Huaneng Renewables Corporation Limited Global Offering Technical Assessment

Final Report

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Huaneng Renewables Corporation Limited

Confidential

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Content

1. Executive Summary

1.1 Introduction

Mott MacDonald Limited (MM) has been appointed by Huaneng Renewables Corporation Limited (Huaneng Renewables) to act as Technical Consultant on the Company's global offering project.

MM is a world-class multi-disciplinary consultancy engaged in development, focusing on many aspects of everyday life from energy, transport, health and education, water and the environment to building, industry and communications. MM has won recognition for technical excellence in power engineering, water, transportation, building and infrastructure and, in addition to these technical services, also offers a wide range of strategic planning, financial and business development services.

MM is a wholly independent international company, with headquarters in the UK, an annual turnover in excess of 1 billion Euros, over 14,000 staff and global experience spanning 140 countries. For the third consecutive year, MM has made the top 10 list in the UK's Sunday Times annual '25 Best Big Companies to Work For' employee survey, ranking eighth in 2010.

MM is committed to Quality Assurance and is accredited to ISO 9001 and ISO 14001.

With offices across Europe, Asia and the Pacific, the Middle East, Australia, New Zealand, Africa and the Americas, MM has in-depth knowledge and understanding of local conditions and practices, backed by its global resources.

MM played a leading role in the electricity sector restructuring in Hong Kong, Ukraine, Malaysia, Indonesia, Thailand, Philippines, Pakistan, Northern Ireland, Ireland, Singapore, Iran and Qatar where it advised the respective governments on the financial/technical options best suited to the country in question, as well as regulatory, efficiency and contractual issues. MM has been involved in regulatory reviews of electricity utility companies, which have either been corporatised or privatized and has advised various major investors on prospective power plant and distribution company acquisitions. Additionally, MM is involved with the development of privately funded power projects throughout the world as independent advisers to both owners and lenders.

MM is experienced in all types of power generation and transmission technologies and works in partnership with its clients, ensuring through total commitment that MM adds maximum value to every project. MM has engineered over 200 GW of power plants world-wide. The strength of this company lies in a rich diversity of expertise which covers the complete spectrum of disciplines and skills. It has extensive experience with the technical and power network aspects of wind power (both onshore and offshore). Its roles included providing consultancy services to financiers, potential investors, project developers, owners and contractors as well as governments, local authorities and regulatory bodies. It has undertaken a wide range of roles in project development, appraisal and implementation and is able to bring the full range of resources to its assignments in both the onshore and offshore sectors.

MM has undertaken over seventy projects in China totalling over 32 GW including wind, hydroelectric, biomass, waste-to-energy, gas and coal power plants.

MM carried out an independent technical assessment of Huaneng Renewables' assets. This review includes wind resource assessment, power generation, availability, operational and maintenance arrangements, wind turbine technologies, grid connection arrangements and compliance with grid codes.

The assessment covers twelve representative wind farms out of the thirty-one projects included in the portfolio.

The majority of the information from which the report was compiled comprises of documents provided by Huaneng Renewables, and discussions and meetings with relevant Huaneng Renewables staff. MM's professional judgment was exercised with regards to the validity and use of all information submitted from external sources. MM's knowledge of the Chinese power sector has been utilized throughout the independent technical assessment process.

A large number of wind farms are included in the asset portfolio and are spread across a wide area of China. These wind farms were designed by various local design institutes based on the same Chinese standard and the turbines were supplied by a number of domestic and international manufacturers. For these reasons it was agreed that the report would be compiled with specific reference to representative wind farms. These wind farms were selected to best encapsulate and represent the diversity of all wind farms controlled by Huaneng Renewables. Particular attention was paid to the following factors when selecting the representative wind farms:

- Wind resources and geographic coverage — The representative wind farms selected are located in areas with abundant wind resources including Guangdong, Yunnan, Shandong, Hebei, Inner Mongolia and Liaoning, as shown in Figure 2.1.
- Turbine types — The representative wind farms selected include turbines produced by both domestic and international manufacturers as detailed in section 3.3 of this report.
- Year of operation — The representative wind farms selected have different operation start dates as detailed in Table 4.1.

1.2 Project Participants

Huaneng Renewables is a wholly owned subsidiary of China Huaneng Group, formed in November 2002. Its business focuses on the investment, construction and operation of new energy projects, and mainly relies on the development and utilization of wind energy. Meanwhile, it is exploring other renewable energy technologies with a focus on solar power.

In BTM's report dated March 2010, Huaneng Renewables was ranked third operator in China in terms of attributable wind installed capacity as at 31 December 2009, and first amongst the top 15 global wind power generation companies in terms of percentage growth of total installed capacity in 2009.

Based on the projects reviewed, we are satisfied that Huaneng Renewables is capable of acting as the owner of the wind farms.

Huaneng Renewables chose several international and domestic WTG suppliers to supply and maintain the turbines on its wind farms. These suppliers specifically include but are not limited to Sinovel, Dongfang, Gamesa, Suzlon and Vestas. All the WTG suppliers for the reviewed sites are renowned in the worldwide wind industry. We are satisfied that all the WTG manufacturers used are capable of delivering their role in the reviewed projects.

The transmission and distribution network in China is state-owned. There are three grid corporations in China, the State Grid Corporation of China (SGCC), the China Southern Power Grid Co., Ltd. (CSG) and the Inner Mongolia Power Company, acting as grid operators. By the end of 2009, all transmission network companies have held the public electricity transmission licenses issued by regulatory agencies. There were 2,929 distribution network companies holding public electricity supply licenses in China.

We have gained experience with SGCC, CSG and Inner Mongolia Power Company through the wind farm projects in China and the Hong Kong Electricity Market Development project. We currently have no concerns with regards to the general capabilities and experience of China transmission and distribution companies acting as grid operators.

