DEVELOPMENT OF RENEWABLE ENERGY PROJECTS IN HONG KONG
Hongkong Electric's Experience

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Abstract

In support of Government's sustainable development policy to have 1 to 2% renewable energy of the total power generation in HK, HK Electric has been embarking on developing renewable energy projects in recent years, mainly concentrating on wind and solar energies. With the successful commissioning of HK's 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, targeting for commissioning in 2015. Apart from exploring wind energy, HK Electric is also active in developing solar power projects. It has just commissioned a solar PV system of 550kW capacity in Lamma Power Station in July 2010, which is the largest of its kind in HK.

First Commercial Scale Wind Project – Lamma Winds

Recognizing the importance of sustainable development and the pressing need to improve air quality in Hong Kong, HK Electric commissioned the Lamma Winds, Hong Kong's first grid-connected wind power station, in February 2006 at Tai Ling on Lamma Island. The 800kW wind turbine is the first utility scale renewable energy facility ever built by power companies in Hong Kong. By end October 2010, Lamma Winds has generated more than 4.3 million kWh of green electricity offsetting more than 3,600 tonnes of carbon dioxide emission. It represents an average capacity factor of about 13% over the past years with the highest in year 2009 at 15.7%.

Fig.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.

Development of an Offshore Wind Farm in Hong Kong

To help meet the renewable energy target set out in the First Sustainable Energy Strategy for Hong Kong in 2005, HK Electric is keen to increase wind energy application. As revealed from the Council for Sustainable Development paper, an onshore wind farm viable to produce 1% of the electricity need for Hong Kong requires a space equivalent to 240 Victoria Parks. Experience from Lamma Winds also supports that developing sizable onshore wind farms in Hong Kong is not favorable due to lack of land and onshore wind resources. Therefore, HK Electric has planned to develop a 100MW class offshore wind farm within Hong Kong territorial waters to help combat climate change issues.

Site Selection

HK Electric has conducted a comprehensive territory-wide Site Selection exercise and Environmental Impact Assessment (EIA) study since 2006 to address all key environmental related issues for development of the proposed offshore wind farm. Related environmental, physical and social constraints have all been taken into consideration in order to identify the most appropriate location for the wind farm such that potential environmental impacts on sensitive areas can be minimized.

The wind farm siting assessment has been undertaken in accordance with the EIAO-TM such that 8 short-listed sites have eventually

been identified. Among those 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 support 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 resources support during operational phase.

