# Operation Experience of & Maintenance Strategy for the First Commercial-Scale Wind Turbine in Hong Kong

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***Abstract*— HK Electric is the first company in Hong Kong to support the development and application of Renewable Energy (RE) by installing a commercial-scale wind turbine, Lamma Winds, at Tai Ling on Lamma Island. Since its commissioning in February 2006, Lamma Winds has generated more than 4 million kWh of green electricity, reducing over 1,400 tonnes of coal consumption and avoiding emission of more than 3,200 tonnes of carbon dioxide. This paper introduces the operation and maintenance (O&M) experience gained by HK Electric in running the wind turbine under the local environment and the O&M strategy adopted by the Company.**

## I. Introduction

The erection of Lamma Winds enables HK Electric to acquire knowledge and experience in the design, construction, operation and maintenance of a wind turbine in the local environment and promote public awareness of the benefits as well as limitations of utilizing wind as renewable energy for power generation. The wind turbine is built at Tai Ling of Lamma Island, as shown in Fig. 1. The wind-turbine station also houses an exhibition area providing educational information on different forms of renewable energy.

Fig. 1 – Lamma Winds at Tai Ling

## II. Wind Turbine System

The wind turbine is designed and supplied by Nordex Energy GmbH of Germany. It is Nordex's standard N50 machine with a blade diameter of 50 m and a rated power of 800 kW. The wind turbine is of stall-regulated, "horizontal axis" design and will automatically track the wind direction. Major components of the nacelle and its construction are shown in Fig. 2.

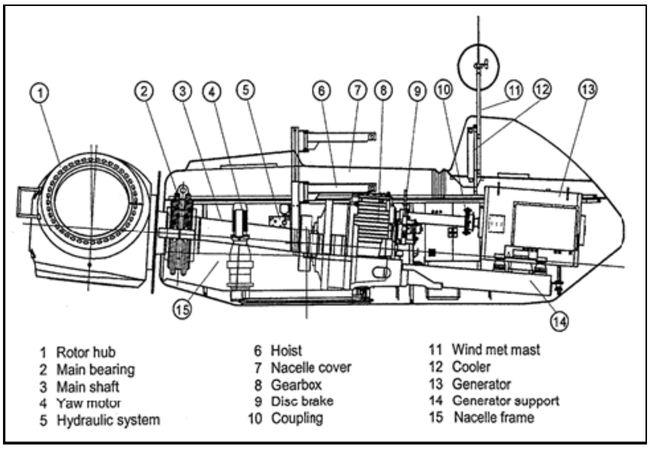


Fig. 2 – Nacelle of Nordex's N50 Wind Turbine

The rotor blades are made of fibre-reinforced plastic (GRP). The blade tips are pivotable and can be swivelled 85 degrees relative to the main blade to act as aerodynamic brakes. The generator is of double winding, 4/6 pole water-cooled squirrel-cage asynchronous type. Wind direction and wind speed are constantly monitored by two mutually independent wind sensors above the nacelle. If the wind direction is different from the orientation of the wind turbine, the wind turbine will yaw actively to face the wind.

The grid-connected 800 kW wind turbine system is designed for automatic operation and will generate electricity when wind speeds are in the range of 3 to 25 m/s. Operation of the wind turbine is monitored and controlled through a monitoring system located at the No. 2 Central Control Room of Lamma Power Station. The wind-turbine site is unmanned and requires attendance of operational personnel only when required.

Power output from the 800 kW wind turbine is about 1,000 MWh/yr under an average wind potential of 150 W/m$^2$. This will help save around 350 tonnes of coal annually and reduce the associated emissions.