1.3 Wind Turbine Generator (WTG) Technologies

Representative wind farms include WTGs produced by both domestic and international manufacturers. All WTG models reviewed here have a modern design in line with current technology standards and with a rated power range of 750 kW to 3 MW. All installed WTG models have been selected according to site specific conditions.

Huaneng Renewables uses several models of WTG on its sites, including SL1500, FD70B, FD77B, G52-850, S82-1.5 MW STV, V52-850, WD50/750 and H93-2.0 MW. CSIC (Chongqing) Haizhuang Windpower Equipment Co., Ltd. did not provide a sufficient track record. Therefore, we considered a warranty period of at least three years as a reasonable mitigant. Huaneng Renewables successfully negotiated a five year warranty period with Haizhuang. Thus, we are satisfied with the mitigation applied by Huaneng Renewables as most of the models used by Huaneng Renewables have substantial track records and we consider the technology of these WTGs as mature and the models as reliable.

1.4 Wind Resource Assessment

From the pool of studies reviewed, we can conclude that there is a consistent approach to wind resource assessment and the adopted methodology is largely consistent with standard international practice. The Chinese standards have been derived from well-known international publications, although due to differences in requirements there are some differences in approach. For example, the Chinese approach does not place as much emphasis on analyzing uncertainty in energy yield prediction compared to the wider international practice. Nevertheless, there is evidence of conservatism in the following process and in the assumptions made by Huaneng Renewables. In particular, the losses applied to calculate the net yields are, in general, generous compared to those typically seen from our experience in other areas of the world. From the pool of studies reviewed we noted a tendency for the actual production to exceed the prediction.

We consider that the Chinese approach to wind resource assessment has been designed according to the nature of Chinese requirements. From the pool of studies reviewed, the applicable operational data is in good agreement with the predictions, providing confidence in the methods.

1.5 Grid Connections Assessment

The transformers at most wind farm step-up substations are appropriately sized and have sufficient capacity to export the maximum power under normal operation scenarios. However, it has been noted that the size of the 75 MVA main transformer at Weihai Wind Farm step-up substation will only just support the full output of the current units in Weihai and Rongcheng Wind Farms which are rated at 75 MW. Therefore, we consider that it is likely that the transformer will be overloaded when all WTGs of Weihai (installed capacity 69 MW) and Rongcheng (installed capacity 6 MW) simultaneously produce at their nominal full capacity; indeed it is possible for WTGs to produce power at a higher level than the nominal power rating. As a result, WTGs from these wind farms may be curtailed during periods of high output, depending on the grid power factor at the time. However, we understand from Huaneng Renewables that the grid power factor is normally maintained at one, which would avoid the need for curtailment. However, the Grid Code, which governs grid operation, does not state that a power factor of one will be maintained. In addition, we have received further information from Huaneng Renewables that a new step-up substation will be constructed at Rongcheng Wind Farm and the two 3 MW WTGs from Rongcheng wind farm will be connected to the new substation.

It appears that all overhead/cable lines are rated appropriately to export full capacity of the wind farms to the grid. All wind farms visited are connected to the grid substation via a single line connection. According to the last version of Chinese Grid Code (Trial) of wind farm grid connection published in 2006, in order to facilitate operation management and control, and to simplify system topology, it is not required to meet the ‘N-1’ security criteria for the transmission network between the wind farm substation and the grid connection point. In the updated version of Chinese Grid Code (Revision) of wind farm grid connection published in December 2009 there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network between the wind farm substation and the grid connection point.

All the representative wind farms have appropriate switchgear installed to withstand fault current at both the wind farm step-up substations and the grid connection substations. No issue regarding switchgear rating has been identified at any of the representative wind farms. Appropriate protection schemes have been applied to all wind farms, including differential and over-current protection, which seems to be the common practice for most Chinese wind farms. Lightning protection equipment has also been installed to prevent lightning damage to the wind farm equipment. No significant issues have been raised regarding the equipment condition.

All wind turbines have controllable power factors at grid connection point as required in the Chinese Grid Code. Most wind farms have reactive power compensation equipment installed to provide reactive power support as required by the grid connection study report. Since there is no requirement to consider the installation of reactive power compensation equipment on the grid connection, there are no reactive power compensation equipment installed at Changdao, Weihai, Rongcheng and Changyi Wind Farms. In addition, all the main transformers are equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the High Voltage winding. Therefore, we would consider that the wind farms have sufficient reactive and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

The updated Chinese Grid Code (Revision) of wind farm grid connection requires an assessment of the power quality and low voltage ride through (LVRT) to ensure that the relevant indices are within the given limits and in accordance with technical standards. The relevant tests are required to be finished before the wind farm is connected to the grid, as most existing Chinese wind projects, including the twelve representative wind farms, will be required to be technically upgraded so that they can meet relevant requirement in the updated Chinese Grid Code in the near future.

Most of the local power grids have sufficient capability to accommodate the connection of the wind farms so that they will be able to operate during normal conditions and export the generated power to the grid as expected. However, it is noted that in Baolongshan and Zhurihe Wind Farm 1, the power generation may have to be curtailed to some extent due to local power grid's insufficient capability to adjust active power and the requirement of heat supply using thermal power plants in winter. We understand that the local network should have sufficient capability to accommodate Huaneng Renewables wind power and we would expect that this problem could be solved by future reinforcement of the local network.

In general, we consider the grid connection of Huaneng Renewables wind power projects to be well-planned, without any major constraints found to prevent power export under normal system operating conditions. The only exception is when the local power system operates under specific scenarios, like Tongliao power system in winter. However, it is likely that such a situation can be eliminated in the medium term by future network reinforcement.

1.6 Performance of the Wind Farms

Of the twelve representative wind farms reviewed, six wind farms only started commercial operation in the last year, therefore those wind farms do not have enough operational data (at least 12 months of normal operational data is usually required) in order to assess whether the production would be in line with the estimates from the feasibility studies.

