THE HONG KONG
INSTITUTION OF ENGINEERS
ELECTRICAL DIVISION

The 33rd Annual Symposium

Thursday

29th October 2015

DRIVE FOR EFFICIENCY

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 **Registration and Coffee**

09.00 **Welcome Address**
— Ir P.K. Chan
Chairman, Electrical Division, The HKIE

09.05 **Opening Address**
— Ir C.C. Chan
President, The HKIE

09.10 **Keynote Speech**
— Ir Professor Victor O.K. Li
Head
Department of Electrical and Electronic Engineering
University of Hong Kong

1. Power to Drive

09.40 **A Systematic Approach for Improving Power Station Performance**
— Ir Nicky H.C. Lai, Senior Production Manager
— Mr Johnny M.C. Lee, Shift Engineer
— Ms Maggie Y.L. Go, Service Engineer
— Mr Alex C.S. Man, Business Engineer
Generation Business Group
CLP Power Hong Kong Limited

10.00 **A Robust Regulatory Platform to Deliver Quality & Innovation**
— Ir T.C. Yee, General Manager (Corporate Development)
— Ir W.K. Leung, Manager (Regulation & Policy)
The Hongkong Electric Co. Ltd.

10.20 **Discussion**

10.40 **Coffee Break**

2. EVs & Charging Infrastructure

11.10 **Eco-friendly Online Electric Vehicles using Shaped Magnetic Field in Resonance (SMFIR) Technology**

— Professor Dong Ho Cho, Director
Online Electric Vehicle Project
Korea Advanced Institute of Science and Technology

— Professor Nam Pyo Suh, Cross Professor Emeritus
Department of Mechanical Engineering
Massachusetts Institute of Technology, USA

11.30 **Study of Market Model of Charging Infrastructure for Electric Transportation**

— Mr Maarten Noom, Business Strategy Senior Manager

— Mr Paul Ubbink, Business Strategy Senior Manager

— Ir Stanley K.W. Leung, Senior Manager
Accenture Company Ltd.

11.50 **Discussion**

12.15 **Lunch**

3. Energy Efficiency

14.10 **Upgrading of the Grading Standard under the Mandatory Energy Efficiency Labelling Scheme**

— Ir S.C. Wong, Chief Engineer

— Ir Y.K. Chan, Senior Engineer

— Ir C.Y. Shum, Engineer
Electrical & Mechanical Services Department
The Government of the HKSAR

14.30 **Winning Multiple Efficiencies through Elevator Modernization**

— Ir Louis Y.N. Yiu
Modernization Sales Engineering Manager
Mitsubishi Elevator Hong Kong Co. Ltd.

14.50 **Discussion**

15.10 **Coffee Break**

4. Mass Transit - Future Development

15.40 **The Future of the City Bus - A Potential Scenario**

— Mr Manfred Josef Schmidt
Senior Director
Sales and Marketing Hybrid Drives
Siemens AG, Germany

16.00 **Enhancement of E&M Systems and Railway Operation Efficiencies of New Railway Projects in Hong Kong**

— Ir William K.F. Lee
Engineering Manager - Services
MTR Corporation Limited

16.20 **Discussion**

16.45 **Summing Up**

— Ir Siu-kwong Ho
Symposium Chairman
Electrical Division, The HKIE

Closing Address

— Ir Professor S.L. Ho
Chair Professor of Electricity Utilization
Hong Kong Polytechnic University

Acknowledgement

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Speakers / Authors

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Ir Y.K. Chan
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Ir Louis Y.N. Yiu
Mr Manfred Josef Schmidt
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Paper No. 1

A SYSTEMATIC APPROACH FOR IMPROVING POWER STATION PERFORMANCE

Speakers: Ir Nicky H.C. Lai, Senior Production Manager
Mr Johnny M.C. Lee, Shift Engineer
Ms Maggie Y.L. Go, Service Engineer
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Paper No. 1

ABSTRACT

CLP Power operates the Black Point (BPPS), Castle Peak (CPPS) and Penny's Bay Power Stations in Hong Kong. Entering service in the 80's and 90's, the stations have been in operation for decades. Consequently, performance deterioration due to aging, change of fuel type, retrofitting of additional equipment, etc. has been observed.

With an aim of maintaining station performance, dedicated performance teams were set up to closely monitor the fleet performance and to develop improvement initiatives. A systematic approach has been adopted to drive plant performance towards excellence in four areas: Generation Capacity, Thermal Efficiency, Reliability and Air Emissions. The approach comprises four key elements, namely Awareness, Identification, Evaluation and Implementation, which nurtures collaboration and a proactive mind-set amongst teams to solve plant issues.

This paper describes the strategic framework of the plant performance excellence and includes several case studies to illustrate how the systematic approach is implemented to drive plant performance in the stations towards excellence.

1. INTRODUCTION

Castle Peak Power Station (CPPS) comprises four 350MW and four 677 MW coal-fired generating units which were built, in the 1980s as one of the means to meet high growth in Hong Kong's electricity demand. CPPS pioneered the use of sub-bituminous coal in the early 2000's instead of using bituminous coal as in the original design. This was to improve the emissions performance and CPPS continuously strives for better emissions performance including retrofitting the Flue Gas Desulphurization and Selective Catalytic Reduction systems for reducing SO_x and NO_x significantly in late 2000's.

Black Point Power Station (BPPS) was the first natural gas-fired combined cycle gas turbine plant in Hong Kong. The plant consists of eight 312.5MW combined cycle units with a total installed capacity of 2,500MW. Since the first unit was put into commercial operation in mid-1996, BPPS has been continuously improving its performance and has achieved a world-class level of performance.

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Figure 1 Overview of CPPS and BPPS

A strategic framework is applied to cascade our goal into actions through teamwork with a continuous improvement mindset (See Figure 2 below). Our aspiration is to become the benchmark of power generation in Asia from one generation to the next. With a clear vision, we do not just settle for being "good enough" and fail to do the hard work of building outstanding capabilities. In order to achieve our aspiration, a systematic approach is developed with four key elements, namely Awareness, Identification, Evaluation and Implementation (See Figure 3). This approach is important to cultivating the behavior and proactive mindset among our engineers. Capabilities are those things that we must do exceedingly well in order to deliver on aspiration. Our core capabilities are the operation and maintenance expertise, engineering and commercial knowledge, which includes analytical and diagnostic skills with the utilization of advanced plant computing and monitoring tools. Finally, a system is in place to support our core capabilities and activities. It includes a well-considered and practical process for measuring whether the strategy is working or not. From an organizational point of view, an integrated plant performance team with a leader is also required to drive the process.

Figure 2 Strategic Framework of Plant Performance Excellence

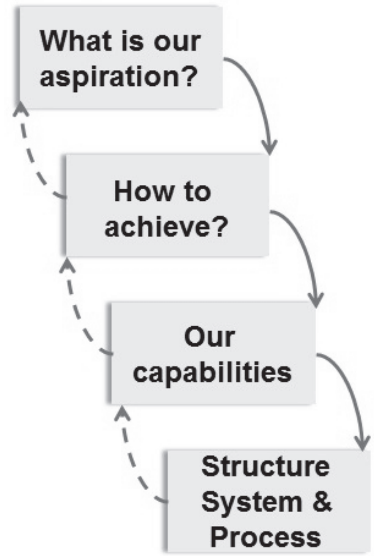
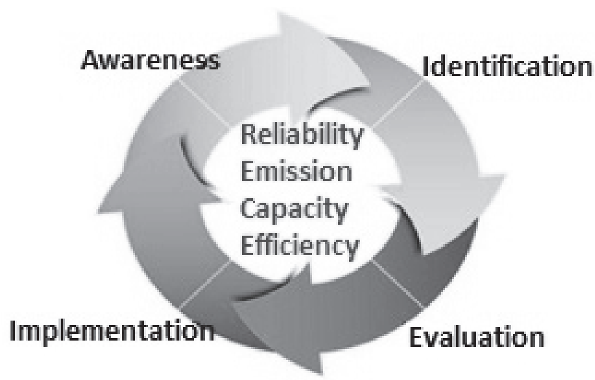


Figure 3 Approach of Achieving Plant Performance Excellence



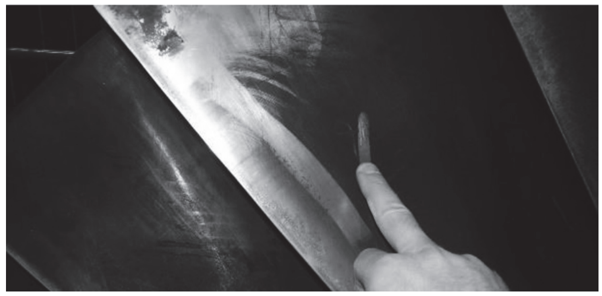
To achieve plant performance excellence, the systematic approach is implemented focusing on four core areas – Generation Capacity, Thermal Efficiency, Reliability and Air Emissions. The first step of the systematic approach is Awareness, which involves staff from different levels to understand the plant conditions and potential issues. This can be done by analysing past operating data and trending. Next step is to identify potential initiatives to improve plant performance. This includes the joint participation of operation, maintenance, engineering and business staff through the plant Asset Ownership Scheme (AOS), in which the AOS teams are responsible for their allocated systems and manage the assets in a comprehensive and collaborative manner through engagement of all stakeholders. After the identification process, the options of the improvement initiatives are studied and evaluated to develop the most appropriate solutions based on consideration of technical feasibility, cost benefits analysis and risk assessment. The identified initiatives are then implemented safely and effectively to achieve the planned targets and outcomes. To illustrate how the systematic approach is adopted in CPPS and BPPS to achieve excellence in Generation Capacity, Efficiency, Reliability and Air Emission, case studies are described to include the methodology used, success factors, significance and benefits of implementation.

2. CASE STUDIES

2.1 GENERATION CAPACITY

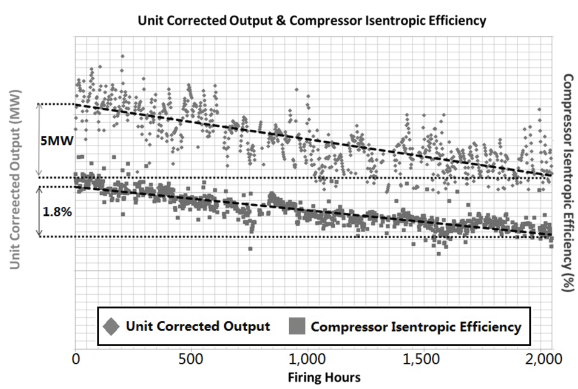
The performance degradation of Combined Cycle Gas Turbine units over time results in a loss of power output and efficiency and an increase in fuel consumption. Compressor fouling (See Figure 4 below) contributes to 70 to 85 percent of gas turbine performance losses accumulated during operation[1]. This loss can be restored by compressor water washing. Through monitoring of the unit output and compressor isentropic efficiency, a compressor offline water wash program is developed to determine the wash frequency.

Figure 4 Fouled Compressor Blade



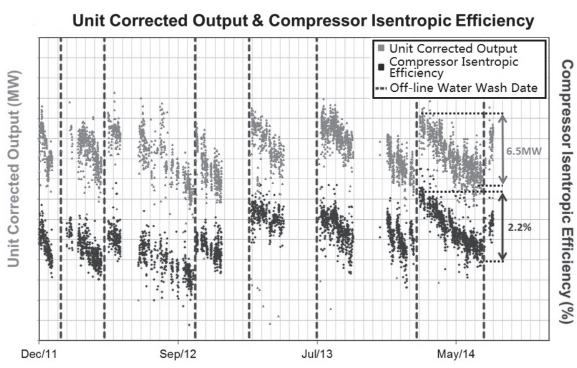
Despite pre-filtering of the air by a pre-filter and high efficiency filter prior to the compressor; foulants in the parts per million (ppm) range can still cause deposits on compressor rotating and stationary parts. This results in severe performance degradation. The efficiency of the axial flow compressor depends on the smoothness of the blade aerodynamic surfaces. Deposits on the blade surfaces cause changes in the blade shape and profile, resulting in an increase in the blade surface roughness and profile loss of the blading[2]. The observable effect of the compressor fouling is a drop in unit output, thermal efficiency and compressor isentropic efficiency over time as observed in Figure 5 below.

Figure 5 Drop in Unit Output & Compressor Efficiency Against Firing Hours



To regain the unit capacity loss due to fouling, in addition to the daily compressor on-line water wash, compressor off-line water wash is scheduled to effectively clean the compressor through soaking and rinsing cycles with chemical agents. Since the rate of compressor fouling is highly dependent on its unique site condition and characteristics, each unit has its own particular fouling rate. To optimize the frequency of off-line water wash, operating data from each unit is collected to perform cost and benefit analysis based on the cost of washing plus the loss of generation revenue when operating the unit with degraded performance and during the plant outage period. Unit specific triggering criteria, including the accumulated firing hours, drop in unit output and compressor isentropic efficiency, were developed to schedule compressor off-line water wash frequency in BPPS. In average, off-line water wash is carried out with accumulated firing hours of 1,800 to 2,200 and drop in unit output of 5MW (See Figure 6).

Figure 6 Effect of Compressor Off-line Water Wash



2.2 THERMAL EFFICIENCY

The two main functions of a condenser in a steam turbine are to condense exhaust steam from the turbine for reuse in the thermal cycle and so maximize turbine thermal efficiency by maintaining proper vacuum. A graphical representation of the turbine and condenser is indicated in Figure 7 below. When the condenser vacuum increases, the enthalpy drop of the expanding steam in the turbine increases which increases the turbine power output and efficiency.[3]

Figure 7 Typical Thermal Cycle of Steam Turbine

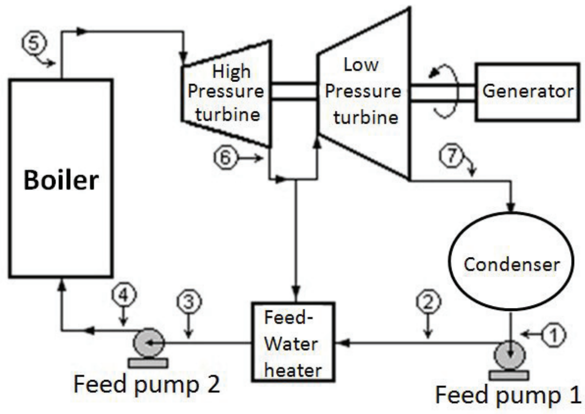
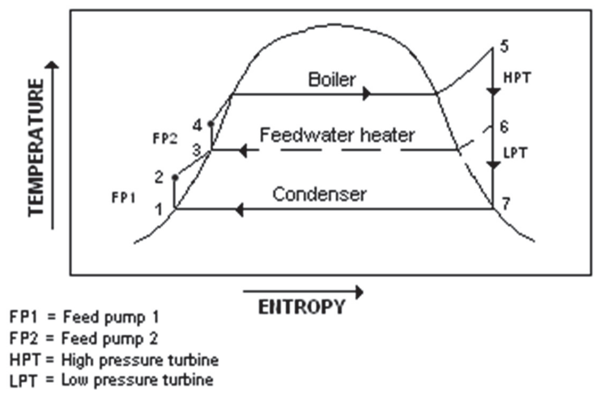


Figure 8 Rankine Cycle of Steam Turbine



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The performance of a condenser may deteriorate over time due to various reasons including insufficient cooling water flow, dirty condenser tubes or air ingress. Therefore, it is crucial in identifying the parameters which can determine the cause of the deterioration so that proactive maintenance work can be conducted in an organized manner.

At the condenser tubes where seawater is used as a coolant to condense the saturated steam, the temperature gradually rises along the sea water flow path from inlet to outlet of the condenser. The difference in temperature between steam exhaust and seawater cooling water, called the Terminal Difference, is largest at the inlet and decreases towards the outlet. Ideally, the condensate temperature is equal to the seawater outlet temperature so that the Terminal Difference is zero, when the back pressure is at a minimum condition. While a high Terminal Difference indicates poor heat exchange in condenser tubes, a low Cooling Water Differential Temperature indicates lack of cooling water flow or poor heat transfer.

Figure 9 Relationship of Condensate and Cooling Water Temperature

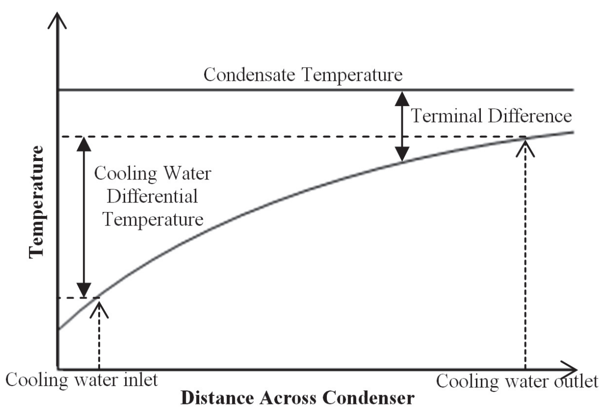
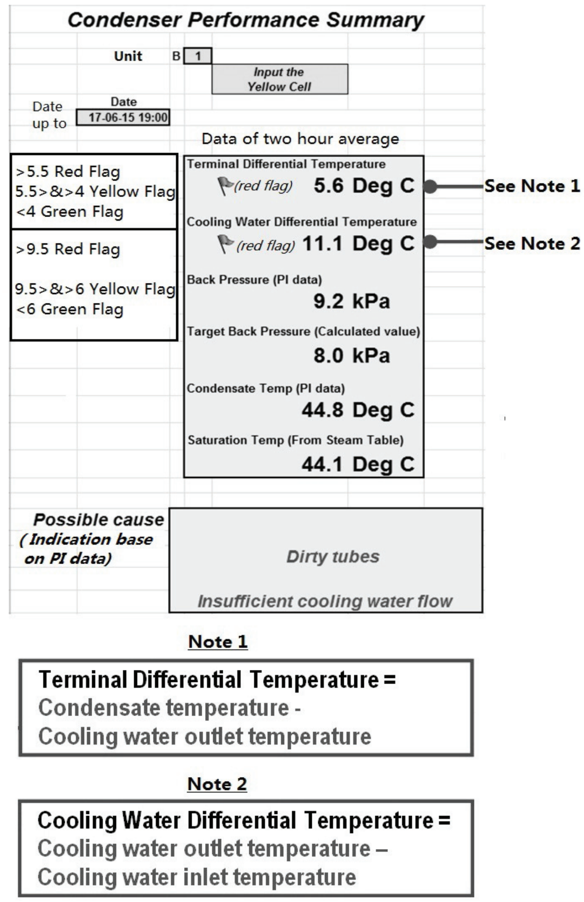
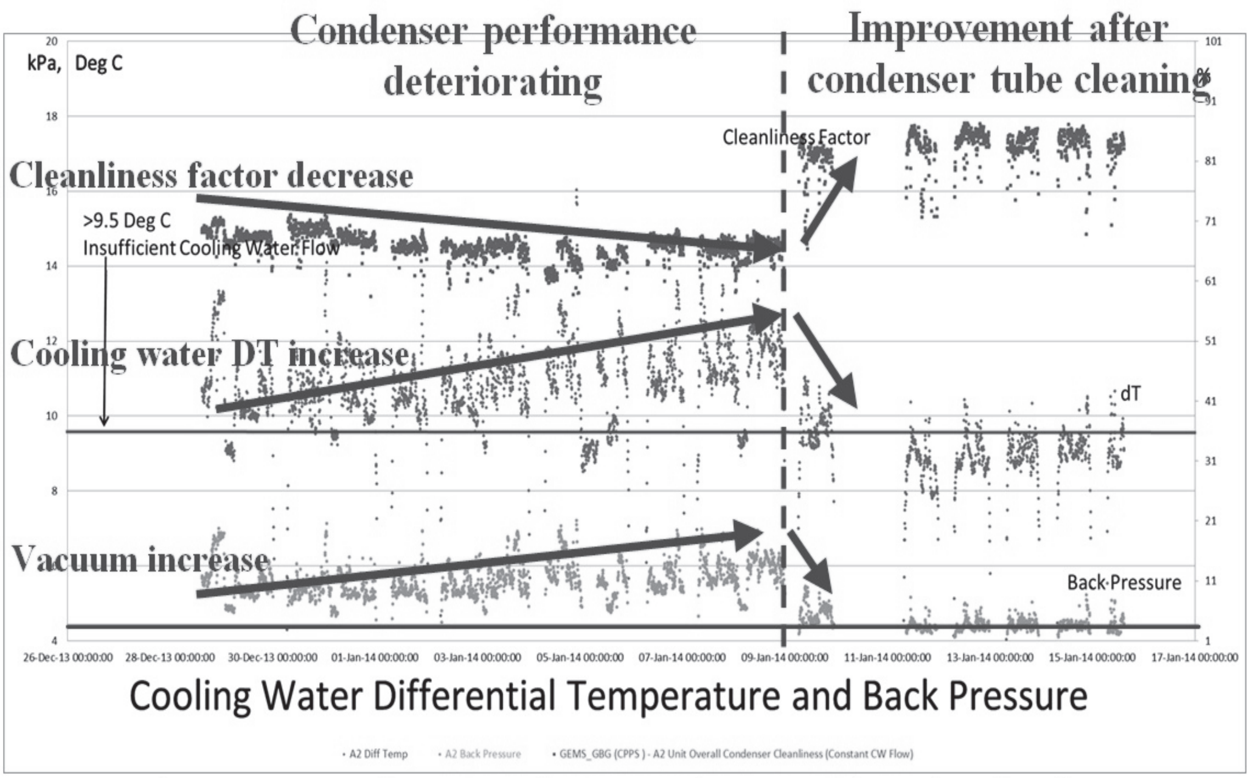


Figure 10 Condenser Performance Analysis Tool



Based on the aforementioned theory, a Cleanliness Factor was derived based on Terminal Differential Temperature, Cooling Water Differential Temperature and the back pressure with an aim to provide early warning of dirty tubes and insufficient cooling water flow in the condenser. Usually, a deteriorating condenser performance can be reflected by a decreasing trend of the factor. A typical application of the Cleanliness Factor is shown in Figure 11, in which advanced condenser cleaning works were initiated based on the decreasing trend of Cleanliness Factor. During the subsequent cleaning works, it was revealed that 60% condenser tubes were blocked and the Cleanliness Factor improved significantly after conducting the condenser tube cleaning.

Figure 11 Condenser Performance Improved by Tube Cleaning

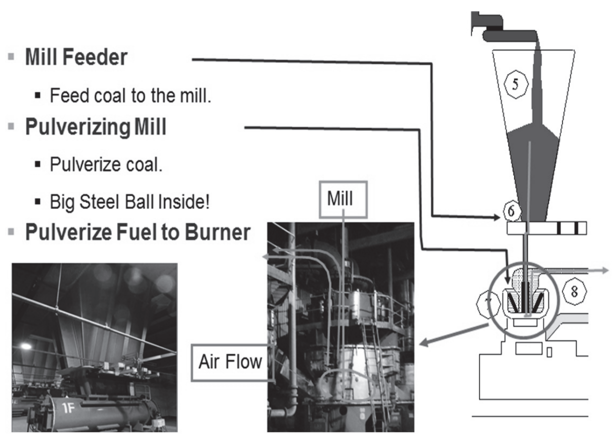


In conclusion, the Cleaning Factor provides an early warning for remedial works which in effect saves a lot of force outages for the unit.

