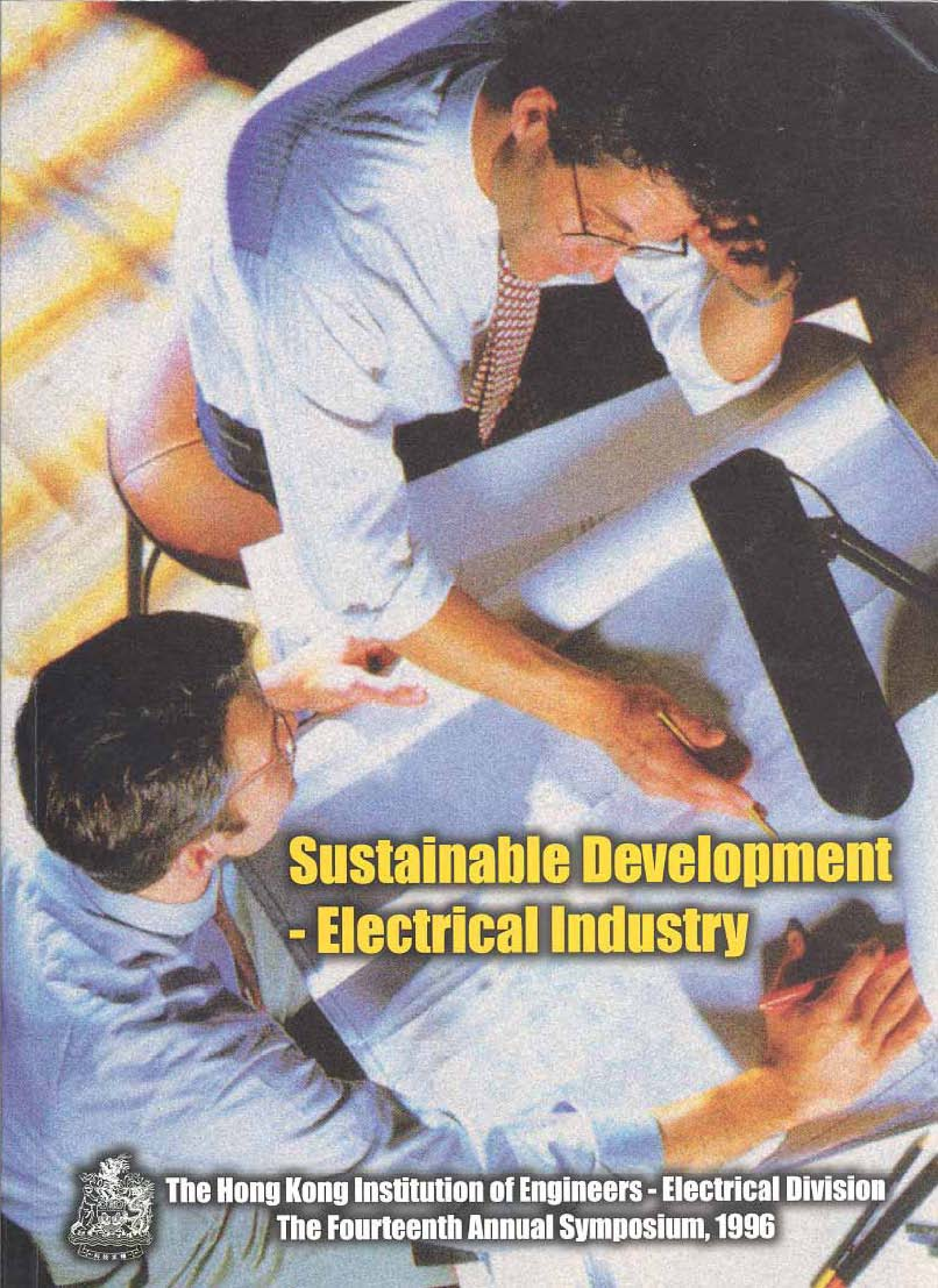

Sustainable Development - Electrical Industry

The Hong Kong Institution of Engineers - Electrical Division

The Fourteenth Annual Symposium, 1996

THE HONG KONG
INSTITUTION OF ENGINEERS
ELECTRICAL DIVISION

The Fourteenth Annual Symposium

Tuesday

29th October 1996

SUSTAINABLE DEVELOPMENT – ELECTRICAL INDUSTRY

at

Silver Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 Registration and Coffee

09.00 Welcome Address
- Ir Simon Kum
  Chairman, Electrical Division, The HKIE

09.05 Opening Address
- Ir Barry Stubbings
  President, The HKIE

09.10 Keynote Speech
- Prof. Poon Chung-kwong, JP
  President
  The Hong Kong Polytechnic University

1. Energy Audit

09.40 Energy Audit
- Mr Dominic K.K. Tai
  Customer Services & Business Development Manager
  Mr C.P. Chui
  Economist
  China Light & Power Co., Ltd.

10.00 Draft Building Energy Codes
- Ir Ronald S. Chin
  Chief Engineer / Energy Efficiency
  Ir Lee Chun-kau
  Senior Building Services Engineer
  Energy Efficiency Office
  Electrical & Mechanical Services Department
  Hong Kong Government

10.20 Discussion

10.50 Coffee Break

2. Energy Conservation and Management

11.20 Latest Development of Energy-saving Air-conditioners
- Mr Takaaki Oka
  Chief Engineer
  Control Devices Engineering Department
  Air-conditioner Division
  Fujitsu General Limited, Japan

11.40 Energy Management in Hotel
- Ir Joseph Leung
  Director
  Ir W.S. Fung
  Associate Director
  RUST Asia Pacific Ltd

  Mr Mahinda Gunewardena
  Director of Engineering
  Sheraton Hong Kong

12.00 Discussion

12.30 Lunch

3. Technical Development

14.00 Operation Strategy of Comprehensive Voltage Reactive Power Regulator in Distribution System
- Mr Yu Kunshan
  Senior Engineer
  Electric Power Research Institute, PRC

14.20 AC Motor Drive for New Light Rail Vehicle in Hong Kong
- Ir Thomas Chow
  Senior Rolling Stock Manager
  Kowloon-Canton Railway Corporation - LRT

  Mr Obi Hideo
  Manager
  Mr Higashimura Mitsuaki
  Engineer
  Transportation System Department
  Mitsubishi Electric Itami Works, Japan

14.40 Discussion

15.10 Coffee Break

4. Environmental Impact

15.40 ISO 14000 and Its Application to the Electrical Industry

– Dr Thomas Tang
Principal Consultant
Dr Peter Ying
Consultant
ERM-Hong Kong, Ltd.

16.00 Environmental Management of Castle Peak Power Station

– Mr Shaun Knight
Corporate Environment Manager
China Light & Power Co, Ltd.

16.20 Discussion

16.50 Summing Up

– Symposium Chairman,
Ir K.W. Tong, JP
Electrical & Mechanical Services Department
Hong Kong Government

17.00 Closing Address

– Mr Stephen Ip, JP
Secretary for Economic Services
Hong Kong Government

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Paper No. 1
(Keynote Speech)

SUSTAINABLE ENERGY DEVELOPMENT: A CHALLENGE FOR ECONOMIC GROWTH

Speaker : Professor Poon Chung-kwong, JP
President
The Hong Kong Polytechnic University

SUSTAINABLE ENERGY DEVELOPMENT: A CHALLENGE FOR ECONOMIC GROWTH (Keynote Speech)

Professor Poon Chung-kwong, JP
President
The Hong Kong Polytechnic University

It is my pleasure to meet you all at this important Symposium organized by the Electrical Division of the Hong Kong Institution of Engineers.

This year, the theme of the Symposium is on Sustainable Development of the Electrical Industry. The topic has been well chosen by the organizer because it truly reflects the concerns not only of the electrical industry but also the community at large. In my remarks today, I would like to give some of my views on the importance of sustainable energy development as a means to support long-term economic growth, particularly in Asian countries. In addition, I would also like to raise some concerns over the impact of energy consumption on the environment.

According to the statistics from the Organization for Economic Co-operation and Development (OECD), developing countries will account for 65 per cent of the increase in energy demand between 1996 and 2010. The most drastic increase in Energy use is going to occur in the Asia-Pacific region, particularly in East Asia, South Asia and China. The growth in these region's energy consumption by the year 2010 is likely to be larger than has been anticipated and it will be driven by much faster economic and population growth, in particular by successful industrialization in China. The economies of the region are currently growing at rates of six to eight per cent. The International Energy Agency (IEA) predicts that energy use in these areas will be nearly 125% higher than in 19921.

Needless to say, energy is the robust force behind rapid economic growth. Unless the need for energy is fulfilled, accelerating rates of economic growth will not be sustainable and Asian countries will not be able to maintain a competitive edge in the global economy.

The most rapid increase in demand for final forms of energy will be for electric power. Global demand for electricity is expected to increase about 3% per annum through the year 2010, but the rate of increase in developing countries will be twice the rate of increase in OECD countries, with demand in Asia expected to grow at over 6% per annum. The primary factors behind the rapid increase in electricity use in non-OECD countries are those associated with high demand for infrastructure due to modernization and economic growth to maintain their competitiveness in the global economy, the increase in urban population, rapid growth in household income, and further penetration of electric appliance use. IEA predicts that overall, developing countries will need to increase electric power generating capacity by more than 730 Gigawatts (GW) by 2010, which is similar to the entire current installed capacity of the United States (760GW). China alone will require nearly 280GW of new generating capacity over the next 15 years, which is equivalent to adding a 1,000MW power generation plant to the system each month1.

In supporting this rapid growth in electricity demand, both practicing engineers and research institutions have an important role to play.

Apart from meeting the need for professional manpower, tertiary institutions have to develop applied research to bring about innovations in the electric energy industry by developing improved and more efficient technologies in generation, transmission, distribution and utilization of energy, to reduce the amount of energy required without sacrificing our quality of life. I am proud to say that the research effort in The Hongkong Polytechnic University in this area is of the highest standing with several experts well known in industry. It is also crucial for electrical engineers, who have been working on the frontiers of the industry, to work together with research institutions for the successful introduction of the latest technology and for the well-being of the community.

While energy is vital for economic growth, the high demand for energy also calls for a sound government policy to ensure energy security and environmental protection. The prime purpose of such a policy is to achieve a balance between low cost, security of supply and minimum environmental damage. Energy is the lifeblood of all developed societies but, like water, supply is not unlimited. Although renewables and other form of energy may some day provide us with efficient, adequate and secure supplies, we must recognize that from a practical perspective we still have a fossil fuel future for as long as we can foresee. Most countries will become increasingly dependent on imported oil in the next 15 years, and the major source of that oil will be a small number of countries in the politically fragile Middle East.

The production of energy through the burning of fossil fuels, is also a source of pollution. Sustainable development requires that we not only consider economic growth and energy security but also the environmental consequences of our thirst for energy. That is to say, we must consider the three E´s concept of sustainable energy development - continuing Economic growth, Energy security and Environmental considerations.

Increasing concern about the potential harmful effects of global warming and the role played by carbon dioxide have resulted in pressures on both industrialized and newly-industrializing countries to reduce emissions of gases such as carbon dioxide and sulphur dioxide (CO2 and SO2). On a regional scale, similar problems are arising from the transport of acid precipitation across regional boundaries. On a local scale, smog and water and land pollution in and around major cities continues to pose health and environmental problems. It is important to note that countries of highest economic growth are also of highest environmental pollution. This pressure on the environment will demand measures to curb environmental damage and has elevated environmental problems to the top of policy agenda in the region.

The greatest challenge for the electrical industry and research institutions in the twenty-first century is to develop higher power generating capacity without undermining the environment which is already at stake. And that is exactly the essential meaning of sustainable development - meeting the needs of the present without compromising the ability of the future generations to meet their own needs. This is a major challenge to our resourcefulness and intellectual capacity.

After all, it is the responsibility of every community to ensure the proper protection of the environment so that the objective of sustainable development can be achieved. Responsibility for environmental action is not a responsibility for government alone, but an obligation on every member of the community. As members of the scientific community, we should take the lead and commit ourselves to the concept of sustainable development for the future generation.

To achieve this economic and environmental sustainability requires research into novel alternate approaches to energy supply and use. In the Polytechnic University we have started on some very novel research topics in improving transmission and end-use efficiency. However, to make it successful, it will also require considerable investment from the industry and government to develop and commercialize new energy sources and efficient energy use technologies. There are immense export opportunities for innovations in equipment, services and technology to supply or use energy more cost effectively, cleanly and efficiently.

Meeting the future demand for energy while satisfying environmental constraints is certainly one of the most technically challenging and economically important problems facing the region. The high quality of life we seek depends upon thriving environment and sufficient energy to meet our needs.

Later today, the participants will go in depth to look into various issues of great concern to the industry. I am certain that with the sharing of your experiences and your wholehearted participation, you will be able to gain more insight in these areas for the betterment of the industry and the community in the years to come.

REFERENCES

Caruso, G.F., "The Asia-Pacific Region in the IEA's World Energy Outlook and Sustainable Energy Development", Keynote Paper, Proc. Int. Symp. on Sustainable Energy Development in Asia, Hong Kong, 8-10 May 1996, pp. 1.1-1.4.

Paper No. 2

ENERGY AUDIT
A CASE STUDY ON AUDITING LIGHTING SYSTEMS IN OFFICE BUILDINGS

Speakers : Mr Dominic K.K. Tai
Customer Services & Business Development Manager
Mr C.P. Chui
Economist
China Light & Power Co., Ltd.

ENERGY AUDIT
A CASE STUDY ON AUDITING LIGHTING SYSTEMS IN OFFICE BUILDINGS

Mr Dominic K.K. Tai
Customer Services & Business Development Manager
Mr C.P. Chui
Economist
China Light & Power Co., Ltd.

ABSTRACT

There is a growing concern about energy consumption and its impact on the environment. Energy consumption for buildings accounts for a significant proportion of the total consumption in Hong Kong. The purpose of an energy audit is to examine the efficiency of an energy system for buildings and ensure that energy is being used as efficiently as possible.

To promote energy efficiency and conservation, CLP has been implementing demand-side management in which energy audit is one of our considerations.

As lighting is an area which offers immediate potential for energy savings, CLP has engaged the Hong Kong Productivity Council to conduct an energy audit of lighting systems for a sample of office buildings in Kowloon and the New Territories.

This paper summarises the findings from the audit and identifies areas with potential for energy savings.

1. BACKGROUND

China Light & Power (CLP) has been growing with Hong Kong for more than 90 years.

During that time, Hong Kong - unlike quite a few of its Asian neighbours - has never suffered from a shortage of electricity. This has stimulated our enviable expansion and development.

Looking ahead, with a Gross Domestic Product growth forecast at about 5 percent, we see a continued need for an electricity supply that is both abundant and reliable.

However, while we are enjoying the many electricity-produced benefits of modern life, we must not let our attention be diverted from the importance of energy efficiency. This is vital for ensuring that our economic growth is sustainable.

This is why China Light, as a responsible corporate identity, has dedicated a great deal of effort and resources to Demand Side Management (DSM).

Energy audit is one of the effective tools to identify potential areas for implementing DSM programmes.

Energy audit is an examination of an energy system in a building or an industrial plant to ensure that energy is being used as efficiently as possible.

It mainly comprises the three stages of historical data collection, preliminary survey and detailed investigation. By conducting energy audit through these three stages, major areas in which energy is being inefficiently used can be identified.

Lighting is estimated to take up 20 per cent to 30 per cent of the total electricity consumed in commercial buildings and also an area which offers immediate potential for energy savings. CLP has engaged the Hong Kong Productivity Council (HKPC) to conduct an energy audit on lighting systems for a sample of office buildings in Kowloon and New Territories, to identify potential areas for energy savings and more importantly to help formulate the DSM programme in this area. This energy audit could also be regarded as a case study from which reference could be made for conducting energy audits in other areas.

This paper summarises the findings from the audit and identifies areas with potential for energy savings on lighting systems.

2. INFORMATION COLLECTION

Since the primary objective of this energy audit is to examine the existing lighting systems for office buildings, thereby promoting energy efficient lighting systems, the following information is needed to be identified :

(i) the efficiency of the lighting systems being used in local office buildings, including light sources, luminaires, lighting control and management systems;

(ii) the penetration level of energy efficient lighting systems; and

(iii) the barriers to the use of energy efficient lighting systems.

3. SELECTION OF BUILDINGS

Lighting systems installed in buildings depend on their grading and age. High graded buildings are usually equipped with the latest lighting technology at the time of completion whereas lower graded buildings are usually equipped with basic lighting system. Similar situations occur in office buildings with different ages.

In order that the information to be collected could indicate the prevalent lighting systems, a sufficient number of buildings would be selected from different categories (grade and age) for conducting energy audit.

In selection of buildings, criteria were based on the Hong Kong Property Review in which the categorisation are defined as follows :

Grade A :
modern (or up to modern standards); high quality finishes; generally spacious lobbies; effective central air-conditioning; good lift services; good management.

Grade B :
plain, good quality finishes; adequate lobbies; central or free-standing air -conditioning; adequate lift services; average or above average management.

Grade C :
generally small, on cramped sites; basically finished; basic lobbies; generally without central air-conditioning; barely adequate or inadequate lift services; minimal to average management.

In consideration of the fact that building age is another factor determining the lighting system being installed, it was finally decided that the buildings in the following four categories were the targeted buildings for the study :

(i)	Grade A	< 5 years
(ii)	Grade B/C	< 5 years
(iii)	Grade A	> 5 years
(iv)	Grade B/C	> 5 years

Of over 60 buildings approached, 12 buildings (evenly distributed in these four categories) were ultimately selected to conduct energy audits. On-site audits and surveys were conducted for each building to examine their respective lighting systems, thus identifying opportunities for energy savings.

4. ON-SITE ENERGY AUDIT

On-site energy audits were conducted for each office building with an aim to examining the prevalent lighting systems, product type, energy consumption and resulting illumination level related to the lighting systems.

The energy audit consisted of two pans - the collection of general building information and walk-through survey.

The general building information mainly covered age and area of buildings, lighting system operational practices, etc.

The walk-through survey was to record the information about the existing lighting systems installed in the buildings. An office building usually comprises public area and office area. Public area includes lift lobbies and corridors, staircases, public toilets and plant rooms etc.. Office area is a generic term for general office purpose.

Within an office area, there would be different function areas such as for office use, conference rooms, computer areas and reception areas etc.. Different areas are usually equipped with different lighting systems and configurations. In a walk-through survey for different types of area, lighting system information such as light source, ballast, luminaries, and control system were collected. The electricity consumption was estimated by physically counting the number of lamps and adjusted for appropriate ballast loss.

Photometry measurements were also taken to identify lit areas when comparing with international standards.

5. SURVEY

In addition to on-site energy audits, survey was also conducted with an aim to obtaining the opinion of the building occupants, office owners and building landlords towards energy efficient lighting. Since the above different parties are likely to have different opinions due to the different involvement with the buildings, four versions of the questionnaires were prepared for the following four groups of people.

(i) an office owner who purchased an office area from the building landlord and then let the area to another party, known as tenant;

(ii) an office owner who is also the occupant of an office area;

(iii) a landlord directly let an office area to his tenant; and

(iv) a landlord who is also the occupant of the office area.

The purpose of the survey was to identify :

(i) the reason for not installing an energy efficient lighting system if given a chance;

(ii) the most important factors that affect the decision for selecting lighting systems for their corresponding purposes; and

(iii) the conditions under which the respondents would consider installing, or would recommend the buildings owners to install energy efficient lighting systems.

6. ON-SITE ENERGY AUDIT RESULTS

(i) average illuminance in the surveyed buildings

Over 30% of the enclosed offices, 16% of the open offices and 27% of the conference areas were found to be lit with over 800 lux while over 39% of the reception area were lit with over 500 lux (Please refer to Appendix 1).

According to the illuminance Engineering Society of North America and the Chartered Institution of Building Services Engineer, the illumination level of 500 lux is recommended in general offices whereas 300 lux is recommended for reception areas. In comparison with these international standards, the lux level exceeding the recommended level is quite common in the office buildings, irrespective of grading and age.

(ii) light source

Of over 50,000 lamps examined, fluorescent lamps are by far the most common light source (69%) and they account for nearly 69% of the lighting electricity consumption for these 12 buildings. 17% are compact fluorescent lamps (CFL) whereas only 4% are incandescent lamps (Please refer to Appendix 2).

It also indicated that new buildings (less than 5 years of age) tend to install more T8 fluorescent lamps than T10/T12 and the reverse situation occurred in older buildings.

The average lighting power density of the 12 buildings is 34W/m2 which is higher than the level of 25 W/m2 recommended in the draft copy of the Hong Kong Code of Practice for Energy Efficiency of Lighting Installation. However, new buildings tend to have lower lighting power density (Please refer to Appendix 2).

(iii) ballast

Electronic ballast, which is more energy efficient in comparison with magnetic ballast, was seldom used in office buildings.

(iv) fluorescent luminaires

Almost all of the luminaires provided direct lighting and about 2/3 were of open, parabolic type, which yields better light output than the prismatic diffuser type.

(v) lighting control system

Only one building (single user) employs a building management system to switch general office lighting on/off according to a pre-set schedule. All other buildings have manual switches. No occupancy sensor, lighting level detector or other forms of automatic control was found in any of the buildings. Timers, however, were found to be rather common for light control of public areas of the buildings.

7. SURVEY RESULTS

In total 307 office units were sent questionnaires. It was indicated from the response rate that large offices would be more likely to participate in the survey.

The response rate of the tenants was 26%. Almost half of the respondents indicated that they would consider adopting lighting systems that cut the original lighting consumption by half. For those respondents not considering this lighting system, over 50% of the reasons were "not aware of such systems" and "lack of information/expertise" (Please refer to Appendix 3).

For the owners who are also the office occupants of the buildings surveyed, the response rate was 34%. 29% of the respondents indicated that they would consider adopting lighting systems that cut the lighting consumption by half. For those respondents not considering these lighting systems, about 60% of the reasons were "lack of information/ expertise" and "the existing lighting system is good enough" (Please refer to Appendix 3).

When being asked for the level of importance of different factors when selecting new lighting systems, the most important factors were brightness and comfort whereas initial cost and operating costs were relatively less important (Please refer to Appendix 3).

For the conditions under which the respondents would consider installing or recommend the building owners to install energy efficient lighting systems, less than 40% of the respondents regarded short pay-back and high subsidies as primary considerations.

The response rate for the survey conducted for the landlords and the owners, who are not the occupants, are relatively low. No conclusion could be made on their views related to energy efficiency lighting systems.

