steps up generator voltage of 18 kV to 500 kV.

The high voltage side of the main transformer is connected to the 500 kV GIS system. The GIS system has four CB connected in a ring configuration. The 500 kV GIS has two lines output and are connected to the outdoor switchyard via 2 sets of 500 kV oil filled cable. The total length of each cable is about 600 m long with an elevation of 200 m.

Power from GPSPS is transmitted via two 500 kV overhead lines through the Guangdong grid and the Nuclear transmission network (500 kV and 400 kV) to the CLP grid. The station is designed to be capable of fully remote controlled by the two Dispatching Centres through high degree of automation and an advanced Supervisory Control and Data Acquisition (SCADA) system.

3. MANAGEMENT

The station organisation, based on Electricite de France (EdF) management system modified in accordance with PRC actual conditions and CLP power station management experience, is a successful mingle of multiple cultures and systems. The current GPSPS manpower of only 88 staff (including both PRC and HK) share the responsibilities of management, operations, maintenance, work preparation and safety of the station. The organisation is slim, especially by PRC standard which allow 872 staff for a station of such size. Each staff is thus assigned a wide range of responsibilities, e.g. a COC normally carries out troubleshooting on his own.

Table 3. Motor/Generator Gharacteristics

Rated generator output	300 MW
Maximum generator output (p.f.=1)	333 MVA
Rated motor output	
309.7 MW	
Rated voltage	18 kV
Rated power factor (generator)	0.9 (lagging)
Rated power factor (motor)	> 0.95
Rated speed (generator)	500 rpm
Rated speed (motor)	500 rpm

A slim organisation relies on a systematic and scientific management system. The workforce carry out their work in accordance with written Operating Instructions, job cards, quality check sheets, etc. so the quality of work can be ensured. The staff are continuously trained on new technologies and management skills to improve their ability.

Networked office computers are used extensively in the station. Data and information on plant drawings, stores materials, operational statistics, station reports, defect management system and letter management system can be accessed via the computer network. An in-house developed software system allows real-time plant data to be accessed by users in the Administration Building located outside the powerhouse.

Station performance targets are established each year and displayed prominently to give a clear guidance to station staff. Each department therefore prepares its detailed monthly work plan, and monitors the status and progress accordingly. Weekly meeting is held between station management and middle level staff to make everybody aware of important issues and tasks. Meetings and dedicated groups are also timely organised to deal with specific plant and management problems.

The station management reports on finance and management matters to the JMC formed between GPSJVC and PSDC which is the highest management organisation in the PRC/HK co-operation project. Furthermore, the IOMC is formed among GPSJVC, CLP, GPHC and PSDC to look after operation of the interconnected network. The station performance is audited by GPHC and MOEP.

4. OPERATIONS

The pumped storage units are extremely flexible in operation, being capable of operating in synchronous condenser modes and launcher mode apart from generating and pumping. These units also contribute significantly to the safe operation of the Daya Bay nuclear units, by offering night time loads to absorb nuclear power such that deloading of nuclear units can be minimised.

Moreover, the units can be operated in different ways with very quick response to satisfy the requirements of the two grid systems. Firstly, almost instant large capacity spinning reserve can be offered to the system by operating units on part load. Secondly, quick load (including both generator start and pump-to-generator start) can be offered to meet system emergency. A specific low frequency stop pump and high frequency stop generator protection scheme is designed for this purpose. Thirdly, assistance to regulate system voltage can be offered by operating as synchronous condenser. Quick starting and interruptible pumping load made it indispensable in both GD and CLP network. The starting times for various modes and mode change times are shown below in Table 4.

Table 4. Mode Change Transition Times

Mode change	Time
Stop --> generator	120s
Stop --> pump	460s
Pump --> generator (normal)	360s
Pump --> generator (emergency)	150s
Pump --> stop	240s
Generator --> stop	315s

In general, both Dispatching Centres can exercise remote control by sending capacity and load setpoints to GPSPS. The SCADA system then computes the combined setpoints to determine the optimum control actions including starting or stopping units in pump or generator mode, increase and decrease of unit load. The software is designed to operate machines in the most economic way to satisfy the dispatching requirements under different differential heads. In addition, since the units are connected to the GPHC grid, GPHC can also send voltage setpoint and synchronous condenser start commands to control the system voltage. Major operational issues are discussed in the IOMC operation group meeting. Energy transferred between the parties is recorded by the REMS system.

Since January 1995, the Central Control Room has been manned by only a single operator per shift. This operator is responsible to perform all daily routine monitoring and operational duties, including diagnosis and clearing minor defects. A group of experience staff is put On-call to provide back up to the operator in case major defects or incidents occurred. On-call staff should arrive at the site within 15 minutes of receiving the call. More important incidents will also be reported to On-call management staff.

Table 5. Major Control Features

Control function	CD	GD	CR	LC
Set capacity setpoint	√	√	√	
Set load setpoint	√	√	√	
Set unit priority	√	√	√	
Set no. of sync. condensers		√	√	
Set 500 kV voltage		√	√	
Open/close 500 kV CB		√	√	
Start/stop individual unit			√	√
Control active/reactive power			√	√

Safety is a top performance indicator of the station. Up to the end of August 1997, GPSPS maintain an accident free period of 1288 days. GPSPS has established a safety management system which includes safety authorisation level scheme to limit level of work according to competence of individuals. Work Permit system, mechanical key interlock system are in strict adherence to ensure safe isolation and avoid mis-operation of key electrical equipment. GPSPS also started to adopt the NOSA 5-star safety audit system since 1996 in view of CLP's experience.

Care for the environment is also a high priority in GPSPS, and a lot of effort has been spent to preserve or improve the station environment. Even though hydro power is a very clean source of energy with practically no emission, reservoir water quality checks are done regularly to ensure cleanliness of downstream river. Reservoir water quality actually improved since impounding. Landscaping of exposed excavated areas are done extensively, including total landscaping area of 110,000 sq.m., growing of over 400,000 trees along access roads and hydroseeding to grow grass on rocky hill slopes.

5. MAINTENANCE

The maintenance department in GPSPS adopts different systems to effectively satisfy requirements of both networks by providing good plant performance with optimal cost. These systems includes the On-call system, MECEP system, Technical supervisory system, Technical modification system, Manufacturer defect system, Spare replacement (SR) system, Stores and Purchasing system.

The On-call system is a shift roster system changing shift once a week. Each shift includes one management staff, one operation COC, one staff each from electrical, automation and mechanical maintenance branches. When a fault occur in the plant that requires attention, the on duty operator will page the relevant on-call person. When this person receive a page call, he is required to arrive the powerhouse to attend to the problem within 15 minutes. The on-call system guarantee 24 hours attendance to any fault and it also guarantee quick action in eliminating plant failures and dealing with emergencies.

The MECEP system provides a platform for systematic and exact routine maintenance plan. The MECEP system is developed by EdF, it has three types of procedure namely C1, C2 and C3. C1 procedure is for routine maintenance work involving no equipment or plant outage. C2 procedure is for equipment outage routine maintenance work and C3 procedure is for plant outage routine maintenance work. The C1, C2 and C3 procedures provides full details and instructions enabling staff to carry out the routine maintenance work safely and soundly.

The Technical supervisory system is a continuous technical monitoring of the power plant. Periodic assessment in 9 technical areas are made to ensure specific standards are maintained. Condition based maintenance techniques are used while the following advanced techniques are being pursued to reach predictive maintenance objectives:

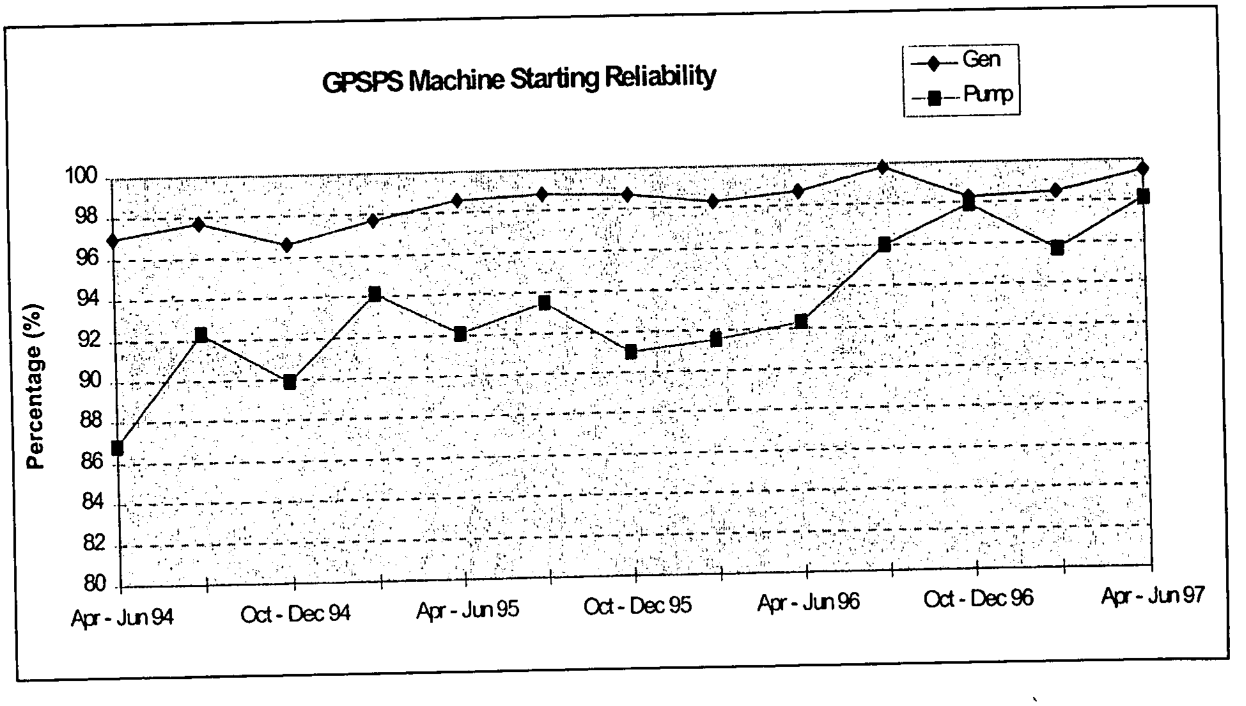
- on-line shaft line monitoring
- generator partial discharge
- thermovision on electrical equipment
- auxiliary plant surveillance data acquisition

The Technical modification system provides a channel on site for enhancement of plant efficiency and performance, or rectification of plant defects and deficiencies caused mainly by inadequate design. In each case, suggestion of technical modification with description of the technical deficiency or plant defect are made by the staff. His or her suggestion will then be reviewed by the Chief engineer. When the suggestion is judged to be a potential solution, a further meeting will be held with all parties involved to decide on the implementation of the modification. After continuous efforts to rectify defects, pump and generator starting reliability has risen significantly since commercial operation as shown in the start reliability chart.

The Manufacture defect system keep on track of plant defects arising from different causes with the most common one being manufacturer design deficiencies. All plant defects are categorized according to manufacturer responsibility and are kept in computer database so that it can be traced. Defects that are cleared will have a work report recorded and problems that are not solved will be continuously put forward to the manufacturer until they are solved.

The Spare replacement system provides the plant with constant replenishment of spares

Paper No. 2



that were used. With each equipment that were faulty and need to be replaced, the faulty equipment will be send back to the manufacturer in exchange for a replacement part or to be repaired. This system guarantee replenishment of spares from the manufacturer so that availability of the plant can be maintained.

The stores system in GPSPS are very systematic. All spares are numbered according to their types and all records are kept in an in-house developed computer system. In the system, a specific spare part could be searched according to it's name, manufacturer, stock number, sub-service unit or type. The system also provides the user with information such as storage locations, stock and re-ordering level and quantities. Purchasing of non-stock spares and goods can be requested simply by filling out a goods requisition form. The requisition is reviewed by the station manager and purchasing is made flexible with local and overseas option.

6. CONCLUSION

Considerable time and effort were deployed in the early commissioning and operation stages, firstly to sort out the optimal and practical management systems among the French, Hong Kong and PRC experiences; secondly to resolve different plant problems. Excellent multi-cultural co-operation, excellent site location and conditions, good civil construction, balanced staffing (experienced vs. young), dedicated effort in resolving problems and achieve first class performance, all level dedication in implementing good management systems and computerised management are all important factors for the success of GPSPS.

At the end of 1996, the Ministry of Electric Power, PRC awarded GPSPS a "First Class Hydro Power Station" title, which is the first one in PRC. GPSPS are still striving to achieve a world class standard with only a management team for both Phase I and II, meaning less manpower per MW and more cost effectiveness.

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Paper No. 3

TRANSMISSION AND DISTRIBUTION OF ELECTRICITY IN HONGKONG ELECTRIC - PAST, PRESENT, AND FUTURE

Speakers : Chan Loong
Chief Construction & Maintenance Engineer
Chan Ping Kee
Senior Protection Engineer
The Hongkong Electric Co. Ltd.

TRANSMISSION AND DISTRIBUTION OF ELECTRICITY IN HONGKONG ELECTRIC - PAST, PRESENT, AND FUTURE

Chan Loong
Chief Construction & Maintenance Engineer
Chan Ping Kee
Senior Protection Engineer
The Hongkong Electric Co. Ltd.

Paper No. 3

ABSTRACT

The Hongkong Electric Co. Ltd. (HEC) began supplying electricity in Hong Kong on 1st December 1890 until the war broke out in 1941.

The normal electricity supply resumed after the war. In the 50 years from 1946 to now, the consumption of electricity on Hong Kong Island increases 138 folds; while the number of customer accounts only increases 13 times. The period has seen major evolutions of the HEC's transmission and distribution (T&D) system which is to satisfy the ever-growing needs. It includes the continuous expansion and upgrading of the network, application of advanced technology, marked improvement in supply reliability and customer services. As a result, the HEC T&D system has developed into one of the most reliable and efficient supply networks in the world.

In the paper, the authors present the key stages of development for the HEC's T&D system in these 50 years, the achievement and experience learned, and look forward to future development and challenges ahead for the years to come.

1. INTRODUCTION

The Hongkong Electric Company Limited (HEC) was incorporated on 24th January 1889 and began to supply electricity to Hong Kong Island on 1st December 1890. By the 30's, HEC had already been supplying to almost every part of the urban and rural areas of Hong Kong Island from West Point to Shaukeiwan, from Victoria to Aberdeen, until December 1941 when the power station in North Point was shut down and abandoned due to the invasion of Hong Kong by Japan. Following liberation, the HEC employees returned to the North Point Power station in August 1945 and resumed the electricity supply to Hong Kong in early October.

The 50 years from 1946 to 1996 saw only 13-fold increase in the number of customer accounts, while a 138-fold increase in the electricity consumption on Hong Kong Island, Ap Lei Chau Island and Lamma Island as shown below.

Year	No. of Customer Accounts	Units Sold	
		Million kWh	Compound Growth Rate Over 10 years
1946	38,200	64	---
1956	74,300	263	15 %
1966	155,400	815	12 %
1976	250,400	1,979	9 %
1986	385,300	4,822	9 %
1996	504,000	8,873	6 %
Compound Growth Rate (46 -96)	5.3 %	10.4 %	

In the meantime, the HEC's transmission and distribution (T&D) system has undergone evolutions in various aspects to satisfy the ever-increasing needs of the society with a sustained growth rate of electricity demand of about 10% per annum. As a result, it has developed into one of the most reliable and efficient supply networks in the world.

Presented in the following sections are the key stages of development of the T&D system in the past 50 years. These include the continuous expansion and upgrading of the power network, application of advanced technology, marked improvement in electricity supply reliability and customer services. Moreover, the achievement and experience learned, together with possible future development and challenges ahead are described.

To start with, let us look at the brief history of the HEC power stations and the evolution of the transmission and distribution voltages.

2. FROM NORTH POINT POWER STATION TO LAMMA POWER STATION

When the North Point site was purchased by the Company in 1914 for a new power station, it was only a marine lot of what was in effect seabed on the shorefront of an uninhabited area. The North Point Power Station was commissioned five years later and remained the only power station after the war.

In 1964, North Point district became a densely populated residential area and the Company realised that the coal/oil-fired North Point Power Station, which had an installed capacity of 225MW, would no longer be suitable for generation in the next decade on environmental ground. Also, it would not be able to meet future demand. A new oil-fired power station was therefore built at Ap Lei Chau and it was commissioned in 1968. The North Point Power Station was closed down in 1976.

In 1982, a new power station of HEC on the remote Lamma Island began to generate electric power and part of the generating capacity at Ap Lei Chau Power Station was then migrated to Lamma. When Ap Lei Chau Power Station was decommissioned in 1989, Lamma Power Station became the only power station of HEC. Its installed capacity was 2,995 MW in 1996.

As can be seen from the above, there were two complete changes in the location of power generation source in the past 50 years. Each time the new power station had higher installed capacity, but was further and further away from the load centres situated along the northern belt of Hong Kong Island. To cope with such changes, new transmission networks were planned, installed and commissioned **in advance** in order to deliver the bulk of the electric power to the same load centres.

3. FROM 6.6KV TO 275KV AND FROM 200V TO 220V

Before the laying of the first 22KV cable from North Point to Central in 1949, power from the North Point Power Station was transmitted and distributed at 6.6KV only. As the power stations were getting larger and further away from the city and with increasing load density in Hong Kong, the transmission and distribution voltages were upgraded in stages as shown below.

Year	Maximum Demand	Transmission Voltage(s)	Distribution Voltage(s)
1946	14	6.6KV	6.6KV
1949	29	22KV	6.6KV
1958	75	33/22KV	6.6KV
1961	114	33/22KV	11/6.6KV
1964	184	66/33/22KV	11/6.6KV
1971	342	132/66KV	11KV
1982	932	275/132/66KV	11KV

In retrospect, the use of 33KV as transmission voltage in 1958 was rather short-lived as it was completely phased out in just ten years by 1968. On the other hand, the 275KV network has been serving the Company well in the past 15 years and can lead us into the 21st century.

The use of 11KV as the distribution voltage and the complete phasing out of the 6.6KV has proved to be a decision with foresight.

On the low voltage side, 200/346V was first adopted in 1920 and the voltage prior to that was only 100V. To be in line with the commonly adopted low voltage system in other parts of the world, the voltage was upgraded to 220/380V by adjusting the tappings of 3,297 distribution transformers in the HEC network between January 1993 and February 1997.

4. FROM OVERHEAD LINE TO SUBMARINE AND TUNNEL

When the decision to move the power station to Ap Lei Chau was made in 1964, overhead pylon-borne transmission rated at 132KV was constructed to overcome the mountainous terrain between the south and north of Hong Kong Island. The overhead lines were first commissioned in 1969 for power transmission at 66KV and later the voltage level was upgraded to 132KV in 1971.

In 1979, Hong Kong was hit by Typhoon Hope. A few 132KV overhead line circuits fed by Ap Lei Chau Power Station were tripped due to flying debris. Since then the Company has adhered to the belief that underground T&D system is best suited to the weather conditions of Hong Kong. With a few exceptions in the southern part of Hong Kong Island and on Lamma Island, all the T&D networks of HEC are now purely underground. In addition to its reliability against typhoons and lightning strikes, the dominance of underground cable circuits has resulted in the least intrusion into the environment.

Transmission submarine cables were first commissioned in 1981 at 132KV for interconnection with the China Light and Power Co. Ltd across the Victoria Harbour. 275KV submarine cables were introduced in 1982 to deliver the power from Lamma Island to Hong Kong Island through the busy Lamma Channel.

When new routes between the south and north were required for the 275KV circuits, the tunnel option instead of overhead arrangement was chosen. A 3.1 Km tunnel between Wah Fu and Bowen Road was constructed for two 275KV circuits in 1988. Five years later, another 5.7 Km tunnel was drilled between Nam Fung Road in the south and Chaiwan Road in the east for another two 275KV cable circuits.

The use of submarine cable and tunnel options for transmission of electric power from power station will probably continue into the next century as it is most likely that the land for the future power station(s) will only be available outside Hong Kong Island.

So much on the global aspects, we now turn to take a look at the equipment aspects below.

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5. FROM OIL INSULATED TO OIL-FREE EQUIPMENT

Mineral oil is an excellent electrical insulant and arc quenching medium. It is widely used in the electric power industry, e.g. for transformers, cables and switchgear etc. The major drawbacks of using mineral oil are fire risk and pollution. With high-rise commercial and residential buildings incorporating a substation or right next to a substation, any sizeable fire of the substation may have grave consequences.

In Asia, other than Japan, HEC was one of the few utilities which started using 132KV SF6 gas insulated switchgear (GIS) in as early as 1974. The use of GIS not only reduces the fire risk, it also renders a much smaller size of the switching station which can as a result be located right in the middle of the town centre. Through redevelopment and uprating exercises, all transmission switchgear in HEC are now SF6 gas insulated.

On the distribution side, the Company switched to non-oil 11KV switchgear in the late 1970's by using air at first, and later SF6 as insulation media together with vacuum circuit breakers (VCB) and SF6 rotating arc circuit breakers. Replacement programs were carried out since 1987 and all oil circuit breakers will be completely phased out by the end of this year.

For the power cables, XLPE cables were introduced in 1978 for LV and in 1979 for 11KV to substitute the Paper Insulated Lead Sheathed Cable (PILC) and now account for over 70% of all distribution cables. 132KV XLPE cables were introduced for short-length circuits inside substation in 1987 and for long interconnector circuits in 1992. It is envisaged that the use of 275KV XLPE cables will be feasible when the corresponding production technology and jointing technique become mature in a couple of years.

To achieve completely oil-free substations, the biggest challenge is transformer. After detailed study, HEC started using SF6 gas insulated 11KV distribution transformers in 1981 and now they represent over 75% of the distribution transformer population. In 1990 the first 275KV/11KV 30MVA gas insulated zone transformer was commissioned and since then, gas transformers rated from 40 to 60MVA have been widely used in HEC zone substations.

With all the necessary oil-free components in place, the first completely oil-free 132/11KV zone substation was commissioned in 1992. By early next century, we could expect to have completely oil-free substation even at the 275KV level with the introduction of 275KV XLPE cable.

6. POWER SYSTEM PROTECTION - FROM FUSES AND ELECTRO-MECHANICAL RELAYS TO STATIC AND NUMERICAL RELAYS

The past 50 years saw the application of more and more sophisticated protection relays as a result of the advancement in technology. At first, only fuses and simple electro-mechanical relays were used to protect the primary apparatus. Though they are still widely used in the HEC's T&D system for their reliable performance and economic advantages, their application is confined to cases where only simple functions/characteristics are required. On the other hand, static and numerical relays are adopted in cases where more complex characteristics and better accuracy are needed.

Static relays were first introduced in 1971 to provide distance protection for the HEC 132KV overhead lines and cables. Since then, other types of static protection devices have been used.

With the advent of the 275KV system in 1980's, static phase comparison relays and distance relays were initially employed to protect the 275KV cables. However, comprehensive studies performed in the mid-1980's revealed that very large transient high frequency surges and low order harmonic contents would appear in the 275KV system during fault conditions for the following years. Also, the fault current would have a high d.c. component with a long decay time. As a result, the above-mentioned static relays might have either slow operation under in-zone fault or unnecessary operation under out-zone fault. To overcome the problems, new types of relays including numerical current differential and numerical distance relays were introduced in 1989 for the protection of the 275KV cables.

Modern numerical relays have many advanced features and technical advantages over static relays - for example, continuous self-monitoring feature, more sophisticated relay characteristics, ability to capture system fault information, ability to allow remote communication with office PC for interrogation etc. Therefore, it is envisaged that HEC will migrate from static relays to numerical relays progressively in the future.

7. COMMUNICATION NETWORK - FROM METALLIC PILOT CABLES TO DIGITAL MICROWAVE RADIO AND OPTICAL FIBRE SYSTEMS

To meet the stringent requirements of day-to-day operation of the power system, an effective and reliable communication network is essential for the transmission of information among the Company's power stations and operational premises. The communication channels are primarily used for system protection signalling, high speed intertripping, in-house telephone systems, computer data links and SCADA systems etc.

Before 1981, communication of the above mentioned signals between the power stations and 132KV substations depended mainly on the in-company pilot/telephone cables, which were laid in common trench with the power cables.

In early 1981, the first large capacity digital microwave radio link was commissioned in conjunction with the Lamma 275KV transmission project to provide reliable and interference-free communication channels to the major load receiving substations for operational needs.

In terms of quality, reliability and capability, microwave radio link is an excellent transmission medium for power system operations. However, due to geographical constraints, the microwave radio system can hardly be further extended to those major substations located on the northern part of Hong Kong Island. This has triggered the necessity to establish a wideband digital optical fibre communication system to cope with the ever-increasing demand on reliable and high-grade channels for the power transmission network.

As a result, the first phase of the digital optical fibre system linking among Lamma Power Station and other operational premises was put into service in mid 1987 in conjunction with 275KV transmission project. The broadband optical fibre communication network has been extended to cover all major load receiving substations to satisfy the ever-demanding requirements on high performance broadband channels for power system operations and control.

8. COMPUTERISATION- SUBSTATION CONTROL AND MONITORING, MAPPING COMPUTER, CUSTOMER AND OPERATIONAL INFORMATION SYSTEM

HEC was among the first few companies in Hong Kong to employ computers in both business and engineering applications. Computerised billing was introduced in 1969, the same year when single tariff replaced the previous multiple metering arrangement for 'Lighting' and 'Power'. Supervisory Control and Data Acquisition (SCADA) system for primary substations was also introduced in 1969 and it covered all the HEC primary substations within a short period of two years.

The concept of remote control and monitoring was applied to distribution substations in 1980. After the first batch of 112 substations in Central district were successfully connected to the distribution system computer, extensive pilot cable laying and switchgear replacement programs were launched to include all the 3,000 plus distribution substations in the SCADA system by 1996.

To enhance the effectiveness of keeping/ retrieving the underground cable records, the Company embarked on Mapping Computer System in 1979. In the absence of any digitised base maps, it took the Company nearly two years to convert both hard copy cable records and maps of Hong Kong Island to digital form. Over 100 man-years were spent in the data conversion and the first generation Mapping Computer System was operational in 1981.

The application of computers soon extended to the handling of customer service/emergency calls and maintenance scheduling for T&D equipment in 1984. To date, a large number of customer and operational information systems have been computerised, rendering better utilisation of resources, improved safety and reliability as well as providing better customer services.

Computerisation has been instrumental in the operation and management of the T&D system in the past 30 years. We expect the trend will continue into the next century. While in the past the development was driven by the availability of technology, it is envisaged that future applications will be more customer services orientated and aimed at adding value to the core product that we have been delivering in the past 107 years.

9. THE ACHIEVEMENT

HEC has achieved the status of being one of the most reliable electric utilities in the world as reflected in the reliability rating of supply in the recent years shown below.

