Case Study 5 – Use of Wind Turbine Technology

1. Context

Hong Kong relies on an adequate and reliable electricity supply for its economic development. Our electricity needs are met by the two electricity companies, China Light and Power which operates Black Point Power Station (1,875MW), Castle Peak Power Station (4,108MW) and Penny's Bay Power Station (300MW); and Hong Kong Electric which operates Lamma Power Station (3,420 MW).

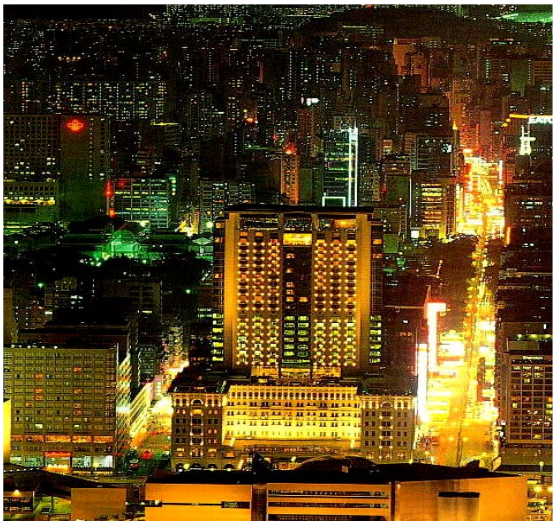

Figure 1. Hong Kong needs electricity

2. Air Pollution Problem

In 2003, according to Government statistics, electricity power plants contributed over 90% of the local levels of SO_2,, 60% of the local levels of NO_X and 45% of local RSP emissions. The generation of these air pollutants is directly as a result of the combustion of fossil fuel, mainly coal.

Renewable energy is an alternative to fossil fuel. Hong Kong though has limited options to adopt for renewable energy technologies (e.g. wind, solar, waste-to-energy, thermal and hydroelectric), but nonetheless should not overlook the feasibility of such measures.

In 2002, the Energy Office of the Electrical and Mechanical Services Dept (EMSD) commissioned a study on the potential for renewable energy generation in Hong Kong. The study reviewed local implementation issues before proposing a future renewable energy generation target for Hong Kong as 1% by 2012.

In 2004, the Council for Sustainable Development further addressed the issue of renewable energy. The challenge was to see whether there is a way to obtain regular and cost-effective electricity from renewable sources for consumers, especially given that

current renewable technologies tended to be land-intensive. Through the Council's work[1], the objective was refined to "between 1 and 2% of Hong Kong's total electricity supply met by power generated from renewable sources by the year 2012, with this target being subject to regular review in the light of advances in technological solutions and emerging sustainability considerations".

3. Solution

Hong Kong Electric has undertaken a feasibility study of utilising wind energy for power generation as an on-going effort to explore the use of renewable energy resources in Hong Kong.

Principles of Energy from Wind

The principle of converting wind power to usable electricity is based on using the wing profile of a wind turbine to transform the lift forces generated by the wind into a rotating motion of a rotor. The rotor drives a generator to produce electricity.

The most common configuration of a modern wind turbine consists of three rotor blades, a nacelle and a tubular tower. Blades rotate around a horizontal hub which is connected to a gearbox and a generator. The nacelle houses the electrical components and is mounted at the top of the tower. Wind turbines can range in capacity from several watts to several megawatts. The crucial parameter is the diameter of the blade – the longer blade, the larger the area swept by the rotor and, hence, the greater the energy output (see Figure 2).

