THE HONG KONG INSTITUTION OF ENGINEERS ELECTRICAL DIVISION

The 29th Annual Symposium

Tuesday

18th October 2011

FRONTIER OF CARBON NEUTRAL ELECTRICAL TECHNOLOGY

at

Ballroom

Sheraton Hotel

Nathan Road

Kowloon

Hong Kong

SYMPOSIUM PROGRAMME

08.30 Registration and Coffee

09.00 Welcome Address

– Ir Dr K.M. Leung
Chairman, Electrical Division, The HKIE

09.05 Opening Address

– Ir Dr F.C. Chan
President, The HKIE

09.10 Keynote Speech

– Mr Jilong Pu
Committee Member
National Nuclear and Radiation Safety
Expert Committee, PRC

1. Power Plant and Network

09.40 Smart and Green Grid

– Mr C.M. Kwan
Senior Smart Grid Development Manager
CLP Power Hong Kong Limited

10.00 Development of an Offshore Wind Farm in Hong Kong

– Ir Frank F.H. Lau, General Manager (Projects)
– Ir Y.L. Kwan
Chief Mechanical Engineer, Projects Division
The Hongkong Electric Co. Ltd.

10.20 Discussion

10.50 Coffee Break

2. District Cooling and PV

11.20 Engineering Design for Power Supply to District Cooling System

– Ir S.K. Lo, Senior Engineer
Electrical & Mechanical Services Department
The Government of the HKSAR
– Ir Simon F.W. Chung, Director
– Ir Barry K.P. Lau, Associate
Ove Arup & Partners Hong Kong Ltd.

11.40 High Concentration Photovoltaic: Cost Competitive Systems for a Sustainable Energy Production

– Mr Gianni Borelli
Senior Researcher & Product Manager
BECAR S.R.L. (Beghelli R&D Centre), Italy
– Mr Spes Stanley Ku, General Manager
Beghelli Asia Pacific Limited

12.00 Discussion

12.30 Lunch

3. Railway and Building

14.10 Mapping the Carbon Footprint of Electrical Railway Vehicles

– Ir Richard K.Y. Kwan
Manager - Environmental
MTR Corporation Limited

14.30 Integrating Low Carbon Electricity Networks with Low Carbon Buildings

– Mr Steven Mullins
Global Lead, Smart Grid and Mobility
Siemens Metering Services - Energy Sector

– Dr Vincent Thornley
Solution Manager for Smart Grid Applications
Siemens UK

– Dr Cristiano Marantes
Low Carbon Networks Development Manager
Future Networks, UK Power Networks

14.50 Discussion

15.15 Coffee Break

4. Carbon Neutral Initiatives

15.45 The Potentials of Energy-saving Solid-state Lighting

– Dr Anthony H.W. Choi
Assistant Professor
Department of Electrical and Electronic Engineering
The University of Hong Kong

16.05 Carbon Neutral - A Dream or Reality?

– Ir Albert W.K. To
Director
J. Roger Preston Ltd.

16.25 Discussion

16.45 Summing Up

– Ir Geoffrey L. Chan
Symposium Chairman
Electrical Division, The HKIE

Closing Address

– Ir Edmund K.H. Leung, JP
Chairman
Energy Advisory Committee
Environment Bureau
The Government of the HKSAR

Acknowledgement

The Electrical Division of The Hong Kong Institution of Engineers would like to express its sincere appreciation and gratitude to the following persons and organizations for their contributions to the Symposium :

Speakers / Authors

Mr Jilong Pu
Ir Edmond K.H. Leung, JP
Ir Dr F.C. Chan
Mr C.M. Kwan
Ir Frank F.H. Lau
Ir Y.L. Kwan
Ir S.K. Lo
Ir Simon F.W. Chung
Ir Barry K.P. Lau
Mr Gianni Borelli
Mr Spes Stanley Ku
Ir Richard K.Y. Kwan
Mr Steven Mullins
Dr Vincent Thornley
Dr Cristiano Marantes
Dr Anthony H.W. Choi
Ir Albert W.K. To

Sponsors

Siemens Ltd.
CLP Power Hong Kong Ltd.
The Hongkong Electric Co., Ltd.
Junefair Engineering Co. Ltd.
Kum Shing Group
The Jardine Engineering Corporation Ltd.
MK Electric (China) Ltd.
Schneider Electric (Hong Kong) Limited
Keystone Electric Wire & Cable Co. Ltd.
Ducati energia S.p.A.
Supremetech Engineering Co. Ltd. / ABB China Ltd.
MTR Corporation Ltd.
Greenland Engineering Co., Ltd.
Mitsubishi Electric (Hong Kong) Ltd.
TE Connectivity Hong Kong Ltd.
Wenden Engineering Service Co., Ltd.
Metrix Engineering Co., Ltd.
Chat Horn Engineering Ltd.
FSE Engineering Group Ltd.
Beghelli Asia Pacific Ltd.
Gammon E&M Ltd.
The Hong Kong & Kowloon Electric Trade Association
Hong Kong Electrical Contractors' Association Ltd.

29TH ANNUAL SYMPOSIUM ORGANIZING COMMITTEE

Symposium Chairman	**:**	**Ir Geoffrey L. Chan**
Members	**:**	**Ir Dr K.M. Leung**
		Ir Simon F.W. Chung
		Ir S.K. Ho
		Ir Gary C.W. Ko
		Ir Albert W.K. To
		Ir C.L. Leung
		Ir Stanley K.W. Leung
		Ir Mandy M.Y. Leung
		Ir C.L. Wong
Hon. Secretary and Treasurer	**:**	**Ir Y.K. Chu**

Paper No. 1

SMART AND GREEN GRID

Speaker : Mr C.M. Kwan
Senior Smart Grid Development Manager
CLP Power Hong Kong Limited

SMART AND GREEN GRID

Mr C.M. Kwan
Senior Smart Grid Development Manager
CLP Power Hong Kong Limited

Paper No. 1

ABSTRACT

Smart grid uses megabytes of data to move megawatts of electricity more efficiently, reliably and affordably. Through power grid modernisation, pervasive communications and information technology; a smart grid engages renewables at scale; improves reliability, security, and efficiency of an electric system from generation, through power grids to energy customers and a growing number of renewable energy. As they are developed and deployed, the smart grid technologies and applications will bring new capabilities to utilities and energy customers in keeping our environment green.

This paper will first describe the world-wide drivers and focuses on smart grid development, followed by CLP's energy vision, and finally the CLP definition on smart grid, strategic focuses, and phased approaches to transform our traditional grid into a "smart and green grid".

1. INTRODUCTION

Power grid, hailed as the most significant engineering achievement of the 20th century, continues to keep our lights on, our business productive and our energy users comfortable in hot summers as well as in cold winters. However, the grid was never built to respond to today's clean-energy challenges.

Compared to other industries like information technology and mobile phones, the power grid has been largely bypassed by technology innovation until relatively recently. Over the past few years, the utility industry has witnessed the progress on two fronts: i) the transition to the clean-energy economy, and ii) the centrality of strategic infrastructure investment and the engagement of customers to help utilities achieve their carbon emission reduction targets.

CLP has evaluated world-wide smart grid initiatives as well as their value propositions and established a Smart Grid Development Roadmap. Initially, CLP will focus on strategic areas such as integration with intermittent renewable energy sources, transmission and distribution network management, customer interaction, last-mile communication networks and information technologies. CLP already has various pilot projects, varying from self-healing systems for critical equipment through to advanced metering infrastructure and communication technologies.

2. WORLD-WIDE FOCUSES ON SMART GRID DEVELOPMENT

2.1 RE-ENERGISE ENERGY UTILITIES TO PROMOTE GREEN FUTURE

Smart grid deployment covers a broad array of power supply chain capabilities and business models enabled through pervasive communications and information technology.

By overlaying power grid with two-way digital communication, digital automation and smart meters to the grid, power utilities envisage real time monitoring and intelligent control from the power grid to customers' appliances in order to dynamically respond to many conditions of power imbalance. The smart grid also helps integrate more variable renewable sources of electricity, in addition to facilitating the use of electric vehicles and energy storage.

With the emerging clean-energy economy, integrating distributed renewable energies to the main grid has created a lot of system control and reliability issues. There is a new horizon for smart grid for managing distributed generation, including renewables, energy storages and micro-grids; encouraging innovation to spur the development of new green technology and business models.

Smart grids have been widely adopted by power utilities around the world as a way of addressing energy independence, global warming and emergency resilience issues. The main drivers of smart grid are:

- Reduce energy usage and carbon emission;
- Wisely use renewable energy;
- Improve supply reliability; and
- Optimise grid management.

2.2 THE SMART GRID TODAY

The evolution towards a 21st century grid is already taking place, but until now an end-to-end smart grid has yet to be fully developed. This finding reflects smart grid is still relatively new as compared to traditional power grid developments.

We have seen an influx of new smart grid technologies. And in this time we have also witnessed the continued deployment of millions of smart meters and communication networks across the U.S., Europe, Australia, Brazil and many other nations. In terms of focus areas, there are five main categories:

- Smart metering: Smart meter is a key component in demand-side energy conservation programme. Many utilities in the United States, Europe and Australia are deploying millions of advanced electric meters. Up to mid-2010, over 6.2 million smart meters were installed in North America. In Europe, Italy has the world's largest smart meter deployment. Up to 2010, 32 millions of smart meters are in place.

- Demand response: Making use of Smart Meter, Home Area Network (HAN) and Advanced Metering Infrastructure (AMI), demand response systems have been rolled out in the United States to save demand on peak days. By accessing and leveraging energy usage information, smart appliances reduce energy consumption by lowering their output during the peak-demand periods.

- Demand response (DR) helps consumers manage their energy consumption – 24-hours a day, 365 days a year – in a way that enables the effective use of the power grid and both renewable and traditional power plants. DR provides energy consumers the opportunity to adjust their power usage in real time in response to grid conditions or price signals. Typically thought to be about reducing energy usage, demand response is also about increasing demand when energy is plentiful and additional consumption can help balance the grid. The ISO is working with stakeholders to identify new DR opportunities and increase DR participation in the ISO markets.

- Grid modernization: China's vision in smart grid development is to build a "Strong and Smart Grid", one focus of which is to uphold reliability of the transmission networks integrating an Extra-High Voltage AC (500kV) and DC (±450kV) networks linking major resources (coal, hydro and renewables) and load centres. The State Grid Corporation of China said it will invest $590 million to Smart Grid through 2020. On distribution level, some other countries devote plentiful resources to distribution automation for changing loads and failure of the distribution systems, usually without operator intervention.

- Distributed energy resources: In Japan, wind generation reached 1,850MW in 2008 and solar power (photovoltaic panels) had reached 2,400MW in 2009. Since the Fukushima incident, smart grid developments in Japan have focused on large penetration of distributed energy resources, especially renewable integration and even micro-grids.

- Energy storage: Utilities worldwide, including US, Canada, South Korea and Sweden, are collaborating with research parties to design and implement highly reliable, cost-effective energy storage solution to complement with the intermittent nature of renewable energies, with the aid of advanced energy management systems through precision control and complex power capabilities.

3. CLP'S ENERGY VISION

In 2009, CLP published "Towards a Greener Pearl River Delta - A Roadmap for Clean Energy Generation for Hong Kong" to outline our vision for energy for the next ten years. We will play our part and work with all concerned parties to help the community achieve their aspiration for improved air quality in Hong Kong.

3.1 INFRASTRUCTURE INTEGRATION ENABLES CLEANER POWER

With economic cooperation throughout the Pearl River Delta (PRD) growing fast, infrastructure planning and development is becoming more integrated to support growth in both Hong Kong and Guangdong. Energy supplies are no exception - their integration is just as important as other infrastructural development, such as transportation.

CLP's electricity network is linked to Guangdong - it allows us to import nuclear power from Daya Bay and supply power from Hong Kong to Guangdong. In addition, an 800km pipeline between Hainan and the Black Point Power Station has been providing us with natural gas to generate cleaner power for Hong Kong.

As economic integration accelerates, strengthening electrical and energy infrastructure links between Hong Kong and the PRD will provide mutual benefits.

3.2 CLEANER FUEL MIX REDUCES CARBON FOOTPRINT

CLP has been using coal, natural gas and nuclear power to meet Hong Kong's demand for electricity. This fuel diversification strategy has enabled us to provide electricity in a reliable and environmentally responsible manner. In view of the challenge of climate change, we believe a well-balanced mix of cleaner fuel including natural gas and nuclear will be essential for allowing us to be less reliant on carbon-emitting coal and contribute to a greener Hong Kong.

Looking ahead, in order to further reduce our carbon footprint, we can expect the reducing use of coal which is mainly to meet demand fluctuations and as a back-up to ensure supply reliability in case of interruptions arising from the electricity transmission network in South China. Maintaining a certain level of coal-burning capability within our system is also important for reducing our exposure to gas or other energy supply interruptions or volatility.

3.3 PROMOTING LOCAL RENEWABLES COMBATS CLIMATE CHANGE

Recognising our role in the collective effort in combating climate change, CLP Group has been working towards de-carbonising its generation portfolio. Renewable energy is one of the technologies that will help us meet our targets. Our renewable energy efforts are not limited to electricity generation only; they also include supporting the public in their installation of renewable energy sources and their connection to the electric grid.

3.4 PROMOTING ENERGY EFFICIENCY CHANGES ENERGY CONSUMPTION BEHAVIOUR

Energy conservation plays an important role in the collective efforts against climate change. Recognising its importance, CLP Power has been raising awareness about the importance of using energy wisely through offering energy efficiency-related services and educating the public.

4. CLP'S DEFINITIONS OF SMART GRID

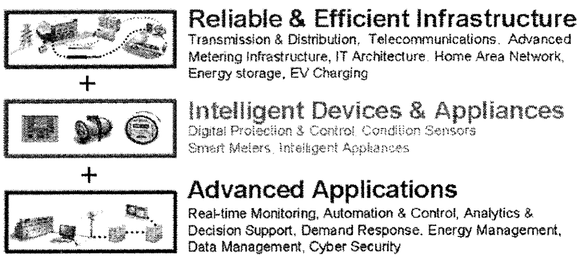
Although smart grid has been adopted by utilities worldwide, different countries and different utilities have yet to agree on a common definition of a smart grid.

CLP followed its Energy Vision and established CLP's definition of smart grid as follow:

"A reliable and efficient infrastructure that integrates with advanced applications, intelligent devices and appliances to enhance system

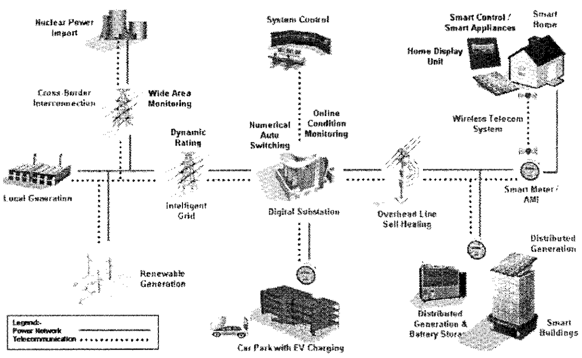
resilience against disruptions, engage customers in energy efficiency, accommodate renewable energy & energy storage, and optimise asset performance & investment."

Figure 1 CLP's Definitions of Smart Grid



The following picture illustrates the future CLP's smart grid.

Figure 2 High-level System Diagram of the Future CLP's Smart Grid



5. CLP'S COMMITMENT TO BUILDING SUSTAINABILITY INTO THE POWER GRID

In CLP Power, we believe only an end-to-end smart grid solution will bring the real benefit to whole society. CLP follows its Energy Vision and has established an end-to-end smart grid development roadmap. We already have numerous pilot projects in progress, varying from renewables to self-healing system for critical equipment and all the way down to smart home/commercial buildings. They will synergise efficiency programmes, demand response, renewable energy sources and distributed generation to a degree previously unattainable. The future CLP smart grid will enable energy users to exercise control over how and when they use energy to reduce carbon emission.

5.1 RENEWABLE ENERGY – ENABLING A CLEANER ENERGY FUTURE

Renewable energy (RE) comes from natural resources such as sunlight, wind, flowing water, tides, biological material and geothermal heat, which are naturally replenished. However, RE also has its weaknesses. It is difficult to generate sufficient electricity to meet the demand of power supply, often relies on the weather for its source of power. This can be unpredictable and uncontrollable.

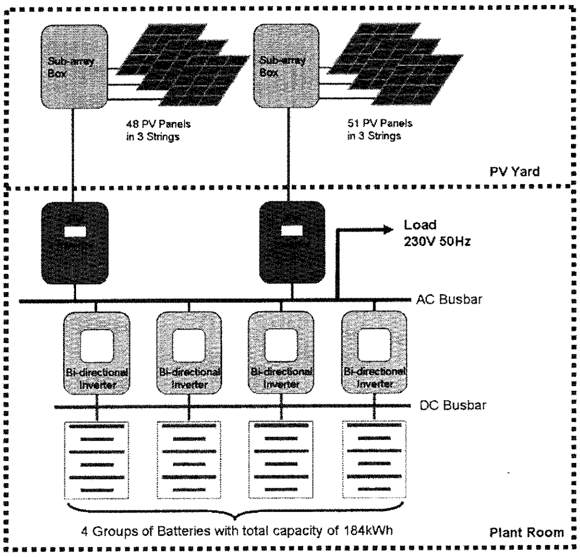
The best solution is having a balance of conventional power sources and renewable energies. Smart Grid can connect, predict, monitor, analyse, store and control unstable RE. Currently, CLP is implementing RE projects such as solar and wind power.

In early 2010, CLP commissioned the first commercial standalone renewable energy system in Hong Kong and delivers electricity to the residents on Town Island. The system supplies electricity by photovoltaic arrays with nominal capacity of 19.8kW. Further expansion of the renewable energy system in Stage 2 of the project is expected so as to meet the demand growth on the island.

The first stage of the system is now in service and relevant operating and ambient data are being collected. Further analysis of these data would provide more insight on the type of renewable energy system and facilitate future development of similar renewable energy installations in Hong Kong.

Figure 3 PV Yard on Town Island

Figure 4 System Schematic of Stage 1 Town Island Renewable Energy Supply System



5.2 SMART METER AND ADVANCED METERING INFRASTRUCTURE – LAYING THE FOUNDATION FOR CARBON SAVING

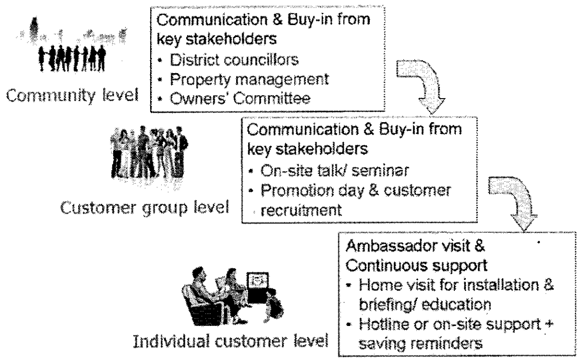
Advanced Metering Infrastructure (AMI) tightly integrates with smart meters to measure, collect and analyse energy consumption in intervals of an hour or less.

The collected consumption data will then be sent to a central Meter Data Management System (MDMS) via telecommunication networks either on a schedule or on request for consumption monitoring and billing purposes.

AMI could provide the ability for two-way communication between utility and energy users for demand response, remote connection/dis-connection, time-of-use tariff scheme, integrated voltage/VAr control, and potential use for outage detections.

CLP is piloting smart meter and AMI to test technology feasibility, explore its potential benefits to customers and the community, test technology feasibility, the acceptance and responsiveness of community and customers. An engagement programme has already been put in place to test the technologies and customer responsiveness.

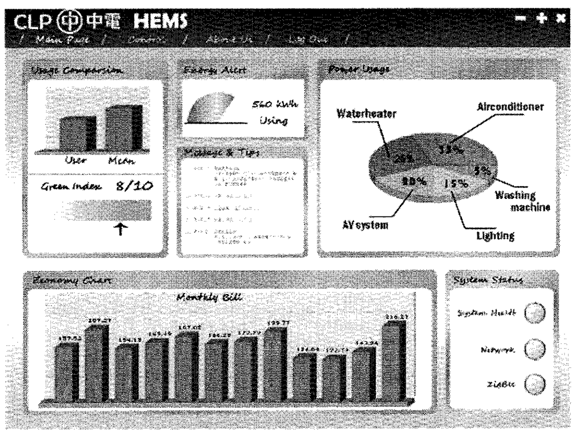
Figure 5 Engagement Programme for AMI Pilot Project



5.3 SMART HOME & SMART COMMERCIAL BUILDING – ENABLING GREEN POWER MANAGEMENT

CLP is exploring and piloting a series of advanced information exchange technologies such as AMI, Home Area Network (HAN) and Home Energy Management System (HEMS) to enable energy efficiency and demand response programmes.

Figure 6 CLP's Home Energy Portal



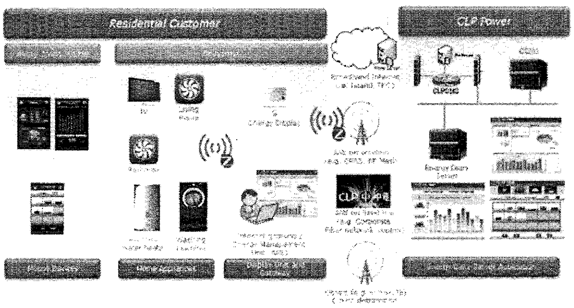
A typical HEMS could be broken down into four key areas: i) mobile device and application – allow users to monitor and control their energy usage and cost, ii) smart appliances and devices – collect and transmit energy consumption data generated by individual appliance, iii) communications – HAN and last mile communication network to enable bi-directional communication between customers and CLP, and iv) back-office

Paper No. 1

SIEMENS

information systems – process and analyse energy usage data for billing, remote management of appliance in real-time and further optimisation of customer energy efficiency.

Figure7 System Diagram of Home Energy Management System



The HAN comprises a home display unit and linkages to the energy user's various house-hold appliances such as air conditioners, heaters, washing machines and lighting systems. The network enables energy customers to manage energy consumption and energy costs of their home appliances more effectively. For example, on a cool day, the HAN would send a signal and your air conditioner will adjust temperature based on your preferences and reduce energy use. Some major home-appliance manufacturers have announced that they will make their entire electronically controlled appliances smart home compatible by 2015.

Home Display Unit (HDU) is a part of the HAN, energy customers can have a clear picture of energy consumption and usage patterns at home. This information can help them to improve home energy cost performance and keep the environment green by controlling the electric appliances and adjusting room temperatures remotely and/or automatically.

Reducing operating cost is a crucial part of commercial building management. With the development of smart grid and installation of building management systems, two-way data transmission between the commercial buildings and smart grid is made possible, with the application of latest communication and information technologies. This provides greater flexibility of regulating electricity demand of the buildings and improving energy efficiency, and ultimately driving the building's operating costs down.

CLP is piloting Distributed Energy Management System (DEMS) in some CLP's office buildings. DEMS automatically measures, forecasts and validates energy consumption according to floor area. The system bases on weather and energy demand to identify potential energy conservation measures and perform demand response. Since lighting and air-conditioning consume more than 50% of total energy consumptions in a commercial building, DEMS could, according to timing, weather and environment, wisely reduce the lighting intensity and raise temperature inside the building to achieve considerable energy savings.