Nevertheless, within the six remaining wind farms, five projects have higher annual productions than planned with the same annual average wind speed as in the feasibility study.

Moreover, regarding Laoting Wind Farm which showed lower performances than expected, we understand, from the available information, that lower annual average wind speed was the main reason for the lower performance. In addition, 2009 is the first operational year of the wind farm. Indeed, before May 2009, all WTGs were under commissioning and their power generation was lower than forecasted.

Overall, the equipment and facilities are well-maintained and of a high standard. The design, construction and installation are in line with our expectations.

1.7 Operation and Maintenance of the Wind Farms

Overall, Huaneng Renewables' Operation & Maintenance arrangements for its wind farms are above our expectations and in line with international standards. We consider that these arrangements should be suitable for Huaneng Renewables as they have similarities with Operation & Maintenance structures from other companies while being specifically developed in order to be integrated within Huaneng Renewables' organizational structure.

Although we believe that the preventive maintenance strategy for the WTGs main components could be improved, the structural organization of Operation & Maintenance, the treatment to the outage, the purchase and storage of spare parts and the Quality, Health & Safety and Environment (QHSE) requirements of Huaneng Renewables wind farms are generally acceptable and well-organized.

2. Introduction

2.1 Overview

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A large number of wind farms are included in the asset portfolio and are spread across a wide area of China. These wind farms were designed by various local design institutes based on the same Chinese standard and the turbines were supplied by a number of domestic and international manufacturers. For these reasons it was agreed that the report would be compiled with specific reference to representative wind farms. These wind farms were selected to best encapsulate and represent the diversity of all wind farms controlled by Huaneng Renewables. Particular attention was paid to the following factors when selecting the representative wind farms:

- Wind resources and geographic coverage — Representative wind farms selected are located in areas with abundant wind resources including Guangdong, Yunnan, Shandong, Hebei, Inner Mongolia and Liaoning, as shown in Figure 2.1.

- Turbine types — The representative wind farms selected include turbines produced by both domestic and international manufacturers as detailed in section 3.3 of this report.

- Year of operation — The representative wind farms selected have different operation start dates as detailed in Table 3.1.

The process of technical assessment was carried out in China and the UK through a variety of procedures including, but not limited to: site visits, data collection, discussion, analysis, and report production.

2.2 Assets Overview

2.2.1 General Overview

As of the end of 2009, Huaneng Renewables owned a total of 31 operational projects. The total capacity equivalent was 1,549.8 MW. All the wind farms are operated by its subsidiaries across China. The consolidated wind power portfolio including the projects in construction phase reaches 2,511.3 MW.

Wind turbine technologies adopted in the portfolio are from renowned Chinese Wind Turbine Generator (WTG) manufacturers such as Dongfang and Sinovel and international suppliers such as Suzlon, Gamesa and Vestas. The size of the turbines varies from 750 kW to 3 MW.

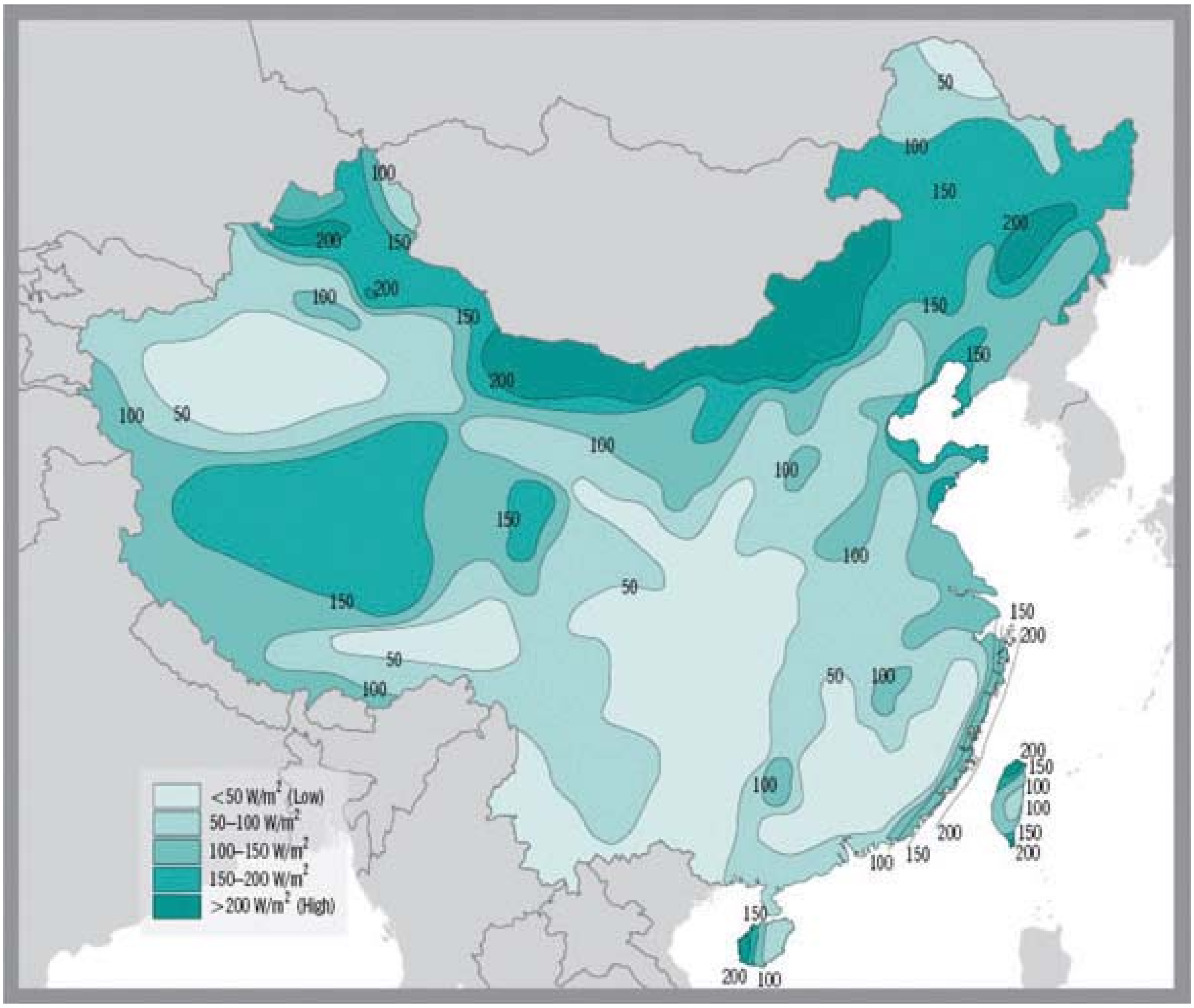
2.2.2 Selection of Representative Wind Farms