2.3 RELIABILITY

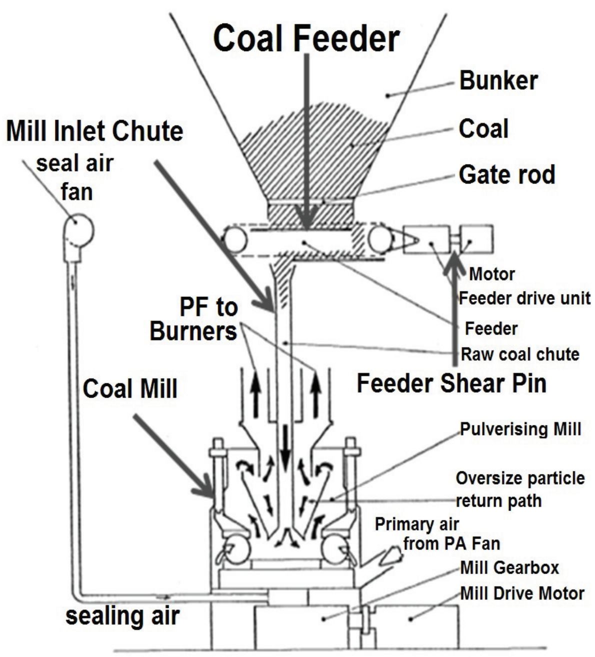
The 677MW unit in CPPS is equipped with seven pulverizing mills, each of which is driven by an electric motor via a reduction gearbox. Coal feeder is installed above each mill and is supplied by a coal bunker as shown in Figure 12. Coal is transferred to coal feeders through rod type gates which can be used for regulating the bunker flow pattern if needed. Inside the coal feeder, coal is conveyed in a controlled manner to the inlet chute of the mill, where it is pulverised into fine powder for conveying to the burners for combustion. Therefore, continuous supply of coal powder is vital for ensuring a reliable and stable output from the generator.

Figure 12 Coal Pulverizer in Castle Peak 'B' Power Station



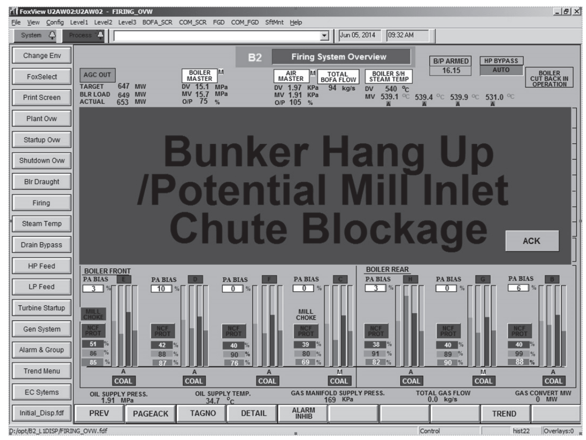
In the early 2000s, CPPS pioneered the use of sub-bituminous coal to improve emissions during electricity generation. However sub-bituminous coal is usually soft, crumbly and friable due to its high inherent moisture content, it is easy to cause mill inlet chute blockage and results in overloading of the feeder motor. As a mechanical protection, a shear pin (Figure 13) has been installed as a safeguard designed to disconnect the motor should overloading occur. Once the pin is sheared, a short mill outage, in terms of hours, is required for restoration of the feeder to service.

Figure 13 Feeder Shear Pin between Coal Feeder and Motor



Due to the inhomogeneous nature of coal, blockage of the mill is unpredictable and intermittent. Therefore, a series of experiments was conducted to capture the related equipment parameters immediately before the pin sheared for analysis. This revealed both mill and feeder motors torque usually increased just before the pin was sheared. Therefore, an alarm system, which was determined by mill and feeder motor current, was developed to alert the operator in advance. A typical example of the alarm page is shown in Figure 14.

Figure 14 Mill Inlet Chute Blockage Alarm System



Once the operator received the alarm, the feeder output is lowered to reduce the coal flow rate through the feeder to alleviate the blockage. In addition, the feeder gate rod position is adjusted to reduce the amount of coal entering the feeder. After the feeder rides through the intermittent blockage and both feeder and mill motors current return back to normal, the operator can resume normal coal flow without hampering the mill operation. After full implementation of the alarm system, the number of outages due to feeder shear pin failure reduced significantly which in effect enhances the performance of the mill system.

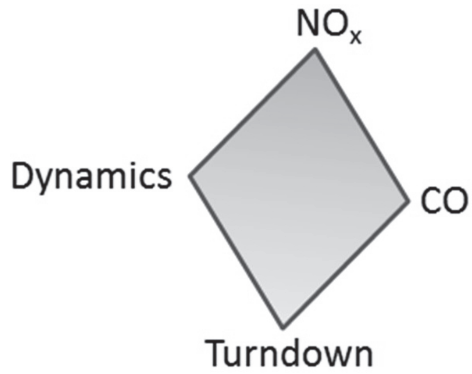
2.4 AIR EMISSION

Natural gas is a clean fossil fuel with negligible amount of SO_2 and Respiratory Suspended Particulates

(RSP) produced as combustion by-products. To achieve high unit efficiency, firing temperatures as high as 1,288 degrees Celsius is common in combined cycle gas turbines. However, such a high firing temperature leads to the formation of NO_x through high temperature oxidation of the diatomic nitrogen in combustion air. In order to achieve a high thermal efficiency with low NO_x emission, BPPS has adopted General Electric's Dry Low NO_x (DLN) 2.0 burners to achieve low NO_x emission in the 25ppm range. The DLN system regulates fuel distribution to various sets of fuel nozzles to establish diffusion, piloted premix and lean premixed flame according to the unit loading and firing temperature in a bid to achieve the lowest possible NO_x level at different operating stages.

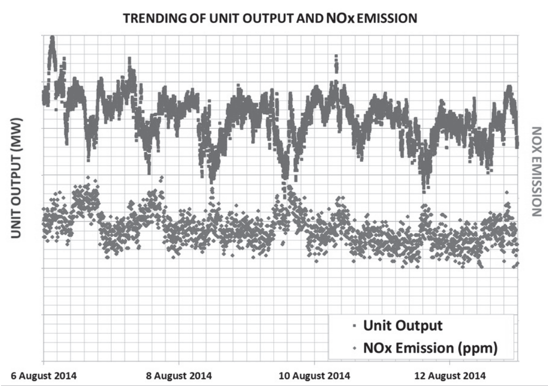
The design of a successful DLN combustor system for a heavy-duty gas turbine depends on the optimum balance between air emissions level, system operability and combustion dynamics. Hardware features and operational methods are required that simultaneously achieve low NO_x by keeping the equivalence ratio and residence time in the flame zone to be low enough, but at the same time, with acceptable levels of combustion noise (dynamics), part-load operation stability and sufficient residence time for CO burnout, hence as shown in Figure 15 the designation of DLN combustion design as a "four-sided box".[6]

Figure 15 Optimum Balance of DLN System



As per requirements in the Air Pollution Control License, the nitrogen oxides (NO_x), sulphur dioxide (SO_2), and carbon monoxide (CO) are measured continuously by Continuous Emission Monitoring System (CEMS) for all generation units in BPPS. As shown in Figure 16, the real-time NO_x emission performance of the operating units is closely monitored by the operation and performance team to ensure it meets the license requirement and the combustion system behaves within the operation envelop of Figure 15. However, if the NO_x emission is close to the license limit, operation actions such as reduction of generation output or even shutdown of the units will be taken.

Figure 16 Real-time Monitoring of NO_x Emission



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With the further tightening of emissions requirements, BPPS is planning for major upgrades of the gas turbines and replacement of the current DLN 2.0 combustion system with the advanced DLN 2.6+ system which can further drive down the NO_x emission significantly to 15ppm levels of performance.

3. CONCLUDING REMARKS

CPPS and BPPS have been in operation for 33 and 18 years respectively. To continuously improve plant performance, a systematic approach has been developed and implemented in the power station to further drive the plant performance towards excellence in terms of generation capacity, thermal efficiency, reliability and air emissions. From the results, this approach is effective and the improvements are notable. The success factor of the effective implementation of the integrated approach is the commitment and contribution from staff at all levels to undertake the continuous improvement cycle of awareness, identification, evaluation and implementation in their works. This has successfully nurtured a culture that takes an appropriate balance of cost, performance and risk in a sustainable manner, and continuously works towards our vision of becoming the benchmark of power generation in Asia from one generation to the next. [7]

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Paper No. 1

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Paper No. 2

A ROBUST REGULATORY PLATFORM TO DELIVER QUALITY & INNOVATION

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General Manager (Corporate Development)
Ir W.K. Leung
Manager (Regulation & Policy)
The Hongkong Electric Co., Ltd.

Paper
No. 2. 2

A ROBUST REGULATORY PLATFORM TO DELIVER QUALITY & INNOVATION

Ir T.C. Yee
General Manager (Corporate Development)
Ir W.K. Leung
Manager (Regulation & Policy)
The Hongkong Electric Co., Ltd.

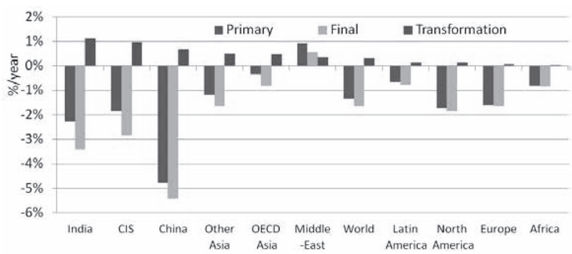
ABSTRACTBTRACT

With climate change as an increasingly significant issue on the global agenda, the promotion of energy efficiency has been well recognized as a key policy approach to tackle the challenge. Following the setting of a new target of reducing Hong Kong's energy intensity by 40% by 2025 from the Government of the Hong Kong Special Administrative Region, the local power sector can further contribute on promoting energy efficiency under the prevailing effective regulatory regime – Scheme of Control Agreements. The current framework effectively balances the interests of customers and power companies by ensuring a reliable, secure and environmentally friendly electricity supply at reasonable tariffs while providing power companies with reasonable investment certainties. This paper draws lessons from overseas jurisdictions, from regulatory and policy perspectives, in promulgating energy efficiency and explore the ways forward for Hong Kong.

1.. INTRODUCTION

With climate change as an increasingly significant issue on the global agenda, it is a consensus at the global level to reduce energy use for suppressing the emissions of greenhouse gases. With global efforts over the years, the primary energy intensity has been decreasing in almost all regions in the world over the past two decades. It was reduced at 1.3% per year on average at the global level between 1990 and 2011. The final energy intensity at the world level has also been going down even more rapidly than that of the primary energy intensity, at 1.6% per year across the same period as shown in Figure 1 [WEC, 2013]. It is envisaged that the promotion of energy efficiency will continue to be the key element in energy policies for further reducing energy consumption.

Figure 1 Variation of Primary and Final Energy Intensity by Region



For Hong Kong, energy efficiency has been factored as a core element in the energy policy objectives set by the HKSAR Government (the Government). In May 2015, the Government unveiled Hong Kong's first ever energy saving blueprint, the Energy Saving Plan for

Hong Kong's Built Environment 2015~2025+, which sets a new and aggressive target of reducing Hong Kong's energy intensity by 40% by 2025 [HK, 2015].

As one of the two power companies in Hong Kong, The Hongkong Electric Co., Ltd. (HK Electric) has been embracing low-carbon technologies and taking initiatives on promoting energy efficiency under the current Scheme-of-Control Agreement (SCA) entered with the Government. The SCA has proven itself a simple, robust, certain and cost-effective regulatory regime for the Government to achieve its energy policy objectives while enabling the power companies to innovate, improve and deliver quality services to customers. As witnessed in the evolution of the SCA over the past half century, innovative features focusing on promoting energy efficiency such as education fund, energy audit and saving incentive schemes, energy efficiency matching fund, were introduced in the latest renewal and mid-term review of the SCA in order to address increasing calls for combating the climate change.

With reference to overseas jurisdictions, this paper reviews Hong Kong's situation and explores the ways forward for Hong Kong in promulgating energy efficiency from regulatory and policy perspectives.

2. GLOBAL REVIEW OF ENERGY EFFICIENCY TARGETS

Leading countries / regions are commonly adopting quantitative energy efficiency targets in forms of energy-efficiency laws or energy laws with a strong component related to energy efficiency for guiding their energy policy formulation (Table 1).

Table 1 Energy Efficiency Targets in Some Leading Countries / Regions

Country / Region	Key Action
China	• 16% reduction in energy intensity by 2015 (the 12th Five-Year Plan) against 2010 level [China, 2012]
EU	• No federal energy efficiency target but state-level "Energy Efficiency Resource Standards" (EERS) • The strongest EERS requirements exist in Massachusetts, Rhode Island, and Vermont, which require almost 2.5% savings annually [ACEEE, 2015]
US	• 20% reduction in energy consumption by 2020 against 2007 BAU projection • The target is further tightened to at least 27% by 2030 [EU, 2015]
UK	• 18% reduction in final energy consumption by 2020 relative to 2007 BAU projection [UK, 2014]
Singapore	• 35% reduction in energy intensity by 2030 against 2005 level [Singapore, 2014]
Australia	• No national energy efficiency target but only National Strategy on Energy Efficiency is established [COAG, 2010]
Hong Kong	• 40% reduction in energy intensity by 2025 against 2005 level [HK, 2015]

3. COMMON POLICY MEASURES ON ENERGY EFFICIENCY

The following table reviews and summarizes some key common policy measures on energy efficiency.

Table 2 Approaches for Implementing Energy Efficiency Measures

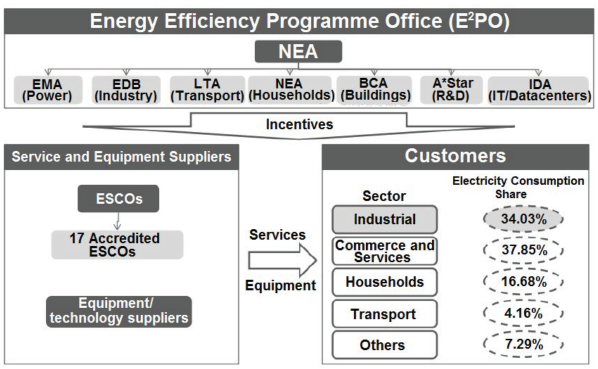
Measure	Approach
Pricing Signal	• Need to provide incentive signals to consumers for behaviour change or to encourage them to acquire energy efficient equipment and technologies, for example: ➢ Re-design energy tariff structure to inclining block ➢ Impose new taxes labelled environmental, energy or carbon tax
Communication & Education	• Enhance public understanding on energy efficiency policies and encourage behaviour changes via public awareness and information campaigns • Convey information on energy efficiency to public via different activities and tools including education & training programmes targeting for younger generations and smart metering for energy usage monitoring by customers • Campaigns to be led by government / NGOs but energy companies energy companies can also be invited to participate
Regulatory Enhancement	• Impose minimum efficiency standards and practices (e.g. energy efficiency labelling schemes and energy audit & reporting) to speed up diffusion of energy-efficient equipment, investment and practices in the community • Set obligations for energy utilities, if necessary, to make energy savings with their customers (e.g. the Energy Company Obligation in the UK) • Set up procedures / mechanisms for ensuring regulatory compliance
Economic Incentives	• Aim to encourage investment in energy efficient equipment and processes by either financial incentives (e.g. direct subsidies or loans) or fiscal incentives (e.g. tax credit/reduction or accelerated depreciation on deploying energy efficient equipment) • Assess carefully possible drawbacks caused by the incentive approach, for example: ➢ Cost of equipment/services will be increased (especially under subsidy schemes) as a result of product/service providers raising their prices in anticipation of the rebates/subsidies ➢ Resources may be diverted to non-target audiences, or “free riders”, who would carry out the investments even without incentives (e.g. high-income households)

4. BRIEF REVIEW ON ENERGY EFFICIENCY POLICIES IN SINGAPORE, THE US AND THE UK FROM THE PERSPECTIVES OF ENERGY SECTOR

4.1 SINGAPORE - GOVERNMENT-LED TOP-DOWN APPROACH

A whole-of-government approach has been adopted in Singapore to implement measures for improving energy efficiency and reducing energy use across various sectors. To this end, the Energy Efficiency Programme Office (E^{2}PO), a multi-agency committee led by the National Environment Agency (NEA) and the Energy Market Authority (EMA) of Singapore has been established (Figure 2) [NEA, 2015 & SGC, 2014]. Through the E^{2}PO, energy efficiency in the industry, households and public sectors is actively promoted through legislation, incentives and providing information.

Figure 2 Structure Illustration of the E^{2}PO in Singapore



Both the industry and power sectors in Singapore are incentivized to adopt energy efficient technologies and measures through tax incentive scheme like one-year accelerated depreciation allowance for capital expenditure on qualified energy efficient equipment and technologies [NUS, 2013]. Both the sectors are also encouraged to improve their work process / generation efficiency by utilizing matching funding up to 50% of equipment costs under the S$10 million Energy Efficiency Improvement Assistance Scheme [EASe, 2015].

4.2 US - REVENUE DECOUPLING BUSINESS MODEL FOR ENERGY UTILITIES

So far, there is no federal energy efficiency standard established in the US but only state-based “Energy Efficiency Resource Standards” (EERSs) that specify long-term targets on energy savings under customer energy efficiency programmes conducted in each individual participating state. In 2014, twenty-four states have established their own EERSs [ACEEE, 2015].

Traditionally, utilities’ revenue generation in the US is tied directly to retail sales. This creates a perverse direct financial disincentive for utilities to support energy efficiency [SEIA, 2015]. To remove this disincentive, some states implemented “decoupling mechanism” by eliminating the link between electricity sales and profits. Under decoupling, instead of linking utility profits to the amount of power sold, profits are linked to the number of customer served. In other words, it is a simple system of periodic “true-ups” exercise in correcting for disparity between the revenue requirements approved by utility regulators and the fluctuations in electricity sales due to energy efficiency. Decoupling was implemented for energy utilities over 25 states in 2014 as shown in Figure 3 [NRDC, 2014].

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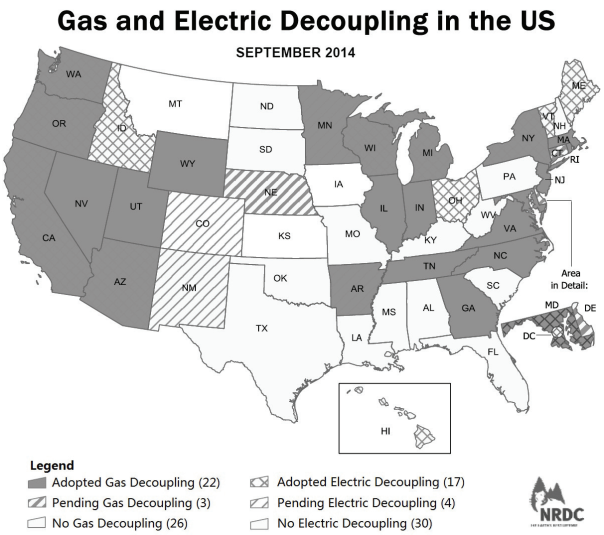
Figure 3 Revenue Decoupling in the US Energy Utilities



4.3 UK – GREEN DEAL & ENERGY COMPANY OBLIGATION

The UK government is committed to realizing the energy efficiency opportunity in the country under its "Energy Efficiency Strategy" released in 2012. Over the years, the UK government has been delivering a rolling programme of action to address the barriers and harvest the potential benefits generated from energy efficiency. Against this backdrop, two key policies, the Green Deal and the Energy Company Obligation (ECO), were introduced in 2013 that focus on the UK energy sector.

The Green Deal is a framework to enable private firms to offer consumers energy efficiency improvements to their homes, community spaces and businesses at no upfront cost, and recoup payments through a charge in instalments on the energy bills (Green Deal charge). A Green Deal provider is required in the scheme to offer Green Deal plan to customers, which enables them to finance work recommended by an accredited adviser and undertaken by an accredited installer [DECC, 2010]. The UK government hoped that the Green Deal could open up a huge and growing market for market players including retailers and energy companies. In fact, three of the biggest six energy companies joined as accredited Green Deal Providers during the initial launch of the scheme. However, the Green Deal was finally terminated in July 2015 due to its poor response rate. From January 2013 to June 2015, out of the 575,936 Green Deal assessments, only 15,596 (~2.7%) Green Deal plans were signed up [Statistics, 2015]. The market imputes the failure of the scheme to high interest rate set on the Green Deal charge, and increased property resale difficulty with financial obligation attached [Sarah Lonsdale, 2014].

Under the ECO, the larger energy companies are set obligations to install insulation and heating measures for their customers to reduce their energy usage and heating costs. The ECO is designed originally to work alongside the Green Deal. The UK energy market regulator, Ofgem, is responsible for monitoring energy suppliers and enforcing compliance under the obligation. Up to end May 2015, over 1.48 million energy efficient measures were installed under the ECO [Statistics, 2015].

5. ENERGY SAVING PLAN FOR HONG KONG

The Government unveiled in May 2015 Hong Kong's first ever energy saving blueprint, the Energy Saving Plan for the Built Environment 2015-2025+ (the

Plan), which sets a new target of reducing Hong Kong's energy intensity by 40% by 2025. The Government will focus on the following key action fields for achieving the new target (Table 3) [HK, 2015]:

Table 3 Summary of Key Actions in Energy Saving Plan for the Built Environment 2015-2025+

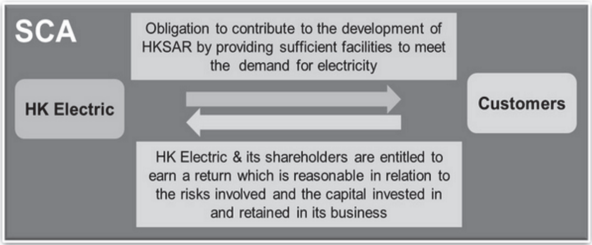
Field	Key Action
Economics	Drive energy-efficiency economy via government-led energy saving/ green initiatives and financial supporting schemes
Regulatory	Periodic review, expand and/or tighten relevant energy-related regulations and standards
Education	Update & strengthen education programmes for schools and public sector
Social	Collaborate stakeholders to develop specific energy efficiency-related campaigns

The two local power utilities are fully recognized by the Government as the key stakeholder partners for Hong Kong in promoting energy saving.

6. EFFECTIVE REGULATORY FRAMEWORK FOR LOCAL POWER SECTOR

Electricity supply in Hong Kong has all along been provided by the two investor-owned and vertically integrated power companies. They are regulated under the SCAs that are bilateral agreements setting out the obligations and rights of the power companies, and providing a framework for the Government to monitor power companies' performances (Figure 4). Under the SCAs, power companies are entitled to receive a permitted return based on their electricity-related fixed assets as recognition of their supply obligations over the regulatory period.