5.4 ELECTRIC VEHICLES – DRIVING TOWARD A CLEANER ENVIRONMENT

CLP is playing a major role in facilitating the introduction of electric vehicles (EVs) to Hong Kong. We have worked closely with Government and the automobile industry to develop the standards and specification required for the long-term sustainable deployment of EV charging infrastructure in the SAR. EV charging stations have now been installed and made available to the public in 26 carparks. CLP waived the fees for the charging stations in 2010 and has extended this waiver through 2011, while the car park with charging stations provides free parking for EV during the same period. In the Hong Kong Parade and Exhibition for the 25th International Electric Vehicles Symposium organised by CLP last year, the EV parade, involving more than 30 different EVs from across the world, was the largest of its kind yet seen in Hong Kong. Over 60,000 members of the public visited the EV exhibition. More than 6,000 guests participated in the EV Ride and Drive, giving them their first experience with electric cars.

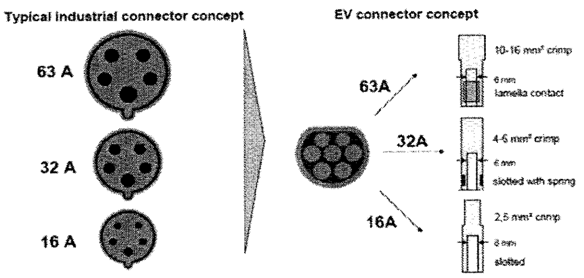
CLP also introduced Hong Kong's first EV Quick Charger for technical trials in February 2010. The Quick Charger takes about 10 minutes to power an EV to run 50km and 120km on just half an hour charge.

To provide an integrated EV charging solution, CLP has applied different technologies to meet safety and payment requirements:

- The charger plug will be locked when charging is in progress;
- Electronic key is used for authentication; and
- Post-charge payment options.

In addition to 13A socket, CLP has also adopted IEC 62196-2 plug and socket system. The IEC standard enables locking feature to disallow unplugging during charging, communication between the EV and the charger to provide smart charging, and one-size-fit-all-current-level plug and socket system.

Figure 8 The Differences between Typical Industrial Connectors and IEC 62196-2 Plug and Socket Systems for EV Charging



6. GREEN POWER IS GOOD BUT SUPPLY RELIABILITY IS EQUALLY IMPORTANT

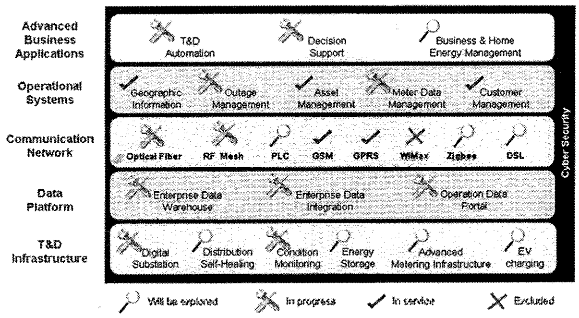
A reliable power grid is a necessary enabler of a successful society. In CLP Power, we constantly challenge ourselves to provide greener and more reliable electricity supply.

The components of a smart grid are intelligent but not magical. A smart grid will only be smart if every part of its components and networks are healthily working together. In the past two decades, CLP Power put tremendous efforts into keeping our power grid strong.

In line with the social and economic development, starting as early as the 1990s, CLP has been striving to improve the reliability and quality of our transmission and distribution systems to bring them to the highest levels.

The following diagram summarizes various essential components of a smart grid. They are grouped into T&D infrastructure, data platform, communication network, operating systems and advanced business applications.

Figure 9 Essential Components of Smart Grid



In fact not all smart grid components are new technologies. CLP is already quite advanced in those areas with a tick, and making progress in some other marked with a hand tool. Those marked with a magnifying lens will be tried out in the next few years through pilot projects.

6.1 ONLINE CONDITION MONITORING

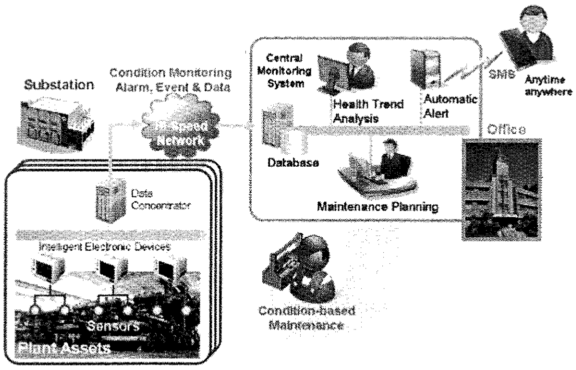
On-line Condition Monitoring enables round-the-clock real-time equipment health monitoring. It improves supply reliability and lowers operating costs. The repair in early stages costs much lesser than when the equipment has broken down.

Instead of periodic on-site health check by maintenance crew, on-line condition monitoring combines advanced sensors, Intelligent Electronic Devices (IED) and advanced monitoring technology to continuously analyse the health condition of power equipment, like transformers and switchgears. The round-the-clock health check helps identify early symptoms of different types of potential failure of equipment, enable proactive maintenance timely at the right location with the correct method. As a result, it eliminates functional failures of equipment.

On the other hand, the time-stamped data collected are very helpful for equipment health trend analysis. This is especially important for aging plant.

In the past few years, the result of our field trial was encouraging. Some equipment problems were identified in the early stage and our proactive actions successfully prevented equipment failure.

Figure 10 High-level Diagram of On-line Condition Monitoring System



The diagram shows how the system works. Inside a substation, IDE process raw data collected from sensors; and then send them to back office through a high-speed data network. The central monitoring system stores and analyses data, lets operators know the health trend of the equipment and enables condition-based maintenance. In case potential problems exceed threshold levels or in emergency, the system will automatically alert the responsible person through SMS.

Wide-Area Monitoring System (WAMS) is a near real-time condition monitoring of interconnecting power grids. It is essentially based on the new data acquisition technology of phasor measurement. The Phasor Measurement Units (PMUs) at strategic locations in the interconnected power grids measure current, voltage and frequency. The measured quantities include both magnitudes and phase angles, and are time-synchronised via GPS (Global Positioning System). The phasors measured at the same instant provide snapshots of the status of the monitored nodes. By comparing the snapshots with each other, the steady state and the dynamic state of critical nodes in transmission networks can be observed.

Figure 11 Monitoring Options of CLP Online Condition Monitoring System

Monitoring Options	Description
Switchgear Monitoring	
Voltage (each phase)	Busbar voltage of GIS panel
Current (each phase)	Load current flow through the GIS panel
SF6 gas density or pressure	SF6 gas pressure in all GIS chambers. The pressure reading shall be adjusted to 25°C.
SF6 gas temperature	SF6 gas temperature in all GIS chambers.
Opening time of Circuit Breaker or Load Break Switch for 400kV shunt reactor circuit	Time between opening signal initiated and the CB main contact fully opened.
Closing time of Circuit Breaker or Load Break Switch for 400kV shunt reactor circuit	Time between closing signal initiated and the CB main contact fully opened.
Circuit breaker arcing current	The magnitude of current flowing through the CB contact during CB opening
D.C supply current for tripping coil	The magnitude of the d.c. current flowing through the tripping coil.
Motor running time for charging spring	The time of D.C. supply to motor for spring charging until motor current stopped.
Air pressure (for compressed air operating mechanism)	Air pressure of central compressor system
Compressor running hours	The time of compressor motor running for charging up air receiver until motor stopped.
Ambient temperature	Ambient temperature of switchgear room
Partial Discharge Monitoring	
No. of Partial discharge (PD) activities	Count of partial discharge inside the GIS in a period.
Magnitude of Partial discharge (PD) activities	Average magnitude of UHF signal generated by PD

CLP's power systems are interconnected with the China Southern Grid which is becoming highly meshed, very complex and with high-energy flow close to its dynamic limits. In the light of these factors, monitoring the dynamics and maintaining the integrity of power systems is becoming more and more important.

The comprehensive intersystem information analysed by the WAMS is sent to Grid Management Systems to generate alarms and alert system operators to evolving disturbances. This advance alert enables operators to take remedial actions and maintain system integrity.

6.2 DIGITAL SUBSTATION

CLP Power is always at the fore front of adopting advanced technology in its transmission and distribution network for continuous improvement in supply reliability, cost optimisation and customer satisfaction.

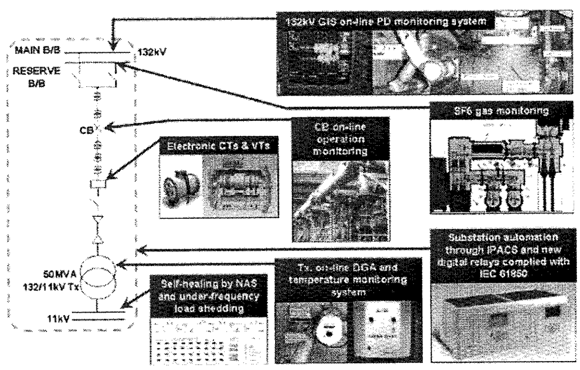
For exploring different self-healing technologies and to finalise the standards for future digital substations, CLP will commission its first digital substation in southeast Kowloon in 2012. The digital substation standards will then be applied to all new transmission substations. For the existing substations, where the business case justifies, CLP will gradually retrofit them with digital protection and control system.

The intelligent features of the digital substation include digitalized information, unified communication platform, standardization of information sharing and applications. They integrate the primary equipment with smart components and enable full spectrum of on-line monitoring, condition assessment, self-healing and automated intelligent operation of primary equipment.

Numerical Auto-Switching (NAS) scheme has been adopted as the self-healing system in digital substation to automatically restore electricity supply. The scheme provides additional flexibility and higher supply reliability for instantaneous power supply restoration in case the substation transformer is tripped on fault.

The Intelligent Protection, Automation, Control and Supervision System (IPACS) integrates and coordinates protection and control systems to enhance operation and management system, for example, support for condition-based Maintenance (CBM), emergency response and Self diagnostic.

Figure 12 Key Digital Features of CLP Digital Substation



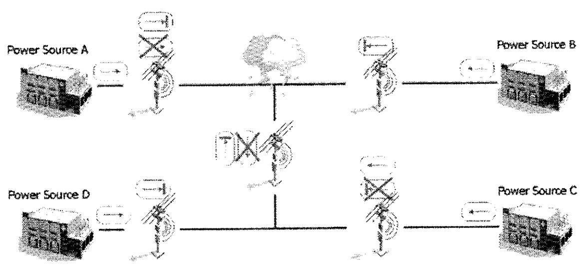
6.3 OVERHEAD LINE SELF-HEALING NETWORK

Overhead lines are exposed to weather and environment. Extreme weather conditions, like typhoons and lightning storms, can lead to power interruptions. To enable overhead line automation for faster supply restoration at rural areas, CLP has installed Pole-Mounted Switches (PMS) with remote control capability in 11kV overhead line network for many years. However, the PMS lacks intelligence to coordinate with other PMS to restore power supply through alternative supply sources.

In order to further enhance supply reliability of our 11kV overhead line system, intelligent switches and devices will form a self-healing network on selected 11kV overhead lines for field trial.

The self-healing function is achieved through continuous monitoring of the network status. The faulty section can be identified reliably by measuring the phase angle difference between fault currents at both ends of a section when downstream fault current also exceeds the over-current setting. The faulty section will then be isolated and the other affected but healthy sections will be restored automatically through alternative supply sources.

Figure 13 Expert Self-Healing Mode Automatically Isolates Faults and Restores Power Supply from Healthy Sources

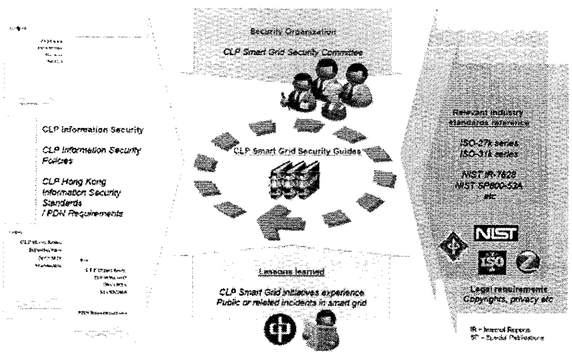


6.4 INFORMATION INFRASTRUCTURE

Information technologies play a vital role in the smart grid. Both the grid operators and energy customers will experience a vast amount of cutting-edge technologies. These technologies are supported by powerful application software through a robust, broadband and high-speed telecommunications infrastructure to provide reliable and accurate information. For instance, customers can remotely monitor and manage the power utilisation of their household appliances with various kinds of software, while engineers can acquire real-time power grid operational data through system applications to ensure a reliable and stable power supply.

As far as information security is concerned, CLP has stringent information security polices and standards in place for many years. Recently, CLP has followed relevant industrial standard, for example NIST IR-7628 & SP800-53A and ISO 27k & 31k series, and established a smart grid security guild.

Figure 14 CLP's Information and Smart Grid Security Framework



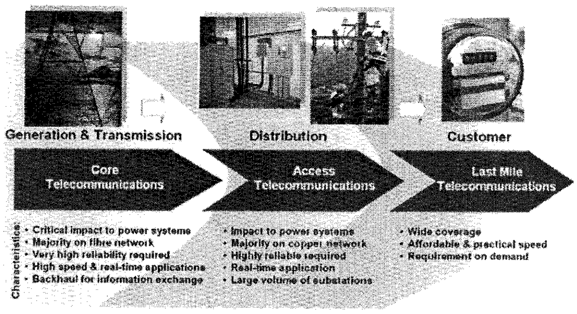
CLP has adopted IEC's Common Information Model (CIM) and industry open standards to establish an Integration Information Infrastructure and Enterprise Data Warehouse for smart grid operation. The systems will put the foundations in place to ensure business-critical data get to the right place at the right time. A web-based Operational Data Portal gathers relevant operational data and transforms them into decisions-support information.

6.5 TELECOMMUNICATION INFRASTRUCTURE

The development of Smart Gird boosts the demand on the support of telecommunications network that have never seen before. Bidirectional data and information are continuously gathered from and sent to multiple locations: energy customers, distribution systems, transmission and generation. The information exchange enables the power grid to adjust itself in order to accommodate dynamic changes in users' behaviour along with the status of countless numbers of system equipment.

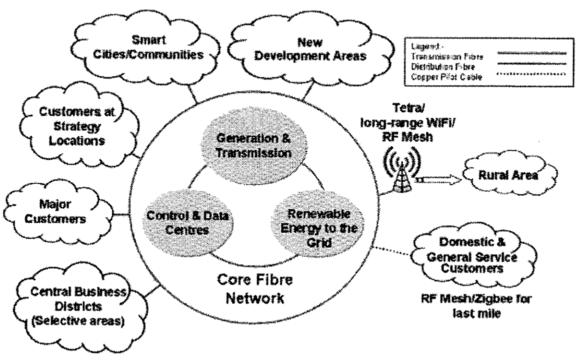
Transiting and managing huge amount of data and information flowing around the smart grid need a robust and optimised telecommunications infrastructure. CLP has adopted a three-level telecommunication architecture: core, access and last mile telecommunications.

Figure 15 CLP's 3-level Telecommunication Architecture



Diversified technologies such as fibre optics, microwave, radio and power line communications will be utilised in an effective way to ensure speedy and reliable connections. Coupled with robust design, CLP's communication network can survive in all weather conditions to provide uninterrupted services. With the extensive reach of our telecommunications infrastructure, all equipment and information in the smart grid will be readily accessible to operators and customers.

Figure 16 Diagram of CLP's Telecommunication Technologies



SIEMENS

6.6 ADVANCED OPERATION TECHNOLOGY

Distribution automation fully utilises advanced electronic, computing, network and field bus technologies to achieve decentralised data collection and centralised monitoring. Distribution automation allows CLP's System Control Centre to remotely monitor and control over 11,000 customer substations in the distribution network. This not only improves operational efficiency but also significantly improve supply reliability.

CLP's Distribution Management System provides a real-time supervisory control and data acquisition utility functions on distribution equipment that eventually delivers electricity to customers. This system is among the largest one of its kind in the world, comprising Remote Terminal Units (RTUs) installed in customer substations throughout the distribution network. The system significantly enhances the operational efficiency and safety of distribution system and its supply reliability.

Trouble Call and Outage Management System (TCOM) tightly integrates with various CLP's operational systems (such as Distribution Management System (DMS), Enterprise Work Management System (EWMS), and Customer Care & Marketing System (CCMS)) to facilitate efficient and effective decisions on outage management and emergency services to restore supply. With the advanced features such as calls grouping, visualized outage locations, and detailed outage analysis reports, CLP is able to provide a reliable supply and high service standard to our customers.

Automated Mapping/Facilities Management (AM/FM) serves as the centralized database that stores geographical information for CLP's entire power network. With its unique powerful geospatial analysis functions in a mapping environment, the system facilitates the various tasks on the planning, design, construction, maintenance of power network. It is a useful tool to deliver reliable supply and world-class customer services to our customers.

7. SMART GRID EXPERIENCE CENTRE

CLP's Smart Grid Experience Centre is the first smart grid centre in Hong Kong. Through display boards, videos and interactive models, the centre demonstrates CLP's end-to-end smart grid solutions from renewables all the way to smart buildings and smart homes. The centre aims to let visitors understand the real benefit that will be delivered by smart grid and how they could participate in energy efficiency and demand response programmes to keep our environment greener.

Figure 17 An Interactive Model illustrates Online Condition Monitoring and the Detection of Partial Discharge inside Transmission Switchgear

Figure 18 An Interactive EV Charging Station

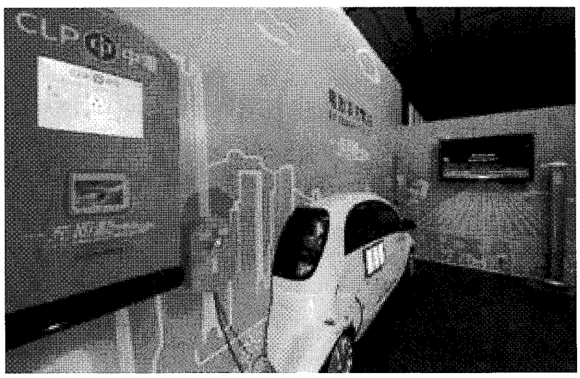
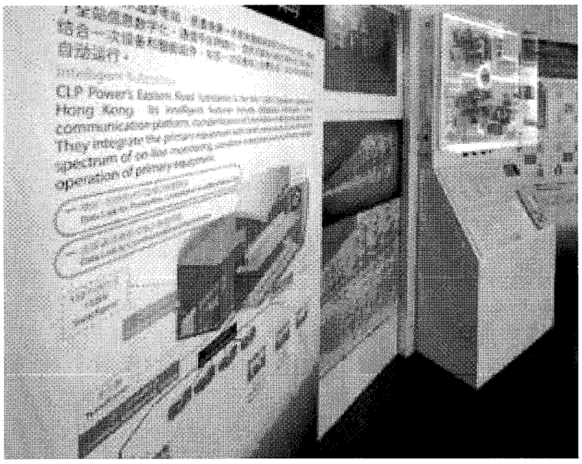


Figure 19 Display Boards and an Interactive Model illustrate Major Functions and a Numerical Auto-switching System inside CLP's Eastern Road Digital Substation



8. CONCLUSION

CLP masters various advanced technologies in every part of the electricity supply chain in order to address the challenges in the coming years. With the development of smart grid, our system will be strengthened to provide power supply reliably and efficiently. As a result, our customers will receive more reliable electricity supply, cleaner energy and world-class services no matter they are at home, in the office or behind the wheel.

CLP has reviewed smart grid developments in various utilities around the world and identified smart grid solutions that best fit the Hong Kong environment. We have established a Smart Grid Development Roadmap. Initially, we will focus on strategic areas such as integration with intermittent renewable energy sources, transmission and distribution network management, customer interaction, last-mile communication networks and information technologies. We have 15 demonstration projects in progress, varying from self-healing systems for critical equipment through to advanced metering infrastructure and communication technologies.

ACKNOWLEDGEMENT

For taking time out of their busy schedules, I am deeply indebted to a number of colleagues in CLP Power. They contributed their efforts in the smart grid pilot projects and change management processes. We are privileged to have a lot of colleagues who are willing to spend their time to explain their work processes and share their great ideas in the new paradigm with us.

Nevertheless, my most sincere thanks go to the management of CLP Power for supporting me to share CLP's strategic focuses on smart grid development in the HKIE Conference.

NOTES

1. CLP Power Hong Kong Limited is the largest electric utility in Hong Kong serving the business and domestic community in Kowloon, the New Territories, Lantau and most of the outlying islands. Operating a vertically integrated electricity generation, transmission and distribution business, CLP Power provides a highly reliable supply of electricity and excellent customer services to over 5.5 million people in its supply area.

2. Outside Hong Kong, CLP Holdings also invests in energy businesses in Mainland China, Australia, India and Southeast Asia. It is the largest external investor in the Chinese mainland electricity industry, and a leading international private sector power company in the Asia Pacific region with a diversified portfolio of power generation from gas, coal, renewables and nuclear.

- Notes and Questions -

Paper No. 2

DEVELOPMENT OF AN OFFSHORE WIND FARM IN HONG KONG

Speakers : Ir Frank F.H. Lau, General Manager (Projects)
Ir Y.L. Kwan, Chief Mechanical Engineer, Projects Division
The Hongkong Electric Co. Ltd.

DEVELOPMENT OF AN OFFSHORE WIND FARM IN HONG KONG

Ir Frank F.H. Lau, General Manager (Projects)
Ir Y.L. Kwan, Chief Mechanical Engineer, Projects Division
The Hongkong Electric Co. Ltd.

Paper No. 2

ABSTRACT

In support of Government's sustainable development policy to have 1 to 2% of the total power generation in Hong Kong coming from renewable energy, HK Electric has been embarking on developing renewable energy projects in recent years. With the successful commissioning of the first commercial scale wind turbine (800kW capacity) on Lamma Island in early 2006, HK Electric has been carrying out further studies for developing an offshore wind farm of 100MW within the territorial waters in Hong Kong. The Environmental Impact Assessment of the project has been completed with the Environmental Permit of this project granted by the Authority in June 2010. An in-situ wind monitoring campaign is to commence towards the end of 2011. The estimated annual generation from the offshore wind farm is about 170GWh accounting for about 1.6% of the total generation of HK Electric system in 2010, which is adequate for consumption of 50,000 Hong Kong families. It can supplant the use of around 62,000 tonnes of coal per annum, hence a reduction of 150,000 tonnes of carbon dioxide. The wind farm is planned to be commissioned by end 2015 and will contribute to a greener Hong Kong throughout its operating life of 25 years.

1. PROJECT BACKGROUND

Recognizing the importance of sustainable development and wider application of renewable energy to combat global climate change, HK Electric first commissioned the "Lamma Winds" in February 2006 at Tai Ling on Lamma Island. The "Lamma Winds" is a 800kW wind turbine, and is the first utility scale renewable energy facility ever built in Hong Kong. By end July 2011, "Lamma Winds" has generated more than 4.9 million kWh of green electricity offsetting more than 4,000 tonnes of carbon dioxide emission. It represents an average capacity factor of about 13% over the past few years with the highest in 2009 at 15.7%.

Figure 1 Lamma Winds

"Lamma Winds" has not only enabled HK Electric to gain precious experience in wind power generation but also laid solid foundation for subsequent exploration of larger scale wind farm project in the territory.

The renewable energy target set out in the First Sustainable Energy Strategy for Hong Kong in 2005 was 1 to 2% of the total power generation in the territory, based on which HK Electric proposed to develop an offshore wind farm within the territorial waters, and CLP Power has similar plan as well. These initiatives from the power sector have been included in Government's consultation document of "Hong Kong's Climate Change Strategy & Action Agenda - 2010", in which the long term plan for renewable energy development by 2020 proposed by Government is set at 3 to 4%. The offshore wind farms of the two power companies will constitute 1 to 2% and the other 2% comes from waste-to-energy generation.