Due to the large number of projects involved in the asset portfolio, it was decided that a representative sample of twelve wind farms will be assessed as part of our due diligence.

The Company provided a list of its wind farms which sets out information including types of Wind Turbine Generators (WTG), their respective size in megawatts, the geographic location and years of operation of each wind farm. All the above elements have been taken into account for selecting the 12 representative wind farms. The 12 representative wind farms are located in six provinces and autonomous regions with a total installed capacity of approximately 700MW and were selected in order to reflect the primary characteristics of the 31 wind farms included in the portfolio of the Company. For instance, wind farms using different WTG were selected so that technology, availability and utilisation hours of different WTG can be assessed and at the same time, warranties agreed amongst different WTG suppliers and the Company can be reviewed. Geographic location was also an important basis for the selection: wind farms at different operation stages located in different areas of North China Region and South China Region were selected so that relevant records of wind farms at different development stages (either in operation or under construction), performance of the wind resource at different locations as well as local grid connection condition are available for our assessment.

China has abundant wind resources, with the Global Wind Energy Council (GWEC) report "Global Wind 2009 Report", estimating exploitable onshore wind resources at approximately 2,380 GW. According to a survey undertaken by the Chinese Renewable Energy Industries Association (CREIA) and the Business Council for Sustainable Energy (BCSE), wind resources are distributed as shown in Figure 2.1. Higher resources are located in the Northern parts of China such as Inner Mongolia, Xinjiang, Gansu Hexi Corridor, some areas of Qinghai-Tibetan Plateau, Northeast China, Hebei, and along the East China coast region from Shangdong to Fujian Provinces. The color tone in Figure 2.1 represents wind density.

Figure 2.1: Wind Resources Distribution in China and Representative Projects' Location



Source: BCSE/CREIA 2006

As indicated by the dark red marks in Figure 2.1 we have selected representative projects located in the wind abundant areas of Inner Mongolia, Shandong, Hebei, Guandong and Liaoning. We also chose a site with a more complex topography in Yunnan province.

2.3 Report Structure

This report provides a detailed review of key information relating to the construction and operation of the projects. It is structured as listed below:

- Project Participants;
- WTG Technologies;
- Wind Resources Assessment;
- Grid Connection Assessment;
- Performance of the Wind Farms; and
- Operation and Maintenance Execution.

2.4 Status of this document

This Final Report presents our views on the current status of the portfolio of projects on 11 August 2010, at the time of issue of this report.

3. Project Participants

3.1 Introduction

This section of the report reviews the project participants and considers their suitability and capability for the roles envisaged. The report considers Huaneng Renewables and the main WTG suppliers. Information has been gathered from our work, discussion with the participants and also from a review of information available on the internet. We have not considered the financial strength of any participants or their suitability from a financial standpoint.

3.2 Huaneng Renewables Corporation Limited

Huaneng Renewables is a wholly owned subsidiary of China Huaneng Group, formed in November 2002. Its business focuses on the investment, construction and operation of new energy projects, and mainly relies on the development and utilization of wind energy. Meanwhile, it is exploring other renewable energy technologies with a focus on solar power.

Huaneng Renewables owns operating wind farms with a total installed capacity of 1,549.8 MW and 961.5 MW under construction as of 31 December 2009.

Huaneng Renewables has formed six wind energy bases located in Northeast, East China, West of Inner Mongolia, North China, Xinjiang and South China.

In BTM's report dated March 2010, Huaneng Renewables was ranked third operator in China in terms of attributable wind installed capacity as of 31 December 2009, and was ranked the first amongst the top 15 global wind power generation companies in terms of percentage growth of total installed capacity in 2009.

Based on the projects reviewed, we are satisfied that Huaneng Renewables is capable of acting as the owner of the wind farms.

3.3 WTG Suppliers

Huaneng Renewables uses many different WTG models supplied by international and domestic manufacturers for its wind farms. WTG selection is crucial for improving the electricity production. It considers a number of factors such as suitability for site conditions, energy yield, price and technology. Huaneng Renewables manages all procurement and engineering activities of WTGs centrally from its headquarter in Beijing, and its regional subsidiaries operate those WTGs. The following sub-sections assess the capability of all WTG manufacturers utilized on the representative wind farms we visited.

3.3.1 Sinovel Wind Group Co., Ltd.

Sinovel is the main Chinese WTG manufacturer. It is engaged in development, design, manufacture, marketing, sale and operation & maintenance of both onshore and offshore WTGs.

According to its website, Sinovel has operating factories in Beijing, Tianjin, Dalian of Liaoning Province, Baotou, Xing'anmeng and Bayannaoer of Inner Mongolia, Dongying of Shandong Province, Yancheng of Jiangsu Province and Jiuquan of Gansu Province.

In 2009, Sinovel supplied 3,510 MW and has supplied 5,658 MW of the cumulative installed capacity. This growth has allowed Sinovel to be the first WTG supplier in China and the third in the world in terms of installed capacity in 2009. According to the report by BTM dated March 2010, the global market share of Sinovel was 3.5% in terms of cumulative installed capacity worldwide.