Figure 4 Illustration of the SCA



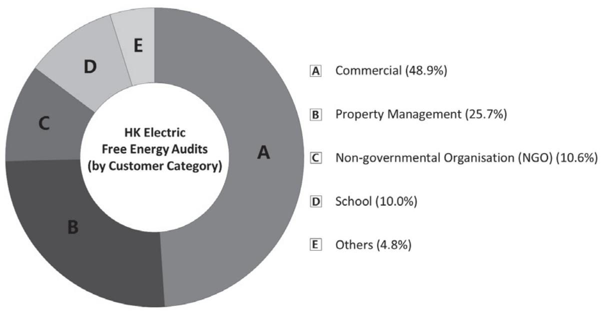
Since its inception in 1964, the SCAs have taken on refinements during renewals and mid-term reviews in a gradual and prudent manner in response to the changing operating environment and rising customer expectations. For example, performance incentive mechanisms on customer services and energy efficiency have been incorporated in the SCAs since 2008 renewal and they are further enhanced during the Mid-term Review in 2013. The SCA framework is regarded as a light-handed regulatory approach that provides flexibility for the Government to implement energy policies and allow power companies innovation to design and promote energy efficiency initiatives that best suit their customer needs.

7. ENERGY EFFICIENCY INITIATIVES UNDER THE SCA

7.1 FREE ENERGY AUDIT AND INTEREST-SUBSIDIZED LOAD

Under the SCA, HK Electric is incentivised to provide at least 50 free-of-charge energy audits each year for its non-domestic customers to help them identify energy saving potential at business premises. From 2009 to 2014, over 300 energy audits were conducted covering diverse customer segments (Figure 5), in particular those not familiar with energy efficient technologies such as small & medium enterprises (SMEs), non-government organizations (NGOs) and schools.

Figure 5 Customer Segments of HK Electric's Energy Audit Services



HK Electric also collaborates with banks to provide the audited customers interest-subsidised loans to implement the energy saving initiatives identified in energy audits. It is estimated over 30 million units of electricity could be saved annually if all audited customers fully implement the energy saving opportunities identified in energy audits.

7.2 ENERGY EEFFICIENCY EDUCATION FUNDN

Since the commencement of the existing SCA in 2009, HK Electric has established an Energy Efficiency Education Fund with an annual budget of HK$2.5 million to promote energy efficiency to its customers. Green messages have been spread to students and the general public over the years via a wide spectrum of activities like the annual Smart Power Campaign.

7.3 SMART POWER FUND

In June 2014, Hong Kong Electric launched the Smart Power Fund, which provides subsidy, on a 50/50 matching basis, to the owners of residential buildings to improve the energy efficiency of buildings services installations at communal areas. Priority is given to single tower residential blocks and aged buildings without ancillary facilities. Funding is provided by the energy efficiency incentive earned under the SCA mechanism on a yearly basis until 2018. Up to July 2015, the Fund approved 12 projects with a total provisional subsidy of over HK$2.3 million.

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8. HK ELECTRIC'S SELF-INITIATED ENERGY EFFICIENCY MEASURES

8.1 PIONEER IN ENHANCING TARIFF STRUCTURE

Since its introduction in 1994, progressive tariff structure has been adopted by HK Electric for its domestic customers to encourage energy efficiency and to help protect the environment. Upon successful implementation in the domestic sector, this was extended to non-domestic ordinary customers in 2002. The tariff structure has been continuously enhanced in recent annual Tariff Reviews to further encourage energy conservation.

On top of this, HK Electric further introduced a "Super Saver Discount" for its domestic customers in 2013. Under the scheme, domestic customers consuming no more than 100 units of electricity in any month are given a 5% discount on their electricity bills. This not only encourages energy conservation, but also helps ease the tariff burden on those in need.

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8.2 FULL RANGE OF ENERGY MANAGEMENT AND ADVISORY SERVICES

HK Electric has launched over the years various energy management and advisory services to foster energy efficiency and conservation in different customer segments. Some of those services are outlined in Table 4.

Table 4 Summary of HK Electric's Self-initiated Energy Efficiency Measures

INITIATIVE	OUTLINE
Energy Management Services for SMEs	To provide SMEs with tariff advisory services, energy audit and load profile services on request
Customer Care Programme	To pay the corporate customers regular "ambassador visits" under our Customer Care Programme and to provide them with "one-stop" service on technical and account matters
Smart Power Centre	To provide advice on the choice of electrical equipment or appliances and general knowledge on the safe and smart use of electricity
Promotion of Energy-efficient Electrical Appliances	To provide a wide range of market information to the commercial and domestic customers for promoting the use of energy-efficient electric equipment (including electric kitchen)
Publication of "Smart Use of Electricity" Booklet	To provide customers with updated information about the smart use of electricity focusing on energy efficiency and electrical safety
On-line Energy Survey Tool	To provide online tools allowing customers to obtain smart tips on energy efficiency and to carry out virtual energy survey for home or office
Low-carbon App	To provide information on energy efficiency and safety, help customers to estimate their electricity consumption, and learn more about carbon footprint, and to recommend saving plans and energy efficiency tips for customers
Enhanced Billing Information	To enable domestic customers to track their electricity consumption for up to 25 months and understand their electricity usage and carbon footprint
Account-On-Line Services	To promote paperless billing while showing more details including the month-to-month temperature to help customers better understand their electricity consumption behaviour
Smart Metering	Pilot scheme has been launched to test the application of smart meter technologies in Hong Kong while the roadmap for the territory-wide deployment will be further reviewed after the result of the pilot scheme is thoroughly assessed

9. CONCLUSION AND WAY FORWARDS

For combating climate change and pursuing low-carbon sustainability, fostering of energy efficiency and conservation has been prioritized in energy policies of overseas jurisdictions. In Hong Kong, following the public's increasing awareness in energy efficiency and with the well-established regulatory regime for power sector in place, Hong Kong community is enabled to harness potentials of low-carbon economy.

The current SCA framework is well-proven as a cost-effective and light-handed regulatory tool that provides flexibility for the Government and the power companies to design and implement energy efficiency policies initiatives innovatively. Building on this cornerstone, the relevant incentive mechanisms under the SCA framework can be further enhanced for driving Hong Kong into a more energy-efficient metropolis.

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Paper No. 3

ECO-FRIENDLY ON LINE ELECTRIC VEHICLES USING SHAPED MAGNETIC FIELD IN RESONANCE (SMFIR) TECHNOLOGY

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Department of Mechanical Engineering
Massachusetts Institute of Technology, USA

ECO-FRIENDLY ON LINE ELECTRIC VEHICLES USING SHAPED MAGNETIC FIELD IN RESONANCE (SMFIR) TECHNOLOGY

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ABSTRACT

KAIST has developed the Shaped Magnetic Field in Resonance (SMFIR) technology that transfers a large amount of energy to electric vehicles when they are running or stationary. The wireless charging SMFIR technology provides a solution to the commercialization barriers of electric vehicles such as the problems of batteries and charging infrastructure.

Using 20-kHz wireless power transfer system based on the SMFIR technology, our eco-friendly On Line Electric Vehicle (OLEV) bus was wirelessly powered by 100 kW through a power grid embedded under the road. On the other hand, using high-capacity, high-efficiency and low-cost 60kHz power supply and pickup systems based on the SMFIR technology, tram and high speed train were wirelessly powered by 180 kW and 1 MW through a power grid built in rail roads, respectively.

The commercial OLEV tram has been operated commercially from July 2011 in Seoul National Grand Park. Also, the OLEV shuttle bus has been operated for convenience of students and faculty members at KAIST campus since Oct. 2012. In addition, the world's first intra-city OLEV bus with 100 KW pickup capacity has been operated commercially at Gumi city from March 2014. Then, airgap is about 20 cm and maximum power transfer efficiency is 85 %.

1. INTRODUCTION [1]

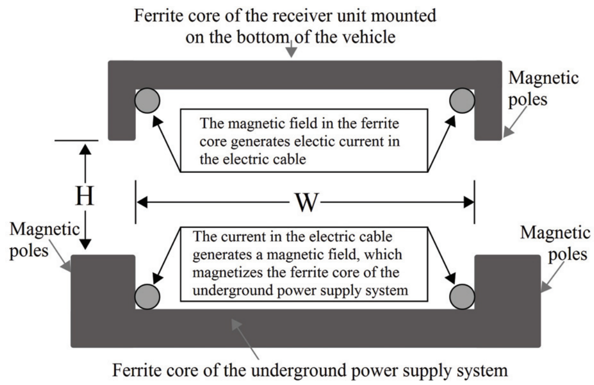
Although continuing effort will be made to improve lithium and other batteries, they are heavy, bulky, expensive, and even hazardous. Furthermore, the planet may not have enough lithium. It is estimated that only about ten billion kilograms of extractable lithium reserves exist in the world. If all of this were used to make lithium batteries, we could make about four billion Electrical Vehicles (EVs). But there are already more than one billion cars on the road today and it's not hard to imagine what would happen to the price of lithium in the meantime. Even now, governments subsidize EVs to deal with the pollution problem, since EVs with lithium batteries are too expensive for most consumers to afford.

The OLEV avoids these problems of conventional EVs by receiving its electric power wirelessly via roads equipped with an underground power supply system. To provide autonomous mobility on roads without the underground power supply, OLEV carries a small battery on board. The externally supplied electric power both propels the OLEV and recharges the battery.

The OLEV system is designed so that the electric charge in the battery returns to its original charge state when the vehicle makes a complete round trip. This charging occurs automatically when it is moving on roads with the underground power supply system, without any input from the vehicle's operator. The battery size for an OLEV bus is 30% to 50% of the size needed for an all-battery-powered EV bus. The length of the underground power supply system is optimized to minimize the overall cost of the OLEV system, which includes the cost of installing the underground power supply system, the cost of the battery, and the cost of the vehicles themselves while maximizing the speed of the vehicle and the range of autonomous driving on the roads lacking the underground power supply. According to the data obtained in Gumi city in KOREA and other estimates, the cost of operating an OLEV bus for ten years is less than 50% of the cost of running a Compressed Natural Gas (CNG) bus, including the cost of underground power supply, vehicle, and energy, as well as depreciation and carbon tax.

Figure 1 shows the schematic arrangement of the SMFIR design that is given by the design matrix. To have the strongest field extend from the underground magnetic pole to the pole of the pickup unit under the vehicle, width of ferrite core structure W must be much larger than air gap H. Having the electric current flow perpendicularly to the ferrite cores (parallel to the direction of motion of the vehicle) satisfies to deliver the electric power to the vehicle while it is in motion.

Figure 1 Schematic Design of SMFIR



To create an alternating magnetic field above the ground, the ratio of ferrite core width over air gap, W/H must be much larger than 1, i.e. W/H >> 1. The shielding of EMF, can be satisfied by either reactive or passive shielding. Passive shielding would consist of placing a barrier in the ground and grounding the Electromagnetic Force (EMF) picked up around the receiving unit; reactive shielding would consist of generating a signal that is opposite to the EMF emanating from the receiver unit.

SMFIR is unique in its transmission of electric power to moving vehicles. This feature is achieved by creating a two-dimensional magnetic field that is not a function of the direction of vehicle motion, i.e. the magnetic field created is a two-dimensional planar field perpendicular to the vehicle's direction. Therefore, the pickup unit mounted on the vehicle sees the same magnetic field while the vehicle is moving, independent of the vehicle's position along the direction of motion, and the vehicle's motion does not affect power transfer and its efficiency. This is why OLEV can receive electric power while in motion.

The power transfer efficiency of SMFIR decreases when the magnetic poles of the receiver unit mounted on the bottom of the vehicle are not aligned with the poles of the underground power supply system. However, because these poles are far apart (~ 25 cm), the transmission efficiency is not too sensitive to slight misalignment.

Many wireless power transfer system systems use circular coils for the transmitter and the receiver, but this requires that the centers of two coils should be well aligned and the coils are close together for maximum power transfer. Such a model can be used only when a vehicle is stationary. This is a major shortcoming of many other systems in use today.

2. MODELLING AND ANALYSIS OF WIRELESS POWER TRANSFER SYSTEM BASED ON SMFIR

Since the pickup unit must be designed using a coil and ferrite core, it can be characterized as an RLC circuit built inside a ferrite core. We can choose capacitance, inductance, a convective air channel, and a shaped ferrite core.

The purpose of the optimal design is to maximize the power collection. If we denote the power collected as P_C, and the power collecting voltage as V_C, P_C is proportional to the square of V_C. That is, $P_c \propto V_c^2$.

The power collecting voltage may be expressed as

$$V_c = F\,(f_r, I_s, N_1, N_2, H, W, S_c, C_c)$$

where f_r = resonant frequency, I_S = feed current, N_1 = number of winding coils of the primary side (the power cable module), N_2 = number of the winding coils of the secondary side (the power pickup module), H = distance between the power cable module and the power pickup module, W = width of a power transfer system, S_C = power transfer core structure, and C_C = material characteristic of a power transfer core, e.g. permeability and a frequency characteristic. V_C may be expressed by

$$V_c \propto \frac{f_r I_s N_2 W}{N_1 H} \qquad (1)$$

Another object of the optimal design corresponds to maximizing a current collecting efficiency. The efficiency E may be expressed as

$$E = \frac{Output\ Power\ of\ Regulator}{Input\ Power\ of\ Inverter}$$
$$\frac{P_c}{P_s} = \frac{\frac{V_c^2}{R_c}}{I_s^2 R_s} = \frac{V_c^2}{R_c I_s^2 R_s} \qquad (2)$$

where R_C is the current collecting resistance, and R_S is the current supply line resistance .

In designing the current supply device, the distance, H, may be expressed by

$$H = F\left(f_r, I_s, \frac{N_2}{N_1}, W, S_c, C_c\right) \propto f_r I_s \frac{N_2}{N_1} W \qquad (3)$$

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For example, maintaining H to be greater than or equal to 12 cm may be necessary for a case of a sedan, and 20 cm for a case of a large-sized vehicle such as a bus. Then, given the value of H, W can be determined, fixing the value of all other variables.

The magnitude of EMF should be less than a predetermined value. In particular, the magnitude of the EMF generated L_{emf} is represented as

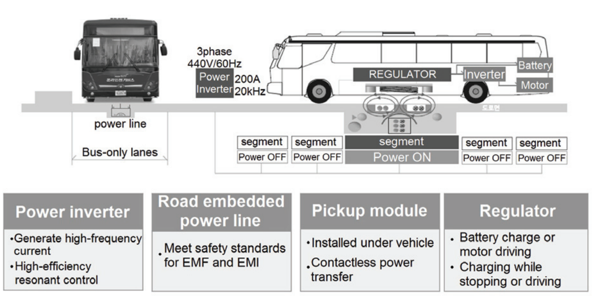
$$L_{emf} = F\left(f_r, I_s, \frac{N_2}{N_1}, W, S_c, C_c, H\right) \propto f_r I_s \frac{N_2}{N_1} W\ H \quad (4)$$

For the OLEV, the maximum allowable Lemf < 62.5 mG must be satisfied at a predetermined point in Korea.

3. DESIGN AND DEVELOPMENT OF ELECTRIC BUS SYSTEM BASED ON SMFIR [2,3,4]

We can solve the battery and charging problems of the bus application by developing the OLEV system, which enables wireless electric power transmission while the vehicle is stationary or in motion. The overall system is depicted in Figure 2.

Figure 2 Overall Diagram of OLEV System



The OLEV system consists of four subsystems: a power inverter, a road-embedded power line, a pick-up module, and a regulator. The power inverter provides power to the power line module as a current source, and power lines carry generated current and generate magnetic flux. The pick-up modules generate power from induced voltage and current, and the regulators convert gained AC power to DC and control the output voltage that is input to batteries and motors.

The maximum and rated power of an electric bus motor is 240 kW and 100 kW, which is very high compared to a small electric car. And the road-to-pick-up gap, i.e., the distance between the road and the bottom side of the pick-up module, should be greater than 200 mm to prevent collisions with obstacles on the road.

Figure 3 Overall Block Diagram and Power Circuits of Proposed OLEV System for Electric Bus

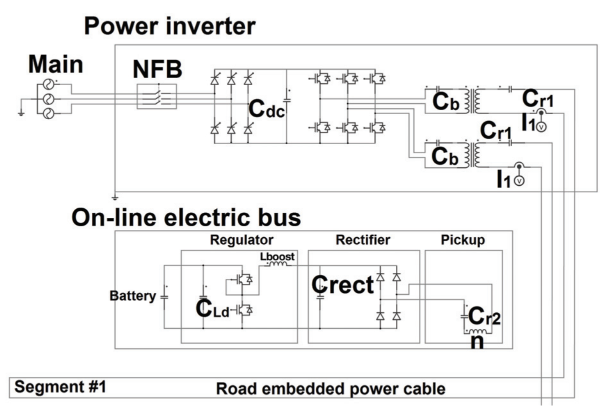


Figure 3 shows the overall block diagram and power circuits of the proposed system. As illustrated, in the internal circuit of the power inverter, three-phase AC voltage is rectified and controlled as a variable DC-link voltage by a phase-controlled rectifier. This DC-link voltage is converted as an isolated single-phase voltage source by a single-phase inverter and high-frequency

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transformer, where a DC blocking capacitor Cb protects the saturation of the transformer. The turn-ratio for this transformer was 1:1.

As shown in Figure 3, in the secondary part of the transformer, equivalent inductance Lr1 is measured by power cable and core in the embedded road rail, the value of which varies with the length of the rail and is about 20uH in case of a 5-meter rail. The embedded rail shown in Figure 3 is divided into two segments (or tracks), #1 and #2. Because the road-embedded rail has two segments and the power inverter can supply current to each segment, the common cable is necessary on the bottom side of the rail. In this case, each segment of road consists of 1-turn of high-frequency power cable with internal litz wires and W type ferrite core.

Figure 4 Measured Results of Output Power, Power Loss, and Power Transfer Efficiency as Functions of Pick-up Current

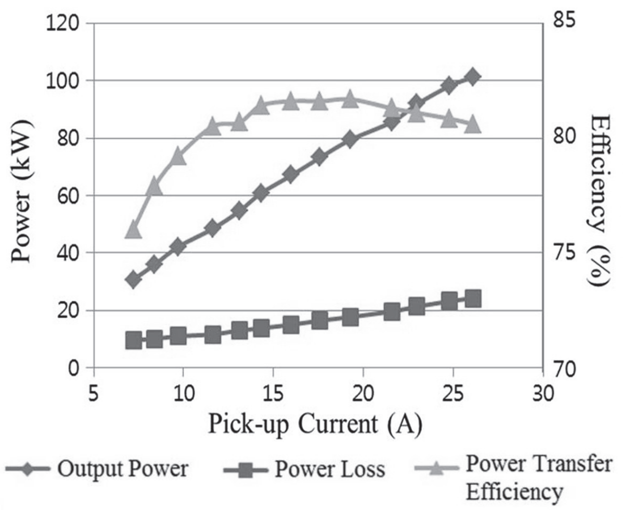

Figure 4 shows the results of measurement for the prototype pick-up device. Measured parameters were output power, power loss, and power transfer efficiency. From this result, we can see that power loss and output power are proportional to pick-up current.

4. DESIGN AND DEVELOPMENT OF TRAIN SYSTEM BASED ON SMFIR [5]

Electric trains and trams typically receive power from roof-mounted pantographs. Due to friction, however, the pantograph has become a major obstacle to improving train speed. Pantographs and overhead wires are also costly to construct and maintain. With a wireless power transfer system, the pantograph can be eliminated.

The basic concept of proposed on line electric tram system is depicted in Figure 5. An inverter generates 60 kHz high-frequency current and transfers it to the power line. The power line is installed between the rails, so additional space is not needed.

The major difference between the bus system and the train system is that the train system uses a 60 kHz resonance frequency. The rated power of the motor we developed for an electric tram is 180 kW, and the distance between the road and the bottom side of the pick-up module was 50 mm, which is a distance that fluctuates slightly depending on the speed of the tram.

Figure 5 Overview of Proposed On-Line Electric Tram System

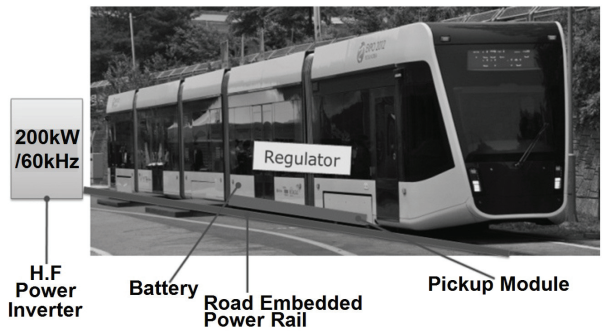

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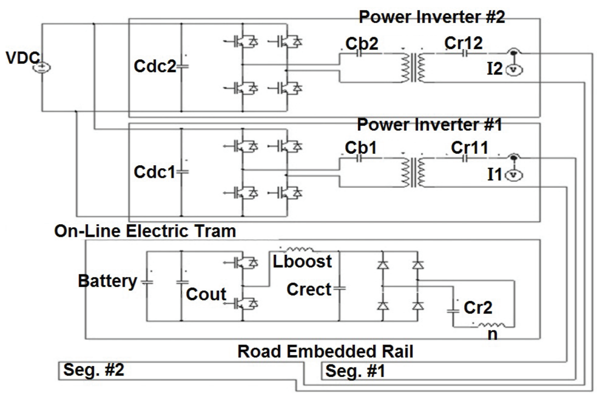
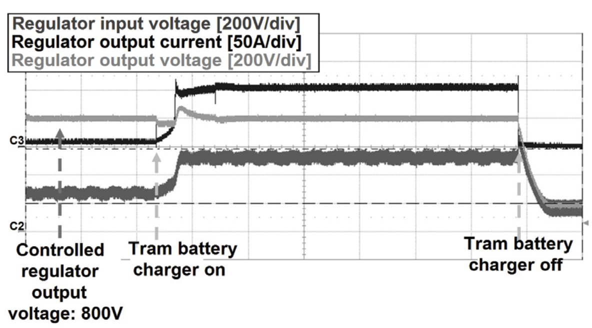
Figure 6 shows the overall block diagram and power circuits for the proposed system. In this case, we used a 60 kHz switching frequency to obtain higher output power compared to the OLEV bus. Total power transfer efficiency was also increased from 85% to 90%.

Figure 6 Overall Block Diagram and Power Circuits of Proposed System for Electric Tram



From the waveform in Figure 7, we can see that the rated output voltage of the regulator for the tram is 800Vdc. The total power efficiency for the wireless charging system of the tram is 85% to 90% depending on the input power.

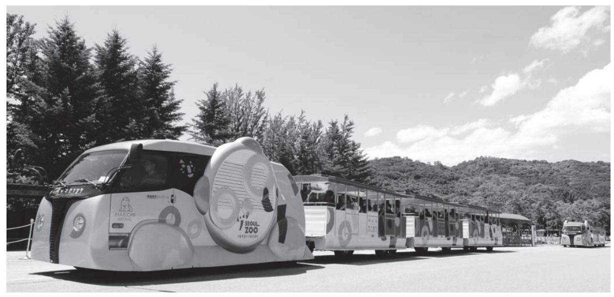
Figure 7 Input and Output Experimental Waveform Measured in Regulator



5. COMMERCIAL OPERATION

To promote the commercialization of this wireless power transfer system based on SMFIR technology, we conducted three demonstration projects. The first project was the commercial operation of an OLEV tram at Seoul Grand Park in 2011 as shown in Figure 8. The power line was installed on 372.5 m (16%) of the tram's 2.2 km route. This project demonstrated the feasibility of commercializing the OLEV system. Six OLEV trams have been operating continuously without problems since 2011.