TABLE I
TECHNICAL PARTICULARS OF THE WIND TURBINE

| | |
|---|---|
| Wind Turbine Type | N50/800 kW |
| Number of Rotor Blades | 3 |
| Rotor Blade Diameter | 50 m |
| Hub Height | 46 m |
| Swept Area | 1,964 m$^2$ |
| Rotational Speed | 15.3 / 23.75 rpm |
| Cut-in Speed | 3 m/s |
| Cut-out Speed | 25 m/s |
| Generator Output Voltage / Frequency | 690 V/ 50 Hz |

## III. OPERATION EXPERIENCE

Since the wind turbine was connected to the power grid on 26 September 2005, a total of 4,869 MWh electricity was produced over a period of 64 months as on 25 January 2011. This translates to a capacity factor[1] of about 13.0 % which matches with the anticipated value of 13 % in the design stage. Below are performance data of Lamma Winds in 2010.

TABLE II
PERFORMANCE DATA OF LAMMA WINDS IN 2010

| | 1st Quarter | 2nd Quarter | 3rd Quarter | 4th Quarter |
|---|---|---|---|---|
| Total Electricity Generated, kWh | 284,496 | 259,798 | 145,865 | 286,756 |
| Average Electricity Generated per Day, kWh | 3,161 | 2,855 | 1,585 | 3,117 |
| Capacity Factor | 16.5 % | 14.9 % | 8.3 % | 16.2 % |
| Availability | 98.8 % | 99.2 % | 93.9 % | 99.2 % |
| Mean Wind Speed, m/s | 4.6 | 4.6 | 3.8 | 4.7 |
| Max. Gust, m/s | 19.6 | 24.7 | 26.0 | 20.0 |
| Total number of outage hours due to malfunction /defects | 0 | 14 | 89 | 16 |
| Number of Unscheduled Outages | 0 | 2 | 4 | 1 |

Remarks: All wind data were measured by anemometers on top of the nacelle of the wind turbine.

TABLE III
COMPARISON OF PERFORMANCE DATA OF LAMMA WINDS FROM 2006 TO 2010

| | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|
| Total Electricity Generated, MWh | 840 | 865 | 807 | 1,099 | 977 |
| Capacity Factor, % | 11.98 | 12.34 | 11.49 | 15.69 | 13.94 |
| Availability, % | 93.0 | 98.3 | 94.8 | 95.3 | 97.8 |
| Mean Wind Speed, m/s | 4.3 | 4.2 | 4.2 | 4.6 | 4.4 |
| Max Gust, m/s | 38.4 | 31.7 | 44.5 | 44.4 | 26 |