3.3.2 Dongfang Turbine Co., Ltd.

Dongfang Turbine (Dongfang) was set up in 1989. It is a large state-owned company focusing on research, design and manufacture of large scale equipment used in power plants. It started to develop WTGs in November 2004 using WTG technologies from REpower. Nowadays, Dongfang WTGs are in operation in several provinces in China including Shandong, Inner Mongolia, Heilongjiang, Xinjiang, Jilin, Gansu, Jiangsu, Hebei and Shanxi Provinces.

Dongfang has two factories in Deyang of Sichuan Province and Tianjin and plans to build a third factory in Gansu Province. According to the report by BTM dated March 2010, in 2009, the capacity supplied by Dongfang was 2,475 MW in China, placing the company as the third largest WTG supplier in China and the tenth in the world. Its cumulative installed capacity was 3,765 MW, The global market share of Dongfang Steam Turbine was 2.4% in terms of cumulative installed capacity worldwide at the end of 2009.

3.3.3 Suzlon

Founded in 1995 with 20 people, Suzlon is now a leading wind power company with over 14,000 people in 21 countries. In 2009, Suzlon acquired most of the shares of REpower which gave the Indian-owned company an increasingly firm foothold in Europe. By the end of 2009, Suzlon had installed 9,671 MW across the world. According to the report by BTM dated March 2010, this Indian company was ranked as the fifth main WTG supplier with a global market share of 9.1% (including REpower) in terms of total cumulative installed capacity worldwide.

Suzlon Energy (Tianjin) Limited is Suzlon's wholly-owned subsidiary company and was commissioned in 2007. The plant manufactures rotor blades, nacelles, nacelle covers, control panel systems, hubs and generators. It already has several projects with a cumulative capacity of 825 MW which is equivalent to almost 600 WTGs. Suzlon supplied capacity in 2009 was 293 MW. Its cumulative installed capacity was 605 MW, giving it a ninth place ranking in the Chinese market in term of cumulative installed capacity.

3.3.4 Zhejiang Windey Engineering Co. Ltd

Zhejiang Windey Engineering Co. Ltd (Windey) was founded in 2001 as a result of a joint investment between Zhejiang Institute of Mechanical & Electrical Engineering and Zhejiang Windey Equipment Co. Ltd. Nevertheless, the development of WTGs started in these companies in 1970s.

Windey's principal activities are development, manufacture, sale, marketing and maintenance of WTGs. Windey is also involved in the design and construction for WTG engineering, development of WTG components and equipment, wind farm planning and consultancy services.

Windey supplied capacity was 261 MW in 2009 and its cumulative installed capacity was 594 MW, ranking tenth place in the Chinese market in terms of cumulative installed capacity. Currently, Windey has two operating production facilities located in Deqing of Zhejiang Province and Zhangbei of Hebei Province. It also has a factory and research center being built in Hangzhou of Zhejiang Province. In July 2008, the first WTG with blades made of bamboo fiber, developed by Windey, started operation. The company has some long-term cooperation relationships with Mita a developer of control systems located in Denmark, and Garrad Hassan, a British technical engineering company located in several countries worldwide.

3.3.5 CSIC (Chongqing) Haizhuang Windpower Equipment Co., Ltd.

CSIC (Chongqing) Haizhuang Windpower Equipment Co., Ltd. (CSIC or Haizhuang) was founded in 2004. It specializes in the development and manufacture of large WTGs and their related main components. The company was established by the integration of CSIC's affiliated companies and research institutes. This integration gives CSIC access to technologies in several fields such as system integration, gearbox, generator, computer control, steel structure and hydraulic system. Currently, CSIC has three factories in Chongqing, Shandong and Inner Mongolia.

3.3.6 Gamesa

With over 15 years of experience in energy technologies, primarily wind, Gamesa is the leader in WTG design, manufacture, installation and maintenance in Spain, and one of the largest in the world. According to the report from BTM dated March 2010, in 2009, the company was ranked as the fourth main WTG supplier in the world in terms of the cumulative installed capacity worldwide. It occupied 12.0% of the whole global market. Gamesa supplied capacity was 276 MW in 2009, and cumulatively 1,829 MW in China, ranking at fifth place in the Chinese market in terms of cumulative installed capacity.

Gamesa entered into the Chinese market in 2000 and it is one of the main investors in the wind power industry in China. Currently, the company has four manufacturing plants for blades, generators, gearboxes and nacelles assembly in Tianjin. The fifth plant in Da'an of Jilin Province is being built and scheduled to begin operation in 2011. It will manufacture G8X-2.0 MW WTGs and should have a production capacity of 250 WTGs per year. To date, Gamesa has installed a total of 2,000 G5X-850 kW turbines in China in over 60 locations. As for its wind farm development business in China, Gamesa has several wind farm projects totalling 2,400 MW at varying stages of development in the pipeline.

3.3.7 Vestas

With a 24.8% global market share in terms of cumulative installed capacity worldwide in 2009, Vestas remains the largest WTG supplier worldwide. It has over 40,000 WTGs installed in several countries. In February 2009 Vestas announced the production of two new turbine types, the 3 MW V112 and the 1.8 MW V100. The new models will be available on the market in 2010.

Vestas entered into the Chinese market more than twenty years ago and first erected its WTG in the Hainan and Shandong Province in 1986. By 31 December 2009, Vestas has supplied 2,043 WTG in 13 Provinces in China with a cumulative installed capacity of 2,107 MW. Currently as the leading international supplier in China, Vestas has a head office in Beijing, a procurement office in Shanghai, and factories in Tianjin, Xuzhou and Hohhot with more than 80% of components for its WTGs being produced in China.

3.3.8 NEG-Micon

NEG-Micon is a former Danish WTG manufacturer which is now owned by Vestas. It was formed in 1997 as a result of a merger between two former WTG suppliers. NEG-Micon offers a broad variety of WTGs, ranging from 600 kW to 2.0 MW.