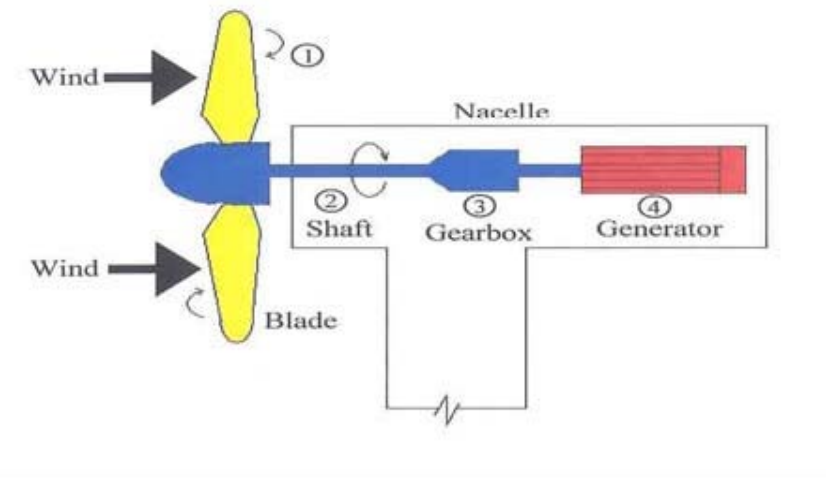

Figure 2. Schematic of Wind Turbine

Notes:

(1) Wind blowing over the blades causes the blades to rotate

(2) Rotating blades keep the shaft turning

[1] Source: Council for Sustainable Development, "First Sustainable Development Strategy for Hong Kong" (2005)

(3) & (4) The gear will increase the rotational speed of the shaft and drive the generator to produce electricity

The power available from the wind is a function of the cube of the wind speed. Therefore if the wind blows at twice its normal speed, its energy content will increase eight-fold.

Theoretically a wind turbine is able to extract 59% of the energy inherent in the flow of air. In practice, however, the extraction of energy is only about 40-45% due to conversion losses.

4. Implementation

Wind Resource Mapping

Lamma Island was selected to test the feasibility of Hong Kong Electric's wind power project. In 2001, wind data was collected over a period of a year. These results were used to prepare a wind atlas for assessing wind potential and identifying a suitable site on Lamma Island.

Analysis of data revealed that over 50% of land area on Lamma had specific wind energy above 100 W/m^2. The southern part of the island had, in general, better wind potential than the north. The relatively high wind potential areas (i.e. over 150 W/m^2) were found in the hill tops and ridges.

By normalising the wind speed data using HK Observatory data, it was found that scaled annual average wind speed was 6.11m/s.

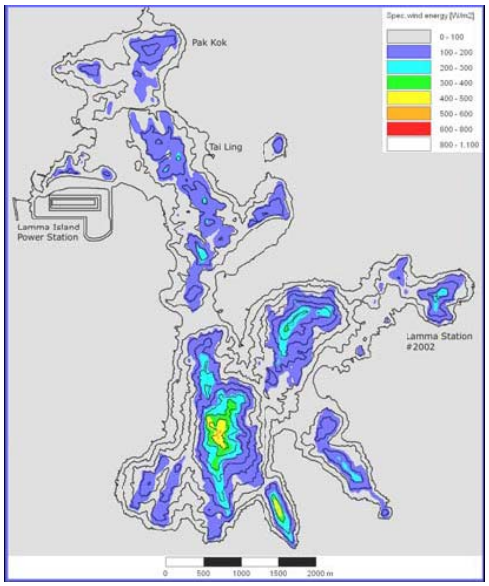

Figure 3. Wind Atlas of Lamma Island

Results of the feasibility study hence revealed that it was feasible to install a 600-850 kW wind turbine as a demonstration project to utilise wind energy for power generation to residents of Lamma Island.

Planned Wind Turbine

The wind turbine capacity was selected based on the following considerations:

- Proven design with a large number of installations worldwide.
- Smallest size class available from the majority of the suppliers due to worldwide trend for large capacity machines; and
- Maximum size of machine complying with the aviation height restriction at the site.

The system was designed and supplied by Nordex Energy GmbH of Germany based on Nordex's standard N50/800 kW machine with a rotor diameter of 50m and a rated power of 800 kW.

The wind turbine is of a stall-regulated, "horizontal axis" design and is commonly mounted up-wind. The major components of the nacelle showing its construction are shown in Figure 4. The rotor blades are made of fibre-reinforced plastic, and the blade tips are pivotable and can be swiveled 85^{O} to the main blade to act as aerodynamic brakes. The generator is a double-winding, 4/6 pole water-cooled squirrel-cage asynchronous type. The wind direction and wind speed are constantly monitored by two mutually independent wind sensor systems above the nacelle. When the wind direction is different from the direction of the wind turbine, the wind turbine is yawed actively.