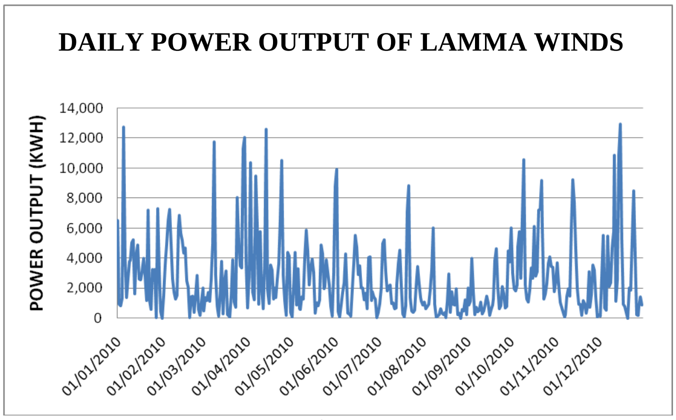

Fig. 3 Daily Electricity Generation of Lamma Winds in 2010

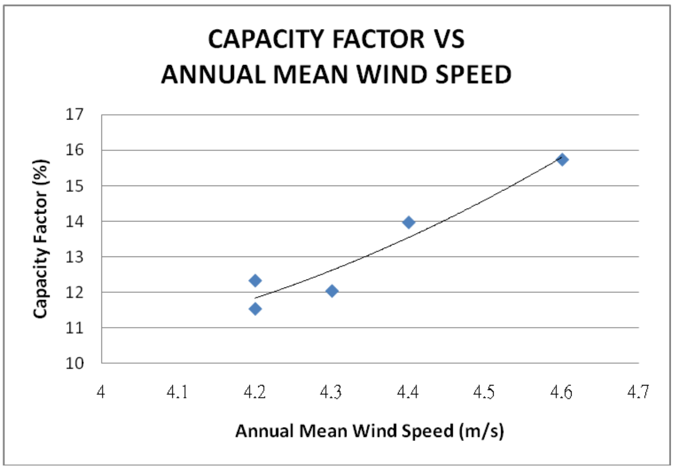

Fig. 4 Relation between annual mean wind speed and capacity factor

Salient points observed from the operating data are as follows:

1. On 19th April 2008, a maximum output of about 17,875 kWh was recorded with an average wind speed of 13.9 m/s due to the effect of northeast monsoon. But on a calm day the output could be zero. The intermittent nature of

[1] Capacity factor is the ratio of actual annual energy output divided by the theoretical maximum output, if the machine were running at its rated (maximum) power during all times of the year.

wind energy means that electricity supply from the wind turbine cannot be guaranteed.

2. Due to monsoons in Hong Kong, more wind energy is harvested by the wind turbine in winter. Maximum mean wind speed was mostly reported in the fourth quarter while maximum gust reported in the third quarter. The climate of Hong Kong is a monsoon-influenced subtropical climate. In late winter and early spring, the weather is typically overcast and occasional cold fronts are experienced. Northeast monsoon in the first and fourth quarter results in high mean wind speeds. In summer and early autumn, typhoons, thunderstorms and heavy rain are common. The maximum gust in third quarter is normally due to severe tropical storms.

3. Total energy produced in the fourth quarter is 96.6 % higher than that of the third quarter although the mean wind speed in the fourth quarter is only 23.6 % higher than that of the third quarter. The amount of wind energy that can be harvested not only depends on the mean wind speed, but also depends on wind quality. Comparing the operating data of the wind turbine in periods affected by monsoon (in the fourth quarter) and tropical cyclones (in the third quarter), it can be concluded that more energy is produced during the monsoon periods. This is due to the requirement of locking the wind turbine if the wind speed exceeds 25 m/s.

4. When there is strong gust, the 'Power Maximum[2]' alarm may operate and cause the wind turbine to stop and start frequently. It causes excessive wear and tear of the rotor disc-brake. It is therefore required to stop the wind turbine under this condition.

It is evident that wind energy cannot be regarded as a reliable source of energy if a stable and continuous electricity supply to a load centre is required. However, such impact on HK Electric's system is insignificant as the amount of power generated from Lamma Winds is small and any transient fluctuation in power quality can be comfortably absorbed by the grid without affecting the consumers.

## IV. Maintenance Experience

For Lamma Winds, maintenance is normally arranged on weekdays as there would be fewer visitors. Maintenance would not be carried out at night for safety reasons. Moreover, no work is allowed to be carried out on the drive side when the wind speed exceeds 12 m/s.

With the exception of some switchgear and power conversion equipment, most of the equipment of Lamma Winds is accessed by climbing the tower. A safety code of practice has been prepared for working on the wind turbine. For safety reasons, a crew of at least two persons is required for any activity which involves climbing up the tower. The wind turbine is equipped with a small lifting hoist. All tools and equipment, in addition to spares, must be lifted into the nacelle. Space is limited inside the nacelle and working position is awkward. For working outside the nacelle, including transition into the hub, safety harnesses and lanyards must be worn for obvious reasons.

### A. *Maintenance Service by Wind Turbine Supplier*

Maintenance service contract was established with the wind turbine supplier for the initial two years of operation. It covered the following areas:

- Scheduled maintenance and servicing of the wind turbine including checks of all components of the system plus the tower,
- Round-the-clock remote monitoring.

After the first two years, service from the supplier has been provided on an ad hoc basis.