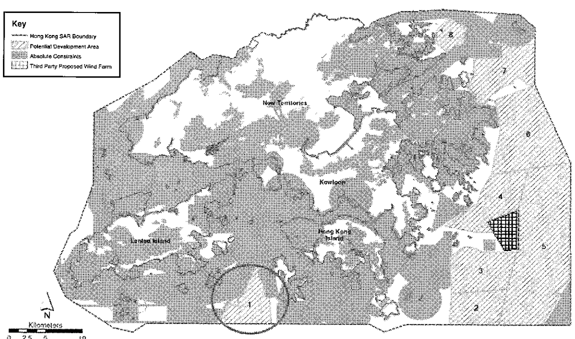
SIEMENS

2. SITE SELECTION

For obvious land constraint reasons, finding suitable land space in the territory to develop sizable onshore wind farms is not feasible. Experience from "Lamma Winds" also shows that land-based wind resource is not affluent. HK Electric has therefore shifted the focus to potential offshore sites and conducted a comprehensive territory-wide site selection exercise to identify feasible offshore site(s) for development of an offshore wind farm since 2006.

The wind farm siting assessment identified 8 short-listed sites. Among these short-listed sites, the most preferable site is located at about 4km southwest of Lamma Island as it has the least overall environmental impacts. There are also other technical merits of the southwest Lamma site, including shallower water depth and shorter transmission cable linking to Lamma Power Station compared with other potential sites on the eastern waters of Hong Kong. In addition, more convenient logistic and land supports can be offered from the existing Lamma Power Station for temporary storage and pre-assembly of large wind turbine components during construction phase of the project, as well as other resource supports during operational phase.

Figure 2 Potential Offshore Wind Farm Sites



3. ENVIRONMENTAL IMPACT ASSESSMENT

Detailed EIA study on Southwest Lamma Site commenced in mid 2008. It covered impacts on water quality, terrestrial ecology, marine ecology, landscape & visual, fisheries and other aspects. The EIA report has envisaged no significant adverse impacts on the environment, especially on water quality and fishery, associated with the wind farm construction and operation. The wind turbine foundation will altogether take up 0.16 hectare of Hong Kong waters. The report has also revealed that loss of fishery operation habitat will be less than 1% of Hong Kong waters even if fishing is prohibited within the whole wind farm area. A string of mitigation measures has been proposed to further minimize any potential disturbance to the environment, particularly on the marine mammals and avifauna species, including:-

- Restrict the speed of working vessels;
- Use quieter hydraulic tools for foundation work;
- Establish an exclusion zone of 500m radius around the work area and scan the zone for at least 30 minutes prior to piling to ensure clearance of marine mammals.

The EIA report was approved on 14 May 2010 and HK Electric was granted an Environment Permit on 8 June 2010.

Apart from the EIA study, HK Electric has also engaged various consultants to look into the technical feasibility of the project, including verification of wind resources by computer simulations, technology review on the wind turbine models, design options of the wind monitoring station, impact on grid stability, as well as potential marine navigation and aviation impacts. Close contacts with major suppliers in the market and the offshore marine specialists have been maintained to explore the most practical solutions for tackling all the challenges associated with the project. Every detail is carefully studied and optimized, ensuring the success of the project. These efforts will help draw up clearer criteria and direction for selecting suitable key components including type of wind turbine foundation, size and class of wind turbines, as well as location and configuration of the substation.

Paper No. 2

4. GENERAL INFORMATION OF WIND FARM

The planned capacity of the offshore wind farm is about 100MW comprising 28 to 35 sets of 2.3 to 3.6MW class wind turbines which will be linked up by cables to an offshore or onshore substation where the output voltage will be stepped up for connecting to HK Electric's switching station in Lamma Power Station. The site boundary of the wind farm occupies an area of about 600 hectares and the water depth ranges between 17 and 23m. The preliminary layout is shown in Figure 3.

Figure 3 Proposed Southwest Lamma Offshore Wind Farm

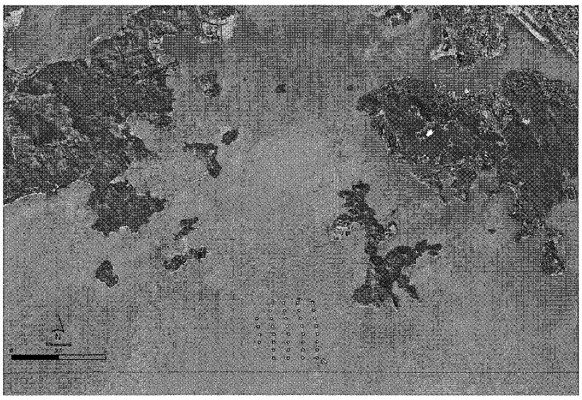


Table 1 General Information of Offshore Wind Farm

Location	**4km Southwest of Lamma Island**
Wind Farm Capacity	**100MW**
No. of Wind Turbines	**28 – 35nos.**
Wind Turbine Capacity	**2.3 – 3.6MW each**
Hub Height	**80m above mean sea level**
Site Boundary Area	**600Ha.**
Water Depth	**17 – 22m**

5. WIND TURBINE MODELS

Offshore wind turbines with capacities in the range of 2.3MW to 3.6MW are considered in EIA study as they have been widely installed in Europe. IEC Class 1 wind turbine models will be adopted to withstand typhoon condition with a maximum gust of 70m/s. Available models in the market include Vestas V90-3.0, V112-3.0, Siemens SWT-2.3-82, SWT-3.6-107 and SWT-3.6-120, GE 4.1-113 and Sinovel SL3000.

Table 2 Wind Turbine Models Commonly Available in the Market

Supplier	Model	Capacity (MW)	Rotor Dia (m)	Cut-in / Cut-out / Rated Wind Speed (m/s)
Vestas	V90-3.0MW	3	90	3.5 / 25 / 15
	V112-3.0MW	3	112	3~4 / 25 / 12~12.5
Siemens	SWT-2.3-82	2.3	82	3.5 / 25 /13
	SWT-3.6-107	3.6	107	3~5 / 25 / 13~14
	SWT-3.6-120	3.6	120	3~5 / 25 / 12~13
GE	GE 4.1-113	4.1	113	3.5 / 25 / 14
Sinovel	SL3000	3	91.3	3.5 / 25 / 13

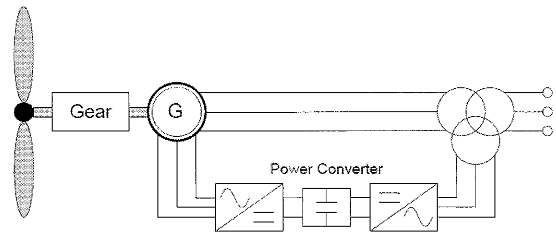
6. GENERATOR DESIGNS FOR WIND TURBINES

Three most common designs of electrical generator adopted by various wind turbine models are as follows:

6.1 DOUBLY FED INDUCTION GENERATOR (DFIG)

DFIG has been the conventional approach for multi-megawatt wind turbine generator design. Vestas V90-3.0 is a typical DFIG machine which employs a traditional multi-stage step-up gearbox in conjunction with a DFIG. In this type of wind turbine generator, the generator stator is directly connected to the grid whereas the rotor is connected to a power electronic converter. The power converter controls the rotor frequency and thus the rotor speed which in turn controls the torque on the gearbox. Rather than operating at fixed speeds, variable speeds over a prescribed range are made possible. One of the main advantages of DFIGs is that they work with a smaller converter, typically sized at 30% of full rated power. Smaller converters mean less losses, and lower costs in components. However, a major downside of DFIG is its limited ability to fulfill the latest or upcoming grid connection codes. In addition, DFIG efficiency drops at speeds below nominal because the rotor draws active power. This limits useful speed range and becomes significant with recent trend to operate turbines at lower wind speeds.

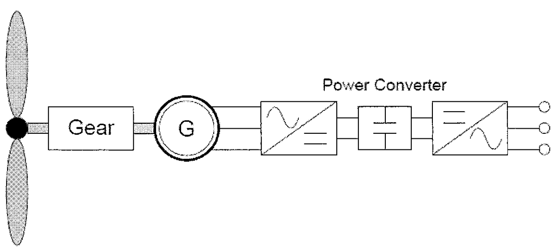
Figure 4 Schematic Diagram of DFIG



6.2 SQUIRREL CAGE INDUCTION GENERATOR (SCIG)

An example of wind turbine models employing SCIG is Siemens SWT-3.6-107. SCIG requires a full power converter. Being fully disconnected from the grid allows a greater speed range for SCIG than that of DFIG, and also enables complete control of active and reactive power. More losses occur through the power converters which operate at 100% of rated capacity, and thus more cost is involved.

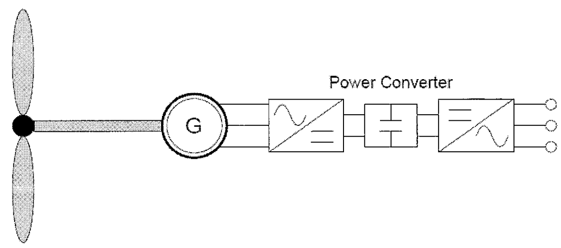
Figure 5 Schematic Diagram of SCIG



6.3 PERMANENT MAGNET GENERATOR (PMG)

In this type of wind turbine generator, permanent magnets are placed on the rotor to create excitation which is a major factor in delivering greater efficiency, as this design virtually eliminates rotor losses. By driving the generator with an optimal power factor using PMG technology, stator-side losses are also minimized. PMGs do not require separate excitation systems, thereby reducing cost, simplifying the system, and improving system efficiency. Further, no slip rings are used, which greatly reduces maintenance needs. By allowing a wide range of speeds, the drive train can run at the optimized operation point for the turbine. Control is based on the optimum turbine curve and is not limited by the drive train, thereby providing better partial load rates. Unlike Vestas V90-3.0 that adopts DFIG, the larger rotor version of Vestas V112-3.0 is a PMG machine with a full power scale converter and gearbox. On the other hand, GE 4.1-113 is a Direct Drive PMG machine without a gearbox. In general, Direct Drive PMGs have minimal wearing parts, making them more reliable. It is noted that GE will launch its first prototype of GE 4.1-113 by end 2011 and the product line will only be commercially available in the latter half of 2012.

Figure 6 Schematic Diagram of Direct Drive PMG



There is an increasing trend of moving towards generator with full power converter for better grid support capabilities. Direct drive generator is also receiving more attention for application in offshore wind turbines in the near future.

7. FOUNDATION DESIGN

Different types of foundation design, viz: monopile, tripod, gravity base and suction caisson foundations have been considered. Monopile foundation of 5-7m diameter is adopted in various offshore wind farm projects in Europe and the associated construction time is short. Piling of 30 wind turbines can be completed in about 4 months time.

8. WIND TURBINE INSTALLATION

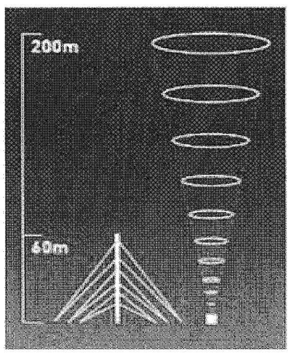
The turbine components will be delivered to the quayside at Lamma Power Station Extension with a lay down area located adjacent to the quay for pre-assembly. Once assembled, the turbine components will be transferred to an installation vessel for the subsequent on-site erection works.

9. WIND MONITORING

To facilitate detailed engineering design and wind farm optimization, HK Electric is setting up a wind monitoring station at the wind farm site to collect one-year meteorological and oceanographic data that are necessary for detailed design of the wind farm. The wind monitoring campaign is expected to commence towards the end of 2011. The station will be in the form of a Light Detection & Ranging (LIDAR) system, which makes use of the Doppler shift of a laser beam scattered by microscopic airborne particulates to measure the wind speed. The LIDAR system in now receiving more attention from developers and consultants in the field in recent years as it has several technical advantages when compared with the tower structure wind monitoring mast, including:

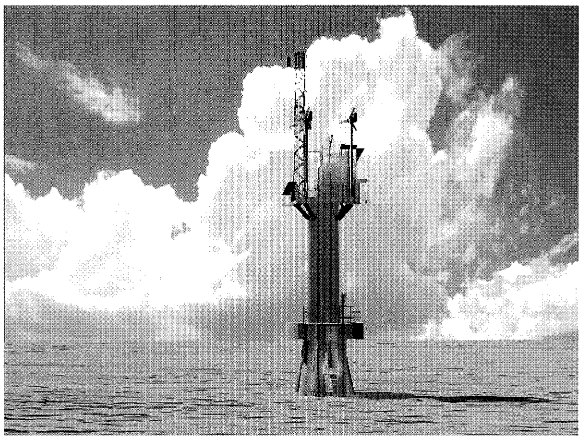
- Capturing meteorological data by measuring the Doppler shift of the laser beam scattered by microscopic airborne particulates.

Figure 7 LIDAR Technology



- High portability suitable for adopting as temporary installation for 1-year wind monitoring.
- Design requirement for temporary foundation platform will be far less stringent, hence substantial reduction in foundation cost.

Figure 8 LIDAR System on Offshore Platform



The wind monitoring station will be powered by renewable energy installations comprising three sets of small wind turbine and fourteen pieces of solar PV panels with a diesel generator as back-up supply. Safety facilities including marine navigation lights, fog horn, remote surveillance, aviation lights, aviation marking and radar reflector will be provided.

10. STUDY ON GRID STABILITY

As high wind farm output and low electricity demand is expected in winter time with North-East monsoon wind prevailing, a study has been conducted to carry out computer modeling for the impact of the 100MW offshore wind farm on HK Electric's power grid system.

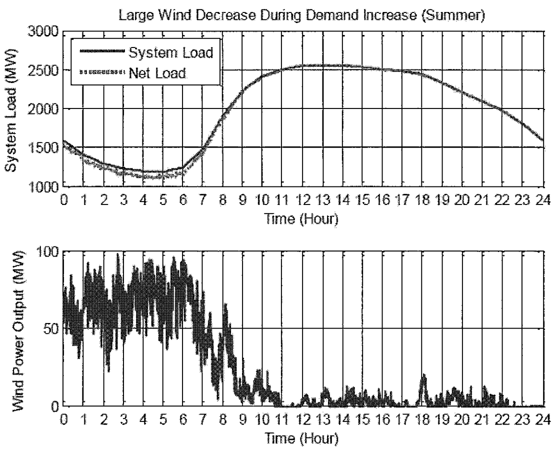
The study covers the following tasks:

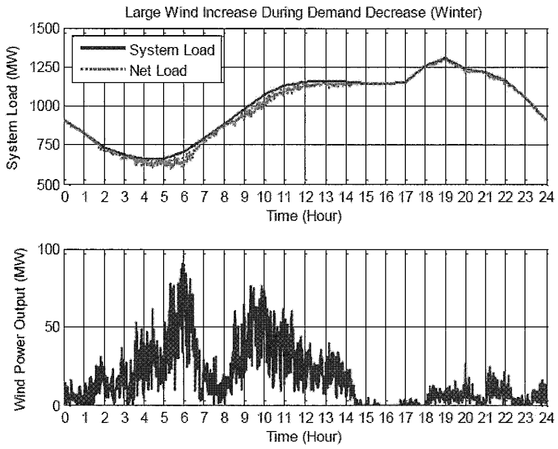
- Review of wind farm impacts on the power grid;
- Forecasting of wind power generation of wind farm;

- Analysis of the wind farm seasonal and daily power output characteristics and the correlation between wind farm power variation and system load demand variation;
- Analysis of wind farm power output and its impact on power generation scheduling and dispatch;
- Analysis of maximum step changes in power output of wind farm and its impact on the power grid;
- Analysis of reactive power and voltage control required for the integration of the wind farm in the power grid;
- Analysis of wind farm short-circuits contribution and transient stability on the power grid;
- Analysis of power quality issues caused by the integration of the wind farm to the power grid; and
- Recommendation of mitigation measures to cope with the operational and grid connected issues with the integration of wind farm in the power grid.

Figure 8 shows the two scenarios on large wind power variations during the peak and valley load periods in the HK Electric's power grid system. It can be seen in the figure that wind is out of phase with load during the morning rise in summer and midnight drop in winter.

Figure 9 Wind Farm Output Vs System Load





The primary finding of the study is that due to its erratic nature wind power imposes challenges to power system operation and planning. The fluctuating nature and the uncertainty associated with predicting wind farm output levels result in an increase in overall system variability as measured by the net load. In response to these increased operational challenges, review on operational practices is being carried out.

When large variations in wind power are encountered in real time dispatch, wind generation outputs can be controlled through options such as ramping rate limitation on how fast the output of a wind farm can change or by limiting the total output of wind farm. Energy storage facilities can also provide a number of benefits that will help leveling the mismatch between wind farm output and the daily load pattern of the system. Some energy storage technologies can provide regulation services, contingency reserves, and reactive power for voltage support. However, in view of the very limited availability of cost-effective energy storage options in Hong Kong, further work would be required to study the measured site specific data to ascertain changes in wind speed across the wind farm site.

11. STAKEHOLDER ENGAGEMENT

Stakeholder engagement is essential towards successful project development. As is the case for other offshore wind farm projects in Europe, development of the proposed offshore wind farm project in Hong Kong requires extensive consultation and engagement with stakeholders. Pursuant to conditions of the Environmental Permit, HK Electric has set up a Stakeholder Liaison Group, and a Fisheries Review and Consultation Programme to solicit views from relevant stakeholders and the fishery sector in relation to development of the proposed offshore wind farm project.

11.1 STAKEHOLDER LIAISON GROUP (SLG)

The purpose of setting up the SLG is to establish communication between the project proponent and relevant stakeholders. A total of 15 SLG members comprising representatives from the academia, green groups, local community groups and fishery sector have been engaged aiming to solicit their views and suggestions towards successful development of the project throughout the design, construction and operation phases.

The SLG was established in the end of 2010 with the inaugural meeting held on 20 January 2011. SLG meetings are to be convened on a half yearly basis and the 2nd SLG meeting was held on 2 August 2011.

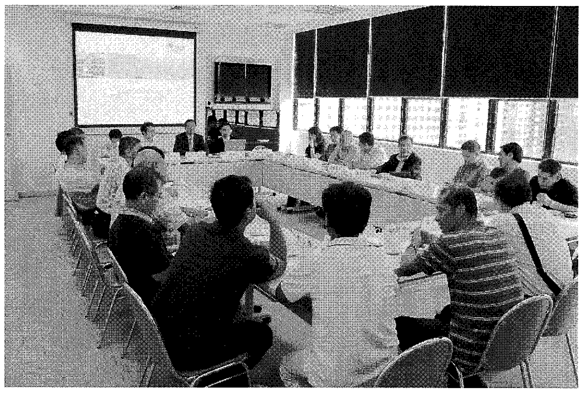
Figure 10 SLG Meeting

11.2 FISHERIES REVIEW AND CONSULTATION PROGRAMME (FRCP)

A committee for the FRCP comprising 21 representatives nominated from various fishermen organizations has been set up with the inaugural meeting held on 3 May 2011. The objective of the FRCP is to review in consultation with the fishery sector the feasibility of opening up the wind farm for fishing activities and to explore measures to enhance fishery resources within the wind farm waters. Representatives from the Agriculture, Fisheries and Conservation Department, Environmental Protection Department and Marine Department have also been invited to join the Fisheries Review and Consultation Committee (FRCC) meetings.

Two specific task groups on Artificial Reef and Fishery Operations have been set up under the FRCC to come up with proposals for further discussion at the FRCC meetings.

Figure 11 FRCP Meeting



12. ENVIRONMENTAL BENEFITS

The estimated annual generation from the wind farm is about 170GWh accounting for about 1.6% of the total generation of HK Electric system in 2010, which is adequate for consumption of 50,000 Hong Kong families. It can supplant the use of around 62,000 tonnes of coal per annum, hence a reduction of 150,000 tonnes of carbon dioxide.

The wind farm is planned to be commissioned by the end of 2015 and will contribute to a greener Hong Kong throughout its operating life of 25 years.

13. CONCLUDING REMARKS

For the past few years, HK Electric has put in great engineering efforts and resources to develop renewable energy projects in support of government's sustainable development policy while fulfilling its commitment to helping combat climate change and improving air quality in Hong Kong.

Following the introduction of the first wind turbine of 800kW capacity on Lamma Island as a demonstration project, HK Electric has been embarking on developing a 100MW offshore wind farm at a potential site about 4km southwest of Lamma, targeting for operation by the latter half of 2015.

Apart from harnessing wind energy, HK Electric also explores solar power generation. The successful commissioning of the largest solar PV system (550kW) at Lamma Power Station in June 2010 marks another milestone for HK Electric in developing renewable energy (RE) for power generation in Hong Kong. HK Electric is also planning to install more of the PV panels in Lamma, aiming at achieving a total capacity of the solar power system of up to 1MW in 2012.

HK Electric will continue its efforts in exploring more opportunities of renewable energy applications for power generation in Hong Kong.

REFERENCE

[1] "Development of an Offshore Wind Farm in Hong Kong – EIA Report", ERM – Hong Kong, Jan 2010

[2] "Sustainable Development: Making Choices for Our Future", Council for Sustainable Development, 2004

[3] "Preparing HK Electric For a Low Carbon Future", HK Electric, Apr 2010

ACKNOWLEDGEMENT

This paper is published with the kind permission of the management of The Hongkong Electric Company Limited.

- Notes and Questions -

Paper No. 3

ENGINEERING DESIGN FOR POWER SUPPLY TO DISTRICT COOLING SYSTEM

Speakers : Ir S.K. Lo, Senior Engineer
Electrical & Mechanical Services Department
The Government of the HKSAR

Ir Simon F.W. Chung, Director
Ir Barry K.P. Lau, Associate
Ove Arup & Partners Hong Kong Ltd.

ENGINEERING DESIGN FOR POWER SUPPLY TO DISTRICT COOLING SYSTEM

Ir S.K. Lo, Senior Engineer
Electrical & Mechanical Services Department
The Government of the HKSAR

Ir Simon F.W. Chung, Director
Ir Barry K.P. Lau, Associate
Ove Arup & Partners Hong Kong Ltd.

ABSTRACT

The Kai Tak Development (KTD) will generate substantial new demand for air-conditioning. The Government is grasping this opportunity to promote energy efficiency in the provision of air-conditioning in this area by implementing a District Cooling System (DCS) for public and private non-domestic developments.

The DCS is a large scale centralized air-conditioning system which produces chilled water at the central chiller plants and distributes the chilled water to user building for air-conditioning purpose. The DCS is an energy-efficient air-conditioning system as it consumes 35% and 20% less electricity as compared with traditional air-cooled air-conditioning systems and individual water cooled air-conditioning systems using cooling towers respectively.

With this new central cooling network, the need for chiller plants and cooling towers on top of each building in future will be taken away. Apart from the reduction of upfront capital cost for chiller plants at the buildings, this also allows more flexible building designs and be so beneficial to the designers. Moreover, the DCS is more adaptable to the varying demand for air-conditioning than individual air-conditioning.

To meet the high expectation and requisite of reliability for a district cooling system, there is a genuine need for a dual feed supply from power company to enhance the power reliability for the southern and northern DCS plants cum seawater pump house. And, resilience design is adopted for the engineering design of the landlord 11kV and LV power supply distribution.