Year	Reliability Rating
1993	99.9955%
1994	99.9976%
1995	99.9979%
1996	99.9987%

10. CHALLENGES AHEAD

The challenges we are facing are driven by (a) the customers who are always looking for improved services and better value for money and (b) the environment in which the space available for installing new equipment including cables is getting more scarce.

With the ever commercialisation on Hong Kong Island and pursuit of better quality of life by the Hong Kong people, the demand for electricity is expected to continue to grow, though at a lower rate when compared with the past 50 years. HEC will install new generating capacity and expand the T&D networks to meet the demand. Also, as a service provider, HEC will strive to deliver electric power safely, reliably and efficiently by improving the existing T&D system.

To overcome the space constraint, HEC will continue to look for environmentally friendly, reliable, safe and compact equipment that can be installed in limited space left. Higher voltage, new materials and novel installation methods are just some of the possible means.

A reliable electricity supply is a pre-requisite for the quality of life. It is believed that with good engineering practice, judgement and vision, we could exceed the expectations of our customers.

11. ACKNOWLEDGEMENT

The authors would like to express their sincere thanks to the Management of The Hongkong Electric Co. Ltd for the permission to present this paper.

12. APPENDIX

- Simplified HEC Transmission Network

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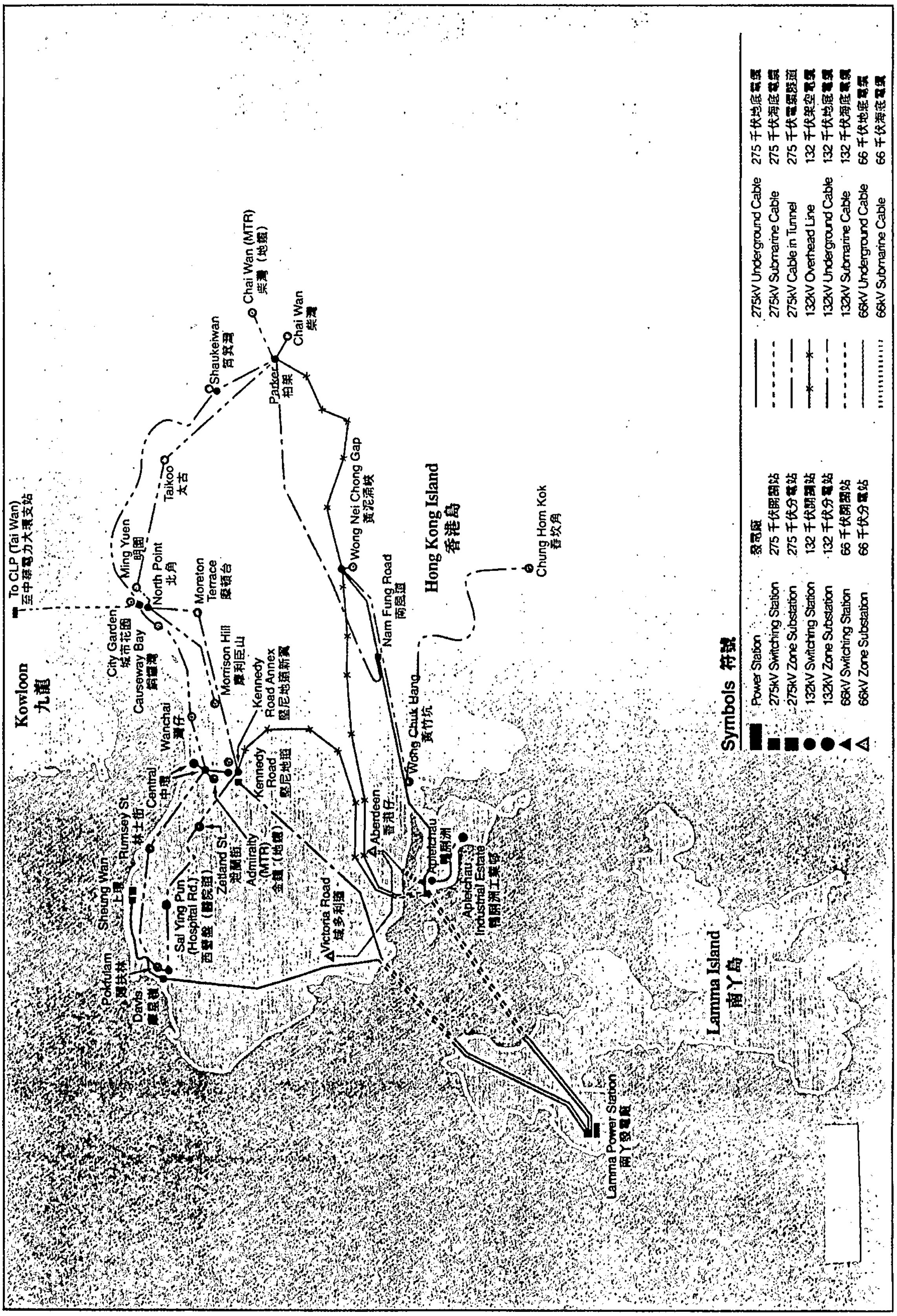
Paper No. 3

Appendix - Simplified HEC Transmission Network



Paper No. 4

STEAM, DIESEL AND ELECTRIC - 50 YEARS OF DEVELOPMENT IN KOWLOON - CANTON RAILWAY

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STEAM, DIESEL AND ELECTRIC - 50 YEARS OF DEVELOPMENT IN KOWLOON - CANTON RAILWAY

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Paper No. 4

ABSTRACT

The paper describes how KCR switched over from steam traction to diesel traction in the early 1950s, followed by the double tracking and electrification programme in late 1970s to the early 1980s.

For the ten years between 1985 and 1995, KCR also saw tremendous number of projects to enhance capacity and performance to meet patronage growth which was substantially above that predicted by the planner in the late 1970s.

The paper also describes the planning, construction, commissioning and start of operation of the Light Rail System.

1. STEAM AGE

When the British Section (BS) of Kowloon-Canton Railway (KCR) opened for traffic in 1910, it possessed a total of four steam locomotives, two for mainline operation and two for shunting. With a bunker capacity for 3.5 tons of coal and water tank capacity of 2,500 gallons, each mainline locomotive could provide a maximum tractive force of 23,350 lbs (104 kN) and could operate at a maximum speed of around 40 mph. The fleet gradually expanded to a total of eight mainline locomotives in the 1920's, four of which could provide a maximum tractive force of 33,700 lbs (150 kN). KCR (BS) continued to be operated by steam traction until the first two diesel-electric locomotives were introduced in 1955. The last steam locomotive was scrapped in September 1963 which formally marked the end of the steam age in KCR (BS).

2. DIESEL AGE

2.1 BACKGROUND

Dieselization of KCR (BS) started in 1955 with the arrival of two General Motors Class G12 diesel electric locomotives from Clyde Engineering in Australia. Each locomotive was rated at 1,125 hp, provided a continuous tractive force of 28,000 lbs (125 kN) and could operate with a maximum speed of around 100 Km/h. The fleet of diesel electric locomotives continued to grow both in number and horsepower until 1977 when there were twelve General Motors diesel electric locomotives with the largest one, class G26 rated at 2,000 hp and capable of providing a continuous tractive force of 56,000 lbs (250 kN). This fleet of diesel electric locomotives still operates in KCR today, mainly for freight trains, shunting and engineering trains.

2.2 DIESEL ELECTRIC LOCOMOTIVES

Each locomotive is fitted with a diesel engine directly driving a dc generator, the output of which feeds the dc series wound traction motors through an array of contactors. Speed control is achieved through one or more of the following means:-

a. Changing the speed of the diesel generator in eight steps from 275 to 835 rpm which in turn varies the output voltage of the generator;

b. Changing the traction motor connection between series-parallel and parallel;

c. Adding diverter to the traction motor field.

3. ELECTRIFICATION

3.1 PLANNING

In January 1977, consultants from Transmark commenced a study on the feasibility and viability of modernizing KCR (BS) to cope with the rapid growth of patronage. The consultancy was completed by the end of 1977 and in early 1978 Hong Kong Government accepted Transmark's recommendation to electrify KCR (BS) including other associated provisions such as resignalling, construction of new stations and maintenance depot, and the acquisition of new rolling stock. The total project cost was estimated to be around $3 billion, to be met entirely from Government and railway resources with no outside finance.

3.2 THE PROJECT

The electrification programme started in 1980 with award of contract to Balfour Beatty for the installation of the power supply and overhead line equipment based on the 25 kV 50Hz single phase ac catenary system. 3 or 1.5 kV dc systems were ruled out because they were becoming increasingly rare for mainline systems. Any system using track level current collection was also out of the question on safety grounds. A 25kV system had the added advantage that the same system had been adopted by the Chinese side as the electrification standards for railways and it was expected that the date might not be too far away when electric trains could travel between China and Hong Kong.

3.3 COMMISSIONING

The electrification programme was divided into two stages. Stage one was from Hung Hom to Racecourse which was completed in May 1982. Stage two was for the remaining section which was completed in July 1983. Resignalling of the railway was also completed in time for full electric train services from Hung Hom to Lo Wu to start on 15 July 1983 with a ceremony officiated by the late Governor of Hong Kong, Sir Edward Youde.

4. ELECTRIC MULTIPLE UNITS (EMU)

KCRC East Rail's EMU fleet consists of 351 cars, which were designed and manufactured by the British-based company Metro-Cammell Ltd with traction equipment supplied by GEC. Each of the 12-car train includes four motor cars and eight trailer cars. Passenger carrying capacity is 3500 at crush load. The train is designed to obtain power from the overhead 25 kV, 50 Hz single phase supply and to operate at a maximum speed of 120 km/h. Each motor car has four traction motors with each one rated at 700 V, 228 kW.

4.1 EMU WITH TAP-CHANGER POWER CONTROL

For the first batch of 15 trains, the tap-changer power controller utilises the different voltage output from the transformer tapping for speed control. The ac voltage from the transformer secondary is rectified through an uncontrolled full bridge rectifier. The output feeds to the series wound dc traction motors dir.ectly.

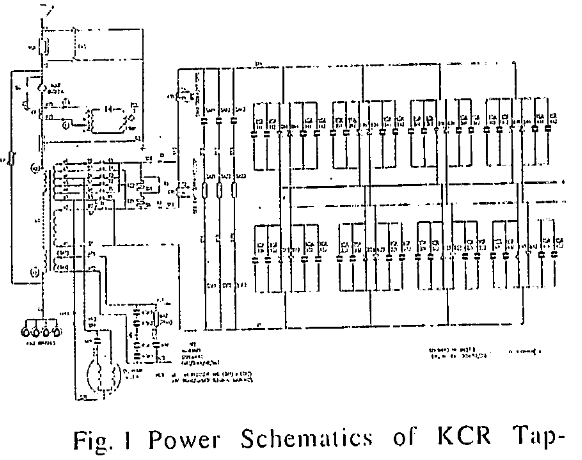

Fig. 1 Power Schematics of KCR Tap-Changer EMUs

This the simplest voltage control technique for dc drives under an ac line. However, jerk appears during acceleration due to the step change of input voltage and current.

4.2 EMU WITH THYRISTOR CONTROLLED DC DRIVES

The later batch of electric trains adopts thyristor controlled rectifier technique for controlling the speed of the dc traction drives. Voltage control is achieved by varying the firing angle of thyristors. A phase-control thyristor is turned on by applying a short pulse to its gate and turned off through natural commutation. In the KCRC EMUs, two converters are connected in series, as shown in FIG. 2, so as to operate at higher voltages and to improve power factor. The vehicle performance is controlled by a single ėlectronic control panel which converts the driver's speed command from the master controller to voltage and current signals. The feedback provided by the current measuring devices in the traction motor circuit advances the thyristor bridge firing angle to maintain the motor current as the train accelerates. This provides smooth acceleration. When the train accelerates up to half voltage, the upper bridge takes over with the lower bridge fully conducting. When full conduction of the upper bridge has been reached, and weak field has been set, the weak field switch closes to initiate weak field so that the traction motors can operate optimally at higher speeds.

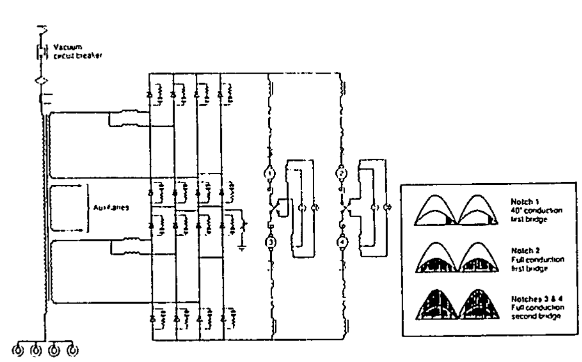

Fig. 2 Power Schematics of KCR Thyristor Control EMUs

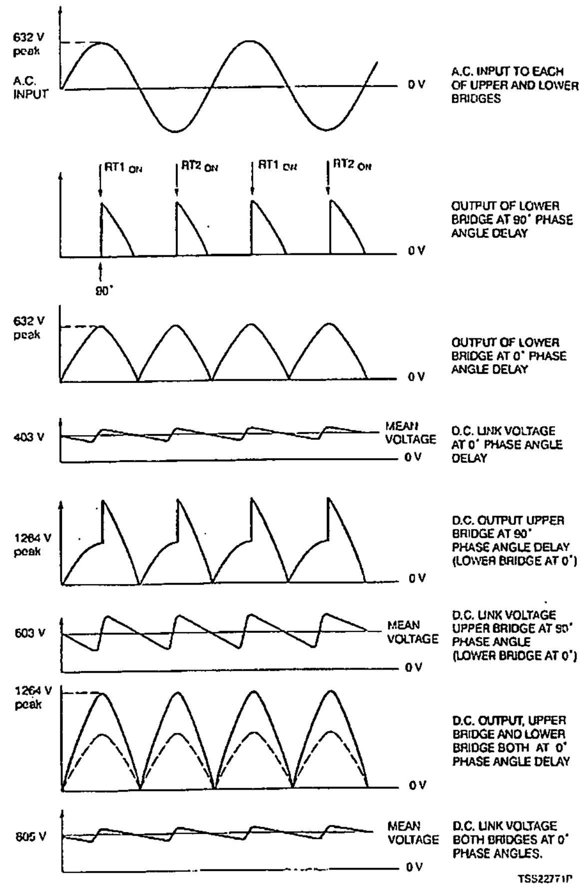

Fig. 3 Voltage Waveform in Thyristor Control EMUs

4.3 AUXILIARY POWER SUPPLY

Each of the four motor cars in the electric train are fitted with a 200 kW Motor-Alternator Set to provide the 3 phase, 60 Hz, 440 V auxiliary power supply for the air-condition and lighting system.

4.4 REFURBISHED EMU

To cope with rapid growth in patronage, all the EMUs are being extensively refurbished to increase passenger capacity by 15%. All transformer tap-changers will also be replaced by thyristor controlled rectifier to improve reliability and passenger comfort through reduced jerking.

5. LIGHT RAIL VEHICLES (LRV'S)

The Tuen Mun, Yuen Long Light Rail System

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started operation in 1988 with a 750V dc overhead current collection system and 70 Light Rail Vehicles manufactured by Comeng in Australia. In 1992, 30 LRVs manufactured by Kawassaki in Japan were added to the system. The vehicles have a maximum acceleration of 1.3 m/s2 and can operate at a maximum speed of 80 Km/h. AEG is the traction equipment sub-contractor for the whole fleet of 100 LRV's.

5.1 EXISTING LIGHT RAIL VEHICLES

The existing LRV uses chopper technology for acceleration/deceleration control. The micro-processor of the Chopper Control Unit regulates the traction motor current such that the resulting acceleration is proportional to the driver hand controller position, quite independent of the LRV passenger loading or gradient climbing.

The LRV mixes with road traffic. The brake performance must be compatible with road vehicle. There are four braking mechanism, the electric brake, mechanical disc brake, magnetic track brake and the sanding for wheel slip-slide protection. During electric brake, the traction motor serves as a generator either to feedback electric power to the overhead line or dissipate power to the brake-resistor.

In emergency brake, the deceleration is higher than 2.7m/sec. The electric brake can operate from 70 Km/h down to 9 Km/h in theory. In practice, the electric brake stops at 15 Km/h. The disc brake takes over at speed below 15 Km/h, so as to have more wear on brake pad, to reduce the brake pad glazing problem. During emergency brake, the magnetic track brake is energized and attracted to the rail top to provide more frictional force.

The disc brake will be applied when electric brake fails. Therefore the LRV brake had full redundancy when running at speed above 15 Km/h. There will be less brake redundancy at speed below 15 Km/h.

5.2 NEW LIGHT RAIL VEHICLES

To cope with the growth of patronage order for 20 new LRV's were placed in September 1995 with Goninan as the main contractor and Mitsubishi as the sub-contractor for traction equipment. The new LRV's employs ac propulsion technology. Each LRV carries two static traction inverters to convert the 750V dc from overhead wire to a variable voltage, variable frequency (VVVF) three phase ac source to drive the ac traction motors. The speed of LRV is controlled by frequency of the traction inverter output. The control of induction motor is based on fuzzy theory to obtain fine slip/slide characteristics which is more than 18% of adhesive coefficient at powering mode.

There are two ac motors per bogie. Each axle of the bogie is driven by a motor independently, so that wheel wear due to the wheel slide/slip or curve negotiation will be reduced.

There are two independent traction inverters, one for each bogie. Forced air ventilation system is adopted to reduce the size and weight of the equipment.

5.3 FEATURES OF NEW LRV'S

The inverter uses high power Insulated Gate Bipolar Transistor (IGBT) as the switching element. Traction inverter adopts 2-level system with six 1,600V, 1,000A IGBTs. The application of IGBT brings about several features such as less power consumption in both main and control circuit, smoother operation, less audible noise, weight, size and easier maintenance.

The range of the output frequency is from 0 up to 180 Hz while the maximum output modulation frequency is 1 kHz.

There is an on-board information system, Train Monitoring System to support the maintenance staff.

When troubles occur during revenue service, such fault records/indications of operations will be memorized/indicated in the display, to ease faults finding, and reduce LRV down time.

The precise data can be supplied to the inspection section when necessary.

When fault occurs, the wave form of the power circuit voltage/current will be recorded in the high speed monitor for a brief period before and after fault occurrence.

The recorded data can be utilized for understandings of the phenomenon and analysis of the cause of the trouble easily, quickly and simply.

TGIS (Train General Information System) is an information management system for the LRV. The system concentrates the monitoring information of main on-board devices with the terminal on each car connected by the serial transmission line, to support the maintenance of devices and the driving operation. The operation data of main on-board devices is continuously collected and transmitted to the Display Unit, so that maintenance staff can easily grasp the status of the devices during operation. The main on-board devices are constantly monitored, and any failure is recorded. This supports fast and accurate measures to be taken, and helps early discovery of the cause of failure.

TGIS has the following features:

a. The system collects the self monitoring information of the main on-board devices using the serial transmission, to improve the monitoring performance.

b. The system adopts the high performance and high resolution graphic display and touch-screen input system.

c. The IC card facilitates the transportation of the recorded data to depot equipment. The failure data and trial running result data stored in the IC card are output to the depot equipment.

6. KCRC THROUGH TRAIN (KTT) WITH PWM AC DRIVES

The Ktt will operate a high quality inter-city express passenger train service between Hong Kong and Guangzhou. It has 12 double-deck passenger coaches manufactured by Kinki Sharyo and is hauled by two 6 MW ABB Lok 2000 electric locomotives working in tandem. It can carry a maximum of 1268 passengers. The train is designed to be powered by 25 kV, 50 Hz single phase overhead catenary and operates at a maximum speed of 160 km/h. The expected journey time is about 96 minutes.

6.1 TRACTION SYSTEM OF KTT ELECTRIC LOCOMOTIVE

The Ktt electric locomotive is driven by four 3 phase induction motors. A series of power converters are used as the power linkage, including two four-quadrant input converters and four PWM inverters. Bi-directional power flow between the 25 kV supply and the motors are possible, hence it can regenerate power to the 25 kV power network when the train is in braking mode.

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The main transformer has six secondary traction windings to transfer the power collected from 25 kV overhead line to the four-quadrant converters as shown in FIG. 4 AND FIG. 5. The two four-quadrant input converters, one for each bogie, feed two independent dc-link with nominal voltage of 2100-2800 V. One resonant filter from each dc link is tuned to compensate the power pulsation at 100 Hz. Together with the link capacitors, the filter will ensure the de-coupling of the line converters from the respective PWM inverters. Four GTO inverters, one for each motor, drives the motor with PWM technique. A sampling rate of 1600 Hz results for the primary of the supply transformer by synchronized triggering of the thyristor assemblies in the proper sequence. The corresponding primary current is a good approximation of sinusoidal curve and therefore the spectrum and the amplitudes of harmonics fed back into the primary system are relative low, i.e. a low psophometrically weighted interference current. According to some test results, the highest harmonic current is at 9th and 11th harmonic orders which is approx. 0.5 % of the fundamental components at full load situation (I_o = 324.5A)

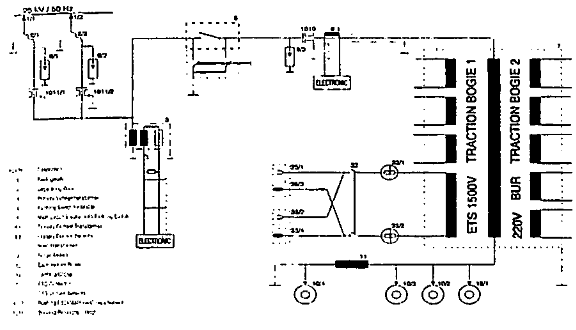

Fig. 4 Ktt Locomotive Power Schematics

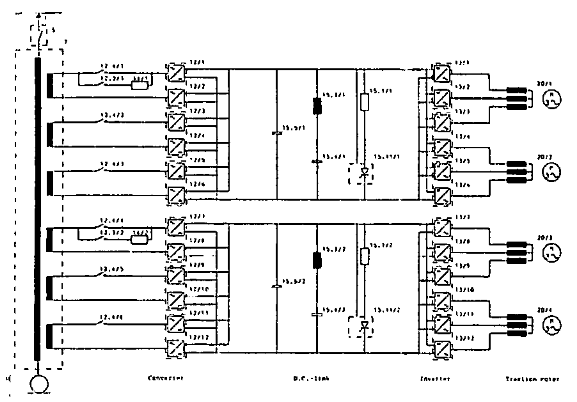

Fig. 5 Ktt Locomotive Traction Converter and Drives System

The power factor achieved by the four-quadrant converter and PWM inverters approach unity. The overall efficiency for motoring achieves a high level as well, due to the high efficiency of ac motors.

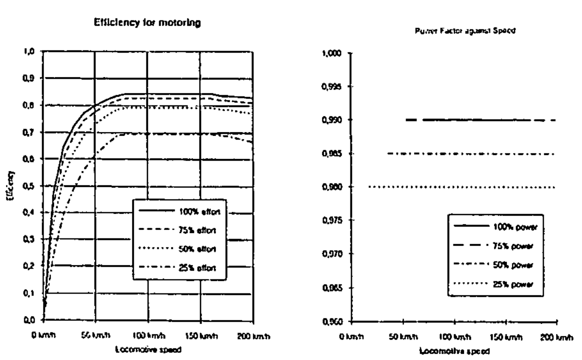

Fig. 6 Efficiency and Power Factor of the Ktt Locomotive

The waveform of the input voltage and current is measured as in Fig. 7, which shows a very good power factor.

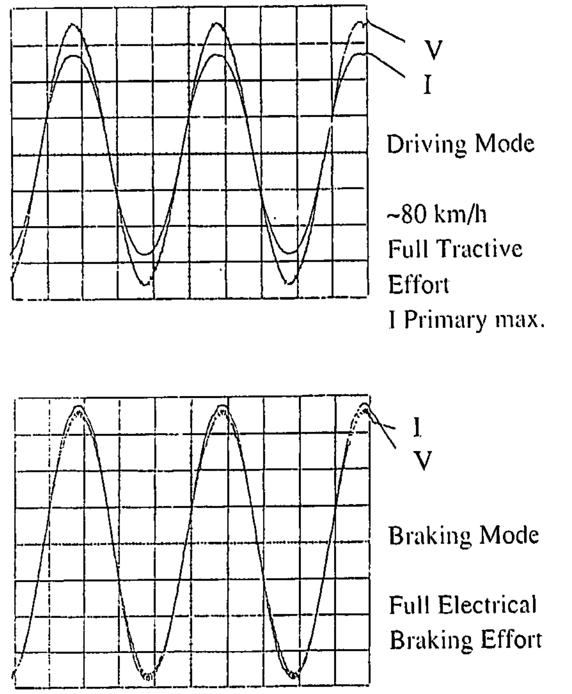

Fig. 7 Input Current and Voltage Waveform

6.2 AUXILIARY POWER SUPPLY SYSTEM FOR THE PASSENGER COACHES

In each of the 12 double-decked coaches there is a 140 kVA converter to supply the auxiliary loading in the coach. It converts the 1500 V ac single phase supply to 380 V 3 phase 50 Hz output. In order to boost the performance and to reduce the size and weight of the converters due to the roof space constraints, IGBT technology is adopted. On the input part of this auxiliary power converter, a rectifier bridge unit is used for converting ac power from the tertiary windings of the main transformer to dc power for the IGBT inverter. The rectifier bridge unit delivers suitable voltage inputs to the inverter by phase control.

The inverter bridge consists of six IGBTs which are controlled using the PWM technique. ac output is shaped approximately to a sine wave before stepping down to 380 V by galvanic isolation transformer.

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Paper No. 5

POWER SUPPLY SYSTEM FOR THE YANGPU ECONOMIC ZONE, HAINAN ISLAND

Speakers : Dave K.Y. Wong
Director & Vice-President
Eric C.H. Chui
Assistant Vice-President
Thomas K.C. Chan
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Parsons Brinckerhoff (Asia) Ltd

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Paper No. 5

ABSTRACT

Yangpu is a designated economic zone at the north-west corner of the Hainan Province. It has an area of about 30 km^2 and will potentially accommodate 400,000 people in its residential towers, hotels, offices, retail stores, factories and heavy industries. When fully developed, it will have a power demand of 1,350 MW. As Yangpu is intended to be a self-contained development, its infrastructure will have to be built by the developer. This paper will focus on the planning of the complete power supply system for Yangpu and will describe the initial phase of the system which has been completed in early February 1997. Subjects discussed will cover load forecast for 15 years, power system planning and right of way for transmission lines, design standard, power plant and transmission and distribution system configurations, protection system, and equipment selection.