Fig. 5 Routine Maintenance of Wind Turbine

### B. *Scheduled Maintenance*

There are four types of scheduled maintenance for the wind turbine:

Type 1 Between 300 and 500 operating hours after commissioning, work items of Type 1 Maintenance are similar to those of Type 3 Maintenance

Type 2 Annual intermediate maintenance which includes visual inspection of rotor, main bearing, gearbox, rotor brake, generator, yaw system, hydraulic system, generator cooling system, panels, nacelle cover and cabin; replenishment of bearing grease; replacement of filter for gear oil; changing of air filter mat in top box; and function test of turbine.

Type 3 Annual main maintenance which includes Type 2 Maintenance plus other work items such as torque check of all bolts and nuts of main bearing, brake adapter, generator carrier and rotor; sample torque check of the bolts and nuts of the tower structure and hub; taking samples of gearbox oil; changing pressure filter of hydraulic system; and checking properties of generator coolant.

Type 4 Maintenance after 5 years of operation which includes Type 3 Maintenance plus additional work

[2] 'Power Maximum' alarm operates when the power output exceeds the maximum designed value of the wind turbine.

items such as servicing rotor blade-tip mechanism; torque check of all the bolts and nuts of the tower structure and hub; checking and changing V-ring on main shaft, if required; checking generator alignment; changing oil in yaw gear and crane gear; and changing rubber elements and batteries.

### *C. Unscheduled Maintenance*

Major incidents of Lamma Winds recorded so far are summarized below:

*1) "Power Maximum" Alarm*: Under strong gusts, the 'Power Maximum' alarm operated and reset automatically frequently. It caused the wind turbine to stop and restart frequently. As the brake had to be applied many times under high wind speed, excessive wear of the turbine-rotor's brake-pads was found. After an adjustment to the pitch angle of the blades, occurrence of the "Power Maximum" alarm decreased.

Fig. 6 Adjustment of the pitch angle to the required value by loosening and re-tightening the bolt.

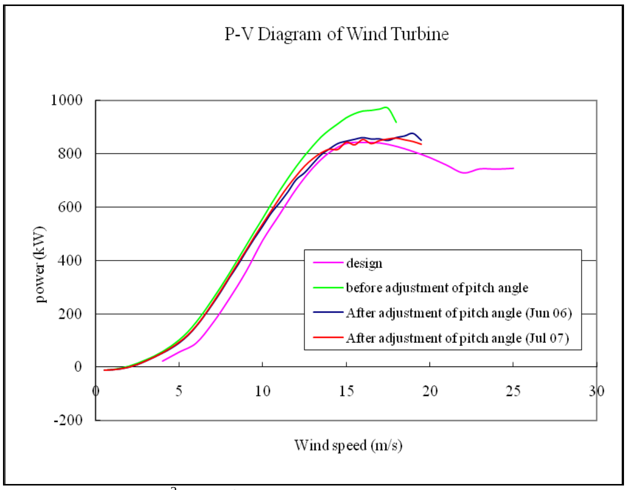


Fig. 7 Power Curve[3] Modified by Adjustment to Fan Blade's Pitch Angle

*2) "Brake Wear Stop" Alarm*: Life of the brake pads was shorter than expected and caused the "Brake wear stop" alarm to operate. The brake pads have to be renewed regularly.

The relatively short lifetime of the brake pads is due to the frequent automatic starts and stops of the generator when the wind turbine operates at low wind speeds of 2.5 m/s to 3 m/s, as well as the problem with the "Power Maximum" alarm mentioned above.

Fig. 8 Brake pads wore down to less than 5 mm

*3) Abnormal Noise from Yaw[4] Brake-disc*: Abnormal noise was generated from the yaw brake-disc. After cleaning the rust and particles on the disc, the abnormal noise disappeared. Routine cleaning of the brake disc every 3 months has been implemented subsequently.

Fig. 9 Rust particles accumulated on the yaw brake-disc may generate high pitch noise.