NEG-Micon entered into the Chinese wind market more than ten years ago. In 1997, the same year as its creation, NEG-Micon set up a joint venture to provide technology services and the development and manufacture of WTGs in Shunyi of Beijing. The company installed WTGs in Xinjiang, Gansu, Inner Mongolia, Liaoning, Hebei and Guangdong Provinces. In 2004, NEG-Micon was merged with Vestas and is now known under the name of the main WTG supplier.

3.3.9 Conclusions

Most WTG suppliers chosen by Huaneng Renewables to supply and maintain the turbines on its wind farms are renowned in the worldwide wind industry and we are satisfied that these WTG manufacturers are capable of delivering their role in the reviewed projects. However, Haizhuang did not provide a sufficient track record. Therefore, we considered a longer warranty period of the WTG as a reasonable mitigation. Huaneng Renewables successfully negotiated a five year warranty period with Haizhuang. Thus, we are satisfied with the mitigation applied by Huaneng Renewables and it is above our expectations.

3.4 Grid Operators

The transmission and distribution network in China is state-owned. Currently, there are three grid corporations in China, the State Grid Corporation of China (SGCC), the China Southern Power Grid Co. Ltd. (CSG) and the Inner Mongolia Power Company, including 38 transmission grid utility companies that are responsible for the operation and management of the transmission grids at a provincial level and above.

The distribution network companies are responsible for the operation and management of the distribution network and supplying electricity to the customers.

3.4.1 Grid Operators in selected Wind Farm

As detailed in section 2.2.2, the 12 wind farms we visited are distributed in regions covering from the North east to the North and Southeast to the South area. These wind farms have been connected to the 220 kV and 110 kV transmission & distribution network owned by SGCC, CSG and the Inner Mongolia Power Company.

The grid operators for the selected wind farm have been listed in Table 3.1, including local, provincial and regional Grid companies affiliated to SGCC, CSG or the Inner Mongolia Power Company.

Table 3.1: Grid Operators in Representative Wind Farms

	Wind Farm	Capacity (MW)	Grid Operator				Connected point Voltage
			Local	Provincial	Regional	National	
1	Fubei Wind Farm Phase II	1.5 MW x 200 = 300 MW		Liaoning Electric Power Company			
2	Baolongshan Wind Farm Phase I	1.5 MW x 33 = 49.5 MW			Northeast China Grid Company Limited	SGCC	220 kV
3	Zhurihe Wind Farm 1 Phase I	2 MW x 24 = 48 MW					
4	Maoming Wind farm Phase I	1.5 MW x 33 = 49.5 MW	Baotou Power Supply	Inner Mongolia Grid Company			220 kV

	Wind Farm	Capacity (MW)	Grid Operator: Local	Grid Operator: Provincial	Grid Operator: Regional	Grid Operator: National	Connected point Voltage
5	Niutouling Wind Farm Phase I	0.75 MW x 18 = 13.5 MW	Shantou Power Supply	Guangdong Power Grid Company	CSG		110 kV
6	Qingao Wind Farm Phase II	0.85 MW x 53 = 45.05 MW					
7	Dali Dafengba Wind Farm	0.75 MW x 64 = 48 MW	Dali Power Supply	Yunnan Power Grid Company			
8	Changdao Wind Farm	0.85 MW x 32 = 27.2 MW	Yantai Power Supply	Shandong Electric Power Company	North China Grid Company Limited	SGCC	110 kV
9	Weihai Wind Farm Phase I	1.5 MW x 13 = 19.5 MW	Weihai Grid Company				
10	Rongcheng Wind Farm	3 MW x 2 = 6 MW					
11	Changyi Wind Farm Phase I	1.5 MW x 33 = 49.5 MW	Weifang Grid Company				
12	Laoting Wind Farm	1.5 MW x 33 = 49.5 MW	Tangshan Grid Company	Hebei Electric Power Company			

3.4.2 State Grid Corporation of China (SGCC)

The SGCC was founded on 29 December 2002 as a pilot state-owned corporation by the State Council. Its core business is to construct and operate power grids and provide secure and reliable power supply for economic development. SGCC owns and manages five regional electric power grid companies and twenty-six provincial-level electric power grid companies. There are now 2,240 distribution network companies in SGCC.

SGCC supplies electricity to 88% of the national area, in twenty-six provinces. It also provides power services to 1 billion customers. In 2009, SGCC sold 2,274.8 TWh of electricity, the length of transmission line at 110 kV and above is 553,382 km, and the company's annual revenue was RMB 1,265.98 billion.

We have gained experience with SGCC through the wind farm projects in China. We currently have no concerns with regards to the general capabilities and experience of SGCC.

3.4.3 China Southern Power Grid (CSG)

China Southern Power Grid Co., Ltd. (CSG) was founded on 29 December 2002 as a result of the power sector reform in China in 2002. CSG invests, constructs and operates the transmission and distribution networks in Guangdong, Guangxi, Yunnan, Guizhou and Hainan provinces (autonomous region) and cross-regional interconnections. It is in charge of the dispatching backbone network in five provinces, providing secure and reliable power supply and trading services. CSG owns and manages five provincial electric power grid companies and 401 distribution network companies.

CSG supplies electricity in five provinces — covering 1,000,000 km^2 and 230,000,000 customers. In 2009, CSG sold 523.9 TWh of electricity; the length of transmission line at 110 kV and above is 139,286 km; the company's annual revenue was RMB 310.8 billion.

We have gained experience with CSG through the wind farm projects in China and Hong Kong Electricity Market Development project. We currently have no concerns with regards to the general capabilities and experience of CSG.