8. CONCLUSION

Based on the on-site energy audits and questionnaire survey conducted on the selected 12 buildings, the major findings are as follows :

a) Around 20% of the offices were over 800 lux, which is higher than the recommended level of 300-700 lux for offices;

b) T8 fluorescent tubes and CFLs were found to be widely used. T8 tubes accounted for 61% of all fluorescent tubes and CFLs were used four times more than incandescent lamps;

c) Electronic ballast was seldom used in office buildings;

d) Other than manual switches or timers, no lighting controls were installed; and

e) Both office tenants and owners (who are also occupants) indicated that they lack information related to energy efficient lighting systems. They also opined that comfort and illumination level were the primary considerations when selecting lighting system. Initial cost and operating cost were considered less important.

Since the lux level exceeding the recommended level is quite common in office buildings, substantial energy could be saved by simply detaching surplus lamps. It could also reduce the lighting power density down to a recommended level.

In addition to the fact that T8 fluorescent tubes have been widely used in office buildings, it also indicated that CFLs, albeit their relatively high price compared to traditional light bulbs, have a higher market share than incandescent lamps in the commercial sector.

Expensive electronic ballast and lighting control systems have a long pay-back period and thus a low penetration level in the market. However, an integrated approach to retrofit the whole lighting system, incorporating electronic ballast and lighting control systems, can help shorten the pay-back period.

The audit results indicated that lack of information instead of monetary incentive is the major barrier to the use of energy efficient lighting systems, more educational efforts should be made to arouse interest in the energy efficient lighting systems.

Based on some price indications for lighting systems obtained from major lighting product suppliers, assuming that the light systems are operated 3,500 hours per year and electricity tariff for small commercial offices (General Service Tariff of CLP) is applied, only fluorescent tubes and CFLs offer a pay-back period of less than or about 2 years.

Assuming all the office units are willing to install the energy efficient light sources and luminaires, the annual savings of these 12 individual buildings surveyed was estimated to be from 4,000 kWh/year to 271,000 kWh/year. The pay-back period ranged from 0.4 of a year to 4.5 years. The overall saving of the 12 buildings is estimated to be 1,048,000 kWh/year. Its pay-back period is 1.9 years. There is no clear relationship between the total annual electricity savings of a building and its age or the office grade.

A pilot programme of efficient lighting in commercial office buildings is being prepared by CLP based on this case study.

Appendix 1

Findings on the Illumination Level of All Buildings

Area Type	Lux		
	<500	500 - 799	>=800
A	21.1%	46.9%	32.0%
B	0.0%	0.0%	0.0%
C	35.5%	48.0%	16.5%
D	12.1%	60.7%	27.2%
E	3.2%	92.7%	4.2%
F	55.7%	39.4%	5.0%
G	98.1%	1.9%	0.0%
H	42.6%	38.2%	19.2%

Definition of Area Type:

A. Office category 1 : Enclosed offices, all open plan offices without partitions or with partitions lower than 1.4m below the ceiling

B. Office category 2 : Open plan offices $80m^2$ or larger with partitions 1 to 1.4m below the ceiling

C. Office category 3 : Open plan offices $80m^2$ or larger with partitions higher than 1m below the ceiling

D. Conference room

E. Computer office

F. Reception

G. Circulation area (lift lobby, etc.)

H. Others

Appendix 2

Findings on the percentages of the Light Source Types, its Quantity & its Power Consumption to its Total

Light source	Number of light source (%)	Power consumption (%)
Fluorescent lamp T8*	42.1%	68.9%
Fluorescent lamp T10/T12	26.7%	
Incandescent lamp	3.8%	7.5%
CFL	17.2%	11.2%
Halogen	9.8%	11.7%
High intensity discharge lamp	0.2%	0.5%
Others	0.3%	0.2%

* T8 fluorescent tube is smaller in diameter and consume 10% less energy than T10/T12 fluorescent tubes.

Findings on the Lighting Power Density in Buildings (W/m^2)

Building Type	Lighting power density (W/m^2)
Grade A < 5 years	25 - 34
Grade A > 5 years	34 - 45
Grade B/C < 5 years	34 - 37
Grade B/C > 5 years	35 - 47

Appendix 3

Paper No. 2

Reasons for not Adopting Energy Efficient Lighting System

Tenants	%
Not aware of such system	51.4%
Lack of information/expertise	51.4%
The existing lighting system is good enough	42.9%
No incentive (we won't install lighting for the owner because we are only tenant)	37.1%
Too expensive	34.3%

Owners (occupants of office)	%
Lack of information/expertise	60.0%
The existing lighting system is good enough	60.0%
When installing new lighting system, it would interrupt daily operations	53.3%
Not aware of such system	40.0%
Don't bother to evaluate such system	26.7%

Importance Level of Selection Criteria for New Lighting System

Tenants	Average Rating (1-7, 7 being the most important criteria)
Brightness	5.6
Comfort	5.6
Initial Cost	4.9
Lighting Operating Cost	4.9
Aesthetics/Style	4.4
Contractor/Designer Recommendation	4.2

Owners (occupants of office)	Average Rating (1-7, 7 being the most important criteria)
Comfort	6.5
Brightness	6.4
Initial Cost	5.8
Lighting Operating Cost	5.4
Aesthetics/Style	4.4
Contractor/Designer Recommendation	4.3

Paper No. 3

DRAFT BUILDING ENERGY CODES

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Ir Lee Chun-kau
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Energy Efficiency Office
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Hong Kong Government

DRAFT BUILDING ENERGY CODES

Ir Ronald S. Chin
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Energy Efficiency Office
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Paper No. 3

ABSTRACT

The Energy Efficiency Office (EEO) was established in August 1994 in the Electrical & Mechanical Services Department to give added impetus to the implementation of energy efficiency and conservation programmes drawn up by the then Energy Efficiency Advisory Committee (EEAC), whose work has recently been absorbed by the Energy Advisory Committee (EnAC) since July 1996. This aspect of the work of the EnAC would be taken up by the Energy Efficiency & Conservation Sub-committee (EE&C SC) which would be formed in October 1996. One major area of the EEAC's activities is in the development of a comprehensive set of Building Energy Codes (BEC). The first of these codes was the Code of Practice for Overall Thermal Transfer Value (OTTV) in Buildings which has come into effect since July 1995 on all new commercial buildings and hotels. The other proposed Building Energy Codes are being undertaken by the EEO and they deal with energy efficiencies of lighting, air-conditioning, electrical, lifts and escalators installations and also centralised control & monitoring systems (CCMS). Currently the draft Lighting Code and the draft Air-conditioning (A/C) Code have been prepared. The consultation exercise for these two codes commenced in February 1996 and April 1996, respectively. This paper addresses the development process of the BEC and the technical requirements of the draft Lighting Code and the draft A/C Code. A special task group consisting of members drawn from professional and academic institutions and trade associations has been set up to develop suitable implementation proposals for these codes.

ABBREVIATIONS

A/C	Air-conditioning
APEC	Asia Pacific Economic Cooperation
BEC	Building Energy Codes
CCMS	Centralised Control & Monitoring Systems
COP	Coefficient of Performance
EEAC	Energy Efficiency Advisory Committee
EE&C SC	Energy Efficiency & Conservation Sub-committee
EEO	Energy Efficiency Office, Electrical & Mechanical Services Department
EnAC	Energy Advisory Committee
LPD	Lighting Power Density
NBWG	New Buildings Working Group
SWG	Sub-working Group

1. INTRODUCTION

The EEO is currently undertaking a wide spectrum of energy efficiency and conservation programmes aimed at the designers, consumers, operators and energy users. One major area of the EEO's activities is in the development of a comprehensive set of BEC, the first of which is the Code of Practice for

Overall Thermal Transfer Value (OTTV) in Buildings which has come into effect since July 1995 on all new commercial buildings and hotels. The EEO is undertaking the development of the BEC to deal with energy efficiencies for the following systems: -

- *Lighting Installations*
- *Air-conditioning Installations*
- *Electrical Installations*
- *Lifts And Escalators Installations*
- *Centralised Control & Monitoring Systems*

The primary objective of these energy codes is to set out the minimum requirements of energy efficiency for different kinds of building services installations. These energy codes are targeted at professionals engaged in the field of buildings construction.

2. WHY DO WE NEED BUILDING ENERGY CODES ?

Hong Kong has to import all of its energy needs and in 1995, according to the Hong Kong Energy Statistics Annual Report 1995 Edition [1], the total primary energy consumption has increased from around 290,000 TJ or about 6.3 million tonnes of oil equivalent (mtoe) in 1985 to about 495,000 TJ or 11 mtoe in 1995, an increase of about 74% in a decade averaging at a growth rate of about 5.7% p.a. or 3.5 times that of the world's primary energy consumption growth rate of about 1.6% p.a. in the same period. In order to act on the environmental issues associated with unrelenting energy use, the third review of the 1989 White Paper *Pollution in Hong Kong - a time to act* [2] has included several measures to promote energy efficiency and conservation as part of the initiatives for Hong Kong to head towards Sustainability. Therefore promotion of energy efficiency and conservation in buildings is a major step towards meeting sustainable energy use for Hong Kong.

Of course Hong Kong is not unique in its position concerning the challenges put forward by the potential effects of rapid growth on energy and the environment. In the Asia Pacific Economic Cooperation (APEC) fora, in which Hong Kong is a member, a declaration after the recently held APEC Energy Ministers' Meeting agreed *that meeting APEC's rapidly increasing demand for energy in an environmentally responsible way will be essential if the region's economic growth potential is to be fully realised.*

3. OVERVIEW OF THE DRAFT BUILDING ENERGY CODES

The OTTV Code of Practice [3], which has become effective since July 1995, provide designers with guidelines to comply with the Buildings (Energy Efficiency) Regulation, Cap. 123. *Figure 1* shows Hong Kong's electricity consumption broken down into the main sectors. It is clearly shown that the commercial sector has been the largest growing consumer of electricity and the decreasing share of industrial sector consumption showed the change in the structure of Hong Kong's economy. In Hong Kong, commercial buildings consume a significant portion of total primary energy. Among all building services installations, the electricity consumption of air-conditioning and lighting installations constitute a major part of a total energy consumption profile of a typical commercial building. Therefore, the drafting of the Lighting Code and the A/C Code has taken precedence over the other energy codes.

4. DEVELOPMENT OF THE BUILDING ENERGY CODES

In 1991, the Hong Kong Government established the Energy Efficiency Advisory Committee (EEAC) to advise the Hong Kong Government on proposals to improve energy efficiency in Hong Kong and to formulate a comprehensive energy efficiency policy in the long run. The EEAC established the New Buildings Working Group (NBWG) and a number of Sub-working Groups (SWG). The drafting of a comprehensive set of Building Energy Codes was one of the major task of EEAC.

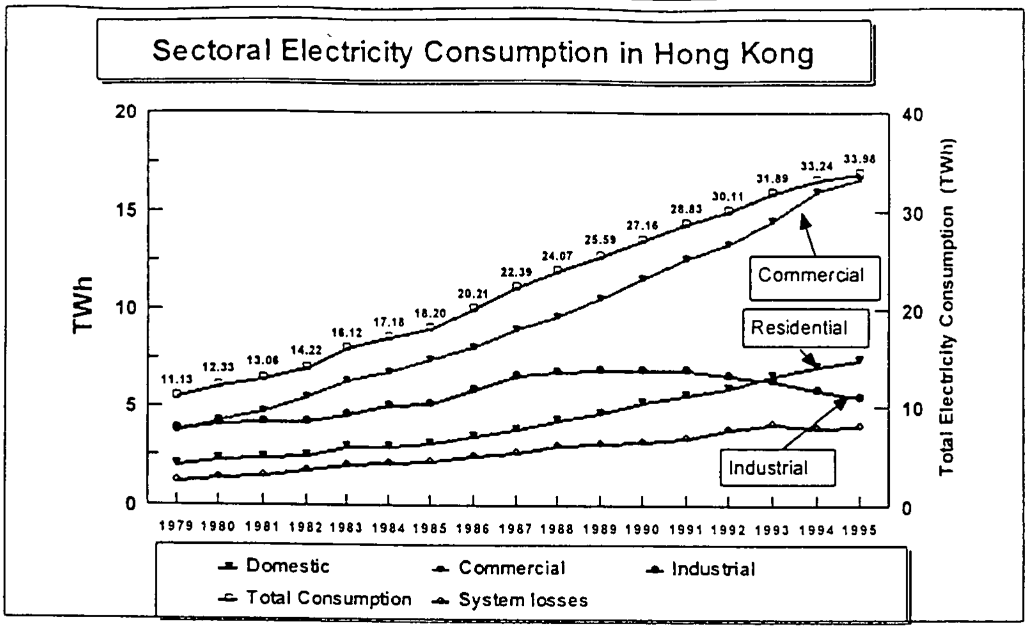
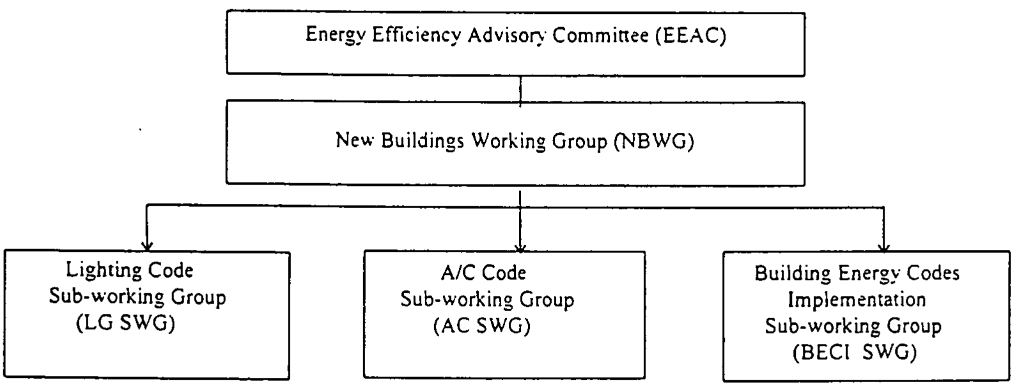


Figure 1



Membership for the EEAC, NBWG and Various Sub-working Groups				
EEAC Members	NBWG Members	LG SWG Members	AC SWG Members	BECI SWG Members
• Professional Institutions • Power Companies • Trade Associations • Govt. Depts.	• Professional Institutions • Power Companies • Trade Associations • Govt. Depts. • Academic Sector	• Professional Institutions • Power Companies • Trade Associations • Govt. Depts.	• Professional Institutions • Power Companies • Trade Associations • Govt. Depts. • Academic Sector	• Professional Institutions • Trade Associations • Govt. Depts. • Academic Sector

Table (1) : Membership for the EEAC, NBWG and Various Sub-working Groups

The drafting of technical requirements of the BEC were undertaken by different Sub-working Groups. For instance, the Lighting Code was drafted by the Lighting Code Sub-working Group. The draft energy codes have gone through an endorsement process that basically involved three levels of committees - SWG, NBWG and EEAC. Each committee would take a different perspective of the energy codes. The mechanism of energy codes development process could be illustrated in Table 1. It is clear that the each interested party had ample opportunities to contribute to the development of the energy codes.

After the endorsement of the draft energy codes by the EEAC, the published draft energy codes have been introduced for consultation to interested parties.

The consultation exercises for the draft Lighting Code of Practice [4] and the draft A/C Code [5] were completed in June 1996 and September 1996, respectively. The parties invited to participate in the two consultation exercise included building services and architectural consultants, learned institutions. trade associations, public utilities, academic sector, equipment suppliers and the World Trade Organisation.

In general, the returned comments showed agreement with the code's fundamental structures and rationale. The invited parties generally accepted the idea of setting a common set of energy efficiency standards for buildings in Hong Kong.

Many organisations expressed their concern about the way of implementing the energy codes. As far as the code's technical requirements are concerned, many parties agreed with the general approach to the control of building energy efficiency. But controversies about the proposed values of certain specific control figures do exist. All these comments are being considered by the Sub-working Group members and fine tuning of the codes' requirements is in progress.

Since the establishment of the Energy Advisory Committee (EnAC) in July 1996, a new sub-committee named "Energy Efficiency & Conservation Sub-Committee (EE&C SC)" will be formed under the EnAC. This EE&C SC will take over the work of the EEAC.

5. DEVELOPMENT OF TECHNICAL REQUIREMENTS OF THE DRAFT CODES

The development process of the draft energy codes' technical requirements can be divided into a number of stages as listed below :

Stage (1) : *Study relevant energy codes of other countries and regions*

Stage (2) : *Prepare an energy code framework that includes all possible control measures*

Stage (3) : *Form a Task Force to jointly develop the 1st draft code*

Stage (4) : *Prepare a first version of the draft energy code based on the framework*

Stage (5) : *Carry out surveys to substantiate the proposed control figures*

Stage (6) : *Revise the code a number of times until a final version is made*

Stage (7) : *Go through the code endorsement procedures*

Stage (8) : *Carry out consultation with concerned parties*

Stage (9) : *Collate and consolidate the comments returned from the consultation exercise*

Stage (10) : *Revise the energy code based on the returned comments*

The Surveys undertaken by SWGs to substantiate the proposed control figures (ref. Stage 5) for the draft Lighting and A/C codes are summarised in the following table :

Survey	Description
Survey on Lighting Power Density (W/m^2) of typical Functional Spaces of Buildings in Hong Kong.	*To get design data of Lighting Power Densities from building services consultant firms and relevant government departments*
Survey on Energy Efficiency of Lighting Equipment	*To collect data of lamps' luminous efficacy and controlgear loss from lighting equipment suppliers and manufacturers*
Survey on Design Parameters of A/C Systems	*To get the following design data from building services consultant firms and relevant government departments :* • *A/C Load Calculation Method* • *Outdoor & Indoor Design Conditions* • *Outdoor Air Requirements* • *Standards of Air Ducts Design, Construction & Testing* • *Design Parameters of Fan and Pumping Systems*
Survey on Energy Efficiency of A/C Equipment	*To collect data of Coefficients of Performance (COP) of air-conditioning equipment from equipment suppliers and manufacturers*

6. DEVELOPMENT OF THE BUILDING ENERGY CODES IMPLEMENTATION SCHEME

A special task group consisting of members drawn from professional and academic institutions and trade associations has been set up to develop suitable implementation proposals for these codes. They will consider, together with the comments received from the consultation exercises for the draft Lighting and A/C Codes, whether mandatory, voluntary or other administrative approaches would be suitable for implementing these codes.

draft Lighting Code	draft A/C Code
The Lighting Code applies to any indoor space of hotels, offices, shops, department stores, schools, carparks, restaurants, places of public entertainment, places of public assembly and any other place used for commercial purposes. The scope excludes *a) any indoor space used for domestic inhabitation or industrial processing,* *b) any indoor space of a hospital, a clinic or an infirmary, and* *c) any indoor space used for utility service.* The Lighting Code does not apply to the following lighting installations : *a) specialised lighting installations used for academic / industrial research application, television broadcasting, theatrical production or audio-visual presentation.* *b) display lighting for exhibit or monument* *c) emergency lighting of non-maintained type*	The A/C Code applies to all buildings provided with air-conditioning installations that are designed for human comfort except Domestic Buildings, Medical Buildings, Industrial Buildings and any area or any part of a building that is constructed, used or intended to be used for domestic, medical or industrial purposes.

7. THE DRAFT LIGHTING CODE AND A/C CODE

The scope of the draft Lighting Code is based on the type of indoor space. On the other hand, the scope of the draft A/C Code is based on the type of building.

As far as indoor lighting installations are concerned, the lighting requirements are governed by the type of visual task undertaken in a particular space. For instance, the lighting requirements for different *office spaces* should generally be similar. Therefore, the scope of the Lighting Code is classified in accordance with the space type.

On the contrary, energy efficiency of an air-conditioning installation generally refers to the A/C system rather than the air-conditioned space. Therefore, it is not practical to set out energy efficiency standards for A/C installations based on space types.

8. OBJECTIVE OF THE DRAFT BUILDING ENERGY CODES

The primary objective of the Building Energy Codes is to set out minimum requirements for design of energy-efficient buildings without imposing any adverse constraint on building functions nor hindrance to comfort or productivity of building occupants.

8.1 PRESCRIPTIVE REQUIREMENTS

The proposed requirements of the draft Building Energy Codes are mainly prescriptive. A *"prescriptive requirement"* sets out the performance standard of a building element in a definite way. For instance, the luminous efficacy of a particular lamp type must be equal to or higher than a minimum value specified in the draft Lighting Code. Generally, prescriptive requirements are direct, explicit and easily understood by people. Moreover, prescriptive requirements can be implemented effectively since the compliance path is definite.

To provide design flexibility, trade-off of certain kinds of prescriptive requirements is under consideration. This trade-off approach allows the performance of some building elements to be reduced if improvements are made elsewhere. Consequently, the increase in energy consumption of some building elements is counter-balanced by corresponding reduction in energy consumption of the others.

8.2 REQUIREMENTS AND RATIONALE OF THE DRAFT LIGHTING CODE

The draft Lighting Code's requirements are expressed in terms of the following four categories :

- *Luminous Efficacy of Lamps*
- *Lamp Controlgear Loss*
- *Lighting Power Density of an Indoor Space*
- *Interior Lighting Control Points*

Each requirement parameter is clearly defined (see Table below) in the draft Lighting Code to maintain consistency of definitions throughout the code :

Definitions of Requirement Parameters stated in the Draft Lighting Code	
1.	*Luminous Efficacy (lm/W) = Lamp Luminous Flux at Prescribed No. of Initial Operating Hours (lumen) / Nominal Lamp Wattage (Watt)* *where the Prescribed No. of Initial Operating Hours is 2000 hours for MCF and 100 hours for other lamp types (i.e. CFN, CFG, MBI, MBF, SOX, SON, MBTF, GLS, TH).*
2.	*Lamp Controlgear Loss (Watt) = Power Loss of a Single Controlgear (Watt) / No. of Lamps connected to a Single Controlgear*
3.	*Lighting Power Density (W/m²) = {N1}x{CW1} + {N2}x{CW2} + ...+ {Nm}x{CWm} (Watt) / Area of a Space (m2)* *where* *{N1}, {N2}, ..., {Nm} refer to quantities of m different types of luminaires installed in a space, and {CW1}, {CW2}, ..., {CWm} refer to Circuit Wattage (i.e. Nominal Lamp Wattage + Lamp Controlgear Loss) of m different types of luminaires installed in a space.*
4.	*A "Lighting Control Point" refer to any lighting control device designed for use by occupants of a space*

8.3 GENERAL APPROACH TO THE CONTROL OF LIGHTING ENERGY EFFICIENCY

In broad terms, the draft Lighting Code adopts a dual approach to the control of lighting energy efficiency - the *Microscopic Approach* and the *Macroscopic Approach*. The *Microscopic Approach* concerns energy efficiencies of lamps & luminaires whereas the *Macroscopic Approach* concerns the total installed power (i.e. lighting power density) of a lighting installation. This dual approach provides control flexibility to different kinds of indoor spaces. For instance, the Macroscopic Approach (i.e. the prescriptive control of Lighting Power Density) does not apply to indoor spaces of restaurants, shops, department stores *(ref. para. 1.4 of the Lighting Code [4])*. However, the *Microscopic Approach (i.e. prescriptive requirement of lamps' luminous efficacy and controlgear losses)* still applies to these spaces.