1. INTRODUCTION

Under the leadership of Kumagai Gumi Ltd of Hong Kong, a group of investors has taken out a 70-year lease on a site of about 30 km^2 at Yangpu at the north-west corner of the Hainan Province from the Chinese Government. The site, which is known as Yangpu Development, is designated as a free trade and special economic zone. Some 400,000 people are expected to live and work in the zone when the site is fully developed.

According to the development plan, the whole site is geographically divided into 15 districts comprising residential and commercial areas, warehouses, light and heavy industries, and transportation facilities, and will be developed progressively over a 15 year period. For the sake of planning, the development is divided in three stages (namely Stages 1, 2 and 3). Each stage has a duration of five years. As Yangpu is intended to be a self-contained development, its infrastructure will have to be built by the developer. This includes a complete road system, water supply and sewage disposal, communications systems, and power supply system. Although the whole site is intended to be developed in three 5-year periods, it was paramount to construct the power supply system at an early stage to supply electricity to various essential utilities and the very first residential, commercial and industrial tenants. As such, the first three years was earmarked as Stage 1A during which time a starter power generating plant and the associated transmission and distribution system are to be completed.

A comprehensive load forecast was carried out to determine the load growth to suit the development planning Stages 1A, 1, 2 and 3. The types of loads in 15 districts consisting of residential, commercial, industrial, transport and ware house demand. Based on the development stage plan, the intended site usage in each district and the electricity usage diversity factor, the total power demand for the four stages was estimated to be 1,417 MVA. Table 1 summaries the peak power demand requirement in the whole development and is graphically illustrated on Figure 1. The complete power plant will be constructed in a phased programme to meet the estimated electrical load growth for the first fifteen years. The total capacity of the power plant will be 1,356 MW.

In the initial phase of Stage 1, the power generation system includes three 12 MW diesel and two 138 MW gas turbine generators. The power plant was completed in January 1995. The next phases of the project will comprise a number of combined-cycle units which will include steam turbines, waste heat boilers, water treatment plant and a sea water cooling system. The start date for the next phase will depend on the economy development of Yangpu.

Light diesel oil is used as the fuel for the power plant. Fuel supplied to the tank farm is received at a jetty located at the south-eastern end of the power station via pipelines. One number of loading arm was installed initially to handle and transfer the fuel from tankers to the tank farm.

2. POWER TRANSMISSION SYSTEM

Electrical power from the power plant is stepped up from 11 kV to 132 kV by generator transformer. From the 132 kV switching station, electricity is transmitted via overhead lines to various Zone Substations in different parts of the site.

A voltage level of 132 kV was selected for power transmission for the development as this level is a well-proven transmission voltage and was considered appropriate for the range of electrical power to be transmitted for the transmission distance involved.

3. POWER PLANT SUBSTATION

The initial design was a double bus, single breaker scheme utilizing two main buses of equal rating with a tie breaker for the Power Plant Substation. Each outgoing circuit would have two bus selector disconnect switches so that the outgoing circuit could be connected to either bus. When closed, the tie breaker would allow the transfer of a circuit from one bus to the other without deenergizing the circuit. Although this scheme would allow a fair amount of flexibility in operation and emergency system recovery, it is poor in reliability, particularly so when there is a tie breaker failure which would take the entire substation out of service. This situation would be unacceptable as the Power Plant Substation is the only link, at least for several years to come, of power transfer from generators to consumers. Recognising these shortcomings, a breaker-and-a-half scheme was selected. This scheme is more superior in flexibility, reliability and safety, although the protective relaying and auto-reclosing scheme are more complex. See Figure 2.

The Power Plant Substation switchgear is 132 kV gas-insulated switchgear (GIS) of the indoor compact type which is superior in performance compared to conventional air insulated switchgear. GIS has the distinct advantage of compactness in construction, resulting in a substantial reduction of the site area required.

The GIS has a total capacity of 720 MVA and a fault rating of 9,145 MVA symmetrical.

4. TRANSMISSION LINES

The initial design proposal included lattice type double-circuit transmission towers with the vertical configuration of conductors which have a base of approximately 5 m by 5 m, and a height of approximately 35 m. This would require a wide right-of-way and is aesthetically unacceptable. High installation cost and long erection time were also other causes of concern. In response to these shortcomings, 22.5 m tubular steel poles was proposed as an alternative, see Figure 3. The merits of the poles compared to the conventional towers are that the poles:

- Are simple in design.
- Require short delivery time.
- Are easy to erect and maintain.
- Have smaller footprint.
- Require less separation space between poles of different circuits.
- Are more aesthetically acceptable.
- Have a smaller impact due to wind load.
- Have no specific limitation on orientation during design of routing.

The overhead lines are fixed to the steel poles along the "green corridors". Each pole will carry two circuits. The planned routing of the overhead lines for the development areas in Stages 1A and 1, 2 and 3 are shown on Figures 4 to 6 respectively. It is noted that all of the transmission lines are using the same corridor between the power plant and various districts and may pose a concern that a lightning strike or a major incident at the bottleneck of the corridor may cause complete outage of the transmission lines and hence power supply to the whole of Yangpu. This risk can be reduced by having 132 kV underground cables for some or part of the circuits when the extra expenditure is justified and affordable. Nevertheless, the current planning will facilitate a more conservative definition of the right-of-way for power transmission.

For the initial stage, there are two circuits, each with a route length of about 6 km. Phase conductors are twin bundled 300 mm^2 aluminium-conductor steel-reinforced (ACSR) arranged in a vertical configuration with single suspension string at an average span of 100 m. The twin bundle is in a vertical plane and provided with two spacers to minimize relative movement of the conductors of the same bundle under fault conditions. Vibration dampers to dampen wind-induced motion however are not expected to be necessary on the phase conductors. Each overhead line circuit has a continuous rating of 250 MVA and an emergency rating of 300 MVA. Aluminized steel static wire together with a fibre optic signal cable are installed at the top of the 22.5 m high steel poles to provide 35° shielding angle from vertical of the pole against lightning strikes. The predicted outage rate due to lightning impact was calculated as 2.7 outages per 100 km-year. The initial system has been in use for over 30 months and there has not been any outage recorded due to lightning.

5. ZONE SUBSTATIONS

There are two zone substations for Stage 1A. The substations are located at strategic locations to cater for the load demand. Each zone substation is provided with 132 kV GIS in a double bus, single breaker configuration to receive the two transmission lines. Initially, one or two outgoing circuit(s) connecting to the respective 40 MVA 132/11 kV outdoor power transformer(s) is (are) provided per zone substation. However, each zone substation had been designed for three transformer bays. See Figure 7.

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The zone substations also house the 11 kV switchboards, 11/0.38 kV auxiliary transformers for substation services, street lighting and traffic signal power supply, and other control equipment.

Electricity is distributed from the 11 kV switchboards of the zone substations to the various consumer substations through an 11 kV underground cable network. Each outgoing feeder is rated at 7 MVA and arranged in a closed ring configuration. To minimize future road work construction for laying underground cables, cable trenches have been reserved along the footpath of Stage 1A areas and galvanized steel pipes are provided under the carriageway for cabling from the zone substations to the consumer substations.

Each 11 kV distribution feeder circuit is provided with vacuum circuit breakers and the associated 11 kV cables are provided with pilot wire Solkor protection. The 11 kV networks typically consist of closed ring circuit to ensure that in the event of a cable fault, the faulty section will be disconnected automatically and the system can be re-configured to supply the load with minimum distruption.

6. PROTECTIVE RELAYING

6.1 PROTECTION PHILOSOPHY

Each outgoing 132 kV line is protected by primary and backup relaying, and coordinated with transmission line relaying at the Power Plant Substation. The zone substations are equipped with line fault isolation capabilities. The planned arrangement for the zone substations is that each will have line-fault isolation capabilities operating mutually with its adjacent zone substation and/or the Power Plant Substation.

Primary line phase fault protection is provided by zone-distance (Device 21) relaying with two zones of protection. The Zone 1 relay is set to cover 90 % of the electrical distance (impedance) of the line to the first zone substation. The Zone 2 relay, acting through a time delay, is set to protect 150 % of the distance to the first zone substation, thus, in effect, protecting a portion of the primary windings of that zone's substation and also on the transmission line beyond that point when that zone's substation is connected to a subsequent zone substation along the line. Secondary line phase fault protection is provided through pilot wire comparison transfer trip relaying between the Power Plant Substation and the first zone substation along each line. Breaker failure transfer trip will be effected over the same pilot wire.

Primary and backup earth fault (E/F) protection (Device 51N) for each line is provided by directional overcurrent (O/C) relays (Device 51N) calibrated for high speed protection to the first zone substation along the line (with line-fault isolation capabilities).

An automatic breaker reclosing feature is provided and normally activated for reclosing on line-fault trip, but may be disabled if automatic reclosing is not desired for the particular high voltage (HV) circuit. Bus differential fault protection is provided and each individual circuit breaker is incorporated as a part of the particular breaker failure cascade-type of fault clearing scheme.

6.2 132 KV LINE BREAKERS

Two separate (primary and backup) E/F directional relays (Device 67N), having directional controlled instantaneous and time O/C units, are provided on each line breaker. The relays are zero sequence voltage polarized from the broken delta connection of auxiliary potential transformers to the bus potential transformers.

Both the O/C and E/F relays have additional contacts which will operate a breaker failure auxiliary relay.

6.3 132 KV LINE BREAKER RECLOSING

All 132 kV circuit breakers are provided with automatic reclosing features. A "disable - reclose" switch is provided in the control circuits of each breaker and mounted on the breaker control panel adjacent to the control switch. Placing this switch in the disable position will prevent automatic reclose, requiring operation of the control switch by the operator to reclose the breaker.

6.4 BUS PROTECTIVE RELAYING

Both 132 kV buses are protected by bus differential relays (Device 87B). The busbar differential relays as well as the necessary auxiliary relays and matching current transformers are located in one busbar protection cubicle. Undervoltage relays (Device 27) are also provided to trip the appropriate circuit breaker(s). The bay protection is basically the same as that for the busbar protection system. Each bay consists of two stubs which is equipped with two independent differential relays (Device 87B). The stub protection zone overlaps with the busbar and line protection.

6.5 BREAKER FAILURE PROTECTION

Breaker failure protection consists of a timing unit, supervised by three O/C and one E/F detectors per breaker. The breaker failure relay timer will be initiated by the contacts of the auxiliary relays which are energized by the protective relays, or by a separate contact of the protective relay. Upon failure of a breaker to trip, the timer will time out and close its contacts and cause isolation of the faulted breaker by tripping of the adjacent protective zone.

6.6 MAIN GENERATOR TRANSFORMERS

Faults within the area of protection of the generator transformer will trip the associated generator circuit breaker and intertrip the Power Plant Substation circuit breaker connected to this transformer. Three single phase instantaneous O/C directional relays (Device 67) and an instantaneous E/F directional relay (Device 67N) are provided for each breaker directly connected to a generator main transformer as backup protection and to prevent backfeed to that unit.

7. CONTROL AND MONITORING

The Power Plant Substation is designed for remote control and operation. The control of the switchgear will either be from the Power Station Control Centre or from the Substation Control Room.

However, remote control and monitoring at a central control centre will not be provided for the zone substations and consumer substations for the initial stage to make the system simple to build and easy to commission, and to reduce start-up costs. Instead, local control and monitoring devices are provided. It is expected that the zone substations will be manned 24 hours a day. In the event of operation of the switchgear or alarm, the technician on duty can communicate with the duty engineer at the Control Centre via telephone and walkie talkie to establish follow-up actions.

When the load demand increases further and more zone substations and consumer substations are needed, a fully integrated supervisory control and data acquisition system will be designed.

8. YANGPU - HAINAN POWER LINK

Due to the slow progress in the development of Yangpu, the power demand of the Yangpu Development is well below plan. To maximize the utilization of the power plant, Yangpu Power Company has decided to export power to the rest of the Hainan Province. Power is stepped up from 132 kV to 220 kV at the power station and transmitted via overhead lines suspended from lattice type double-circuit transmission towers to a Hainan Power Bureau Bulk Substation some 45 km from the Yangpu power station. A 3-winding 220/110/10 kV 120/120/60 MVA power transformer with automatic voltage control is provided to distribute the power to its neighbourhood area. Construction of this 300 MVA power link commenced on May 1995 and was completed by February 1997.

9. ACKNOWLEDGEMENT

This paper is a brief summary of the initial power supply system which was constructed between December 1992 and February 1997 and cannot adequately reflect the depth of expertise spent by various designers, consultants, contractors and power company operators. The authors wish to acknowledge with thanks the permission granted by the General Manager of the Yangpu Power (Hainan) Co. Ltd. for them to prepare and present this paper.

TABLE 1 PEAK POWER DEMAND SUMMARY

(All figures are in MVA)

District No.	Residential Power Demand	Commercial Power Demand	Industrial Power Demand	Transport & Ware House Demand
2	3	29	10	0
1	0	0	225	0
2	17	168	15	0
10	0	0	45	0
4A	25	25	38	0
5A	44	43	0	0
7	0	0	0	1
8B	0	0	87	0
11	0	0	50	0
13	0	0	59	1
14A	0	0	62	1
15A	0	0	0	12
15B	0	0	0	7
3	26	174	0	0
4B	12	0	0	0
5B	10	0	0	0
6A	49	49	0	0
6B	0	0	0	1
8A	0	0	0	1
9A	0	0	0	2
9B	0	0	189	0
12	0	0	107	0
14B	0	0	0	1

Development Plan Stage	Associated District(s) for Development
1A	2
1	1, 2, 10
2	4A, 5A, 7, 8B, 11, 13, 14A, 15A, 15B
3	3, 4B, 5B, 6A, 6B, 8A, 9A, 9B, 12, 14B

FIGURE 1 POWER DEMAND PROJECTION

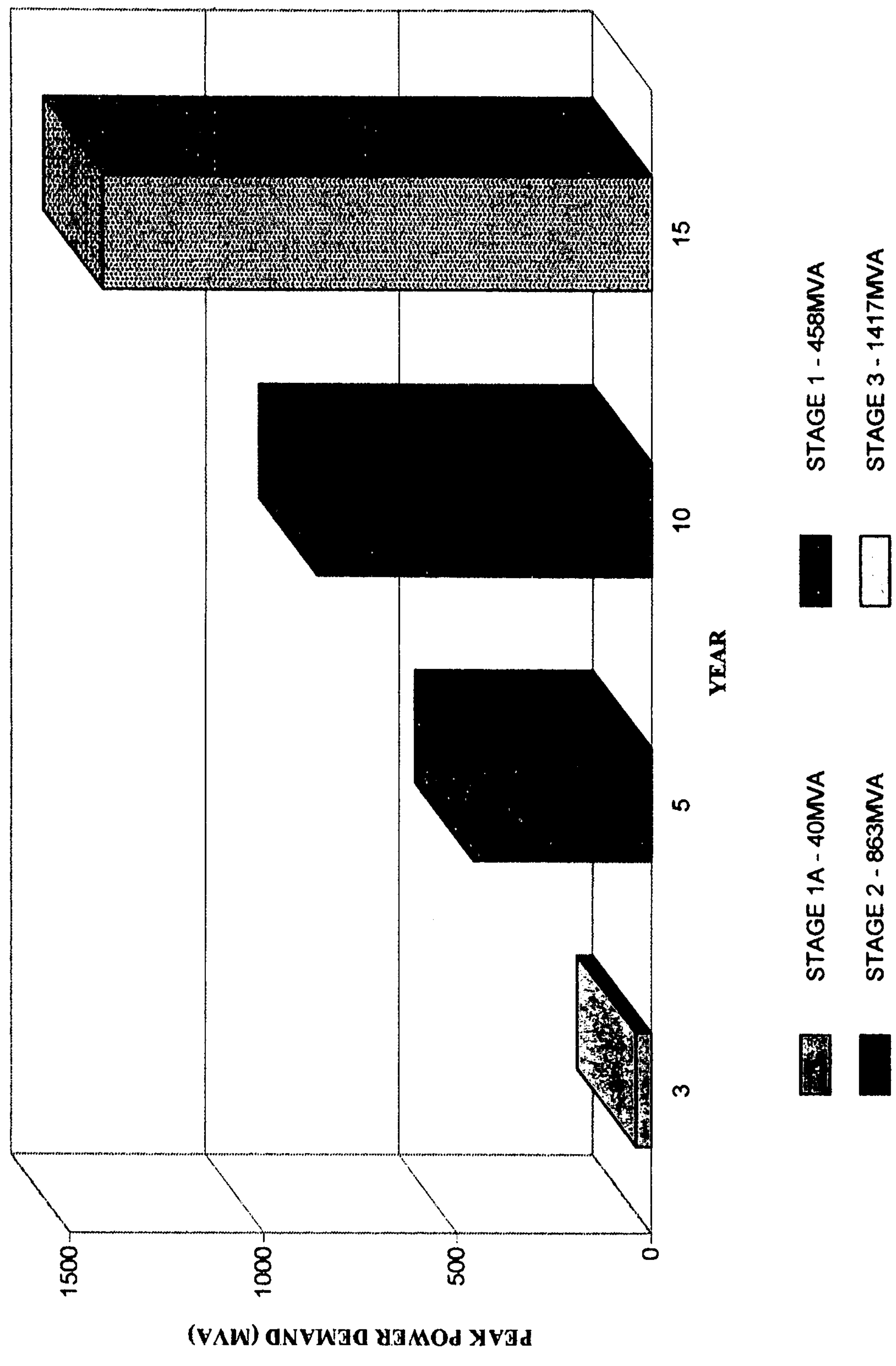

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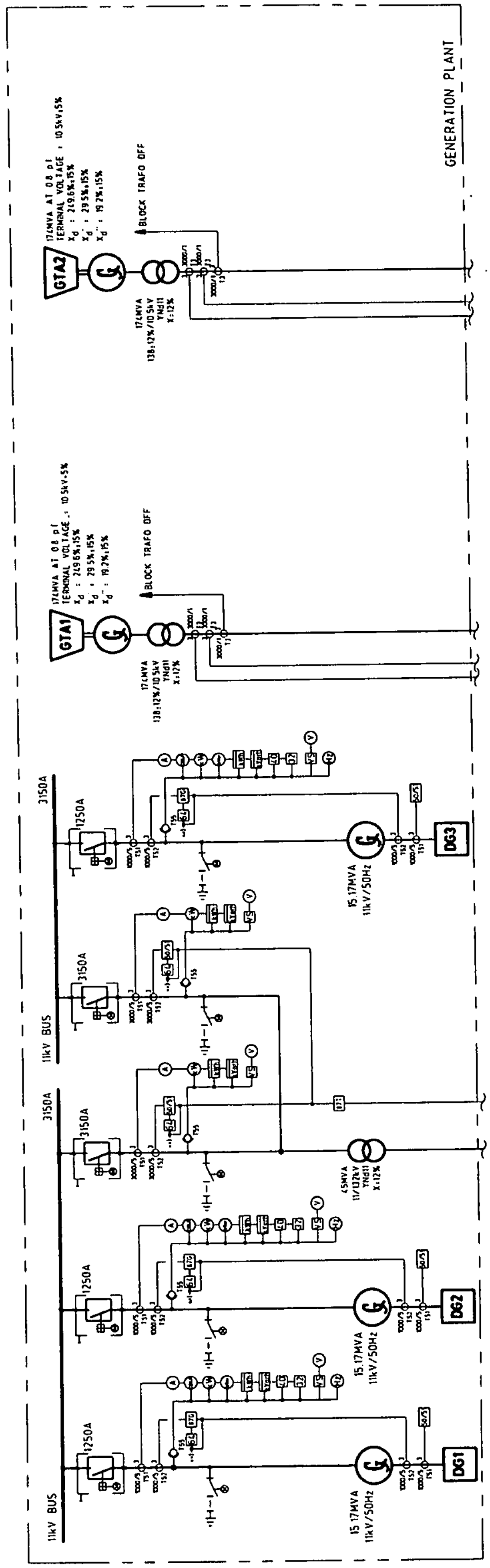
FIGURE 2 YANGPU POWER PLANT - STAGE 1A (SHEET 1 OF 2)



FOR THE CONTINUATION PLEASE REFER TO FIGURE 2 (SHEET 2)

FIGURE 2 YANGPU POWER PLANT - STAGE 1A (SHEET 2 OF 2)

FOR THE CONTINUATION PLEASE REFER TO FIGURE 2 (SHEET 1)