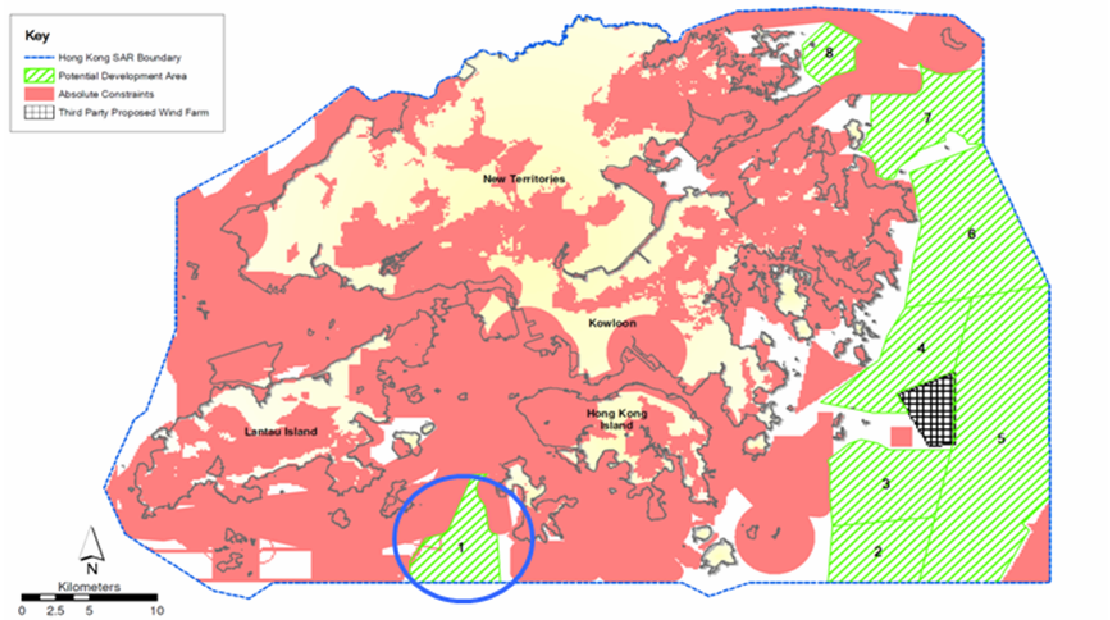

Fig. 2 - Potential Offshore Wind Farm Sites

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 if fishing is prohibited within the wind farm footprint area. A string of mitigation measures has been proposed to further minimize any potential disturbance to the environment, particular 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. If a marine mammal is observed in the exclusion zone, piling will be delayed until they have left the area

- Construction work will be temporarily suspended when a marine mammal is spotted by qualified personnel within the exclusion zone, and will not resume until the observer confirms that the zone has been continuously clear of the marine mammal for a period of 30 minutes.

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 engaged various consultants to look into the technical feasibility of the project, including verification of wind resources by computer simulations, technology review on the shortlisted wind turbine models and the design options of the wind monitoring stations, etc. 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 facing ahead. 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.

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 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 Fig. 3.

Fig.3 - Proposed Southwest Lamma Offshore Wind Farm

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

Table 1. General Information of Offshore Wind Farm

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 1A wind turbine models should be adopted to withstand typhoon condition with a maximum gust of 70m/s for a consecutive period of 3 second. Available models in the market include Vestas V90-3.0, Siemens SWT-2.3-82 and SWT-3.6-107, GE 4.0 and Sinovel SL3000.

Supplier	Model	Capacity (MW)	Rotor Dia (m)	Cut-in / Cut-out / Rated Wind Speed (m/s)
Vestas	V90-3.0MW	3	90	4 / 25 / 15
Siemens	SWT-2.3-82	2.3	82	3.5 / 25 /13
	SWT-3.6-107	3.6	107	3-5 / 25 / 13-14
GE	4.0	4	110	3 / 25-28 / 14
Sinovel	SL3000	3	91.3	3.5 / 25 / 13
RE Power	5M	5	126	3 / 30 / 13

Table 2. Wind Turbine Models Commonly Available in the Market

Foundation Design

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

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.

Wind Monitoring

To facilitate detailed engineering design and wind farm optimization, HK Electric will set 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 in the latter half of 2011. The station can be in the form of a met mast designed as a tower structure of 80m high, or 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.

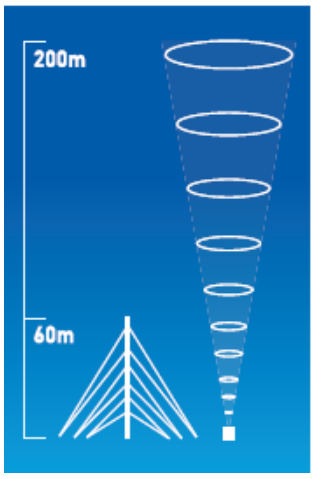

Fig. 4 - LIDAR Technology

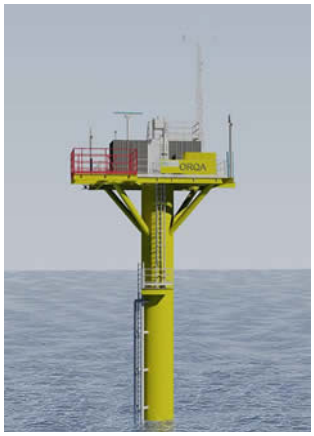

Fig.5 - LIDAR System on Offshore Platform

- 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.