1. INTRODUCTION

A District Cooling System (DCS) is a large scale centralized air-conditioning system to produce chilled water at its central chiller plants and distributes the chilled water to user buildings of various air-conditioning loads. The DCS is an energy-efficient air-conditioning system as it consumes 35% and 20% less electricity as compared with traditional air-cooled air-conditioning systems and individual water-cooled air-conditioning systems using cooling towers respectively. The technology has been widely adopted around the world.

From the perspective of individual users, the DCS would bring about the following benefits:

- reduction in upfront capital cost for installing chiller plants at their buildings, the reduction is estimated to be about 5 – 10% of the total building cost;
- user buildings do not need to install their own chillers and the associated electrical equipment thus allowing more flexible building designs;
- noise and vibration arising from the operation of heat rejection equipment and chillers of air-conditioning plants in buildings can be reduced as there will not be any need for such equipment for buildings subscribing to DCS; and
- the DCS is more adaptable than individual air-conditioning system to the varying demand for air-conditioning.

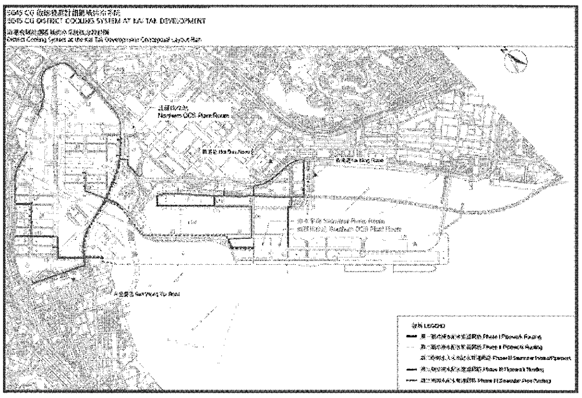
KTD, with a planned total of about 1.7 million square metres (m^2) in public and private non-domestic air-conditioned floor areas requiring about 284 megawatt (MW) cooling capacity, presents a unique opportunity for implementation of a DCS in Hong Kong. As announced in the 2008-09 Policy Address, the Government plans to implement a DCS at KTD to promote energy efficiency and conservation.

The DCS project can bring about significant environmental benefits. By implementing the project, the maximum annual saving in electricity consumption will be up to 85 million kilowatt-hour, equivalent to a reduction of 59,500 tonnes of carbon dioxide emission per annum.

The project is to construct a large scale centralized air-conditioning system which produces chilled water at its central chiller plants and distributes the chilled water to user buildings in KTD through an underground water piping network. The scope of works comprises (a) construction of a northern chiller plant; (b) construction of southern underground chiller plant cum underground seawater pumphouse and above-ground operational facilities; (c) laying of seawater intake and discharge pipelines; (d) laying of chilled water distribution pipe networks; and (e) provision of connection facilities including heat exchangers at user buildings.

The project is currently implemented in three phases to match with the development schedule of KTD. The Phase I and II works include the construction of core facilities comprised of the northern and southern plant rooms and pipelines to the first package users, such as Cruise Terminal Building. The contracts for Phase I and Phase II have been started in February 2011. The Phase III works, which is mainly the pipe laying and installation of chillers, are under planning and will be implemented in accordance with the development schedule of KTD. A conceptual layout plan of the proposed DCS is shown in Figure 1.

Figure 1 Conceptual Layout Plan of DCS



The DCS is for public and private non-domestic developments at the KTD. All public developments in the region will connect to the DCS provided that their implementation programme can match the development schedule of the DCS. With a view to increasing the subscription rate and maximizing environmental benefit of the project, the Government has actively explored the feasibility of the suggestion of mandatory connection of private non-domestic projects in KTD to the DCS by prescribing such requirements in the land lease conditions.

To meet the high expectation of reliability for a DCS serving the whole area of KTD, the electrical supply and distribution system is a key factor to the secure and continuous operation of the plant.

2. ELECTRICAL INSTALLATION

2.1 RELIABILITY OF DISTRICT COOLING PLANT

According to the District Cooling Best Practice Guide published by the International District Energy Association, DCS shall achieve a reliability exceeding 99.94%.

In view of this, the power supply design to the DCS in both HV power supply from power company and customer distribution transformers side are also targeted to achieve this criterion.

The DCS will be taken to have a robust commercial arrangement of 3-legged cable supply from power company. This arrangement offers 99.99% reliability level such that each of the cable carries 50% of the required electrical load, therefore failure of any one of the cable will result in no reduction in the power supply condition.

2.2 11kV INCOMING POWER SUPPLY FROM POWER COMPANY

To secure power supply reliability for DCS, 11kV power supply fed from two supply sources is adopted such that when one source fails, the power supply will be automatically switched over to the other source.

The 11kV switchboards inside the power company zone substation should be of double busbar arrangement. With the closed ring circuit system, there will be no power interruption in case of fault of any one cable or during installation of additional customer substation.

2.3 POWER COMPANY ZONE SUBSTATIONS FOR DCS

The DCS requires both HV (11kV) and LV (380V) electrical supply to Southern Plant (underground seawater pump house & underground southern DCS plant) and Northern Plant (northern DCS plant) as shown in Figure 1.

Southern Plant and Northern Plant will be supplied from separate zone substations in order to further minimize the interruption to the DCS in case of power supply failure.

The power for Southern Plant will be supplied by the zone substation at Cruise Terminal. In the meanwhile, the Northern Plant will be supplied by the power company zone substation at Eastern Road which is currently under construction and will be commissioned by the first quarter of 2012.

In view of the long distance cables run and minimization of energy loss in power transmission, HV (11kV) supply taken from the power company substation will be adopted.

The step down from 11kV to 380V for equipment will be accomplished by landlord distribution transformers inside the two Plants. Cast-resin dry type transformers are to be provided with the following advantages: -

- insulated with an epoxy resin/quartz powder mixture, an environmentally friendly material, that makes the windings maintenance-free, moisture resistant, flame-retardant and self-extinguishing;
- no gas inclusions in the epoxy resin casting process;
- more compact; and
- as quiet as oil-immersed types.

Paper No. 3

2.4 HV POWER SUPPLY TO DCS BY LANDLORD

Apart from the 11kV/380V transformers and switchgears, 11kV landlord supply to HV chillers is also required due to large capacity of chillers. Thus, HV distribution system with vacuum circuit breakers is adopted for power supply to the HV chillers to provide longer design life, less maintenance but higher reliability.

Electronic protection relays are applied in view of its advanced features and technical advantages over conventional relays such as continuous self monitoring and self diagnostic features, sophisticated relay characteristics, fast protection time, ability to capture system fault information, remote communication, built-in control and metering functions, etc.

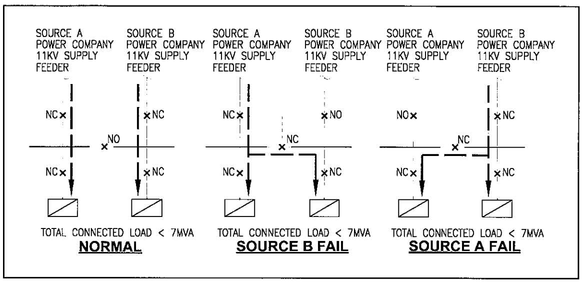
2.5 RESILIENCE DESIGN OF POWER SUPPLY TO DCS

As to achieve resillence and reliability of the power system and eliminate single point of failure in both 11kV and 380V electrical distribution, the following arrangements will be adopted: -

- In the 11kV side, every two 11kV supply feeder will be paired-up to work as a group to achieve 100% redundancy in terms of power supply capacity. It means that one feeder takes up 50% of the total load supply for the reason as stated before. Each pair of

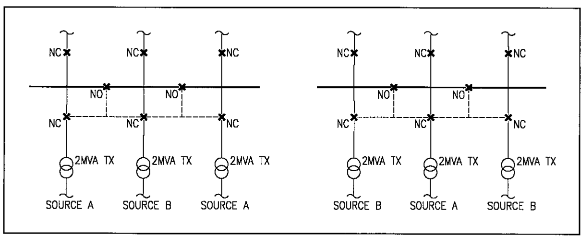
11kV 7MVA supply feeders will be arranged from two different sources (namely source A & B) so that in case of failure of source A 11kV feeders, source B 11kV feeders will take up 100% of the connected loads by closing the tie section breaker. (Figure 2)

Figure 2 Power Company 11kV Supply Arrangement



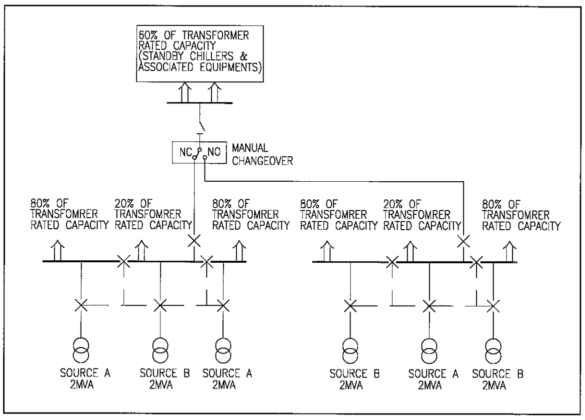
- In the LV side, customer transformers are grouped together in groups of three (3) customer transformers. Each transformer group will be normally loaded to maximum at 80% - 20% - 80% respectively for optimization of resilient design by offering minimal spare capacity of the transformers and to ensure no interruption to the loads in case of breakdown of any one of the transformers within the group. In case of failure of a transformer, another transformer can take up 100% of the connected loads by closing the tie section breaker. In addition, the supply source to the three transformers will be arranged in "Source A – Source B – Source A" or "Source B – Source A – Source B" so that supply to LV switchboards will be maintained even the changeover mechanism from source A to B (or source B to A) if the HV side failed. (Figure 3)

Figure 3 Transformers and LV Supply Arrangement



- To achieve higher utilization of the 20% loaded transformer in the "80% - 20% - 80%" arrangement, standby plant equipment including chillers, associated chiller pumps and cooling towers, etc. will be connected to the 20% loaded transformer with changeover mechanism to other 20% loaded transformer. (Figure 4)

Figure 4 Arrangement to Achieve Higher Utilization of the 20% Loaded Transformer



Practically, standby plant equipment remaining idle for long time may deteriorate or result in dysfunction when put into operation even with regular checking during routine maintenance. To avoid this, N+1 arrangement of equipment is to be adopted on rotation basis. Each equipment will have to operate as duty one according to the programmed sequence. As such, each of the equipment group will operate continually and the 20% loaded transformer will be loaded more in accordance with the operation sequence.

3. TOTAL POWER DEMAND

3.1 TOTAL POWER DEMAND OF ENTIRE DISTRICT COOLING SYSTEM AT ULTIMATE PHASE

A total of about 90 MVA power supply will be required for the entire DCS, which demands for 28nos. 7MVA 11kV supply feeders. The 28nos. 11kV supply feeders will then distribute to HV chillers and 32nos. 2,000kVA dry-type customer transformers.

3.2 HV TARIFF METERING

Utilities meters and its associated metering panels will be provided and located in the 11kV switchrooms of the power company. Summation metering will be applied.

During DCS operation, record of on-site electricity consumption will be taken through the District Cooling Instrumentation, Control and Communication Systems (DCICCSs).

4. TRANSIENT OVER-VOLTAGES AND HARMONICS

Apart from the reliability of power supply to DCS, concerns on surges (transient over-voltages) shall also be considered as it may cause disastrous consequences due to power interruption incurred.

4.1 LIGHTNING STRIKES AND SWITCHING

Lasting from microseconds to milliseconds large transient over-voltages can be caused by the secondary effects of lightning by electromagnetic pick-up (inductive coupling) or differences in potential between two connected earths (resistive coupling). Moreover, intentional or unintentional switching operation (earth faults or short-circuits) can cause surges too.

To mitigate the surges, surge protection devices (or referred to as arresters) are to be installed at mains power supplies to divert transient surges and to limit impulse currents.

4.2 MOTOR STARTING

Motor starting methodology of large capacity motors (in the order of several hundred kW) is taken into consideration in mitigating the high inrush current and voltage sag during start-up. In this regards, variable speed drive (VSD) will be used for starting of water pumps.

The VSD shall protect itself against the following: -

- phase unbalance at the supply port;
- earth fault at the output terminals;
- over current;
- over temperature;
- over voltage;
- under voltage; and
- loss of control.

The VSD shall protect the motor against the following: -

- short circuit;
- overload;
- over temperature;
- phase unbalance and single phasing; and
- earth fault.

Paper No. 3

4.3 HARMONICS

The impacts of harmonics to mains power supply and electrical installation is commonly known and aware nowadays. DCS uses large amount of non-linear equipment like VSD, switching mode power supplies, electronic devices that may cause adverse effects. Harmonic filters shall be provided for all VSDs and major non-linear loads to achieve the requirements specified in COP for the Energy Efficiency of Electrical Installations.

5. CONCLUSION

To ascertain the deliverable benefits of DCS – convenience, flexibility, reliability, maintainability and energy efficiency, the design of power supply and distribution to DCS plant equipment plays a crucial role. The design engineers are continuously working closely with the power utility company, contractors and DCS operator so that a sophisticated and comprehensive electrical installation can be accomplished in a complete-solution approach throughout the whole project including procurement, construction, and commissioning of a high-efficiency DCS plant.

SIEMENS

- Notes and Questions -

Paper No. 4

HIGH CONCENTRATION PHOTOVOLTAIC: COST COMPETITIVE SYSTEMS FOR A SUSTAINABLE ENERGY PRODUCTION

Speakers : Mr Gianni Borelli
Senior Researcher & Product Manager
BECAR S.R.L. (Beghelli R&D Centre), Italy

Mr Spes Stanley Ku
General Manager
Beghelli Asia Pacific Limited

HIGH CONCENTRATION PHOTOVOLTAIC: COST COMPETITIVE SYSTEMS FOR A SUSTAINABLE ENERGY PRODUCTION

Mr Gianni Borelli
Senior Researcher & Product Manager
BECAR S.R.L. (Beghelli R&D Centre), Italy

Mr Spes Stanley Ku
General Manager
Beghelli Asia Pacific Limited

Paper No. 4

ABSTRACT

Worldwide photovoltaic (PV) markets have grown significantly recently. While silicon flat panel PV modules have traditionally dominated the overall solar market, a range of different solar energy conversion technologies are starting to gain market share for power generation. One such class of solar technologies is high concentration photovoltaic (HCPV) which is ready for commercialisation as cost effectiveness for electricity supply. Research and development is a major driving force for constant cost reduction in HCPV and consequently enables a fast diffusion of HCPV as part of the sustainable energies.

This paper describes reliable HCPV performance and cost effectiveness of HCPV technologies used for utility-scale solar power. Specifically, it explains the rationale behind the use of HCPV and the latest development of HCPV technologies. It describes innovations in the areas of HCPV systems as to meet the needs of the low cost of electricity market

1. INTRODUCTION

It is by now widely accepted that we have to think about energy issues in a new way, in relation to the 21st century. The second half of the last century saw an exponential increase in global energy consumption. The overall use of energy has grown by a factor of 1.5 and greenhouse gas emissions spiked 1.4 times. There are a variety of estimates for the coming 10 to 15 years, but none of them are reassuring. There is the need to create renewable energy sources to gradually replace fossil fuel consumption. Among these is the sun, which gives the Earth from 1,000kWh/m^2 to more than 2,000kWh/m^2, depending on the geographic area, every year, ready for use and storage. According to scientists like Zhores Alferov, Nobel Prize winner in Physics, an industry founded on the use of solar energy should not be considered as no more than a safe and reliable choice, but rather as the only possible alternative for the human race over as a long term source of energy. The need to create renewable energy sources to gradually replace plants powered with fossil fuels has generated support from the institutions and energy sector regulatory bodies.

According to Jeremy Rifkin, economic advisor to the European Union (EU) and several of its member states, energy, economy and ecology must grow in parallel. The main characteristics of the third industrial revolution are distributed energy production and innovation in computer technology to gather together all the small scale energy sources and make them available as a single stream for use by all. Industrial facilities are already in possession of new technologies, in particular solar energy, aimed at achieving parity between the cost of photovoltaic (PV) energy and grid energy. To achieve this revolutionary – and yet essential – change, we must set in motion a cultural revolution: to move away from geopolitics based on nation states competing for resources, to a bio-politics which gives priority to the environment in which we live.

In this devastating scenario, there are signs that policymakers are beginning to change their outlook. At least as far as the industrialised nations are concerned, there is a real search for the key to saving our environment. The President of the United States, Barack Obama, has initiated the "Green New Deal" which sets aside 10% of his administration's recession-fighting budget to finance green projects. For the time being, the EU has set its own targets which made more stringent at the Copenhagen Summit of industrialised and underdeveloped countries.

The European Council laid down the targets for 2020, i.e. to reduce greenhouse gas emissions by at least 20% by 2020, and to increase the percentage of power generated by renewable sources to 20% by 2020; this objective significantly upgrades the already stringent objectives of the Kyoto protocol.

2. THE PHOTOVOLTAIC MARKET

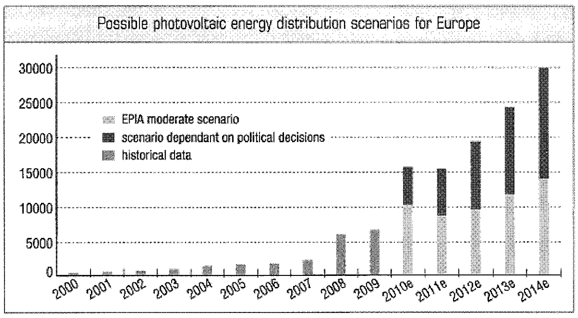
Photovoltaic is the fastest growing electricity generation technology in the world and has achieved a constant high learning rate over the last decades. Ongoing public and corporate research and development has created the basis for this success. PV technology is poised to help Europe achieve its goal of sourcing 20% of its energy need from renewable energy by 2020 as proposed by the European Strategic Energy Technology (SET) Plan to accelerate the availability of low-carbon energy technologies.

2.1 THE TIME HAS COME FOR PHOTOVOLTAIC ENERGY

The "SET for 2020" study, conducted by European Photovoltaic Industry Association (EPIA) of the European Union, is based on interviews released by approximately 100 key figures operating in the industrial sector, research institutes, utilities companies, regulatory bodies and public administration bodies throughout Europe and in other parts of the world, with the aid of the company's global experts network. The study constitutes a more in-depth analysis several PV energy distribution scenarios in Europe, and proves that the most ambitious scenario is not only achievable, but is also the most desirable. The study demonstrates that PV energy will be able to cover 12% of the European Union's electrical energy needs by 2020, compared to the current 1%.

Based on the cross-checking of data and the consolidation of complementary market project methods, EPIA has derived 2 scenarios for the future development of PV industry namely the Moderate scenario which is based on the assumption of a "business-as-usual" market behaviour which does not assume any major enforcement of existing support mechanisms but takes into account a reasonable follow-up of the feed-in-tariff aligned on the systems prices, and the Policy-Driven scenario which EPIA expects the follow-up and/or introduction of support feed-in-tariff accompanied by a strong political will to consider PV as a major power source for the coming years. EPIA expects Europe could install as much as 13.5GW in 2014 in the Policy-Driven scenario.

Figure 1 European Photovoltaic Market in Moderate and Policy-Driven Scenarios (in MW)



Source: European PV Industry Association (2010)

The installation of PV systems for the production of power, is expected to increase significantly over the coming years, mainly due to the following three factors:

- the growing support by governments to this type of energy production, as shown by the "SET for 2020" objectives;
- the increasing interest of companies in seeking business opportunities in this sector, with government incentives and the rise in

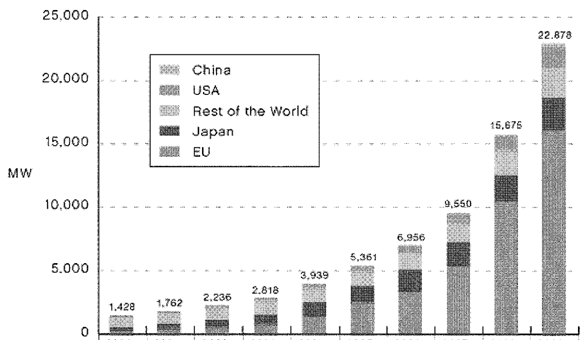
the prices of energy products and services, and the opportunity to improve its public image;

- the reduction in costs which will be presumably associated with the accumulation of experience in relatively recent development sectors and with accelerated technological developments and breakthroughs.

2.2 GLOBAL PHOTOVOLTAIC MARKET

It is expected that there will be a global increase in the installed capacity of renewable energy of 425% by 2020, with reference to 2015, with some segments, including solar energy, increasing even more (growth in installed capacity of more than 3,000% by 2020) according to Worldwatch Institute. The global PV market has developed considerably over recent years, increasing from the cumulative figure of 729MW in 2000 to almost 23GW in 2009. Europe is leading the way in with almost 16GW of installed capacity in 2009, representing about 70% of the global cumulative PV power installed at the end of 2009. The following diagram highlights the strong market growth.

Figure 2 Historical Development of World Cumulative PV Power Installed in the Geographies



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
China	19	30	45	55	64	68	80	100	145	305
USA	139	169	212	275	365	479	624	831	1,173	1,650
ROW	763	825	913	1,000	1,044	1,051	1,235	1,422	1,870	2,347
Japan	318	452	637	860	1,132	1,422	1,708	1,919	2,149	2,633
EU	189	286	429	628	1,334	2,341	3,309	5,279	10,338	15,943
Total	1,428	1,762	2,236	2,818	3,939	5,361	6,956	9,550	15,675	22,878

Source: European Photovoltaic Industry Association (2010)

This result has been possible thanks above all to the systems installed in buildings and connected to the electric grid. The greatest increases in installed power are undoubtedly those in Japan, USA and Germany. The experience and the international comparison show how the incentivisation system based on energy saving incentives may contribute significantly to the market development, since it guarantees a minimum selling price for the energy produced by PV sources, protecting the investments of the entrepreneurs in the sector. Until now, the weakness of the traditional PV systems was the low efficiency of the cells in converting solar energy into electric energy. The conversion efficiency of the PV modules currently on the market is approximately in the range 10-15%, with some models peaking at 18%, with much higher prices.

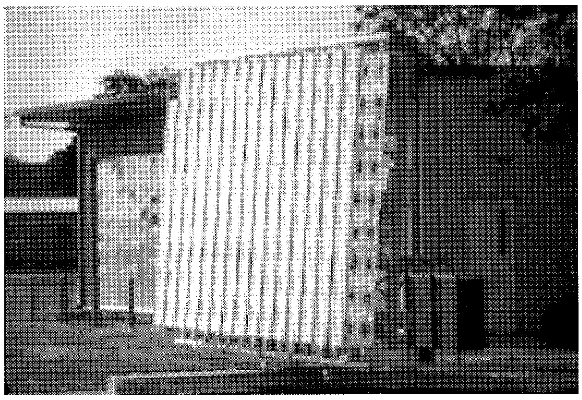
As a result of this, large subsidies have been provided by governments for PV modules. However, this is not a sustainable solution in the long term. If it continues to exist thanks to subsidies, it will remain a marginal form of energy. The power produced by PV systems currently costs approximately 40-50 euro cents per kWh, i.e. three or four times the average cost of the power produced by conventional fuels in the USA and Western Europe.

However, concentrated solar energy offers the chance to change this ratio. With the type of conversion efficiency expected from this new technology, the production cost of power from concentration photovoltaic (CPV) systems will in the long term approach that of conventional fuels.