Figure 8: OLEV Tram at Seoul Grand Park



The second project was a circulator shuttle bus operated on the KAIST campus in 2012 as shown in Figure 9. The power line is installed on 60 m (1.6%) of the total 3,760 m route. Two OLEV buses have been operating every 15 minutes without problems since 2012.

Figure 9: OLEV Circulator Shuttle on KAIST Campus

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The third project was an OLEV bus operated commercially as an intracity bus on general roads in the Gumi city of South Korea as shown in Figure 10. The power line was installed on 144m (0.6%) of the total 24km route. This was the first commercial deployment of a wirelessly powered electric bus. Two intracity OLEV buses have been operating continuously without problems since March 2014. Two OLEV buses will be added this year.

Figure 10 Intracity OLEV Bus in Gumi

6. CONCLUSION

In this paper, we have described SMFIR technology, explaining the detailed technology for bus and train applications, and presenting examples of successful commercial implementations of the OLEV buses. The wireless charging technology based on SMFIR will be useful to promote the market of electric transportation system due to solving battery and charging problems.

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STUDY OF MARKET MODEL OF CHARGING INFRASTRUCTURE FOR ELECTRIC TRANSPORTATION

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ABSTRACT

Electric transportation is currently in the spotlight as a sustainable alternative means of transportation. A large number of companies and organizations, varying from car manufacturers to electricity retailers as well as governments are starting with electric vehicle initiatives to develop expertise and experience on electric transportation.

The large-scale introduction of electric transportation in the Netherland involves the integration of a large number of charging points in the electricity network. This requires intensive collaboration between parties in different sectors (Energy sector, Transport sector, etc).

Energie-Nederland (formerly called EnergieNed) and Netbeheer Nederland, an energy suppliers and a grid operation respectively, recognize the need to anchor agreements on charging and payment of electric transportation services in a market model. Both companies jointly initiated the study of development of a broadly accepted charging infrastructure market model enabling consumers to charge and pay for electricity consumed for electric transportation. However, the energy sector has neither the mandate nor the intention to enforce a market model. The outcome of the study was to provide a start for a dialogue with relevant stakeholders from different sectors that may play a role in the domain of electric transportation.

The question this study tried to answers was: “What market model, with associated roles and supporting legislation, is required for the large scale implementation of electric transportation in the Netherlands?”

Preconditions & Method
Important preconditions of the study are:

- The charging infrastructure market model must aligned with the current setup of the electricity market model in the Netherlands energy sector;
- The charging infrastructure market model is applicable for the Dutch market for electric transportation.

To answer the question, the study followed the following methods:

a. Analysis of relevant aspects of market models in other sectors, the Banking sector and the Telecommunication sector;

b. Perform a market consultation to 43 companies/organizations (divided in 8 groups) that are involved in the development of electric transportation in the Netherlands;

c. Define three possible variants of market models;

d. Determine the criteria and their respective weighing for evaluation of the three possible variants;

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e. Evaluate the three variants based on the qualitative score and to determine the best preferred model;

f. Refining the preferred model, including a description of the impact on law and legislation.

The application of the above methods in this study will be described in the following sections.

1. INTRODUCTION

1.1 BACKGROUND

Electric transportation is perceived as a sustainable alternative achieving the climate objectives by 2050. A large number of organizations from car suppliers to energy suppliers, and also governments have been active in the development of through several pilot projects, acquired knowledge and experience on electric transportation. Electric transportation is expected more visible within the years to come.

The role of charging infrastructure in electric transport, involves the process of taking care of charging the battery, consists of a collection of charging stations at various locations with communication and payment infrastructure. The development of electric vehicles and charging infrastructure is linked, as electric vehicle will not be able to work without a charging infrastructure and vice versa.

When realizing and establishing the charging infrastructure, several questions could be raised, including:

- Who is the owner of the charge spot?
- Who is responsible for requesting the charge spot?
- Who installs and maintains the charge spot?
- Who is responsible for the exploitation of the charge spot?
- How will a customer with an electric vehicle pay for the electricity consumed?
- How will market parties deal with the settlement of costs?

Within the domain of electric transport, there is an active role for the automotive and energy sectors. Companies and organizations from other sectors can take a so-called “market role”, for example by being the owner of a charge spot. These companies and organizations thus far did not have any business relationship with the energy sector. Adjustments for the existing and new work agreements between the various parties will be necessary. Work agreements between parties will be registered in a market model. A market model describes (high-level) the market roles, responsibilities of the different market roles, and the relationship between market roles and processes. A market model for the charging infrastructure for Electric Transportation consists of an open system of work agreements between all parties to support the charging and payment of Electric Transportation in the best possible way. The model captures the minimum requirements for correct functioning of the market, while leaving enough room for commercial parties to distinguish themselves.

1.2 CHALLENGE

The present system of work agreements (current market model) for the supply of electricity to household and large consumers is not (fully) applicable to Electric Transportation. The current market model in the energy sector is mainly equipped to produce, trade, transport and supply electricity and connections to households, large users, etc. The widespread introduction of Electric Transportation in the Netherlands means that a large number of charge spots needs to be included in the existing electricity grid. This requires an intensive cooperation between different parties from different sectors (Energy sector, Transport sector, etc). The market model for charging infrastructure shall be a "level playing field": new parties must have equal opportunities in the market.

The Electric Transportation brings additional burden to the current electricity grid, since the expected consumption pattern differs from standard household, peaks could be higher or evolve at another time of the day. Grid operators are responsible for creating and managing the electricity network, maintain the balance between supply and demand, and find solutions to these problems whenever they occur. Next to this, following on the rising demand and the higher number of peaks, new bottlenecks in the production of electricity will arise.

1.3 SCOPE

The charging infrastructure market model was developed on behalf of Electric Transportation, being applicable to the Dutch market. The scope of this study covers approximately 1 million electric vehicles in 2025. Currently, charging Infrastructure exists in two areas:

- Private domain – for example at home on the driveway, at a commercial business area, or a commercial parking;
- Public domain – for example at parking places along the road.

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The study focuses on the public domain. For charging infrastructure in the private domain, the current market model already meets the requirements. The charging infrastructure distinguishes between fast and slow charging, however, this distinction is not relevant in the development of the market model.

The study describes new processes around the charging infrastructure that is not set in the current market model for electricity. For example, the application and realization of charge spots, closing of a contract, linking the electric vehicle(s) to a contract, the measurement of reduced energy to the charging infrastructure, payment and settlement of the costs. Support processes are not described in detail. These processes need to be developed at a later stage. It is important though that the current market model is not restrictive of the tuning of the anticipated support processes. The central governments (including ministries such as energy authority and the Office of Energy) are not part of the market model, as they do not take part in the different market processes.

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Demand-side management is the process of monitoring and controlling the charging process:

- To optimize the available capacity of the electric power required by demand-side management and based on the physically available capacity on the local grid;
- To optimize the battery life-time, this requires demand-side management at battery level;
- To enable the delivery of cheap and sustainable produced energy

The first form is part the market model while the other two are not part of this study. The later two forms of demand-side management are based on agreements between customers and commercial parties that need to be established depending on the commercial propositions that will arise.

The market model does not make choices for specific technologies or standards, such as plug types or identification system (RFID, OV-chip card, etc.). Components of the Energy transition, e.g. Electric Transportation, the sustainability of energy production, the development of distributed generation and forms of energy management, may make changes to the current market model. This study was limited to changes within the charging infrastructure for Electric Transportation.

1.4 RESEARCH QUESTIONS

The key question answered by the study is: “Which market model, with associated roles and supporting legislation, will best fit the large-scale deployment of Electric Transportation in the Netherlands?” EnergieNed and Netbeheer Nederland have formulated the following research questions:

a. What (open) system of work arrangements (market model) with their roles and supporting legislation is required for a large-scale development of Electric Transportation in the Netherlands?

b. What are the potential and desired roles (energy supply, measurement, offset etc.) to be filled in by the various parties (government agencies, commercial and regulated parties) in the value chain of Electric Transportation?

c. How does the market model fit within current regulations and current industry models for energy supply and transport? If this is not the case, what adjustments are required in relation to point b?

1.5 APPROACH AND CONTENTS

The study on a market model on the charging infrastructure for Electric Transportation consists of:

- An analysis of the relevant aspects of different market models in related sectors.

- For this study, 43 companies and organizations from various sectors have been interviewed for ideas and preferences related to Electric Transportation.

- Based on relevant aspects of market models from related sectors and the market consultation, three marker model options for potential market products have been selected.

- The market models are evaluated and weighted according to a fixed set of criteria.

- Details regarding the roles, responsibilities, relationships and processes are described.

2. ANALYSIS OF RELEVANT ASPECTS OF MARKET MODELS IN OTHER SECTORS

In regard of the study on an adequate market model for the charging infrastructure Electric Transport, a couple of market models from other sectors, Banking and Telecommunication have been analyzed.

Banking:

- Withdrawal Model:
  The Withdrawal model applies when customers withdraw funds from a foreign bank, either at home and abroad.

- Transfer Model:
  The Transfer model applies when customers transfer money to another bank account.

Telecommunication:

- Roaming Model:
  The Roaming model applies when users log on to a foreign network.

- Unbundling Model:
  The Unbundling model applies when a service uses a physical infrastructure of another party.

Elements defined in the market models mentioned above which may be relevant in a market model for the charging infrastructure of Electric Transportation are further examined. The analysis answers the following questions:

- What are the main features of the analyzed market model?

- What aspects of the market model may be relevant to the market model for the Charging Infrastructure for Electric Transportation?

- Have specific technologies and systems been used that may be applicable to the market model for the Charging Infrastructure for Electric Transportation?

Analyzing the market models applied in the Telecommunication sector and Banking sector resulted in the following key insights that may be relevant for a market model for the Charging Infrastructure for Electric Transportation:

- Customer have a single point-of-contact for the delivered services;
- Market participants make use of each others infrastructure when delivering services to the customers;
- Market participants mutually offset their costs through a centralized system for clearing and settlement.

3. MARKET CONSULTATION

3.1 METHODOLOGY

A market consultation including 43 companies and organizations in 8 groups was performed in order to support the development of a market model. The eight groups covered gas stations, car suppliers, interest groups, energy suppliers, fleet owners, grid operators, new entrants and the government. The market consultation focused on processes around the charging infrastructure in the public domain.

The results from the survey are used for the development of the market model in three ways:

- Basic principles for a market model;
- Preferred options for typical design choices in a market model;
- Rating of criteria based on score.

3.2 RESULTS

3.2.1 Topics on which Companies and Organizations have Similar Ideas

Starting Points:

- Users of electric vehicles should be able to charge their vehicles at all charge spots in the public domain;
- Drivers from abroad should be able to charge their vehicles at all charge spots in the public domain.

Preferred Options for Design Choices:

- The charging Infrastructure should allow multiple service providers at each charge spot;
- Customers should be able to pay for their consumption by standard payment methods (PIN, Chipknip, OV chip card, monthly billing, etc.);
- Market players, except for Car suppliers, prefer the ownership of the charge spots to be in private hands;
- New market roles that specifically arise for Electric Transportation should not be controlled by the central government, unless there is a clear reason for it;
- Market participants provide an important role for the local authorities in granting approval for the realization and installation of the charging infrastructure in the public domain;

- Not changing the tariff structure currently applied in the energy sector for charging access and transport costs. This enhances transparency for the members, and by maintaining the fee, the costs for the regulated Grid operator are covered.

3.2.2 Topics on which Companies and Organizations do not have Similar Ideas

Parties seem to have different views on:

- The type of contract a customer needs to close for charging services (linked to a contract for a household connection or a separate contract for the electric vehicle);
- The profile category to be allocated for a certain connection point where the charge spot is connected to (a new profile class or a modification of existing profile categories).

Parties seem to have no specific preference or no clear view on:

- The method of payment for the purchased electricity (paid via a contract or by a common ordinary transaction);
- The payment systems that should be available at the charge spots (all possible payment systems, integration with the existing payment infrastructure or a selection of payment systems);
- The specific demands raised by Decentralize Government roles, network managers and owners on the charging infrastructure. These issues will need to be further discussed and elaborated.

4. VARIANTS OF MARKET MODELS

4.1 METHODOLOGY AND STARTING POINTS

Three options of potential market models have been identified and a high-level overview has been developed. The models have been compared on the basis of a predetermined set of criteria. As a result of this comparison, the Workgroup Electric Transportation of EnergieNed and the Project-group Electric Transportation of Netbeheer Nederland agreed on further elaboration of a specific market model. The principles for the different options for market models to be developed are:

- The market model is applicable to the Dutch market;
- The study focuses on the public domain, freely available for customers;
- The market model should be compatible with the existing market model that distinguishes between two types of connections: small consumers and terminals with a larger capacity (>3x80A);

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- The central governments (including ministries, NMa, Office of Energy) are not part of the market model;
- The market model does not attempt to make choices for specific technologies or standards, such as a plug or an identification system (RFID, OV chipcard, etc.);
- In the current situation, supply of electricity takes place at the connection for consumption. In some cases, electricity is "sold" to third parties, which is the case in constructions for rent (all-inclusive rental rate). The study is consistent with this;
- Electric vehicles should be able to charge their vehicles at all charge spots;
- Drivers from abroad should be able to charge their vehicles at all charge spots.

4.2 DESCRIPTION OF THE MARKET MODEL OPTIONS

The three selected options are:

- The Camping model, Figure 1;
- The Provider model, Figure 2;
- The Porter model, Figure 3.

The three different market models contain a total of nine possible roles in market:

- Customer: owner of the electric vehicle (optional: including the battery);
- Provider: provider of charge services at the charging infrastructure;
- Charge Spot Operator: facilitating party in the charging infrastructure;
- Charge Spot Owner: the owner of the physical charging infrastructure;
- Energy supplier: supplier of Electricity in the connection (licensed);
- Grid operator: manager of the grid and the connections;
- Metering responsible: supplier of measuring services;
- Program responsible: provider of service program responsibility;
- Decentralize Government: owner of the public space

In the description of the different model, a subset of the potential market roles is taken, whereby the responsibilities for each single market role may differ per model.

4.3 OPTION 1: THE CAMPING MODEL

The first option does best fit into the current market model for electricity. The

Camping model is described by the following characteristics:

- The Charge Spot Operator will be connected to the grid of the Grid operator;
- The Charge Spot Operator buys electricity from an Energy supplier. As a consequence of this, changes in the existing market model are limited;
- The Charge Spot Operator grants the Customer access to a charge point, delivers loading supplies and has a direct commercial relationship (settlement costs) with the Customer for the entire duration of the charging process;
- Payment for the energy consumed will be done by standard payment methods (e.g. PIN, chip, credit card, OV chipcard), with load transactions being settled directly at the charge spot;
- The market roles of E-Supplier, Grid operator, Program responsible and Metering Responsible will be maintained in accordance with the current market model.

Typical roles, responsibilities and relationships of the Camping model are:

i. Grid operator and Charge Spot Operator;
Grid operator and Charge Spot Operator have a contractual relationship where the Grid operator will provide connection and transport services to the Charging Spot Operator in exchange for a fee.

ii. Metering responsible and Charge Spot Operator;
The Metering responsible and Charge Spot Operator have a commercial relationship where the Metering responsible will provide measurement services to the Operator in exchange for a fee.

iii. Program responsible en Charge Spot Operator;
The Program responsible and Charge Spot Operator have a commercial relationship where the Program responsible will provide program responsibility to the Operator in exchange for a fee.

iv. Energy supplier and Charge Spot Operator;
The Energy supplier and the Charge Spot Operator have a commercial relationship where the Energy supplier delivers electricity to the Charge Spot Operator in exchange for a fee (in line with current electricity conditions).

v. Decentralize Government and Charge Spot Operator;
The Decentralize Government and the Charge Spot Operator have a contractual relationship where the Decentralize Government will deliver the rights to be able to realize and operate a charging infrastructure at a specific location in the public domain.

vi. Charge Spot Owner and Charge Spot Operator:
The Charge Spot Owner and Charge Spot Operator have a

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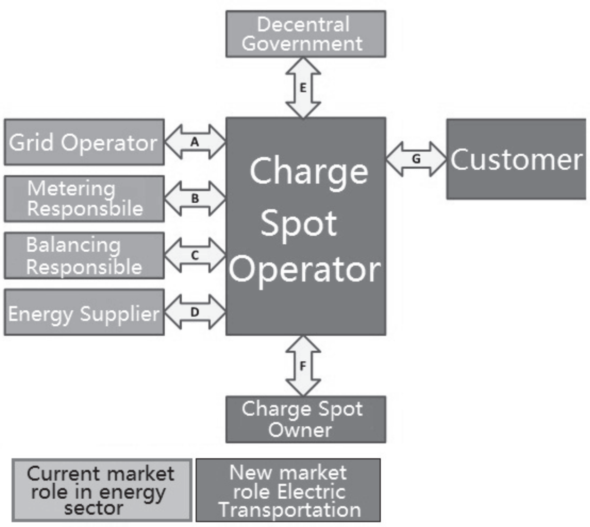
contractual relationship where the Charge Spot Operator will compensate the Charge Spot Owner for the charging infrastructure.

vii. Charge Spot Operator and Customer;
The Charge Spot Operator and Customer have a brief business relationship whereby the Charge Spot Operator will provide access and charging services to the Customer in exchange for a fee. The commercial relationship will last for the entire charging process.

Figure 1 Option 1: Camping Model



4.4 OPTION 2: THE PROVIDER MODEL

The second option is best described as an extension of the Camping model where the responsibilities for the charging infrastructure and service have been separated. The Provider model is described by the following characteristics:

- The Provider will be responsible for the access of a Customer to the charging infrastructure of a Charge Spot Operator, where Providers and Charge Spot Operator will make appointments about granting access to the charging infrastructure for customers of the Provider (several bilateral agreements);
- The Provider has a direct (long term) commercial relationship with the Customer, where the Provider will offer charging services and settles with the Customer afterwards;
- The Charge Spot Operator provides the Customer with access to the charging infrastructure after showing a right of access;
- The Charge Spot Operator is connected to the grid of the Grid operators;
- The Charge Spot Operator and Provider mutually offset charging transactions with each other (use power and charging infrastructure);
- Payment is done by a contract (post and prepaid) between the Provider and Customer;
- The market roles of the Energy supplier, Grid operator, Program responsible and Metering responsible will be maintained in line with the current market model.

Typical roles, responsibilities and relationships of the Provider model are:

i. Grid operator and Charge Spot Operator;

The Grid operator and Charge Spot Operator have a contractual relationship where the Grid operator will provide transport services to the Charge Spot Operator in exchange for a fee.

ii. Metering responsible and Charge Spot Operator;
The Metering responsible and Charge Spot Operator have a commercial relationship where the Metering responsible will provide measurement services to the Charge Spot Operator in exchange for a fee.

iii. Program responsible and Charge Spot Operator;
The Program responsible and Charge Spot Operator have a commercial relationship where the Program responsible will provide program responsibility to the Charge Spot Operator in exchange for a fee.

iv. Energy supplier and Charge Spot Operator;
The Energy supplier and Charge Spot Operator have a commercial relationship where the Energy supplier will provide electricity to the Charge Spot Operator in exchange for a fee (in line with the current electricity condition.

v. Decentralize Government and Charge Spot Operator;
The Decentralize Government and the Charge Spot Operator have a contractual relationship where the Decentralize Government will deliver the rights to be able to realize and operate a charging infrastructure at a specific location in the public domain.

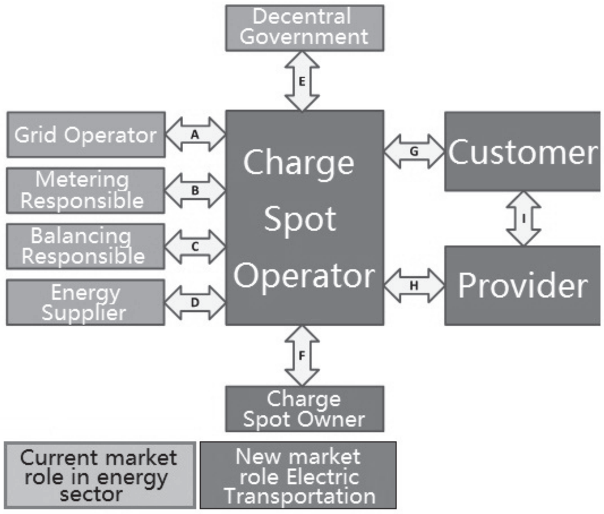
vi. Charge Spot Owner and Charge Spot Operator;
The Charge Spot Owner and Charge Spot Operator have a contractual relationship where the Charge Spot Operator reimburses the Charge Spot Owner to compensate for the use of the charging infrastructure.

vii. Charge Spot Operator and Customer;
The Charge Spot Operator and Customer have a contractual relationship where the Charge Spot Operator will provide access and charging services to the Customer after showing prove of a contract relation with the Provider.

viii. Charge Spot Operator and Provider;
The Charge Spot Operator and Provider have a commercial relationship where the Charge Spot Operator offers access to the charging infrastructure of the Charge Spot Operator in return for a fee.

ix. Provider and Customer;
The Customer and Provider have a commercial relationship where the Provider charges the Customer with the costs of the charging transaction and in return for a payment will provide access to the charging infrastructure (own and from third party) and will offer a payment method.

Figure 2 Option 2: The Provider Model



4.5 OPTION 3: THE PORTER MODEL

The third option is an extraction from the Provider model in which the energy supplier takes the role of the Provider. The Porter model is described by the following characteristics:

- The Energy supplier will be responsible for a Customer"s access to the charging infrastructure of a Charge Spot Operator, where the Energy supplier and Charge Spot Operator agree on granting access to the charging infrastructure for customers of Energy suppliers (several bilateral agreements);
- The Charge Spot Operator will be connected to the grid of the Grid operator;
- The Charge Spot Operator offers a choice of Energy suppliers at the charge point. The Customer chooses at the time of charging, either directly or by manifesting a contractual relationship with an Energy supplier connected to the grid;
- The Energy supplier has a direct (short or long) commercial relationship with the customer, where the Energy supplier, in addition to providing access, will offer charging services to the Customer, with settlement taking place afterwards;
- The Charge Spot Operator and Energy supplier offset the usage of the charging infrastructure with each other;
- The Grid operator will facilitate the ability to have more Energy suppliers on one connection;
- Payment will take place by a contract between Energy supplier and Customer or by standard payment methods;
- The market roles Program responsible and Metering responsible will be maintained in line with the current market model.