8.4 SCOPE CONFINED TO INDOOR SPACES

The requirements of the draft Lighting Code essentially apply to fixed lighting installations in indoor spaces. In view of the popular use of *High Intensity Discharge (HID) lamps* in outdoor lighting applications, the proposed scope of the code excludes outdoor lighting installations. Based upon a *progressive requirement approach*, the scope of the Lighting Code may be extended to outdoor lighting installations after future review of the code.

8.5 CONTROL OF LAMPS' LUMINOUS EFFICACY

The draft Lighting Code prescribes minimum allowable values of luminous efficacy for different lamp types. When the proposed values of *minimum allowable luminous efficacy* for different lamp types are plotted on a graph, the resulting control line for each lamp type will be in a form of rising steps rather than a horizontal line. These control lines are mainly derived from manufacturers' data of luminous efficacy (lm/W) for lamps of different wattages. Generally, the characteristic curve of *lamp's luminous efficacy vs. lamp nominal wattage* has a shape similar to a logarithmic curve. The number and sizes of steps of a control line basically depend on the shape of that characteristic curve.

8.6 CONTROL OF LAMP CONTROLGEAR LOSS

The proposed maximum allowable values of lamp controlgear loss apply to tubular fluorescent lamps (MCF) and those compact fluorescent lamps without built-in ballasts (CFN). For lamp types other than MCF & CFN, there are no prescriptive limits on lamp controlgear losses. This approach is based on the fact that the High Intensity Discharge (HID) Lamps (e.g. SON, SOX, MBI) are very energy-efficient when compared with MCF & CFN. Therefore, setting out minimum allowable values of luminous efficacy for HID lamps is a sufficient measure to control lighting efficiency of HID lamps. Likewise, CFG lamps *(i.e. Compact Fluorescent Lamps fitted with built-in ballasts)* are also considered energy-efficient since these lamps are normally fitted with electronic ballasts which have low values of energy loss. Without any upper limits on controlgear losses of HID and CFG lamps, lighting designers are encouraged to make use of these lamp types in suitable applications.

As a first step, the proposed maximum allowable values of lamp controlgear loss are mainly derived from relevant manufacturers' data pertinent to electro-magnetic controlgears. Thus, it is expected that controlgears of *low-loss type or electronic type* can normally meet the proposed requirements.

8.7 CONTROL OF LIGHTING POWER DENSITY

The proposed requirements on Lighting Power Density (LPD) are derived from survey data obtained from local consultant firms. Reference has also been made to the results of LPD computations for various kinds of indoor spaces. Manufacturers' data were used in these LPD computations.

The proposed maximum allowable values of LPD are categorised in accordance with six

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major types of indoor spaces - *Offices, Hotels, Educational Institutions, Public Areas, Indoor Sports Grounds and Space for Common Activities.*

For offices and educational institutions where tubular fluorescent lamps are usually adopted, the maximum allowable LPD is set to be 25 W/m2. For hotels' function rooms, banquet rooms or ball rooms where incandescent lamps are commonly used to create a warm visual environment, a higher limit of 40 W/m2 is proposed. A similar reason apply to seating areas inside a cinema or an auditorium where incandescent lamps are usually employed to be connected with a light dimming system. A lower LPD limit of 16 W/m2 is set for indoor swimming pools where energy-efficient HID lamps are commonly used for general lighting. Comparatively speaking, a higher LPD limit of 33 W/m2 is set for atriums/ foyers so as to allow lighting designers to have a greater freedom of lighting design. For this special kind of indoor space (e.g. entrance foyer) where indoor lighting not only provide general illumination but also exerts a strong effect on aesthetic appearance of the space, designers may prefer to select a wide range of light sources and thus the resulting overall value of LPD tends to exceed 25 W/m2.

8.8 INTERIOR LIGHTING CONTROL POINTS

A *"lighting control point"* may refer to a manual ON/OFF switch, a lighting dimmer or any sophisticated lighting control devices. If a lighting installation is designed for operation by space occupants, these lighting control points should be located at positions that are easily accessible to the occupants. Moreover, any indoor space that is classified as an open plan office, a cellular office or a drawing office should be equipped with certain minimum number of lighting control points. The objective of these requirements is to encourage the use of *localised lighting control* for different regions of a large indoor office. By this means, lighting in any unoccupied region can be switched off to maximise energy saving.

8.9 REQUIREMENTS AND RATIONALE OF THE DRAFT A/C CODE

Generally, the proposed requirements of the draft A/C Code could be divided into the following major categories :

System Load Sizing

- *Methods of Load Calculation*
- *Indoor Design Conditions*
- *Outdoor Design Conditions*

Air Side System Design Criteria

- *separate air distribution systems*
- *air leakage limit on Air Ducts*
- *total fan power for CAV and VAV Systems*

Water Side System Design Criteria

- *requirements of a variable flow water pumping system*
- *friction loss of water piping system*

Prescriptive Requirements of System Control

- *provision of thermostatic control and humidity control for space cooling/heating*
- *provision of individual thermostatic control for each air-conditioned zone*
- *provision of off-hour control*

Insulation

- *minimum thermal insulation thickness for chilled water pipes & refrigeration pipes*
- *minimum thermal insulation thickness for air ducts*

Minimum COP of AC Equipment

- *Minimum COP for factory-designed and prefabricated A/C equipment*
- *Minimum COP for field-assembled equipment*

8.10 SIZING OF A/C SYSTEM LOAD

In the course of drafting the A/C Code of

Practice it was clear that proper sizing of A/C plants involved proper A/C loads estimations. One reasonable requirement that could be imposed on designers was to require the use of internationally recognised methods and procedures for calculations of A/C loads.

According to the surveyed results, it was found that several popular A/C load computation methods - e.g. ASHRAE Method and CIBSE Method - were widely adopted by designers in Hong Kong. As each method has its own merit depending on many other factors, e.g. plant sizes, building complexities and usage, designers' experience and assumed design factors etc., there is no single method being superior to other at all conditions. Therefore, the convenience for monitoring would not be justified enough to lead to specification of only one single method. The Code would allow designers to use any internationally recognised methods without imposing unnecessary constraint on designers' choices.

8.11 INDOOR AND OUTDOOR DESIGN CONDITIONS

The indoor and outdoor design conditions had a direct effect on the results of A/C load computations. The indoor design conditions are generally governed by the type of indoor applications and the requirement limits set in the draft A/C Code were mainly based on the results of the *Survey on Design Parameters of AC systems.* The outdoor design conditions are set based on the survey and information provided by Royal Observatory.

8.12 AIR SIDE SYSTEM DESIGN CRITERIA

The objective of setting limits on air duct leakage is to minimise energy loss due to air leakage from ductworks. It is believed that the Code should focus on energy matters but not ductwork construction details and workmanship. The requirement on air leakage rate is set based on some international standards.

The proposed requirements on Total Fan Motor Power Per L/s of Supply Air Quantity were developed based on the results of the Survey and control figures used by energy codes of other countries. Due to the great variety of fan applications, it would be difficult and impractical to establish fan power limits that are applicable to all fan applications; in one case the limit may be overly stringent while in another the limit is easily met. Therefore, the fan power limits set in the Code will really only have impact on relatively large fan systems (5KW or above).

Another control measure is to control power consumption during part load. For any individual VAV supply fan with a motor power of 5kW or above, the control should limit the fan motor demand to no more than 55% of design wattage when operating at 50% design air flow. This requirement would prohibit the use of some inefficient control methods, e.g. volume control dampers and some inlet guide vane controls with improper selection of fans.

8.13 WATER SIDE DISTRIBUTION SYSTEM

If the control valves of a pumping system are designed to modulate or step open/closed as a function of load, that variable flow system should be capable of reducing system flow to 50% of the design flow or less.

High friction loss of water pipes not only causes energy wastage, but also leads to pipe noise and erosion problems. Therefore, the maximum pipe friction loss is set to be 400 Pa/m after considering the survey results and the recommended figures used by some international standards.

8.14 MINIMUM INSULATION THICKNESS

Due to humid climate of Hong Kong, the minimum values for insulation thickness are developed based on the equations to calculate minimum insulation thickness to prevent condensation. The calculation shows that the insulation thickness, in general, is greater than those adopted in U.S. and Canada. As a result, the energy loss will be lesser in Hong Kong.

8.15 CONTROL OF A/C SYSTEMS

The supply of heating and cooling energy to each zone should be controlled by individual thermostatic controls responding to space temperature within the zone. Where both heating and cooling energy are provided to a zone, the controls should not permit heating of previously cooled air, cooling of previously heated air or simultaneous heating and cooling of air. Furthermore, the control system should be capable of reducing energy consumption by control setback or equipment shutdown during the period the air-conditioned space is not occupied.

Where space humidity control is used for comfort purpose, the humidistat should be capable of preventing energy use for increasing R.H. above 30% during humidification or for decreasing R.H. below 60% during dehumidification. It is because these ranges are already within the comfort zone of human bodies. Additional use of energy to raise the humidity further or to remove more moisture would waste energy with no apparent benefit.

All these proposed requirements encourage designers to consider energy effectiveness of an A/C control system.

8.16 MINIMUM COP OF A/C EQUIPMENT

To maintain consistency of equipment efficiency requirement, all specified values of minimum COP for pre-fabricated A/C equipment are based on a common set of standard conditions. The proposed requirements are mainly derived from a survey on A/C equipment of different manufacturers. Since there is very little data returned from manufacturers for part-load COP, it is unable to formulate part-load COP requirements based on the survey. Meanwhile, doubt is also cast on whether the integrated part load values (IPLV) adopted by U.S. is applicable to all building types and Hong Kong situation. In view of above, part-load COP is not recommended in the Code for the time being.

9. GUIDELINES

As a complement to the BEC, the EEO is developing a set of guidelines on recommended practices for energy efficiency and conservation on the design and operation of various building services systems. The proposed guidelines will include those related to A/C and lighting systems. The intention of the guidelines is to provide recommended practices for the designers to adopt that would not only satisfy the minimum requirements stated in the BEC, but also to enable a better efficiency in energy use of the designed installation to be made in other areas not indicated in the BEC and especially regarding operational aspects for the operations engineers.

10. CONCLUSION

As a result of the completion of the consultation exercises for the draft Lighting Code and the draft A/C Code, the returned comments on the codes' technical aspects are being consolidated and reviewed. Meanwhile, a number of options for implementing the BEC are being developed by a special task group taking into consideration the returned comments on the codes' implementation. The development of the remaining codes including those for Electrical Energy, Lifts & Escalators and CCMS Codes, will be continued.

As a complement to the BEC, the EEO is developing a set of guidelines on recommended practices for energy efficiency and conservation on the design and operation of various building systems. The proposed guidelines will include those related to A/C and lighting systems.

Therefore it is hoped that through the introduction of a set of comprehensive energy codes that will set the minimum benchmark for energy efficiency; and by complementing these with a set of guidelines for recommended practices, Hong Kong's design professionals, building owners, and building management and building services operators could further enhance the efficient use of energy and contribute to Hong Kong's sustainable development.

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Paper No. 4

LATEST DEVELOPMENT OF ENERGY-SAVING AIR-CONDITIONERS

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LATEST DEVELOPMENT OF ENERGY-SAVING AIR-CONDITIONERS

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ABSTRACT

The amount of electric power consumption at households has been increased in recent years due to the popularization of various electric appliances. We, however, are under such difficult situation as energy supply issue due to earth environment issue and others.

Accordingly, it will be a very important task for us to promote energy saving in our development of all electric products hereafter.

Therefore, concerning the air conditioner of which power consumption rate is specially high in households, we proceed to enhance comfort that is our original purpose and to develop energy saving positively.

In Japan, inverter air conditioners are widely penetrated from the view point of their comfort and energy saving and further improvement of them is requested.

Based on such background, we proceeded a new development relating to both of refrigerating cycle and control technology and attained 35% of energy saving compared to our non-inverter air conditioner.

Our inverter air conditioners and its energy saving technology are introduced in this report.

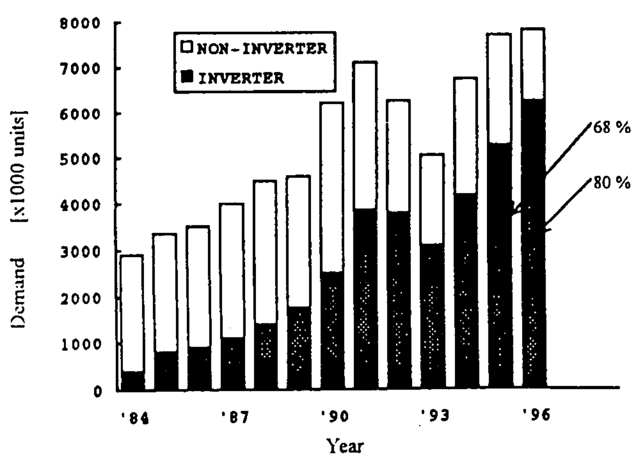
1. INTRODUCTION

THE TREND of life style preferred more comfortable, and demands for room air conditioner are being increased as shown in Fig.1.

For the realization of more comfortable living environment, the air conditioning technology will be improved in character, especially room temperature, humidity, air flow, noise reducing, etc. and it is forecast that the demand of air conditioners will be increased more and more.

However, the energy supply will be severe condition because of electric power consumption's peak issue and earth environment issue. Therefore, it is the most important task for manufacturers of air conditioners to develop the energy saving technology.

FIGURE 1 Demand trends for the air conditioners in Japan



The energy saving technology of air conditioners applies to compressor, heat exchanger, fan, refrigerant, etc. as well as the control technology which controls them efficiently.

The air conditioner controls the room temperature by exhausting heat in the room to the outdoor during cooling operation and by taking heat into the room from the outdoor during heating operation by means of refrigerant. Therefore, the cooling/heating capacity of air conditioner is affected by the outdoor temperature significantly.

Non-inverter air conditioner is equipped with compressor motor of constant speed, and therefore, it is required to be operated intermittently to keep the room temperature at a specified temperature. This operation causes not only fluctuation of room temperature and less comfort but large energy loss.

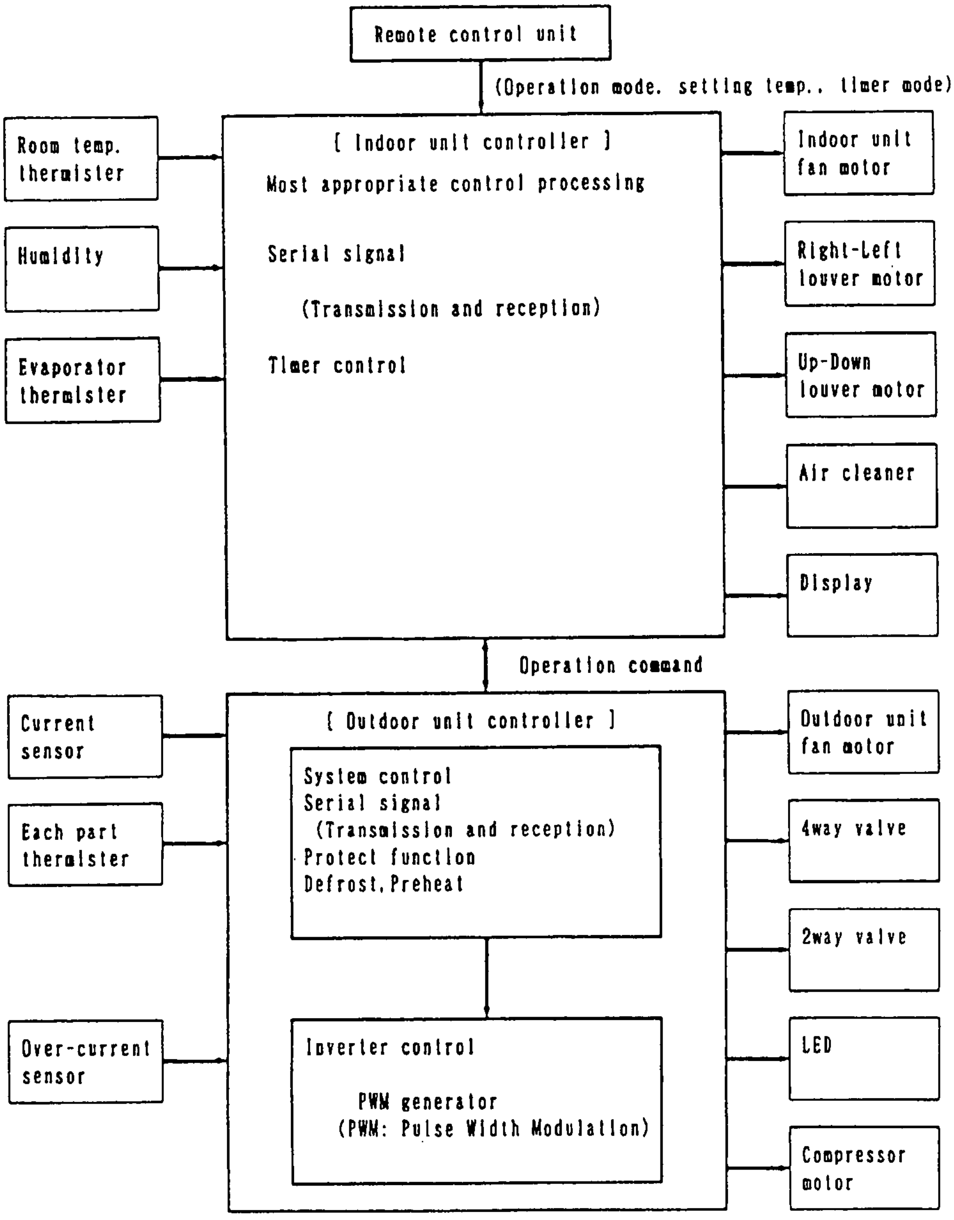
In order to eliminate these defects, in Japan, the inverter air conditioner which is capable of varying its cooling/heating capacity continuously by changing the number of rotation of compressor motor has been penetrated rapidly.

Our inverter air conditioner and its energy saving technology will be introduced bellow.

2. INVERTER AIR CONDITIONERS

The inverter air conditioner is an air conditioner which has the function of controlling compressor motor by an inverter and of changing the cooling/heating capacity continuously in response to the air conditioning load.

FIGURE 2 Control system of inverter air conditioners



The outline of its control system is shown in Fig.2.

The indoor unit and the outdoor unit are equipped with the control part respectively and the whole air conditioner is controlled by the indoor unit control part.

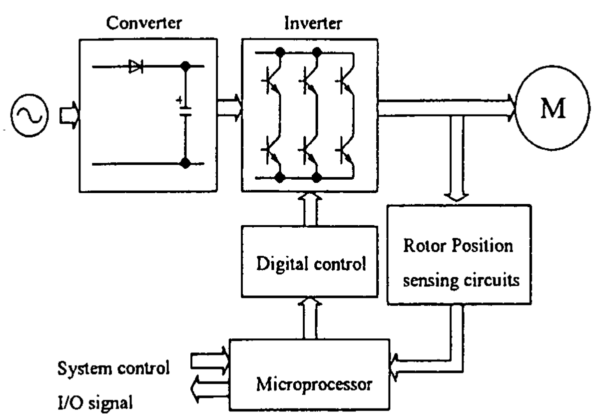
The indoor unit control part transmits an operation command to the outdoor unit through serial communication line based on input (operation mode, room temperature setting, fan, etc.) from the remote controller as well as input from various sensors.

The outdoor unit control part (inverter part) so controls the refrigerating cycle system and compressor motor such that they operate at optimum conditions, according to the operation command from the indoor unit and information from various sensors of the outdoor unit.

The basic construction of the inverter is shown in Fig.3. The power supply circuit for compressor consists of converter part that converts commercial power supply into DC and the inverter part that converts DC into 3 phase AC by 6 power transistors.

The inverter air conditioner is able to change the power supply frequency in a range of 9 - 130 Hz and the rotation speed of compressor motor is 540 - 7800 rpm subject to capacity command from the indoor unit.

FIGURE 3 Block diagram of inverter



3. INVERTER AIR CONDITIONERS AND ENERGY SAVING

As the inverter air conditioner is capable of changing its capacity responding to the air conditioning load, it operates at high capacity when it starts its operation and with the approach of the setting temperature, it changes its capacity to lower one automatically and operates at low power input. During low capacity operation, there is surplus capacity of heat exchanger comparing to the capacity of compressor. This enhances EER (Energy Efficiency Ratio) and enables to operate at high efficiency. Accordingly, a large energy saving can be attained in practical use of which operation at low or middle capacity is long.

And as the energy loss due to ON-OFF operation that is made in non-inverter air conditioners is reduced (as shown in Fig.4), the value of energy saving by the inverter air conditioner can be in the range of 20-30% per year in comparing with our non-inverter air conditioner of the same capacity.

Moreover, for more improvement on energy saving, we adopt DC brush-less motor of high efficiency instead of former induction motor for compressor motor.

As for comfort, the inverter air conditioner has excellent characteristics as laid below:

(a) By high capacity operation, the room temperature reaches the setting temperature in a short time of period.

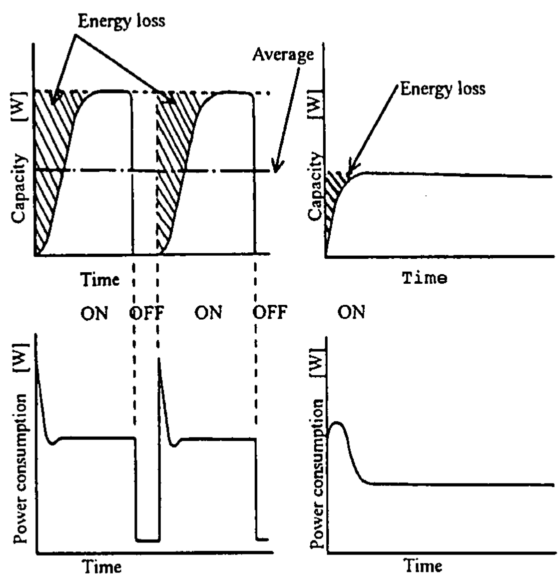
(b) There is no uncomfort due to temperature difference because ON-OFF operation of the compressor is extremely few.

(c) As the cooling operation at low capacity is possible, it can operate to lower humidity only without lowering the room temperature excessively.