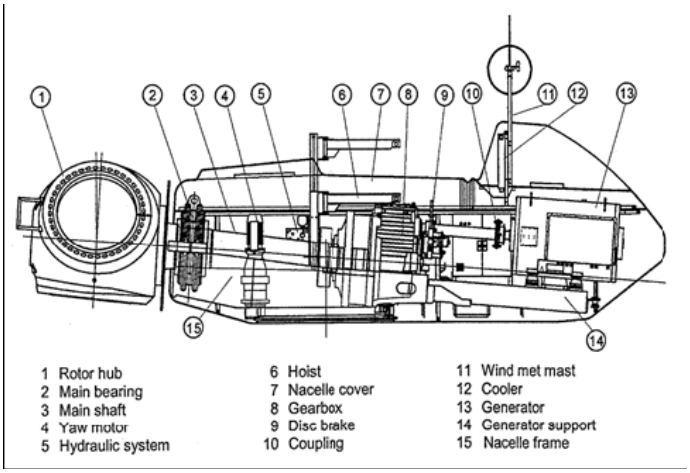

Figure 4. Nordex's N50 Wind Turbine

System Design

The grid-connected 800 kW wind turbine system was designed for automatic operation and generation of electricity for wind speeds in the range of 3 to 25 m/s.

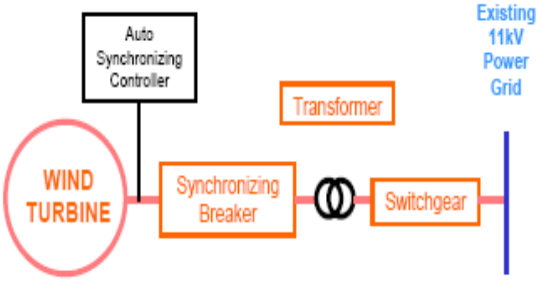

Figure5. Schematic System Design

In Figure 5, the output of the wind turbine is be transmitted to the existing 11 kV power grid via a transformer, switchgear and power conditioning devices housed inside a high voltage distribution pillar (HVDP) next to the wind turbine. Power cables were buried underground for connecting the wind turbine, HVDP and nearby 11kV power grid onto the 275kV cable route.

The operation of the wind turbine is to be monitored and controlled through a central monitoring system located in a control room of Hong Kong Electric's Lamma Power Station. The wind turbine site itself would be unmanned and require attendance of operational personnel only during emergency or routine maintenance

5. Outcomes

The wind turbine is currently under construction but Figure 6 shows an artist's impression of what it will look like[2].

Figure 6. The Future for Lamma - Artist's Impression of Wind Turbine

Power output from the 800 kW wind turbine under an average wind potential of 150 W/m^2 is projected to be about 1,000 MWh/yr. This would help to avoid the equivalent consumption of 350 tonnes of coal and reduce associated air emissions every year.

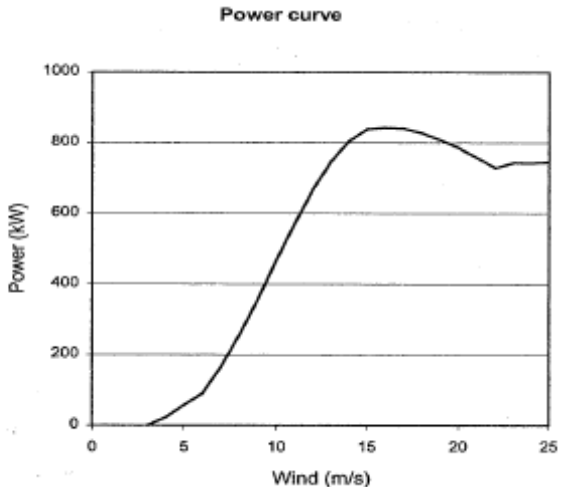

Figure 7. Power Curve for N50

Figure 7 shows the power curve outputs for the wind turbine.