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 2009, 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 year 2015 and will contribute to a greener Hong Kong throughout its operating life of 25 years.

Development of the Largest Commercial Scale TFPV System in Hong Kong

Apart from wind energy application, HK Electric also explores wider use of solar energy to generate more clean electricity.

In mid 2009, HK Electric conducted feasibility studies for installing a solar photovoltaic system in Lamma Power Station. Reference was made to the operating experience of other installations in HK, including the solar PV systems at EMSD's Headquarters (350kW), the PV system at Hong Kong Science Park (198kW), as well as other small PV panels installed at some of HK Electric's existing premises.

The Lamma Thin Film PV System

The following key factors were considered in locating the PV modules within Lamma Power Station:

i) Large flat area
ii) Allowable loading on the rooftops of existing buildings
iii) Orientation of PV modules
iv) Any shading effect
v) Visual impact
vi) Ease of grid connection
vii) Access for operation and maintenance

After detailed consideration of above factors, the most preferable location for installation of PV modules would be on the rooftops of the Main Station Buildings of Lamma Power Station.

The total area available on the Main Station Building roofs was estimated to be 35,000 m2. These areas has been fully utilized to accommodate 5,500 PV modules with dimension 1,410 mm (L) x 1,110 mm (W) x 35 mm (D). As each PV module has a rated output of 100W, so the total capacity of the solar PV system is approximately 550kW.

Fig 6. Lamma TFPV System

Selection of PV Module

There are two main types of solar cell available in the market, namely amorphous silicon (a-Si) thin film PV and crystalline silicon (c-Si) PV. Comparing the pros and cons of these two types of PV modules, a-Si TFPV was finally chosen due to the following:

- The thickness of silicon materials for TFPV is only 1/200 of that for crystalline PV so that less silicon is required for production. The energy payback period for a-Si TFPV is 1.5 years, while that for c-Si PV is 2.4 years.

- Temperature coefficients for maximum power output (Pm) of a-Si TFPV and c-Si PV modules are -0.25% and -0.4% per ºC rise on module temperature respectively, which means TFPV's ability to maintain power output level at high temperature is better than crystalline PV module.

- Rate of decrease in conversion efficiency at weak light for a-Si TFPV module is less significant than c-Si PV module. Hence TFPV modules are able to produce power more effectively at low irradiance conditions, resulting in a higher capacity factor throughout the year.

Fig. 7 - Amorphous Silicon Thin Film PV Panel

All the TFPV panels were manufactured in the Shenzhen plant of Du Pont Apollo Limited (Du Pont Apollo). Established in 2008, the plant was a pilot project under the "Shenzhen-Hong Kong Innovative Circle" co-operation agreement made between Shenzhen Municipal Government and the Hong Kong SAR Government for promotion collaboration of technology research and development. HK Electric is their first customer for installation of a commercial scale TFPV system when order was placed in 2009.

Dimensions of PV Module	**1,410 mm x 1,110 mm x 35 mm**
Effective Conversion Area	**1.4 m2**
Weight of PV Module	**Approximate 26kg**
Max. Power Output per PV Module	**100 Wp**
Operating Temperature	**-40 ~ 85 ºC**
Maximum Mechanical Load	**5,600 Pa**
Maximum System Voltage	**750V**

Table 3 - Specification of amorphous silicon thin film photovoltaic module

TFPV System Design

The TFPV modules are mounted on concrete supports facing southward at about 22º inclination in order to capture maximum solar irradiation. The modules are connected in series and grouped in PV strings through combiner boxes, which are connected to PV inverters for converting to AC 380V 3-phase power supply for grid connection to the electrical system. Associated electrical components such as AC power panels, isolation transformers, metering panels and cables have been installed to form a complete workable system. To cater for the adverse outdoor conditions, all electrical equipment installed outdoor are weatherproof type with proper protection from sunlight, lightning and overvoltage.