There are other characteristics. When the compressor starts, the starting current is low because the input power is of low frequency and low voltage. And it is possible to control the load current so as input current not to exceed the specified value.

FIGURE 4 Efficiency of compressor motor

[Non-inverter] [Inverter]



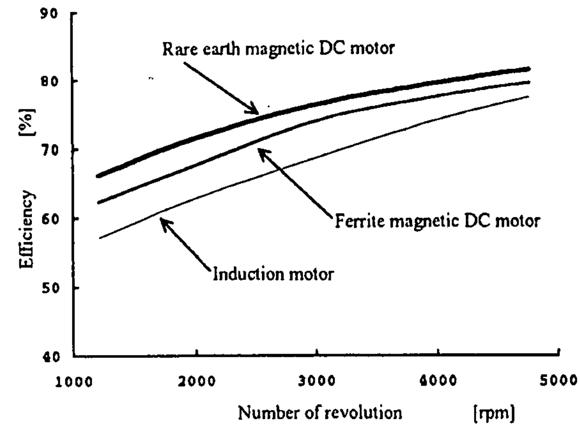
4. IMPROVING EFFICIENCY OF COMPRESSOR

(1) DC compressor motor

Induction motors are used for compressor which is the heart of the air conditioner from the viewpoint of their controllability and cost. However, the induction motor is inferior to DC motor in efficiency because copper loss is generated due to secondary current in the rotor.

We improve the motor efficiency by using brush-less DC motor which has a rotor with permanent magnet to eliminate above mentioned loss .

FIGURE 5 Efficiency of compressor motor



And, as shown in Fig.5, to further improve the motor efficiency, as a magnet of rotor, we adopt rare earth metal containing magnet of which magnetic force is stronger and higher efficiency than those of ferrite magnet.

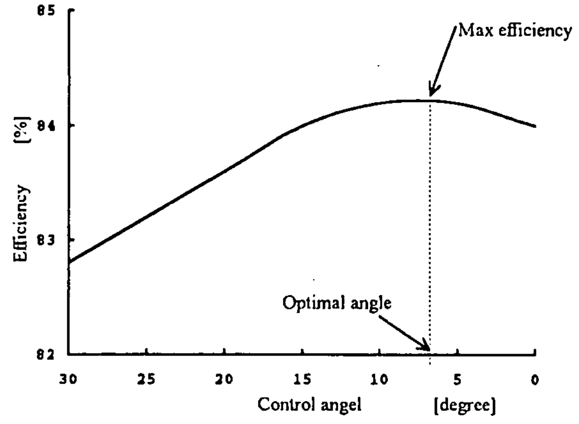
(2) Optimizing control

To control the brush-less DC motor, it is necessary to detect the rotor position and to switch the stator windings which applies the voltage based on its rotor position. The detection of rotor position is made by detecting induced voltage generated in stator windings by rotor's rotation.

In relating to DC inverter that controls the DC motor, the technology containing detection of position of rotor's magnetic pole is vary important and this detection accuracy highly affects the motor efficiency. Therefore, we develop our own digital control system which includes direct detection of winding's terminal voltage, which eliminates position detecting errors.

Moreover, as shown in Fig.6, we increase the motor efficiency by developing the digital optimizing control which switches the voltage applied to the motor at the point where the motor efficiency always at its maximum.

FIGURE 6 Optimal control

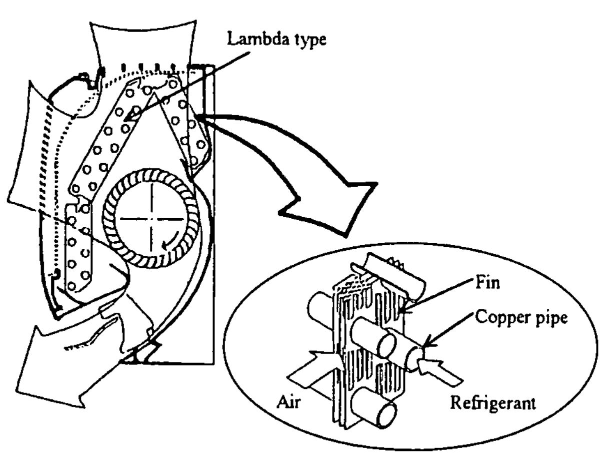


We achieved max. 10% of efficiency improvement compared to the induction motor by above-mentioned improvements.

5. IMPROVING EFFICIENCY OF HEAT EXCHANGER

The heat exchanger, as shown in Fig.7(b), consists of copper pipe in which refrigerant flows and aluminum fin which transfers heat from refrigerant to air. It is important to know the amount of heat can be transferred from refrigerant to air. The heat conductivity and heat transfer coefficient of air are lower than those of refrigerant. Therefore, to increase heat exchange efficiency, the area of heat-transfer surface for air side must be expanded and the heat exchanger must be enlarged. For this reason, the indoor unit becomes larger in size.

FIGURE 7 Heat exchanger for the indoor unit



(a)Cross-sectional view of the indoor unit (b)Configuration of heat exchange

FIGURE 8 F i n

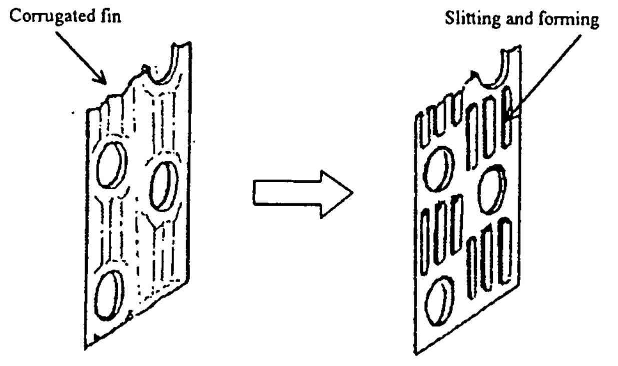
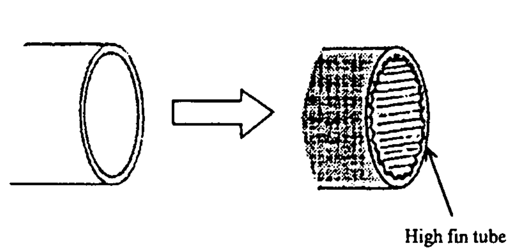


FIGURE 9 Copper pipe



So, we develop Lambda type heat exchanger which is divided and bent and surrounds the fan as shown in Fig.7(a) and succeeded in mounting large heat exchanger in a compact cabinet of indoor unit. This heat exchanger was newly developed for the first time in the world. As Lambda type heat exchanger surrounds the fan, air-flow into the heat exchanger is uniform and so heat exchange efficiency is increased.

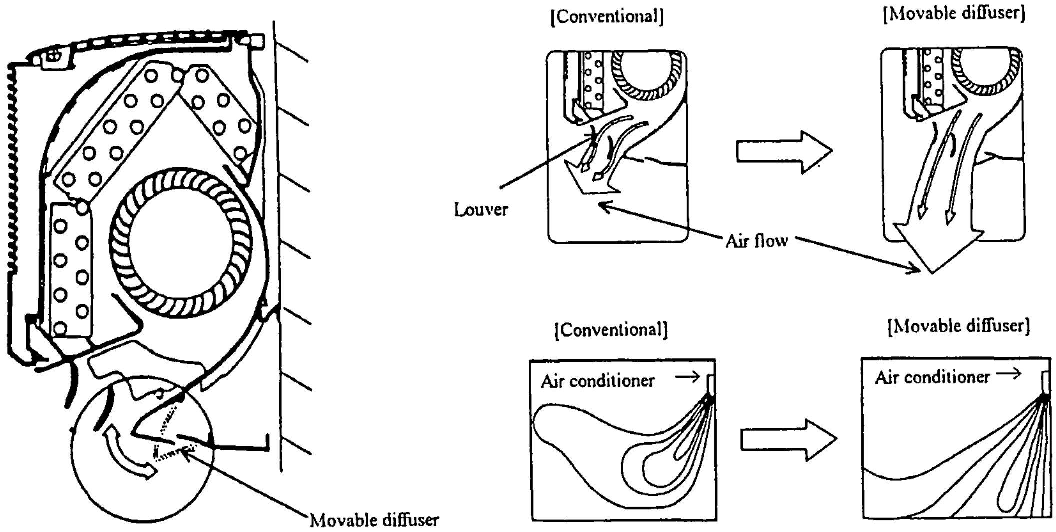
Moreover , by changing the sharp of fin from corrugated one to slitting and forming as shown in Fig.8, heat transfer coefficient is elevated and more heat transfers to air more easily.

Another means to promote heat transfer, by adopting High fin tube of which copper pipe is provided with grooves on its inside surface to increase its inside surface area as shown in Fig.9, heat of refrigerant is easily transferred to fin.

We have improved heat exchange performance of heat exchanger remarkably by carrying out the above-mentioned.

Paper No. 4

FIGURE 10 Effect of air flow movable diffuser



Room temperature distribution during heating mode

6. IMPROVING EFFICIENCY OF FAN SYSTEM

In Japan, approximately 70% of the annual electricity rate by air conditioners is due to heating operation.

During heating operation, hot air flows downward. However, the area of opening of air conditioner is too small to supply sufficient volume of hot air. Accordingly, hot air does not reach feet or floor level and heating effect is lowered and energy loss is occurred.

We newly developed movable diffuser mechanism(Fig.10) of which opening is movable during downward air flow in order to supply sufficient volume of hot air, the first mechanism in the world.

Thus, heating effect is increased remarkably and energy loss is eliminated.

7. OTHERS

(1) DC fan motor

Up to the present, induction motors have been used for fan motors in the outdoor unit and indoor unit of air conditioners as shown in Fig.11. An increasing of motor efficiency will be attained by changing induction motor to DC brush-less motor.

DC fan motor is able to operate at a wide range of ultra low speed and high speed, ganged operation of DC fan motor and refrigerating cycle system will increase their efficiencies.

FIGURE 11 Motors used for air conditioners

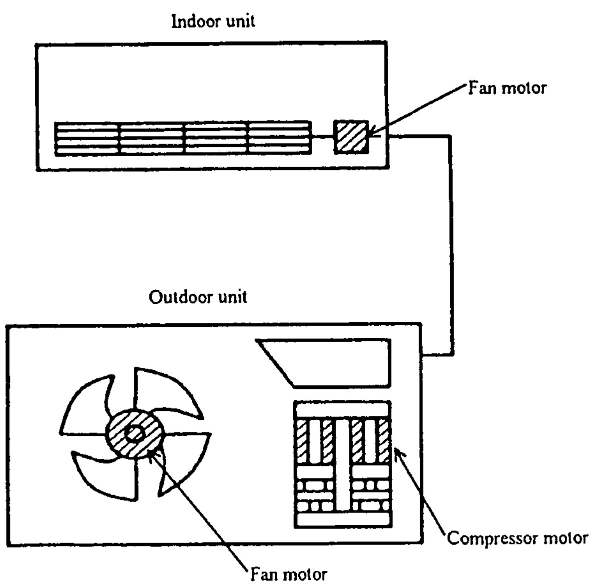
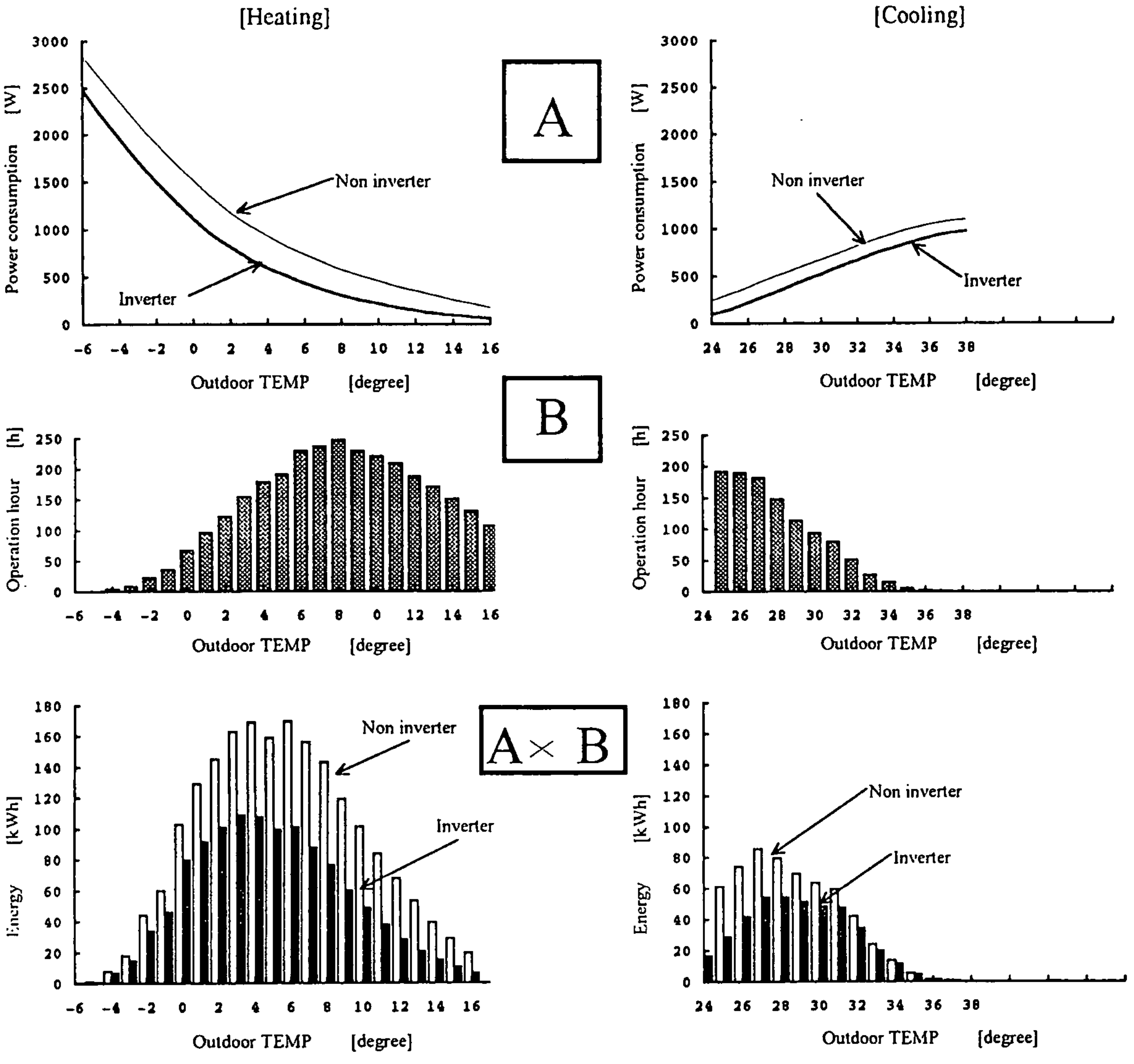


FIGURE 12 Comparison of power consumption year [Tokyo, Japan]



Paper No. 4

8. CONCLUSION

Concerning energy saving technology of inverter air conditioner, the technology of compressor, heat exchanger, fan, refrigerating cycle system and the control technology which controls them are introduced.

As the result of developments and improvements, energy saving of approx. 34% during cooling operation, approx. 36% during heating operation and approx. 35% in the amount of power consumption for a year (Tokyo, Japan) were achieved (these above figures are calculated by our original way). The power consumption and the amount of power consumption to the external temperature during cooling operation and those during heating operation are shown in Fig.12.

9. R&D IN FUTURE

We will proceed to enhance comfort required to the air conditioners and to develop energy saving positively.

For example, miniaturizing and improving efficiency of compressor, heat exchanger, fan system and refrigerating cycle, and developing optimum control technology will be proceeded.

And as for inverter, reduction of loss by developing new switching devices will be proceeded.

To cope with the earth environmental issue, we will proceed to develop more efficient air conditioner using alternative refrigerants.

Paper No. 5

ENERGY MANAGEMENT IN HOTEL

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ENERGY MANAGEMENT IN HOTEL

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ABSTRACT

Why energy management is important in hotel operation? What design consideration should be given to the suitable provision of mechanical and electrical systems to save energy while facilitating the hotel operation? A general review of the draft Code of Practice for energy efficiency of air conditioning installation does not suggest a major impact on the energy management for hotel at the present moment. However, it does raise a great concern to the hotel engineering professionals as to how to cope with the future trend of energy efficiency management in various types of building including hotel. More so, the introduction of Energy Code, Lighting Code and other relevant Code of Practices might in some way constrain or affect the operation of the hotel.

1. INTRODUCTION

The objective of energy management applied in various type of buildings is to save energy by running their plants most efficiently and to provide the appropriate comfort and environment for various accommodation based on guidelines set down in the relevant Code of Practice. However, the main objective of a hotel operation is to delight the guests and to provide the expected comfort level for all guests contact areas, guestrooms, ballrooms, function rooms, business centre, restaurants, shops etc and their business and leisure activities while staying in the hotel. Logically, the senior management of the hotelier put emphasis on the guestroom comfort, by creating a relaxed and elegant environment, best service quality and service culture to satisfy their customer (tourist or business) expectations. Hotels are operated for many type of guests (tourists, families of expatriate businessman, affluent self-proprietors, top echelon of travellers, and government officials) coming from the local community and all parts of the world. They all have different levels of expectation on the services provided and their decision on future or repetitive patronage are dependent on how good the services they received in the hotel during their stay be it short or long. Obviously, there is a slight difference in the objective for an energy efficiency approach versus an efficient hotel operation. It is also worth mentioning that the hotel operators will do their very best to comply with their own "Code of Practices" that is "Delighting their guests" and "Acting with responsibility".

The running energy costs for the hotel operation is not only the running cost of the plant and systems in itself, but it is also treated as an important cost element from the business point of view. The management would like as much as any one else to conserve energy and save energy costs for a higher return, but their priority would be very much influenced by satisfying customers as their prime goal for continuous or repetitive patronage, word-of-mouth etc. Their experience and knowledge in hotel operation according to the guests habitual behaviour during various seasons, occasions, business gathering, tourist groups might to some extent not fully align towards satisfying the objective of energy efficiency. An example is that during the usual daily peak hours (5:00pm to 7:30pm), the hotel guests might rush into the guestroom for a quick wash immediately followed up by a dressing up for the scheduled occasion. Using the card key to reset the room space temperature to say 26 °C when the room is unoccupied, the air-conditioning system might not be able to respond fast enough during his/her short stay in the room before they rush back out. Energywise, lots of energy is saved during his many hours of departure from the room but what it might end up with is a very unsatisfied customer who continue to sweat during his 15 minutes of stay in the hotel room hoping to be cooled down by the air-conditioning system. The senior management in a commercial hotel would be very unlikely to compromise with the energy conservation under such situation while a tourist resort hotel with more relaxed mode of operation might be able to tolerate.

2. IMPACT ON CODE OF PRACTICE FOR ENERGY EFFICIENCY OF AIR CONDITIONING INSTALLATION AND LIGHTING INSTALLATIONS

The draft Code of Practice for Energy Efficiency of Air Conditioning Installation has imposed certain design limitation on hotels. Some of which are highlighted as follows:

(a) Indoor design conditions should be:
Minimum 22 °C db in summer.
Maximum 24 °C db in winter.

(b) Total fan motor power required for a CAV fan system should not exceed 1.6w per /s of supply air quality.

(c) The frictional loss of a piping system should not exceed 400Pa/m.

(d) Thermostatic control should be capable of adjusting to set point temperature up to 29 °C for cooling and down to 16 °C for heating.

(e) Each hotel guestroom and multiple room suite should be provided with a single master switch at the main entry door that turns off the conditioned air supply to the room(s) or set the thermostatic setting to reduce energy use during the period of non-use.

(f) Coefficient of performance (COP) of AC Equipment should not be less than 2.2 to 2.7 depending on the type of air cooled equipment and 3.2 to 5.2 depending on the type of water cooled equipment.

The draft Code of Practice for Energy Efficiency of Lighting Installation has set maximum allowable value of lighting power densities for hotels as follows:

- bed room - 15w/m2
- banquet room / function room/ballroom -40w/m2

3. DESIGN FOR HOTEL BUILDING SERVICES

There are various energy conservation methods which can be effectively applied in hotels. However a lot of their application need to be planned and incorporated in the early design stage, otherwise their implementation may be hindered by lack of plant space, access and maintenance space, disruption in hotel operation, additional cost in modification of the existing system etc.

Examples of some energy conservation methodology commonly adopted in hotels are listed as follows :

(a) Switching off guest room lighting and electricity supply by card key. In general, power to lighting is cut off when the guest leaves the room by removing the card key. Lighting has the highest contribution to cooling load and should be switched off when the room is not in use. Some hotel operators may agree to cut off the air conditioning also but some (especially for the high class hotels) refuse to do so (despite saving energy costs) in order to maintain a high customer's satisfaction.

(b) Heat pump in dehumidification and heating of indoor swimming pool - Refer to Figure - 1 and 2.

Heating swimming pool in winter by electricity or gas are always found to be too expansive as compared to the relatively small number of swimmers in winter. For indoor swimming pool hall, it is desirable to introduce dry outdoor air for fresh air supply and for humidity control. The heat pump extracts heat of the warm exhaust air emitted from the pool hall as heat source for heat pump application, which is around 28 °C instead of using the cold outdoor air as heat source. Average C.O.P. of heat pump can be easily improved from 2.5 to 4.0 comfortably. A lot of supliers arrange the heat pump to heat the pool water first and then provide space heating. Some manufacturers of heat pump incorporate the application of heat-pipe heat exchanger or economizer to further improve the performance of dehumidification.