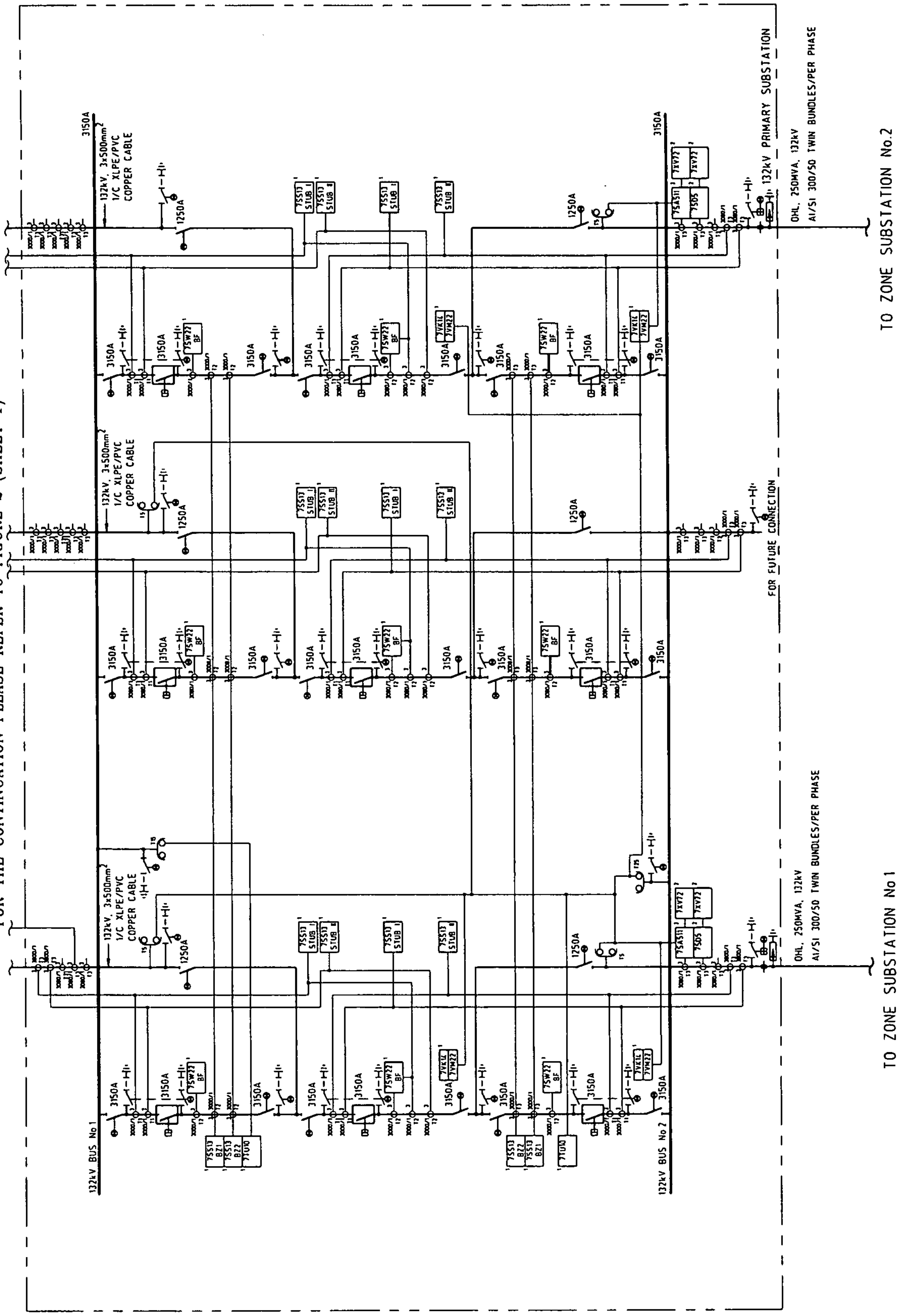


FIGURE 3 132kVA TRANSMISSION POLE

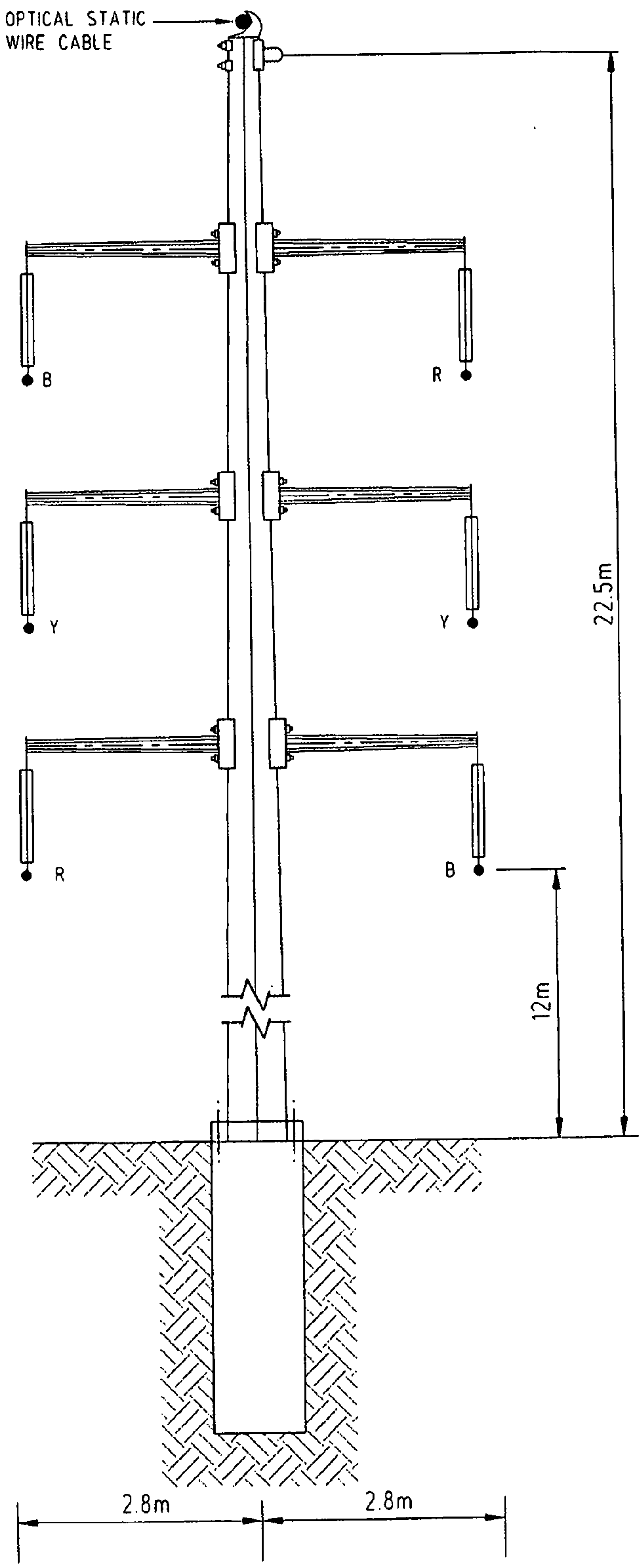


FIGURE 4 OVERHEAD LINE STAGE 1 ROUTING

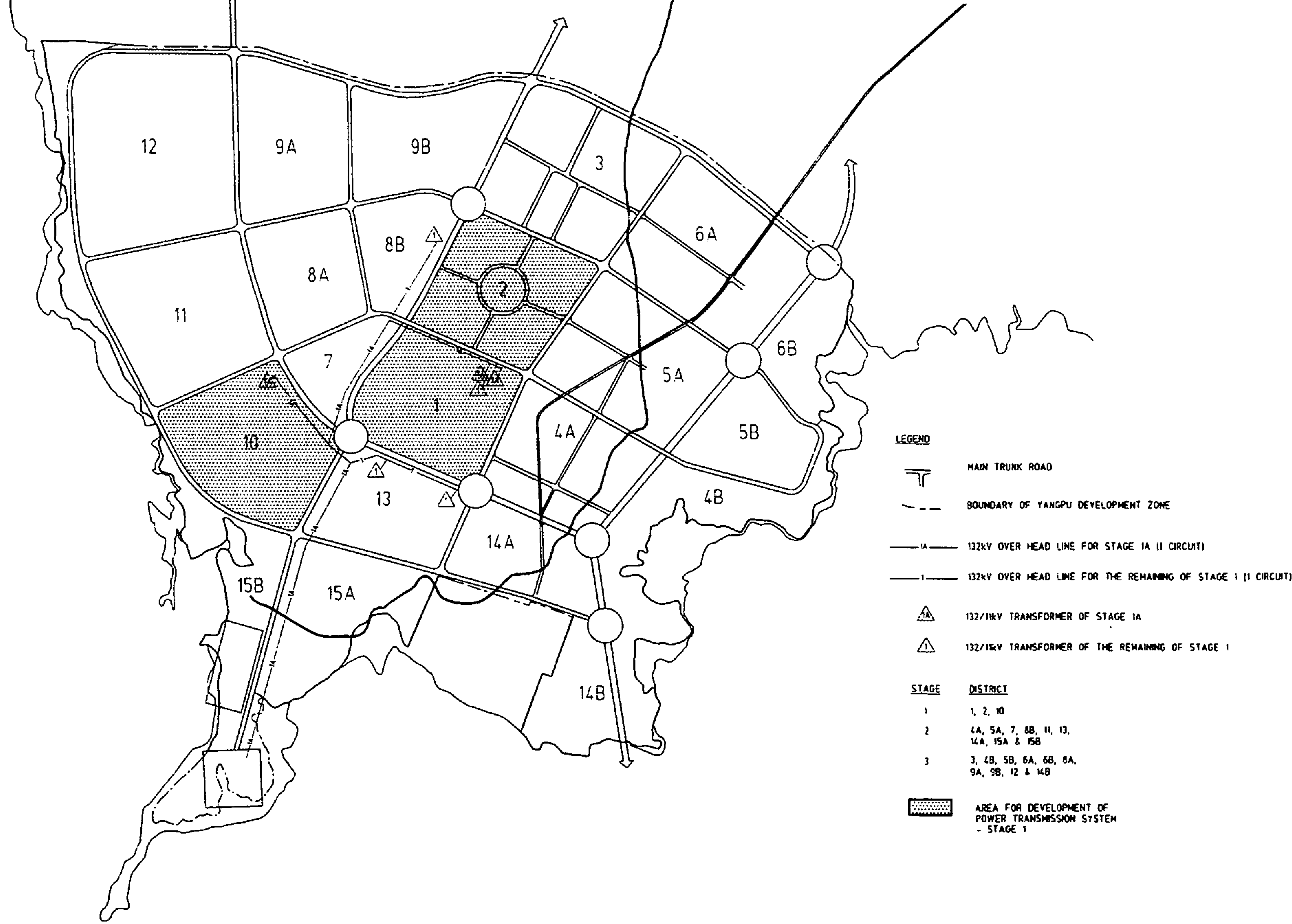


FIGURE 5 OVERHEAD LINE STAGE 2 ROUTING

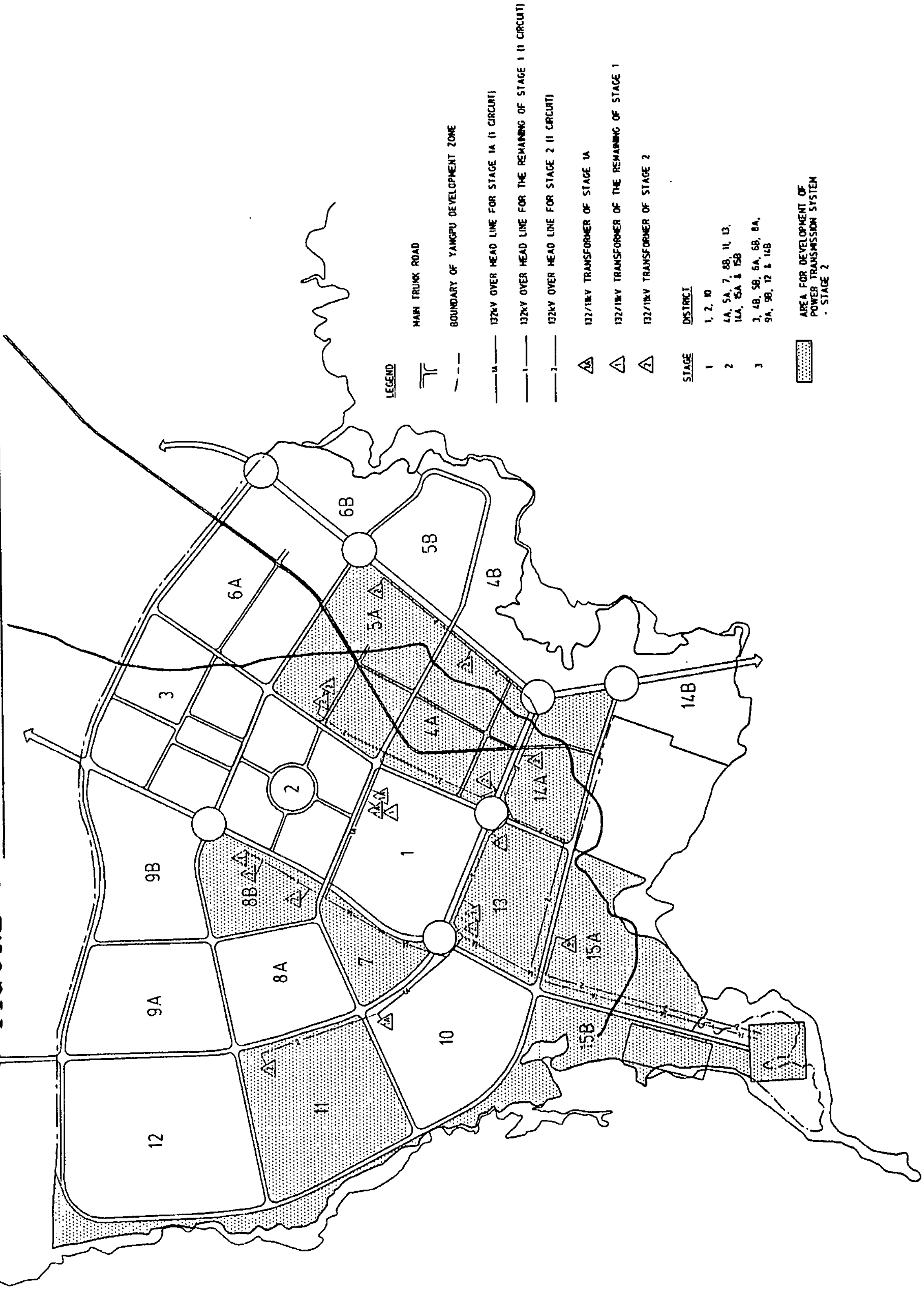


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FIGURE 6 OVERHEAD LINE STAGE 3 ROUTING

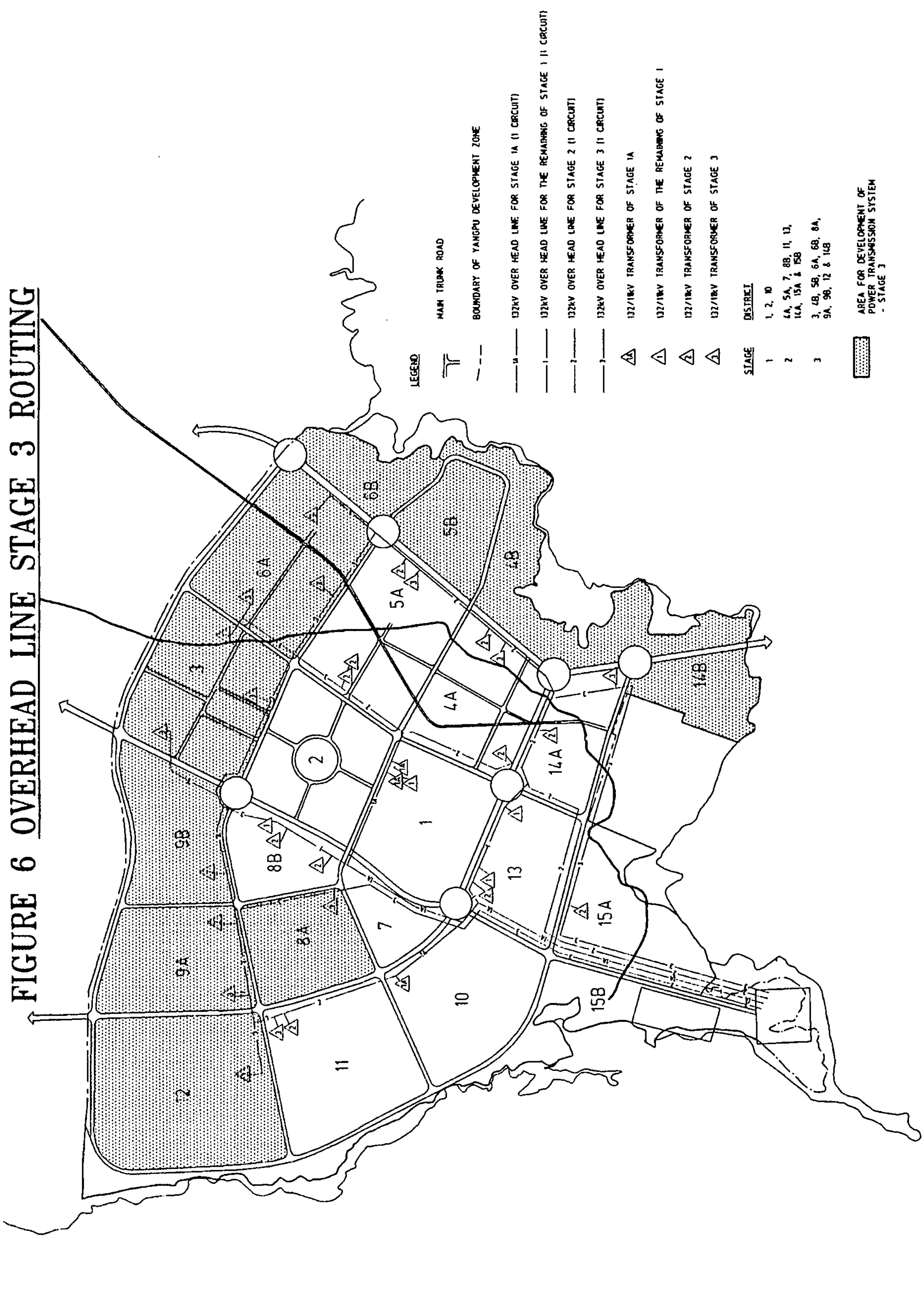


FIGURE 7 ZONE SUBSTATION SCHEME (SHEET 1 OF 2)

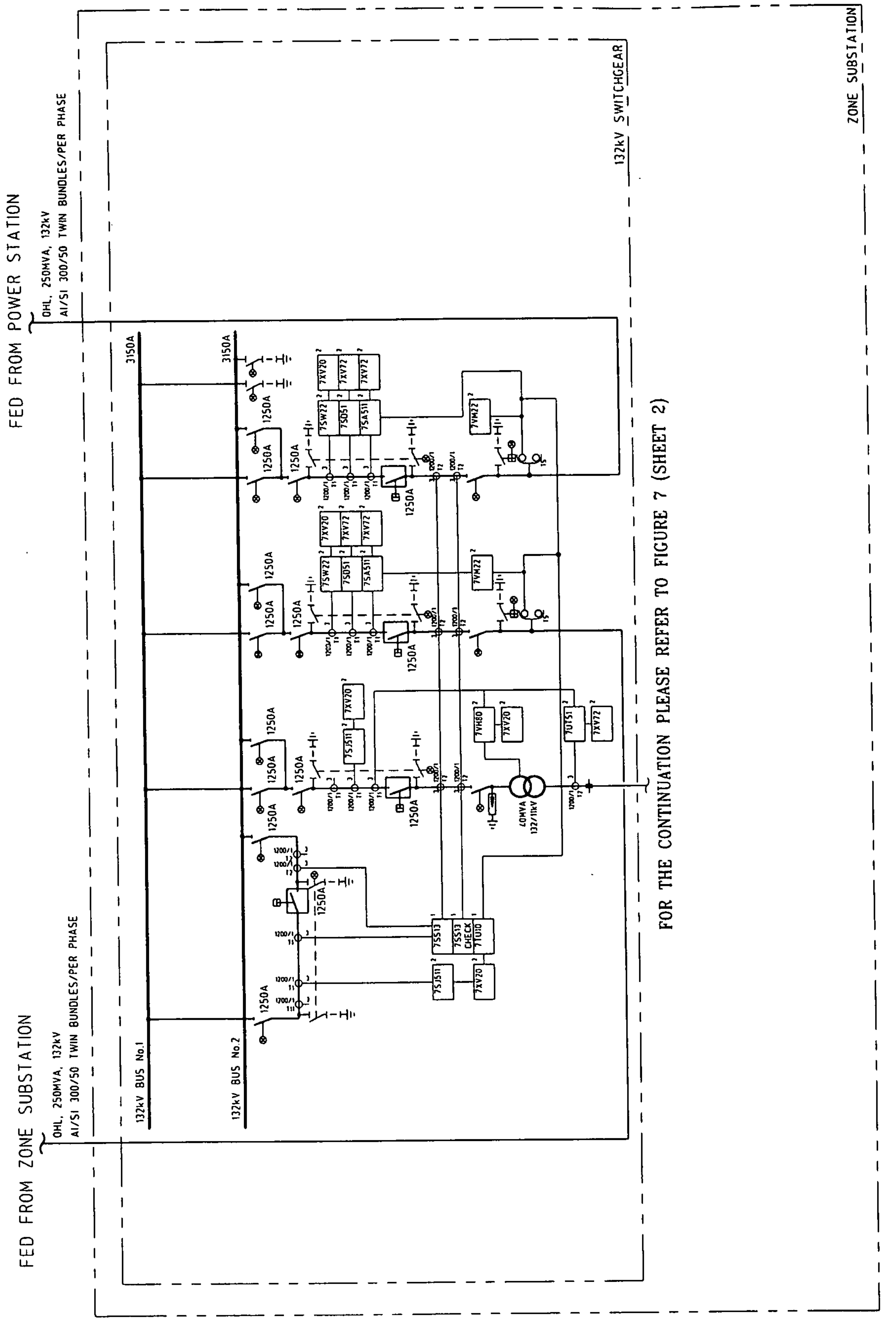
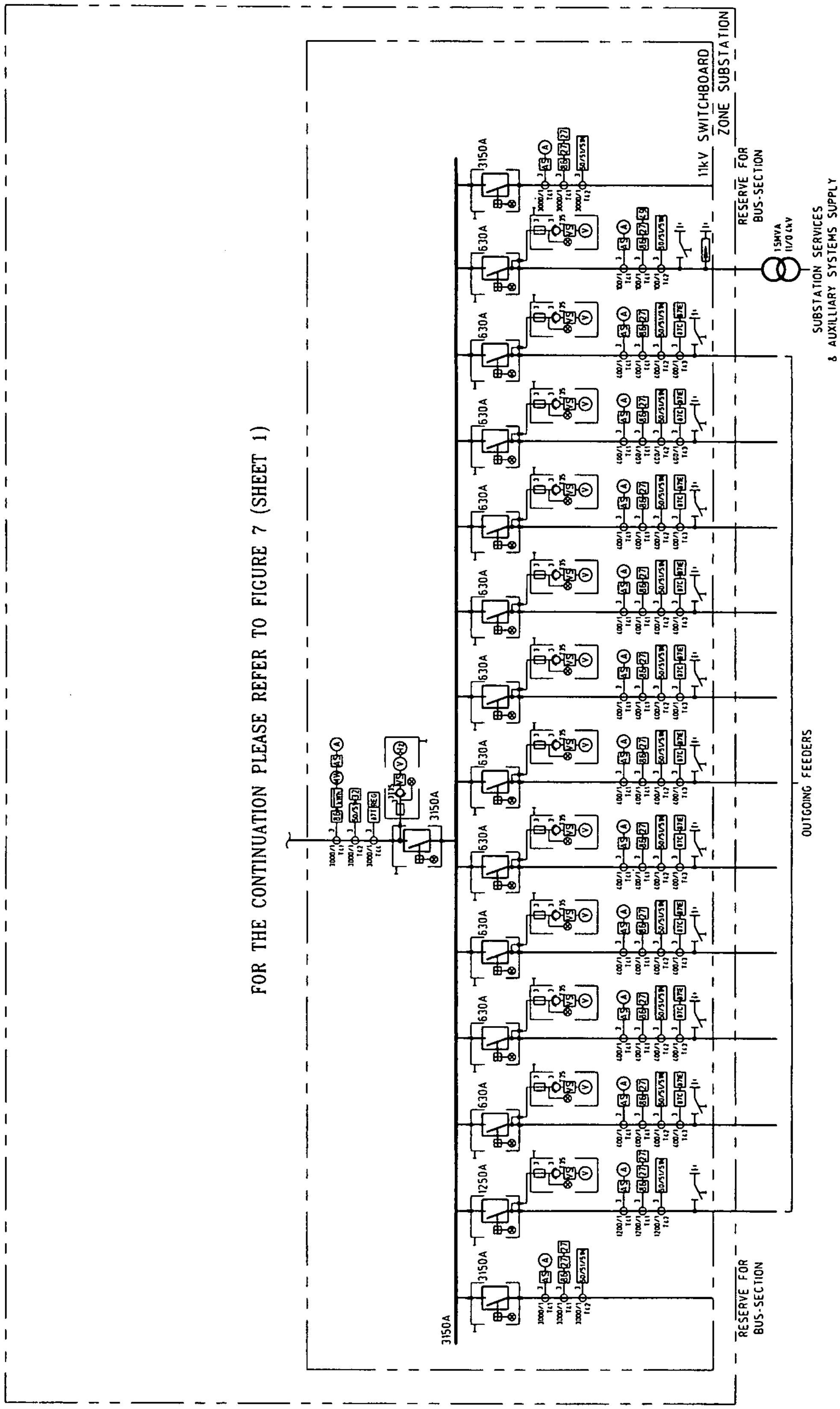


FIGURE 7 ZONE SUBSTATION SCHEME (SHEET 2 OF 2)



Paper No. 5

LEGEND

- TRANSFORMER, RATING AS SHOWN
- GAS INSULATED CIRCUIT BREAKER, RATING AS SHOWN
- WITHDRAWABLE UNIT, MANUAL OPERATED EQUIPPED WITH VACUUM CIRCUIT BREAKER, MOTOR OPERATED, RATING AS SHOWN
- ISOLATING CONTACT
- DGX — DIESEL ENGINE, RATING AS SHOWN 'X' - DENOTES REFERENCE No.
- GTAX — GAS TURBINE, RATING AS SHOWN 'X' - DENOTES REFERENCE No
- G — GENERATOR, RATING AS SHOWN
- BUSBAR, RATING AS SHOWN
- 1250A — DISCONNECTING SWITCH, 3-POLE, MOTOR OPERATED, RATING AS SHOWN
- 3 3000/5 — CURRENT TRANSFORMER 3 - INDICATES QUANTITY 3000/1 - INDICATES 3000 TO 1 AMPERE RATIO
- VOLTAGE TRANSFORMER
- INSULATED GROUNDING SWITCH, 3-POLE, MOTOR OPERATED
- INSULATED MAKE PROOF GROUNDING SWITCH, 3-POLE, MOTOR OPERATED
- INSULATED GROUNDING SWITCH, 3-POLE, MANUAL OPERATED
- SURGE ARRESTER
- A — AMMETER
- AS — AMMETER SELECTOR
- V — VOLTMETER
- VS — VOLTMETER SELECTOR
- MW — MEGA WATT METER
- KW — KILOWATT METER
- Hz — FREQUENCY METER
- cosφ — POWER FACTOR METER
- kVar — KILOVARMETER
- kWh — KILOWATT HOUR METER
- 27 — UNDER VOLTAGE RELAY
- 32 — DIRECTIONAL RELAY
- 40 — LOSS OF EXCITATION RELAY
- 49 — TEMPERATURE ALARM
- 64 — EARTH FAULT RELAY
- 50/51/51N — 50 - INSTANTANEOUS OVERCURRENT RELAY; 51 - AC TIME OVERCURRENT RELAY; 51N - EARTH FAULT CURRENT RELAY
- 86 — LOCKOUT RELAY
- 87C — CABLE DIFFERENTIAL PROTECTION RELAY
- 87IE — INJECTION EQUIPMENT FOR 87C RELAY
- 87T — TRANSFORMER DIFFERENTIAL PROTECTION RELAY
- REG — VOLTAGE REGULATION RELAY
- TYPE — PROTECTION RELAY (REFER TO TABLE BELOW)

PROTECTIVE RELAY TYPE AND APPLICATION TABLE :

TYPE	APPLICATION	ANSI
7SS13	DIFFERENTIAL PROTECTION	
	- BUSBAR DIFFERENTIAL	87B
	- STUB	87ST
7SW22	BREAKER FAILURE PROTECTION	50BF
7VM22	SYNCHRO CHECK RELAY	25
7VK14	AUTORECLOSING RELAY	79
7SA511	DISTANCE PROTECTION	21
7SD51	LINE DIFFERENTIAL PROTECTION	87L
7SJ511	OC/EF PROTECTION	50N/51N
7XV72	TEST SWITCH	
7XV20	TEST SOCKET	
7TU10	UNDER VOLTAGE RELAY	27
7VH80	RESTRICTED E/F PROTECTION	64
7UT51	TRANSFORMER DIFFERENTIAL PROTECTION	87

Paper No. 6

THE ADVANTAGE OF EMPLOYING MICROPROCESSORS FOR MOTOR SOFT STARTERS

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Nick Allen
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THE ADVANTAGE OF EMPLOYING MICROPROCESSORS FOR MOTOR SOFT STARTERS

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Paper No. 6

ABSTRACT

The paper addresses the advantages of using soft starter on motor starting process. The introduction of micropossor to control the firing of thyristors, as well as providing comprehensive control functions, has been proved to be far more beneficial when compared with analogue control. Various advanced features with digital soft starter have also been discussed in details.

1. INTRODUCTION

Modern industrial processes use at least one, often many individual drives. By far the most common form of drive is the asynchronous squirrel cage induction motor. These motors have a wound stator, and a rotor constructed from a number of heavy conductors embedded within a laminated core and short circuited by solid end-rings. The resulting machine is robust and economical to manufacture. It also provides a reliable, efficient power source which is available in a comprehensive range of output ratings to suit individual applications.

An induction motor, which is efficient at full speed, will have low impedance at standstill. It is because of this that consideration must be given to starting needs. Conventional methods of starting include :-

1.1 DIRECT-ON-LINE (DOL)

As the name implies, the motor is connected directly across the supply lines, usually by means of a contactor. The current is, therefore, free to rise to an initial value, determined only by the standstill impedance. It can remain at a high value until the machine approaches full speed when the effective impedance is sufficient to reduce the current to normal values. See Fig. 1.

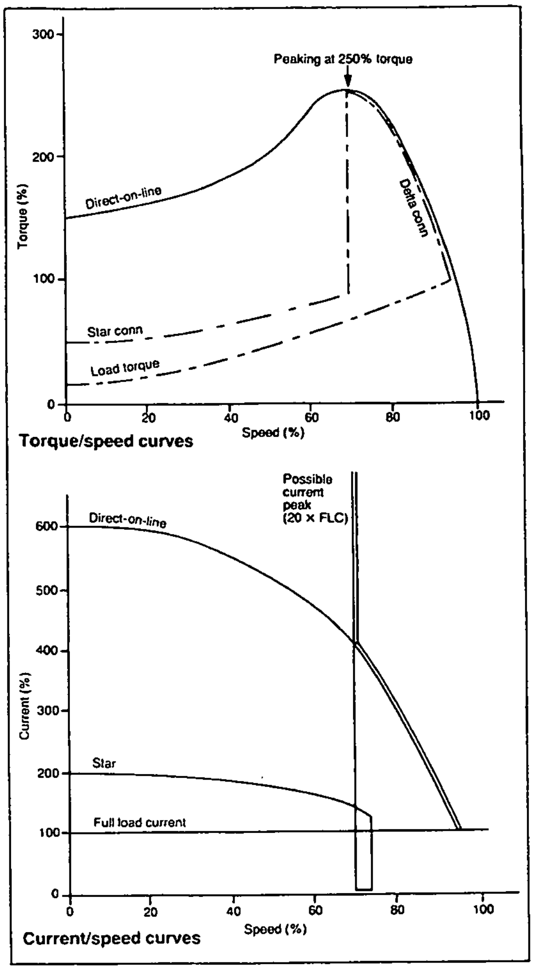

Fig.1 Typical DOL and Star/Delta Characteristics

1.2 STAR/DELTA

Motor windings are initially connected in a star configuration across the supply. After a suitable time delay, during which the motor should reach virtually full speed, the windings are open circuited before being reconnected, in a delta configuration, across the supply lines. The surge, or peak current, at changeover is determined by the value of the residual e.m.f. and the phase relationship between this and the supply voltage at the instant of reconnection. This current can be higher than that experienced in a DOL start, though of shorter duration because the motor is still revolving. Star/delta starting calls for a slightly non-standard machine with all its windings brought out to terminals, and available for interconnection by appropriate control gear. Refer to Fig.1.