Typical roles, responsibilities and relationship of the Porter model are:

i. Grid operator and Charge Spot Operator;
Grid operator and Charge Spot Operator have a contractual relationship where the Grid operator will provide connection and transport services to the Charge Spot Operator in exchange for a fee.

ii. Metering responsible and Charge Spot Operator;

The Metering responsible and Charge Spot Operator have a commercial relationship where the Metering responsible will provide measurement services to the Operator in exchange for a fee.

iii. Program responsible and Charge Spot Operator;
The Program responsible and Charge Spot Operator have a commercial relationship where the Program responsible will provide program responsibility to the Operator in exchange for a fee.

iv. Energy supplier and Charge Spot Operator;
The Energy supplier and Charge Spot Operator have a commercial relationship where the Energy supplier will provide electricity to the Customer in exchange for payment in case the Customer does not show prove of contract relation.

v. Decentralize Government and Charge Spot Operator;
The Decentralize Government and the Charge Spot Operator have a contractual relationship where the Decentralize Government will deliver the rights to be able to realize and operate a charging infrastructure at a specific location in the public domain.

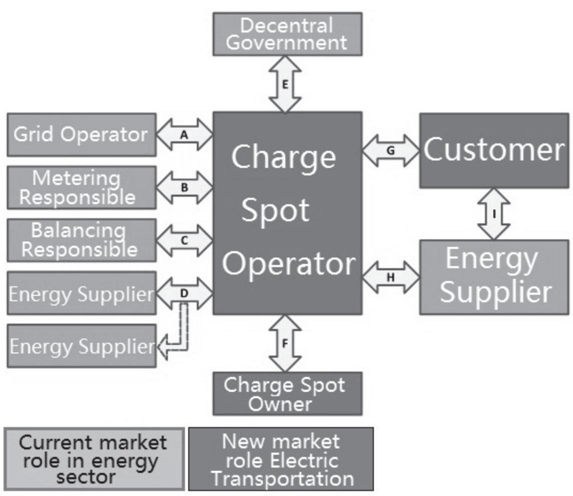
vi. Charge Spot Owner and Charge Spot Operator;
The Charge Spot Owner and Charge Spot Operator have a contractual relationship where the Charge Spot Operator reimburses the Charge Spot Owner to compensate for the use of the charging infrastructure.

vii. Charge Spot Operator and Customer;
The Customer and Charge Spot Operator have a contractual relationship where the Charge Spot Operator provides access and charging services to the Customer after prove of a contract relation with the Energy supplier.

viii. Charge Spot Operator and Energy supplier;
The Energy supplier and Charge Spot Operator have a commercial relationship where the Charge Spot Operator offers access to the charging infrastructure of the Charge Spot Operator in return for payment.

ix. Energy supplier and Customer;
The Energy supplier and Customer have a commercial relationship where the Energy supplier charges the Customer the costs of the charging transaction and in return for payment will provide access to the charging infrastructure (own and third party) and will offer a payment method.

Figure 3 Option 3: The Porter Model



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5. EVALUATION OF MARKET MODELS

The third option is an extraction from the Provider model in which the energy supplier takes the role of the Provider. The Porter model is described by the following characteristics:

5.1 METHODOLOGY

5.1.1 Criteria and Weightings

The models are compared based on a set of criteria from five categories with a total of 23 sub-criteria. The main criteria are:

- Customer 40%:
  In terms of customer expectation, freedom of choice, privacy, the ease of access and location.

- Feasibility – Market leveraging 10%:
  The impact on the current market model and the possibility that the selected model enables for charge control and advanced techniques, e.g. Vehicle to Home and Vehicle to Grid.

- Feasibility – Regulation 20%:
  The extent to which a selected model is available for new entrants, the degree of adjustments to be made in existing laws and regulations and the complexity of regulated tariff structures.

- Feasibility – Technology 10%:
  The impact on ICT (processes, interfaces, systems and data), the availability of technology and the degree of standardization.

- Costs 20%:
  The amount of the initial investments to be made and operational costs.

5.1.2 Qualitative Evalution and Relative Score Variants

There are also sub-criteria under the main criteria. Each of the models was qualitatively assessed on each of the 23 sub-criteria. Sub-criteria can referred to the detail study report.

6. CONCLUSIONS

As a result of the evaluation, the Work group Electric Transportation of EnergieNed and the Project group Electric Transportation of Netbeheer Nederland agreed a preferred model based on the *Provider model* supplemented with the option of charging directly at the charge spot to pay for the purchased electricity.

6.1 CUSTOMER

The preferred model provides the Customer with full access to the charging infrastructure, both through a contract with a provider or by means of an everyday payment to access the charging infrastructure. In ensuring the accessibility, there is an important role for the Decentral Government. The Decentral Government exerts influence on the accessibility, for example through licensing or issuing concessions for charging infrastructure in public spaces.

Accessibility is also dependent on technical developments like a standard for a plug and a single payment method. Although technical standards are out of scope of the market model, they certainly do contribute to a wide accessibility of the charging infrastructure.

In addition, the Customer will have the freedom to choose a Provider for charging services. The Customer will, in accordance with the contract agreement with the Provider, be provided with charging services at all the charge spots in the public domain. The availability of the necessary payment infrastructure may stimulate the roll-out of the charging infrastructure.

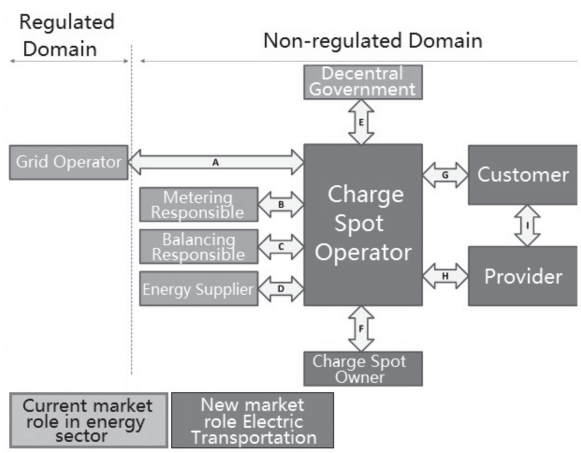
Privacy remains an important issue. In the principals of the market model, only the necessary exchange of information has been foreseen in order to handle the payment with the Customer. The confidentiality of customer information must be secured. It is not possible to obtain commercial advantage as a result of the distribution of customer information.

The exchange of data and information is in accordance with current arrangements regarding the payment of fuel with a fuel card and the use of a mobile phone while being abroad (roaming). The safeguarding of Customer data will be dependent on the chosen medium. The robustness of the medium will influence the degree of fraud sensitiveness.

Table 1 Category vs Information

Category	Information
Customer related information	Unique identifier for a Customer (Customer ID)
Consumption data	Decreased energy (kWh) Duration of loading operation (start or end)
(Optional) information on behalf of charging process	Battery charge profile (power profile) Information for charging control

Figure 4 The Preferred Model



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6.2 FEASIBILITY: MARKET FACILITATION

The preferred model is aligned with the current market model for electricity. Moreover, the availability of (long term) contractual relationships between the Provider and Customer enhances the predictability for the expected supply of electricity, allowing for agreements between Charge Spot Operator and Provider that in turn will prevent congestions in the network.

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The Customer will be able to capture certain frameworks on Charge Steering in the contract terms, which allows for more insight in flexibility for the players in the market. Finally, the Customer will be able to capture conditions regarding regeneration in the contract.

Compared to the Camping model, in the preferred model the responsibilities for managing and maintaining the connection, the charging infrastructure, and services towards the customer, are explicitly separated. Separating the roles Charge Spot Operator and Provider increases the complexity of market processes as well as work agreements to be developed between the players.

6.3 FEASIBILITY: REGULATION

The preferred model provides new entrants with the opportunity to take different roles depending on their own wishes. The preferred model raises no barriers for participating in the market model, in contrast to which is the case in the Porter model (supply license). In addition to this, it is expected that both the technical, infrastructural and commercial side innovation and development of Electric Transportation will be stimulated at a maximum level. Each party is free to fill in the new roles, where motivations for this might differ among parties.

For the new market roles Charge Spot Operator, Charge Spot Owner and Provider there is no conclusive reason or wide worn need from the market to transfer one of these roles under the direct supervision of the central government like the Ministry of Economic Affairs or the Office of Energy. New entrants (Charge Spot Owners, Charge Spot Operators and Providers) are free to realize, operate and grant charging services to the charging infrastructure. Decentralize Governments (municipalities, provinces) play an important role in granting licenses and setting standards for the charging infrastructure. Local authorities impose restrictions on the deployment of charging infrastructure. Therefore, there is a finite amount Charge Spot Operators, but an unlimited number of Providers.

6.4 FEASIBILITY: TECHNOLOGY

The preferred model provides room to any given party to develop commercial propositions for Customers. Due to the large number of interests at stake, delays can be expected in making adequate work agreements as well as the development of uniformity and standards like for systems to get access to the charging infrastructure and payment systems. The number of parties in the Camping model and the Porter model is limited.

In addition, all players willing to participate in the market model should be aware of the investments. There will be a duly impact on ICT. Market players need to be prepared for the implementation of business processes, minimum required IT systems, and need to be able to communicate the minimum necessary data about the customer and the charging process.

6.5 COSTS

Relevant expenses applicable in the preferred model consist of two parts, namely:

- Investments;
- Operational costs.

6.6 INVESTMENTS

The investments include all costs that should be incurred in achieving the charging infrastructure. High-level, this contains the following cost components:

- The realization of new connections or the strengthening of existing connections;
- The realization and installation of charge spots;
- The realization and installation of the meter;
- The realization and installation of payment systems in case of direct payment to the charge spot.

6.7 OPERATIONAL COSTS

The operational costs include all recurring costs of maintenance and management of the charging infrastructure together with the associated payment systems, being:

- The maintenance and management of the charging Infrastructure;
- The maintenance and management of the communication and payment infrastructure;

The preferred model imposes a financial impact due to the possibility of installing Direct Pay systems on the charging infrastructure. The investment in payment terminals will be substantial compared to the costs of a charge spot, and moreover, the operational costs of a Direct Pay method are considerably higher than payment by a contract. Initial indicative calculations and insights turn out that the transaction costs of direct payments via standard payment methods (e.g. PIN, Credit Card, etc.) are about 5 to 6 times higher than the transaction costs for payment through a contract. Dependent on Customer needs, having Decentralize Government in place, other results of alocal business case, the Charge Spot Operator will be able to equip the charging infrastructure with the appropriate payment methods.

Low transaction costs are required in the preferred model due to the fact that the expected revenue per charging transaction will be close to a couple of euros for a full battery (comparing to 50 Euros, which is the price for a full tank).

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UPGRADING OF THE GRADING STANDARD UNDER THE MANDATORY ENERGY EFFICIENCY LABELLING SCHEME

Speakers: Ir S.C. Wong, Chief Engineer
Ir Y.K. Chan, Senior Engineer
Ir C.Y. Shum, Engineer
Electrical & Mechanical Services Department
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Paper No. 5

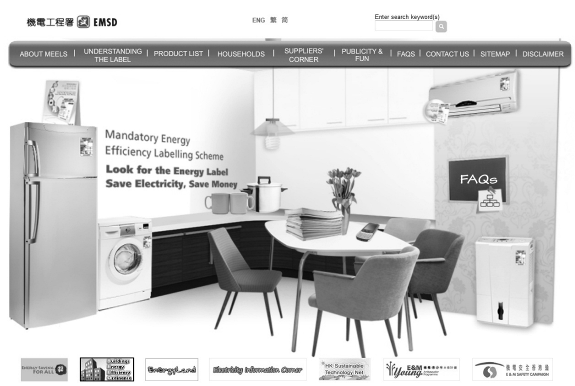
ABSTRACT

Significant energy savings could be achieved by using more energy-efficient appliances, which would help reduce the emission of greenhouse gases and other air pollutants from power plants. In Hong Kong, the Mandatory Energy Efficiency Labelling Scheme (MEELS) was introduced through the Energy Efficiency (Labelling of Products) Ordinance (Cap. 598) (EELPO) which was enacted in May 2008. Under the EELPO, energy labels are required to be shown on all prescribed products for supply in Hong Kong to inform consumers of their energy efficiency performance. The MEELS currently covers five types of prescribed products, namely room air conditioners, refrigerating appliances, compact fluorescent lamps, washing machines and dehumidifiers, altogether accounting for about 60% of the annual electricity consumption in the residential sector. Under the EELPO, a Code of Practice on Energy Labelling of Products (CoP) is issued to set out the practical guidance and technical details in respect of the requirements on energy labelling for the prescribed products. This paper briefly introduces the MEELS and outlines the upgrading of the grading standard for room air conditioners, refrigerating appliances and washing machines under the MEELS.

1. INTRODUCTION

The MEELS establishes the technical requirements and determination of the energy efficiency grading for the prescribed products. Under the EELPO, energy labels are required to be shown on all prescribed products for supply in Hong Kong to inform consumers of their energy efficiency performance. EMSD maintains a dedicated website at http://www.energylabel.emsd.gov.hk, namely "Energy Label Net", for the MEELS (Figure 1), in which its most current information including the latest news, information of product models, CoP, forms, circulars, publicity materials, etc. can be found.

Figure 1 Snapshot of the MEELS Website



The MEELS was implemented in phases. The initial and second phases were fully implemented on 9 November 2009 and 19 September 2011 respectively, covering five types of prescribed products, namely room air conditioners, refrigerating appliances, compact fluorescent lamps, washing machines and dehumidifiers.

2. MEELS SCOPE OF COVERAGE

Currently, the MEELS covers five types of prescribed products with the following scope of coverage:

2.1 ROOM AIR CONDITIONERS

It includes non-ducted and air-cooled single package type (or window type) and single split type room air conditioners that operate by using vapour compression cycle with a rated cooling capacity not exceeding 7.5 kiloWatts.

2.2 REFRIGERATING APPLIANCES

It includes refrigerators, frozen food storage cabinets, food freezers and their combinations that operate by using vapour compression cycle with a rated total storage volume not exceeding 500 litres.

2.3 COMPACT FLUORESCENT LAMPS (CFLs)

It includes integrated type CFLs with screw or bayonet cap that have rated lamp wattage up to 60 Watts.

2.4 WASHING MACHINES

It includes horizontal axis type and vertical axis type washing machines with or without built-in dryers that have a rated washing capacity not exceeding 7 kilograms.

2.5 DEHUMIDIFIERS

It includes self-contained dehumidifiers that operate by using vapour compression cycle with a rated dehumidifying capacity not exceeding 35 litres per day.

These five prescribed products altogether account for about 60% of the annual electricity consumption in the residential sector.

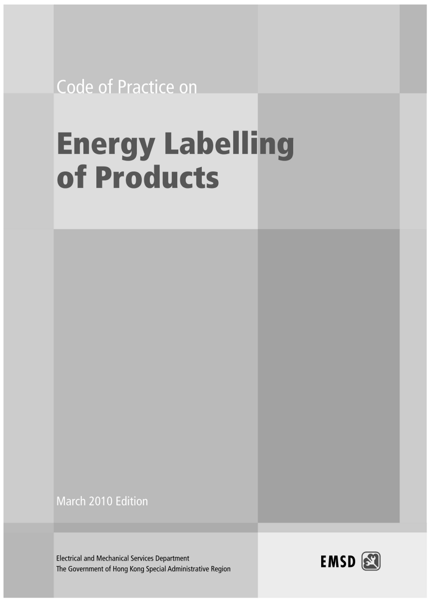
3. MEELS LABELLING REQUIREMENTS

3.1 ENERGY PERFORMANCE TESTING

Similar to most of the overseas mandatory energy efficiency labelling schemes, the MEELS in Hong Kong operates on the basis of a self-testing system under which manufacturers or importers of the prescribed products are required to conduct tests in accredited testing laboratories (Figure 2). The testing laboratories include accredited laboratory under the Hong Kong Laboratory Accreditation Scheme (HOKLAS) or under an accreditation scheme operated by a laboratory accreditation body in other economies with which HOKLAS has concluded a mutual recognition arrangement (MRA). The tests must be carried out in accordance with the CoP issued under the EELPO (Figure 3).

Figure 2 Energy Performance Testing

Figure 3 CoP (2010 Edition)



The CoP provides practical guidance and technical details about the energy efficiency labelling for the prescribed products. It specifies the relevant test standards, calculation methods and determination of energy efficiency grading levels of prescribed products, in accordance with which the energy efficiency performance of the product models are tested and assessed.

3.2 SUBMISSION OF PRODUCT INFORMATION

The manufacturers or importers of the prescribed products shall submit Form 1 (Figure 4), test report and associated product information to EMSD for assignment of reference number for the product model.

Figure 4 Form 1

機電工程署 EMSD

Form 1 表格一

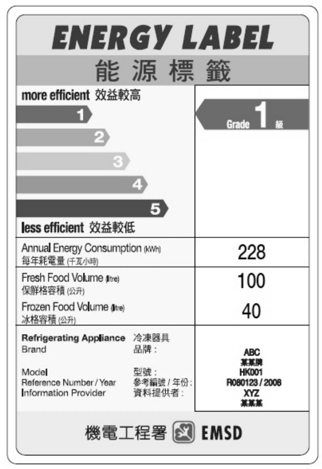
The Government of the Hong Kong Special Administrative Region
Energy Efficiency (Labelling of Products) Ordinance
(Chapter 598, Section 6)
Submission of Specified Information and Specified Documents

香港特別行政區政府
能源效益（產品標籤）條例
（第 598 章第 6 條）
呈交指明資料及指明文件

Official use only
此欄不用填寫

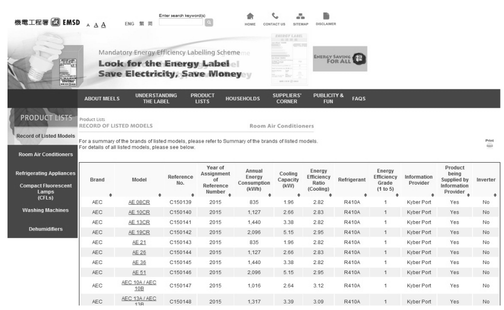
If the Director of Electrical and Mechanical Services is satisfied with the information submitted, he will issue a letter of notification informing the manufacturers or importers of the reference number assigned to the product model concerned. The manufacturers or importers are required to attach energy labels in the prescribed formats (Figure 5) specified in the EELPO before supplying these products in Hong Kong. All local suppliers (including wholesalers and retailers) cannot supply the specified products which do not bear the energy labels.

Figure 5 Energy Label Sample



As at the end of July 2015, over 6,800 product models have been listed under the MEELS. Consumers can check the information of these product models in the Energy Label Net (Figure 6).

Figure 6 Information of Listed Models



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Since the launch of the MEELS, the MEELS has been effective in -

(a) promoting energy saving by informing potential customers of the energy performance level of the products and facilitating customers in choosing the more energy- efficient models;

(b) encouraging product suppliers to make available more energy-efficient products to meet customers' demand; and

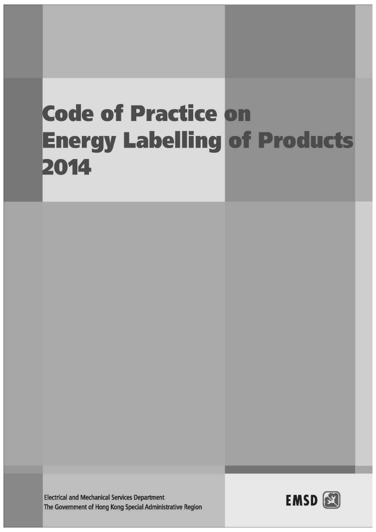
(c) increasing the penetration rate of energy labels through the introduction of legislation to mandate the display of energy labels.

The first two phases of the MEELS which cover five types of electrical products contribute to an annual saving in electricity of about 175 million kilowatt-hour (kWh) and an annual reduction of carbon dioxide emissions by about 122,500 tonnes.

4. REVIEW OF GRADING STANDARDS

A review of the grading standards of room air conditioners, refrigerating appliances and washing machines was completed in late 2014. In reviewing the grading standards of these products, due regard has been given to such factors as the distribution of the appliances among various existing grades; grading systems adopted overseas; development of testing standards; technological development and potential energy savings arising from further tightening of the grading standards, etc. The energy efficiency grading standards of the three products has been tightened and promulgated through issuance of a revised CoP (Figure 7). The revised CoP was published in gazette in October 2014. Full implementation will take place in November 2015, after which the three products to be supplied into the market must bear energy labels under the new energy efficiency grading standards.

Figure 7 Revised CoP (2014 Edition)



To give an overview, the new grading standards for room air conditioners, refrigerating appliances and washing machines under the MEELS are briefly outlined below.

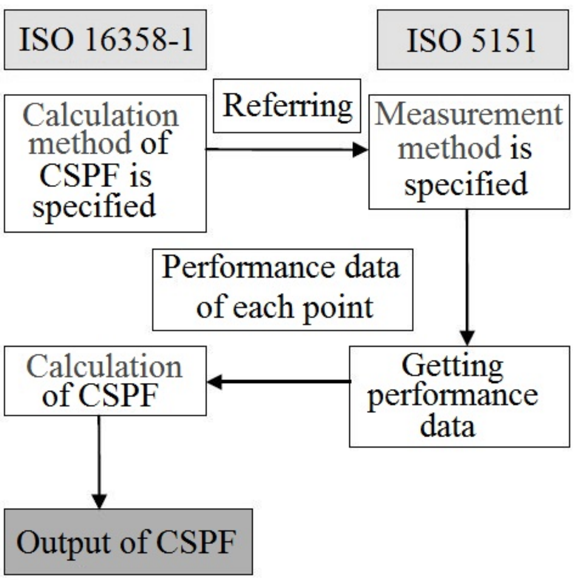
4.1 ROOM AIR CONDITIONERS

With increasing application of inverter technology in air conditioning in recent years, it allows inverter air conditioners to operate at part-load in response to room air temperature. In accordance with the revised CoP, Cooling Seasonal Performance Factor (CSPF)[(1)] is adopted to measure the energy efficiency performance of a room air conditioner and determine its energy efficiency grade in order to take into account part-load performance of inverter air conditioners. The CSPF is briefly defined as "the total cooling output during a typical cooling season divided by the total energy consumption during the same period" and is calculated as follows:

$$\text{CSPF} = \frac{\textbf{Cooling Seasonal Total Load}}{\textbf{Cooling Seasonal Energy Consumption}}$$

The room air conditioner is tested in accordance with ISO 5151[2] and ISO 16358-1[3]. The relationship between ISO 5151 and ISO 16358-1, and the workflow of measurement and calculation for CSPF is diagrammatically shown below (Figure 8).