3. HIGH CONCENTATION PHOTOVOLTAIC SYSTEMS (HCPV)

The idea of photovoltaic power generation using concentrated sunlight is about as old as the first activities in terrestrial PV and the early demonstration projects in 70's and 80's. The general principle that characterizes CPV systems is that they use lenses or mirrors to concentrate sunlight onto a small solar cell. There are a myriad of designs employing different configuration of concentrators but the overall concept of reducing semiconductor remains similar – the areas of the semiconductor material is roughly reduced by the level of the concentration. Thus, the cost of the bigger cells used in conventional flat PV systems is replaced by the cost of the cheaper optics and other auxiliary components. This reduced cell size allows the use of expensive high-efficiency multi-junction solar cells which have a conversion efficiency which is more than two times higher than the one of conventional silicon cells.

Figure 3 The Sandia Labs 1kWp Concentrator System of 1976



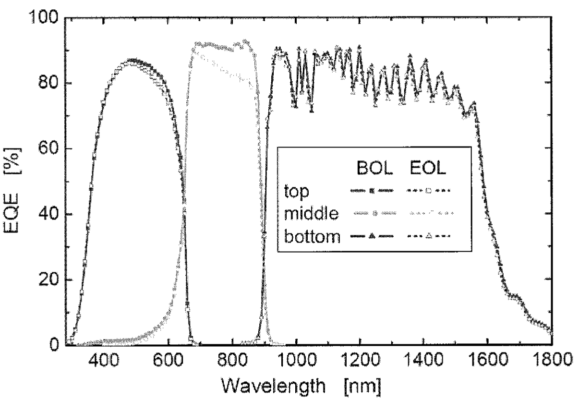
CPV is now leading the development of future low cost renewable energy sources in two ways: on one hand offering high efficiency systems, and on the other, being most capable of reducing manufacturing cost. It is currently at the initial stage of industrial development, and only of a few producers have started marketing the first industrialised CPV systems. Many research institutes have carried out investigations and studies on various solutions for the development of concentration systems, producing suggestions for further research.

CPV technology relies particularly on three areas: high efficiency cells, high performance optics and reliable, accurate sun trackers. In each of these areas there have significant developments in the last five years, leading to current commercial CPV systems already competitive in the current market.

3.1 HIGH EFFICIENCY TRIPLE JUNCTION CELLS FOR CPV APPLICATION

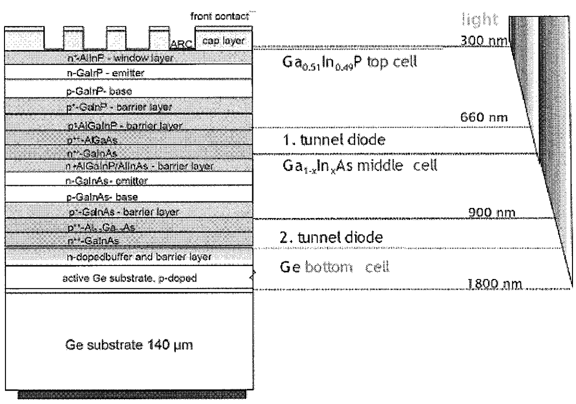
Cell technology has been greatly improved and the efficiency consequently increased. The best improvement in cell technology lies in the use of compound III-V semiconductors. Also, III-V technology allowed the development of multi-junction solar cells. Two or more p-n junctions are monolithically integrated into a single device. The use of these cells allows a better use of the solar spectrum as each of the junctions is optimized to capture the radiation of a different part of the spectrum. Based on the spectral response, the theoretical limit efficiency of traditional silicon cells is 40%, whereas multi-junction III-V cells could potentially reach 86%.

Figure 4 The Measured Spectral Response (External Quantum Efficiency, EQE) of a GaInP/GaInAs/Ge Triple-junction Solar Cell



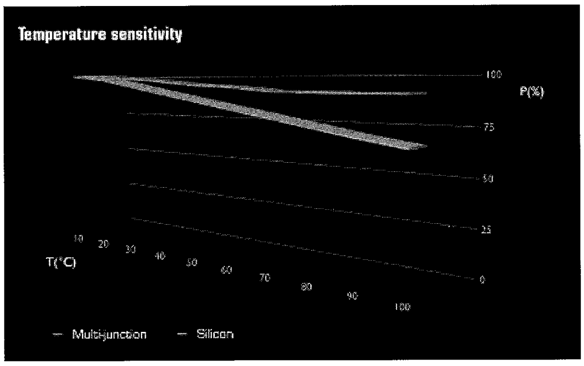
BOL = Beginning of Life EOL = End of Life

Figure 5 Schematic Layer System of a GaInP/GaInAs/Ge Triple-junction Solar Cell on Ge Substrate



Moreover, the multi-junction cells with these III-V elements like GaAs together with In, Al and P are extremely stable in high temperature. This kind of cells has been developed many years ago for space application in satellites, which now proves their reliability over the time. The III-V cells have better temperature behaviour than silicon cells. As it is showed in the following figure, the III-V cells lose about 5% of power at 100°C, compared to the 30% loss of silicon at the same working temperature.

Figure 6 III-V Materials Multi-junction Solar Cell has Best Performance at High Temperature

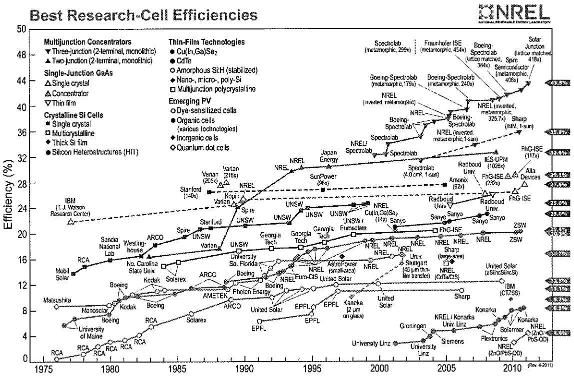


The use of III-V semiconductor materials has elevated the level of interest in CPV beyond anyone's imagination. The high efficiency of the multi-junction III-V materials, over 40% on average under concentrations of a few hundred suns, has revived hopes that CPV systems can actually achieve low cost via increased module efficiency. In fact, the efficiency of the multi-junction solar cells is quite leveraging in terms of cost reduction.

Current records for laboratory multi-junction cell are 43.5% at concentration greater than 400 times and 43.0% out to 1,000 times from Solar Junction in April 2011. The 43-45% efficiency level cells for HCPV market will be reached in the next 2-3 years.

These very high efficiencies would allow as well the reduction of the cell size down to 100mm^2 or even 10mm^2. This decreasing area also allows

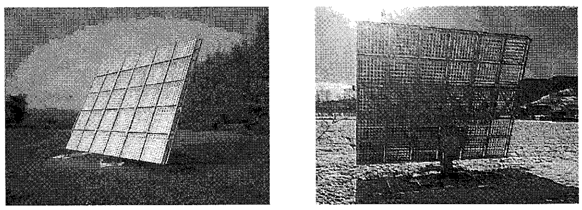
Figure 7 Historic Summary of Champion Cell Efficiencies for Various PV Technologies



Source: National Renewable Energy Laboratory, USA (2011)

the improvement of the thermal behaviour and the reduction of the serial resistance, improving the working efficiency. Currently, almost all systems using multi-junction cells have concentration ratios of more than 350X, while the majority feature more than 450X (Concentrix-Soitec, Solfocus, Arima), with some using ratios of up to even higher than 1,000X (Beghelli and Isofotón). The way is paved to proceed to higher concentrations.

Figure 8 Photographs of the Grid-connected HCPV Systems with 1,000 Times Concentration



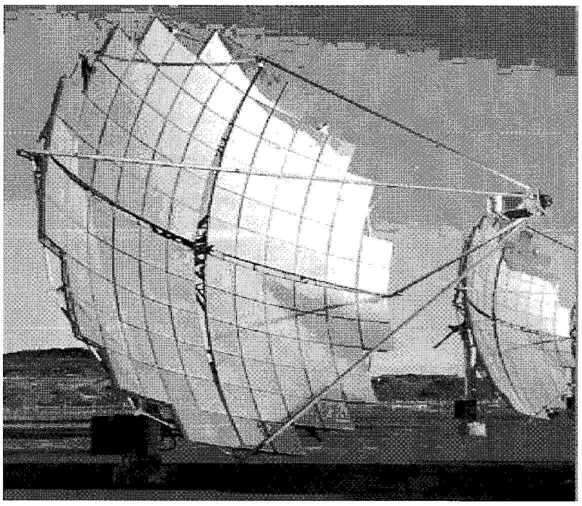
Most companies are pursuing designs using 400X to 1,000X HCPV systems that require the use of two-axis trackers to maintain to optical alignment with direct insulation as the relative of the sun changes throughout the day. These high concentration designs have cell efficiencies ranging from 30% - 40% with III-V cell for current large-scale commercial installations.

SIEMENS

3.2 OPTICS

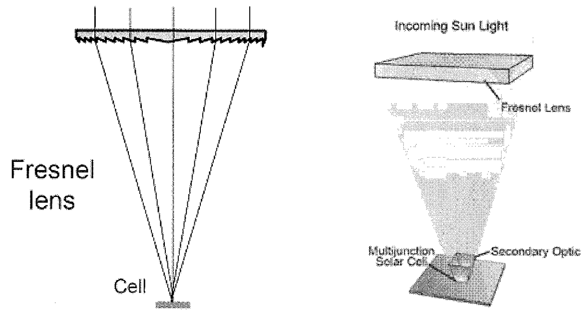
In order to design CPV systems, optical designs that meet the strict criteria are keys to new HCPV concepts. Traditionally designers need to define whether the concentration will be achieved via reflective or refractive optics. HCPV modules can be made with reflective optics (Beghelli, SolFocus, Boeing) or with refractive optics (Concentrix-Soitec, Arima, Isofotón). A reflective optics system is also used for the so called "dense array" concentrators. This is the case of the Solar Systems module currently operating in central Australia. The cells operate at a maximum temperature of only 45°C. With dense arrays, the module needs active cooling system to maintain the cells at reasonable operating temperature.

Figure 9 Photograph of Field of Solar Systems with Reflector Optics in Australia



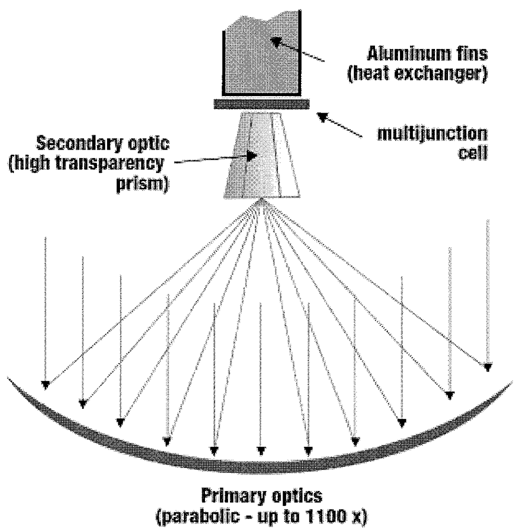
In systems using refractive optics, the Fresnel lens is still the optical element of choice in which a parquet of Fresnel lenses concentrates the sunlight on individual cells mounted on a heat sink, as shown in Figure 10. Since the cells are spaced far apart from each other, this approach allows passive cooling of the cells without raising the temperature signigicantly above the ambient. The expected temperature rise above the ambient is dependent on the wind speed, as with any passive cooling system.

Figure 10 Principle of Concentration Photovoltaic with Fresnel Refractive Lens Focusing the Sunlight onto the Solar Cell



Recently, a company has been developed a new reflective optical system composed of an array of high reflective micro parabolic dishes and secondary optical prisms with very high geometrical concentration factor of 1,350 times. The secondary non-imaging prism has been designed to improve the acceptance angle of the system and allow a better light distribution on the cell. Consequently, this secondary optics improves the collection of sunlight and further enhances the overall performance of the system. In this patented design, which makes use of a single reflection of the sunlight, the cells are mounted on thin aluminum fins which are on front side of the module and remove the heat in the most efficient way improving the thermal behavior of the HCPV module.

Figure 11 Schematic Diagram of Reflective and Refractive Optical and Thermal Design

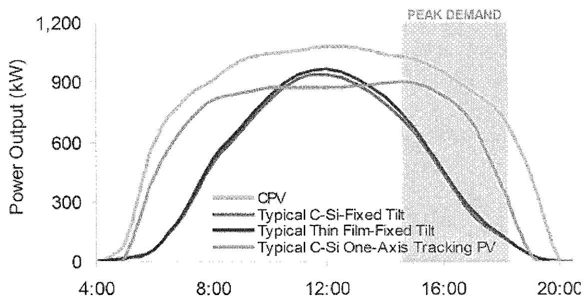


3.3 TRACKER

The HCPV system must follow the sun in its apparent motion to ensure the collection of the direct irradiation from the cells through the optics. The tracking of the sun gives a significant improvement in the energy collection, as it allows for a constant maximal intercepted area of the modules for the sunlight. This act permits to improve the energy of 30-40% respect to fixed installations of same peak power, with this percentage depending on the latitudes of the installation.

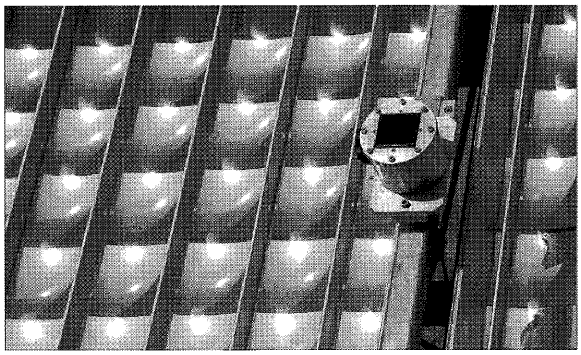
Thus, for an economical point of view, the additional costs introduced by the sun tracker have to be balanced by the gain in the energy production; this is the straightforward evaluation in the case of standard modules; for CPV the trackers are fundamental parts of the systems. It is an integral element and must be considered as an essential component. For these reasons, high efforts in the designing and production of cheap and reliable trackers are fundamental for the CPV establishment. CPV systems, depending on the technology employed for the modules and cells, can use single axis trackers and two-axis trackers. While for the HCPV the two-axis sun tracking with a very high accuracy is mandatory.

Figure 12 CPV Systems with 2-axis Sun Tracker have Consistent Energy Production



The control of the tracking system can be carried out in open loops (sun movement equation) or closed loops (light sensor). Use of a single control method can pinpoint tracking errors, while tracking accuracy can be reduced by using an open loop control on a system that has not been precisely installed and positioned. A closed loop system will not work properly if there are clouds shadowing the light sensor. Current systems use hybrid control, which include both sun movement algorithms and radiation or power output sensors.

Figure 13 The Sun Position Sensor on the HCPV System

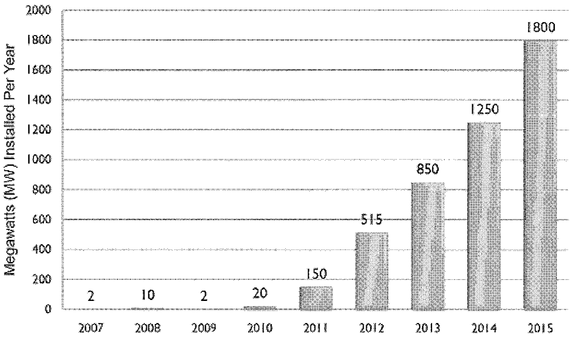


The construction of trackers must be optimised with respect to size, load-capacity, stability, stiffness and material consumption. This demands for a close co-operation with engineers for industrial load carrying constructions. Although HCPV industries did not describe trackers as a serious problem, trackers are known to require periodic maintenance, and glitches in performance or outright mechanical failure can decrease performance and increase maintenance costs substantially.

4. HIGH CONCENTRATION PHOTOVOLTAIC MARKET

The market for CPV, thanks to the already excellent performance of the system, the ability to work more efficiently at high temperatures, the special cells that can transform 40% of solar radiation into electricity, is expected to have a very high growth. According to the new market research report, "Concentrated Photovoltaic and Solar Photovoltaic Global Market (2009 - 2014)", published by MarketsandMarkets, the total CPV market is expected to be worth USD 266 million by 2014. Europe is expected to command the maximum market share at 59.3%, followed by the Americas, which are expected to hold 32% of the global CPV market.

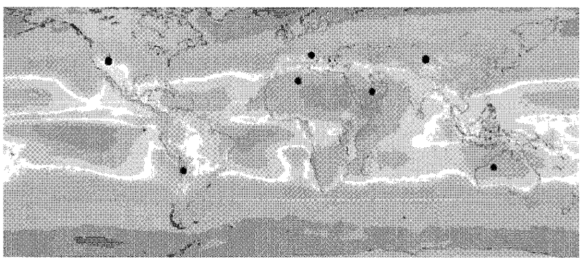
Figure 14 CPV Market Forecast



Source: 2010-2015 CPV Consortium Report

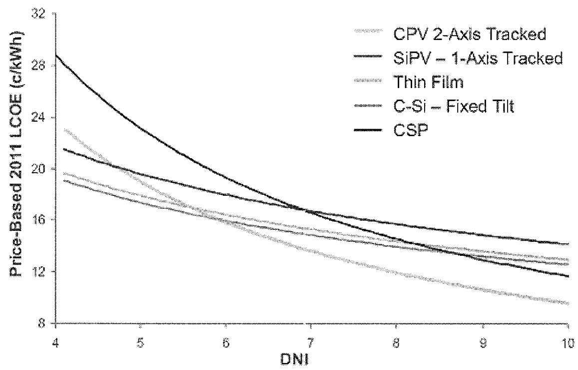
The CPV market includes the submarkets for Low Concentration PV (LCPV), Medium Concentration PV (MCPV), and High Concentration PV (HCPV). Among all segments, HCPV commands the large share of global CPV market. The conversion of HCPV systems lowers land requirement, and facilitates higher energy consistent production at lower costs. HCPV technology is thus expected to achieve cost parity with conventional sources of electricity at a faster rate than other PV technologies by increasing system efficiency with technological improvement and decreasing manufacturing costs of an increase in cumulative production. The economic learning curve estimates a reduction in costs for PV technology of 15% - 20% every time the installed cumulative capacity is doubled according to International Energy Agency (IEA) report.

Figure 15 World Map of Solar Irradiation



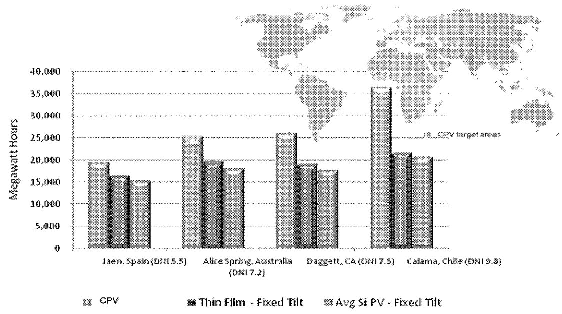
The initial high growth opportunity for the CPV market lies in regions with high direct normal irradiance (DNI) or direct solar radiation and high cost of grid electricity. In fact, CPV systems make use of only the direct radiation, and cannot convert the diffused portion of the sun power and so perform best in areas with maximum direct irradiance. These regions include southwest Europe, southwest America, western and central Australia, Middle East, and Northern Africa. Hence, CPV systems can have a competitive levelized cost of energy (LCOE) in these target markets (> 6kWh/m^2/day DNI) with greater future potential comparing to other PV technologies.

Figure 16 CPV has a Leading LCOE in High DNI Market



It is estimated that in the medium term, HCPV systems have the potential to provide lowest costs of energy production and in line with those of more traditional power production such as coal and oils, etc. especially in regions with a high solar irradiation. Thanks to the HCPV technology it will be possible to fix a 5 years time target to reach the grid parity, i.e. HCPV energy production cost equal to purchasing energy cost, in certain European southern regions (in Europe the typical cost of energy for a small to medium user is 0.16 euro/kWh).

Figure 17 CPV Systems with 2-axis Sun Tracker have Highest Energy Yield in High DNI



Source: CPV Consortium 2011

It is an important first step that will revolutionise the significance of energy: it will combine economy and ecology, creating systems that will no longer need to be subsidized from governments. Prudential forecasts show more than 4GWp installed over the next five years in the world, with an expected annual growth of 75%!

The technology developments in the CPV systems are currently concentrated in Spain, Germany, Italy and the U.S. However, the government support for CPV technologies in countries such as Australia, Japan, China, India are expected to drive future CPV market growth.

5. CASE STUDY OF ENERGY PRODUCTION OF A HCPV SYSTEM

The Installation of a Life Tree HCPV system in Bologna, Italy as one of the first systems in the country for commercial application, takes aim to promote the industrialization of HCPV technology through demonstration of reliability and performance of the system.

The system integrates 48 high concentration modules and is rated 8,160Wp at 900W/m^2. Each single module, with a nominal power of 170W at 900W/m^2 has its own high performance inverter which allows the maximum possible energy production, despite of shadows or modules mismatching, and is a complete DC/AC grid connected converter with efficiency greater than 95%. The high concentration module makes use of the best available multi-junction solar cell technology with an energy production conversion up to 40%. Each module is made of 64 solar cells each with its own bypass diode which ensures the module's operation even in the event of single cells failures. The high concentration factor is over 1,300 times with a system efficiency of more than 24%. This excellent result makes it possible to build compact and easy to mount high concentration solar modules. The Life Tree system solar tracker has an automatic hybrid control system that continuously keeps the system aligned to the sun with an angular accuracy better than 0.1 degrees and makes use of brushless motors for minimizing the maintenance. The system has been designed to withstand the wind force up to 30m/s and for an operational lifetime of at least 20 years with minimal maintenance.

Table 1 The HCPV Module and System Technical Specifications

Technical Details	Value
Module Peak Power (918x918x174)mm	170Wp@900W/m^2 DNI AM 1.5
Module maximum power point (MPP) voltage	176V
Module open circuit voltage	198V
Module maximum power point (MPP) current	0.96A
Module short circuit current	1.1A
Module efficiency	> 24%
System peak power	8,160Wp@900W/m^2 DNI AM 1.5
System operation temperature	- 40°C to + 85°C

The energy production of the Life Tree HCPV system in various locations of the northern and southern of Italy, and the energy output of the modules have confirmed the expected figures. It is estimated that the system is able to produce up to 1,200 kWh/kWp in Bologna, in north of Italy and up to 1,600-1,800 kWh/kWp in south of Italy. The following table gives details the expected yearly energy production of the Life Tree HCPV system in different part of the world. The NASA data bases for the available DNI have been used for the forecast calculations.

Paper No. 4

Table 2 Estimation of Energy Production of the Life Tree HCPV System vs Fixed Flat-plate Silicon Module in Different Countries

ANNUAL ESTIMATED ELECTRICAL PRODUCTION (KWH/KWP) - SOURCE: NASA							
Country	City	Life Tree energy yield	Fixed crystalline PV yield	Country	City	Life Tree energy yield	Fixed crystalline PV yield
ALGERIA	Algeri	1764	1554	MOROCCO	Casablanca	1866	1632
AUSTRALIA	Alice Springs	1923	1714	OMAN	Muscat	2068	1744
AUSTRALIA	Perth	1643	1539	QATAR	Doha	1966	1679
BAHREIN	Manama	1961	1681	SPAIN	Valencia	1811	1561
BRASIL	Fortaleza	1561	1571	SOUTH AFRICA	Johannesburg	1840	1702
CHILE	Santiago	1897	1708	TUNISIA	Tunisi	1687	1500
CYPRUS	Nicosia	1760	1542	UAE	Dubai	1816	1610
EGYPT	Il Cairo	1710	1565	USA	Albuquerque	1794	1652
GREECE	Athens	1445	1348	USA	Phoenix	1858	1654
ISRAEL	Tel Aviv	1664	1529	USA	San Diego	1776	1598
JORDAN	Amman	2656	1532				

During the numerous tests carried out in Italy the actual energy production for a clear and high DNI day was measured over 95% of the design specification. As a result, the HCPV system represents a great source to generate renewable energy. After just six months, the HCPV system has already produced all the energy that was spent for its construction compare to the two years of the traditional silicon modules.