1.3 AUTO TRANSFORMER

A conventional three terminal motor can be used with the supply being taken initially via an auto transformer is set by the tappings provided (typically 65%, 75% and 85% of nominal supply voltage). Again, after a suitable time delay to allow the machine to run up to speed, the auto transformer is switched out of circuit and the mains supply is connected directly onto the motor windings. Current surges, or peaks, still occur during this transition period and will be maintained until the machine is up full speed. The correct use of the tappings can, however, generally reduce the initial current surge to an acceptable value, but once set, it cannot automatically adjust to match different load requirements. This method of starting is therefore only suitable for applications where the load characteristics at starting do not vary appreciably.

Whenever current surges occur, the supply system has to withstand these peaks without an excessive voltage drop. In addition, the mechanical shock is transmitted throughout the machine and must be absorbed by the drive shaft, gears, belts etc. . When the starting sequence is not easily controlled, difficulties are often experienced with certain types of load (e.g. crane loads can swing and items on conveyors could easily be displaced).

For providing a controlled start feature and where variable speed is an advantage, variable frequency control should first be considered.

The latest trend, however, is towards equipment designed primarily as a soft start unit, which is intended to run the motor smoothly and efficiently up to full speed, without the feature of actual speed control.

2. THE SOFT STARTER

The soft start unit (Fig. 2) uses solid-state technology. It is designed to provide an improved method of starting which eliminates current and torque surges, allowing the motor to be started smoothly under full control as shown in Fig. 3. Present day electronic components are extremely reliable and consistent in operation which, if not abused, will outlast even the best of the electro-mechanical devices.

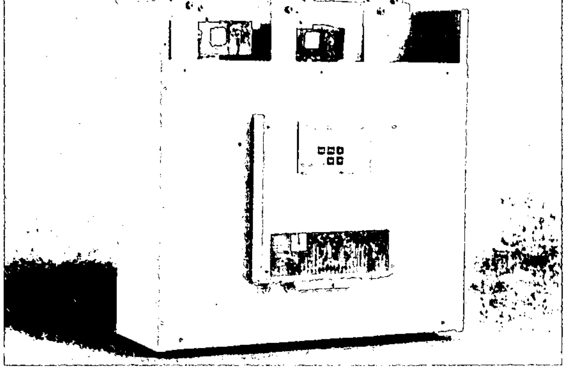

Fig. 2 Typical Soft Start Unit Complete with Preparation for Bypass

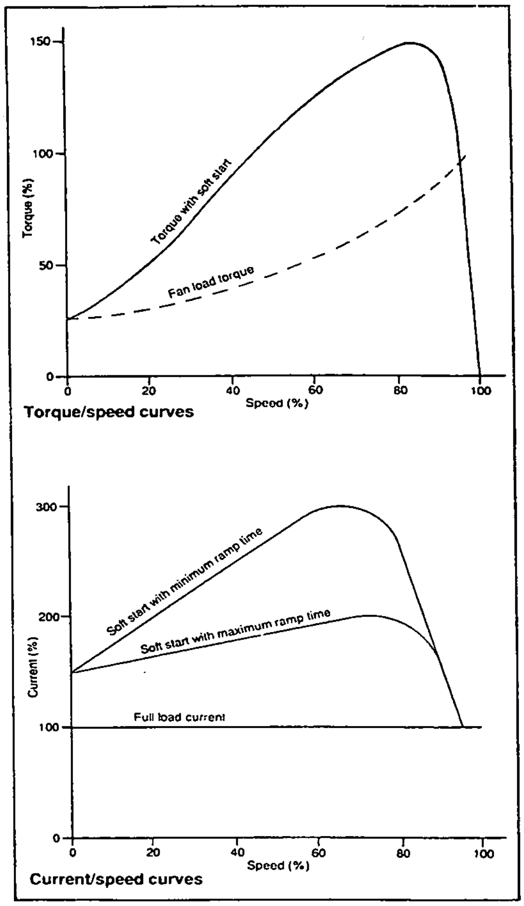

Fig. 3 Typical Characteristics of Microprocessor Controlled Soft Start

The basic element in the system is the thyristor. Current flow through this device is triggered by a brief pulse of current (usually only milliamperes) into the control gate. The main current flow then continues until the next current zero, or until the current falls below the minimum holding current of the device (see Fig. 4).

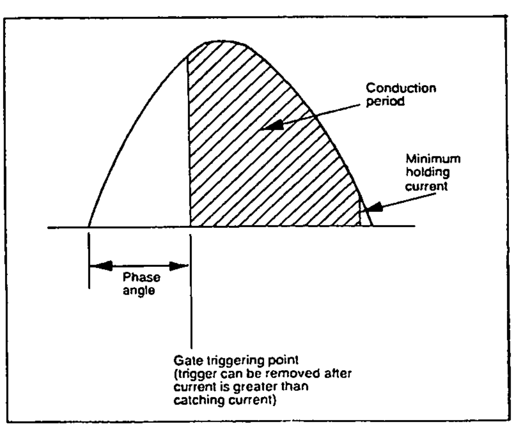

Fig. 4 Gate Triggering Point

This characteristic can be used with considerable effect on a.c. supplies to control current flow during each positive half cycle. However, if full control throughout both half cycles is required, it will be necessary to fit a pair of thyristors connected back-to-back. If a three-phase system is to be controlled, it is possible to use a simple diode for the negative half cycle because the current flow, during this part of the cycle, would be controlled by the current conducted by the thyristors in the other two phases. Although this is cheaper than two thyristors, and requires only a single gate signal per phase, it allows third and even harmonics to flow in the motor. A thyristor/thyristor arrangement restricts the flow of even harmonics. Triacs can also be used and have similar characteristics to a pair of thyristors, but with the advantages of only a single gate and with everything encapsulated within a single package. Unfortunately, they are restricted to low current, low voltage systems. The various devices are shown in Fig. 5.

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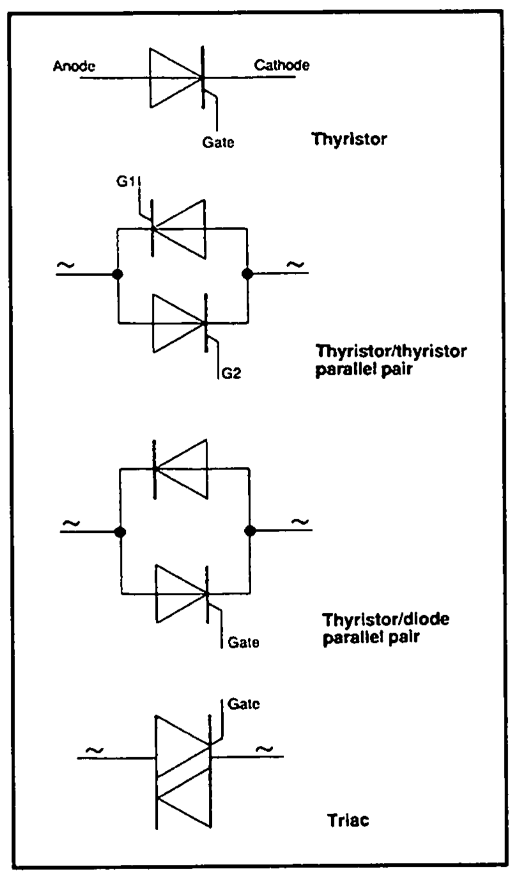

Fig. 5 Elements of the System

Triggering of the thyristors is, of course, very critical and the specific details are to a certain extent dependent upon the type of system on which the unit is to be used. The three most common configurations for a thyristor arrangement are :-

(i) Six thyristors controlling a four wire system

A total of six trigger pulses will be required, each feeding one of the thyristors and with a separation of 60 degrees (electrical). This relationship must be maintained throughout the required run-up range of 180 degrees and also while in the fully conducting mode (see Fig. 6).

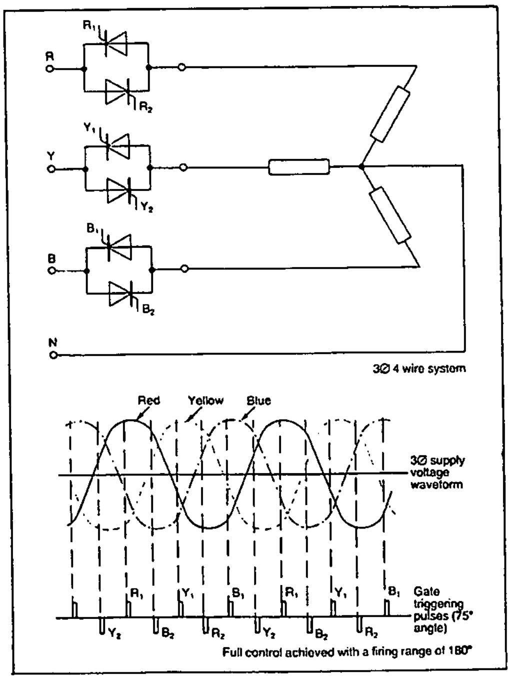

Fig. 6 Six Thyristors Controlling a Four Wire System

(ii) Six thyristors controlling a three wire system

Although this system is similar to i) the six triggering pulses must be in the form of six different pairs of pulses (i.e. for power to be delivered to the load it is necessary for at least two thyristors to be conducting simultaneously, one in each of two phases). Therefore, it is essential that two pulses, 60 degrees apart, are applied to the gate of each thyristor during each cycle. The triggering sequence could be simplified by retaining the initial pulse to each gate for the full 60 degrees. This could mean that during certain parts of the cycle, the gate would be triggered with the device reversed biased. This is sometimes detrimental to the thyristor, apart from the greatly increased gate power required. Again, the precise relationship between the respective pulses must be maintained throughout the full operating cycle (see Fig. 7).

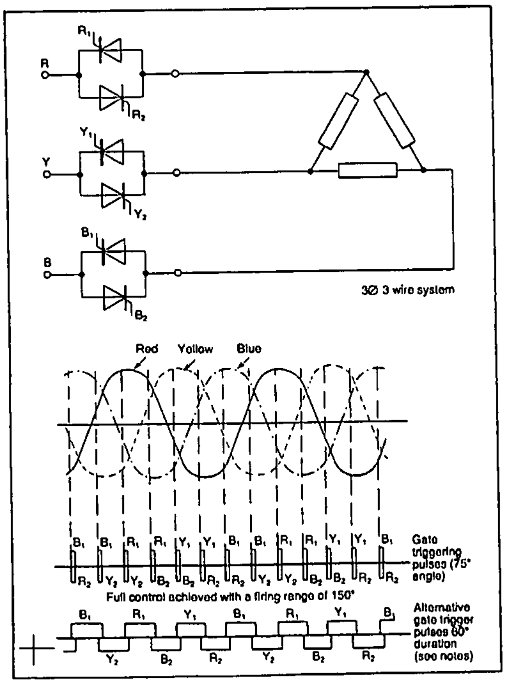

Fig. 7 Six Thyristors Controlling a Three Wire System

(iii) Three thyristor, three diode system

This is simpler in operation than the previous arrangements because only three gate triggering pulses are required, each controlling one thyristor and having a mutual separation of 120 degrees (see Fig. 8).

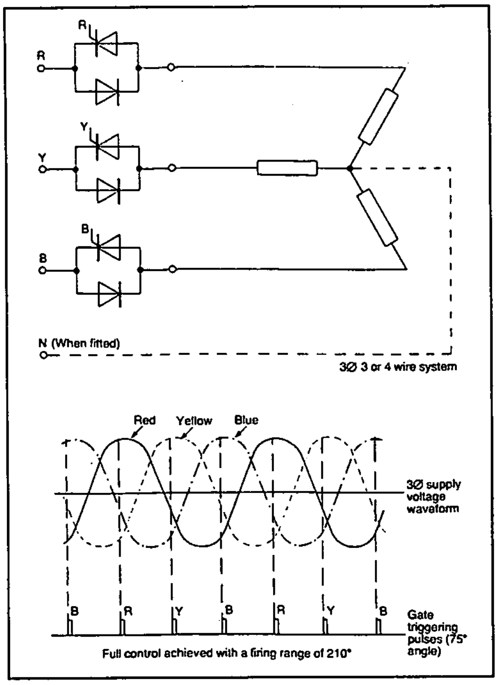

Fig. 8 ThreeThyristor, Three Diode System

Any comparison between the respective circuits would normally include the firing angle range, the harmonic content of the output and the actual value of the output available.

The firing angle ranges required can be obtained without much difficulty, although that for system (iii) is slightly more difficult to achieve. Systems (i) and (ii) do however, require six output pulses whilst system (iii) requires only three.

System (ii) has the best harmonic content. The amplitude of the lowest harmonic (the fifth) is approximately two thirds that of the lowest harmonic (the third) in system (i) and system (ii). In the four wire systems most of the harmonics are dispersed along the neutral.

Irrespective of the type of system used, it is important that the correct phase relationship is maintained between the supply voltage and the appropriate trigger pulse. This usually takes the form of a single printed circuit board assembly which, using the main supply frequency as a datum, will provide all the necessary gate triggering pulses at precisely the right intervals (Fig. 9). Integrated circuits are used where possible on even the most basic boards. The latest devices use a microprocessor to control the complete board, especially now that these devices are available with extensive memory facilities. The memory is usually in the form of an erasable programmable read only memory (EPROM) which can be programmed to suit specific applications and makes the microprocessor an ideal device to provide full and comprehensive control systems requiring little and simple setting up by the customer.

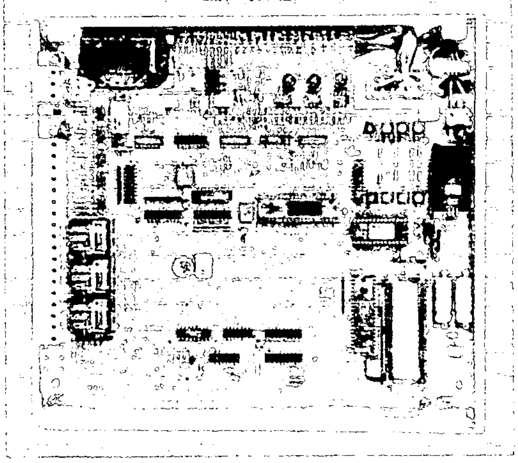

Fig. 9 Printed Circuit Board

In addition many digital soft starts have communication via RS 485 - MODBUS protocol to offer full remote control and supervision.

Even the simplest soft starters provide a realistic and reliable system which, with a little understanding by the customer during commissioning, can be used on the majority of applications. The three controls provided for adjustment on site generally comprise :-

(i) Ramp up time

This determines the rate at which the firing angle is adjusted to bring the output up to full voltage. It is usual to specify the ramp up time (typically 3-20 seconds) but this can cause some confusion as it is often assumed this is the time the motor will take to reach full speed. The ramp up time is actually the time for the output voltage to reach a maximum. If the motor is not heavily loaded it may have reached full speed some time previously.

(ii) Starting torque

This determines the motor initial starting torque by controlling the initial point of triggering the thyristors. Its intention is to start the motor immediately the power is applied. If set too low a slight delay would occur while the output is ramped up to that required to drive the maximum load envisaged. If too high, a slight snatch could still occur when starting against a very light load.

(iii) Current limit control

This is used to restrict the current flowing to the motor to some predetermined value (it can usually be adjusted between 200-400% FLC). However, as torque is proportional to current squared, care is necessary when setting this control. If it is set too low the motor will not develop sufficient torque on starting to move the load. Measurement of current is normally only necessary in one phase of the system, because the electronic circuitry is arranged to check that current is flowing in all three phases. If there is any discrepancy between phases the unit automatically initiates the shut down sequence.

Most soft start electronic circuits have a number of protection features built into them. These are an inverse time electronic overload which becomes operational after the end of the acceleration process and the overload point is usually adjustable between 75% - 150% of full load current. A short circuit protection is provided by an electronic fuse and would be initiated if the current exceeds 9 -10 times FLC in less than one cycle. Usually there is protection of the motor in the event of loss a phase or under voltage. Most soft starters will have a thermal sensor to protect the thyristors from overheating.

The most modern microprocessor based system have all the controls mentioned above and usually other user additional features including communications. The controls normally made available to the customer is the ramp time (i.e. the time required for the controller to reach full volts. rather than the time to reach full speed). The initial voltage to determine the initial torque and the current limiting.

One feature that has not been mentioned is the Ramp down time which is used to control the deceleration of high friction loads. Stresses can also occur within the system when a motor is disconnected from the mains supply when switched off. The existing thyristor stack can be used to provide a controlled and snatch free run down; by gradually reducing the voltage supplied to the motor until such time as the motor is not able to drive the particular load. At this stage the main contactor can be opened and the motor completely isolated from the supply. This arrangement is used for a motor and load which would normally stop too quickly, and is generally known as '-soft stop'-.

Another operating parameter is to provide Pulse starting which is intended to start high friction loads by a high voltage pulse to break the load free then condition return to those set.

A microprocessor system, when programmed correctly, is far more versatile than the original analogue schemes. It will adapt not only to differing load conditions during starting, but can also be programmed to suit applications. Programming is via a simple key pad with instructions being displayed on a Liquid crystal display. The key pad should be user friendly, menu driver with instructions available in a number of languages to suit a world wide market.

The communications via a RS 485 MODBUS protocol allow for remote control of the soft start from a computer terminal. In addition the soft starter with be able to send information back to the computer to enable decisions to be made. The type of information would be current insulation, faults and statistical data to ensure the maximum efficiency of the motor is obtained.

Soft starters need to be protected and must be provided with appropriate snubber circuits and specially rated high speed semiconductor type fuses, to protect the thyristor stacks. As an additional precaution against mains transients, the various manufacturers recommend that thyristors having at least a rating of 1200 VRRM are used for all 415V industrial applications. It is usual to resort to additional filtering and suppression circuits across the incoming terminals, by using varistors, especially when it is known that the supply system may be susceptible to any form of transient spikes.

Protection of the motor against overloads can be achieved by means of a conventional thermal overload relay, connected in series with the soft start unit and with its trip contact connected in the coil circuit of the main contactor. Care should be taken to ensure that the particular overload relay chosen will not trip during starting, especially when a current limit is required and the subsequent run-up time is extended. Certain electronic overload relays can also be used. Some devices are liable to object to the chopped waveform during the starting period (i.e. they often see this as a form of malfunction) and trip the contactor unnecessarily.

Standard soft start are suitable for retrofit application and should be installed between the existing DOL starter and the conventional squirrel cage motor. If required, units can also be supplied incorporating both starter and suitable overload within a common enclosure. This provides an arrangement which is particularly advantageous in new applications, since the labour costs for both wiring and installing the unit can be considerably reduced. The contactor is, however, still required, together with a main isolator to provide the complete circuit isolation as recommend by the Health and Safety regulations. These should already exist in a retrofit application, but for all new installations they could be included within a combined soft start / contactor / overload and isolator unit.

The rating of a soft start unit is dependent upon the duty cycle to which it is to be subjected. The limit is usually a thermal restriction and is primarily that of the junction temperature within the thyristor stack. Very precise calculations are necessary if the units are to be run up to their limit. Unfortunately, the duty cycle cannot normally be accurately defined. Hence only an estimate of the ultimate rating can be obtained. This results in the published data regarding ratings being rather conservative ; and provides an additional safety factor which consolidates the long and trouble free life associated with this equipment. Even when fully conducting, the thyristors are subject to a voltage drop between their input and output terminals (usually 1-1.5 volts). Consequently they will have to dissipate an appreciable amount of heat from within the enclosure. As a rough guide, this can be quantified as approximately 1-1.5 watts / thyristor / phase / amp. In a three-phase system this means that the heatsink, on which these devices are mounted, will have to be capable of dissipating approximately 3-4.5 watts per amp (i.e. each thyristor will only carry current for 50% of the cycle). The heatsink can be designed to dissipate these losses by natural ventilation, but for the higher current rating it is often necessary to provide forced ventilation by means of one or more cooling fans.

The thermal considerations are of paramount importance with this type of equipment. It is common practice to fit some form of temperature sensor onto the heatsink itself so that if the temperature should exceed some predetermined value the unit will automatically shut down. Unfortunately, it is not possible to provide a temperature sensor on the internal junction. An estimate of the thermal gradient between this junction and heatsink is included in the calculations, to determine the precise setting of the heatsink mounted sensor. A heavy duty cycle is particularly demanding upon the internal junction temperature. This is basically because there is insufficient time available between consecutive starts for the heat generated within the junction during the previous starts to be dissipated from the heatsink. Therefore, though standard soft start units are normally rated for 4 starts per hour at 400% normal current, but up to 60 starts per hour at low loads. It is always assumed that these will be evenly spaced throughout. Should an alternative rating be required, it is essential that the duty cycle be defined as accurately as possible, so that the appropriate calculations can be carried out to ensure the internal junction temperature never exceeds the specified limit at any time throughout the cycle.

Many installations involve very infrequent starts. The unit then spends the majority of its operating period in a fully conducting mode, yet still dissipates appreciable power into the heatsink, etc. If this is known it is possible to reduce the overall power to be dissipated by using a by-pass contactor to short out the thyristor stacks after they have ramped up to full voltage. This is useful in applications where it could be difficult to get rid of the heat being generated (i.e. totally enclosed equipment, etc.).

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ADVANCED TECHNOLOGY OF POWER SYSTEM ENGINEERING IN JAPAN

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ABSTRACT

In this paper, the present situation and problems of the country-wide power system interconnection in Japan are described. The advanced technologies in power system engineering under development or recently introduced are also explained. Among them are UHV AC and HVDC transmission, FACTS, substation and distribution automation, power system simulator. Finally, consideration to the new power system operation under future deregulation and developments in load management are introduced.

1. INTRODUCTION

In the early day about 100 years ago, AC generators in the east side of Japan were imported from Europe, whereas those in the west side were from USA. Since then the nominal system frequency in east and in west are 50Hz and 60Hz respectively. In the east 50Hz power system, there are three electric power companies. They are Tokyo (TEPCO), Touhoku and Hokkaido Electric Power. The northern island Hokkaido power system is interconnected with Honshu main island power system by ±250kV, 600MW DC submarine transmission lines. (see Fig.1)

In the west 60Hz power system, seven electric power companies exist. Except the southernmost Okinawa island power system being isolated , other six electric power companies Kansai (KEPCO), Chubu, Hokuriku, Chugoku, Shikoku and Kyushu are interconnected by 500kV AC transmission lines. Between the west 60Hz and east 50Hz power systems, two back-to-back frequency converter stations being shown in Fig.1, Sakuma 300MW and Shin-Shinano 600MW are in operation. Generally speaking, these AC/DC interconnections between two electric power companies' grids are only one or two based on point-to-point policy.

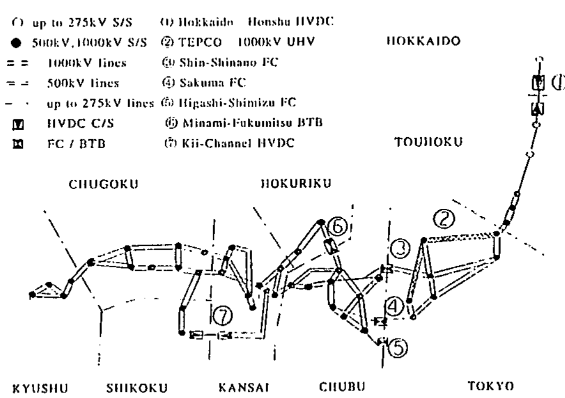

Fig.1 Interconnection of Power Systems around 2005

Due to severe earthquake conditions and economy of sea-water cooling of condensers, all nuclear and large fossil fuel power stations are installed on the strong rock-bed along seashore. Some power stations with several thousands MW generation are about 200km apart from large metropolitan load centers such as Tokyo, Osaka and Nagoya. Total installed

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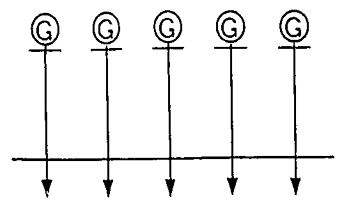
power generation capacity of Japan in March,1997 was 210GW which consists of thermal 125.1GW, hydropower 43.1GW and nuclear 42.5GW. The hydropower 43.1GW includes 23.1GW pumped-storage stations. Thermal power stations include coal 20.4GW, oil 47.1GW, LNG 48.6GW, LPG and other gas 5.5GW . The statistical data of generation capacity, annual electricity generation and demand of power companies in FY 1995 are shown in Table 1.

Electric Power Co.	Genera-tion capacity (GW)	Hydro-power (GW)	Thermal Power (GW)	Nuclear Power (GW)	Genera-tion (TWh/yr)	Demand (TWh/yr)
Hokkaido	5.4	1.2	3.0	1.1	25.8	24.4
Touhoku	12.4	2.4	8.6	1.3	54.6	63.8
Tokyo	51.2	7.6	29.0	14.5	249.1	254.3
Chubu	27.5	5.2	18.7	3.6	111.5	112.6
Hokuriku	5.5	1.8	3.1	0.5	21.5	23.4
Kansai	36.8	7.3	19.2	9.7	133.3	133.8
Chugoku	10.6	2.6	6.7	1.2	42.4	49.4
Shikoku	6.3	1.1	3.1	2.0	28.7	22.5
Kyushu	16.9	2.3	10.5	4.0	65.3	66.6
Okinawa	1.5	–	1.5	–	4.8	5.8
Sumof10 EPCs	173.7	31.6	103.2	38.4	737.6	757.0
EPDC	12.3	7.6	4.6	–	43.7	–
other wholesalers	16.8	2.7	11.3	2.8	86.7	–
EPCs Total	202.9	42.0	119.2	41.2	868.1	–

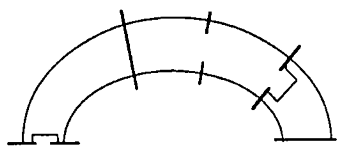
Table 1 Statistics of Electric Power Companies in FY 1995

2. CHARACTERISTICS AND PROBLEMS OF ELECTRIC POWER SYSTEM

The demand and supply in each power company area in the west 60Hz power system is comparatively balanced. Therefore, maximum 500kV tie line power flow is about 3GW. However the total length of 500kV trunk lines from the southernmost of Kyushu to the easternmost of Chubu reaches 1000km and the whole system structure is longitudinal as shown in Fig2(a). Because of this structure, the low frequency (0.3 to 0.5Hz) tie-line power oscillation appears during system disturbances. Under some conditions, the damping of this low frequency oscillation is weak and may cause dynamic instability.



(a) Long Distance Longitudinal Power System (West 60Hz)



(b) Double Semi-Ring Power System(East 50Hz)

Fig. 2 Features of the Power Systems

On the other hand, in the east 50Hz power system the regional balance of demand and supply is not so good. The maximum power from the east side of Tokyo to west side reaches 8GW. For this heavy power transmission, 500kV AC trunk lines of TEPCO constitutes loop system. In other word, these 500kV transmission lines form a double semi-ring right-of-way surrounding Tokyo metropolitan area. (Fig.2(b)) Under open loop condition or at night when pumped storage power stations are operated in pump-mode, the transient stability becomes critical if severe disturbance occurs. Another problem is the increase of short circuit current which may reach the limit value of 63kA.