For better operation flexibility and overall system availability, HK Electric has adopted 10kW and 12.5kW 3-phase PV inverters instead of using large capacity PV inverters. Such PV inverters will connect to the grid automatically when the grid voltage and frequency are within operating range.

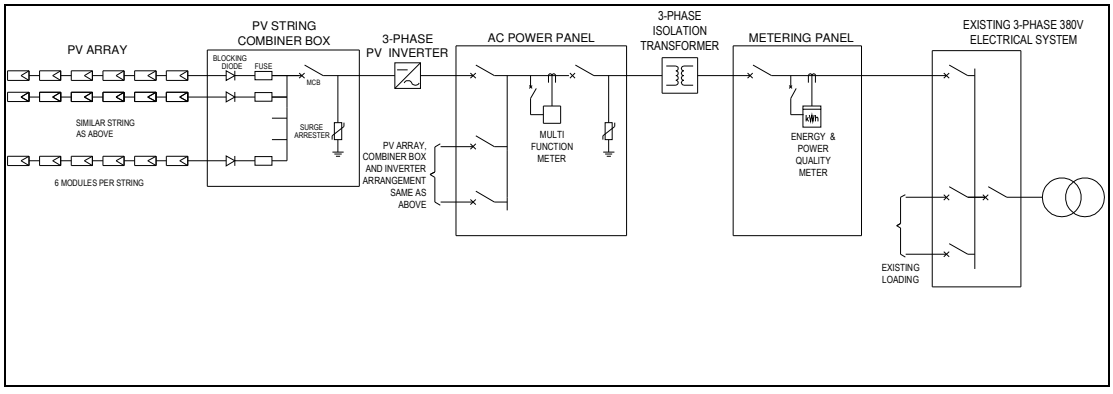

Fig. 8 - Simplified Single Line Diagram of PV System

To facilitate systematic, efficient and effective monitoring and control of the TFPV system, a Remote Monitoring System has been set up in the Central Control Room of the Power Station to monitor and control the overall performance of the PV system, environmental data, PV inverter status, as well as individual equipment status.

Fig. 9 - Remote Monitoring Computer at Central Control Room

Construction Challenges

Since the TFPV system is physically located on the rooftops of the Main Station Buildings, a large quantity of PV modules, concrete blocks, PV module fixing accessories, electrical equipment, cables and cable supports were required to be transported from ground for installation. A 250 tonne class mobile crane was employed for the lifting work. Absolute care had to be exercised to ensure perfect site safety during the uplifting work, especially during raining and windy conditions. Overall project schedule lasted for about 15 months from commencement of feasibility study in April 2009 till the total completion in end June 2010.

4 ~ 9/2009	Feasibility Study
10~ 11/2009	Request for Offer
12/2009	Order Placing
4 ~ 6/2010	Construction, Testing & Commissioning

Table 4. Lamma TFPV Project Schedule

Plant Performance

Lamma TFPV is designed to give annual electricity production of about 620,000kWh with a capacity factor of 12.9%, which is adequate for the consumption of 150 Hong Kong families. Since commissioned in end June 2010, the TFPV system has generated a total electricity output of 307,213kWh in early November 2010, accounting for a capacity factor of 18.33%, which is well above the designed value of 12.9%.

Electricity output of TFPV system varies with solar irradiance condition. Figure 10 shows the actual irradiances and output data of a hot summer day on 18 July as well as a stormy day on 22 July on which "Black Thunderstorm" signal was hoisted in the afternoon. The result shows that electricity generated from the PV system under cloudy and rainy conditions was still about 1/3 of that generated under sunny condition with strong solar irradiance.