3.4.4 Inner Mongolia Grid Company

The Inner Mongolia Grid Company is an independent provincial Grid Corporation. It invests and constructs the transmission and distribution networks in Inner Mongolia. The Inner Mongolia Power Grid consists of the western Inner Mongolia Power Grid and the eastern Inner Mongolia Power Grid. The western Inner Mongolia Power Grid and the eastern Inner Mongolia Power Grid operate separately due to power system stability reasons. The Inner Mongolia Grid Company only operates the transmission and distribution networks in western Inner Mongolia. The eastern power grid is operated by Northeast China Power Grid Company.

We have gained experience with Inner Mongolia Grid Company through the wind farm projects in China. We currently have no concerns with regards to the general capabilities and experience of Inner Mongolia Grid Company.

3.4.5 Conclusion

The transmission and distribution network in China is state-owned. There are three grid corporations in China, the State Grid Corporation of China (SGCC), the China Southern Power Grid Co., Ltd. (CSG) and the Inner Mongolia Power Company, acting as grid operators. By the end of 2009, all transmission network companies have held the public electricity transmission licenses issued by regulatory agencies. There were 2,929 distribution network companies holding public electricity supply licenses in China.

We have gained experience with SGCC, CSG and Inner Mongolia Power Company through wind farm projects in China and the Hong Kong Electricity Market Development project. We currently have no concerns with regards to the general capabilities and experience of China transmission and distribution companies acting as grid operators.

4. WTG Technologies

4.1 Key Wind Turbines Involved

As detailed in Table 4.1, representative wind farms include WTG produced by both domestic and international manufacturers. All WTG models reviewed have a modern design in line with current technology standards and with a rated power range of 750 kW to 3 MW. All installed WTG models have been selected according to site specific conditions. In Table 4.1 the operation date means the date all wind turbines started to be in commercial operation after commissioning completed successfully.

Table 4.1: WTG installed in Representative Wind Farms

Ref	Wind farm	Capacity (MW)	Operation Date	Manufacturer	WTG Model	Rated Power (kW)	WTG No.
1	Changdao	27.20	2006	Gamesa	G52	850	32
2	Changyi — Phase 1	49.50	2010	Suzlon	S82	1,500	33
3	Dali Dafengba	48.00	2009	Windey	WD50/750	750	64
4	Damao Maoming — Phase 1	49.50	2010	Dongfang	FD70B	1,500	33
5	Fuxin Fubei — Phase 2	300.00	2009	Sinovel	SL1500	1,500	200
6	Kezuozhongqi Zhurihe — Site 1Phase 3	48.00	2010	CSIS HZ	H93-2.0	2,000	24
7	Laoting	49.50	2009	Sinovel	SL1500	1,500	33
8	Niutouling — Phase 1	13.50	2000	NEG-Micon	NM48/750	750	18
9	Qing'ao — Phase 2	45.05	2007	Vestas	V52	850	53
10	Rongcheng	6.00	N/A	Sinovel	SL3000	3,000	2
11	Tongliao Baolongshan — Phase 1	49.50	2009	Dongfang	FD77B	1,500	33
12	Weihai — Phase 1	19.50	2007	Sinovel	SL1500	1,500	13

4.1.1 Sinovel SL1500-1.5MW

In 2009, Sinovel's installed capacity was 3,510 MW and was mainly based on the wind turbines of the SL 1500 series. Sinovel developed its WTG technology jointly with the established German manufacturer Fuhrländer and is produced under a license agreement with AMSC Windtec. The SL1500 is a three blade, horizontal shaft WTG with a double-fed generator, active pitch, and active yaw system with variable speed operation. The wind turbine is available as a normal and low temperature version.

Overall, we consider the design of the SL1500 to be in line with the industry standards.

Table 4.2: Technical Summary of Sinovel SL1500

	SL1500/77	SL1500/82
Hub Height	70 m	70 m
Rotor Diameter	77.4 m	82.9 m
Rated Power	1,500 kW	1,500 kW
IEC Classification	IEC III	IEC II
Certification	Germanischer Lloyd	Germanischer Lloyd
Cut-in Wind Speed	3 m/s	3 m/s
Nominal Wind Speed	11 m/s	10.5 m/s
Cut-out Wind Speed	20 m/s	20 m/s
Generator	Double-fed asynchronous, water cooling	Double-fed asynchronous, water cooling
Gearbox	Two planetary stages + one spur gear stage	Two planetary stages + one spur gear stage
Gearbox Ratio	1:104.1	1:104.1
Power regulation and control	Electromechanical blade pitch	Electromechanical blade pitch

4.1.2 Sinovel SL3000-3.0MW

With a capacity of 3 MW, the SL3000 is designed and produced under a license agreement with AMSC Windtec. Within 2009, a total of 100 SL3000 units were manufactured by Sinovel and a few of these turbines have been put into service in Shanghai Donghai Daqiao Project since September 2009 and successfully passed a 240 hours pre-acceptance test.

The SL3000 follows a classic design, employing a traditional multi-stage step-up gearbox in conjunction with a double-fed induction generator (DFIG). This is a standard design approach, used by a number of other manufacturers of multi-megawatt machines. Furthermore, the wind turbine features advanced power generating technologies such as variable speed control and a pitch regulated system. Four series of this wind turbine are available; namely as a 50Hz and 60Hz version for both onshore and offshore applications.

Although the SL3000 does not have a substantial track record, its design applies the same standard to WTGs of this range. We would therefore expect a similar level of reliability as WTGs of other renowned manufacturers.

Table 4.3: Technical Summary of Sinovel SL3000

Hub Height	80 m
Rotor Diameter	105 m
Rated Power	3,000 kW
IEC Classification	IEC IIA
Certification	Germanischer Lloyd
Cut-in Wind Speed	3 m/s
Nominal Wind Speed	12 m/s
Cut-out Wind Speed	25 m/s
Generator	Double-fed asynchronous, water cooling
Gearbox	Two planetary stages + one parallel shaft stage
Gearbox Ratio	1:84.6
Power regulation and control	Servo motor blade pitch

4.1.3 Dongfang FD77B/FD70B-1.5 MW

Dongfang Turbine manufactures WTGs under a production license with REpower. The design of the Dongfang FD77B and FD70B is based on REpower's MD70. This design was available from 1997 and has been upgraded continuously. Based on this consistently implemented and optimized technology, the FD77B/FD70B can be considered as mature technology. In 2009, according to the BTM report dated March 2010, the cumulative installed capacity of Dongfang Turbine amounted to 3,765 MW.