Figure 8 Relationship between ISO 5151 and ISO 16358-1



For determination of CSPF, the following minimum test points for different types of room air conditioners are required in accordance with ISO 16358-1:

- Fixed capacity room air conditioners - one test point at full load
- Inverter room air conditioners - two test points, one at full load and one at 50% full load

The calculation of the CSPF is determined in accordance with the method specified in ISO 16358-1 as well as the following defined cooling load and outdoor temperature bin distribution for cooling:

Table 1 Defined Cooling Load

Parameter	Zero Load	Full Load
Cooling Load	0%	100%
Outdoor Temperature (°C)	23	25

Table 2 Outdoor Temperature Bin Distribution for Cooling

Bin no.	Outdoor temperature (°C)	Bin hours (hour)
1	24	67
2	25	117
3	26	147
4	27	177
5	28	210
6	29	183
7	30	114
8	31	75
9	32	56
10	33	33
11	34	15
12	35	5
13	36	1
Total	--	1,200

After calculation of the CSPF, the energy efficiency grade of the tested room air conditioner is determined according to the following table:

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Table 3 Energy Efficiency Grading for Room Air Conditioner

Energy Efficiency Grade	Cooling Seasonal Performance Factor (CSPF), F_{CSP}	
	Single Package Type	Split Type
1	$3.00 \le F_{CSP}$	$4.50 \le F_{CSP}$
2	$2.80 \le F_{CSP} < 3.00$	$3.50 \le F_{CSP} < 4.50$
3	$2.60 \le F_{CSP} < 2.80$	$3.15 \le F_{CSP} < 3.50$
4	$2.40 \le F_{CSP} < 2.60$	$2.80 \le F_{CSP} < 3.15$
5	$F_{CSP} < 2.40$	$F_{CSP} < 2.80$

4.2 REFRIGERATING APPLIANCES

Under the MEELS, refrigerating appliances are classified into eight categories. The following parameters are measured in the test in accordance with IEC 62552[4]:

- Storage temperatures of compartments
- Storage volumes of compartments
- Energy consumption test
- Freezing test

After measurement, Energy Consumption Index $(I\varepsilon)$ is calculated and used for determination of the energy efficiency grade of the tested refrigerating appliance. Energy Consumption Index $(I\varepsilon)$ is calculated by dividing the measured energy consumption by average appliance energy consumption and is tightened as follows:

Table 4 Energy Consumption Index

Energy Efficiency Grade	Tightened I_ε (%)	Existing I_ε (%)
1	$I_\varepsilon \le 35$	$I_\varepsilon \le 63$
2	$35 < I_\varepsilon \le 44$	$63 < I_\varepsilon \le 80$
3	$44 < I_\varepsilon \le 55$	$80 < I_\varepsilon \le 100$
4	$55 < I_\varepsilon \le 69$	$100 < I_\varepsilon \le 125$
5	$69 < I_\varepsilon$	$125 < I_\varepsilon$

4.3 WASHING MACHINES

Under the MEELS, washing machines are classified into two categories and tested in accordance with the following standards:

- IEC 60456[5] for horizontal axis type washing machine
- JIS C 9606[6] for vertical axis type washing machine

The following parameters are measured in the test:

- Energy consumption
- Water consumption
- Washing performance
- Water extraction performance

After measurement, Specific Energy Consumption (E_{sp}), defined as the energy consumption per kg during a washing cycle, is calculated and used for determination of the energy efficiency grade of the tested washing machine and is tightened as follows:

Table 5 Energy Efficiency Grading for Washing Machine

Energy Efficiency Grade	Horizontal Axis Type	
	Tightened E_{sp}	Existing E_{sp}
1	$E_{sp} \le 0.130$	$E_{sp} \le 0.208$
2	$0.130 < E_{sp} \le 0.150$	$0.208 < E_{sp} \le 0.247$
3	$0.150 < E_{sp} \le 0.172$	$0.247 < E_{sp} \le 0.286$
4	$0.172 < E_{sp} \le 0.195$	$0.286 < E_{sp} \le 0.325$
5	$0.195 < E_{sp}$	$0.325 < E_{sp}$

Energy Efficiency Grade	Vertical Axis Type	
	Tightened E_{sp}	Existing E_{sp}
1	$E_{sp} \le 0.0160$	$E_{sp} \le 0.0211$
2	$0.0160 < E_{sp} \le 0.0184$	$0.0211 < E_{sp} \le 0.0251$
3	$0.0184 < E_{sp} \le 0.0208$	$0.0251 < E_{sp} \le 0.029$
4	$0.0208 < E_{sp} \le 0.0232$	$0.029 < E_{sp} \le 0.033$
5	$0.0232 < E_{sp}$	$0.033 < E_{sp}$

4.4 POTENTIAL BENEFIT OF THE UPGRADING OF GRADING STANDARD

It is estimated that the upgrading of the energy efficiency grading standards of the three products could bring annual electricity saving of about 300 million kWh and an annual reduction of carbon dioxide emissions by about 210,000 tonnes.

5. CONCLUSION

With the implementation of the MEELS that serves as one of the key drivers for energy saving, Hong Kong has taken the very major step forward in addressing to the impacts of climate change brought about by energy consumption of electrical appliances. Building on the success of the first and second phases of the MEELS and with a further step in encouraging product suppliers to make available more energy efficient products to meet customers' demand as well as facilitating customers in choosing more energy efficient products, the Government reviewed and tightened the energy efficiency grading standards of room air conditioners, refrigerating appliances and washing machines in order to capitalize further energy saving.

ACKNOWLEDGEMENT

Sincere thanks are extended to members of the Taskforce on Upgrading of the Grading Standard under the MEELS in offering their advice and support in the development of the new grading standards.

NOTES

(1) *CSPF is also called Seasonal Energy Efficiency Ratio.*

(2) *ISO 5151: "Non-ducted air conditioners and heat pumps – Testing and rating for performance"*

(3) *ISO 16358-1: "Air-cooled air conditioners and air-to-air heat pumps – Testing and calculating methods for seasonal performance factors – Part 1: Cooling seasonal performance factor". This standard was published in April 2013.*

(4) *IEC 62552: "Household refrigerating appliances – Characteristics and test methods"*

(5) *IEC 60456: "Clothes washing machines for household use – Methods for measuring the performance"*

(6) *JIS C 9606: "Electric washing machines'*

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REFERENCES

[1] HKSAR Government *Energy Efficiency (Labelling of Products) Ordinance (Cap. 598)*

[2] EMSD *Code of Practice on Energy Labelling of Products (2010 Edition)*

[3] EMSD *Code of Practice on Energy Labelling of Products (2014 Edition)*

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Paper No. 6

WINNING MULTIPLE EFFICIENCIES THROUGH ELEVATOR MODERNIZATION

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WINNING MULTIPLE EFFICIENCIES THROUGH ELEVATOR MODERNIZATION

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Paper No. 6

ABSTRACT

With rapid property development in the past two decades in Hong Kong, there were many elevators installed and commissioned in residential, commercial and composite buildings. However, the types of motor, their drives and the control logic at that time were comparatively less efficient than the technologies being applied nowadays. Elevator modernization is the best way to upgrade the outdated elevator systems, so that they could behave as brand new elevators in terms of efficiency, performance, reliability and safety.

In this paper, we focus on the analysis of efficiency improvement after elevator modernization. Efficiencies can be interpreted in the following areas for an elevator system:

- Energy Efficiency: Energy savings after elevator modernization.
- Traffic Efficiency: Reduction of passenger average waiting time so as to improve the people's flow inside the building.
- Maintenance Efficiency: How remote monitoring and maintenance system can improve the maintenance efficiency and increase the usability of an elevator.

1. INTRODUCTION

In 1980s and 1990s, Hong Kong experienced rapid economic growth. Many high-rise commercial, residential and composite buildings were built, in which elevators and escalators are undoubtedly indispensable for transportation of occupants. However, due to the technology at the time when the elevators were installed, the motors, their drives and the control systems were comparatively less efficient than those being used nowadays. Elevator modernization is a good countermeasure to upgrade the efficiency of an elevator to cope with the latest technologies.

In the sections below, efficiency performance before and after elevator modernization will be studied and reviewed in terms of the followings:

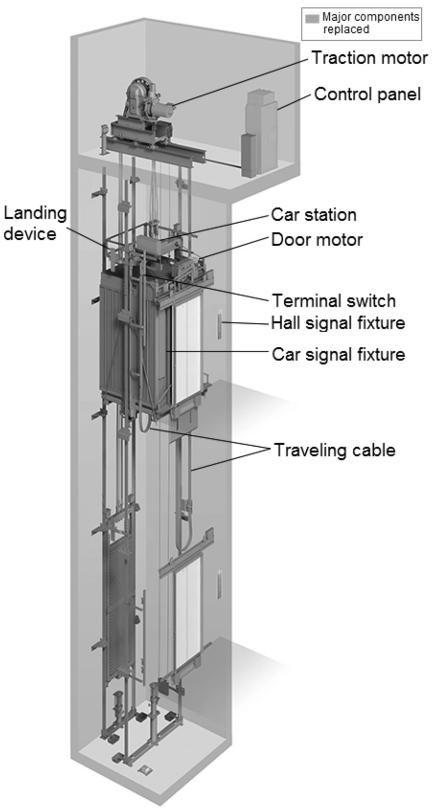
- Motor and its drive
- Control panel, control algorithm and traffic intelligence
- Remote maintenance and monitoring

2. MODERNIZATION SCOPES

Before going into the efficiency improvement, it is better to understand the scope of elevator modernization. Generally speaking, three modernization plans are popularly adopted in the market, namely, CM-1, CM-2 and SM.

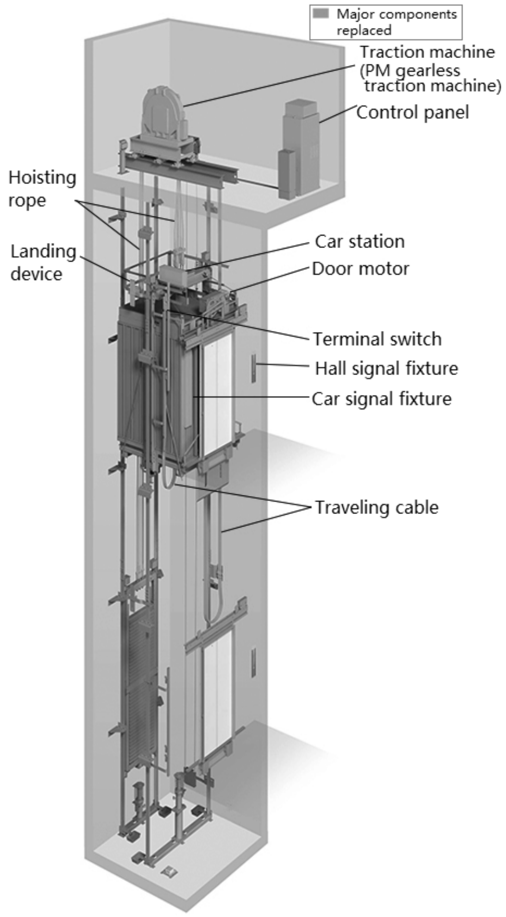
CM-1: The abbreviation CM means Control Modernization. As its name implies, the entire control system of the elevator is replaced, including the control panel (drive is incorporated in the control panel), shaft signalling and the car top station etc. “1” means the replacement of traction motor (while the traction sheave, brake system and gear box are retained) in order to match with the new motor drive. In addition, car and hall signal fixtures are replaced. Illustration is shown in Figure 1.

Figure 1 CM-1



CM-2: Same as CM-1, the only difference is that the entire traction machine (i.e. traction sheave, gearbox, brake system and traction motor) is replaced by a Gearless Permanent Magnet Motor Traction Machine which is the meaning of “2”. Illustration is shown in Figure 2.

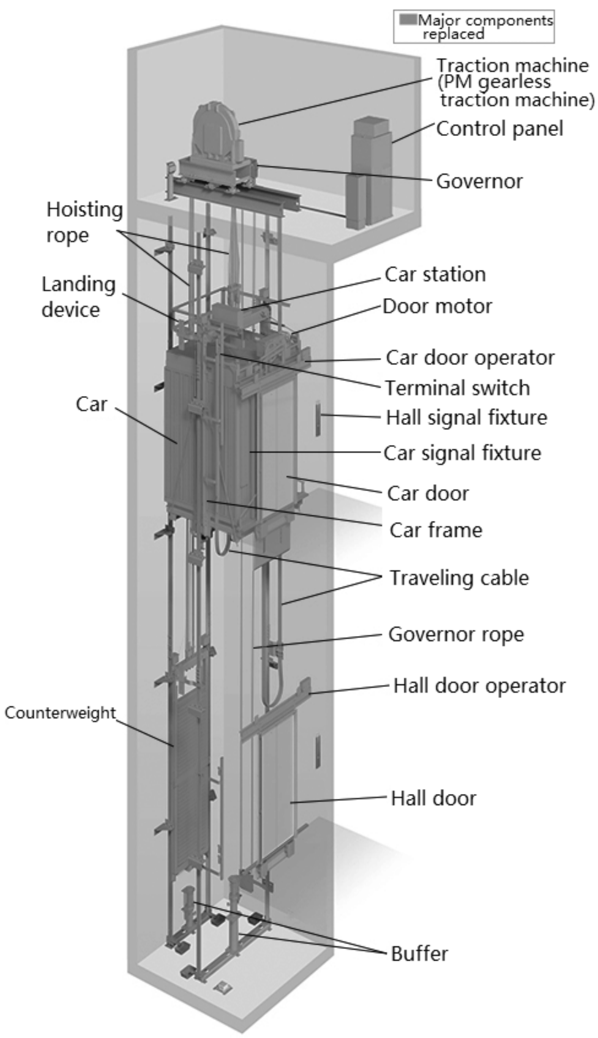
Figure 2 CM-2



SM: SM is the abbreviation of Semi-Modernization which means except guide rails, all elevator components are replaced. Illustration is shown in Figure 3.

From the above descriptions, it is understood that after modernization, no matter which plan is used, the drive, motor and the control system are replaced. These would contribute to the improvement of energy efficiency, traffic efficiency and maintenance efficiency which are briefly explained in the following sections.

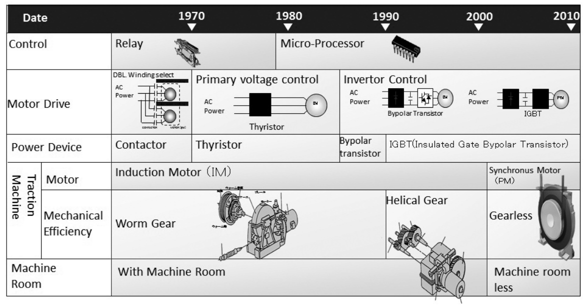
Figure 3 SM



3. ENERGY EFFICIENCY

Figure 4 shows the development history of low speed elevator.

Figure 4 Development of Low Speed Elevator



In 1970's, the main component of an elevator was 3-phase induction motor driven by alternating current with 2-speed (AC-2) motor drive. The control panel was relay type. The speed of the elevator was controlled by the specific combination of contactors, so that the motor could be run at rated speed (i.e. the high speed mode by connecting the motor to be 4-pole) or "climbing speed" (a low speed mode by changing the contractor's combination to connect the induction motor to be 16-pole) when landing. Finally brake was applied in order to stop the elevator cabinet at the landing position. As such, it can be imagined that the passengers would experience sudden speed change and a shock when being stopped at the landing.

In 1980's, the elevator technology was still using 3-phase induction motor, but the motor drive was changed to Alternating Current Variable Voltage

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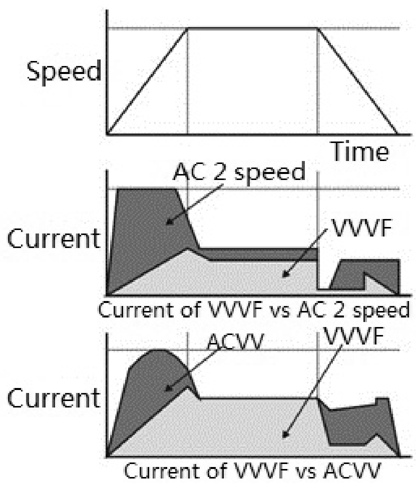
Control (ACVV). The control panel was the transition period of relay type and PCB type (or say semi-computerized). At that time, thyristor was used as the switching component in the motor drive to control the voltage level to the 3-phase induction motor. However, by this technology, the saturation occurs during acceleration and deceleration. As such, this kind of motor drive is energy inefficient.

In 1990's, the Variable Voltage Variable Frequency (VVVF) technology was introduced to the market for improving the control system of the 3-phase induction motor which was still commonly used at that time. By keeping the ratio between voltage and frequency to be constant, saturation could be avoided and hence the energy efficiency was improved. Figure 5 shows the relationship between current and speed of induction motor for AC2, ACVV and VVVF drives.

Figure 5 Current vs Speed of Induction Motor



LEGEND:
1. AC 2 speed - AC 2 speed motor drive
2. ACVV - AC motor drive with variable voltage controller
3. VVVF - Variable voltage variable frequency controller

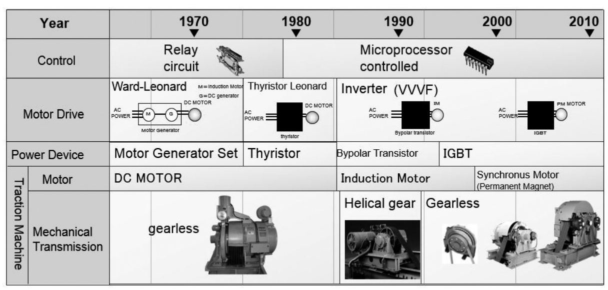
(http://ee.emsd.gov.hk/english/lift/lift_tech/lift_tech.html)

Courtesy of HKEE Net

Although the three generations of motor drive were implemented as mentioned above, 3-phase induction motor with worm-gear gear box was still be adopted to be the major component to drive the elevator. However, energy loss is unavoidable in the worm-gear mechanical transmission for that kind of system. But starting from 2000's, Permanent Motor (PM motor) was introduced to the market. With it's high torque and low speed speed-torque characteristics, gearbox can be eliminated for reducing the mechanical loss and the VVVF is widely used as the motor drive system.

The history of high speed elevator is shown in Figure 6. In 1970's, due to the advantage of the linearity control of Direct Current (DC) motor, motor-generator set (M-G set or Ward-Leonard system) was widely used for high speed elevators. However, it was obvious that generator would impose certain losses in the system and so this was regarded as an energy inefficient system.

Figure 6 History of High Speed Elevator



In 1980's, the advancement of power electronics, DC chopper was used to drive the DC motor directly. Elimination of generator set can obviously improve the energy efficiency.

In 1990's, again, with the development of VVVF technology, AC motor could behave as a DC motor in the control aspects. VVVF drive plus AC induction motor was commonly utilized in high speed application.

After 2000's, PM motor is now being applied no matter in low speed or high speed elevators.

It is noted that in high speed elevators, no matter it is DC or AC machines, they don't have gearbox because it doesn't require gearbox to reduce the speed.

So what is the improvement of energy efficiency quantitatively in nowadays? We had done many modernization projects to modernize elevators from old motor drive technology to the latest one. We found that the energy saving was at least 30% at most of the time. Figure 7b shows the data got in one elevator modernization project in a residential estate.

Figure 7a Example of Modernization Project

(Left: Before Modernization; Right: After Modernization)

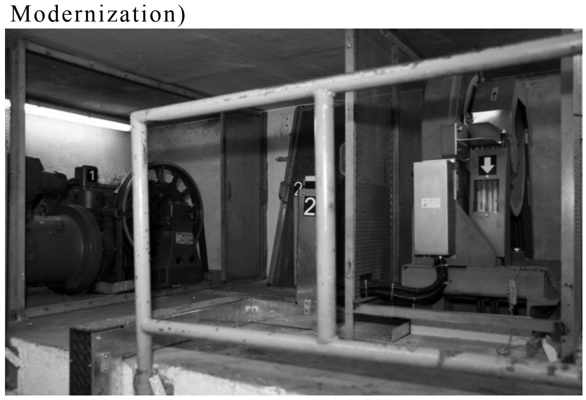


Figure 7b Energy Saving Analysis in One Residential Estate

		Measurement Start Date	Measurement Finish Date	No. of Days	No. of Start	Energy Consumption (KWh)	Average No. of Start per Day
Blk1 #1	Before	22/09/2006	9/10/2006	17	9330	495	549
	After	08/06/2007	11/06/2007	3	2095	51	698
Blk5 #1	Before	23/09/2006	09/10/2006	16	12277	531	767
	After	08/06/2007	11/06/2007	3	2673	54	891
Blk9 #1	Before	23/09/2006	09/10/2006	16	11631	473	727
	After	08/06/2007	11/06/2007	3	2667	57	889
Blk15 #1	Before	09/10/2006	23/10/2006	14	9224	406	659
	After	08/06/2007	11/06/2007	3	2147	56	716

		Average Energy Consumption per Start（KWh）	Average Energy Consumption per Day（KWh）	Reduction % (per Start)	Reduction % (per Day)
Blk1 #1	Before	0.0531	29.1	-54%	-42%
	After	0.0243	17.0		
Blk5 #1	Before	0.0433	33.2	-53%	-46%
	After	0.0202	18.0		
Blk9 #1	Before	0.0407	29.6	-47%	-36%
	After	0.0214	19.0		
Blk15 #1	Before	0.0440	29.0	-41%	-36%
	After	0.0261	18.7		
			Average per Block	-49%	-40%

The evolution of motor drive and the motor technologies could contribute to the energy efficiency around 30%~40% in general. In addition, regenerative convertor technology can even generate electricity back to the grid. Figure 8a and Figure 8b shows the principle of regenerative convertor.