Since the steeple summer peak demand is due to air conditioners which constitutes about 35% of total demand in peak time, Japanese power companies have to carefully control time-to-time power and reactive power supply. However, due to the constant-power load characteristics derived from the inverter for variable frequency control of induction motors in air conditioners, voltage stability may be critical under some conditions.

3. ADVANCED TECHNOLOGIES IN POWER SYSTEM ENGINEERING

3.1 UHV AC AND HVDC TRANSMISSION

In order to solve the above-mentioned heavy power transmission and short circuit current problem , TEPCO jointly with three major Japanese manufacturers, Mitsubishi Electric (MELCO), Toshiba and Hitachi, has developed 1000kV UHV (Ultra High Voltage) AC apparatus as the next higher voltage in Japan succeeding the present 500kV. These apparatus composed of GIS (Gas Insulated Switchgear), transformer, and control/protection equipment are now under long time endurance test in TEPCO's Shin-Haruna substation. TEPCO has constructed the 1000kV designed transmission lines being at present operated at 500kV. These 1000kV right-of-way forms the outer power transmission corridor to the existing 500kV loop system.(Fig.1) TEPCO will start operation of 1000kV transmission after year 2003.

In the west side of Japan, KEPCO, Shikoku Electric Power and EPDC (Electric Power Development Co.) are now constructing the ±250kV 1400MW HVDC submarine transmission lines across Kii Channel between Shikoku island and Kansai. (Fig.1) This HVDC transmission will start operation in year 2000. In the HVDCconverters ,manufactured by MELCO, Toshiba and Hitachi,the world largest 6 inch diameter thyristor rated at, WkV 3600A and directly triggered by light signal is adapted. New method of controlling converters which realizes continuous converter operation during AC fault,is developed. The basic specifications of Kii Channel HVDC link are shown in Table 2.

Type of main circuit		One bipole , Metallic return
Grounding of neutral line		Direct grounding at one end (Anan Convertor Station)
Transmission capacity , voltage, current(in the year 2000)		1400MW , ±250kV , 2800A (3500A at overload)
Transmission capacity , voltage, current(final)		2800MW , ±500kV , 2800A (3500A at overload)
Cables	Submarine	Steel wire armored , Lead sheathed , OF , 3000mm^2 , 48km
	Inland	Aluminum sheathed , OF , 3000mm^2 , 3km
Overhead lines	Main	TACSR/AC , 810mm^2 × 4 , 51km
	Neutral	TACSR/AC , 610mm^2 × 2 , 51km
AC system voltage		500kV

Table 2 Basic Specifications of Kii Channel HVDC Link

3.2 FACTS-FLEXIBLE AC TRANSMISSION SYSTEM

The concept of FACTS is the enhancement of power system stability with the application of power electronics technology. As the world first large scale commercial STACOM (Static Synchronous Compensator), a 80MVA self-excited type static reactive power compensator was manufactured by MELCO and is now operating at Inuyama Substation of KEPCO. The configuration of this STACOM is shown in Fig.3 This unit contributes the enhancement of power system stability in a 154kV transmission line. Another application is the active filters compensating the fluctuating transmission or distribution line harmonics instantaneously.

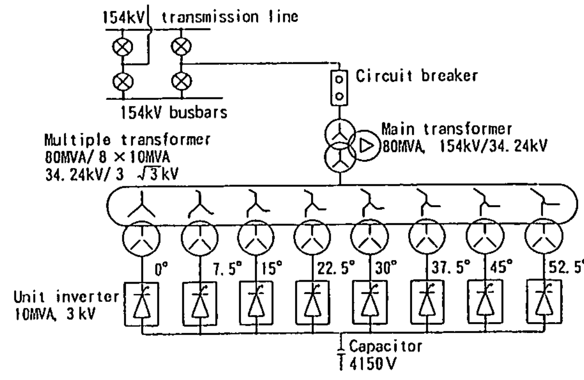


Fig. 3 System Configuration of Inuyama 80MVA STACOM

In addition to Kii Channel HVDC transmission lines, another two HVDC projects are now under construction. They are the 3rd frequency converter station of size 125kV 300MW at Higashi-Shimizu and the BTB (Back-To-Back) non-synchronous interconnection at Minami-Fukumitsu between Chubu and Hokuriku Electric Power Companies. Both systems are shown in Fig.1 and will start operation in year 1999.

3.3 EMERGENCY CONTROL OF POWER SYSTEM

To prevent the large area blackout due to cascading trips during a power system disturbance, various emergency control systems which sustain power system stability,

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were developed. The largest emergency control system, BSS (Block System Stabilizer) was manufactured by MELCO and is now under operation in KEPCO . This system is fully duplicated resulting in total 450 control and signal processing panels connected together through many dedicated microwave signal transmission channels.

Since KEPCO power system is the central among the six interconnected 60Hz power systems in the west, its system frequency stability and phase-angle stability are very important when contingency occurs, such as tripping-out of a large power station or a heavy-loaded trunk line. Under such conditions, BSS will shed some generation, load or tie-line within 0.2 to 0.5sec, thus not only sustaining system frequency but also providing damping to the above-mentioned low frequency power oscillation as shown in Fig.4.

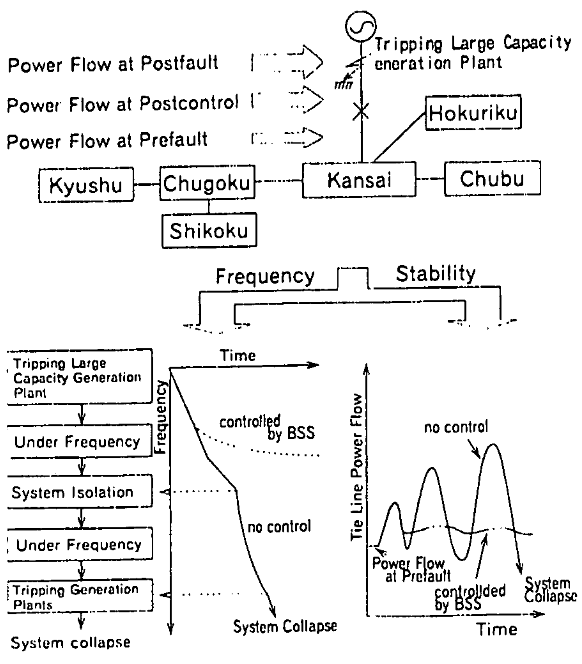

Fig. 4 Effect of Control of BSS

3.4 SUBSTATION AND DISTRIBUTION SYSTEM AUTOMATION

Application of the open distributed computer control systems realizes highly reliable digital protection, monitoring and control systems for substations. These systems utilize engineering work stations (EWS), personal computers (PC), optical fiber signal transmission, digital micro-processor protective relays and local area networks (LAN). Conventional protective relays are substituted with micro-processor relays. The protection of main transmission lines mostly utilizes the micro-processor current differential relays with digital microwave or optical fiber signal transmission. The configuration of the substation automation system is shown in Fig.5.

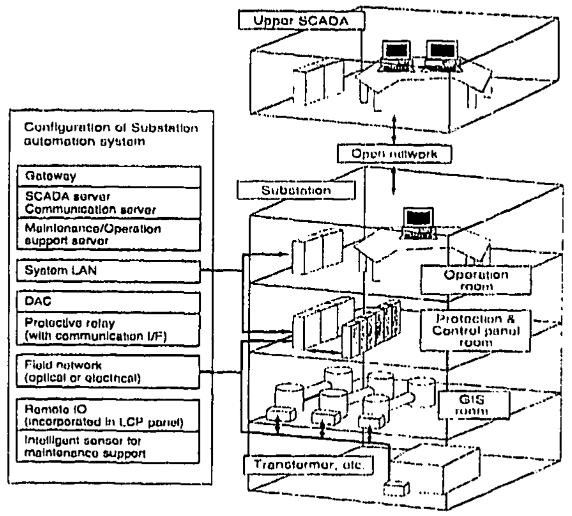

Fig. 5 Basic Configuration of Substation Automation System

The total distribution automation system consists of three fields. They are distribution automation system (DAS) monitoring and controlling distribution lines, high-grade customer service such as an automatic meter reading (AMR) and distribution management system (DMS) including automatic mapping (AM) and facility management (FM). DAS monitors the faulty section in distribution lines, and minimizes the interruption time and area by switching the sectional and bypass switches of the faulty distribution line. The configuration of DAS is shown in Fig.6.

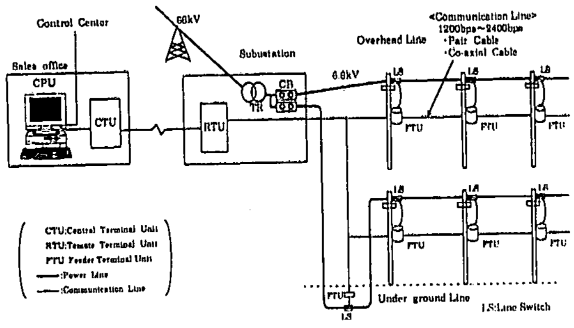

Fig. 6 DAS Configuration

3.5 POWER SYSTEM ANALYSIS SUPPORT SYSTEM - POWER SYSTEM SIMULATORS

To realize real time simulation of large-scale power systems with up to several hundred generators, a new digital simulator utilizing the hyper-cube structure super-parallel computer n-CUBE, was jointly developed by TEPCO and MELCO. This simulator calculates the root-mean-square (RMS) values of voltages and currents for dynamic simulation, and is connected to an analog simulator which calculates the instantaneous values, thus operating as an A/D hybrid simulator.

Another application of real time simulation is realized in analysis of Kii Channel HVDC transmission by the analog simulator which MELCO introduced from TEQSIM, Canada. This simulator is for middle-scale power systems up to several tens of generators and calculates the instantaneous values. Generators are modeled with digital controllers. The progress in power system analysis tool is shown in Fig.7.

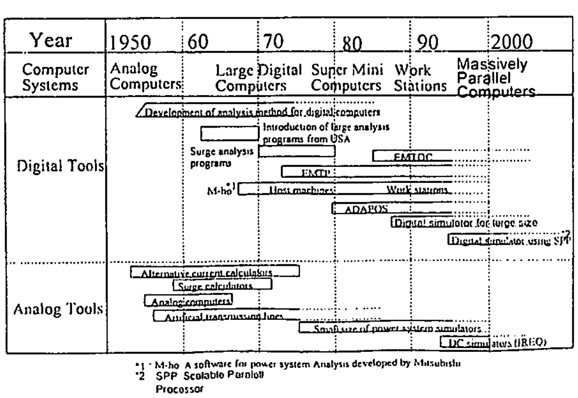

Fig. 7 Progress in Power System Analysis Technology

4. TECHNOLOGIES FOR CHANGING POWER SYSTEM CHARACTERISTICS

The trend for the competitive electric power supply market is slow but steady in Japan compared to reformations in USA and UK. Since the high electricity price (average about 19 yen/kWh) harms the competing power of industries, the power generation market was recently open to independent power producers (IPP) in order to decrease electricity price by competition. In the next step of the deregulation of power supply, transmission and distribution systems may also be open to these IPP. This situation raises another new problem how to and to what degree the present highly reliable and totally economic power dispatch will be sustained under individual selection for economic transmission lines by IPP. The development of new paradigm is under discussion.

Another effort is in progress in the field of demand side management (DSM) or load management. Since suitable sites for new large capacity pumped hydropower stations are difficult to find, new energy storage systems which utilize off-peak electric power at night to decrease daytime peak generation, are under development. A 30MW pumped hydropower station using sea water and lower reservoir of Pacific Ocean, is tested at Okinawa island. The 2nd method is the battery storage system in substations and customers. For example, TEPCO is developing the 500kW to 6 MW NaS battery units. The 3rd method is the cold heat storage system such as an icing during nighttime and utilizing the ice in the daytime for air-conditioning.

5. CONCLUSION

The power system engineers have developed new technologies by applying the advanced micro-electronics, distributed computer configuration, communication and power electronics technologies. Besides, new concepts and methods in software engineering have been adapted in power system planning and control. They are the expert system, artificial neural network, fuzzy control and genetic algorithm. For the economical, secure, reliable and environmentally suitable operation of the huge and complicated power systems, we should continue development efforts in power system engineering by the adequate combination of these software technology with hardware technology.

Paper No. 8

ELECTRICITY SAFETY LEGISLATION - PAST, PRESENT AND VISION OF THE FUTURE

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ELECTRICITY SAFETY LEGISLATION – PAST, PRESENT AND VISION OF THE FUTURE

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ABSTRACT

The Electricity Supply Ordinance and its subsidiary legislation, the Electricity Supply Regulations, were first introduced in 1911 to regulate the supply of electricity in Hong Kong. The safe use of electricity in factories and other work places became one of the major concerns of Government due to the rapid economic growth in the 60's and 70's. As a result the Factories and Industrial Undertakings (Electricity) Regulations were introduced in 1982 to address the issue. The need for new legislation on the safe use of electricity to enhance public safety was high in government's agenda in the 80's. Wide public consultations were carried out leading to the enactment of the Electricity Ordinance in 1990. The Electricity Ordinance is now the main enabling legislation in Hong Kong setting out the legal framework encompassing four major areas of concern, namely, electricity supply, wiring installations, registration of electrical workers and contractors, and electrical products. This paper highlights the development of the safety legislation relating to the supply and use of electricity in Hong Kong since the beginning of the century with a vision of its further development into the next century.

1. INTRODUCTION

Electricity, as a commercial product, has been serving us for over 100 years. In 1882, the Holborn Viaduct Power Station began supplying electricity in London, and this was one of the first commercial power stations in the world. The Hong Kong Electric Company Limited celebrated its 100th birthday in 1990, and is also one of the world's oldest electricity supply companies. Although the other electricity supply company in Hong Kong, The China Light and Power Company Limited, did not start to produce electricity until 1903 with an installed capacity of 225 kW at Hung Hom, it has now more than 1.8 times generating capacity than The Hong Kong Electric and is one of the leading electricity supply companies in South East Asia.

Electricity has been one of the fastest growing form of energy in the world because of its flexibility, multitude and simplicity of use, the relatively ease and speed of distribution, and unparalleled cleanliness in end use. This is particularly true in Hong Kong with Hong Kong's population growing from 625 thousands in 1921 to over 6.4 millions in 1996. Over the same period of time, the total installed capacity and electricity sales in the territory have also increased rapidly from 11.5 MW to 8,490 MW and from 18 GWh to 31,192 GWh respectively. In the 1950's, an electric lamp might be the only electrical product in a family in Hong Kong and an electric fan or a radio was considered as a luxury possession at that time. Today, it will be difficult to find a family in Hong Kong which has less than 10 items of electrical products. While we enjoy the benefits arising from the use of electricity, very often it is easy for us to forget its potential dangers. It is therefore important that effective legislative measures are introduced to protect the public over the supply, delivery and use of electricity.

2. LEGISLATION INTRODUCED BEFORE 1990

2.1 ELECTRICITY SUPPLY ORDINANCE

The first piece of electricity safety related legislation in Hong Kong was the Electricity Supply Ordinance which was first enacted on 19 May 1911. The objective of the Ordinance was to regulate the supply of electricity for lighting and other purposes. It was based on a similar U.K. legislation enacted shortly after the introduction of domestic electricity and was mainly targetted at "company" supplying electricity in Hong Kong. It was not until 1924 when the definition of "company" was amended to mean any person and any body of persons corporate or unincorporate by whom electricity is generated or supplied. The main provision of this Ordinance was the power to make regulations which shall apply to every company generating or supplying electricity within Hong Kong. The Electricity Supply Regulations, as described in the following paragraph, were made under such a provision in 1911.

2.2 ELECTRICITY SUPPLY REGULATIONS

The Electricity Supply Regulations (ESR), which were based on similar U.K. legislation, stipulate in details the requirements and specifications of the electricity supply systems and equipment, including quality of power supply to consumers, construction of electric lines and conductors, protective measures for electricity supply systems, protection against lightning, minimum heights of overhead lines from ground, etc. Since the Regulations were first made in 1911 under the Electricity Supply Ordinance, there had been relatively few amendments, which incidentally are still in force. The first amendment to the ESR was made in 1972 when wooden supports were accepted as alternatives to the iron, steel or reinforced concrete supports for line conductors. Another amendment was made in 1982 when the Electrical and Mechanical Services Department was formed to take over from the then Public Works Department as the enforcement authority of the Regulations.

2.3 ELECTRICITY SUPPLY (SPECIAL AREAS) REGULATIONS

In the 60's and 70's, many refugees from the mainland lived in squatter areas and their need of electricity was undeniable. However, the power companies were reluctant to provide electricity to these special areas because they were required under the law to ensure the safety of their installations. Besides, illegal connection of electricity supply was very common in those days and this had created tremendous problems to the power companies not only to the loss of revenue but also with regard to electrical safety and fire risk. As a result, the Electricity Supply (Special Areas) Regulations were made in July 1976 aiming to make special provisions for the power companies to overcome these problems in supplying electricity to the squatter areas in a proper and safe manner. Under the electricity supply scheme to the squatter areas, the metering position would be installed in either a meter room specially constructed for this purpose or a pole-mounted meter box supplied by the power companies. In particular, each outgoing wiring connection from the meter to the consumer's premises would be protected by a suitable fuse or circuit breaker to ensure electrical safety. Also, the responsibilities of the power companies and the consumers were defined. These Regulations thus set up the safety standards for the supply of electricity to those special areas and are still in force. With Government's policy to clear the squatter areas, it is anticipated that these Regulations could be repealed in the near future.

2.4 FACTORIES AND INDUSTRIAL UNDERTAKINGS (ELECTRICITY) REGULATIONS

As early as 1955, the Commissioner of Labour had raised concerns on the inadequacy of precautionary measures against the potential danger of electrical accidents commonly found in factories and other work places. The situation was aggravated by the rapid growth of local industry in the 60's and 70's. The Labour Department was of the view that the periodic testing requirement at intervals of not more than 5 years to be conducted by the power companies as stipulated in the ESR was not sufficient for factories. It was because factories would normally have a large variety of electrical equipment, as compared to domestic dwellings or shops, which were more heavily used in an industrial environment and hence subjected to more abuses and greater degree of wear and tear than domestic equipment. Also, some of the electrical equipment and machinery in factories were more sophisticated and used higher voltages than that for domestic purposes, resulting in higher risks to persons and properties. Hence, for industrial safety, a separate set of legislation to be enforced by the Labour Department was considered necessary.

The Factories and Industrial Undertakings (Electricity) Regulations were subsequently made in 1982 under the Factories and Industrial Undertakings Ordinance, Cap.59. The Regulations are applicable to all industrial undertakings in which electricity is generated, transformed, distributed and used with the exception of the electricity supply companies, railway and tramway companies, the facilities of which were considered as special installations requiring different regulatory controls. Besides specifying some general safety requirements, these Regulations also stipulate special safety requirements in respect of specific types of electrical equipment, including switches, conductors, electric motors, switchboards, lighting and substations. It also makes provisions for the use of protective equipment, precautions to be taken when persons are working on apparatus and safe access to underground substations. It is the duty of the proprietor of every industrial undertaking to ensure that the relevant provisions of these Regulations are complied with. It should be noted that the provisions of these Regulations are in addition to and not in derogation from the provisions of the Electricity Ordinance, Cap.406.

2.5 ELECTRICITY SUPPLY (AMENDMENT) REGULATIONS 1984

One of the main provisions of the original ESR was the obligation of the power companies to test periodically all electrical installations to ensure that the installations remained safe. As a result of the rapid developments in Hong Kong in the 60's and 70's, the enforcement of this provision had become impracticable. In 1977, the power companies requested the Government to relieve them of such obligation on the ground that the cumulative extent of the obligation had rendered its scrupulous performance unfairly onerous, while at the same time the reason for its imposition had largely fallen away owing to the continuous improvement in the quality of workmanship and material used for electrical installations. The proposal had to be examined very carefully since the abolition of this obligation would give rise to a variety of problems, including the appropriate extent of the statutory responsibilities to be imposed on consumers, the power companies and the Government, in relation to electrical safety. The specific problem of periodic testing was later temporarily solved by the making of the Electricity Supply (Amendment) Regulations 1984, in which the Director of Electrical & Mechanical Services was empowered to grant exemptions to the periodic testing requirement, pending comprehensive review of the electricity safety legislation which was being conducted at that time. Subsequently the obligation of periodic testing of certain categories of electrical installations was transferred to the owners of electrical installations when the Electricity (Wiring) Regulations were put into operation in 1992.

2.6 SUPPLY VOLTAGE UPGRADING

Historically, the supply voltages in Hong Kong were 346/200V alternating current, three phase and single phase respectively. These supply voltages had long been discarded by other countries in the world. Although the issue was discussed in Government in the 70's, it was not until a lot of consultation and research work had been carried out that in the early 90's, the Government considered it opportune to upgrade the supply voltages to the more internationally used voltages of 380/220V. A voltage upgrading programme was implemented during 1990-92 for all government buildings which was satisfactorily completed in November 1992. The Electricity Supply (Amendment) Regulation 1992 was then made to amend the ESR by stipulating the new supply voltage levels and their applications. The territory-wide voltage upgrading programme, first launched in January 1993, was smoothly and successfully completed in March 1997.

3. LEGISLATION INTRODUCED SINCE 1990

3.1 ELECTRICITY ORDINANCE

Reappraisal of the Electricity Supply Ordinance and its subsidiay legislation started in the late 60's and it was concluded that the legislation should be replaced. A bill for such purpose was drafted in 1972 but was later taken out of the legislative drafting programme as it was decided that priority should be given to the enfranchisement of the power companies and the drawing up of the Scheme of Control Agreements with the power companies. While the operation of the power companies has been successfully monitored by the Government under the Scheme of Control Agreements, the need for new legislation on the safe use of electricity to enhance public safety remained high in the Government's agenda in the 80's. The Electricity Ordinance, Cap.406 was enacted in 1990 to repeal and replace the outdated Electricity Supply Ordinance. The Electricity Ordinance is now the main enabling legislation on electricity safety and is supported by subsidiary legislation in the form of Regulations, as well as Code of Practice and Guidance Notes introduced by the enforcement authority, the Electrical and Mechanical Services Department (EMSD).

The Electricity Ordinance aims to set out the legal framework encompassing all the areas within which the concerned legislation shall apply. It serves to provide for the registration of electrical workers, contractors and generating facilities; to provide safety standards and requirements for electricity supply, electrical wiring installations and products; and to provide powers for electricity suppliers and the Government in investigating electrical accidents and enforcement of the Ordinance. The Ordinance also defines the duties and obligations of each and every concerned parties, including the electricity suppliers, the owners of electrical installations, the electrical workers and contractors, as well as the duties and powers of the authority administering the Ordinance. Besides, to safeguard the interest of the general public, provisions are built into the Ordinance to discipline electrical workers and contractors who fail to comply with the requirements of the Ordinance, and to allow for appeals against decisions made by the power companies and the enforcement authority.

The subsidiary legislation made under the Electricity Ordinance include the Electricity Supply Regulations, the Electricity Supply (Special Areas) Regulations, the Electricity (Exemption) Regulations, the Electricity (Registration) Regulations, the Electricity (Wiring) Regulations, the Plugs and Adaptors (Safety) Regulation and the new Electrical Products (Safety) Regulation. As stated above, although the Electricity Supply Regulations and the Electricity Supply (Special Areas) Regulations were originally made under the Electricity Supply Ordinance, they were retained after the Electricity Supply Ordinance was repealed in 1990 and would be reviewed at a later date. The other sets of Regulations were introduced in stages as described below.

3.2 ELECTRICITY (REGISTRATION) REGULATIONS

With the enactment of the Electricity Ordinance in 1990, all electrical workers and contractors engaged in electrical work on fixed electrical installations must be registered with the enforcement authority i.e. EMSD. The purpose of registration is to ensure that electrical work is carried out by qualified electrical workers/contractors in order to ensure the quality of the electrical work and to improve electrical safety.

For electrical workers, there are five grades of certificates of registration, namely, Grade A, B, C, H and R. Grade A is for electrical work on that part of a low voltage fixed electrical installation that has a maximum demand not exceeding 400A, single or three phase. Grade B is for electrical work on that part of a low voltage fixed electrical installation that has a maximum demand not exceeding 2500A, single or three phase. Grade C is for electrical work on a low voltage fixed electrical installation of any capacity. Grade H is for electrical work on a high voltage electrical installation. Grade R may include electrical works on a neon sign installation, an air-conditioning installation, a generating facility installation, or any other types of electrical work or work on any types of electrical installation or premises, that DEMS specifies on a registered electrical worker's certificate of registration.

To be qualified for registration, an applicant must possess the required qualification, training and experience appropriate to the grade as stipulated in the Regulations. As at July 1997, there were about 53,000 electrical workers and 8,000 electrical contractors registered under the Ordinance.

In order to monitor the performance of the registered electrical workers/contractors (REW/REC) and to ensure that the electrical work undertaken by them is in compliance with the safety requirements stipulated in the Electricity Ordinance, in particular the Electricity (Wiring) Regulations, a Performance Monitoring Point System was introduced in January 1994 after full consultation with all parties concerned. This system provides a set of fair and transparent administrative guidelines for EMSD to take appropriate actions against the REWs and RECs for the purpose of improving their performance.

3.3 ELECTRICITY (WIRING) REGULATIONS

The Electricity (Wiring) Regulations specify in details the safety standards and requirements in respect of fixed electrical installations. EMSD has, after making reference to appropriate national and international standards, published a Code of Practice for the Electricity (Wiring) Regulations to give technical guidelines to RECs/REWs on how the statutory requirements of the Regulations can be met. Compliance with the Code of Practice should achieve compliance with the relevant provisions of the Regulations.

Under the Electricity (Wiring) Regulations, a fixed electrical installation shall, after completion (including any work completed after repair, alteration or addition) and before it is energised for use, be inspected, tested and certified by a REC/REW to confirm that the requirements of the Ordinance have been met.

For public safety, a fixed electrical installation located in certain specified types of premises is required to be inspected, tested and certified periodically. The frequency for such inspection, testing and certification is either once every 12 months or once every 5 years depending on the type of premises where the electrical installation is located.

An owner of the fixed electrical installation located in places of public entertainment, premises for the manufacturing or storing of dangerous goods, and premises with a high voltage fixed electrical installations fed directly from a high voltage supply shall have the installation inspected, tested and certified at least once every 12 months.