FIGURE 1 HEAT RECOVERY FLOW DIAGRAM

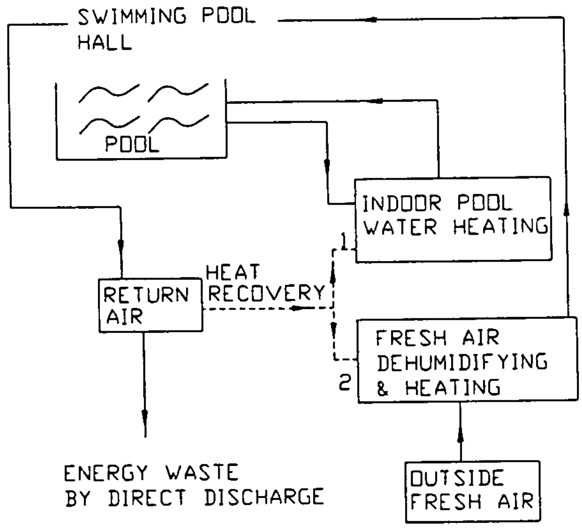
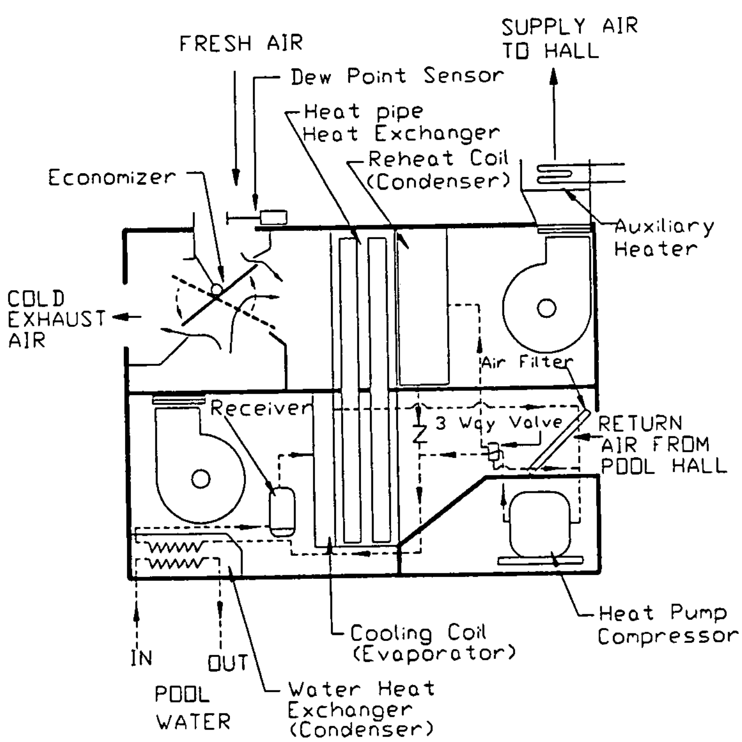


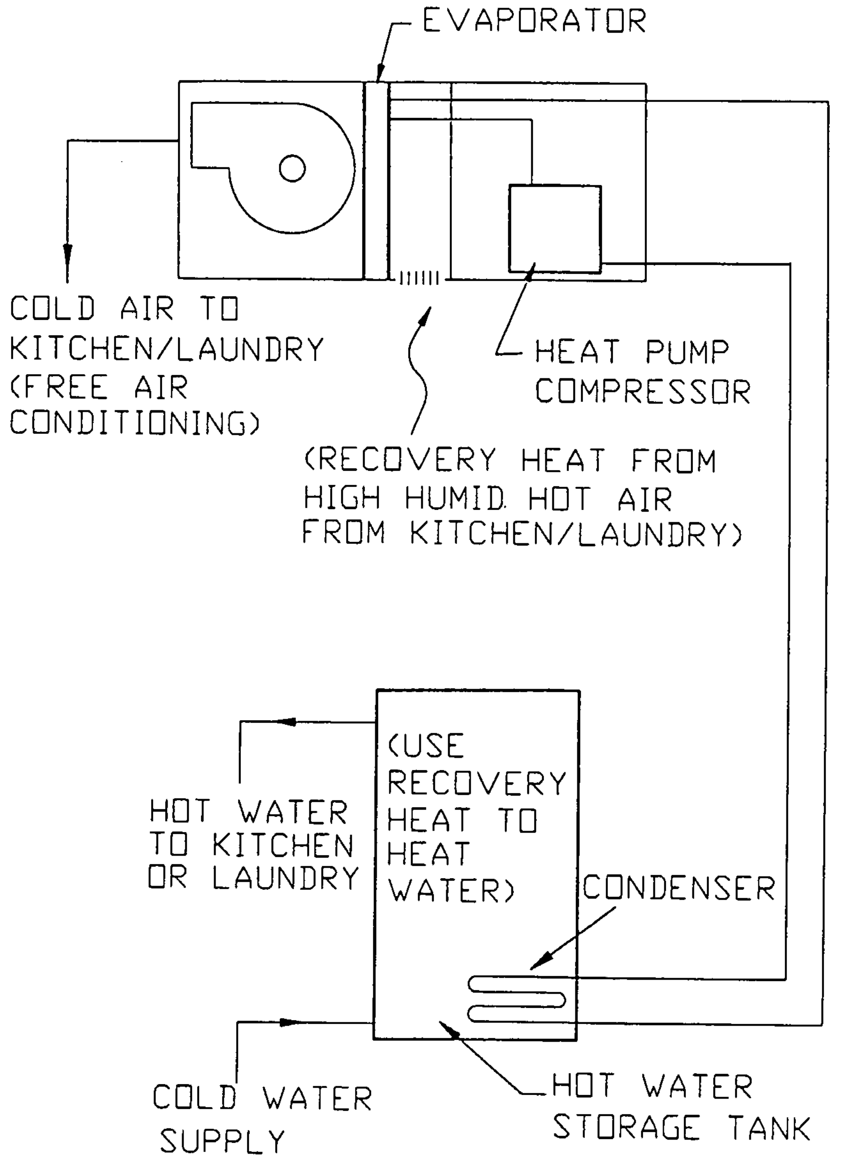
FIGURE 2 HEAT PUMP IN DEHUMIDIFICATION AND HEATING OF INDOOR SWIMMING POOL IN WINTER



(c) Heat pump to provide hot water and free cooling to kitchen and laundry.

To provide an acceptable room temperature in the laundry and kitchen by air conditioning is proved to be very expansive in hot summer time because of the high ventilation rate for laundry and kitchen exhaust. Heat pump installation can provide free cooling to kitchen and laundry by extracting heat from the hot room air to provide hot water to be used in the kitchen and laundry. The high hot water consumption rate in kitchen makes it feasible to continuously running a heat pump by storing the hot water in hot water storage tank. The heat pump system reduces the fuel cost for hot water and at the same time giving free cooling to the kitchen and laundry.

FIGURE 3 HEAT PUMP PROVIDING HOT WATER AND FREE COOLING TO KITCHEN OR LAUNDRY



(d) Master setting of room thermostat in guest rooms with limited temperature range for individual adjustment.

It is a common mistake that people tend to set down the room thermostat hoping to cool a room quickly. Unfortunately, the room eventually becomes over-cooled and waste energy in air conditioning. The use of master setting of room thermostat in guest rooms with limited temperature range for individual adjustment can greatly minimized over-cooling due to wrong setting of room thermostat by guests.

(e) Reducing air conditioning cooling load by using energy saving light source.

The advancement in lamp and luminaires construction makes it possible to reduce the wattage per lumen with improvement in light colour rendering index. Using energy saving light has double saving. Besides saving directly in lighting power it also saves energy through reduction in air conditioning cooling load. Consideration shall be given to its application to Hotel floor corridors, back-of-house, guestroom toilets where mass of space and air-conditioning are involved and the use of energy saving lamp source should also be rationally integrated with the overall quality and aesthetics of the accommodation.

(f) Use of Building Management System

With the use of sophisticated building management system (BMS), there are many design applications which could make the operation of the mechanical and electrical systems more energy efficient. The BMS is also able to forcast trend of energy consumption in various types of plants and load centres. The associated plant controls should allow the hotel operators to identify key loads which are scheduled to be turned on and off in the most appropriate and energy efficient manner. The design provisions for the controls shall provide the required operation flexibility for hotel management and should not unnecessarily attract a high initial capital cost. The design objective of the controls that could satisfy the prescribed hotel operation shall be well established before detail design and installation. The design shall also for allow the energy and power consumption to be tracked and monitored. One should not forget also the main purpose of installating an intelligent BMS is not only for monitoring/ tracking/reporting, but also for providing the necessary intelligence developed from historical data for the hotel management to plan energy saving measures.

(g) Other Considerations

There are also other design consideration available in achieving energy saving and hence the running cost in hotels:

- Use of high performance and energy efficient equipment and plants which could be utilized to best deliver its rated operating conditions with the highest efficiency. Usually, observation and suitable selection of large energy efficient motors and pumps and plants are sufficiently adequate, however there are still tenths or even hundredths of smaller motors and fans which are running at a very low efficiency and very low power factor in a big hotel complex, wasting lots of energy and unknowingly increase the peak kVA penalty charge.
- Lighting load is the most significant load in a typical guestroom. Energy saving lamps sources shall be employed as far as practically possible without unnecessarily degrading the aesthetics of the room interiors. Most of the hotel corridors are also brightly lit throughout the day. Energy efficient lamp source shall be employed to reduce heat and air-conditioning load. The associated controls and the circuitry design shall have built-in flexibility

for automatic switching-off portions of the lighting (but with manual override facility) during night time operation.

- Some hotel management resort to recover heat from the laundry discharged hot water and plan such discharge to coincide with the hours of use of hot water in guestrooms or other areas.
- Automatic adjustment of primary air supply, fan speed and space temperature when the guestrooms are not in use by means of BMS Direct Digital control properly interface with the card key system.

ENERGY SAVING MEASURES IN RENOVATION HOTEL PROJECTS

There are various measures to be implemented when Hotels are being renovated and re-shaped to suit the market needs. The objective of energy efficiency shall be clearly described to the Hotel management to appreciate the needed and long-term benefits in doing so. Some of the Hotel Engineers might need to be re-trained/re-educated in this area in light of modern technology and easily available application energy management software introduced in the past decade. The following design proposals should be discussed during design stage. The implications of the future Code of Practice might intrude into the future management agenda :

- Conversion of lighting and lamps to energy efficient type where appropriate in line with the future Lighting Code.
- Replacement of large and inefficient motors, fans and pumps with adequate power factor control.
- Install building management system controls to provide more accurate and refined fresh air, humidity and temperature control.
- Install air-handling and air-conditioning system components that can respond to different occupancy level in various type of accommodations and guestrooms.

SUMMARY

From the design perspective, there is no rule of thumb for the designers as well as the hotel operators to design and run a most energy efficient hotel, given the difference in objectives. With the introduction of more and more Code of Practices relating to energy efficiency, it remains a challenge to both the designers and the hotel operators to strike the most energy efficient design versus a sustainable business solution. Despite the anomaly revealed earlier, it is an undeniable fact that the common objective is to use the energy wisely and curb wasting energy purposelessly. Nowadays, individual is becoming more and more conscientious and sympathetic about the use of energy and perceive it to be a world-wide environmental protection issue and perhaps ultimately we should treat energy as a living matter with its own substance and right.

4. ENERGY MANAGEMENT BY HOTEL OPERATOR

ENVIRONMENTAL CONSTRAINTS

As a hotel engineer I would like to talk briefly about what I call the environmental constrains to energy management in the hospitality industry.

NATURE OF BUSINESS

Before going into energy management in hotel buildings it is important to first understand the nature of the business that hotel operators are in. Hotels are primarily in the business of providing service to its customers. Therefore unlike most other industries the demand for services such as air conditioning, hot water, laundry and kitchens are not at a time of the managements choosing but is determined by the customers.

RESISTANCE TO CONVENTIONAL ENERGY CONSERVATION

Conventional energy conservation methods are not readily accepted in the hospitality industry due to management concerns of negatively

Paper No. 6

OPERATION STRATEGY OF COMPREHENSIVE VOLTAGE REACTIVE POWER REGULATOR IN DISTRIBUTION SYSTEM

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OPERATION STRATEGY OF COMPREHENSIVE VOLTAGE REACTIVE POWER REGULATOR IN DISTRIBUTION SYSTEM

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ABSTRACT

This paper discribes the problems about voltage - reactive power and harmonic in distribution systems. In order to solve these problems effectively, a comprehensive strategy of distributed reactive power compensation and centralized voltage VAR control is proposed. To show the reasults of above, the paper gives a typical solution for an Iron and Steel Company.

Keywords : distribution system , harmonic, reactive power, Static Var Compensator

1. INTRODUCTION

Cleaner power just means lower electric bills, smoother waveform, more stable voltage and frequencies. In the past, important problems were voltage fluctuations such as sags as consumption increased beyond supply capability. Today, the electric power industry has got a rapid improvement, voltage variation are still of concern. Freedom from impact of reactive power demand variation and harmonic distortion have now become another issue to many users of power. On one hand equipment now are commonly used in industry such as computers and electronic controllers that are less tolerant in power line distortions, on the other hand industrial equipment is more likely to generate the distorting harmonics and absorb larger amount of reactive power. Types of these sources are nonlinear loads, such as rectifiers, converters[1], arc furnances[2], e.t, which can inject harmonics into virtually every power line and feeder in a manufacturing plant, that can result in voltage distortion and variation.

With the cost of manufacturing rising, the effects of har-monic distortion and voltage variation can no longer be ignored. Not only do they cause power to be used inefficiently but also can cause premature or unexpected equipment failure that lead to loss of valuable production time. A sustainable electric power system just means cleaning, stable and highly efficient.

The purpose of this paper is to describe the problems of voltage, voltage-reactive power and harmonic, to give the strategies of conprehensive voltage reactive power compensation, to show the results of practical uses.

Paper No. 6

2. THE CHARACTERISTICS OF VOLTAGE, REACTIVE POWER AND HARMONIC IN DISTRIBU-TION SYSTEM

2.1 VOLTAGE AND REACTIVE POWER

The customers at point of common coupling in a distribution system supplied with good and stable voltage profile during the normal load changes have to deal with the effect of abnormal conditions during and following system faults or switching. Both for the system and customer, the first task is to satisfy the var requirements of the system under all normal and abnormal operating conditions.

2.2 HARMONICS

Harmonics are generated by any load that the ter-minal voltage and current do not exhibit a linear relationship . These nonlinear loads, of which the static converter employing diodes or thyristors is the most significant, absorb real and reactive power at 50 or 60 Hz and transform these fundamental frequencies into currents at harmonic frequencies. These loads thus act as sources of harmonic currents, which when they injected into the system and through the system harmonic impedance and consequently produce harmonic voltages. The latter are superimposed on the fundamental to distort voltage waveform.

Loads which may cause significant distortion in distribution system include:

- Static power converters using thyristors to control the speed and torque of variable speed AC and DC motors used in pumps, fans, machine tools, rolling mills, hoists, oil drilling rigs, etc.
- Controlling for arc welders , furnaces and ovens.
- Switching or phase-controlled AC to DC power supplies, (as used in most electronic equipment) including battery chargers for Uninterruptible Power Supply (UPS).
- Solid-state frequency converters that step up 50 or 60 Hz to a higher frequency, such as 8500 Hz needed for induction heating.
- Transformers operating at or near saturation point.
- Underground and light-rail traction vehicles.

Table 1 shows the Harmonic currents produced by rectifiers. Table 2 shows the harmonic currents produced by arc furnaces.

Table 1 The harmonic currents produced by rectifiers.

Harmonic	six-pulse,3-phase		12-pulse,3-phase	
	theoretical	typical	theoretical	typical
5	20.0 %	17.5 %	—	2.6 %
7	14.3	11.1	—	1.6
11	9.1	4.5	9.1	4.5
13	7.7	2.9	7.7	2.9
17	5.9	1.5	—	0.2
19	5.3	1.0	—	0.1
23	4.3	0.9	4.3	0.9
25	4.0	0.8	4.0	0.8

Table 2 The harmonic currents produced by arc furnaces.

Harmonic	typical
2	17 %
3	16
4	6
5	8
6	5
7	4.5
8	2
9	2.5
10	2

The effects of harmonic distortion on a supply system are typical:

- Overloading of power factor correction capacitors.
- Additional losses and overheating in rotating ma-chines.
- Interference with telephone and data transmission.
- Maloperation of electronic control, protection and metering systems.

In order to limit the level of harmonic over the system, it is required to impose limits on the harmonic distortion for a new load users. These limits which usually apply at the point of common coupling (pcc) are defined in terms of either current injected into the system or more commonly distortion of the voltage waveform.

3. THE PRINCIPLE OF COMPREHANSIVE VOLTAGE-REACTIVE POWER COMPENSATION IN DISTRIBUTION SYSTEM

3.1 POWER FACTOR CORRECTION

It is the best way to compensate the reactive power locally, otherwise:

For users with low power factor , the current of load will be bigger than the current when only real power supplied, the user should not only pay for the added capacity of transmission line and cable but also the added losses of them.

- For systems with low power factor, the generator should generate reactive power efficiently in terms of electric power, the simplest solution in the past was to add a shunt capacitor to correct for the inductive loads, and thus make the loads nearly pure real power.
- A large amount of reactive power supplied by system can make the voltage control more difficult.

The purposes of power factor correction are making the load appear more resistive and moving the power factor closer to unit and increasing power efficiency.

3.2 BUS VOLTAGE CONTROL

Changing reactive power demand will incur voltage variations at the supply point. It can interfere with both the nonlinear user and the other consumer, and to affect power efficiency. The static compensation can be thought as an adjustable shunt susceptance, its capabilities go far beyond those of fixed shunt reactors and capacitors. A continuously adjustable shunt susceptance with sufficiently rapid response would behave as a voltage stabilizing device if it controls voltage.

The SVC can provide a continuously adjustable reactive power which close control of the voltage. It is always designed to meet the need of regulation range.

3.3 LOAD BALANCING

Any multiphase distribution system is inherently unba-lanced. This is caused by many factors , such as physical configuration, not all loads of each phases presented, seasonal and daily load changes, irregular phase load energization, or specific single or double phase loads (as in ac electric traction). Unbalanced loading can damage electrical devices such as induction motors can cause improper voltage regulation and can result in heavier system loss. Some research shows that if the voltage unbalances exceeds 2.5% feeding a three-phase motor, severe overheating may occur. A three-phase motor may have a temperature rise of up to 12.5%. In addition, the currents unbalance in three-phase motors can be 6 to 10 times much than the magnitudes of the voltage unbalance. A highly unbalanced feeder may cause the ground current relay to trip the contact breaker at the substation. A negative sequence current can cause the protection of distance relay with wrong operation.

The unbalanced phenomena have to be tracked and co-rrected occasionally in order to provide a good quality service.

It is sometimes necessary to balance a single-phase load or an unsymmetrical load in general. This can be performed with reactors and/or capacitors. The reactive elements shall be connected with the phase which the negative sequence currents generated by the single-phase load and will be routed through these elements and not enter the network and cause negative sequence voltage drop.

If the single-phase load is changed, the inductive and capacitive elements have to be changed accordingly in order to balance the load all the time. A static compensator with single-phase control is a good means of attain this purpose.

An SVC used for load balancing is normally designed for controlling the positive sequence voltage level.

3.4 HARMONIC FILTERS

Principles of filter

The basic principles of the shunt-connected filter can be described by reference to Fig.1. In the absence of the filter, the current I_n, generates by the load at each harmonic order n and flows through the system harmonic impedance Z_{sn}, to produce harmonic voltage distortion V_n.

In the presence of a filter, having harmonic impedance Z_{Fn}, branched into the filter (I_{Fn}) and the system (I_{sn}) in the inverse ratio of their impedances. Thus if the magnitude of Z_{Fn} is designed to be sufficiently low compared to that of , the current injected into the system I_{sn}, or the voltage distortion I_{sn} Z_{sn}, can be limited to acceptable levels. Z_{sn} and Z_{Fn} are both complex quantities. When designing a filter for

Paper No. 6

one harmonic, care must be taken to ensure that at other order harmonic the reactive component of I_{Sn} does not become equal and opposite to that of Z_{Sn}, because under this condition (known as parallel resonance) I_n is amplified and I_{Fn} and I_{Sn} are limited only by the resistive components of Z_{Fn} and Z_{Sn}. Parallel resonance often occurs when power factor correction capacitors are connected to a system, with the result that apparently innocuous harmonic sources produce excessive distortion.

Types of filter

A filter must have a low impedance at the harmonic frequency but a high impedance at fundamental frequency. A capacitor bank will act as an effective filter at high frequencies, but if required to filter low order harmonics it becomes excessively large.

In a typical filter, therefore, a capacitor bank is tuned with the aid of a linear reactor, and possibly other components. Fig.2 shows the types of filter. The simplest, and most common filter is the single tunes type, Fig.2.(a).

The total impedance Z of that filter as

$$Z = R_L - j(\frac{1}{\omega c} - \omega L) = R_L - j(X_C - X_L)$$

At fundamental frequency the reactance of the linear reactor and the capacitor bank have the following relationship

$$X_{C1} = X_{L1}/n^2$$

At the tuned frequency n, it becomes

$$X_{Ln} = X_{Cn}$$

The overall filter impedance at n therefore comprises only the resistive losses of the components and consequently is very low.

When several frequencies require attenuation it is often economic to replace some or all of the single tuned filters with one high-pass filter, Fig.2.(b), which is designed to have a relatively low impedance over a broad band of frequencies.

Occasionally it is advantageous to utilize the charac-teristics of which are illustrated by Fig.2.(c) and Fig.2.(d).

FIGURE 1 Application Of Harmonic Filter

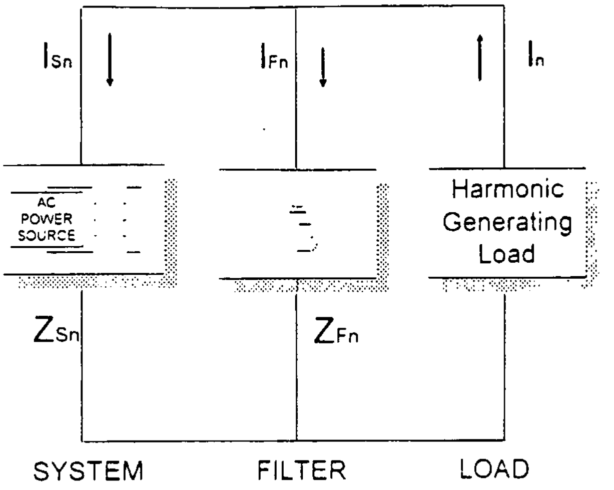
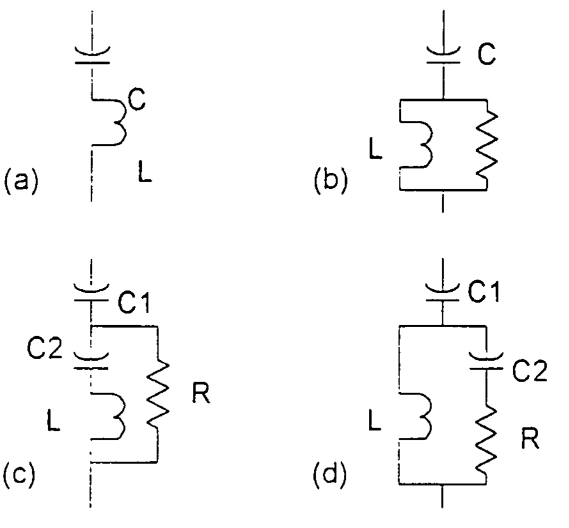


FIGURE 2 Alternative Types Of Harmonic Filters



Application of filter

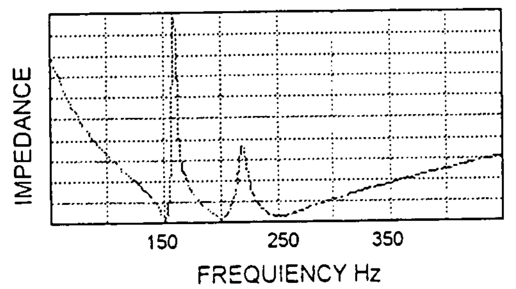
Harmonic filters are designed specifically for each application .The following information is required by the designer:

- Harmonic currents generated by the load(s): Total current at each frequency, with allowance for diversity between multiple loads
- Performance: Permissible limits (Voltage distortion and harmonic currents) at the pcc.