Figure 8a Principle of Regenerative Convertor

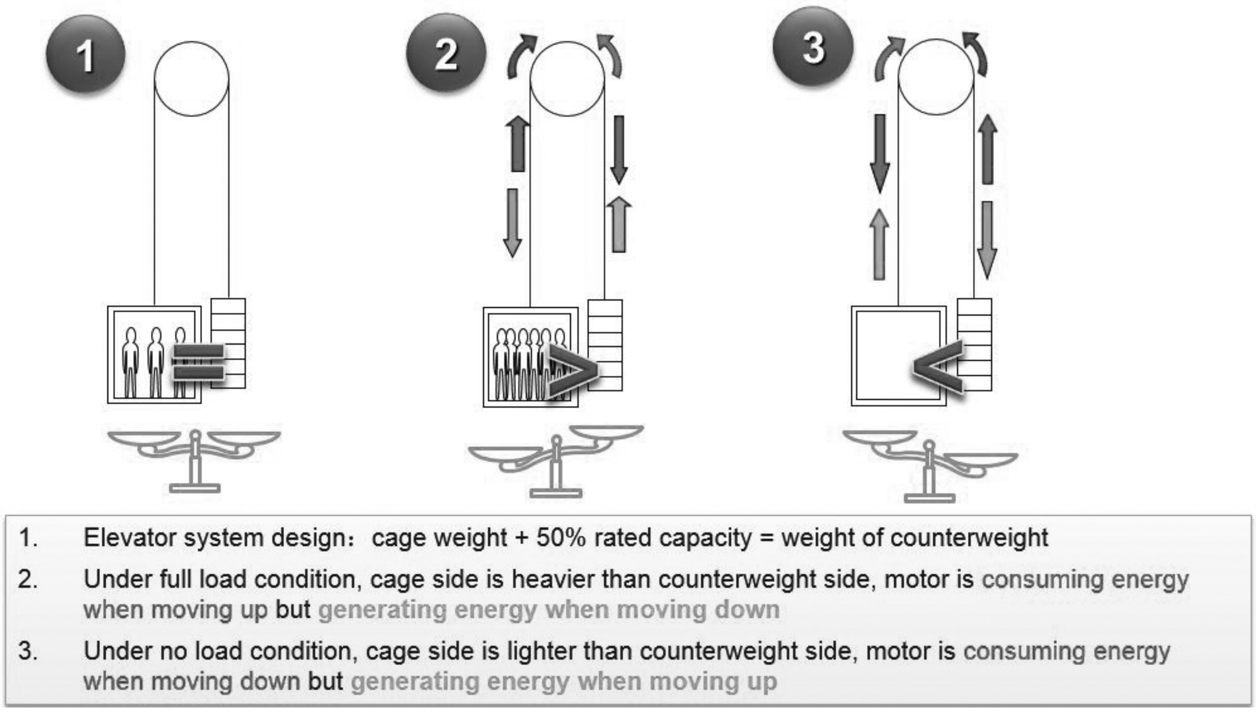
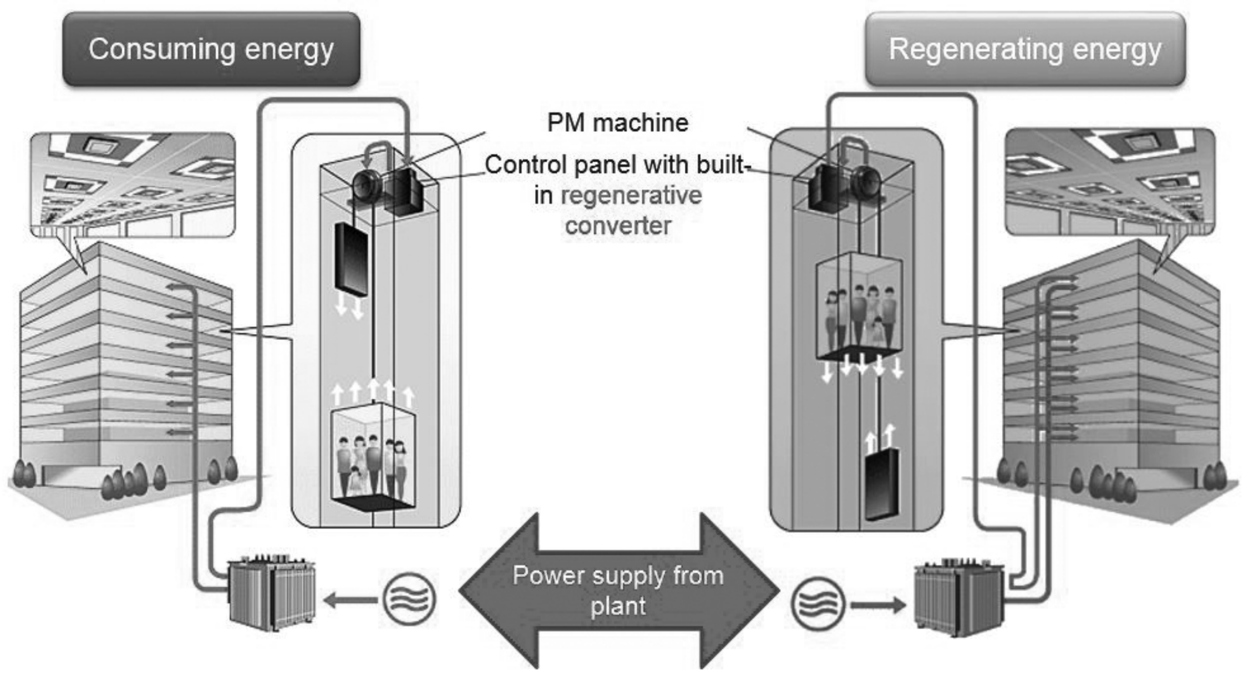


Figure 8b Principle of Regenerative Convertor

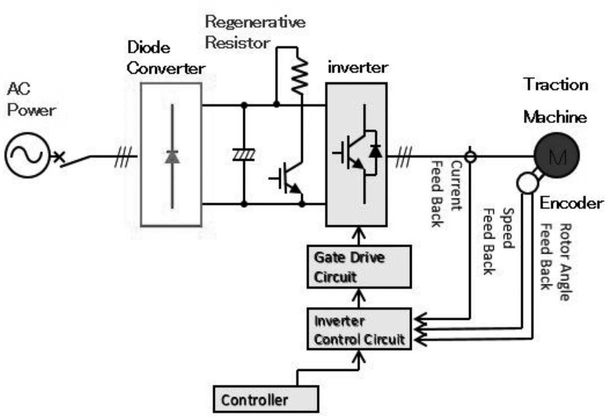


Before going into the details, we have to understand the design of the weight for the counterweight being used. Assume that the lift car dead weight and the rated capacity are P and Q respectively. The designed counterweight's weight shall be P+0.5Q (the common cases). That is to say, when the lift cabinet is full loaded, the lift car side shall be 0.5Q heavier than the counterweight. When the lift cabinet is empty, the counterweight shall be 0.5Q heavier than the lift cabinet.

So, when the full loaded lift cabinet is running from top to bottom floor or the empty lift cabinet is running from bottom floor to the top floor, this action is achieved by gravity and hence no electricity is consumed, in addition, even energy is generated.

When the VVVF motor drive system was introduced in 1990's, the regenerative braking energy is consumed by using resistors. Its operating principle is illustrated in Figure 9.

Figure 9 Regenerative Braking



Around the end of 1990's, the VVVF technology enables the regenerative convertor to convert the regenerated power, with the proper phase angle and acceptable harmonics, back to the main switch. Figure 10 shows the schematic diagram of the operation. It is noted that the regenerative power is fed to the main switch that providing power supply to the lift. That is to say, no special provision is required at the supply side.

Figure 10 New Type of Regenerative Convertor

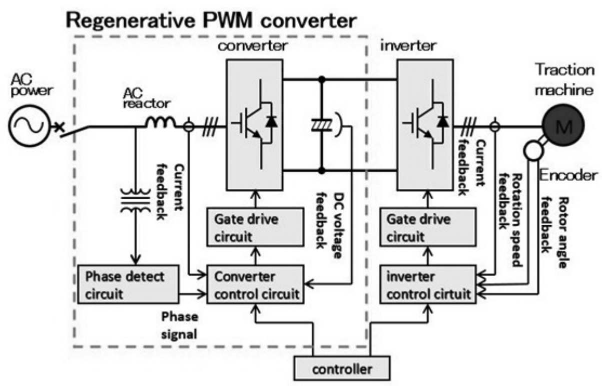


Figure 11 shows the experimental results of the amount of regenerative power generated in commercial buildings and residential buildings. It is interesting to observe that the percentage of regeneration is different between commercial and residential buildings. It is because the amount of regenerative power depends on the traffic pattern. For commercial buildings, the traffic pattern is distinct. During lunch time and after office hour, there are many chances to run in full load down and it is regenerative. However, for residential buildings, the traffic pattern is relatively scattered. As a result, the regenerative power is generally lesser for residential buildings.

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Figure 11 Amount of Regenerative Energy

Project	Commercial Building A	Commercial Building B	Commercial Building C	Commercial Building D
Capacity	1800kg	1600kg	750kg	900kg
Speed	8.0m/s	6.0m/s	3.0m/s	3.5m/s
% Regenerative Energy (24 hours measurement)	45.8%	43.4%	21.6%	27.7%

Note:
Definition of Percentage of Regenerative Energy:
Total energy generated in regeneration mode divided by total energy consumed in motoring

4. TRAFFIC EFFICIENCY

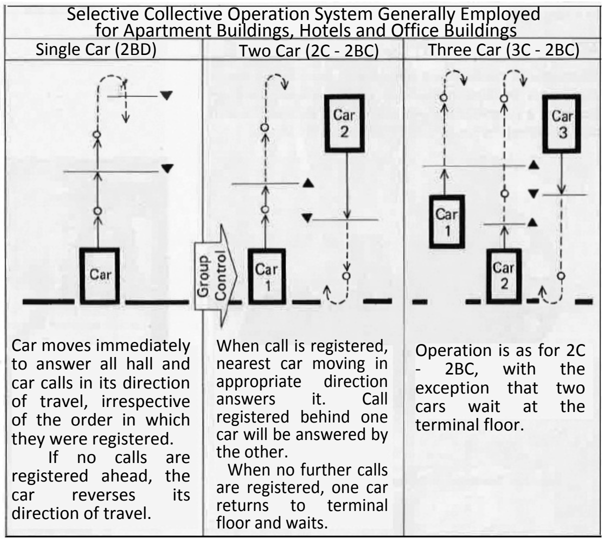
In this section, we are going to discuss 3 generations of group control, namely, 2BC, OS-75 and the most advanced ∑AI-2200C. Group control system can exhibit its function when there are 3 elevators or more being used in the building.

4.1 2BC

This is the most basic group control system being used in 1970's. 2BC means 2 Buttons selective Collective.

When a car is travelling up, it will stop at all floors for which car or hall up calls are registered. Down hall calls have no effect to the car which is travelling up. However, the down hall calls will be answered by another car which is travelling down. Then the car will answer the highest down hall call provided that there is no car or hall up calls registered above. After the last passenger has left and there are no calls registered above, the car will reverse automatically. This is called Highest Call Reversal feature. For handling down calls, the manner is similar and it is called Lowest Call Reversal. Figure 12 shows the concept. This is a simple looping system.

Figure 12 Call Reversal Feature



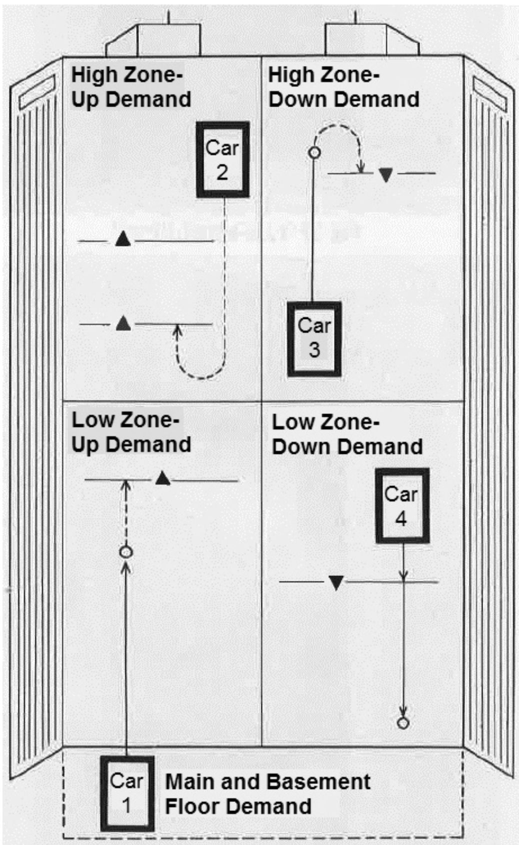
4.2 OS-75

OS means Optimum Service which was widely used in 1980's. At that time, it was the more advanced technology compared with 2BC system. In this group control system, the served floors are classified as different demand zones. Figure 13 shows the concept.

The operation principle is that when an available car is assigned, it will go directly to the assigned zone without stopping at other demand zones and will offer service to the calling floor in that demand zone. This would enable the following features:

- The registered demands are successively handled according to the priority order below:
  - Top floor extension demand
  - Main floor and basement floor demand
  - High zone down demand
  - Low zone up demand
  - Low zone down demand
  - High zone up demand

Figure 13 Optimum Service



- An assigned car expresses to the calls in the assigned zone. And then successively offers service to other landing calls in the assigned zone.

- When a car has finished servicing the landing calls within its assigned zone and enters another zone to answer a car call, it also offers service to the landing calls in the new zone.

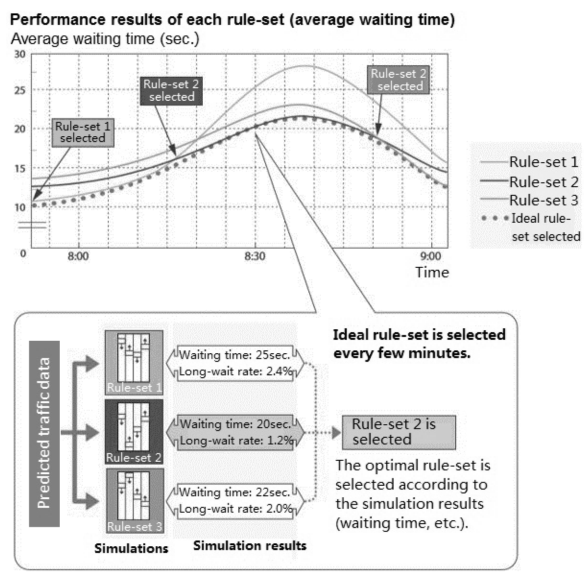
- A car which has finished answering all calls closes its doors at the last floor would become an available car and waits at that location for its next assignment.

With the above operation features, OS-75 can make optimum demand handling and car assignment, and calls being kept waiting for a long time are virtually eliminated. It is because the determination and car assignment is done by classifying the service floors into “up calls” and “down calls”. The services for up, down high zone and low zone are well balanced.

4.3 ∑AI-2200C

∑AI-2200C is an artificial intelligence system for elevator group control. With the rapid development of the strong computational power, many rule sets can be programmed in the computer. The predicated traffic demand is put into the simulator. By applying different rule sets, the average waiting time can be simulated. Then, of course, the appropriate rule set will be selected and implemented with the minimum average waiting time. Figure 14 shows the concept.

Figure 14 ∑AI-2200C



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Features of New Group Control:

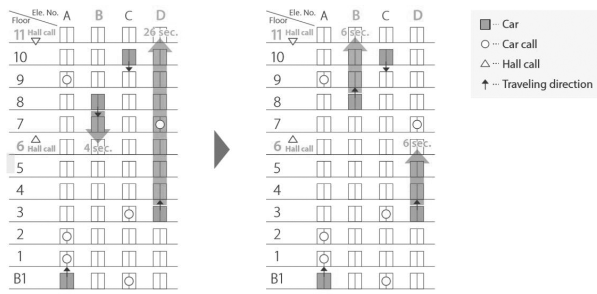
i. Cooperative Optimization Assignment

In the allocation control, a new registered hall call and the hall calls already allocated are the targets of evaluation. In this algorithm, a virtual hall call named "risky call" is assumed although it is not yet realized. All the calls (risky call + new call + calls already allocated) are evaluated as a whole.

An example is illustrated in Figure 15. This figure indicates the situation in which an upward hall calls in whole building, including the "risky call", are evaluated in advance.

- In the left hand side, Lift B can respond to the call from 6th floor. Therefore, Lift B is allocated in the conventional system.
- However, when a hall call is registered on 11th floor immediately after the allocation of Lift B, it takes the waiting time longer, even though the Lift D would respond. This virtual hall call from 11th floor is the "risky call" mentioned above.
- In the right hand side, in the new method, Lift D is allocated to 6th floor in the upward direction in consideration of the above situation. As a result, the Lift B can respond promptly, even if a hall call is registered on 11th floor.
- In this way, the new method achieves the optimized operation which makes multiple cars cooperate, and it keeps the traffic efficiency being improved, even if a call is registered in any floor of the building.

Figure 15 Cooperative Optimization Assignment



ii. Energy Saving – Allocation Control

When a hall call is registered, ∑AI-2200C predicts energy consumption in power running and regeneration, in addition to the waiting time, predication errors, etc. It achieves energy saving by allocation control, which assigns a car with less energy consumed than others.

Furthermore, it could consider that energy saving is important in off-time while waiting time is important in traffic peak time, so that it can keep users convenience, regardless of energy saving.

Figure 16 shows the example in which a new down hall call is registered at the 6th floor of a 9-floor building with 4 cars.

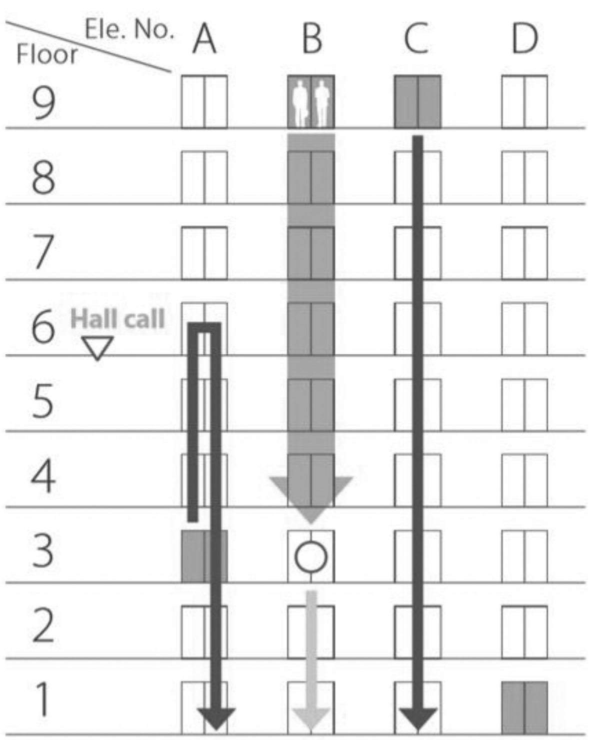
- Waiting time is almost the same in any car that Lifts A, B and C serve the new down hall call. Lift D is not considered since the waiting is the longest.

- The following analyzes energy consumption in case that it assigns Lifts A, B and C.

  • Lift A: Energy consumption is more in running from 6th floor to 1st floor. (It runs far from balance against counterweight because less passengers ride in Lift A.)

  • Lift B: Energy consumption is less in running from 3rd floor to 1st floor. (It runs with balancing itself against counterweight because passengers have already ridden in Lift B.)

Figure 16 Allocation Control



- Lift C: Energy consumption is more in running from 6th floor to 1st floor. (It runs far from balance against counterweight because less passengers ride on Lift C.)

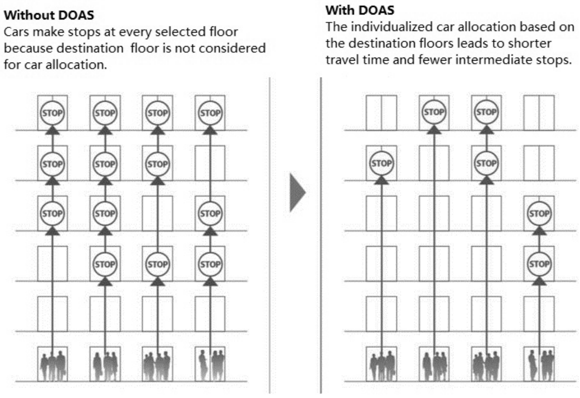
∑AI-2200C will then assign Lift B to the new down hall call in view of energy consumption.

4.4 DESTINATION ORIENTED ALLOCATION SYSTEM (DOAS)

The principle of DOAS is simple. In conventional system, for example, at main floor, passengers register an UP hall call. When the lift car arrives, passengers going to different floors enter the same lift car and hence making the lift car stops at different floors.

However, for DOAS, the group control system can know in advance the destination of each passenger so that the passengers can be assigned to different lift car. In doing so, passengers going to the same floor will be assigned to the same lift car. Finally, the number of stops of the lift car can be significantly reduced. Figure 17 shows the concept.

Figure 17 DOAS



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DOAS could be integrated with security gate. By the combination of the card reader, DOAS LCD indicator and the security gate, seamless operation can be achieved.

Figure 18a LCD Indicator

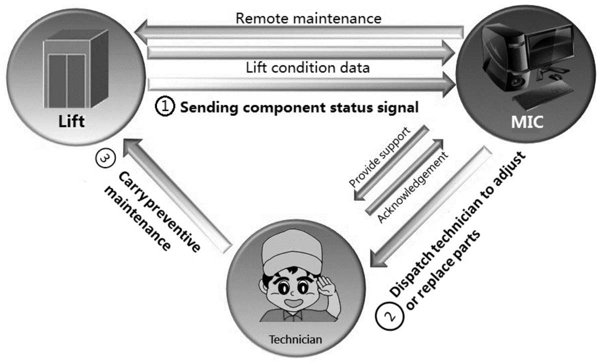
Figure 18b Security Gate

5. MAINTENANCE EFFICIENCY

IoT (Internet of Thing) becomes a hot topic in the recent years. As the elevator control is already computerized, migrating its operation information to the Information Technology is without difficulty.

What we can do is remote monitoring and maintenance. In Mitsubishi, we call "ELE-First". Figure 19 shows the system flowchart.

Figure 19 ELE-First System Flow Chart



First of all, the control panel is supposed to be computerized type. An electronic device is installed on top of the computerized control panel. The electronic device would retrieve the operating data of the whole elevator system and send back to the MIC server (MIC interprets as Mitsubishi Information Center), which is a computer server located at the elevator maintenance company, through reserved telephone line.

Figure 20 MIC Server Located at Maintenance Contractor's Callback Center

The retrieved operating data includes, but not limited to:

- Brake operation conditions
- Main contactors operation conditions
- Door/ push buttons/ car door lock operation conditions
- Landing door lock operation conditions
- Safety switches conditions
- Leveling accuracy
- Rated speed stability
- etc.

After knowing the status of the operation system, the maintenance efficiency would be improved which is explained as follows.

i. In normal practice, routine maintenance service is done twice every 4 weeks by our technicians. By deploying this system, ELE-First can allow to skip one routine maintenance visit. It is because ELE-First can continuously monitor several equipment/ components conditions. Its monitoring ability even can be more powerful than what the technicians can do. For example, the system can sense the conductivity of relays/ contactors, correct status of sensors/ micro-switches and abnormal temperature increase of major equipment. By skipping one routine maintenance service, the usability of the elevators can be increased (no need to suspend the elevator for maintenance).

ii. Since the monitoring is continuous, the following examples show the merits:

- Door Operation: ELE-First can sense and count any unsmooth door operations, such as door motor current abnormal increase, bad conductivity of limit micro-switches etc. This information is then sent back to the MIC server for further analysis by the engineers. After this, the maintenance technicians can focus on that landing door maintenance in next routine maintenance visit. The advantage is obvious. Firstly, before the breakdown happens, we can clear the defects in advance. Secondly, we can save our time to check and identify the problematic landing doors.

Figure 21 Landing Door Maintenance

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- Motor Encoder: ELE-First can compare the encoder (installed at motor end) output with the calculated/ anticipated curve. If there is any abnormality, the maintenance technicians can rectify the situation in next routine maintenance visit, before the breakdown happens.

From the above examples, we can recognize that ELE-First can reduce the chance of breakdown and increase the usability of elevators.

Figure 22 Comparison of Performance Data Before and After Adopting ELE-first

	One Year "Index Figure" Before Deploying ELE-First	15-month "Index Figure" After Deploying ELE-First	Improvement %
Recovery Time after Breakdown (minutes)	100	83	16.5% Reduced
Breakdown Rate	1	0.268	73.2% Decreased
Entrapment Rate	1	0.786	21.4% Decreased

6. CONCLUSION

To conclude, through elevator modernization, we can have a great improvement in regard to the energy efficiency (saving the electricity), traffic efficiency (reduce the passenger's waiting time) and maintenance efficiency (reduce breakdown and increase the usability).

Figure 23 Improvement through Elevator Moderization

Last but not least, through modernization, the replaced equipment will fulfill the up-to-date code of practice and finally improve the safety.

NOTE

Modernization means by replacing some of the major components of the elevator to the result that the elevator can behave or closely behave as a new elevator in regard to the control system and efficiency aspects. It is different from total replacement of an elevator.