6. CONCLUSION

John Lasich, the founder of Solar System says about the technology, "This is a new generation of solar technology. The secret is to be able to make a solar power module work about 1500 times harder than standard solar panels. If you can do this at high efficiency using low cost materials, you have the recipe for an infinite supply of clean at affordable prices.

The concept of using concentration to bring the cost of solar electricity down is not a novel concept. What is new here is the innovation that makes solar technologies economically attractive. In the case of HCPV, the innovation comes primarily from the use of the III-V multi-junction solar cells that were originally developed for space applications.

It has been shown in this paper that the advantages of HCPV are high efficiency potential, lowest cost of energy production in PV technologies in high DNI conditions, high temperature performance, and increase energy production with sun tracker and new optical systems. The HCPV system is ongoing improvements and offers great potential in terms of supplying the world a significant energy source in the electrical energy market. Hence, this green and clean energy will generate important advantages for society and the economy.

REFERENCES

[1] EU Photovoltaic Technology Platform, "Concentration Photovoltaics (CPV)," April, 2006

[2] Sean Connor, "The Growth of Solar Concentrator Photovoltaic Markets in the Southwest of US," April, 2008;

[3] G. S. Kinsey, K. M. Edmondson, "Spectral Response and Energy Output of Concentrator Multijunction Solar Cells," October, 2008;

[4] European Commission, "PHOTOVOLTAIC SOLAR ENERGY Development and current research," 2009;

[5] S. Kurtz, "Opportunities and Challenges for Development of a Mature Concentrating Photovoltaic Power Industry," National Renewable Energy Laboratory, Revised July 2010;

[6] M. McDonald, J. Dittmer, "Accurate Energy Prediction for Tracking HCPV Installation," California, USA, 2009;

[7] A. Anotonini, "Photovoltaic Concentrators – Fundamentals, Applications, Market & Prospective," Italy, 2010;

[8] Global Solar Technology, "New Survey Outlines Challenges and Opportunities for CPV," April, 2010;

[9] MarketsandMarkets, "Concentrated Photovoltaic and Solar Photovoltaic Global Markets (2009 – 2014)," 2010;

[10] F. Muhammad-Sukki, R. Ramirez-Iniguez, S.G. McMeekin, B.G. Stewart & B. Clive, "Solar Concentrators," 2010;

[11] W. Nishikawa, S. Home, "Key Advantages of Concentrating Photovoltaics (CPV) for Lowering Levelized Cost of Electricity (LCOE),"

[12] M. A. Green, K. Emery, Y. Hishika, & W. Warta, "Solar Cell Efficiency Table (Version 37)," October, 2010;

[13] Beghelli Planet Sun – Energy for Life, catalogue 2009;

[14] Beghelli Life Tree High Concentration Photovoltaic System, catalogue 2011;

- Notes and Questions -

Paper No. 5

MAPPING THE CARBON FOOTPRINT OF ELECTRICAL RAILWAY VEHICLES

Speaker : Ir Richard K.Y. Kwan
Manager – Environmental
MTR Corporation Limited

MAPPING THE CARBON FOOTPRINT OF ELECTRICAL RAILWAY VEHICLES

Ir Richard K.Y. Kwan
Manager – Environmental
MTR Corporation Limited

ABSTRACT

Rail travel has always been regarded as environmentally friendly. Over the past few years there has been a worldwide trend to examine this environmentally friendly transport mode in much greater details. And assessing the carbon footprint of railway vehicles is one of the tools employed to provide useful indications of the embodied carbon of this workhorse of the rail transport mode. The paper will share with us the recent MTR initiative of carbon mapping new vehicles, including the successes and challenges.

1. INTRODUCTION

In the railway industry, the electrical vehicle is usually called the Electrical Multiple Unit or in short "EMU". The EMU is a piece of complicated, important, expensive and long lifespan equipment. It weighs approximately 240 tons and has a useful lifespan of 45 to 50 years. During the peak hours, one EMU would carry around three thousand passengers. Everyday it operates over 14 hours and runs about 300km.

Due to these special attributes of EMU, the tool to estimate its carbon footprint should cover from cradle to grave in order to gain an holistic and balanced view from train production to train disposal. Life Cycle Analysis (LCA) is therefore an appropriate tool because it covers the carbon footprint of the entire life cycle. In the West Island Line project, MTR has conducted a Life Cycle Analysis to evaluate the carbon footprint of the new EMU. The LCA covers the carbon emission from new train production to used train disposal. The LCA exercise is still on-going. But we are here to share some preliminary results with the profession.

2. METHODOLOGY AND SCOPE OF LIFE CYCLE ANALYSIS ON EMU

2.1 METHODOLOGY

The LCA is to evaluate the carbon emission. It basically follows the still evolving general principles and guidelines of international understanding and guidance such as:

- ISO 14040-2006, Environmental Management – Life cycle assessment – Principles and framework;
- BSI PAS 2050:2008 - Specification for the Assessment of the Life Cycle Greenhouse Gas (GHG) Emissions of Goods and Services.

These guidelines and standards are in general, user friendly and applicable to different industries. They are, however, not descriptive step by step methodology. In fact, they only attempt to provide general guidance and principles for the LCA.

2.2 SCOPE OF LCA

Based on the evolving international understanding, the LCA has been divided into 4 phrases:

- Goal & boundary definition – set the boundary of the analysis, i.e. what should be included and what should not be included;
- Inventory analysis – collect data and define assumptions and limitations;
- Impact assessment – calculate the carbon emission or carbon footprint;
- Interpretation – recommend improvement actions based on the carbon footprint.

3. GOAL & BOUNDARY DEFINITION

The main goal of the LCA is to evaluate the carbon emission from EMU production, transportation, operations, maintenance and used train disposal at the end of the useful life. Some data are excluded due to unavailability, for example, the raw material delivery mode and route. Therefore, the boundary of the LCA is confined to the raw material itself, manufacturing process, train delivery, train operation and used train disposal.

3.1 EMBODIED CARBON

The carbon emission for the EMU production is called the embodied carbon. It is composed of the carbon emission from the following processes:

- Fuel and power consumption during train production;
- The material, such as metal, glass, rubber and wood used for the train production.

3.2 CARBON EMISSION FROM TRANSPORTATION

The carbon emission from the delivery of EMU from the factory in Changchun to Hong Kong is assessed. It includes both the land and sea transportation.

3.3 CARBON EMISSION FROM OPERATIONS

This is the carbon emission from the operations of EMU within the Hong Kong MTR network. It is estimated from the data collected from the existing operating railways in Hong Kong.

4. INVENTORY ANALYSIS

The LCA needs to collect data from the following process to calculate the carbon emission:

- The weights of the raw material used for the train production
- The fuel and electricity consumption during train production
- The route and mode of train delivery
- The power consumption during train operations
- The expected life span of the train
- The maintenance program of the train
- The train disposal method

Collecting these data is the most difficult stage of the LCA assessment. The data of the larger components such as bogie, traction motor, braking system, etc. can be obtained from the suppliers relatively easily. However, the data of minor systems would need detailed measurement, such as length of wire, weight of panel, etc. It requires a lot of hard and tedious work.

5. IMPACT ASSESSMENT

Impact Assessment is to calculate the overall carbon emission. The calculation is based on the following simple formula:

Weight or Length or Number of Equipment x Emission Factor = Carbon Emission

The formula may be simple. But the work involved is intensive and sometimes complicated.

The emission factors used are from the following local and international sources:

- The Inventory of Carbon & Energy (ICE-v1.6a) launched by the University of Bath (UK)
- Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories
- Notice issued by National Development and Reform Commission. The value is based on the North-Eastern China electricity network, covering Liaoning, Jilin and Heilongjiang Provinces.
- United States Environmental Protection

Agency (USEPA), Appendix H Fuel Emission Factors of Instruction for Form EIA-1605, Voluntary Reporting of Greenhouse Gases.

- EPD / EMSD Guidelines to Account for and Report on Greenhouse Gas Emissions and Removals for Buildings (Commercial, Residential or Institutional Purposes) in Hong Kong, 2010 Edition.

After all the calculations, a master database of carbon emission is formed.

6. INTERPRETATION

Since the LCA exercise is still on-going, we can only share some preliminary results as follows:

- Metal has the highest carbon footprint, the second is polymer (plastic), the third is elastomer (rubber);
- The train production in Changchun has larger carbon emission from fuel consumption than electricity consumption as coal burning is still common in the factories in China;
- Within the life cycle of EMUs, the operational carbon emission is the majority;
- The carbon emission from transportation and maintenance is very minor.

7. CONCLUSION

LCA has been introduced to Hong Kong for several years but it is still not popular nor widely adopted in commercial and industrial sectors. LCA always gives an impression that it is a very complicated and impractical method. Through the LCA on the new West Island Line EMU, we can have an holistic picture on the carbon emission of an EMU from cradle to grave. To reduce the carbon footprint of the equipment with some 45 years life is not easy. LCA can give us some hints on the stages that carbon footprint can be reduced. For example, switching from burning coal to natural gas or electricity can reduce the carbon emission from the production line; using recycled metal can significantly reduce production carbon footprint. LCA provides an alternative method to justify long term investment on carbon reduction upon long lifespan equipment. Although LCA is complicated for large systems, the information gained is valuable.

- Notes and Questions -

Paper No. 6

INTEGRATING LOW CARBON ELECTRICITY NETWORKS WITH LOW CARBON BUILDINGS

Speakers : Mr Steven Mullins
Global Lead, Smart Grid and Mobility
Siemens Metering Services – Energy Sector

Dr Vincent Thornley
Solution Manager for Smart Grid Applications
Siemens UK

Dr Cristiano Marantes
Low Carbon Networks Development Manager
Future Networks, UK Power Networks

INTEGRATING LOW CARBON ELECTRICITY NETWORKS WITH LOW CARBON BUILDINGS

Mr Steven Mullins
Global Lead, Smart Grid and Mobility
Siemens Metering Services – Energy Sector

Dr Vincent Thornley
Solution Manager for Smart Grid Applications
Siemens UK

Dr Cristiano Marantes
Low Carbon Networks Development Manager
Future Networks, UK Power Networks

Paper No. 6

ABSTRACT

As major cities and metropolitan areas embark on the transitional path toward a low carbon economy, a number of technical and commercial challenges emerge for electricity network operators. London shares many common features with other major international urban cities having the highest concentrations of electricity demand and CO_2 emissions in Great Britain and the most demanding carbon reduction targets (60% reduction on 1990 levels by 2025). London's electricity networks are already very highly utilised and its urban environment means that reinforcement costs are high. London also has the greatest scope in the UK for the adoption of distributed generation, micro generation, and electric vehicles.

As part of Ofgem's (the UK energy regulator's) Low Carbon Networks Fund scheme, UK Power Networks put together a project which will develop new approaches to distribution network management to meet growing demand from emerging low carbon technologies such as electric vehicles, heat pumps and distributed generation. The Low Carbon London project will focus on carbon reduction targets and the need to reduce dependency on conventional network reinforcement.

Siemens as a key partner of the LCL project is developing a landmark building, the urban sustainability centre. This building will showcase the latest sustainable technologies and demonstrate excellence in sustainable construction. Through design the building will reduce energy consumption and optimise use of renewable energy to meet its requirements. The project will bring together current established best practice systems, such as photovoltaic cells, solar thermal water heating, rainwater harvesting, ground source heat-pumps and storage.

However, the urban sustainability centre building will not be managed in isolation. It will be integrated with the LCL project, so that the building itself can become an integral part of the electricity network by adjusting its demand in response to network issues and also following or twinning its demand with wind.

1. INTRODUCTION

One of the principal drivers for smart grids is to support the decarbonisation of the energy supply chain. In the UK, two effects of decarbonisation which may result are a substantial increase in variable generation, such as from wind, photovoltaic and marine sources, and an increase in the amount of energy transported through electricity networks, to support electric heating and electric vehicles (EV).

While traditional methods of network design, construction and operation may be able to support the above, smart grid technologies should deliver increased efficiencies, provide flexibility for future unknowns, allow increased market participation and limit the need for new construction. One of the key areas in which smart grid technologies are not simply advancing, but completely changing the technical, commercial and social aspects of our relationship

SIEMENS

with energy, is around the interface between buildings and the electricity network.

This paper describes an initiative ongoing in London that will trial the integration of a modern building management and control system with the operation of the electricity distribution system. The initiative has two parts. Firstly, the Low Carbon London (LCL) project[1] being undertaken by UK Power Networks (UKPN) the Distribution Network Operator (DNO) for London and secondly, the Urban Sustainability Centre[2] which is being constructed. Section 2 of this paper introduces the LCL project, Section 3 introduces the Urban Sustainability building being constructed, Section 4 describes the plans to integrate these exciting projects, and Section 5 provides conclusions.

2. THE LCL PROJECT

LCL is a collaborative project between UK Power Networks (UKPN) and expert delivery partners (Figure 2). The project will work closely with the Mayor of London's Office, Transport for London and the Institute for Sustainability to support their existing energy efficiency initiatives. Imperial College London will develop the 'Low Carbon London Learning Laboratory' to share the learning from the project and act as a portal to the project for industry and interested parties.

Figure 1 LCL Project Partners

The project is exploring a number of use cases as depicted in Figure 1 and briefly described below.

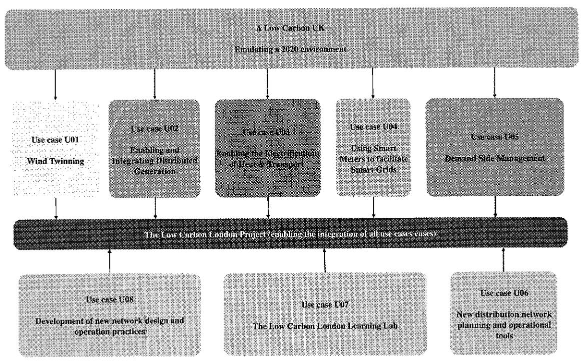
2.1 U01 WIND TWINNING

In this use case, the ability of demand to follow local and national wind energy production and the corresponding impacts on distribution networks will be identified and explored. This form of "twinning" demand with wind generation will be trialled using day-ahead Time of Use (ToU) wind twinning tariffs, which will be designed and offered to a relatively small number of residential and Small and Medium Enterprise (SME) customers by electricity suppliers. The ToU tariff will provide an incentive for customers to plan their use of non time-of-day critical electrical appliances to coincide with times when wind energy output is expected to be high.

2.2 U02 ENABLING AND INTEGRATING DISTRIBUTED GENERATION

In order to support the connection of existing and new Distributed Generation (DG) units on London's distribution network, UKPN will require increased visibility and controllability of network components and parameters, connected devices and DG units. The deployment of technologies such as Active Network Management (ANM) to manage network constraints in real-time will allow UKPN to maximise the use of the existing network, avoiding or delaying the requirement to invest in new network infrastructure. New commercial arrangements with DG developers will be required to permit their output to be regulated by UKPN.

Figure 2 LCL Use Case Structure



2.3 U03 ENABLING THE ELECTRIFICATION OF HEAT AND TRANSPORT

The introduction of heat pumps to properties connected to the network in London is likely to increase loading, resulting in direct impacts on power flow magnitude and voltage profiles. The use of heat pumps may also coincide with existing peak network demand, resulting in a significant additional burden to the distribution network. Heat pump deployments within the Low Carbon Zones and Green Enterprise Districts will be monitored to learn more about this technology, its behaviour and how it impacts on the operation of the distribution system.

Likewise, EV charging deployments will also be monitored to learn more about the nature, behaviour and network impacts of this new technology. Uncontrolled charging of EVs has the potential to add significant loading to the network, resulting in violations of thermal and voltage constraints, and possibly impacting on the quality and security of supply.

2.4 U04 USING SMART METERS TO FACILITATE SMART GRIDS

By 2019 the UK roll-out of smart meters to all residential and most SME customers will have been completed. The LCL project will explore the opportunities to deploy and assess the different means (both technical and commercial) of accessing and using smart meter data. These include the challenges and opportunities associated with distribution network operation and design. The benefits of options for making use of real-time or near real-time data from smart meters in automatic or manual network operation decision making will be explored.

2.5 U05 DEMAND SIDE MANAGEMENT

The LCL project will evaluate the impact of several residential and SME energy efficiency and demand response programmes on the distribution network. This use case will investigate the ability of demand response aggregators to provide demand response services tailored to the requirements of distribution network. The services to be trialled will provide varying magnitudes of demand response over different time periods and will also demonstrate the effectiveness of demand side management of industrial and commercial customers as a tool available to defer/avoid network reinforcement.

2.6 U06 NEW DISTRIBUTION NETWORK PLANNING AND OPERATIONAL TOOLS

Several new tools and systems will be deployed as part of the project including:

i) Operational Data Store

A key component of the London Carbon London project. It will provide a network centric view of all smart meter and half hourly metering data, network data, network events and control actions within a time series database.

ii) Active Network Management

This involves the deployment of systems that, when a breach of network constraints occurs, will automatically regulate the consumption or production of power, or adjust the operating position of network components to ensure the network remains within safe operating limits.

iii) Smart Metering Head-end System

This will manage access to the smart meter communicat-ions infrastructure and translates commands from the market participants' (energy suppliers, network operators, metering agents, etc) systems into the languages used by the meters and devices connected to home area networks.

iv) Carbon Tools

These tools will be used to evaluate performance of the LCL Project with regards to the level of CO_2 reduction achieved will be developed.

2.7 U07 The LCL LEARNING LABORATORY

This will provide a means of disseminating information and learning from the LCL project to a wide audience through the 'Low Carbon London web portal' and other dissemination

Paper No. 6

activities such as workshops and seminars.

2.8 U08 DEVELOPMENT OF NETWORK DESIGN AND OPERATIONAL PRACTICES

The activities and technologies being undertaken as part of the LCL trials present a number of opportunities and challenges and opportunities to DNOs. The LCL project will explore the short and near-term impacts on the planning and operation of distribution networks, identifying the new requirements being placed upon the DNO's business and the development of new standards and methods used to plan and operate distribution networks.

3. SIEMENS' URBAN SUSTAINABILITY CENTRE

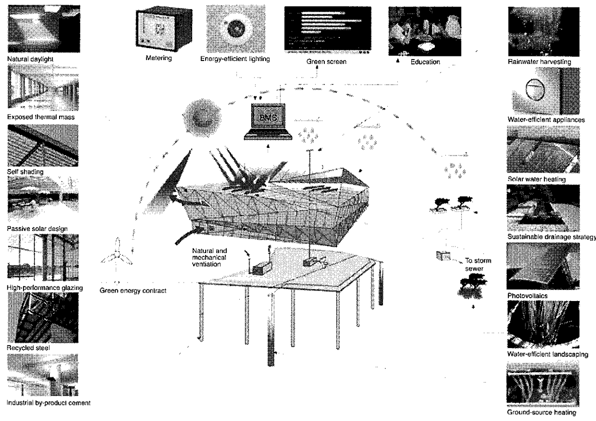
The Urban Sustainability Centre is being constructed in the heart of London's Docklands. Its purpose is threefold:

Firstly, the Centre will provide an exhibition area to give visitors an opportunity to learn about technological solutions to urban challenges such as climate change and urban sustainability. This will be targeted at not only city planners and officials, but also members of the local community and educational groups, from school children to post graduate level students. It is envisaged that the Centre will attract approximately 100,000 visitors every year.

Secondly, the building will "walk the talk". The building itself will showcase many of the same sustainable technologies as are presented in the exhibition area and will demonstrate excellence in sustainable construction.

Thirdly, for its more conventional purpose, the Centre will provide office space for around 250 persons, a 300 seat auditorium as well as a shop, restaurant and café facilities. This aspect is important as it allows demonstration of the use of sustainable technologies in a normal office environment. The Centre has been designed to meet key national and international metrics for environmental standards: Buildings Research Establishment Environmental Assessment Method (BREEAM) Outstanding and Leadership in Energy & Environmental Design (LEED) Platinum ratings. Key aspects of the building are shown in Figure 3.

Figure 3 Key Aspects of the Urban Sustainability Centre



The architecture of the building structure is designed to maximise natural and passive effects for daylight, solar heating, shading and ventilation. This is reinforced through the use of low thermal mass, high performance glazing and energy efficient lighting.

In the use of water the Centre will employ rainwater harvesting and water efficient appliances to reduce mains water consumption, and water recycling for irrigation purposes. The Centre is designed as an all-electric building. The heating, ventilation and air-conditioning system, in support of the building's natural effects, will make use of boreholes and ground source heat pumps.

Photovoltaic (PV) generation will be provided as part of the roof cladding. 1800m^2 of panels will be provided and it is anticipated that this will provide 25% of the annual electrical consumption, with a peak output of 250kW.

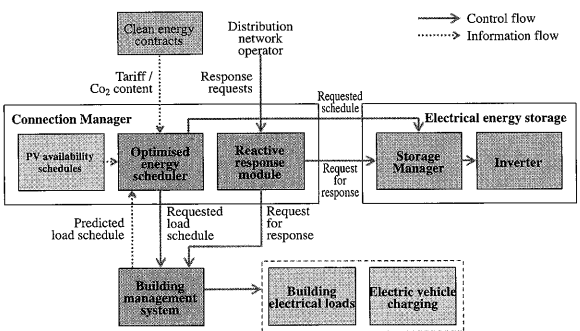
The building will have a variety of charging points for EV, most of which will be public charging points. These will include five 22kW chargers, a 22kW charger, and provision for a 55kW charger. There will also be "private" charging facilities for use of the office-space occupants comprising three 7kW chargers, three 22kW chargers and again provision for a 55kW charger. If all the chargers are in use together this would be a collective load of over 300kW, a significant portion of the load budget for the Centre which is under 1MW.

All the electrical loads in the Centre will be under the direct control of the Building Management System (BMS).

With the electrical loads and control described previously there is both excellent motive and opportunity to make the building smartgrid-ready, in other words to be sensitive to the needs of the grid, to put its resources at the disposal of the grid, and to itself use energy in a way which allows a more-environmentally friendly (i.e. smaller) electrical connection. Key to this is the use of electrical energy storage which is capable of separating in time the use of electrical energy from its delivery to the building.

The energy management of the Centre is divided into two aspects (Figure 4). Firstly, the BMS is responsible for the efficient use of energy throughout the Centre and, while it can be sensitive to DNO's network needs, it must maintain appropriate quality standards for the services it manages.

Figure 4 Control Flow in the Smartgrid Ready, All Electric Building



Secondly, the centre of the building's smart grid interface, termed the connection manager, is capable of optimising the energy resources of the building: electrical load under control of the BMS, PV, battery storage and EV charging.

The connection manager will be capable of minimising the cost of delivering energy to the building and EV charging, minimising the carbon impact of energy delivered, and delivering services to UKPN as part of its LCL project.

4. INTEGRATION OF THE SUSTAINABILITY CENTRE

4.1 USE OF STORAGE

Key to the integration of the Centre to the LCL project is the storage capability within the centre. The following are the functions that the electrical energy storage is designed to achieve:

- Buffer output from PV generation;
- Decoupling energy purchase and use to take advantage of variable price tariffs and make greater use of low carbon electricity sources;
- Provide a source of real and reactive power for grid operations support; and
- Provide a limited standby power source.