- System impedance: Range of impedance at each critical harmonic fre-quency for both the supply system at the pcc and the local electrical system.
- Power factor correction: Required power factor correction in VARs or , alternatively, power factor of load, requires power factor and point and method of measurement.
- Site conditions
- Evaluation of harmonic distortion: There are a number of ways of evaluating the amount of harmonic distortion present in a distribution system, including instrumentation to measure it directly for multiple loads group or calculation to estimate previous for a typical single load.

Fig.3 shows the typical characteristics of combined filters, which including 3rd. 4th. 5th. and high-pass(50Hz System) filters.

FIGURE 3 Typical Characteristics of Combined Filters 3RD. 4TH. 5TH. and High-pass(50Hz System)



4. THE TYPICAL APPLICATION OF CONTROLLING VOLTAGE AND REACTIVE POWER

Fig.4 shows the typical power supply system graph of one Iron and Steel Company. That system includes one 50MVA transformer with two AC-AC cycloconverters and one 10kV distribution line. Two AC-AC cycloconverters are made up of 12 pulse that supply power to Blooming mill. The capability of that rectiformer is 8000kVA. One 10kV distribution line has other four types of loads, and the loads are two kilometers apart respectively. That four types of loads' average power is 1700kW, average power factor is 0.85 or so. At the same time, serialize restrictor which impedance value in is 8% to limit the short-circuit current in lines(port. According to the paper (s discussion on reactive power and harmonic, the analysis that following can be pressed:

- Voltage fluctuation caused by the reactive power of blooming mill.
- Distortion of system voltage be caused by the harmonic produced by blooming mill.
- Reactive power-voltage problem of 10kV distribution load.
- Comprehensive solution.
- Effect of the use in reality.

Fig.5 shows the impact diagrams of active and reactive power, voltage fluctuation with the operation of AC-AC cycloconverter. Fig.6 shows the frequency spectrums of harmonic currant generated by AC-AC cycloconverters. Fig.7 shows the voltage waveformes of feeder bus (10kV) and the currents waveform generated by AC-AC cycloconverters the voltages and currents of each point and period in 10 kV. Table 3 shows the voltages at the feed bar and the points of A, B, C, D at the feeder line under the circumstance of ON/OFF the capacitors. Fig.8 shows the impact diagram of active and reactive power voltage variation with SVC. Table 4 shows the dates of reactive power, voltage and harmonics with/without SVC.

FIGURE 4 The typical power supply system graph of one Iron and Steel Company

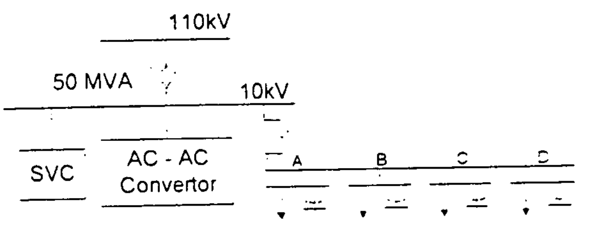


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FIGURE 5 The impact diagrams of active and reactive power, voltage variation with the operation of AC-AC cycloconverter

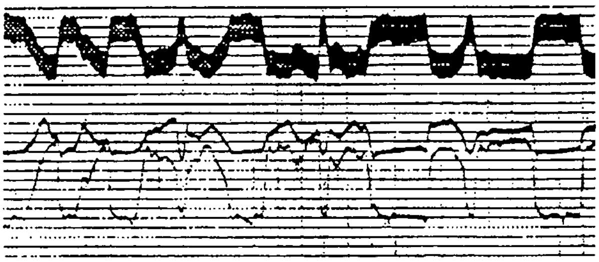

FIGURE 6 The frequency spectrums of harmonic currant generated by AC-AC cycloconverters

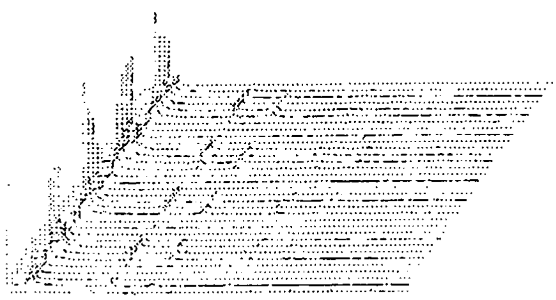

Table 3 The voltages at the feed bar and the points of A, B, C, D at the feeder line under the circumstances of ON/OFF the capacitors

	V0	Va	Vb	Vc	Vd
Capacitors OFF	10.5	10.4	10.16	10.0	9.92
Capacitors ON	10.5	10.49	10.48	10.47	10.47

FIGURE 7 The voltage waveformes of feeder bus (10kV) and the currents waveform generated by AC-AC cycloconverters

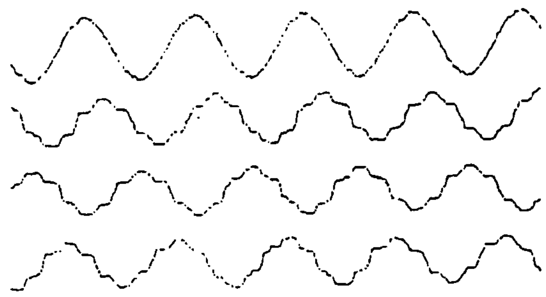

FIGURE 8 The impact diagrams of active and reactive power, voltage variation with the operation of AC-AC converter with SVC.

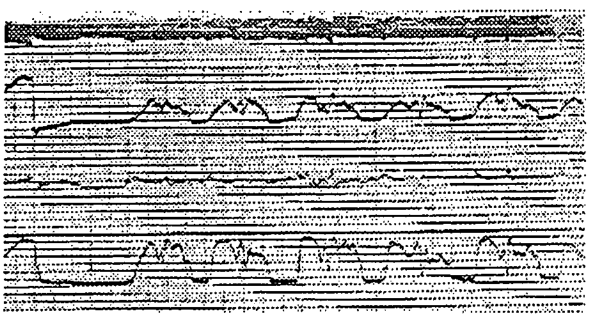

Table 4 The typical dates

	without SVC	with SVC	Admitted value
Voltage Fluctuation(%)	6.4	1.7	2.5%
Real Power(MW)	14.5	14.5	—
Reactive Power(MVAr)	21.7	3.6	—
Current(A)	1400	900	—

Those of the above shows that:

- Separated reactive power compensation in the form of serial power supply can balance reactive power on the spot efficiently, reduce voltage drops and losses.

- Concentrate reactive power compensation efficiently (especially dynamic reactive power compensation), can refine voltage variation and stabilize system voltage in some range.
- When there is harmonic source in power system, selecting reactive power compensation must carefully check harmonic effect, and take preventive measures accordingly.

From the following, comprehensive voltage and reactive power controlling of distribution system, can refine system quality and make power utility more efficiently.

5. CONCLUSION

In today (s power system with their variety of electronic equipment, problems can arise because of voltage influence, voltage distortion, load unbalancing[4]. It is the first step in evaluating the potential for trouble that we identify the causes and measuring the levels of voltage influence, harmonic current and negative sequence in various locations and at different time. This paper mainly emphasized that the effects of voltage-reactive power harmonic and negative sequence at distribution system are not separately occurred. They occur with compound forms. It need to solve these problems with comprehensive forms. Keeping the power system clean and stability is just what power system can develop sustainable.

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Paper No. 6

Paper No. 7

AC MOTOR DRIVE FOR NEW LIGHT RAIL VEHICLE IN HONG KONG

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ABSTRACT

To cope with the increases in patronage, KCRC Light Rail ordered 20 additional Light Rail Vehicles in 1995. KCRC was at the cross-road at that time, whether to go for the state of art technology. AC propulsion, or stay with the existing DC propulsion which KCRC had invested for staff training, maintenance facility and spare holding.

This paper describes the features of AC propulsion, how the advantages of AC propulsion is exploited to enhance the reliability, safety of the LRT System and meanwhile minimize the investment in new facilities to cater for the new technology.

1. BACKGROUND

The Tuen Mun, Yuen Long Light Rail System started operation in 1988 with 70 Light Rail Vehicles (LRV) manufactured in Australia. In 1992, 30 LRVs manufactured in Japan were added to the system. Although the two fleets were manufactured in different countries, the major systems such as electric traction, mechanical brake and wheel trucks (bogies) respectively were from the same suppliers. The purpose is to minimize increases or changes on maintenance facilities, spare holding, staff training or maintenance procedures.

2. NEW LRV ORDER

The patronage increased with market share and growth of population in the transport service area. In September 1995, the daily passenger was about three hundred and fifty thousands. KCRC decided to order 20 more LRVs.

The existing LRVs employed Chopper Control DC motor. This technology was already proven during the design of initial fleet in 1985. KCRC kept on with this technology on the second fleet. New technology were evolved during the past years. With the advancement of power electronic, the AC motor propulsion technology became mature and more performance, price competitive with the DC motor technology. It was a difficult decision for KCRC, whether to go for the new technology or stay with the existing one which KCRC had invested heavily on maintenance set up.

Some tenderers came up with a new approach by adapting the AC motor to the existing bogie. Accordingly, investment on the expensive and space hungry mechanical facilities and spares can be avoided. The 20 new LRVs were finally awarded to the main contractor, Goninan of Australia. The major subcontractors are Mitsubishi Electric for the AC Propulsion and other electrical equipment. The Bogie and Mechanical Brake subcontractors are unchanged, Duewag and Knorr Bremse respectively.

3. PARTICULARS OF EXISTING LIGHT RAIL VEHICLES

The existing LRV uses acceleration/

deceleration control. The microprocessor 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. 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.

The normal running acceleration or deceleration is 1.3m/sec(maximum. In emergency brake, the deceleration is higher than 2.7m/sec(. The electric brake can operate from 70kph down to 9kph in theory. In practice, the electric brake stops at 15kph. The disc brake takes over at speed below 15kph, 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 15kph. There will be less brake redundancy at speed below 15kph.

4. NEW FEATURES FOR NEW LRV

4.1 AC PROPULSION

The 20 new LRVs to be delivered in July, 1997 use AC Traction Motor drive. 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 motor. 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.

Below shows the train performance which is basically the same as existing LRV.

Major Specifications

Line Voltage	750V
LRV Weight Tare	27.35 ton

Acceleration & Deceleration
1.3 m/sec/sec for MOTORING,
1.3 m/sec/sec for NORMAL BRAKING &
2.7 m/sec/sec for EMERGENCY BRAKING, which
2.1 m/sec/sec contributed by AC TRACTION

Traction Capacity	Two 120KW motor per bogie
	Two bogies per LRV

4.2 APPLICATION OF IGBT

The inverter uses high power Insulate 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 facilitate maintenance.

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

One phase of the IGBT VVVF Inverter output wave form is indicated on Fig. 1. The power circuit schematic diagram is indicated on Fig. 2.

The IGBT is also applied to the auxiliary inverter of 61 kVA, of which main circuit configuration is 3-level system for better wave shape and reduce AC filter requirement.

4.3 BRAKING

The braking can be by disc brake or electric brake using the motor as generator. The electric brake can be regenerative or resistive depending on whether the overhead line is receptive. The resistive brake is controlled by another IGBT chopper as well.

4.4 ON-BOARD MONITORING SYSTEM

There is 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.

4.5 IMPROVE FAULT DIAGNOSTIC

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.

The sample recorded chart of the high speed monitor is shown in Fig. 3.

FIGURE 1

OUTPUT WAVE FORM WITH IGBT VVV F INVERTER

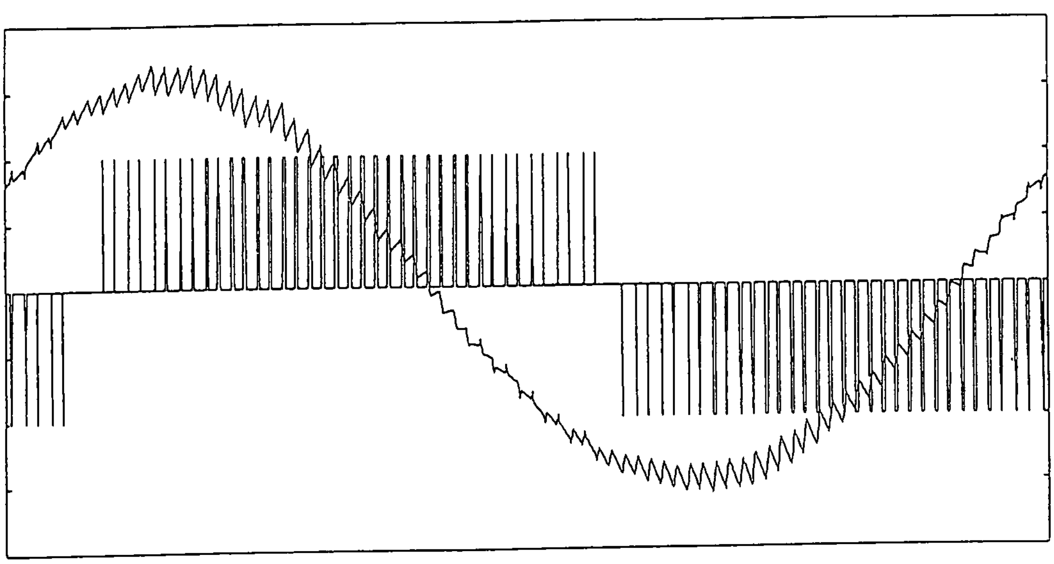


FIGURE 2

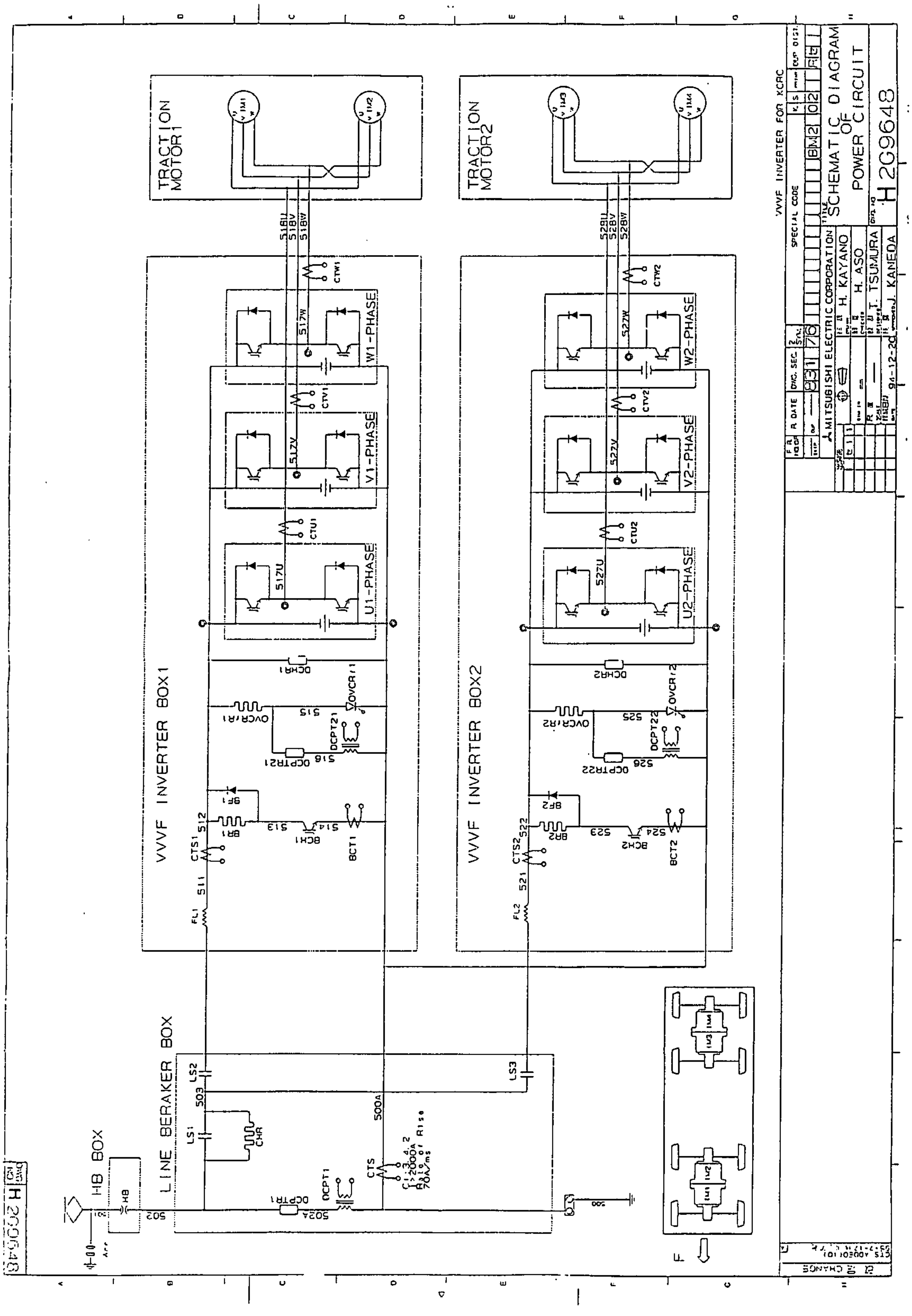

TRACTION MOTOR1
TRACTION MOTOR2
VVVF INVERTER BOX1
VVVF INVERTER BOX2
U1-PHASE
V1-PHASE
W1-PHASE
U2-PHASE
V2-PHASE
W2-PHASE
LINE BERAKER BOX
HB BOX
VVVF INVERTER FOR KCRC
MITSUBISHI ELECTRIC CORPORATION
SCHEMATIC DIAGRAM OF POWER CIRCUIT
H 2G9648
H. KAYANO
H. ASO
T. TSUMURA
J. KANEDA

FIGURE 3

TRACE DATA (VOLTAGE OR CURRENT WAVE)