*4) "Insulation Low" Alarm*: During a severe thunderstorm some time ago, the 'insulation low' alarm operated. Insulation monitoring relay[5] for the 690 V system and some of the transmitters of the wind turbine failed and were replaced. It was suspected that these electrical equipment items were damaged by surge current during lightning. Additional surge

[3] The power curve of a wind turbine is a graph that indicates electrical power output of the turbine at different wind speeds.

[4] The wind turbine's yaw mechanism is used to turn the wind turbine rotor to face the wind.

[5] The insulation monitoring relay monitors condition of the power cables of the wind turbine

arrestors were installed on all vital equipment items subsequently in order to minimize such damages.

## V. HK Electric's O&M Strategy to Improve System Reliability

The availability of Lamma 800 kW wind turbine has been kept above 90 % and maintained at a very high level in the last four years. The O&M strategy implemented by HK Electric contributed to this high availability.

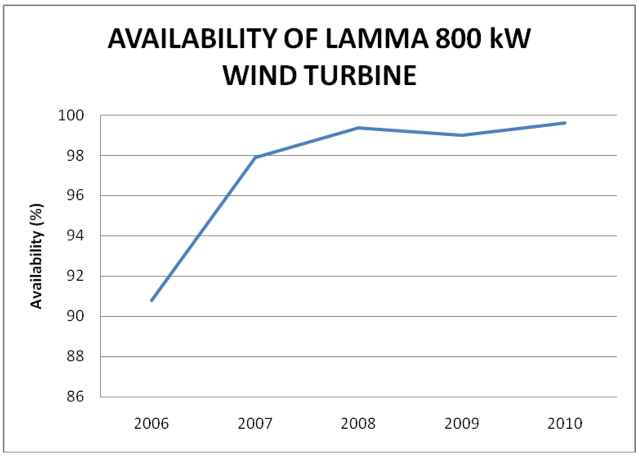


Fig. 9 Availability is kept close to 100 % during the past 4 years

Apart from the routine and scheduled maintenance recommended by the wind turbine manufacturer, HK Electric borrowed the following maintenance strategy established for its fossil-fuel power station and incorporated it in the O&M management of the wind turbine to improve its reliability:

A. Predictive Maintenance
B. Plant Ownership Scheme
C. Routine and Post-Typhoon Inspection
D. Logistics Plan
E. Enhanced Training
F. Improved Maintainability

### *A. Predictive Maintenance*

Predictive maintenance (PdM) is a type of maintenance that emphasizes early prediction of equipment's component failure using non-destructive techniques such as vibration analysis, thermography and oil analysis. Just as in a fossil-fuel plant, maintenance program of Lamma Winds also included PdM.

At present, the PdM techniques applied to Lamma Winds are scheduled vibration monitoring and analysis of gearbox oil which includes analysis of water content, number of metal particles, etc. These two PdM techniques are effective in:

- identifying the repairs needed before incipient failures develop into catastrophic ones which may be costly;
- saving the cost of unnecessary routine maintenance. For example, analysis of gearbox oil will identify when an oil change is required, eliminating unnecessary expense and downtime with routine oil changes based on hours of operation;
- allowing us to schedule repair activities for better efficiency and reduced costs. This can be done by staging equipment and supplies in advance and scheduling repairs and maintenance during periods of low wind speeds according to statistics.

### *B. Plant Ownership Program*

Plant Ownership Program has been applied to Lamma Winds since its commissioning. The Plant Owner is a person made responsible for the performance and expenditure of an asset. He works with in-house electrical and mechanical repair teams to ensure the smooth O&M of the wind turbine.

Performance Pledges of HK Electric Wind Turbine Plant Ownership Program are as follows:

- Annual availability of Wind Turbine is greater than 90 %,
- Any forced outage due to malfunction or defects is less than 72 hours,
- Cases of unscheduled outages are less than eight within a calendar year.

Through the implementation of the Plant Ownership Program, performance of the wind turbine could be closely monitored and maintained. Reliability of the wind turbine has been kept at a high level.