6. Cost Benefits

The capital cost of the wind turbine project including site formation, landscaping and educational exhibits is HK$15 million. The operating cost is roughly 80 cents per kWh. Whilst this is more expensive than the price paid per kWh from conventional fossil fuel

[2] At the time of writing this paper, the wind turbine had not been erected yet.

power generation plant, the reduction of emissions will have a beneficial outcome on the environment.

7. Transferability

Based on the Council's recommendations, the Government is currently working to establish a policy by 2006 on the installation of renewable energy facilities for new Government buildings and major public sector projects. Procedures for renewable energy suppliers to gain access to the existing electricity grid are also being drawn up for the post-2008 electricity market. These measures together with a commitment to develop by 2007 a sustainable energy policy aimed at promoting the use of renewable energy and encouraging energy efficiency and conservation are important for the replication of this project across suitable areas in Hong Kong.

High wind resource areas potentially suitable for wind power applications in Hong Kong tend to be all the high grounds, as well as much of the offshore marine areas. The highest wind resource areas (larger than 600 W/m^2) are generally located at mountaintops in the eastern side as shown in Figure 8 below.

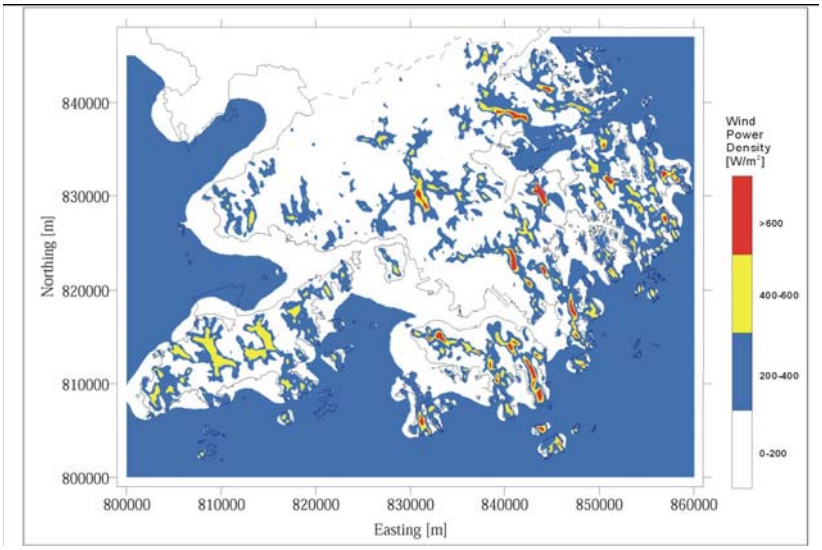

Figure 8. Wind Resources in Hong Kong

In Hong Kong, the area of high wind resource (i.e., 200 W/m^2 or higher) on land has been estimated to be about 393 km^2. For 1,000 wind turbines to be installed, this is equivalent to a density of 2.5 turbines per km^2. This has an estimated potential resource of about 2,630 GWh (equivalent to 7.5% of Hong Kong's annual electricity demand).

Locating wind turbines, though, would need careful siting to avoid significant impacts on sensitive ecology or natural areas of high conservation value. In addition, their construction would need to be properly controlled to avoid any significant environmental impacts (e.g., dust, soil erosion, water quality, etc). Visual intrusion is a further major planning consideration for large wind turbines. Hence, offshore or remote locations would be the preferred option although this would constrain the availability of space and increase the installation cost of the turbine and connection to a grid.

8. Conclusions

The construction of the 800 kW wind turbine project on Lamma Island is a pilot scheme that demonstrates Hong Kong Electric's effort to develop the use of wind energy for power generation in Hong Kong, and to promote public awareness and understanding of the benefits as well as the limitations of wind as source of renewable energy. The project is now at the construction stage and is scheduled for completion by early 2006.

Lessons learnt include:

- To reduce the overall consumption of non-renewable energy resources as well as tackling air pollution issues, we must consider what we can do to encourage sustainable practices;
- Use of wind power as a form of renewable energy is one area where Hong Kong can explore various options; and
- From Hong Kong Electric's wind project, important local knowledge and experience in the design, construction, operation and maintenance of wind turbine will be obtained for wider application of wind energy for power generation throughout Hong Kong.

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