An owner of the fixed electrical installation located in hotel or guest house, hospital or maternity home, school or educational institution, child care centre; the fixed electrical installation in a factory or industrial undertaking that has an approved loading exceeding 200 amperes, single or three phase; and the fixed electrical installation in premises other than those referred above that has an approved loading exceeding 100A, single or three phase shall have the installation inspected, tested and certified at least once every five years.

3.4 PLUGS AND ADAPTORS (SAFETY) REGULATION

In 1993, the Consumer Council revealed in one of its reports that over 80% of samples of plugs obtained in the local market failed to pass the safety tests conducted by the Council. The Consumer Council expressed deep concern on the situation which indicated that without proper statutory control, the manufacturers would not upgrade the quality of their products despite constant efforts by the Council to identify substandard electrical products over the years. The concern of the Consumer Council was shared by the Government and it was considered that the problem of unsafe plugs and adaptors should be addressed as a matter of priority. While the introduction of the more complicated Electrical Products (Safety) Regulation (EPSR) to provide comprehensive control over all household electrical products would require more deliberations at the time, it was decided to make a separate set of Plugs and Adaptors (Safety) Regulation (PASR) in advance of the EPSR. The PASR was subsequently enacted in September 1994 and brought into operation in March 1995 after a six months grace period. The PASR will be repealed when the Electrical Products (Safety) Regulation is brought into effect in May 1998 to cover all household electrical products including plugs and adaptors.

The Regulation applies to any plug or adaptor which is designed for household use at a voltage of not less than 200V alternating current single phase whether it is supplied as a loose part or fitted to an electrical product with the exception of those under transhipment or in transit through Hong Kong, or those manufactured for export. Taking into consideration of the existing electrical wiring and socket systems in Hong Kong which follow the U.K. practice, only plugs and adaptors complying with the relevant British Standards are accepted to ensure conformity and to eliminate the potential danger arising from the use of plugs and adaptors with different dimensions and designs in conjunction with the said socket systems. Besides 2-pin reversible plugs to BS 4573 or EN 50075 for shavers, only 3-rectangular-pin fused plugs rated at 13A to BS 1363 or BS 5733 and 3-round-pin plugs rated at 5A or 15A to BS 546 or BS 5733 together with the corresponding adaptors are allowed to be supplied in Hong Kong. The law also requires that every household electrical product designed to be connected by means of a flexible cord and plug to a socket to be fitted with a plug of correct rating which conforms to the prescribed safety standards.

3.5 ELECTRICAL PRODUCTS (SAFETY) REGULATION

As mentioned above, a new set of subsidiary legislation under the Electricity Ordinance had been proposed to provide comprehensive control over the safety of all electrical products designed for household use and supplied in Hong Kong. The Electrical Products (Safety) Regulation (EPSR) has recently been gazetted and will be put into operation in May 1998 after a 12-month grace period to allow for the trade and the consumers to get acquainted with the new statutory requirements.

The objective of the EPSR is to enhance public safety in the use of household electrical products. The means for achieving this objective as detailed in the Regulation include :

(a) prescribing the safety requirements for the household electrical products;

(b) requiring the suppliers to ensure that their products are in compliance with the prescribed safety requirements and a certificate of safety compliance is issued for every model of electrical products they supplied; and

(c) requiring the suppliers of electrical products which do not meet the prescribed safety requirements to notify the public of the hazardous defects in the products, to accept a return of the products, and to refund the purchasers concerned.

Under the new Regulation, all electrical products will have to comply with the essential safety requirements (ESRs) which are developed based on the Low Voltage Directive adopted in the European Community for the control of electrical product safety. The aim is to ensure that under normal situations the users of electrical products are protected from electrical shock due to direct contact, risk of fire or explosion due to over-heating, and personal injury due to electrical or non-electrical dangers which may arise. In addition to the ESRs, prescribed products will have to comply with certain specific safety requirements derived from international and/or national standards. Initially, 6 types of electrical products including plugs, adaptors, extension units, lampholders, flexible cords and unvented thermal storage type electric water heaters are classified as prescribed products under the EPSR but more prescribed products may be introduced as and when required. EMSD will publish a set of guidance notes in which the relevant international and national standards deemed to satisfy the safety requirements of the EPSR will be listed. In general, electrical products designed to meet the International Electrotechnical Commission (IEC) standards or compatible standards will be able to satisfy the prescribed safety requirements of the Regulation.

It is stipulated in the new EPSR that every model of household electrical product supplied in Hong Kong will have to be issued with a certificate of safety compliance. For prescribed products, only test certificates or reports issued by recognized certification bodies or recognized manufacturers registered with EMSD will be accepted as the certificates of safety compliance. In general, test certificates issued by national certification bodies participating in the CB Scheme of the IEC System for Conformity Testing to Standards for Safety of Electrical Equipment, and endorsed test certificates issued by testing laboratories accredited by the Hong Kong Laboratories Accreditation Scheme (HOKLAS) or those bodies having mutual recognition agreements with HOKLAS will be acceptable. Moreover, a self declaration of conformity issued by the product manufacturer will be accepted as the certificate of safety compliance for non-prescribed products. In essence, this means that every model of household electrical product will have to be certified that it has been tested and found to be in conformity with the safety requirements. The endorsed test certificates or test reports adopted in international trade will normally be accepted as the certificates of safety compliance; as such, electrical products that have been tested for such purpose will not need to be tested again for compliance with the Hong Kong regulatory requirements in this aspect.

4. FUTURE DEVELOPMENTS

With the enactment of the Electrical Products (Safety) Regulation, the introduction of statutory control to improve the safety in the use of electricity are almost complete. Future emphasis will be placed in the development of regulations to improve the safety and security in the delivery of electricity, and the safe operation of the electricity supply companies.

In Hong Kong the two electricity supply companies operate their own electricity transmission and distribution network. The underground cables and overhead lines distribute the bulk of electrical energy generated from power stations to consumers. At present, there are no specific provisions under the Electricity Ordinance to protect these cables and lines from damage by third parties. Prevention of damage to such equipment currently depends upon voluntary liaison between the persons responsible for site activities at the location concerned and the relevant power company. This mechanism appears to be inadequate as statistics indicate that these cables and lines have become increasingly susceptible to damage. During the past three years, there were 1,629 underground cables damage and 161 overhead lines damage incidents reported by the two power companies. It is therefore highly desirable that regulatory measures should be introduced with a view to deterring third parties from damaging underground cables and overhead lines in the interests of safety and minimizing the inconvenience caused to consumers through loss of electricity supply because of such damage.

It is therefore proposed to introduce provisions in the Electricity Ordinance to regulate site activities such as construction works and use of heavy machinery in the vicinity of underground cables and overhead lines. The site contractors and workers will have to follow a "Safe System of Work" practice which includes obtaining relevant information from the power companies, locating underground cables by suitably qualified workers, and adopting safe working practices when carrying out work in the vicinity of these cables and lines, etc. The power companies will have the obligations to provide the relevant information of these cables and lines upon request with reasonable accuracy and within reasonable time, as well as to offer assistance to the site contractors and workers in locating underground cables if accurate information is not available. The public consultation on this legislative proposal has been completed earlier this year and the comments received are being consolidated for drafting the new legislation which is expected to be introduced in 1998/99. A Code of Practice with detailed guidelines and working procedures will be published by EMSD in support of the implementation of the new legislation.

The next step in our legislative programme will be to replace the outdated ESR by a new set of Electricity (Supply) Regulation with an aim to ensure the provision of a safe, reliable and efficient supply of electricity to the consumers in an equitable manner. In response to the rapidly changing electricity supply industries and the advancement of electrical technology, the new Regulation will cover various regulatory control on electricity supply matters while maintaining the spirit of self-regulation on the part of the electricity supply industry. It will stipulate the obligations and responsibilities of the suppliers in the provision of electricity supply and of the consumers in obtaining supply. In the new Regulation, the enhancement of electrical safety and improvement on reliability of electricity supply will certainly be one of the key areas. The Regulation will be aiming to prescribe the manner and conditions in which electricity will be supplied, such as voltage and frequency variations of the supply, power factor and harmonics, as well as the safety standards, performance and maintenance requirements of the electricity suppliers' equipment and installations. Besides, the safety auditing requirements for the electricity suppliers will be specified where appropriate. On the aspect of energy efficiency, the necessity of legislative control to implement demand side management and energy auditing will also be explored. In addition, the regulatory control on implementation of a practicable co-generation scheme will be considered to cater for future developments in the electricity supply industries provided that there is tangible benefit to the electricity suppliers and consumers.

As usual, the technical requirements for the new Regulation will be detailed in the Code of Practice (COP) to be published in consultation with all parties concerned. In addition to the electrical safety aspect, the standard designs and practices adopted for the transmission and distribution network and associated installations (i.e. consumer sub-station, switchgear, cabling, overhead lines, protection/control/metering equipment, harmonic distortion limit at point of supply to consumers, etc.) will also be considered for inclusion into the COP. In line with the concern expressed by the public in recent years on the electric and magnetic fields (EMF) generated from the power companies' electrical installation, the guidelines on limits of exposure to EMF will be considered for inclusion into the COP based on the recommendation of the International Radiation Protection Association and international practices. Moreover, a review of the related Electricity Supply (Special Areas) Regulations will also be carried out at the same time. At present, a research on international practices regarding electricity supply regulations is being conducted with a view to formulating the scope for this new Regulation before initiating a public consultation exercise on the new legislative proposal in 1998. In preparing the new legislation, the development and wind of change in the electricity supply industries will be kept in view.

5. CONCLUSION

The success of a legislation depends greatly on the understanding and acceptance of the general public. The Electricity Ordinance and its subsidiary regulations had gone through the thorough consultation with all sectors of the community during the drafting stages. The successful implementation of the legislation again relies on the co-operation of the community and a constant publicity programme has been put in place to arouse the public awareness of the relevant statutory requirements. As the responsible authority for the legislation, EMSD will continue to keep track of the latest developments in electrical technologies and safety standards in order to upkeep the said legislation in line with international standards.

Paper No. 9

ENERGY LABELLING ON ELECTRICAL PRODUCTS

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Deputy Chief Executive
Consumer Council

ENERGY LABELLING ON ELECTRICAL PRODUCTS

LI Kai Ming
Deputy Chief Executive
Consumer Council

ABSTRACT

About two years ago, the Hong Kong Government started rolling out its voluntary Energy Efficiency Labelling Schemes (EELSs) for refrigerators, freezers and room coolers. As of 16 September 1997, a total of twelve energy labels have been issued. By citing experiences gained in neighbouring countries, this paper recommends that we review the strategies for our appliance energy efficiency measures, so that they will succeed in benefiting the local economy and the consumer.

ABBREVIATIONS

EELS	Energy Efficiency Labelling Scheme
EGAT	Electricity Generating Authority of Thailand
EMSD	Electrical and Mechanical Services Department
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
FATL	Fuels and Appliance Testing Laboratory, Philippines
IIEC	International Institute for Energy Conservation
KEMCO	Korean Energy Management Corporation
UNDP	United Nations Development Program
UNIDO	United Nations Industrial Development Organization

1. INTRODUCTION

Energy saving from the use of electrical products can be achieved by the following market transformation measures:

- Energy Labelling
- Energy Efficiency Standards (minimum energy efficiency requirements)
- Incentives (procurement, rebates and tax)

This paper addresses energy labelling in particular.

There are two types of labelling programmes: comparison and endorsement. Comparison labelling programmes provide consumers with information to compare all products within a given category [1]. Hong Kong voluntary EELSs belong to this type. Endorsement labelling programmes identify and endorse those products that meet a specified high efficiency standard [1]. The Energy Star logo you see on your computer products belongs to this type. This paper mainly deals with the comparison type labels which are dominant in most countries.

Labelling programmes can be mandatory or voluntary. Hong Kong EELSs are voluntary schemes, whereas most of the comparison type energy labels in Australia, Canada, the EU and the US are mandatory.

Paper No. 9

2. CONSUMER COUNCIL TESTS

The Council has been conducting energy efficiency tests on appliances for about twenty years. Our first test on room air conditioners was published in 1978. Since then, we have compared the energy efficiencies of a wide range of appliances including refrigerator-freezer, dehumidifiers, washers and water heaters.

We believe that if consumers can make informed choices, the energy saving potential is great. Our tests on refrigerator-freezers and air-conditioners have shown beyond doubt that the accumulated savings in electricity consumption will be truly substantial if all consumers choose wisely for the more efficient models - so much so that the accumulated savings between the least efficient model and the best model are sometimes enough for purchasing of a new machine [2].

Table 1: Energy Saving Potential of Informed Choices - Room Air Conditioner

Year	Cooling Capacity	Maximum Energy Saving *
1986	1.5 - 2.2 kW	27%
1987	3.1 - 3.4 kW	17%
1989	1.5 - 2.1 kW	29%
1991	2.1 - 2.5 kW	28%
1993	2.2 - 2.5 kW	17%
1995	3.0 - 4.0 kW	28%
1997	4.1 - 5.1 kW	30%

* Maximum Energy Saving refers to the percentage saved in electricity bills, when a decision is made to buy the most energy efficient model instead of the least efficient.

(Source: Consumer Council CHOICE magazine)

3. EXPERIENCES GAINED

The following are some of the experiences gained in neighbouring countries' energy-labelling programmes.

3.1 PHILIPPINES

The Philippine Energy Labelling programme was first conceived in 1983. In 1994, mandatory energy labelling was required for window-type room air conditioners [3].

With the assistance from United Nations Development Program (UNDP) and United Nations Industrial Development Organization (UNIDO), the Philippine government set up the Fuels and Appliance Testing Laboratory (FATL). The FATL, the country's first independent testing laboratory for household appliances, was officially inaugurated in June 1991.

As at the end of June 1997, 17 manufacturers and importers are participating the scheme. A total of 118 air-conditioner models have been issued energy labels.

The energy-labelling scheme on room air conditioners has benefited the national economy in many ways. It has reduced consumers' electricity bills and the demand for power plants. An unanticipated benefit has been that Filipino air conditioners have begun to sell better in export markets due to their high efficiencies. In Hong Kong, at least one well-known brand name has recently started importing air conditioners from the Philippines.

3.2 THAILAND

The Electricity Generating Authority of Thailand (EGAT) was responsible for voluntary energy labelling on room air conditioners and refrigerators. EGAT has voluntary agreement with five major refrigerator manufacturers to affix energy labels to their 140-170 litre models. By February 1995, labels started to appear in shops. EGAT also came to a voluntary agreement with 55 manufacturers to affix energy labels to their room air conditioners. Labels started to appear in February 1996 [4].

EGAT realised that developing technology-related programmes was not enough to persuade the consumer to change behaviour. They now aim to achieve this by means of education, e.g. activities which put emphasis on the practical applications of energy-saving concepts using real energy efficient appliance or technologies [5]. They have launched consumer awareness campaigns, including the productions of numerous television announcement videos. To show the Government's emphasis on energy conservation, their Prime Minister starred in one of these television announcements.

Thailand has a huge budget for its energy conservation programmes. The budget they have for the High Efficiency Refrigerator Labelling Programme, including campaigning, was 195 million Baht. They had a budget of 1,176 million Baht for the High Efficiency Room Air Conditioner Labelling Programme, including campaigning and financial incentives [4].

3.3 SOUTH KOREA

In South Korea, manufacturers must have their products tested by authorised testing agencies and report test results to the Korea Energy Management Corporation (KEMCO), the government agency responsible for the programme [1]. KEMCO said that once they announced that appliances would have to bear energy efficiency rating labels, manufacturers began to increase the efficiency of their products [6].

Since establishing their Energy Efficiency Management System in 1992, energy efficiency has improved and domestic energy consumption has decreased. However, KEMCO admitted that the diversity of the related regulations had made management rather complicated. The lack of testing infrastructure had caused inconvenience to manufacturers.

3.4 AUSTRALIA

Australia has had energy labelling since the early 1980s. Since 1987, the Government has operated a mandatory comparison labelling programme for electric household appliances, including refrigerator-freezers, freezers, air conditioners, dishwashers, clothes washers and clothes dryers. The Australian Gas Association (AGA), an industry association, has operated a voluntary comparison labelling programme for some gas-fired appliances [1] [7].

The effect of energy labelling on the energy efficiency of products has been encouraging. During the two years from 1993 to 1995, refrigerator efficiency (sales weighted efficiency data) had been increasing at 2.1% per year, that of washing machines by 1.9% and clothes dryers up by as much as 4.1%. Past analysis by energy consultants suggests that at least half of the current rate of efficiency improvement is attributable directly to energy labelling. The annual price increase for the same period was 5.1%, 0.7% and 2.1% respectively. The inflation rate has been around 2%-3% during the period. The only real increase in price concerned refrigerators. This could be partly attributed to the fast phasing out of CFCs in Australia prior to August 1994 [8].

Table 2: Annual Change in Energy Performance and Retail Price from 1993 to 1995 (sales weighted data)

	Refrigerator	Clothes Washer	Clothes Dryer
Energy Efficiency	+2.1%	+1.9%	+4.1%
Retail Price	+5.1%	+0.7%	+2.1%

(Source: [8] Harrington, 1997)

4. HONG KONG VOLUNTARY LABELS

In March 1992, the Government endorsed a recommendation made by the Energy Efficiency Advisory Committee to introduce an energy labelling system for electrical household appliances. The Electrical & Mechanical Services Department (EMSD) launched the EELS for Refrigeration Appliances on 15 June 1995 and EELS for Room Coolers on 15 June 1996.

The EELSs were based on the testing requirements in the international standards ISO8187 and ISO5151. For most manufacturers, the tests do not cause difficulties and the costs are affordable. In the US, for example, energy efficiency tests would cost about US$1,000 for room air conditioners and US$2,000 for refrigerators [9].

Paper No. 9

4.1 PROMOTION

During the promotion of these schemes, the Government used pamphlets, posters, seminars, television and radio announcements.

As existing schemes are voluntary, we believe that a lot of resources and effort are needed for promotion.

At the beginning, the industry had been sceptical about the scheme and most manufacturers adopted a wait-and-see approach. Some said they would comply if the schemes became mandatory.

The first refrigerator-freezer energy label was issued some nine months after the launch of the scheme in June 1995. As at 16 September this year, only two refrigerator-freezer models under a single brand name have been issued energy labels.

Having identified the problem, the Consumer Council and the United Nations ESCAP organised a local seminar in March this year. Over 250 people from manufacturers, importers, retailers, utilities and the Government took part. Manufacturers and distributors informed participants that energy labelling would not only benefit the consumers but themselves as well. The seminar not only heightened the awareness of the business community on energy labelling, but also encouraged participants to get involved in the Energy Labelling schemes.

Before the seminar, there were no room air conditioner labels in the shops. During the seminar at least three importers announced their intention to register with the scheme. Since then the number of room air conditioner energy labels has risen to ten (as of 16 September 1997). Room air conditioner importers are still taking interest in the EELS. However, it remains to be seen whether the trend will continue.

Table 3: Status of the Hong Kong Voluntary Energy Efficiency Labelling Schemes (as of 16 September 1997)

	Refrigerator-Freezer	Room Air Conditioner	TOTAL
Number of months since launching	27	15	-
Number of brands registered	1	5	5
Number of models registered	2	10	12

(Source: Electrical and Mechanical Services Department)

4.2 CREDIBILITY OF LABELLED INFORMATION

The credibility of energy labels relies on the accuracy of the label information, in most cases derived from tests commissioned by the manufacturers themselves using samples they provide. It also relies on the honesty of manufacturers to test their new product again if the model is modified.

A comparative test report published by the Consumers' Association in the UK has revealed signs of overclaims on the energy labels of refrigerators. Of fifteen models of refrigerator-freezers, eleven used far more electricity than their labels claimed. The worst model would cost GBP34 a year more in electricity than is indicated by its label [10]. It was reported later that some manufacturers have re-labelled their products after third party testing [11].

In Australia where they have mandatory labelling schemes, there are penalties for manufacturers found to have overclaimed in the labels. As a result, some manufacturers now deliberately place conservative claims on their products to ensure that they never have compliance problems [12].

The Consumer Council would like to know whether random samples have been drawn from local retail outlets and tested and, if so, whether any energy labels have been found to be misleading.

4.3 DISPLAY OF LABELS

The Consumer Council visited a number of major appliance outlets in September. Although twelve energy labels have been issued by the Government, usually only one or two labelled appliances can be found in any one shop. It is therefore feared that some retailers may not always keep energy labels on the appliances displayed, even though they originally come with a label. We therefore hope to see the Government review the situation and look for ways to remedy it.

5. CONCLUSION

The Consumer Council pledges full support to Energy Labelling of appliances as we believe consumer information is crucial to promoting a sustainable consumption lifestyle.

Credibility of the labelled information is extremely important to the success of the schemes. Setting up a testing infrastructure in Hong Kong will certainly facilitate Government monitoring and industry self-policing of energy label information. It is important for energy labels issued to be displayed at retail outlets. Consumers can exercise informed choices only if appliances have clear and verified energy labelling.

Experience in other countries shows that effective implementation is a prerequisite for successful energy efficiency measures. Energy efficiency policies are labour- and management-intensive because they affect so many consumers and companies and are based on ever-changing technology. Effective energy-labelling rules require careful consideration of technical, marketing, bureaucratic and political factors. The private sector is to be closely involved from the very beginning of the programme planning stage. It is important that we learn from the experiences of neighbouring countries [1] [13].

The Government should re-assess the economic impact of energy efficiency measures and provide an adequate budget for its programmes. It is time that we evaluate the implemented energy labelling schemes and consider whether to introduce mandatory labelling. The feasibility of other energy efficiency measures like minimum energy efficiency requirements and endorsement type energy labels should be explored.

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APPENDIX

A. Energy Labeling Programs Around the World

B. Products Covered by Energy Labeling Rules in the United States

C. Examples of Energy Labels

Energy Labeling Programs Around the World

Product	US	Canada	EU	France	Germany	Japan	Australia	Korea	Philippines	Thailand	Brazil	Mexico
Refrigerators	C/E	C/E	C	C	C	C	C	C		C	C	C
Freezers	C/E	C/E	C			C	C					
Air-con	C						C	C	C	C	C	C
Central air-con	C	E										
Water heaters	C	E					C	C				
Space heaters				C			C	C				
Clothes washers	C/E	C/E	E	C			C					
Clothes dryers	E	C					C					
Dishwashers	C/E	C/E	E		C		C					
Furnaces	C											
Ovens	E				C							
Ranges	E	C		C								
Cookpots	E											
Televisions				C								
Vent. Equipment				C								
Lamps	C/E	E						C				
Ballasts	C	E						C				
Windows	C/E	E										
Doors	C											
Skylights	C											
Showerheads	C	E										
Faucets	C	E										
Automobiles	C							C				
Office equipment	E	E										
Motors		E						C/E				
Boilers				C				C				

Note: C = comparison labeling program. E = endorsement labeling program. The table does not include some products covered by endorsement labels in Canada.