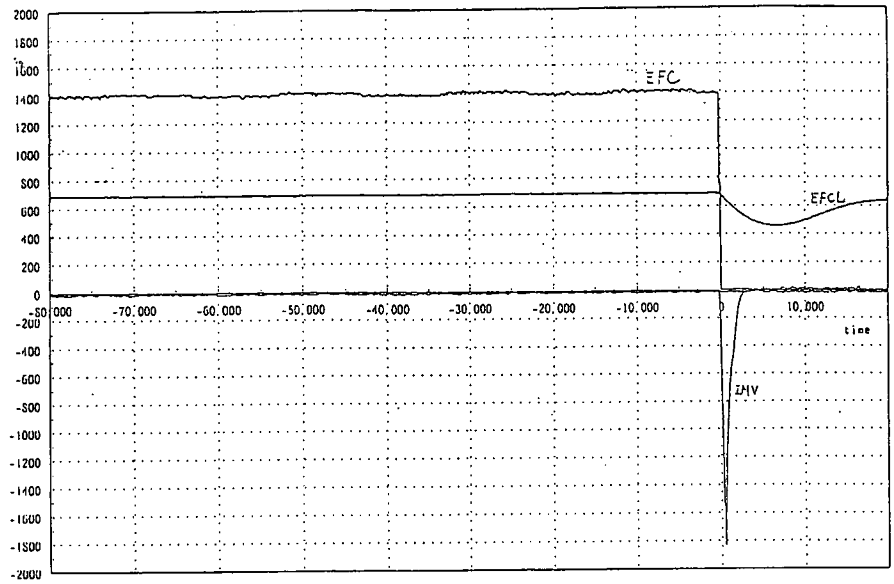


FIGURE 4

SAMPLE MONITOR INDICATION : TRIAL RUN INFORMATION

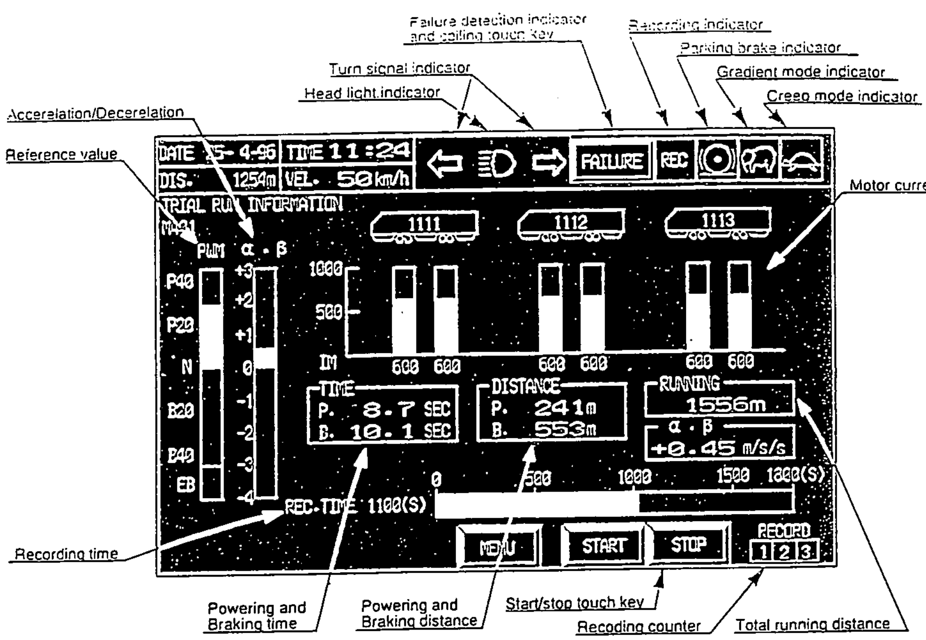


FIGURE 5
SYSTEM CONFIGURATION

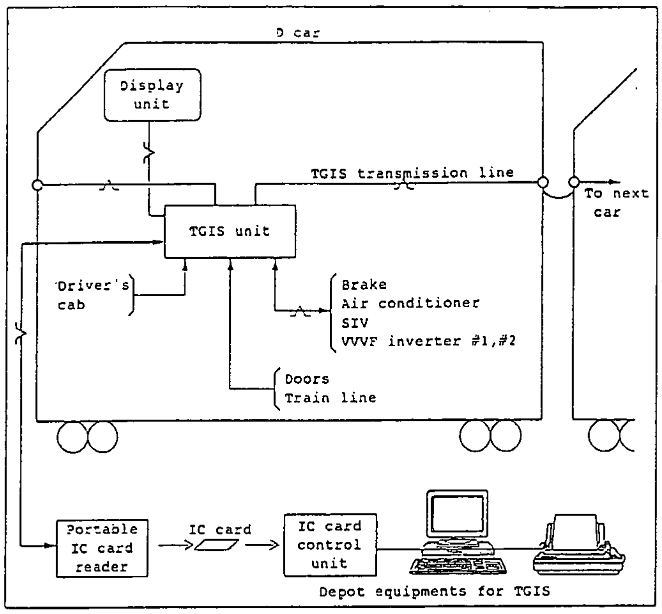


FIGURE 6
COMPARISON OF CONSTRUCTION OF DC AND AC MOTORS

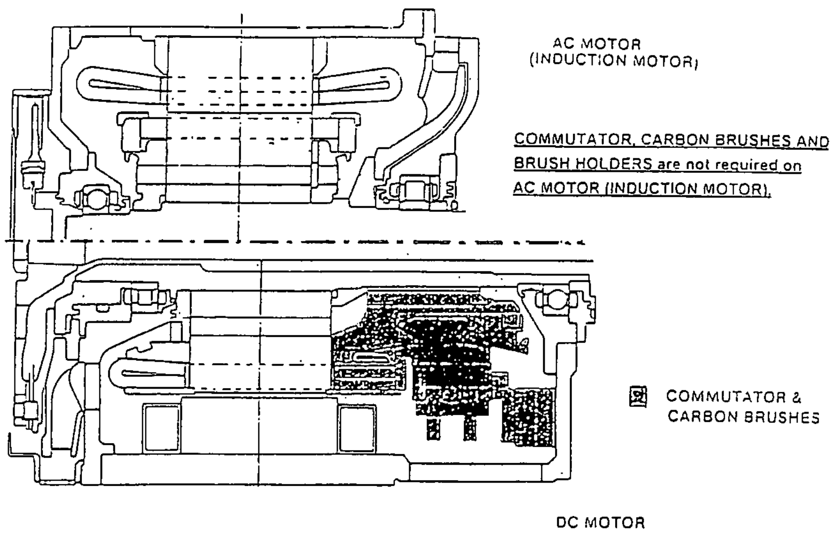


FIGURE 7

LONGTIUDINAL SECTION OF THE MOTOR

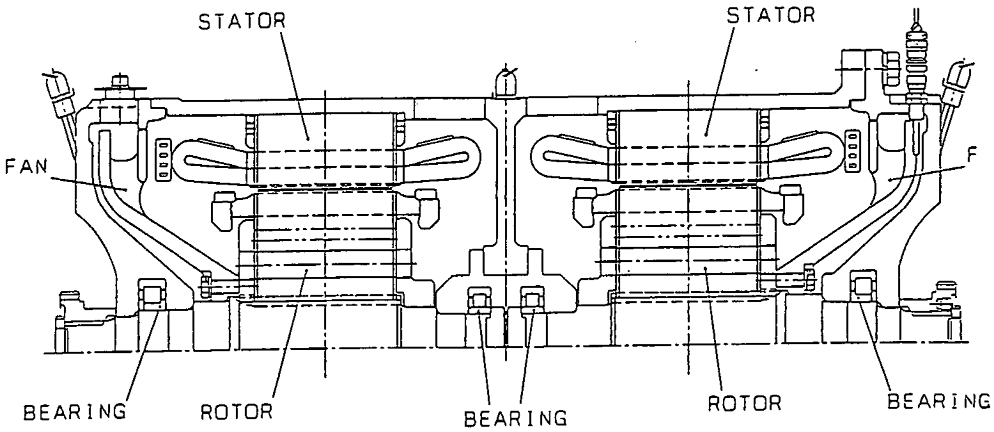
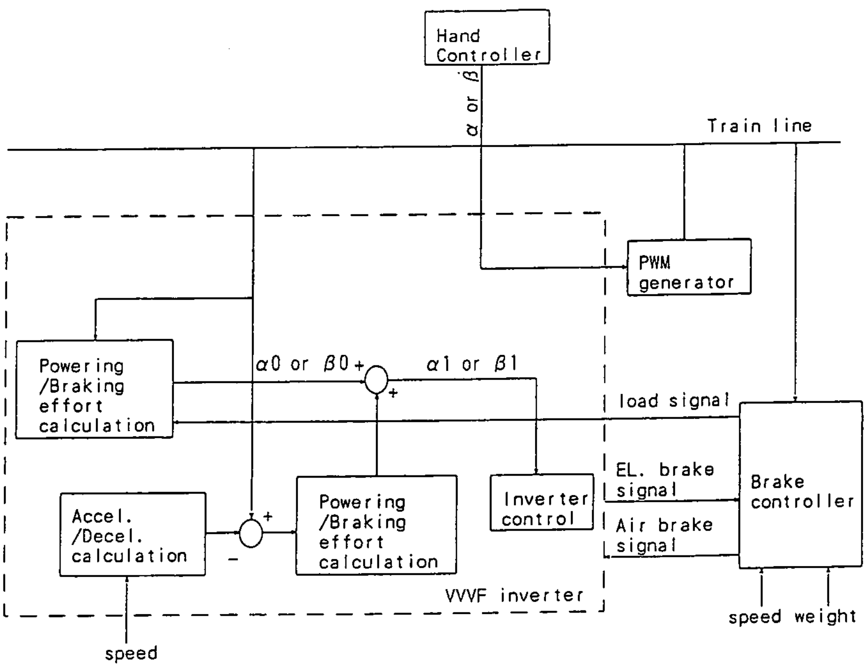


FIGURE 8

BLOCK DIAGRAM FOR CONTROL CIRCUIT



Paper No. 7

4.6 TRAIN GENERAL INFORMATION SYSTEM (TGIS)

Outline of TGIS

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.

Features of TGIS

This system has the following features:

1. The system collects the self monitoring information of the main on-board devices using the serial transmission, to improve the monitoring performance.
2. The system adopts the high performance and high resolution graphic display and touch-screen input system.
3. 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. Samples of display is shown in Fig. 4. The system configuration is shown on Fig. 5.

5. COMPATIBILITY WITH EXISTING VEHICLE

5.1 TWIN AC MOTOR TO ADAPT EXISTING BOGIE, AVOID INVESTMENT ON BOGIE FIXTURE.

The existing LRVs have one DC motor per bogie. The new LRV will have two AC motors per bogie. Each axle of the new LRV bogie is driven by an AC motor independently to reduce wheel wear due to wheel slip slide or curve negotiation. The two AC motors are integrated into one assembly, with two concentric armatures. Each armature drives the axle through a bevel gear box, resilient coupling respectively. The integrated motor had the interchangeability with the DC motor but lighter in weight.

General comparison of the construction for DC and AC motors is shown on Fig. 6. (as single motor). The longitudinal drawing is shown on Fig. 7.

As a result, the existing bogie can be used on new LRV by changing only the motor and some small accessories. Additional spare bogie and different bogie fixtures and testers are no longer required. These spares and equipments are very expensive and space hungry.

5.2 CROSS MONITORING OF ELECTRIC AND PNEUMATIC BRAKE PERFORMANCE AND TAKES OVER IF COUNTERPART FAILS.

During electric brake, the disc brake controller monitors the resulting deceleration of LRV. If the deceleration does reach a certain percent of the required brake rate within a certain time, the disc brake will be applied automatically. Vice versa is for disc brake, the electric brake will apply again if the disc brake does not perform. The AC motor drive can brake down to 2-3 kph. There is full brake redundancy from 70 kph down to 3 kph. The brake control scheme is shown on Fig. 8.

5.3 IMMUNE TO FLOODING DUE TO AC MOTOR, PARTICULAR FOR TROPICAL COUNTRIES.

The stator coils are insulated and vacuum impregnated. So even if there is flood water, the insulation of the motor will be protected, much better than DC motor which has the commutator.

6. CONCLUSION

The life cycle cost of LRV with AC motor drive is now lower than that of DC motor.

1. The initial investment cost of AC drive is competitive with DC drive.
2. The AC traction motor has higher reliability and needs less maintenance.
3. The advances in power semiconductor devices and microprocessor technology enhance the performance, reliability of LRV and facilitate fault analysis.
4. The capability of AC propulsion braking down to 2-3 kph provides redundancy in braking and greatly enhances the safety of LRV.
5. The twin-motor arrangement reduces investment cost on maintenance equipment and spare.

Therefore even with a small fleet of 20 LRVs, it is still worthwhile to go for AC motor drive.

Paper No. 8

ISO 14000 AND ITS APPLICATION TO THE ELECTRICAL INDUSTRY

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ISO 14000 AND ITS APPLICATION TO THE ELECTRICAL INDUSTRY

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ABSTRACT

Modern society is coming to terms with the fact that economic growth and rising living standards cannot continue to increase, without taking into account the impact of such growth on the environment. *Sustainable development* is fast becoming the approach that developed countries are trying to adopt in order to curtail the environmental impacts of their societies. In order to achieve sustainable development, the *International Organization for Standardization* has developed a series of environmental management standards called ISO 14000 to provide companies with a management framework to control the environmental impacts of their operations. The Kowloon-Canton Railway Corporation (KCRC) is a highly visible element of the Hong Kong community, offering various modes of transportation from Kowloon to the border with China. This paper reviews the ISO 14000 standard and the work of ERM - Hong Kong, Ltd in applying this standard to KCRC's operations and services.

1. INTRODUCTION

1.1 Purpose of the Paper

This Paper has been submitted by Environmental Resources Management - Hong Kong, Limited (ERM) to the Hong Kong Institute of Engineers - Electrical Division (HKIE) fourteenth symposium on "Sustainable Development - Electrical Industry".

This paper reviews the ISO 14000 standard and the work of ERM in applying this standard to the operations and services of the Kowloon-Canton Railway Corporation, a major user of electricity.

1.2 Background

The Kowloon-Canton Railway Corporation (KCRC) is a major energy user and a highly visible element of the Hong Kong community, offering various modes of transportation from Kowloon to the border with China.

In common with many of the major corporations in Hong Kong, the KCRC recognises the importance of managing the environmental impacts of their activities to ensure compliance with legislation and corporate policies, and to satisfy the expectations of their staff, customers, shareholders and other stakeholders. To help them achieve this a study has been carried out to implement an EMS for the whole Corporation, using the environmental management standard ISO 14001, to provide a management framework to control the environmental impacts of their operations. A short discussion on the ISO 14000 series of environmental management standards is presented in *Section 2* of this paper.

1.3 Case Study

The Case Study described in *Section 3* reviews the work undertaken by KCRC in developing an environmental management system (EMS), with the stated aim of achieving ISO 14001 certification. The following topics are covered in the Case Study:

- Initial review process through corporate environmental audits.
- Key constraints to the implementation of the EMS.
- Development of the Corporate Environmental Policy.
- Setting of demanding but achievable environmental objectives and targets for each Division.

- Development of EMS documentation to ISO 14001 standards.
- Providing environmental awareness training on the EMS.
- Specifying a Division to implement a pilot EMS with the eventual aim of certification to ISO 14001.
- Next steps for the Corporation.

2. BACKGROUND TO ISO 14000

2.1 Introduction

Standards are commonly accepted now as a core strategic business issue that is integral to the performance of companies wishing to improve and become more efficient. In particular, international standards such as ISO 9000, the quality management standard, are designed to help companies establish a 'systems' approach towards ensuring conformance to certain performance standards. In August 1991, the *Strategic Advisory Group on the Environment* (SAGE) was formed by ISO to assess the need for standardisation in the area of environmental management. The work of SAGE produced two outcomes:

- A series of ISO recommendations submitted to the United Nations Conference on Environment and Development (UNCED) in preparation for the *Earth Summit* held in Rio de Janeiro in June 1992. As a result of this initiative, the call for environmental management within businesses became a key element of *Agenda 21*, the comprehensive policy guidance document on sustainable development.
- The identification of the need to create a new ISO Technical Committee (TC) develop standards for environmental management. This Technical Committee, ISO/TC 207, was later formed in January 1993.

The role of ISO/TC 207 is to develop comprehensive and systems-based standards for environmental management in two main areas: organization and products (see Figure 2.1a). In addition, ISO/TC 207 works in conjunction with another technical committee, ISO/TC 176, in the corresponding quality management and audit standards field as there are a number of common elements in both quality and environmental management. A TC 176/207 Co-ordination Group has been formed to ensure compatibility between the two systems.

2.2 Status of ISO 14000

In June 1995, at the international meeting held in Oslo, six key environmental management system (EMS) documents were upgraded to Draft International Standards (DIS) status in preparation for a six-month review and ballot before publication as ISO standards. These were as follows:

- **DIS 14001:** EMS - Specification with Guidance for Use
- **DIS 14004:** EMS - General Guidance on Environmental Management Principles, Systems and Supporting Techniques
- **DIS 14010:** Guidelines for Environmental Auditing - General Principles
- **DIS 14011.1:** Guidelines for Environmental Auditing - Audit Procedures - Part 1: Auditing of EMS
- **DIS 14012:** Guidelines for Environmental Auditing - Qualification Criteria for Environmental Auditors
- **DIS 14060:** Guidelines for the inclusion of environmental aspects in product standards

Progress is being made in developing documents for environmental labelling, environmental performance, life cycle assessment, terms and definitions. The current status of the ISO 14000 series of documents is presented in *Table 2.2a*.

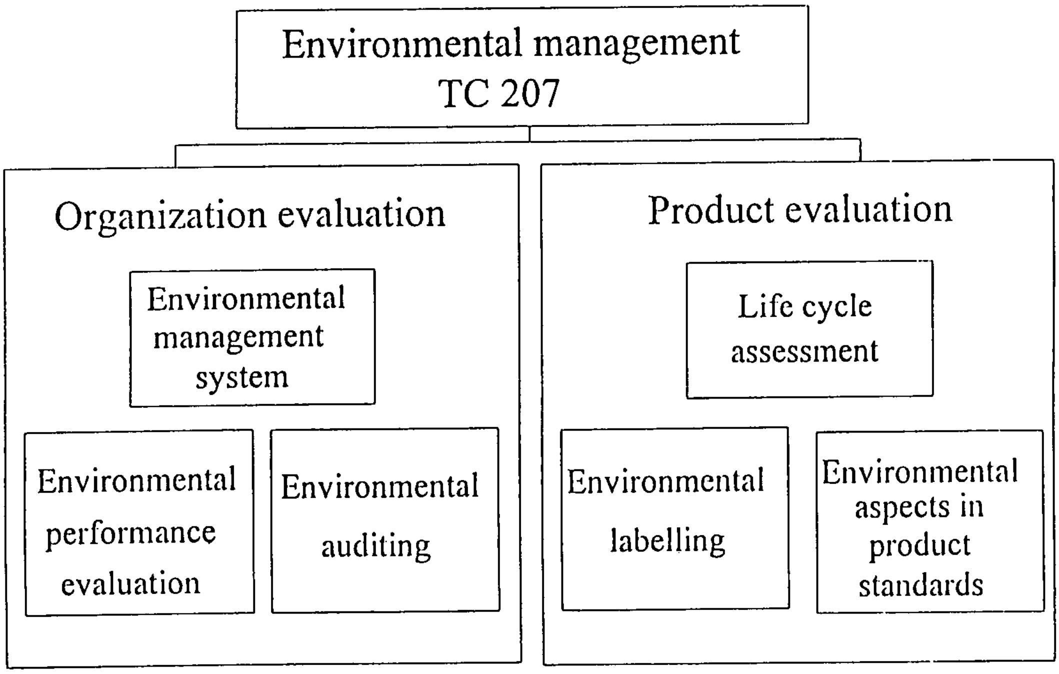
2.3 Implications for the Electrical Industry

Standards, as an instrument of business strategy, are faced with a number of difficulties as they must provide flexible guidelines that enable systematic achievement of environmental objectives as well as development of the business. EMS and ISO 14000 is already regarded by many electrical/power companies with interest and concern on the appropriateness of adopting an EMS to manage the environmental impacts of their businesses. Common queries that arise include:

- Responsiveness of the EMS to resource, expertise, capability and cultural difficulties.
- Integration of the EMS with other management systems and the management style of the company.
- Level of senior management support.
- Defining the quantifiable environmental impacts of the company.

The process of certification is also under discussion with particular regard to making the standard cost-effective and not a drain on resources; enabling companies to undertake internal self-audits which can be independently verified; and ensuring that the standard, once achieved, provides incentives for the company to continually improve on its performance. Many Asia-Pacific trade organizations are looking at ISO 14000 to identify the related benefits for their member companies, particularly with regard to the close links to ISO 9000 and using common certifying bodies.

FIGURE 2.1a : ISO14000 Environmental Standards Framework



Paper No. 8

Table 2.2a *ISO 14000 Series of Environmental Management Documents (as of July 1995)*

	Doc. No.	Document Title	Committee	Status	Target Pub. Date
1.	ISO 14000	EMS - General Guidelines on Principles, Systems and Supporting Techniques	SC1/W2	DIS	Fall '96
2.	ISO 14001	EMS - Specification with Guidance for Use	SC1/WG1	DIS	Fall '96
3.	ISO 14010	EA - General Principles of Environmental Auditing	SC2/WG1	DIS	Fall '96
4.	ISO 14011.1	EA - Audit Procedures - Part 1: Auditing of EMS	SC2/WG2	DIS	Fall '96
7.	ISO 14012	EA - Qualification Criteria for Environmental Auditors	SC2/WG3	DIS	Fall '96
11.	ISO 14020	EL - Basic Principles of all Environmental Labelling	SC3/WG3	Working Draft	-
12.	ISO 14021	EL - Self-Declaration - Environmental Claims - Terms and Definitions	SC3/WG2	CD for Ballot	-
13.	ISO 14022	EL - Symbols	SC3/WG2	Working Draft	Fall '97
14.	ISO 14023	EL - Testing and Verification Methodologies	SC3/WG2	Prep. Stage	Fall '97
15.	ISO 14024	EL - Practitioner Programmes - Guiding principles, practises and certification procedures of multiple criteria (type 1) programmes	SC3/WG1	CD for Ballot	-
16.	ISO 14031	Environmental Performance Evaluation	SC4/WG1 & 2	Working Draft	1998
17.	ISO 14040	LCA - General Principles and Practices	SC5/WG3	CD for Ballot	-
18.	ISO 14041	LCA - Goal and Definition/Scope and Inventory Assessment	SC5/WG2 & 3	Working Draft	Fall '96
19.	ISO 14042	LCA - Impact Assessment	SC5/WG4	Prep. Stage	1998
20.	ISO 14043	LCA - Improvement Assessment	SC5/WG5	Prep. Stage	Fall '97
21.	ISO 14050	Terms and Definitions	SC6	Working Draft	-
22.	ISO 14060	Guide for the Inclusion of Environmental Aspects in Product Standards	WG1	DIS	Spring '97

KEY
- EMS Environmental Management System
- EA Environmental Auditing
- EL Environmental Labelling
- LCA Life Cycle Analysis
- SC Sub-Committee
- WG Working Group
- DIS Draft International Standard

3. CASE STUDY

3.1 Background

The KCRC plays a valuable role in the lives of the people of Hong Kong in transporting people and freight to various destinations in Kowloon, the New Territories and China. The services provided by KCRC ensure the flow of commerce and business activities to and from the Territory, thereby maintaining and supporting the economic vibrancy of Hong Kong. In the discharging of these duties, KCRC is committed to the pursuit of excellence in its obligations to its staff, customers and the community of Hong Kong. This commitment is reflected in the Corporation's mission statement and also extends to protecting the environment. KCRC's mission statement states:

"Our mission is to provide quality transport and related services in Hong Kong and China in a safe, reliable, caring, cost effective and environmentally responsible manner."

3.2 Corporate Environmental Audits

In order to fulfil the mission statement, in early 1995, KCRC commissioned consultants to conduct an independent corporate environmental audit of the Corporation to provide an indication of their environmental performance. The scope of the corporate audit included reviewing the Corporation's existing policies; site audits on a selected number of sites; a questionnaire to selected KCRC suppliers to assess their environmental awareness; and compilation of environmental effects for each Division.

The conclusions from the study was that the overall performance of the Corporation was good as in general all facilities and services were in compliance with Hong Kong Government environmental legislation. However, an environmental audit only provides information on the environmental performance of a company at that moment in time, and does not guarantee continued compliance with environmental legislation. To be proactive, and ensure a process of continual environmental improvement and legislative compliance, only a systematic integration of environmental management into the Corporation's existing management structure could provide this assurance. This "requirement" for compliance, and above compliance, standards of environmental management will become more important when the design, construction and operation of the Western Corridor Railway begins.

3.3 Development of the Environmental Management System

Thus, in early 1996, KCRC re-commissioned consultants to begin development of a Corporation-wide EMS with the eventual aim of achieving ISO 14001 certification for at least one Division. The following sections highlight how the consultants and KCRC approached this demanding project.

3.3.1 Initial Review

Before any company can begin the process of developing an EMS, an initial baseline review must be done of the company's:

- Current environmental performance and environmental programmes;
- Environmental legislative requirements;
- Present management structure;
- The level of commitment to improving environmental performance; and
- Resources available to implement the EMS.

The corporate environmental audits provided ERM with good baseline information on the major environmental impacts, conservation programmes and legislative requirement of each Division, as well as the overall culture and management structure of KCRC. However this information alone was not sufficient to begin the development of the EMS. Further information was required on the management systems in operation at Divisional and Departmental levels, and the degree of commitment to the EMS in the Corporation.

This additional information was gathered through selective management documentation reviews throughout the Corporation, as well as a process of management consultations with the Environmental Steering Committee (ESC), and senior Divisional and Departmental management. The results from this initial review showed that nearly all of the Corporation's Divisions had or were in the process of attaining the quality management standard ISO 9000. Thus, in general the entire Corporation was operated with a quality-driven mindset, which would mean that the response of personnel in the organisation would be positive to the idea of an ordered management system for the environment.

In addition to this strong culture of quality management the Corporation are, through its mission statement, also pledged to protecting the environment. The formation of the ESC which is made up of senior managers from several Divisions and is the focal point for the Corporation's environmental initiatives, represents a serious commitment as a considerable amount of management time and resources is given to the ESC.

3.3.2 Key Constraints

From the data gathered in the initial review, it was clear that the two main constraints for the entire Corporation to attain ISO 14001 certification was firstly the integration of the EMS into the existing quality management and ISO 9000 orientated culture of the company. If this process of integration is not achieved, the EMS will always appear to the management and personnel as a "bolt-on" management system and this will inevitably cause rejection through the "bolt-on" EMS unnecessarily adding additional work, rather than being treated as a day-to-day "matter-of-course" management of the environment. The caveat to this integration of systems is that in certain circumstances a conflict of interest will occur between quality and environmental issues, however the judgement as to which "side wins" will be based upon operational, safety and business dictates.