### *C. Routine and Post-Typhoon Inspection of Wind Turbine*

Monthly routine inspection and post-typhoon inspection of the wind turbine are carried out by HK Electric engineers. The inspection includes visual check of the brake system, oil level, coolant pressure, yaw position etc.

Since it is not desirable to stop the wind turbine at high wind speed, which will lead to wear of the brake pads of the main brake and wasting the wind energy, routine inspection is scheduled in periods with low wind speed of less than 3 m/s.

### *D. Logistics Plan*

HK Electric has developed a comprehensive logistics plan for the wind turbine which identifies major failure events and list the tasks required for performing the repairs. The plan lists the likely failures alongside with the spares inventory, manpower, tools and equipment for carrying out the repairs. By this arrangement, breakdowns are dealt with efficiently and downtime of the wind turbine can be minimized since the turbine is located at a distance from the power station.

In addition, spares, tools and equipment for traditional generating units are shared with the wind turbine. For example, a defective power pack (230 V a.c. / 24 V d.c.) of the wind turbine was replaced with a spare of a generation unit.

### *E. Enhanced Training*

As the global wind energy industry is expanding rapidly, it is difficult to find experienced wind turbine service engineers in the market. It is important for wind-turbine owners to train up their people to handle the O&M of their wind turbines. The service engineers will have to be highly specialised and have to have working knowledge of mechanics, hydraulics, computers and meteorology. Therefore comprehensive training of the service personnel is essential for proper maintenance and effective fault and failure diagnosis.

During the testing and commissioning stage, the wind-turbine manufacturers had conducted training for HK Electric's personnel. The maintenance team also acquired the necessary experience and knowledge by working alongside with the manufacturer's service engineers in the various types of routine maintenance.

### F. *Improved Maintainability*

HK Electric maintenance personnel have developed skills in finding efficient ways to perform routine tasks, and have an understanding of the equipment that was gained from hands-on experience. Their suggestions and comments were routinely incorporated in updated procedures as part of the continuous improvement process. Also, the Nordex's turbine control system provides some diagnostic information on the status of the various subsystems. A history buffer is available to allow a review of events leading up to a fault. Moreover, Lamma Winds is incorporated with a remote monitoring system. The wind turbine manufacturer has resident experts in Beijing and Germany, who can conduct 24-hour monitoring of the wind turbine if necessary, and contact on-site staff with recommendations for fixing a problem.

### G. *Summary*

Scheduled wind-turbine maintenance is done twice a year, resulting in about 12 to 18 hours of downtime for each maintenance event. Unscheduled outages in the past four years were mainly related to accelerated wear of the brake pads under the local environment with unstable wind resources, and equipment damages as a result of lightning strike.

HK Electric's personnel are gaining their knowledge and experience in operation and maintenance of wind turbines through the running of this first commercial-scale wind turbine in Hong Kong.

## VI. Conclusions

The construction of the 800 kW Lamma Winds at Tai Ling on Lamma Island is a pilot scheme that demonstrates HK Electric's effort to explore 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 a source of renewable energy. Though small in scale, the success of Lamma Winds has been exciting and has encouraged us to expand the use of wind power in Hong Kong. We are now planning to build a 100 MW wind farm on Hong Kong's waters. The O&M experience gained from Lamma Winds could be utilized on the future wind farm to enable its smooth operation.

## Acknowledgment

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## References

[1] *Wind Energy Newsletter #1,* Wind Energy Operations and Maintenance Summit 2010

[2] *Technical Description of NORDEX N50,* 2003, NORDEX Energy GmbH, Germany

[3] *Wind Turbine Reliability: Understanding and Minimizing Wind Turbine Operation and Maintenance Costs,* 2009, Global Energy Concepts, LLC

[4] *Hongkong Electrics Wind Turbine for Power Generation on Lamma Island, 2005, The Hongkong Electric Co. Ltd.*