(Source: [1] Duffy, 1996)

Paper No. 9

Products Covered by Energy Labeling Rules in the United States

Product	Effective Date of Initial Labeling Rule
Refrigerator and refrigerator-freezers	1980
Freezers	1980
Water Heaters	1980
Clothes Washers	1980
Dishwashers	1980
Room Air-Conditioners	1980
Furnaces	1980
Automobiles	1980
Central Air-Conditioners and Heat Pumps	1987
Fluorescent Lamp Ballasts	1988
Showerheads	1995
Faucets	1995
Fluorescent Lamps	1995
Compact Fluorescent Lamps	1995
Incandescent Lamps	1995

(Source: US Federal Trade Commission and [1] Duffy, 1996)

Example of Energy Labels

United States

"Energy Star" Label (Example of Endorsement Type Label)

(Courtesy: US EPA & US DOE)

energy

EPA POLLUTION PREVENTER

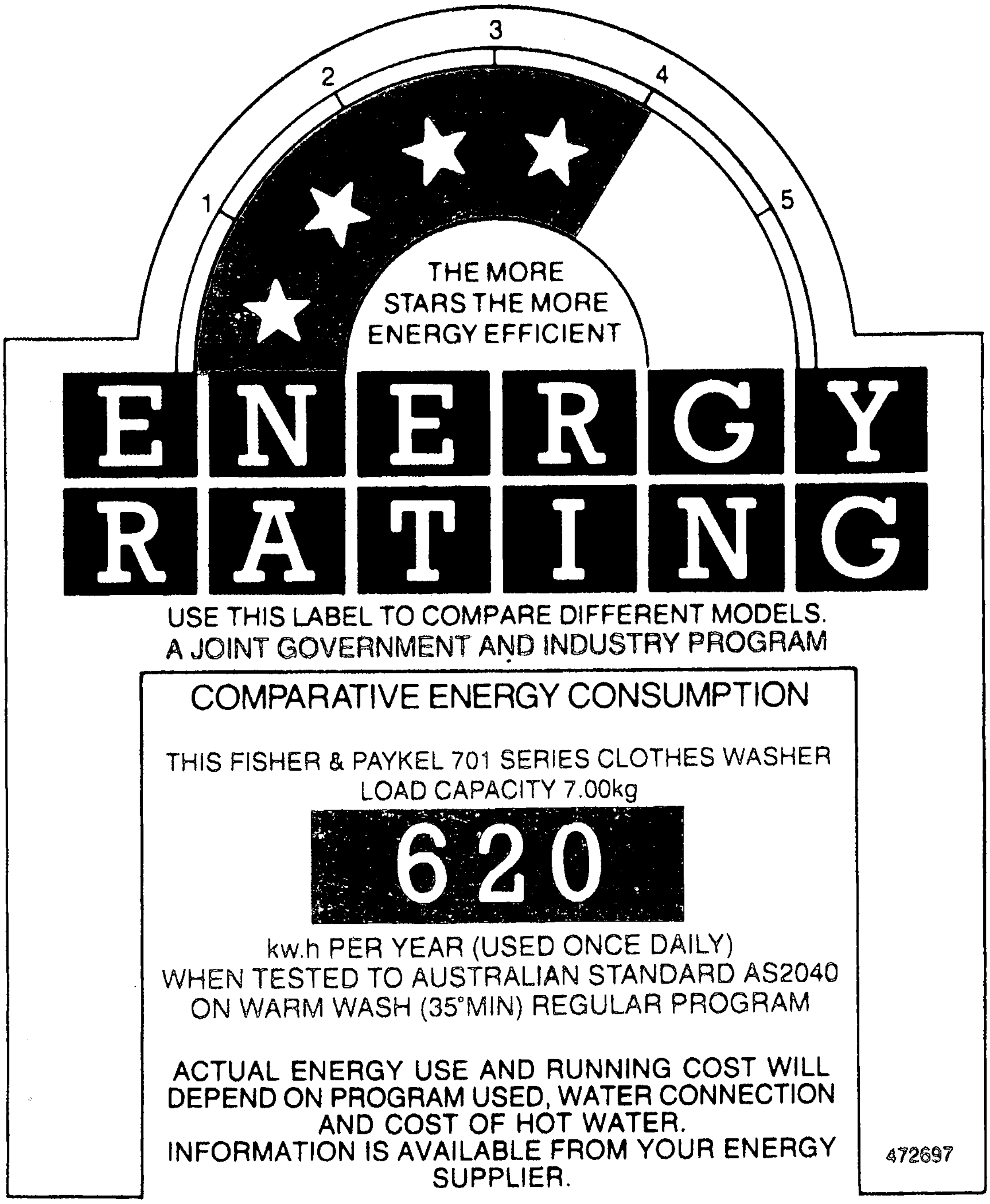
Paper No. 9

Example of Energy Labels

Australia

Clothes Washer "ENERGY RATING" Label

(Courtesy: Fisher & Paykel)

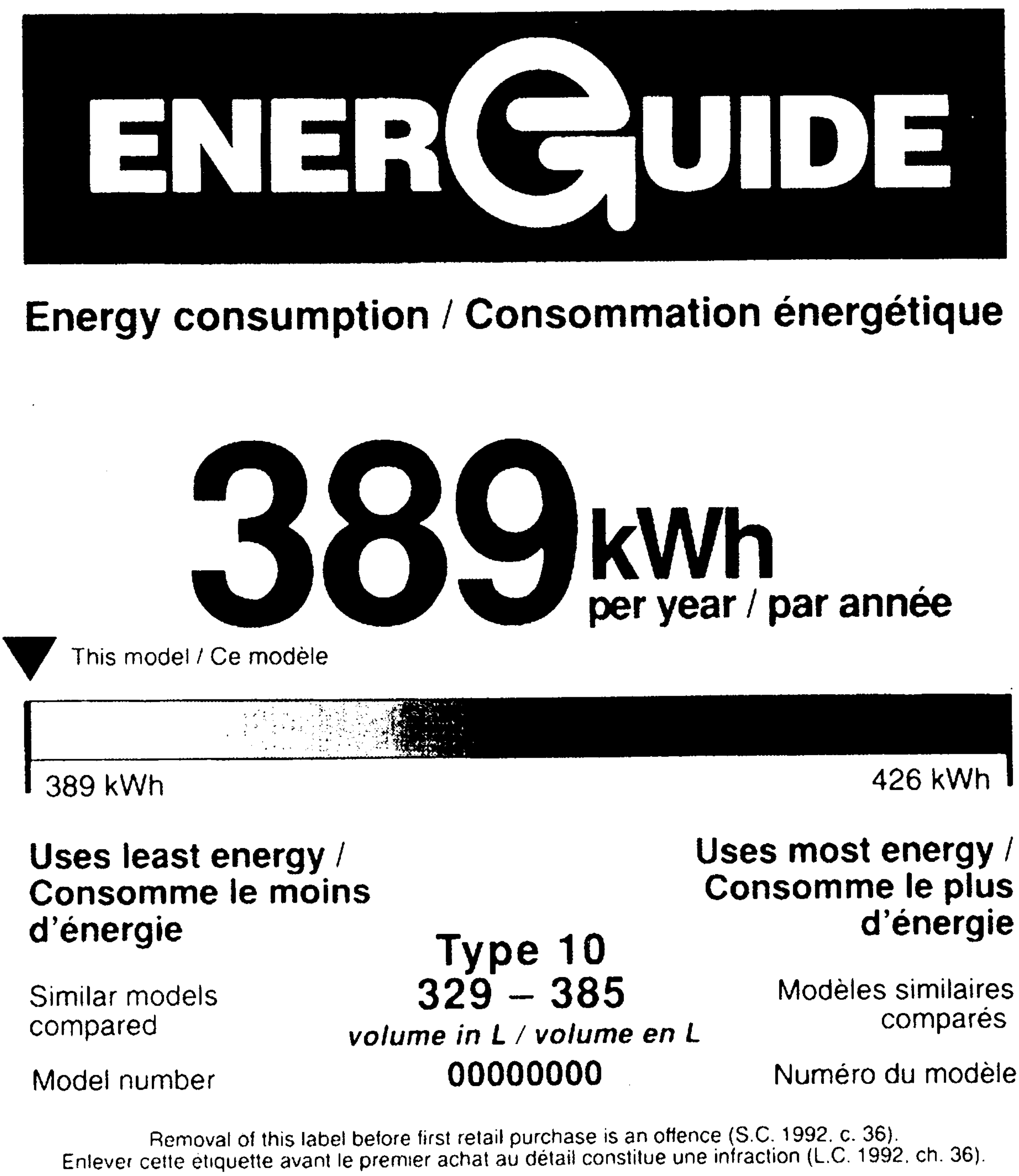


Example of Energy Labels

Canada

Appliance "EnerGuide" Label

(Courtesy: Minister of Natural Resources, Canada)



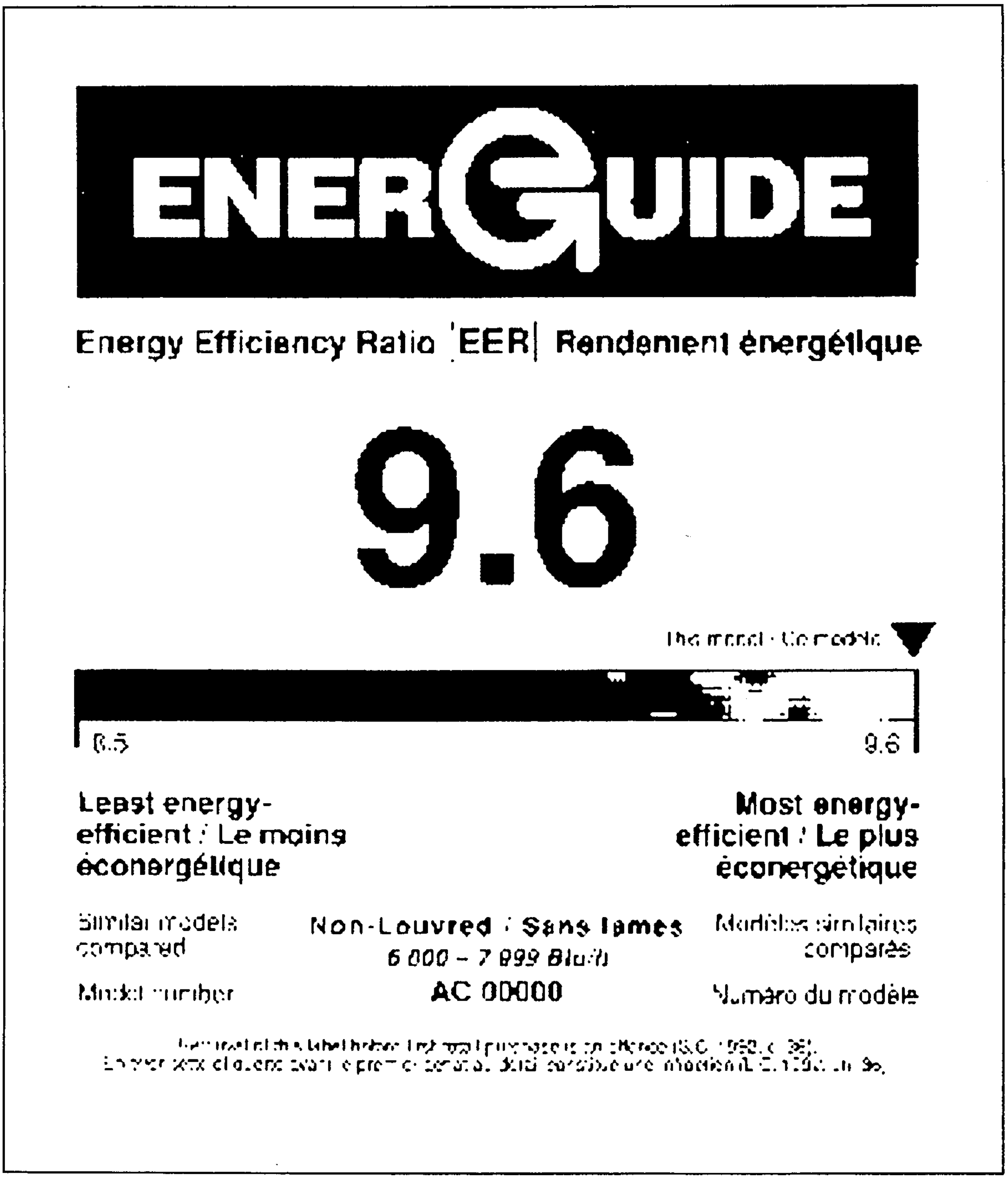
Paper No. 9

Example of Energy Labels

Canada

Room Air Conditioner "EnerGuide" Label

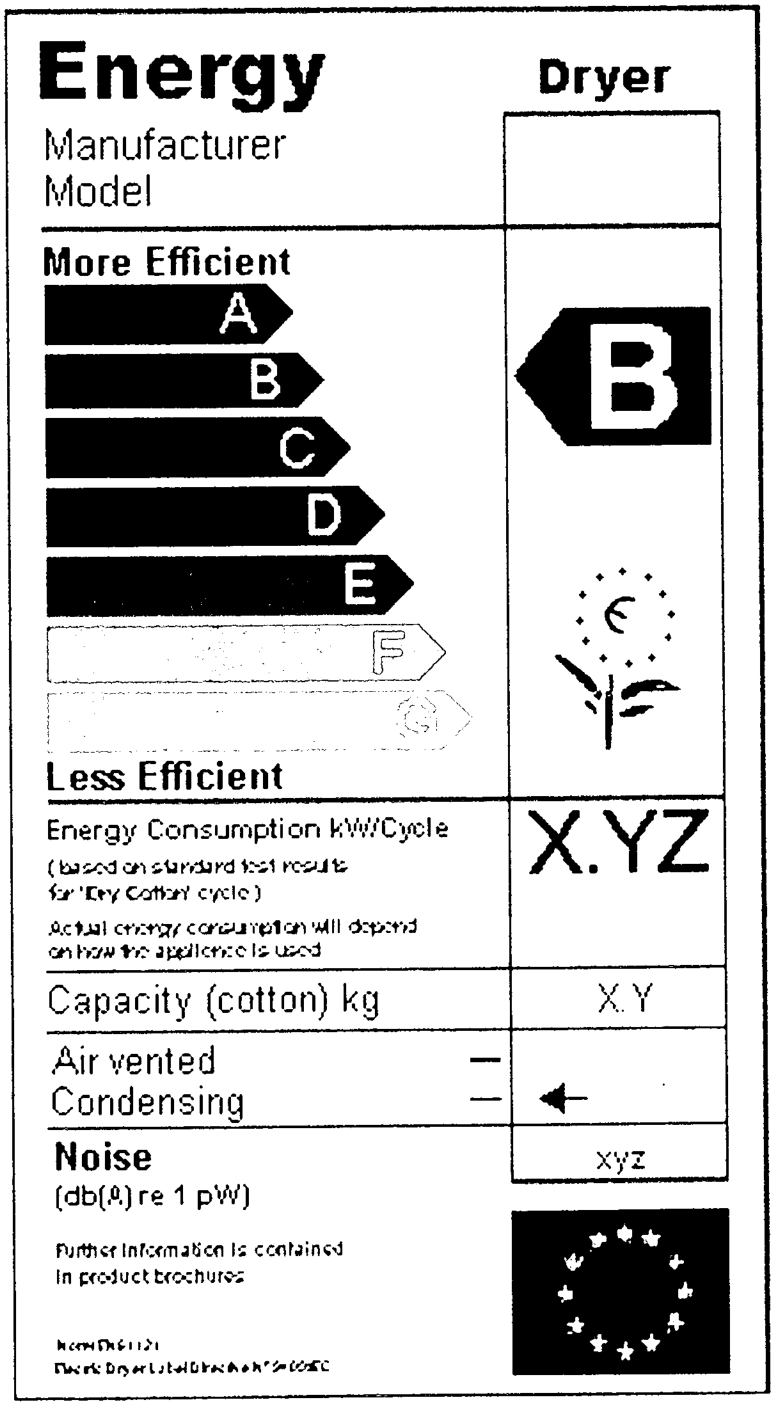
(Courtesy: Minister of Natural Resources, Canada)



Example of Energy Labels

European Union

Clothes Dryer Energy Label



Paper No. 9

Example of Energy Labels

Hong Kong

Refrigerator-Freezer "ENERGY LABEL"

(Courtesy: Alpha Appliances Ltd)

ENERGY LABEL
能源標籤

Brand 牌子	ABC 某某牌
Model 型號	XY-123
Annual Energy Consumption *kWh/yr 每年耗電量 度/千瓦小時 Actual Consumption will depend on where the appliance is located and how it is used 實際耗電量需視乎放置電器的地點及使用方式	752
Energy Efficiency Grade* 能源效益級別 Among the five grades, Grade 1 is the most energy efficient. 在五級別中，第一級為最省電	2
Refrigerator Category *電器類別 Fresh Food Volume (litre) 保鮮格容積（公升） Frozen Food Volume (litre) 冰格容積（公升） Freezing Capacity (kg/24hrs) 冷凍能力（每日公斤）	6 312 148 8 5
EEL Registration Number 能源標籤登記號碼	R 96 - 0002

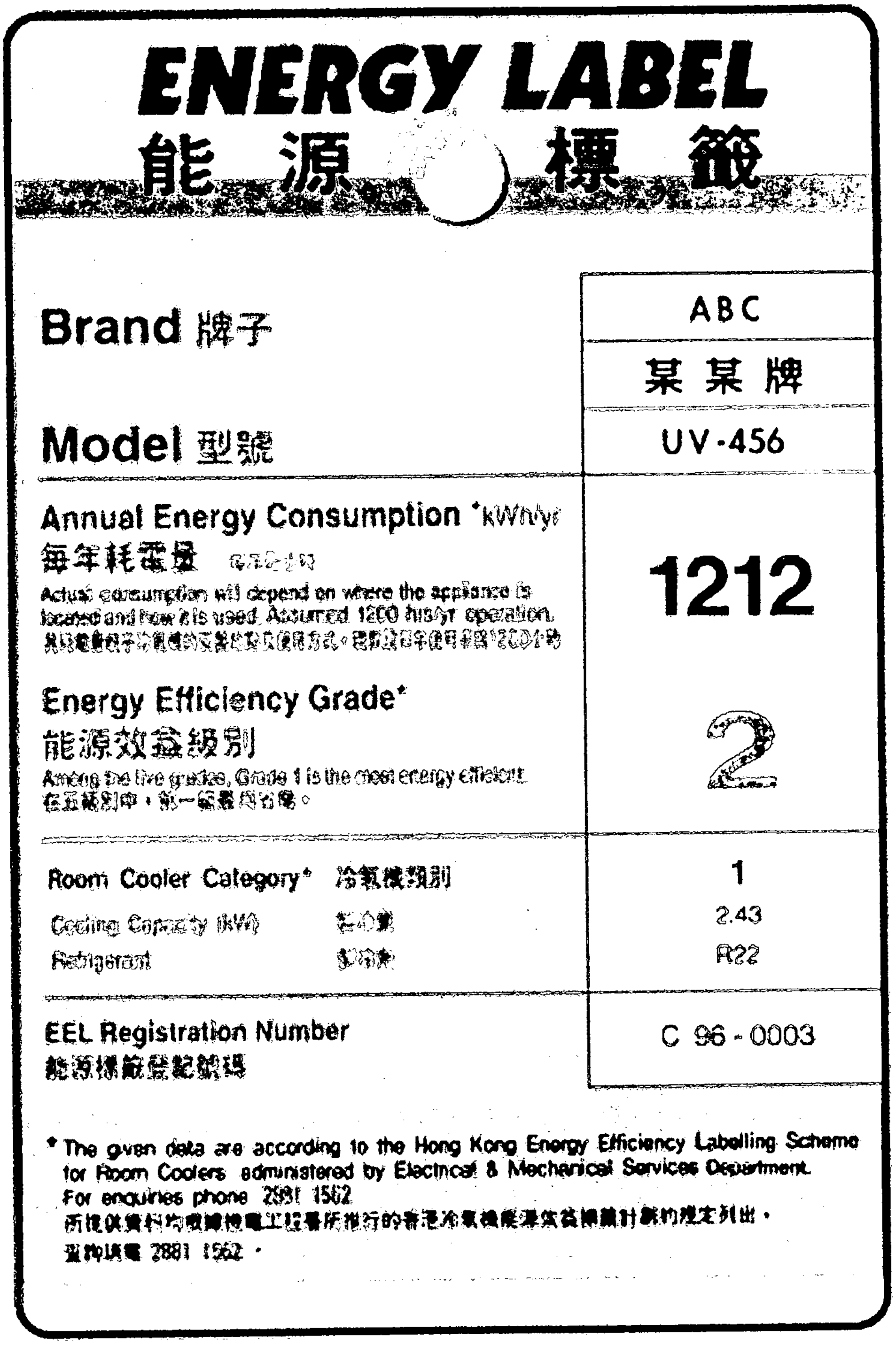
* The given data are according to the Hong Kong Energy Efficiency Labeling Scheme for Household Refrigeration Appliances administered by Electrical & Mechanical Services Department. For enquiries phone 2881 1562
所提供資料均根據機電工程署所推行的香港電器能源效益標籤計劃的規定列出。
查詢請電 2881 1562。

Example of Energy Labels

Hong Kong

Refrigerator-Freezer "ENERGY LABEL"

(Courtesy: Alpha Appliances Ltd)



Example of Energy Labels

South Korea

Room Air Conditioner Energy Label

(Courtesy: Korea Institute of Energy Research)

Example of Energy Labels

Philippines

Room Air Conditioner "ENERGY GUIDE" Label

(Courtesy: DOE Philippines)

____

Brand : ____________________

Model : ____________________

Cooling Capacity: __________ kJ/h

Power Consumption: __________ W

Frequency: 60Hz / Single phase

ENERGY GUIDE

ROOM AIR CONDITIONERS

ENERGY EFFICIENCY RATIO

For units with the same cooling capacity, higher EER means lower electricity cost.

For this model, the minimum EER standard set by the government is ______

The monthly operating cost of this model will be approximately:

RATED POWER DEMAND watt/1000 (kW) X MONTHLY USAGE hours (h) X POWER RATE Pesos / kW-h = COST OF OPERATION Pesos

Data on this label are certified by

This product has been certified to PNS 396.

REMOVAL OF THIS LABEL BEFORE CONSUMER PURCHASE IS A VIOLATION OF REPUBLIC NO. 7394

For information on the cost of operation and selection of correct cooling capacity, ask your dealer or write or call the Office of Energy Affairs, Fuels and Appliance Testing Laboratory, Commonwealth Avenue, Diliman, Quezon City, Tel. Nos. 975-443 or 975-474

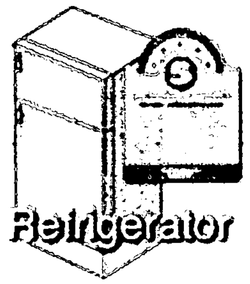
Paper No. 9

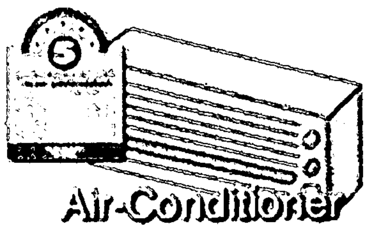
Example of Energy Labels

Thailand

Refrigerator-Freezer and Air Conditioner Energy Label

(Courtesy: EGAT DSM Office Thailand)





Example of Energy Labels

United States

Refrigerator-Freezer "ENERGY GUIDE" Label

(Courtesy: US DOE)

Refrigerator-Freezer
Capacity: 21.0 Cubic Feet

Type of Defrost: Automatic

ENERGYGUIDE

Estimates on the scale are based on a 1993 national average electric rate of 8.30¢ per kilowatt hour.

Only models with 20.5 to 22.4 cubic feet are compared in the scale.

Model with lowest energy cost **$52**

$64
THIS MODEL

Model with highest energy cost **$108**

Estimated yearly energy cost

Your cost will vary depending on your local energy rate and how you use the product. This energy cost is based on U. S. Government standard tests.

How much will this model cost you to run yearly?

		Yearly cost Estimated yearly $ cost shown below
Cost per kilowatt hour	**6¢**	$46
	8¢	$62
	10¢	$77
	12¢	$93
	14¢	$140
	16¢	$160

Ask your salesperson or local utility for the energy rate (cost per kilowatt hour) in your area.

Important: Removal of this label before consumer purchase is a violation of federal law (42 U.S.C. 6302).

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Paper No. 9

Paper No. 10

THE ROLE OF ENGINEERS AND THE CHALLENGES OF ELECTRICAL ENGINEERING EDUCATION

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THE ROLE OF ENGINEERS AND THE CHALLENGES OF ELECTRICAL ENGINEERING EDUCATION

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ABSTRACT

Engineering has become a global profession. Engineering education is undergoing radical changes around the world. This paper discusses the role of engineers and the challenges of electrical engineering education in this changing world.

1. INTRODUCTION

Continuing technology advances are blurring national boundaries. Engineering is no longer, if it ever was, a localized or regionalized profession. Engineering has become a global profession. Although there will always be a need for qualified, professional engineers working in their home countries, more engineers are finding the need or have the desire to practise in other countries. As a result, the engineers of the 21st Century will require greater mobility. How is an employer or a licensing body to ascertain whether the engineer has the requisite skills to practice? The role of engineers in this changing world must be addressed. The need for international standards for engineering education must be examined. Quality assurance in engineering education needs to be addressed through development of accreditation systems with international recognition.

2. THE ROLE OF ENGINEERS

Since the 2nd World War, there has never been a better time for Science, Engineering and Technology. Global forces are driving technology to the top of everyone's agenda; national, international and corporate.

Recently, I attended the 12th Convocation of Council of Academies of Engineering and Technological Sciences (CAETS) in Edinburgh. I learnt the important task was to define simply and clearly, and to disseminate widely to the public, the relationship between Science, Engineering and Technology. As a consequence, the role of Engineer and Engineering in making the future happen will become more clearly evident and be better understood.

Science, Engineering and **Technology:** these words are frequently linked but only when people remember the bit about engineering. More often it is Science and Technology that are coupled together. For example, many countries have a Ministry of Science and Technology. Engineering seems to have to elbow its way into recognition, and when it does somewhat clumsy titles emerge as Science, Engineering and Technology.

What is the relationship between these words? Do we as a profession have an agreed, clear, simple definition. Certainly the scientists seem to , they think that Science & Technology is the natural association of words. Then there is innovation. How do Science, Engineering & Technology relate to Innovation?

Akio Morita, the well-known former chairman of SONY gave the first ever Innovation Lecture in the UK in 1992. His lecture had the title :

S ≠ T
Science does not equal Technology
and
T ≠ I

Paper No. 10

Technology does not equal Innovation

In these two simple equations, Akio Morita captures the problem that has beset us for many years.

At the 12th Convocation of CAETS, Robert Malpas, the Chairman of the British Natural Environment Research Council, further suggested

$$S + E = T$$
$$T + E + M = I$$

where E is for Engineering, M is for Marketing, and I is for Innovation.

We may note that in the annual reports of many industrial companies, the word Technology is mentioned frequently throughout. Engineering and Science hardly appear. It is therefore an urgent need to express concisely and clearly the relationship between **Science, Engineering** and **Technology**, because if we cannot do so to our own satisfaction then we will continue to have a problem of identity both within and without the profession. Worse, we will not gain wide acceptance of the leadership, the bridging role, which naturally befalls the engineer.

Science is a discovery, the knowledge of general truth.

Technology is the means of improving human life by the application of all knowledge and experience. Technology is anything that makes something happen, it may be a product, a process, a system or a methodology.

Engineering bridges Science, Technology and Business to solve real world problems. Engineering makes it all happen. The key components of Engineering are : planning, designing, construction, management, systematic and synthesis.

Therefore, the major roles of engineers are to **bridge** between **science** and **technology**, and to **bridge** between **technology** and the **business world**.

How to achieve global economic development? The powerful economic, commercial and environmental forces are shaping the present and point clearly to the future. We engineers must react pro-actively, taking the lead to obtain new technologies and then to ensure their successful application. It is the successful application that matters, and it is here that the engineers' skills, training and leadership qualities, are most needed.

3. THE CHALLENGES OF ELECTRICAL ENGINEERING EDUCATION.

Economy, Science & Technology, and Education are interdependent. As the rapid development of the economy and of the science & technology, higher education institutions are facing new challenges. Traditionally the missions of a university are two folds : (1) to advance knowledge and (2) to educate students, but now as a modern university, there is one additional mission, that is (3) to transfer technology for sustainable global economic development. Therefore, the major issues are how the quality of research, teaching and management under limited budget may be continuously improved.

The field of electrical engineering stands out as the most dynamic domain of contemporary technology, encompassing the conversion and control of energy, the physics of solids and plasmas, communications, computation and a broad spectrum of man-machine interactions. Major societal concerns - energy, environment, productivity, sustainable economic development and management of the complex demands of society itself - all possess significant challenges for the electrical engineering profession.

To response to the above challenges, we have continuously to update the electrical engineering curriculum and syllabuses within the limited period of study. The elements of project management is worthy of greater attention to accomplish the leadership role of engineers in the society economic development.

Recently, the Accreditation Board for Engineering Technology in the USA has set the Engineering Criteria 2000. These new criteria are based upon what students learn in the course of their program of studies as opposed to what they are presented in a curriculum. Consequently, institutions are required to have educational objectives and to employ outcomes assessment techniques to determine the degree to which program goals and objectives are being attained. The assessment, in turn, is used in an ongoing process of improving student learning through enhancements to the program. The criteria for program outcomes and assessment is stated as follows :

Engineering programs must demonstrate that their graduates have

(a) an ability to apply a knowledge of mathematics, science, and engineering;

(b) an ability to design and conduct experiments, as well as to analyze and interpret data;

(c) an ability to design a system, component, or process to meet desired needs;

(d) an ability to function in multi-disciplinary teams;

(e) an ability to identify, formulate, and solve engineering problems;

(f) an understanding of their professional and ethical responsibilities;

(g) an ability to communicate effectively;

(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context;

(i) a recognition of the need for, and an ability to engage in, life-long learning;

(j) a knowledge of contemporary issues; and

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Electrical engineers are now in a position to expand further their own roles in the world to benefit human welfare and social development. There will be a tendency to pursue the prosperity and co-existence of the global village by harmoniously balancing duties of diversification/specialization, cooperation/competition and independence/coexistence.

4. CONCLUSIONS

The future is heavily dependent upon technology. The engineer and engineering play a central role in its creation and its successful application. Electrical engineering stands out as one of the most dynamic domains of engineering. Electrical engineering education must response to the rapid changes in political, economic, societal and professional environment.

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