The second constraint to achieving a company-wide ISO 14001 certification was the diversity of the Corporation's activities and services. The approach taken for ISO 9000 certification had been to break down the process into more manageable Departmental, Sectional and even Unit operations. Hence the ISO 14001 certification process would follow this path.

3.3.3 Development of the Corporate Environmental Policy

The first draft of the Corporate Environmental Policy was found to be too high level and lacking clear aim. This is not acceptable, because for any EMS to be workable the policy must provide focussed guidance so that the necessary resources to implement the EMS can be sanctioned by the top management. Hence, a re-scripted policy document was provided to fall in-line with other Corporation policy documents, such as safety, to offer more guidance to the Divisions in addition to being a charter committing KCRC to good environmental management.

3.3.4 Setting of Objectives and Targets

The task of setting environmental objectives and targets was an intricate area as the objectives had to be demanding but achievable given the framework of business and operating requirements. The task was made especially difficult due to the diverse impacts, and the differing levels of environmental awareness and commitment amongst management staff in the different Divisions.

The baseline information from the initial review process yielded a preliminary set of Divisional objectives for improvement of environmental performance. However, due to conflicting safety, operational and business requirements, some of these objectives were not acceptable to the Division heads. Thus after an iterative consultation process with senior Divisional managers, a focused collection of useable objectives with quantitative targets were established. These objectives ranged from "hard" issues such as energy usage reductions to "softer" issues such as increasing the environmental awareness of passengers. The use of quantitative targets is necessary as it facilitates monitoring of the progress of the environmental programmes and provides management and personnel a clear sense of achievement when targets are met.

As resources required to implement these objectives would necessitate personnel time, and a specific budget for items such as replacement equipment and monitoring instruments, the date for achieving these targets was set for the end of 1997. This date would allow enough time for an environmental budget allocation to be incorporated into the Divisional business plans.

3.3.5 Development of EMS Documentation

As stated earlier, one of the key constraints in this project was to ensure that the EMS was fully integrated with KCRC's present management systems. One of the critical areas where this had to be accomplished was in the compatibility of the EMS documentation with present management documentation.

As all Divisions were planning or were already ISO 9000 certified, the EMS would have to be workable within the quality management framework. This integration of systems and documentation was made relatively straight forward due to the fact that in the development of ISO 14001, the ISO Technical Committee had taken into consideration that the environmental management standard would have to be congruous with equivalent quality management requirements (refer to *Section* 2). This correlation of environmental and quality standards can be seen in *Table 3.3a*.

In the development of the KCRC EMS documentation, it was considered that the Corporate Environmental Policy document would be sufficient to act as the Corporation charter and general guidance on environmental management, and that one Corporate level manual to describe the EMS would be too generic given the diversity of issues between each Division. Thus a series of EMS manuals flowing down from the policy document were developed and tailored for each Division, but with the basic framework of each manual following the outline of the ISO 14001 requirements to ensure a level of consistency between Divisional systems. *Figure 3.3a* shows the environmental management structure from the Corporate down to individual site level.

In addition to describing the elements of the EMS, the manuals lay out the lines of responsibility for environmental management within each Division. In order to have a focal point for environmental issues, a senior manager within each Division is nominated as an Environmental Management Representative (EMR). The clear advantages of having a senior manager as an EMR, rather than a dedicated environmental manager, lies in the financial savings through integration of the role and the fact that an established manager is familiar with the operations of the Division.

3.3.6 Environmental Training

In order to increase the general level of environmental awareness amongst the management staff and introduce the Corporate Environmental Policy, a succession of training sessions were held for all of KCRC's managers. Besides introducing the concept of an EMS, ISO 14001 and the similarities between quality and environmental management, the training sessions covered the steps required to implement an EMS with a workshop period on how to develop an action plan for implementing the environmental objectives and targets.

3.3.7 Piloting the EMS

As stated earlier in Section 3.3.2, one of the key constraints for KCRC to achieve company-wide certification was the diversity of its operations and activities. Thus, as the ISO 14001 standard allows a company to certify just one part/site of the organisation, the logical step was to test the EMS at one part/site and take that unit through to certification. The advantages of this method would be that the efforts of the consultants and the ESC could be focused, and lessons drawn from the pilot would benefit future Divisions attempting certification.

Certain criteria were employed during the selection of the pilot unit. It was decided that for the EMS to provide substantial benefit, an operational unit with major environmental impacts would reap more rewards than an office-based unit with fewer issues. In addition it was felt that a unit with a well established quality management system would be better able to provide personnel and financial resources, moreover the personnel would be more comfortable with a systems-orientated management structure.

Once a unit had been chosen, the pilot programme was implemented with the objective of assessing the EMS against the ISO 14001 requirements. Once the EMS has been fully established and the final version of the ISO 14001 environmental management standard has been presented, the target will be to certify the pilot unit to the international standard.

3.4 Next Steps

After the successful pilot implementation of the EMS, KCRC will continue to develop its environmental management structure throughout the Corporation. Additional areas that the Corporation could examine to further improve its environmental performance, is the application of environmental requirements for joint venture partners, contractors and suppliers.

4. CONCLUSIONS

KCRC have taken the initiative in Hong Kong by being one of the first companies to actively develop an environmental management system, with the long term goal of achieving total quality management through integration of its internationally certified environmental and quality management systems.

The lessons that can be learnt from this project are:

- A properly implemented EMS can ensure regulatory compliance through systematic management of a company's environmental impacts.
- It is not necessary to employ a dedicated team of environmental managers, especially as this role can be integrated into existing management responsibilities.
- Employing an external advisor, such as a consultant, can provide independent and professional advice on environmental management and avoids the complications of any internal organisational politics.
- The use of quantitative environmental objectives and targets is essential as it focuses the company environmental policy down to all staff.

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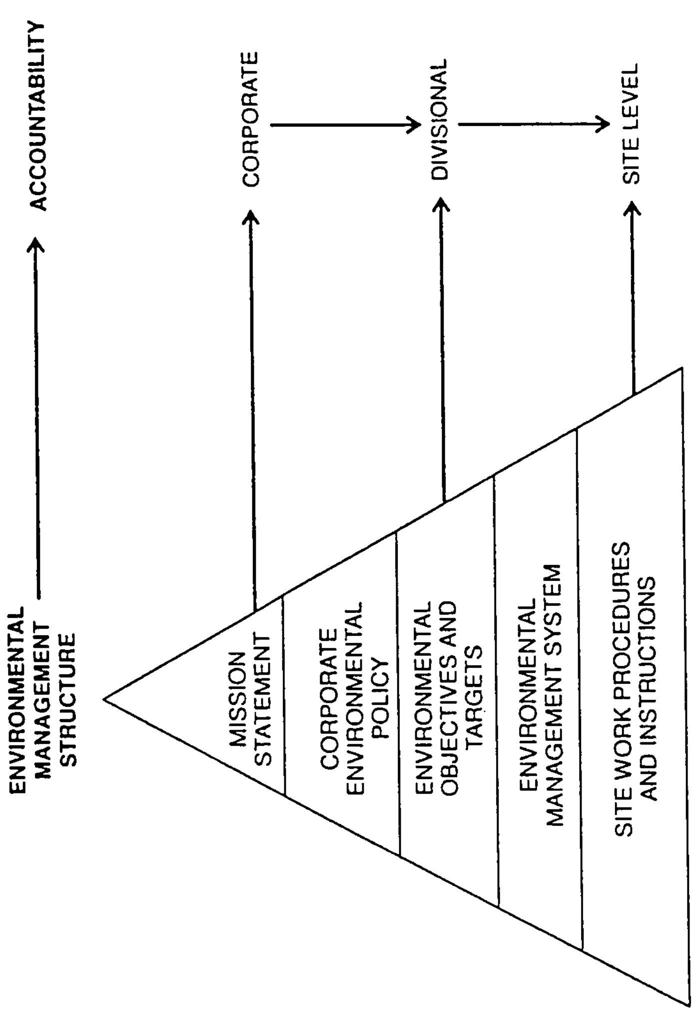

FIGURE 3.3a - KCRC ENVIRONMENTAL MANAGEMENT STRUCTURE

Paper No. 8

Table 3.3a *Correlation between ISO 9000 and ISO 14000*

ISO 9000: 1994 requirements	Heading	ISO 14000 requirements	Heading
4.1	Management responsibility		
4.1.1	Quality policy	4.1	Environmental policy
		4.2.1	Environmental aspects
		4.2.2	Legal and other requirements
		4.2.3	Objectives and targets
		4.2.4	Environmental management programme
4.1.2	Organization	4.3.1	Structure and responsibility
4.1.3	Management review	4.5	Management review
4.2	Quality system	4.0	General
4.2.1	General	4.3.4	Environmental documentation
4.2.2	Quality system procedures	4.3.6	Operational control
4.2.3	Quality planning	-	-
4.3	Contract review	4.3.6	Operational control
4.4	Design control	4.3.6	Operational control
4.5	Document and data control	4.3.5	Document control
4.6	Purchasing	4.3.6	Operational control
4.7	Control of customer-supplied product	4.3.6	Operational control
4.8	Product identification and traceability	-	-
4.9	Process control	4.3.6	Operational control
4.10	Inspection and testing	4.4.1	Monitoring and measurement
4.11	Control of inspection, measuring & test equipment	4.4.1	Monitoring and measurement
4.12	Inspection and test status	-	-
4.13	Control of non-conforming product	4.4.2	Non-conformance & corrective & preventative action
4.14	Corrective and preventative action	4.4.2	Non-conformance & corrective & preventative action
		4.3.7	Emergency preparedness and response
4.15	Handling, storage, packing, preservation and delivery	4.3.6	Operational control
4.16	Control of quality records	4.4.3	Records
4.17	Internal quality audits	4.4.4	Environmental management system audit
4.18	Training	4.3.2	Training, awareness and competence
4.19	Servicing	4.3.6	Operational control
4.20	Statistical techniques	-	-
-	-	4.3.3	Communication

Paper No. 9

ENVIRONMENTAL MANAGEMENT OF CASTLE PEAK POWER STATION

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ENVIRONMENTAL MANAGEMENT OF CASTLE PEAK POWER STATION

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ABSTRACT

Castle Peak Power Station (CPPS), operated by China Light & Power Co. Ltd. (CLP), has an installed capacity of 4460 Megawatts (MW) (coal and gas turbines) and is one of the worlds largest coal fired generating facilities. Castle Peak provides the bulk of the electricity supply to meet the demand of CLPís 1.66 million customers in Kowloon, the New Territories and several outlying islands. Fossil-fired electricity generation has a range of environmental concerns which need to be effectively managed in order to minimise the impact on the surrounding population and environment. These include emissions of air pollutants from stacks, discharges of process and cooling water effluents and management of waste materials and ash by-products .

This paper discusses the environmental impacts from CPPS, the control measures adopted to reduce pollutant emissions, the on-site and off-site environmental monitoring programmes to ensure compliance with regulatory requirements, and the Environmental Management System (EMS) being developed to manage the environmental issues of the facility. Also, it provides an overview of the environmental improvement initiatives currently being pursued by the site management.

1. OVERVIEW OF CHINA LIGHT & POWER CO. LTD. (CLP)

CLP has always recognised that generation and supply of electricity has an effect on the environment. Electricity is indispensable in modern life and is a socially and economically beneficial product. CLP recognises the interaction between electricity and the environment and is committed to maintaining a high standard of environmental care whilst responsibly promoting the wider application of electricity to meet the balanced environmental, economic and social needs of society. CLP has now developed a structured Environmental Management System (EMS) to properly manage its environmental affairs. This system is being implemented at Castle Peak.

In Hong Kong, CLP operations consist of 4108MW of base-load coal-fired power plant at Castle Peak, which is the focus of this paper. This is supplemented by 800MW of oil-fired plant at Tsing Yi and and a total of 802MW of peak-lopping gas turbines at both of these two sites and at Pennyís Bay. The transmission system consists of a supply network that extends over 10,000 kilometers with more than 6,500 substations. CLP is currently building a new natural gas fired 2500MW combined cycle power station at Black Point along with 55km of new 400 (kilovolt) kV transmission line. CLP also has joint venture power projects in the PRC and is currently pursuing new power projects in other Asian countries.

CLP has a good environmental track record and has always adopted high environmental standards. We have endeavored to fully comply with all pollution control licenses and relevant legislative requirements. Also, CLP has pursued several voluntary environmental initiatives. Examples include, the removal and proper disposal of all PCB containing electrical switch gear and transformers in 1987/8, the phased introduction of low-nitrogen oxides (NOx) burners at Castle Peak, the gradual phasing out of halon fire fighting systems, and the use of low sulphur fuel oil and retro-fit of low-NOx burners at Tsing Yi.

2. CASTLE PEAK POWER STATION

Castle Peak Power Station located at Tap Shek Kok in the western New Territories, consists of four 350 MW and four 680MW coal-fired generating units. In addition, there are six open cycle peak-lopping Industrial Diesel Oil (IDO)-fired, gas turbines adding a further 352MW. The site is subject to two main pollution control licences; which are a Air Pollution Control Ordinance (APCO) Specified Process Air Pollution Licence and a Water Pollution Control Ordinance (WPCO) Effluent Discharge Licence. The site is also a Registered Chemical Waste Producer Site as required under the Chemical Waste Regulations.

3. ENVIRONMENTAL IMPACTS OF CASTLE PEAK POWER STATION

3.1 INTRODUCTION

The main environmental impacts associated with operation of large coal-fired power plant include those resulting from air emissions and effluent discharges. Other important environmental issues to be managed include the proper storage and disposal of chemical wastes and the handling and end use of ash by-products. I shall deal with each of these in turn describing the impacts, control and monitoring programmes.

3.2 AIR EMISSIONS

The main air pollutants emitted from the CPPS stacks are Sulphur Dioxide (SO2), Nitrogen Oxides (NOx) and particulates. The level of S02 emission is contrölled at source by specifying the Sulphur content in the fuel (coal). The Air Pollution Control licence requires the fuel to have a less than 1% Sulphur content, however in practice CPPS burns coal with an average sulphur content of 0.6%. The sulphur content of the IDO burnt in the Gas Turbines is also limited to 0.5%, in line with the Fuel Restriction Regulations. NOx levels are a function of the combustion system and at CPPS since 1990 all of the burner systems have been replaced with low-NOx burners. This has resulted in an overall reduction in NOx emission levels of about 50% compared with the original plant. The Gas Turbines have a water injection system which reduces the combustion temperature and hence limits the formation of NOx. Minimum water injection rates are specified as licence requirements to limit the NOx emission. Particulates in the form of fly ash are removed from the flue gas by electrostatic precipitators which when enhanced by Sulphur Trioxide (S03) injection have over a 99% dust removal efficiency.

NOx and dust (opacity) levels are continuously monitored in each stack and the results are sent directly to the Environmental Protection Departmentës (EPD) offices via a telemetry system. Fuel burn and sulphur content data is also reported to EPD separately as are the results of annual stack gas grab samples when they are conducted. In addition CPPS monitor dust levels at the site boundary and a network of Ambient Air Quality Monitoring Stations in the Tuen Mun and Yuen Long area record the ambient levels.

Despite power generation accounting for 85% of the total S02 and 72% of total NOx emission in Hong Kong (Ref1), the above air quality monitoring programme reveals, that despite dominating the share of total emissions, CPPS makes a minor contribution to urban pollution problems. For, example CPPSís contribution to ambient levels of S02 and NOx in the Tuen Mun area represents only about 4% and 3% of the total on an annual basis, and considerably less in problem areas such as Mong Kok, Tsim Sha Tsui, Kwun Tong and Central (Ref.2).

3.3 EFFLUENT DISCHARGES

Effluent discharges arise from cooling water, sewage treatment, coal stockyard and ash handling, and various plant processes. In terms of volume, the cooling water represents the largest source. At full load CPPS discharges over 10 million m3 per day of sea water with a maximum thermal increase between inlet and outfall of around 12 degrees Celsius. The station also uses over 7500 m3 of towns water which is used for a variety of processes including boiler feedwater, dust suppression, fire protection, domestic uses and ash sluicing. After various treatment processes these effluents are discharged either directly to sea or via the cooling water outfall after mixing. For example, ash contaminated water is treated for suspended solids removal, and turbine and transformer area drains are treated for oil and grease removal.

All discharge points are subject to licence control and have appropriate pollutant limits. All discharges are self-monitored by CPPS staff to demonstrate compliance and the results are sent to EPD on a monthly basis. EPD inspectors also routinely conduct compliance visits. In addition off-shore thermal monitoring and oyster monitoring programmes have been successfully completed to demonstrate that the temperature effects and heavy metal loadings have not caused significant environmental impact to the marine environment.

Despite having a good compliance record for effluent discharges, CPPS commenced a study in 1995 to design and construct a centralised waste water management system. This will affect the process water system, not the seawater cooling system. A number of options were considered ranging from individual treatment options to a single effluent collection and reuse system. The decision to opt for the total collection and reuse system has been made and detailed design work has commenced. This scheme will maximise the collection of all waste and storm water in purpose built on-site and off-site lagoons for reuse as dust suppression and ash handling waters. The wet season excess being stored and used in the dry season. This will result in considerable reduction in the use of towns water - which has cost and resource savings - and will minimise the discharge of potentially polluted process waters to sea. This project offers CPPS both environmental, and in the longer term, economic benefits.

3.4 CHEMICAL WASTE AND ASH BY-PRODUCT MANAGEMENT

A number of chemical wastes are generated on site. These include spent lubricating and transformer oils, spent solvents and paints, and spent acids and alkalis. Chemical wastes, and the regulations to handle, store and dispose them; are clearly defined in the Chemical Waste Regulations. CPPS have installed appropriate collection and storage facilities; and appropriate management procedures to ensure all identified chemical wastes are disposed of properly. Rather than send waste oil to the Government treatment facility for incineration, CPPS sends all waste oil to a local oil recycling company who re-manufacture old oils for reuse. This also saves costs and has obvious environmental benefits in terms of recycling. CPPS is also assessing possibilities to reduce to a minimum the arisings of all wastes. This is one the stationís Environmental Improvement Plan initiatives. This paper describes the Environmental Plan in a later section.

In the 1980ís, disposing of the surplus fly ash arising from the combustion of coal required the construction of large ash lagoons located at Tsang Tsui in the western New Territories. At its peak, CPPS produced about 1 million tonnes of ash a year and in the past most of it was disposed of in slurry form to the lagoons. This is an accepted practice adopted world-wide. However, due to an aggressive and successful marketing campaign, CLP now manages to sell all of the ash produced by the CPPS for use in the cement and concrete industry. To improve the quality, and marketability, CLP invested in an Ash Classification Plant at CPPS. This has also improved sales of this previously surplus, but now valuable, by-product. This is yet another CPPS successful project which has both an environmental and economic benefit.

4. CPPS ENVIRONMENTAL MANAGEMENT SYSTEM

The CPPS Environmental Management System (EMS) is a requirement of the CLP Corporate EMS Manual, which was established by the Company in May 1995. The Corporate EMS Manual provides a framework for all CLP operating units and provides information and guidance on the CLP Environmental Policy, roles and responsibilities, preparation of Environmental Effects Registers and Environmental Improvement Plans; and environmental reporting. CPPS have been very proactive in implementing the Corporate requirement to establish an EMS at the site, in many cases going beyond the minimum Corporate requirement.

5. COMPONENTS OF THE CPPS EMS

The focal point of CPPS EMS is the Environmental File which contains a number of key documents, including an EMS Manual, Environmental Directory, Register of Legislation, Environmental Effects Register, Environmental Improvement Plan and other relevant information. The CPPS EMS Manual provides information and guidance on a range of management aspects from CLP Policy and CPPS roles and responsibilities for environment management to document control and auditing. This document is the central source of advice and guidance to other components of the site EMS - i.e. the signpost.

The Environmental Directory is basically a list of the staff who have responsibility for environmental management. It clearly identifies staff and defines areas of responsibility and also cross references to appropriate working procedures. The Register of Environmental Legislation and Environmental Effects Register are specific requirements of the Corporate EMS and are features of most international EMS standards, such as BS7750 and ISO 14001. The first is basically a list of all laws, standards, regulations, codes of practice and permit requirements applicable to the operation of the site. This is continuously updated and interfaces with the Corporate Legal Compliance System which ensures the whole of CLP is aware and compliant with new and existing legislation.

The Environmental Effects Register is a useful management tool which lists all of the potential environmental issues affecting the site. This document must be reviewed and updated annually. The corresponding control mechanism or working procedure is identified for each issue listed. In some cases issues that required new procedures to be developed were identified and action taken to produce one.

The preparation of an Environmental Improvement Plan is a Corporate EMS requirement aimed at meeting the CLP policy commitment to continuously improve. This is also a feature of most EMS standards. The CPPS Plan for 1995/6 followed the Corporate EMS format and provided information on 16 improvement initiatives; listing the objective, target, timescale, responsible person and cost estimate for each. The initiatives range from large capital projects to procedure development. Projects include the development of the waste water management scheme, completion of the low NOx burner replacement programme, development of an emissions inventory, a zero minor oil spill programme and the extension of the coal dust suppression system. The progress on achieving the targets in the Plan will be reviewed at the end of the year. Already CPPS have prepared a draft Plan for next year which will need to be endorsed by CLPís Senior Executive Safety, Occupational Health and Environment Committee.

CLP has introduced an Operations Integrity Management System (OIMS) which encompasses systems and control procedures to ensure that high standards of operation are consistently met. The CPPS EMS is a system within the OIMS. The OIMS specifies a range of operational controls such as formats for procedures and requirements for reviews, measures for risk management and document control arrangements. Many of the procedures for environmental management at the site are already included in the station OIMS. Integrating EMS within the existing station operating system was considered essential, as this would ensure that environmental considerations are an integral part of all operational controls, and not seen as a stand-alone separate system.

Other features of the CPPS EMS include Performance Monitoring and Reporting Procedures, an Incident Reporting, Investigation and Analysis Procedure; Communication and Training; Environmental Audits and an EMS Senior Management Review. The CLP environmental policy requires all sites to be periodically independently audited. The CLP Corporate Environment Department arranged an independent audit of CPPS in 1994 and this will be repeated in 1997. The findings are considered when drawing up Improvement Plans and are considered by the CPPS Management Review and the CLP Senior Executive Safety, Occupational Health and Environment Committee.

6. CONCLUSION

CLP and the management of Castle Peak Power Station recognise the environmental effects of electricity generation and have taken a responsible pro-active approach to ensuring that appropriate controls and management systems are in place to minimise impacts to the surrounding environment. In line with Corporate policy, CPPS have introduced a comprehensive Environmental Management System consistent with international practice which includes a mechanism for continual improvement in environmental performance.

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