Paper No. 7

THE FUTURE OF THE CITY BUS – A POTENTIAL SCENARIO

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THE FUTURE OF THE CITY BUS – A POTENTIAL SCENARIO

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ABSTRACT

Back in 1879, Werner von Siemens presented the first electrically powered locomotive at the Berlin Industrial Exposition. This was followed 18 years later by the first meeting of the newly established Central European Motor Car Association in Berlin. The association's president, Adolph Klose, said the following at the conference: "We can observe three different types of motor cars at the moment: vehicles powered by steam, internal combustion engines, and electricity."

In other words, different drive systems were competing against each other at the dawn of the 20th century. Electric drives established themselves in trains but not in cars, which were soon dominated by gasoline engines. The main reasons for this were as follows: First, continual improvements to engines led to ever-higher vehicle speeds. Secondly, gasoline was a cheap fuel and, finally, gasoline engines had a greater range than electric motors because the latter were powered by weak batteries.

1. EIGHTY PERCENT ELECTRICS AND HYBRIDS BY 2050

Fast forward one hundred years or so and things are now very different, which is why electric vehicles are making a comeback on all levels. For one thing, combustion engines generally run on fossil fuels whose supplies are finite. In addition, global population growth and increasing industrialization in emerging markets are driving up demand for oil. As a result, prices for oil and other raw materials will rise over the medium and long term. New solutions and alternative drive systems are thus needed in order to compensate for the scarcity of fossil fuels and reduce the negative environmental impact of their emissions. The International Energy Agency's (IEA) “BLUE Map Scenario,” whose goal is to cut greenhouse gas emissions in half by 2050, estimates that nearly 80 percent of the cars sold by 2050 will be plug-in hybrids, electric vehicles, or fuel cell cars.

2. THE FUTURE OF MOBILITY IS ELECTRIC - DRIVE TECHNOLOGY AND CHARGING SOLUTIONS FOR SUSTAINABLE FUTURE MOBILITY

In addition to industrial applications, trains or mining trucks, Siemens also electrifies commercial vehicles, buses, and cars. Our drive and charging solutions for hybrid and electric vehicles are helping automobile

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manufacturers around the world to meet their CO_2 targets. Electrified city buses make urban traffic quieter, cleaner, and cheaper for operators.

Two factors, in particular, are expected to give electric mobility a boost: On the one hand, fuel prices will continue to rise because the availability of oil is finite, while, on the other, the rapid increase in automobile traffic worldwide is a key driver of climate change. Because there is no simple way to achieve electric mobility, manufacturers are working on a variety of solutions.

3. ELFA – THE ECONOMIC AND INTELLIGENT WAY TO ZERO EMISSION

Innovative traction systems from Siemens are an essential element in sustainably addressing these complex challenges. Such as ELFA the modular electric hybrid traction system with the highest degree of flexibility. It allows vehicle manufacturers to individually configure the hybrid drive, which in turn allows operators to run city buses and all types of commercial vehicles with reduced energy, favorable costs

Table 1 Variety of Drive System Concepts

Variety of Drive System Concepts

Hybrid (Hybrid electric vehicle - HEV)	The key feature in a HEV is an additional electric motor that supplements the conventional combustion engine. Surplus energy, such as that generated during braking, is stored in a rechargeable battery.
Mild hybrid	In a mild hybrid,the electric motor merely supports the combustion engine; purely electric driving isn't possible.
Full hybrid	A full hybrid can travel short distances on electricity alone.
Plug-in hybrid (Plug-in hybrid electric vehicle - PHEV)	A plug-in hybrid can be recharged at a power socket. Put simply, a plug-in hybrid is a mixture of a full hybrid and an electric vehicle.
Range extended Electric vehicle (Range extended electric vehicle - REX)	A range-extended vehicle is powered exclusively by electric motors. The additional combustion engine it's equipped with is used primarily to generate electricity: It recharges the battery while the vehicle is moving. As the name suggests, the vehicle's range can be considerably extended as a result.
Battery-operated electric vehicle (Battery electric vehicle-BEV)	A battery electric vehicle is powered solely by electric motors that get their electricity from a traction battery.
Fuel cell vehicle (Fuel cell vehicle - FCV)	This type of vehicle is powered by an electric motor that gets its electricity from a fuel cell system that converts chemical energy into electricity.

and low emissions. At the same time, comfort for passengers and drivers is noticeably increased. Summing up – a solution that addresses all requirements.

4. BENEFITS AT A GLANCE

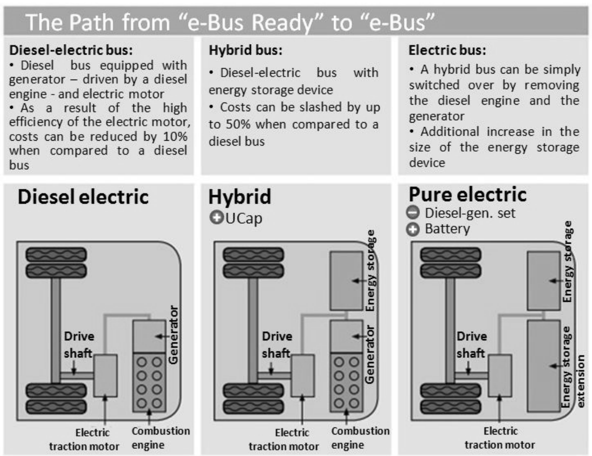
- Significantly reduced energy consumption and emissions
- Zero-emission operation in inner city areas possible
- Noticeable reduction in noise
- Greater comfort thanks to gentle, smooth start-up
- Extremely reliable and low-maintenance traction systems
- A single source for all components: the motor, generator, inverter, and controller
- Modular hybrid system for maximum flexibility and cost-effectiveness
- Proven technology
- Futuristic

5. FROM DIESEL ELECTRIC TO HYBRID TO FULLY ELECTRIC (EBUS). WITH SIEMENS ELFA "YOU CAN".

In the future, city buses will operate completely electrically as a result of increasing emissions in inner-city zones.

Flexible Siemens ELFA traction systems already allow city buses to be operated with diesel-electric drives without requiring any additional infrastructure. The charging infrastructure required for purely electric buses can be established in parallel. With relatively low associated costs, diesel-electric buses can be modified to become purely electric. This allows a gradual entry into pure electric bus operation. These buses are "eBus ready"!

Figure 1 The Path from "eBus Ready" to "eBus"



Paper No. 8

ENHANCEMENT OF E&M SYSTEMS AND RAILWAY OPERATION EFFICIENCIES OF NEW RAILWAY PROJECTS IN HONG KONG

Speaker: Ir William K.F. Lee
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MTR Corporation Limited

ENHANCEMENT OF E&M SYSTEMS AND RAILWAY OPERATION EFFICIENCIES OF NEW RAILWAY PROJECTS IN HONG KONG

Ir William K.F. Lee
Engineering Manager - Services
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ABSTRACT

As about 5.5 million passengers on average ride on the railway systems in Hong Kong each weekday, high efficiencies of E&M systems and railway operation systems under normal and emergency conditions are required to ensure passenger safety and meet passengers' demands. Also continuous enhancing the efficiencies of these systems is essential to the sustainability of the railway systems in Hong Kong.

Five railway projects, namely West Island Line, South Island Line(East), Express Rail Link, Kwun Tong Line Extension and Shatin to Central Link, are being delivered by MTRCL in different districts of Hong Kong. In order to enhance the efficiencies of E&M and railway operation systems, new design requirements or systems have been applied or specified in the E&M systems for these railway projects.

Some of the technologies, systems and equipment which have been applied or specified in the E&M systems for the projects, including Power Supply System, Overhead Line System, Lift and Escalator Systems, Environmental Control Systems, Automatic Fare Collection System, Main Control Systems, Communications Systems and Rolling Stocks, for the five railway projects will be introduced in this paper.

1. INTRODUCTION

To meet the growing demand and public expectations of railway services in Hong Kong, the efficiencies of the railway systems are being enhanced continuously.

For protecting the environment by reducing the greenhouse gas emission, many initiatives to save energy have been implemented in the railway systems in Hong Kong and new ways to reduce energy consumption are continued to be found. The efforts focus on improving the energy efficiency of the E&M systems of the railways and make the very efficient system even more efficient.

To further enhance the efficiencies of E&M systems and railway operation systems under normal and emergency conditions, new design requirements or systems including overhead rigid conductor rail system (ORCR), Energy Storage System (ESS) for Traction System, Efficiency Enhancement Features for Lifts & Escalators, Oil-free Chillers with Variable Speed Drives, District Cooling System, Remote-In-Saloon CCTV (RISTV), Decision Support System (DSS) and 3-in-1 Ticket Machine have been applied or specified in the E&M systems for new railway projects in Hong Kong.

2. ENHANCEMENT OF EFFICIENCIES

2.1 OVERHEAD LINE SYSTEM

The conventional overhead catenary system for both 1500V d.c. traction system and 25kV a.c. traction system have been used in the existing railways of MTR in Hong Kong for over 30 years.

Another type of overhead line system which is the overhead rigid conductor rail system (ORCR) has now been increasingly used in the tunnel sections of underground metro system in Europe, Mainland China and South Korea. The non-tension and low resistance characteristics of the rigid conductor rail system have advantages in enhancing and improving various aspects including energy efficiency, reliability, maintainability and availability of the overhead line system. There is no tensioning device such as balance weight assembly and associated termination accessories for the ORCR system. Overhead rigid conductor rail system has been used or specified in the new MTR extensions including West Island Line, Kwun Tong Line Extension, South Island Line (East) and Shatin to Central Link.

The ORCR system comprises an aluminium conductor profile with a copper alloy grooved contact wire inserted with special conducting grease at the bottom pinch. This profile bears similarity to the messenger wire in conventional overhead catenary system (OCS) in supporting the contact wire and has been standardised among different manufacturers. Other components include roof-mounted or catenary support and ORCR/OCS transition section.

The benefits of the ORCR system are:

- Improved reliability - The aluminium conductor profile as well as the contact wire need not be in tension to maintain the required level. Thus there is no tensioning device such as balance weight assembly and associated termination accessories for the ORCR system. The system is simple and robust.

- Improved availability - Standard length of rigid conductor section is 12m. The recovery time will be comparatively short after damage.

- Improved energy efficiency - The continuous current rating of the standard rigid conductor rail, i.e. the aluminium conductor profile with the single contact wire is 3,000A. This capacity is particularly advantageous for metro with 1500V d.c. system where high current capacity is required. The total resistance per km at 20^{o}C is 0.0137 ohm/km. But for the 1500V d.c. 3000A OCS, the total resistance per km is 0.0221 ohm/km. That means the copper loss of ORCR system is about 40% less than OCS for 1500V d.c. system due to its lower resistance.

2.2 POWER SUPPLY SYSTEM

Regenerative braking has been widely adopted as a standard measure in modern metro systems in recouping braking energy from Electric-Multiple-Units (EMUs). When the train frequency is low coupled with many uphill / downhill sections in the alignment, nevertheless, regenerative braking alone will be ineffective in recycling braking energy.

South Island Line East (SIL(E)) is a new 1500V d.c., standalone, metro line currently being constructed. It is a medium capacity metro with 5 stations. The route length is about 7km with a long tunnel section of about 3.5km. Throughout its alignment there are many uphill and downhill segments. With a much higher headway of 215 seconds (i.e. lower train frequency) during peak hours for the initial operation years, the occurrence of regenerative failures will be much more frequent especially during non-peak hours, implying much lower utilisation of regenerated energy.

To address this problem Energy Storage System (ESS) has been utilised to enhance the effectiveness of the recycling of braking energy. ESS with Electric Double Layer Capacitors (EDLC) has been adopted in SIL(E) to store the surplus braking energy for later reuse by this or other motoring EMUs. Energy flows from a braking train to the ESS, and flows from ESS back to a powering train. EDLC ESS's have been installed at Admiralty Station (ADM) and Lee Wing Street Ventilation Building (LWB) Traction Substations and the energy storage capacity is 20MW.s per unit.

EDLC's are also known as super-capacitors. They have much higher capacitance then traditional capacitors over the same volume. A super-capacitor has high power density and can absorb / discharge large amount of electrical energy over a short duration and can repeatedly charge and discharge up to a million cycles. Moreover, they are virtually maintenance free and pose very low fire hazards. The design life will be up to 15 years.

Based on simulation and assessment, the introduction of the ESS will have the following tangible and intangible benefits during the life-time of the system:

- Expected Annual Traction Energy Saving : 6.5% - 11.5%;
- Saving in the capital and maintenance cost of one rectifier transformer;
- Saving in braking system maintenance;
- Reduce a few hundred tons of CO_2 emission per year ;
- Reduce unpleasant smell generated during frictional braking.

2.3 LIFTS AND ESCALATORS

Efficiency enhancement features have been adopted or specified in the lift and escalator systems for new railway projects.

For lift system, the energy efficiency enhancement features include:

- Power regeneration feature - The induced electric power during upward/downward movement of the lift by braking torque at motor will be regenerated back to the main power line via appropriate inverter and converter which will be used up by other lifts operating at the same lift bank or by other E&M systems;
- High efficiency PM motor - Motor efficiency is greater than 90%;
- 'Sleep' mode for non-peak hours or long idle period - The lift will be automatically set in 'sleep' mode with car lighting and ventilation fans switched off when the lift is idled

over a preset period of time to reduce energy consumption. The lift will resume service once a landing call is received;

- Energy efficient car lighting - Lift car lighting will be provided with energy efficient lights and all the indicators with low energy consumption will be used;

- Lift car decoration weight reduction - Light weight material will be used for lift car decoration to reduce the dead weight of the lift car for unnecessary wastage of motor power.

For maintenance efficiency enhancement, Condition Based Maintenance System (CBMS) for motor bearings and gearbox has been adopted. CBMS provides a comparison of vibration profiles with initial condition to predict the bearing life. With this information, preventive maintenance can be carried out when required.

For escalator system, the energy efficiency enhancement features include:

- Power regeneration feature - The surplus electric power during preset downward movement of the escalator will be regenerated back to the main power line via appropriate inverter and converter which will be used up by other escalators operating at the same escalator bank or by other E&M systems;

- ‘Energy saving mode for long idle period - Subject to station environment, individual escalator will be equipped with energy saving mode that switches automatically from the rated speed to a lower speed (crawl speed) in case of long idle period to avoid unnecessary consumption of energy. The escalator will then pick up to the rated speed promptly upon detecting an approaching passenger;

- Adoption of escalator with lower speed for location with low patronage.

Condition Based Maintenance System (CBMS) for motor bearings and gearbox is also adopted for maintenance efficiency enhancement.

2.4 ENVIRONMENTAL CONTROL SYSTEM (ECS)

(a) Application of Oil-free Chillers

For the Environmental Control System (ECS), it consumes a significant energy among the entire MTR building services system. The two major functions of ECS are smoke extraction and air-conditioning. For air-conditioning system, it composes of chilled water circuit, VRV, split type AC units and some other equipment, and chiller is considered the most important component of the chilled water circuit.

Nowadays, conventional chillers with mechanical bearing compressors are being used in most of the commercial and government projects but oil free chillers are increasing used. For the conventional chiller compressor, the refrigerant contains oil in order to lubricate the moving parts such as to minimize the friction between the shaft and bearings. But for the oil free chiller, the shaft is held in an operating position by magnetic field. There is a very small air gap in between the shaft and bearing so that the shaft does not touch with any other moving parts of the compressor. Therefore oil or any other lubricant is not required for an oil free chiller.

The benefits of oil-free chiller are summarized as follows:

- Breakthrough Energy Efficiency - The magnetic bearing compressor of oil-free chiller is equipped with Variable Seed Drive to deliver high energy efficiency especially when the unit is operating at part load conditions, resulting in great energy savings. The improvements in terms of efficiency and reduction in annual energy cost are maximised when there are long periods of part load operation;

- Increased Reliability - The frictionless magnetic bearing design needs no oil management system, resulting in increased reliability and reduced maintenance. With no oil to coat the heat transfer surfaces, a gain in heat exchanger efficiency can also be realized;

- Reduced Maintenance - The friction losses and the oil management hardware and controls associated with conventional oil-lubricated bearings are now totally eliminated. There is no need for components, such as oil pumps, oil reservoirs, controls, starter, oil valves, etc., that are needed to maintain oil quality. These devices can be a source of problems in conventional chillers, and removing them significantly increases unit reliability and reduces the maintenance efforts;

- Compact Design and Light Weight - The compressor weight and size of oil-free chillers are smaller than those of conventional chillers. This allows a compact design for the chiller unit. It is found that the average footprint and operating weight of oil-free chiller are both 36% less than conventional chiller respectively. Therefore, installing of oil-free chiller is able to reduce the plantroom sizes and structural floor loadings in order to allow higher flexibility of plantroom arrangement.

In all existing MTR stations, depots and ancillary buildings, conventional chillers have been installed. However, oil-free chillers have been specified and will be used in the Convention and Exhibition Centre Station of SCL. In addition, they will be used in existing Urban Lines for replacing exiting chillers under the Asset Replacement Scheme.

(b) Utilizing of District Cooling System

District cooling system (DCS) is a system in which chilled water is distributed in pipes from a central cooling plant to buildings for space cooling. The system contains three major elements, the central cooling source, a distribution system and customer installations.

A survey conducted by the International District Energy Association (IDEA) shows that district cooling systems have a documented reliability exceeding 99.94%, which is significantly more reliable than individual building cooling systems. It is because district cooling systems use highly reliable industrial equipment redundancy; it is staffed with professional operators around-the-clock; operators of the DCS are specialists with expert operations and it is maintained under preventive maintenance programmes.

For the latest Kai Tak District (KTD) DCS, the cooling capacities of the north and south plants are 162MW and

122MW respectively and the total design cooling capacity is 284MW. The total pipe-run within the site are approximately 40km in length. The expected number of DCS users are around 60 which include 2 SCL Stations, namely Kai Tak Station and Sung Wong Toi Station. MTRCL utilizes the DCS because MTRCL has a critical interest in reliability to keep the passengers enjoy the ride on MTR and to avoid dealing with problems relating to maintaining comfort.

The DCS have the following advantages:

High Energy Efficiency

When comparing DCS with traditional A/C systems in individual buildings :

- Save 20% energy when compared with fresh water-cooled chilled water system;
- Save 35% energy when compared with air-cooled chilled water system.

Reduction of Carbon Footprint

Save energy which lead to the reduction of CO_2 emission.

Reduction of Environmental Impact

- More adoptable than individual system to varying demand for air-conditioning;
- Noise, vibration and heat arising from individual plant could be reduced.

Sustainable Overall System Design

Enhance building / architectural design / function, better planned maintenance, reduce heat island effect, etc.

2.5 REMOTE IN-SALOON CCTV SYSTEM (RISTV)

Rolling stock nowadays will be equipped with an In-saloon CCTV System for video surveillance purpose. A trainborne video recorder will be provided to record the real-time video signal captured by each camera.

For railway lines in Fully Automatic Operation (FAO), such as SIL(E), a Remote In-saloon CCTV Monitoring System (RISTV) will be provided to enable remote monitoring of the saloon and train front conditions at the OCC and Depot, in particular during incident handling.

This RISTV comprises of the following key components:

- RISTV Trainborne interface with In-saloon CCTV System;
- A broadband wireless network (covering both running tracks and depots or sidings) which transmits the video signal from the In-saloon CCTV System;
- a RISTV server to process and record video signal transmitted;
- RISTV workstations at Operation Control Centre OCC and Depot Control Centre for remote real-time monitoring.

The key functions of the RISTV are:

- Real-time transmission and monitoring of any combination of live video from different trains (up to 4 cameras) ;
- Human Machine Interface with train map view for easy indication and selection of camera;

- Automatic video transmission from the corresponding camera will commence under the following conditions:

  (i) activation of trainborne Passenger Alarm Device (PAD);

  (ii) upon detection of abnormal events by Main Control System:
  - smoke detector alarm;
  - detrainment door opened (for end detrainment).

The benefits of adopting the RISTV system are:

- The RISTV support the need of speedy incident handling and recovery;
- All video transmitted through the broadband wireless network will be processed and recorded by the RISTV server (retention period is up to 7 days) which allows subsequent searching and playback to facilitate investigation and training.

This system will enhance the efficiency of incident handling and recovery as well as incident investigation.

2.6 DECISION SUPPORT SYSTEM (DSS)

During an emergency situation a control room can be flooded with information coming from many different sources and require immediate action from the controller. This can place an overload on the controller involved. The objective of a Decision Support System is to provide assistance to the controller in determining what the situation is and what course of actions shall be taken in response. Enhanced Decision Support System is required because of:

- Complex station and track environments;
- Complicated railway electrical and mechanical systems;
- Complex railway rules and procedures;
- Busy communication with the relevant internal and external parties during incident handling;
- Enhance efficient and proper handling of incident and service recovery.

Within a control room environment two main functions are served, to communicate and pass information to the relevant parties and to take actions to control particular items of equipment appropriate to the situation. To assist the controller, the DSS will provide an indication of the communication tasks to be performed and guide the controller through the decision process for different control actions. The DSS will also present these tasks in a manner that supports the sequence or time frame in which they shall be performed.

The Enhanced Decision Support System (DSS) consists of procedural check list tool for incident handling (retained), an emergency telephone directory, schematic diagrams of major E&M systems, video clip showing track view, etc.

The DSS will enhance the efficiency of incident handling.

2.7 Automatic Fare Control System

Each type of existing AFC equipment only support single function per equipment type:

- Ticket Issuing Machine (TIM) - Single Journey Smart Ticket (SJST) vending;
- Add Value Machine (AVM) - Add value on Octopus;
- Enquiry Machine (PNP) - Enquiry on Octopus.

For the new 3 in 1 ticket machine, all 3 functions are available.

New features of 3 in 1 ticket machines include:

- Multi-function machine - Single Journey Smart Ticket vending, add Value to Octopus Card and Enquiry on Octopus & SJST;
- Accept cash & Octopus for payment for Single Journey Smart Ticket vending:
    - Accepting cash: maximum 15 coins ($10, $5, $2, $1 & 50c) and max. 15 banknotes including $10, $20, $50 & $100;
    - Change return can contain $10 and $20 dollar banknotes;
    - A customer can buy maximum 10 Adult and 10 concession tickets at one transaction;
    - New add value holding module (support Hit-N-Go) which supports irregular shape Octopus products, e.g. NFC phone, watch etc.

Efficiency has been improved:

- Execute multiple transactions at one machine which save passengers' time;
- Reduce maintenance and operational efforts due to reduced number of machine types and less coins and banknotes handled.

3. CONCLUSION

New design requirements or systems including ORCR, Energy Storage System for Traction System, Efficiency Enhancement Features for Lifts & Escalators, Oil-free Chillers with Variable Speed Drives, District Cooling System, Remote-In-Saloon CCTV (RISTV), Decision Support System (DSS) and 3-in-1 Ticket Machine have been applied or specified in the E&M systems for new railway projects in Hong Kong. With them, both the E&M system efficiencies and operation efficiencies under normal and emergency conditions have been or will be enhanced.

However, as passenger safety is of the highest priority for railway operation in Hong Kong and to meet passengers' demand for better services, continuous enhancing the efficiencies of E&M systems and railway operation systems is required and essential to the sustainability of the railway systems in Hong Kong. New technologies and products are being explored to further enhance the efficiencies of railway services.