	Design	**Actual**
Capacity	550kW	550kW
Annual Output	620,000kWh(*)	320,248kWh(**)
Capacity Factor	12.9%	18.24%(**)
Design Life	20 years	20 years
(*) Adequate for consumption of 150 families (**) From 1/7/10 up to 11/11/10		

Table 5. Lamma TFPV Plant Performance

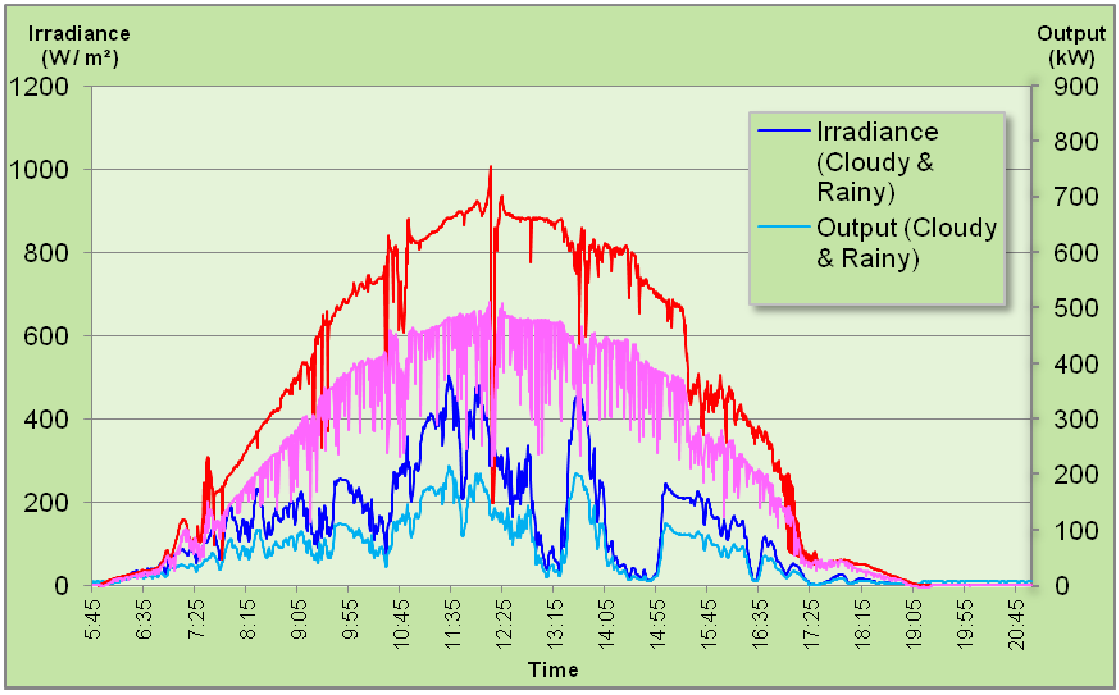

Fig.10 - Power output in response to solar irradiance variation

Environmental Benefits

The anticipated annual output of the PV System is 620,000 kWh, with a capacity factor of about 12.9%. The output from the PV system can offset 520 tonnes of carbon dioxide emission per annum. This is equivalent to planting 22,000 trees. However, from the actual operating data obtained so far, above design output figures might prove to be conservative.

Concluding Remarks

For the past few years, HK Electric has put in great engineering efforts and resources to develop renewable energy projects and other emission control projects in support of government's sustainable policy while fulfilling its commitment to help combat climate change and improve 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 year 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 has further plans to install more of the PV panels in Lamma, aiming at achieving a total capacity of the solar power system of up to 1MW.

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

[4] "What is the energy payback for PV?", U.S. Department of Energy., Jan 2004

[5] “Weak Light Performance and Spectral Response of Different Solar Cell Types”, N.H. Reich – Dept. of Science, Utrecht University, 2005

[6] Web site of Solarbuzz, LLC.

[7] Technology Roadmap Solar photovoltaic energy, International Energy Agency, 2010

[8] “The Largest Solar Photovoltaic System Project in Hong Kong”, HK Electric, Oct 2010

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