Conventional battery storage has been chosen as a proven form of storage technology.

The minimum capacity of the battery has been determined by the requirements for standby power. In this instance it is determined that 250kW for 2 hours is the required level of storage for standby purposes. In reality, it is expected that the battery will be larger and its capacity determined by available space within the building, floor loading and/or heat output (and resulting cooling requirements).

The battery will be connected to the building electrical distribution through an inverter. The inverter is required to charge the battery when instructed to do so by the storage manager, and similarly discharge when instructed.

In addition, the inverter is required to be a four-quadrant inverter and capable of providing adjustments to the operating power factor (or level of reactive energy import/export) in order to provide a controllable source of real and reactive power.

The challenge for operation of the electrical energy storage is to ensure that sufficient stored energy is available for times when it is required (for functions such as standby power, supporting the DNO's network, and offsetting high energy purchase prices and energy with high carbon content). It must couple this with providing sufficient available capacity for storing any surplus locally generated energy from PV and absorbing energy from the network for smart grid purposes or when prices or carbon content is low.

4.2 INTELLIGENT GRID OPERATION

The storage management described in the previous section focuses on best use of the capabilities of the electrical energy storage for the building and being sensitive to the needs of the grid by providing a pro-active capability.

The next element in the approach to smartgrid-readiness is the addition of a channel to communicate the needs of the grid for the building to respond to (reactive response) and the inclusion of demand response capabilities through the BMS.

i) Demand Response of Building Loads

In a domestic environment there may be demand response interventions which have a long time constant before the effect is seen. For a building under BMS control it is likely that the BMS is already recognising these time constants in its operation to improve the operating efficiencies, therefore any responses may have immediately noticeable effects. An example is accounting for the thermal inertia of the building to optimise how the HVAC and heat stores are managed.

The key here is prediction of when response will be requested and to "pre-load" the system in advance. For instance, if it is expected that there will generally be high electrical demand on the DNO's network at 9 am, for EV charging, then the connection manager and BMS between them need to recognise this and pre-heat/cool the thermal stores in the building during the preceding period to allow reduced energy consumption in the 9 to 11 am period.

In this regard the BMS will be responsible for the efficient provision of comfort building operations and the connection manager will optimise the provision of electrical energy. To achieve this, the BMS will provide to the connection manager a predicted schedule of building loads. The connection manager will then combine this with PV output predictions, expected grid requirements and tariff / green energy information to calculate movements in this energy use. The connection manager will then provide to the BMS a forward-looking schedule of desired building load which the BMS will use to optimise its operation.

ii) Demand Response With EV Charging

The anticipated onset of substantial quantities of EV is a source of potential problems and opportunities. On the one hand, if everyone charges together it has the potential to cause substantial grid problems due to the high peak load. On the other hand, EV charging is an ideal load for demand response.

Section 3 introduced the Centre and its two sets of EV charging equipment, public and private. The type of public charging (22kW quick chargers) implies that the users of such stations will expect charging to be complete in a short time, so limiting any opportunity for demand response. However, the private chargers are a different matter.

The office occupants will often be there for the day, which allows plenty of scope for scheduling the charge cycle according to DNO's network needs as part of the proactive response. Once charging is in progress there is the opportunity to interrupt it to provide a reactive response.

While there has been plenty of discussion in the smartgrid community of "vehicle to grid", i.e. using the electrical energy storage of the vehicle to feed back into the grid, there is no intention to support this at the current time, and there are no commercially-available vehicles which could make use of this.

iii) Integration of Response Resources

The connection manager will integrate the response and energy storage resources together to achieve the overall aims which are as follows:

- minimise the financial cost of energy used by the building;
- minimise the carbon impact of energy used by the building;
- Provide support to the DNO through load reduction; and
- provide reactive power support to the network.

The ability for the building loads and EV charging to provide demand response proactively and reactively was discussed previously, and this is summarised in the table below.

Table 1 Proactive and Reactive Responses

Resource	Proactive response	Reactive response
Building loads	Planned load schedules	Typically demand reduction through e.g. lighting
EV charging	Scheduled charging	Interruption of charging
Electrical energy storage	Planned charge/discharge schedules	Instant charging or discharging to meet response requirements

One further area that has not been discussed previously is aim 4 above – provision of reactive power support. The existence of a battery with four-quadrant inverter means that the inverter can deliver power at any power factor requested by the DNO.

5. CONCLUSION

This paper has provided an overview of features currently being built into a building in London to make it smartgrid-ready and the plans to integrate this with UKPN's LCL Project. The aim is to maximise the use of exemplar techniques – including some which are not yet commercially cost effective.

To evaluate the economics of the smartgrid-related techniques, the costs need to be assessed against all the functions included: providing a source of standby energy, delivering financial and low-carbon benefits from a green electricity tariff, and providing support services to the local distribution network. The commercial model of how a building is compensated for providing network support also needs to be determined.

The London distribution network supplying the Centre does not today require the techniques described in this paper. However, in the UK networks are undergoing a revolution in the way they are operated and managed, prompted by the creation by Ofgem of the Low Carbon Networks Fund. From this perspective the smartgrid-ready features, while not commercially justified today, are helping to define new boundaries of operation, reducing the cost of low-carbon electrical energy and supporting the UK's sustainability targets.

Early in the paper three elements of the smartgrid-ready building were introduced, two of which (electrical energy storage and intelligent grid integration) have been discussed in detail. The final element of the smartgrid-ready building is to operate as part of an autonomous microgrid, together with other distributed energy resources in the area. This is a planned future initiative and it is hoped that the Urban Sustainability Centre will be able to play a central role in this smartgrid, linking with public buildings in the area.

In creating this paper it has become evident how central the infrastructure of our cities is to the creation of smart grids. The features embedded within buildings, and available to be applied with the addition of appropriate intelligence, covers many of the features being discussed by the power system community today, including:

- Energy storage,
- Grid integration of renewable energy sources,
- Grid solutions for plug-in EV,

- Dynamic pricing,
- Intelligent demand management,
- Load Forecasting; and
- Energy management and efficiency, and end user benefits.

The key to making the buildings of the future smartgrid-ready is the use of intelligence to deliver the utility and comfort we expect from buildings. If this can generally be delivered, with noticeable impact reserved for the occasional rather than the regular and supplementing demand response with energy storage in all its forms, then the path to a smartgrid is greatly smoothed.

ABBREVIATION

BMS - Building Management System

DG - Distributed Generation

DNO - Distribution Network Operator

EV - Electric Vehicle

kW - Kilowatt

MW - Megawatt

LCL - Low Carbon London

PV - Photo-Voltaic

SME - Small Medium Enterprise

UKPN - UK Power Networks

REFERENCES

[1] Low Carbon London, A Large Scale Low Carbon Smart Grid Project, Marantes and Openshaw. The International Conference on Electrical Engineering 10-14 July 2011, Hong Kong

[2] Urban Sustainability Centre, Siemens plc, 2011. Available at: http://www.siemens.com/entry/cc/features/urbanization_extension/all/en/pdf/centre_brochure.pdf

- Notes and Questions -

Paper No. 7

THE POTENTIALS OF ENERGY-SAVING SOLID-STATE LIGHTING

Speaker : Dr Anthony H.W. Choi
Assistant Professor
Department of Electrical and Electronic Engineering
The University of Hong Kong

THE POTENTIALS OF ENERGY-SAVING SOLID-STATE LIGHTING

Dr Anthony H.W. Choi
Assistant Professor
Department of Electrical and Electronic Engineering
The University of Hong Kong

ABSTRACT

Light-emitting diodes (LEDs) have evolved from the candela-class monochromatic point source good for indicator lights to the present-day 120 lumens-per-watt high power white light lamps widely used as LCD backlighting. The tremendous progress can be attributed to quantum leaps in material epitaxy skills, device design and processing techniques, together with advanced packaging strategies. A brief history of the LED, to the construction of a modern day white light LED, will be described. Although LEDs promise lots of possibilities, many more remaining technical issues need to be addressed before solid-state lighting become pervasive in our cities. The major problems, together with a range of innovative solutions developed at the University of Hong Kong, will be presented.

1. INTRODUCTION

With rising concerns over depletion of energy reserves, or from a practical point of view, increasing costs of electricity, a plethora of strategies are being explored for the sourcing of renewable energy sources and, equally importantly, to reduce energy consumption before a long-term solution has been found. Lighting represents up to 20% of total electricity consumption in an urban city; the main present-day lighting devices are incandescent bulbs and fluorescent lamps. If lighting devices can be twice as efficient as they presently are, a substantial reduction of energy consumption can be achieved. Solid-state lighting is the solution.

2. A BRIEF HISTORY

Solid-state lighting refers to the use of light-emitting diodes (LEDs) as light emission devices, as LEDs are solid-state devices. LEDs, which simply are basic p-n junction devices as found in common diodes, have been around for decades, initially appearing on the front-panel of domestic electrical appliances as indicators, but found little uses beyond that. Why has LED technology developed so rapidly since the 1990s? Do you remember owning mobile phones with blue-backlighted LCD screens during those days? The invention of the blue LED by Shuji Nakamura certainly stirred up a revolution in lighting. However, the visible-light LED wasn't invented by him but by Nick Holonyak Jr. in 1962 and is thus regarded as the father of the light-emitting diode (of course, infrared electroluminescence has been demonstrated decades earlier).

The emission wavelength of a p-n junction (and thus colour) depends on the bandgap of the material used to manufacture the LED. In the early days, the arsenide and phosphide based semiconductors were commonly used, but these materials produces light at longer wavelengths (red and infrared). It was pertinent to find a new material with a larger bandgap capable of emitting light at short wavelengths and Gallium Nitride (GaN) was one of the contenders. However, technical difficulties relating to the growth of the material prevented it from flourishing, until Shuji Nakamura made the breakthrough while he was working at Nichia, demonstrating the first blue-light LED with appreciable brightness. Since then, GaN based LEDs have taken flight, and is taking the lighting industry by storm.

3. WHITE LIGHT GENERATION

The two major reasons accounting for the importance and impact of blue-light LEDs are their short wavelengths, together with the fact that blue is a primary colour. By combining the primary colours at the right proportions, white light can be obtained, a colour which has traditionally been used for general illumination.

As a matter of fact, white light is generated from fluorescent lamps in pretty much the same way. High-energy ultraviolet light is generated by exciting mercury vapour in the gas-discharge lamp, while visible light is produced by excitation of the coated phosphors on the glass tube, causing them to fluoresce. The actual colour of fluorescence depends on the nature of the phosphors. This process of colour down-conversion is possible as energy is conserved: high energy ultraviolet photons are capable of exciting fluorescence of lower-energy visible photons. This also explains why the early-day red-light LEDs were not so useful: they cannot be used to "up-convert" to shorter wavelength photons.

Today, there are two main types of white-light LEDs, both of which rely heavily on a blue-light LED. As mentioned before, white light can be produced by exciting phosphors with a shorter wave light source, an example of which is shown in Figure 1(a). In practice, a YAG phosphor coating is applied to a blue-light LED to generate white light, and such white-light LEDs are most commonly found in the market. These devices are now capable of luminous efficacies of >100 lumens per watt, nearly twice as efficient as the so-called energy saving fluorescent lamps. However, phosphor-converted white-LEDs typically lack emission at longer wavelengths and thus have low colour-rendering indices, making them less desirable illumination sources.

On the other hand, white light can also be produced by combining emission from three (or more) discrete LED chips emitting the three primary colours. Such devices are thus known as RGB LEDs, illustrated in Figure 1(b). In practice, the red, green and blue discrete chips are mounted side-by-side onto a common package, although they can typically be individually driven to produce a colour tuning effect. Due to the presence of red in the emission, RGB LEDs offer higher CRI indices, although the luminous efficacy will suffer as a result. The major issue with RGB LED is not with the performance indices, but with the colour mixing effect. Without external optics (which are lossy), the differently coloured light do not overlap well with each other, so the white effect is never homogeneous nor uniform, making short-distance viewing unpleasant.

4. POTENTIALS AND SHORTCOMINGS

What are the potentials of LEDs? The theoretical luminous efficacy limit of RGB-type white light devices exceeds 300 lumens per watt, substantially higher than incandescent (<20lm/watt) and fluorescent (<60lm/watt) technologies. This potential efficiency is what makes LEDs so promising, but do note that we are only half-way, at best, towards this target. Coupled with down-conversion and regulation losses (LEDs operate on dc-current), are present-day LED products fulfilling the promises?

There are many other issues to be considered including device reliability arising from material growth, device design, wafer processing, and device packaging. Also, the issues of efficiency droop, whereby LEDs become less efficient at high driving currents, remain unsolved. Nevertheless, intense efforts across the nitride research community worldwide are offering new solutions to these issues. The Semiconductor Lighting and Display team at the University of Hong Kong is an active player in the field; our contributions, in the form of developing novel chip geometries, introducing color-tuning capabilities and assembling flat-panel luminaires will be described.

5. OUR INNOVATIVE SOLUTIONS

One of the main limiting factors of LEDs is light extraction. Excessive reflection of light at interfaces results in light confinement and subsequent re-absorption, resulting in heat generation. Therefore, improving light extraction is a direct way of combating heat dissipation issues. Surface texturing, in the forms of random roughening or regular and periodic arrays of microstructures and nanostructures (also known as photonic crystals) has widely been adopted to minimize optical confinement in the vertical direction. However, little attention has been paid to lateral optical confinement, which is dependent on the dimension and geometry of the LED chip. In the highly symmetrical rectangular or square structure, a light ray that is reflected due to total internal reflection at one interface will most likely be reflected at subsequent interfaces. This can be understood from the fact that all interfaces, or facets, of such chips are either parallel or orthogonal to each other; the incident angle of a light ray remains unchanged after successive reflections unless scattered, so that such confined photons are eventually reabsorbed. The situation will change if the facets are not parallel to each other; this forms the basis of our interests in polygonal, circular and 3-D chip geometries.

The enabling technology for realizing LEDs of unconventional geometries is laser micromachining. Although lasers have now been widely adopted for chip dicing, they have continued to be used for making linear cuts even though laser beams can easily be steered to carve virtually any shape. Our chip-shaping experiments are conducted with our custom designed and assembled optical setup in our laboratory.

Table 1 Light Extraction Efficiencies of LED Chips with Different Geometries

Shape	Light extraction efficiency (%)
Triangle	15.07
Square	12.98
Pentagon	15.09
Hexagon	14.39
Heptagon	14.54
Octagon	14.43
Circle	13.98

Our hypothesis is also supported by optical ray-trace simulations. By examining the percentage of light rays that can be extracted from LEDs of different geometries, their efficiencies can be predicted. The results of our set of simulations on LED chips of circular, triangular, squarish, pentagonal, hexagonal, heptagonal, octagonal and circular (the circle is in fact a polygon with an infinite number of sides) geometries are summarized in Table 1. What stands out from the set of figures is the fact that square LEDs have distinctively lower extraction efficiencies than any other shapes. Considering the fact that LED chips in the market are invariably diced into squares or rectangles, device designers should give serious thoughts about re-designing the chip. Packaged but un-encapsulated LEDs chips of the simulated geometries are laser micro-machined using the described setup in our laboratory, as illustrated in Figure 1. Optical measurements of the devices indicate that the simulated results are true and accurate. The square LED is on average ~16% less efficient than other polygons. Of course, one could argue that the chip packing density, and thus chip count across a wafer, might be compromised. Therefore, we propose the use of triangles and hexagons; such shapes can be closed-packed into any array without sacrificing chip space and thus make economic sense. I mentioned about the non-homogenous emission of RGB LEDs, and we have also developed a solution to solve that problem. The monolithic integration of LED chips has also been demonstrated as a viable solution for building color-tunable LED assemblies. Three LEDs chips of the primary colors, cut into truncated pyramidal geometries, were vertically stacked on top of each other in the order of decreasing wavelength from the bottom to the top, as illustrated in Figure 3. The inclined sidewalls are mirror-coated to suppress lateral leakage. With this stacking arrangement, light emitted from chips at the bottom of the stack emits through the upper chips; the top blue LED chip serves as the output window. As the optical paths of the three chips overlap with each other, their colors are naturally mixed along the optical path without requiring additional optics. By individually controlling the intensities of the three colors via bias current, a wide range of colors can be produced with excellent homogeneity and performance, examples of which can be seen from Figure 4. Such stacked devices are obviously useful for building high-resolution LED display panels. However, they are also excellent candidates as plain white light LEDs. Being free of phosphors, the stacked LEDs emit white light with high efficiency, excellent homogeneity, high color-rendering index and long-term stability; all these achieved without color-conversion losses.

At present, LED lighting products tend to adopt the style of conventional lighting, such as a retrofit bulb whereby packaged LEDs are assembled into the shape of a bulb. This is inefficient and costly as two assembly processes are involved. Also, heat flow from the chip to the substrate is highly impeded. We propose the mounting of LED chips directly onto large-area ceramic panels; the entire assembly serves the luminaire. In this way, heat is conducted directly to the large area ceramic panel (with high conductivity). Electrical connections between chips are embedded and integrated onto the panel. This enables spatial separation of chips to enable uniform illumination across the luminaire. The large ceramic panel serves as a huge and thermally conductive heatsink for efficient dissipation of heat; it also doubles as a reflector for reflecting downward emitting light from LED chips.

5. CONCLUSION

Solid-state lighting is a rapidly developing field of research and industry with the capability of drastically reducing electricity consumption, alleviating the pressure from the world's rapidly declining energy reserves. With intense research efforts around the world to solve remaining issues with LED technology, there is no doubt LED lighting will be widely adapted within the next decade.

Figure 1 (a) Phosphor-converted White-light LED and (b) RGB LED

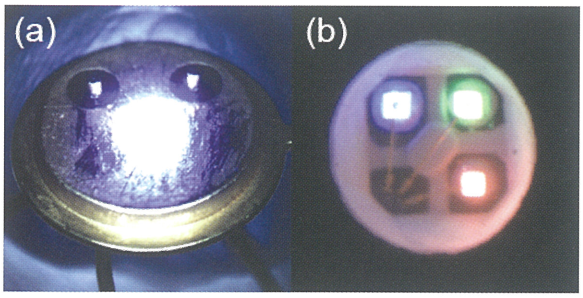


Figure 2 Laser-micromachined LED Chips

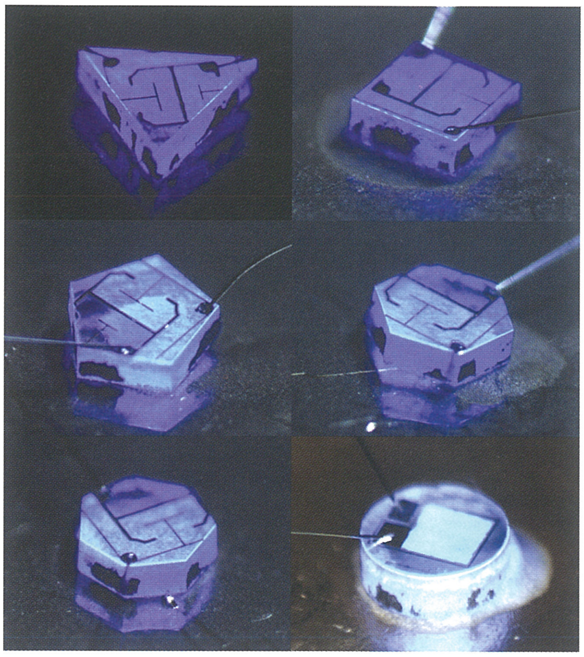


Figure 3 An RGB LED Stack

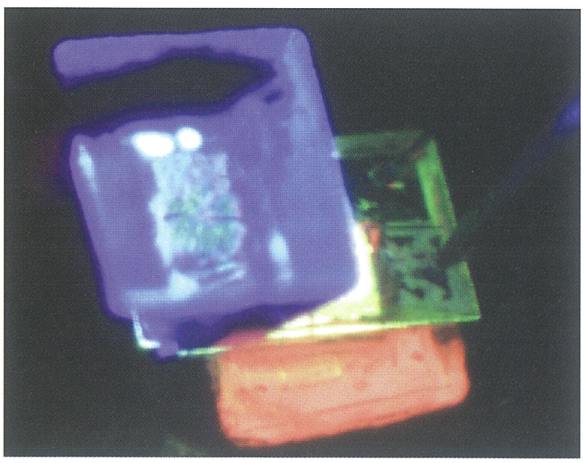


Figure 4 Wide Range of Colors Emitted by a Stacked LED

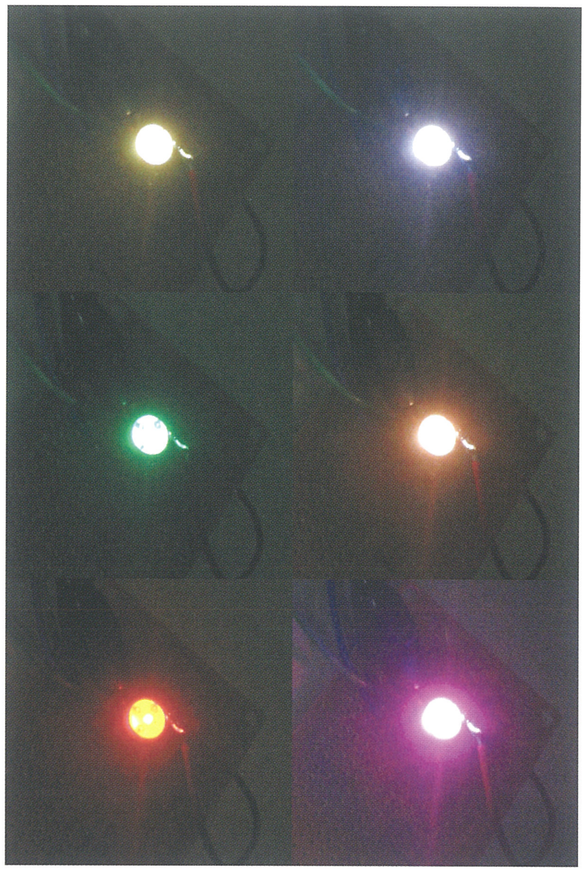
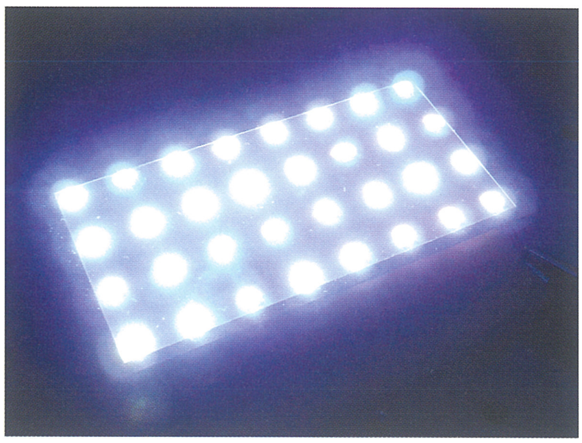


Figure 5 AN LED Ceramic Luminaire



- Notes and Questions -

Paper No. 8

CARBON NEUTRAL – A DREAM OR REALITY?

Speaker : Ir Albert W.K. To
Director
J. Roger Preston Ltd.

CARBON NEUTRAL – A DREAM OR REALITY?

Ir Albert W.K. To
Director
J. Roger Preston Ltd.

ABSTRACT

Carbon neutral is a hot topic nowadays. So far, technology available that are widely used today cannot truly produce a zero carbon footprint project without substantial investment and hence prohibiting to make it commercially viable. Engineers and researchers are working extremely hard to study various options that, one day, hope to be solutions of our present energy crisis. This paper will provide basic information for some of the promising technologies together with its future development.

1. INTRODUCTION

As concerns about climate change grow, the concept of carbon neutrality has captured worldwide attention. The Department of Energy and Climate Change, UK, has published a definition of carbon neutrality in October 2009. It defines Carbon Neutral that – through a transparent process of calculating emissions, reducing those emissions and offsetting residual emissions – net carbon emissions equal zero.

In other words, carbon neutral is a term that it has a net zero carbon footprint. It is an emerging international trend to reduce the climate impacts associated with the products and services that we all consume. Each of our everyday actions consumes energy and produces carbon dioxide emissions e.g. taking flights, driving our cars, heating or cooling offices.

On one hand, the term carbon neutral can be simply used to describe energy that does not cause the release of any carbon dioxide into the atmosphere. For example, solar cells, wind turbines and hydroelectric turbines generate electricity without releasing CO_2. Household hot water can be provided using solar-thermal water heating combined with solar cells to heat water using only the power of the sun. Nuclear power does not release CO_2 during the generation process either.

It is, however, possible to release CO_2 into the atmosphere and still considered as carbon neutral, so long the amount of CO_2 released is balanced by the exact amount sequestered and offset elsewhere. Therefore, one could also achieve net zero carbon emission by balancing the carbon emission released to the atmosphere from burning fossil fuels with renewable energy sources that create an equivalent amount of useful energy to compensate or alternatively use only renewable energies that do not produce any carbon dioxide.

In some cases, the carbon neutral can also be regarded as the condition in which there is no net increase in the global emission of greenhouse gases (GHG) to the atmosphere, by converting the GHG into carbon dioxide equivalent. GHG is critical to the climate change and its reduction is the greatest challenge to globally sustainable development. Hence, the impact GHG has on the living environment is then expressed in an equivalent amount of carbon dioxide.

Section 2 will discuss the basic principle of biomass which is an emerging technology attracting great attention by various governments and institutions. Section 3 will talk about nuclear fusion, though a lot of works yet to be done, will become one of cleanest ways to produce energy that can last for millions of years. Section 4 then focuses on the application of solar vehicle as an alternative technology for electric vehicle.

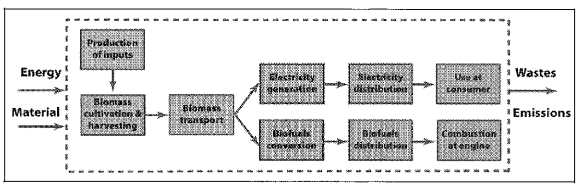
2. BIOMASS

Biomass (plant material and animal waste), or biopower, is one of the critical renewable energy sources used to reduce our emissions of heat-trapping gases like carbon dioxide to levels that scientists suggesting to avoid the worst impacts by global warming. It is a biological material derived from living, or recently living organisms, such as wood, waste, and alcohol fuels.

Photo 1 Switchgrass

Biomass can be used to generate electricity or produce heat. It can be either used directly, or converted into other from of energy product such as biofuel. It can be in form of forest residues, yard clippings and wood chips which can be used as biofuel. However, it does not include organic material such as fossil fuel which has been transformed by geological processes into substances such as coal or petroleum.

Figure 1 Biopower and Biofuel Pathways



2.1 DIRECT COMBUSTION

The most common way to capture the energy from biomass is to burn it directly to make heat to produce steam power. This biomass fired steam power can then be used to turn a turbine and then generate electricity. This is a process in which heat is the dominant mechanism to convert the biomass into another chemical form. The main problem of direct combustion for biomass is that much of the energy is waste and that it can cause some pollution if it is not carefully controlled.

2.2 CO-FIRING AND RE-POWERING

Another way to provide energy with the use of biomass is to mix it with coal and burn at the power plant designed for coal. This method is called co-firing. It can also be co-fired at the natural gas-powered plants through gasification. Furthermore, the plant can also be converted to run fully on biomass, which is known as 're-powering'.

2.3 COMBINED HEAT AND POWER (CHP)

There is heat generated during the direct combustion of biomass, and it would be a waste of energy if it is not used. Hence, in order to better utilize the energy resources, the heat generated can be used to heat building or for industrial processes. A combined heat and power (CHP) system can therefore be significantly more efficient than direct combustion.

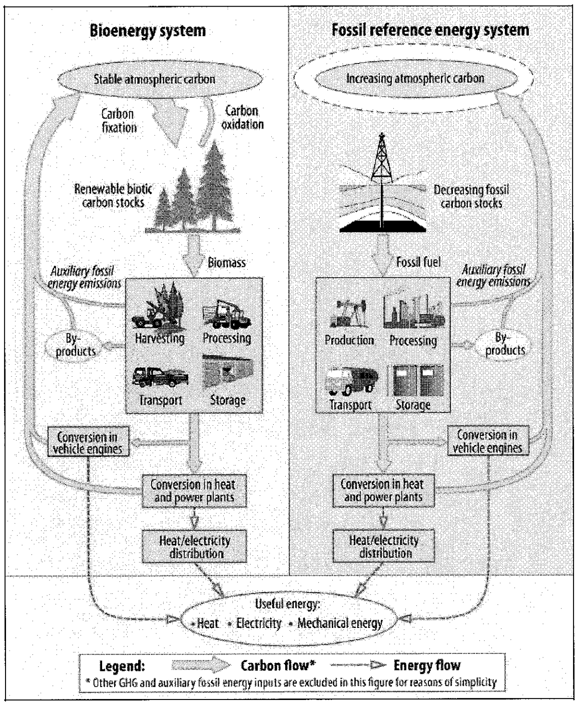
2.4 BIOMASS GASIFICATION

Biomass can be converted into a mixture of hydrogen and carbon monoxide called syngas by heating it with controlled amounted of oxygen and under pressure. The syngas can be used as a fuel to run a gas turbine or steam turbine to produce electricity. Like combined heat and power system, it is more efficient than direct combustion of biomass and it is generally cleaner.

2.5 ANAEROBIC DIGESTION

Biomass can be broken down to produce methane and carbon dioxide by micro-organisms. This can be achieved in a controlled way in anaerobic digesters used to produce sewage or animal manure. Moreover, the biomass in the garbage can also be broken down in a similar process but less-controlled way. The methane produced during the breaking down process can be used to burn for heat and power.

Figure 2 Bioenergy CO_2 Balance vs Fossil Fuel CO_2 Balance



2.6 FUTURE OF BIOMASS AS AN ENERGY SOURCE

Today, biomass accounts for about 10% of the primary energy consumption. This figure shows that it has been an important source of energy. Among this 10% of energy consumption, most of this is traditional fuels used for cooking and heating in the developing world. Until the end of the last century, the use of biomass in the developed world was mainly restricted to niche applications such as combined heat and power generation in the wood and paper industries. However, the perception of biomass today has been changing and it is being recognized as a valuable modern fuel that can provide a renewable energy to replace fossil fuel in power generation. Consequently, biomass will become one of the major renewable sources and its technology will be largely developed over the next two decades.

In the future, technology for "biorefineries" will be developed. It is a technology to convert biomass into a range of valuable fuels, chemicals, materials, and products - much like oil refineries and petrochemical plants do. Biorefineries will produce new biomass-based fuels, chemicals, and other products will help to create a major new domestic industry, and they will provide a wide range of valuable products based on renewable resources. They will also allow us to reduce our dependence on imported oil.

3. NUCLEAR FUSION

3.1 BASIC PRINCIPLE AND CONCEPT OF NUCLEAR FUSION

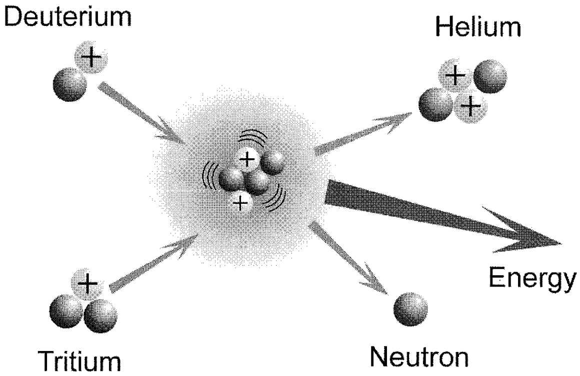
Nuclear fusion as a source of manmade energy is still in the developmental stage within these few years. However, this technology becomes more mature due to its environmental friendly feature and many scientists try their best to optimize their research result to prove us this fusion is safe and efficient. In fact, nuclear fusion is one of the most promising options for generating large amounts of carbon-free energy and attention will be paid in the future to realize our carbon neutral dream.

Nuclear fusion is the process to join the same charge atoms together in order to form a heavier nucleus. To get power from fusion, gas from a hydrogen combination – deuterium and tritium – is heated to 150×10^6 °C condition.

One way to achieve these conditions is a method called 'magnetic confinement' to control a plasma material with strong magnets. The device for this condition maker is a ring shaped magnetic chamber call 'tokamak'.

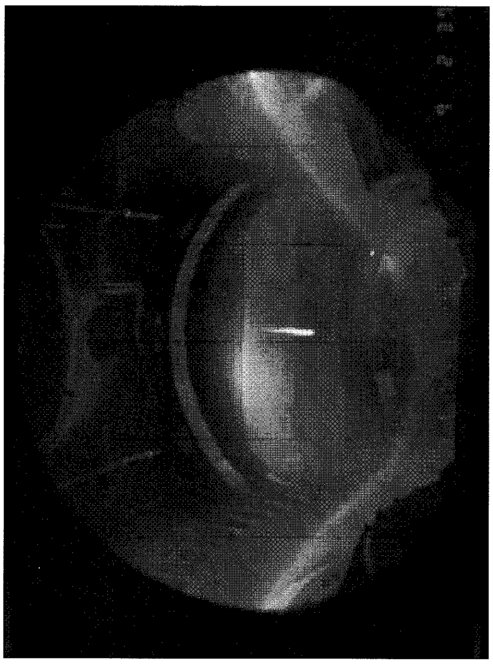
Deuterium can be supplied by industry. Lithium is plentiful in the Earth's crust: if fusion were to provide electricity for the entire world, known reserves of Lithium would last for at least one thousand years.

Figure 3 Energy Production Chain by Nuclear Fusion



Within the tokamak, the changing magnetic fields that are used to control the plasma produce a heating effect. The magnetic fields create a high-intensity electrical current through induction, and as this current travels through the plasma, electrons and ions become energized and collide. Collisions create resistance which results in heat. Heat transferred through high-intensity current is limited to a defined level and is known as ohmic heating. In order to obtain higher temperatures and reach the threshold where fusion can occur, heating methods must be applied from outside of the tokamak.

Photo 2 Atom Injection in Chamber by Camera Capture



3.2 FUEL OF NUCLEAR FUSION

The fuel of nuclear fusion will be carbon-free fuel and is Deuterium and Tritium. Reaction by these two elements will be the main source of nuclear fusion.

Deuterium can be distilled from water. It is a widely available, harmless, and virtually inexhaustible resource – Carbon-free. In every litre of seawater, there are 33 milligrams of Deuterium.

In the Deuterium-Tritium (D-T) fusion reaction, high energy neutrons are released along with Helium atoms. These particles escape the plasma contained within the magnetic fields of the tokamak and are absorbed by the surrounding walls. If surrounding walls contain Lithium, neutron will be absorbed by the Lithium atom, which recombines into an atom of Tritium and an atom of Helium. The Tritium can then be removed and recycled into the plasma as fuel.

3.3 COMPARISON BETWEEN NUCLEAR FISSION AND NUCLEAR FUSION

Nuclear fusion is often confused with nuclear fission. However, they are very different from each other. Nuclear fission is the process of splitting the nucleus of an atom, which normally has the effect of generating a large release of energy. Nuclear fission is the method of how nuclear power plants generate energy.

Table 1 Nuclear Fission vs Nuclear Fusion

	Nuclear Fission	Nuclear Fusion
Definition	Fission is the splitting of a large atom into two or more smaller ones.	Fusion is the fusing of two or more lighter atoms into a larger one
Conditions	Critical mass of substance and high speed neutrons are required.	High electro-magnetic field density and high temperature environment is required.
Energy requiremnt	Takes little energy to split two atoms in a fission reaction.	Extremely high energy is required to bring two or more protons close enough that nuclear forces overcome their electrostatic repulsion.
Energy Ratios	The energy released by fission is a million times greater than that released in chemical reactions; but lower than the energy released by nuclear fusion.	The energy released by fusion is three to four times greater than the energy released by fission.

3.4 ADVANTAGES OF NUCLEAR FUSION

- Clean energy and clean fuel: Carbon-free elements and material shall be used for power generation. The only by-products of fusion reactions are small amounts of helium, which is none of pollution effect to atmospheric.

- Continuously supply of fuel and small quantities of fuel: Deuterium can be produced from water and tritium can be produced from lithium, which is easily found in the earth. Fuel supplies can last for millions of years. Only tiny amounts of Deuterium and Tritium are necessary to fuel the fusion reaction and hence large scale of nuclear accident can be prevented.

- The Effective power generation: One kilogram of fusion fuel can provide the same amount of energy as 10 million kilograms of fossil fuel.

- No long-lived radioactivity waste: Only plant components become radioactive and these will be safe to recycle or dispose of conventionally within 100 years.

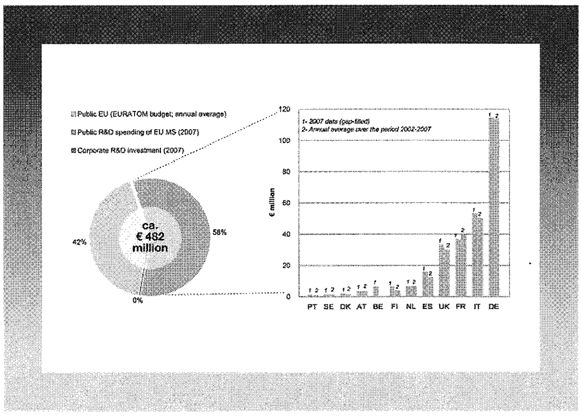
- Reliable power supply: Nuclear can provide large amounts of electricity to a city. At economic view, it is estimated to be similar to other energy sources.

3.5 CHALLENGES

- The problem with generating nuclear fusion lies in getting two atoms having the same charge close to each other. Atoms have the same charge generally repel each other, rather than being brought together. Large amount of energy is a must in this reaction to carry those two atoms to each other.

- This technology is still under research and experimental work. This technology is not widely used in industrial. Power efficiency and reaction stability need to be proved in the future.

Table 2 National Investment Result to Nuclear Fusion



4. EVOLUTION OF SOLAR VEHICLE

Transportation around the world is changing. Car manufacturers are adapting to pressures from increasing world populations and a scarcity of resources as well as responding to legislation requiring ways to reach "zero emission" vehicles.

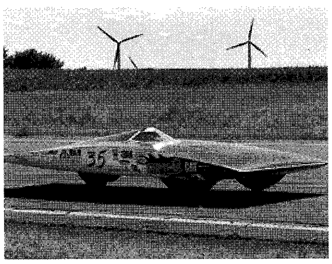
These requirements increased interest in new battery technologies and hybrid technologies. This in turn has interesting implications for the development of solar vehicles.

Paper No. 8

4.1 TECHNOLOGY OF SOLAR VEHICLE

A solar vehicle is an electric vehicle powered completely or significantly by direct solar energy. Usually, photovoltaic (PV) cells contained in solar panels convert the sun's energy directly into electric energy. The term "solar vehicle" usually implies that solar energy is used to power all or part of a vehicle's propulsion. Solar power may be also used to provide power for communications or controls or other auxiliary functions.

Photo 3 PV Powered Car



SIEMENS

The solar vehicle requires hundreds of photovoltaic (PV) cells in a solar array that convert sunlight directly into electricity to run. The PV cells can be made of silicon and other semiconductor materials. The solar arrays are most commonly mounted on to the vehicle in a horizontal or vertical position to collect sunlight. The electricity is stored in batteries, which powers electric motors to turn the wheels of the car. There are various types of batteries that can be used such as lithium ion, lithium polymer, nickel cadmium, lead-acid, or nickel-metal hydrides.

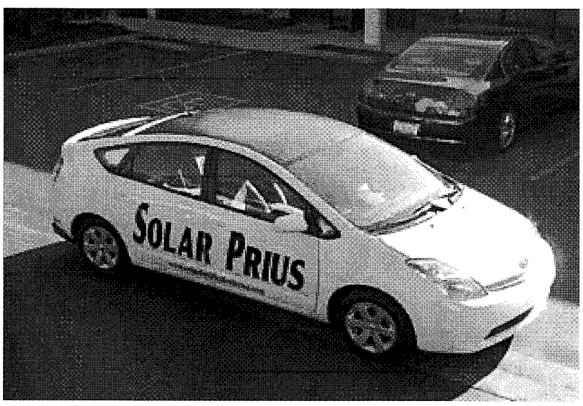
Most of the early attempts at building solar cars were aimed at developing solar power for race cars and for small vehicles that could only seat one person. The biggest obstacle to building commercial solar cars is the amount of space required for solar panels large enough to power a vehicle. Since in most case, they are still too inefficient and expensive, they are not yet available for day-to-day transportation or even for buying if you would want to.

However, with improvements in the efficiency of solar cells, companies are now beginning to produce commercially viable solar vehicles that can fit up to 4 persons in the vehicle.

4.2 SOLAR MODULE

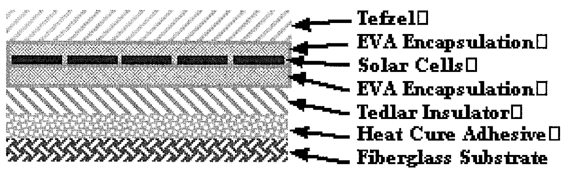
The solar module is fabricated from molded fiberglass to fit on the roof of a standard automobile. Take the Toyota Prius as an example, the solar module includes 146 four-inch-square mono-crystalline cells which are rated at 16% nominal efficiency.

Photo 4 Prototype PV Prius



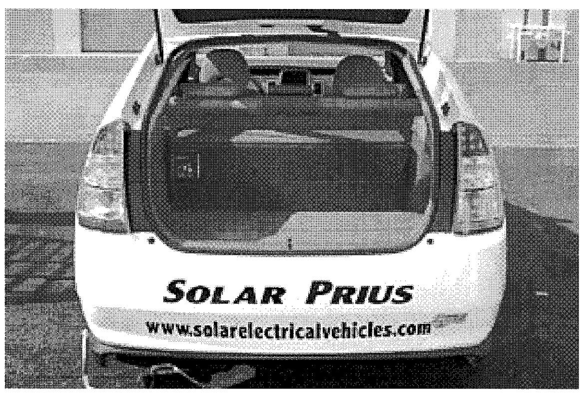
An insulating layer of Tedlar is bonded to the fiberglass with a heat-cure adhesive. The solar cells are series connected and then bonded to the Tedlar insulation with EVA encapsulant. Finally, a Tefzel layer is bonded to the top of the cells for ultraviolet and weather protection. Figure 4 provides a diagram showing the individual layers of the solar module.

Figure 4 Solar Module Component Layers



The solar module is connected to a 48VDC Sealed Lead Acid Battery via a peak power tracking 70V to 48V Battery Charger. The solar energy stored in the sealed Lead Acid Battery is in turn delivered to the car primary motive NiMH Battery pack using a DC-DC converter, which steps up the battery voltage from to 48V to 240V. The Battery Charger and DC-DC converter has a 95% efficiency rating and can provide daily watt-hours and total watt-hour data to the PV Prius's solar monitoring system. Figure 3 provides a schematic of the electrical components, which are added to a stock Prius to convert it to a PV Prius. The battery charger and DC-DC converter are contained in a separate compartment in the battery box.

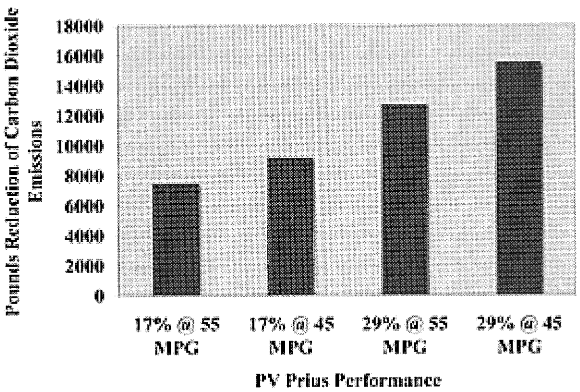
Photo 5 DC-DC Converter installed in the PV Prius



4.3 PROS AND CONS FOR SOLAR VEHICLE

Solar vehicle is completely environmentally-friendly and significantly reducing your carbon footprint. The benefits seem obvious. We do not have to pay for fuel, we could reduce the pollution being emitted into the environment, and we are staying on top of one of the most modern trends there is! But, while solar powered cars have already been made and used, the idea that we are all soon be driving one is still quite a ways off.

Table 3 Reduction in the Number of Pounds of Carbon Dioxide Emitted to the Atmosphere



One of the first problems faced when dealing with solar powered cars is that they need to be extremely lightweight in order to be able to move. Because of this, usually only one person can ride in them at a time because the car cannot power the extra weight of a whole other person.

Another disadvantage to solar powered cars is that currently there is no way to power them other than the solar paneling on the car. Because of this, the car must rely on it having access to the sun in order for it to be powered. This means that those who use parking garages or covers of any kind will not be able to use their solar powered car. And not to mention that if it is a cloudy day, you can pretty much cancel your plans.

4.4 FUTURE OF SOLAR VEHICLE

Solar vehicles are not sold as practical day-to-day transportation devices at present, but are primarily demonstration vehicles and engineering exercises, often sponsored by government agencies. However, indirectly solar-charged vehicles are widespread and solar boats are available commercially.

Development of solar powered vehicles is still in the beginning stage. While the thought is probably on a solar car, there are also several other successful attempts to use solar energy to power vehicles, at least in a scientific phase. In addition to cars; motorcycles, air planes, buses and even boats are being developed.

While solar powered cars are not necessarily an entirely feasible idea yet, they have come a long way. Not only has the research and development of solar powered cars allowed for great strides to be made in other areas of solar powering, but researchers are also coming up with ways for cars to be partially solar powered.

The idea that solar powered cars can be connected to gas lines and batteries is one such advancement. And while these alternatives too, have a long way to go, they are still great advancements that are paving the way for even further development. And who knows where the road of solar powered cars will go?

5. CONCLUSION

The above are just some of the technologies whereby the writer strongly believes that it will eventually be developed to commercially viable products for mass market. Of course, there are other sustainable design but much work has to be done to make it available in a larger scale.

REFERENCES

[1] "How Biomass Engergy Works" by Union of Conventional Scientists.

[2] Kelsi Bracmort, "Is Biopower Carbon Neutral", Congressional Research Service.

[3] An Overview of Biomass Energy", by the Oregon Department of Energy.

[4] "The Evolution of Solar Vehicles", by Solar For Energy.

[5] "PV Prius", by Solar Electrical Vehicles.

[6] Photo 1, extracted from "How Biomass Energy Works" by Union of Conventional Scientists.

[7] Figure 1 & Figure 2, extracted from "Is Biopower Carbon Neutral", by Congressional Research Service.

[8] Photo 3, extracted from "The Evolution of Solar Vehicles", by Solar For Energy.

[9] Table 3, Photo 4, Photo 5 & Figure 4, extracted from "PV Prius", by Solar Electrical Vehicles.