Table 4.4: Technical Summary of Dongfang FD77B/FD70B

	FD70B	FD77B
Hub Height	65 m	61.5 m
Rotor Diameter	70 m	77 m
Rated Power	1,500 kW	1,500 kW
IEC Classification	IEC IIA	IEC IIIA
Cut-in Wind Speed	3.5 m/s	3 m/s
Nominal Wind Speed	13 m/s	12.5 m/s
Cut-out Wind Speed	25 m/s	20 m/s
Generator	Asynchronous	Asynchronous
Gearbox	Combined planetary and spur gear	Combined planetary and spur gear
Gearbox Ratio	1:94.99	1:104
Power regulation and control	Pitch and variable speed technology	Pitch and variable speed technology

The concept behind the REpower MD70, and therefore the FD77B/FD70B, is based on the successful solutions incorporated in the 600-750 kW turbines and adapted to the requirements of the megawatt class. The rotor of the FD77B/FD70B is operated at variable speed and blades are optimized for speed-variable operation. The gearbox is a three-stage design with one planetary and two spur gear stages. A double-fed asynchronous generator enables variable speed operation of the WTG without passing the total power through the power electronics of the converter, thus providing the most efficient conditions for this advantageous mode of operation.

As the technology of the FD77B/FD70B is well-established, we consider that the technology is mature and proven, and this model to be reliable.

4.1.4 Suzlon S82-1.5 MW

Suzlon produces the S82-1.5 MW wind turbine mainly for the Indian and Chinese markets. As of 31 January 2010, Suzlon announced a total of 6,622 WTG installed worldwide; among these 1,212 were of the S82 model.

The wind turbine is designed for a medium wind speed regime and features a robust design with pitch regulated blade operation and a 3-stage gearbox with flexible coupling to the asynchronous induction generator.

As the technology of the S82 is well-established, we consider this model to be reliable for its application of the reviewed projects.

Table 4.5: Technical Summary of Suzlon S82

Hub Height	78 m
Rotor Diameter	82 m
Rated Power	1,500 kW
IEC Classification	IEC IIIA
Certification	Germanischer Lloyd
Cut-in Wind Speed	4 m/s
Nominal Wind Speed	14 m/s
Cut-out Wind Speed	20 m/s
Generator	Single fed induction with variable rotor resistance, air cooling
Gearbox	One planetary stage + two helical stages
Gearbox Ratio	1:95.09
Power regulation and control	Electrical blade pitch

4.1.5 Windey WD50-750 kW

Windey has developed wind turbines since the 70s, producing the WD49/50 750 kW, WD52 800 kW and WD77/82 1,500 kW series today. The WD49/50 750 kW series relies on proven REpower design and are manufactured under a production license. The certification was accredited by Germanischer Lloyd. Based on the growing experience, Windey has successfully undertaken development and manufacturing of further wind turbines based on in-house design.

Overall, we consider the technology of the WD50/750 to be mature and proven, and this model to be reliable.

Table 4.6: Technical Summary of Windey WD50/750

Hub Height	50 m
Rotor Diameter	49 m
Rated Power	750 kW
Certification	Germanischer Lloyd
Cut-in Wind Speed	3.5 m/s
Nominal Wind Speed	14 m/s
Cut-out Wind Speed	25 m/s
Generator	Asynchronous induction generator
Gearbox	one planetary and two spur wheel stages
Gearbox Ratio	1:67.4
Power regulation and control	Mita/Windey controller Mita

4.1.6 CSIC H93-2.0 MW

The design of the H93-2.0 MW was undertaken jointly between CSIC (Chongqing) Haizhuang Wind Power Equipment co. Ltd and Aerodyn Energiesysteme GmbH, Germany, which has been involved in the development of WTG technology since 1983. Technical information has been shown in Table 4.7.

Table 4.7: Technical Summary of CSIC H93-2.0MW

Hub Height	70 m
Rotor Diameter	93 m
Rated Power	2,000 kW
IEC Classification	IEC TC IIIA
Certification	Germanischer Lloyd
Cut-in Wind Speed	3 m/s
Nominal Wind Speed	10.5 m/s
Cut-out Wind Speed	25 m/s
Generator	Double-fed asynchronous
Gearbox Ratio	1:117
Power regulation and control	Pitch and variable speed technology

The H93-2.0 MW is certified by Germanischer Lloyd Certification for a site in Inner Mongolia.

Overall, we consider the design of the H93-2.0 MW to be in line with industry standards. However, due to the lack of a track record for this turbine, we consider a warranty period of at least three years as a reasonable mitigant. Huaneng Renewables successfully negotiated a five year warranty period with Haizhuang. Thus, we are satisfied with the mitigation applied by Huaneng Renewables.

4.1.7 Gamesa G52-850 kW

The design of the G52 is very similar to the Vestas V52 which is recognized as a robust product. This also reflects the common ties of the two companies. Gamesa's G52 technology incorporates features including a double-fed induction asynchronous generator and variable speed generator as summarized in Table 4.8.

Table 4.8: Technical Summary of Gamesa G52

Hub Height	55 m
Rotor Diameter	52 m
Rated Power	850 kW
IEC Classification	IEC IA
Certification	Germanischer Lloyd
Cut-in Wind Speed	4 m/s
Nominal Wind Speed	16 m/s
Cut-out Wind Speed	25 m/s
Generator	asynchronous, double-fed induction
Gearbox	One planetary stage + two helical stages
Gearbox Ratio	1:61.74
Power regulation and control	Pitch and variable speed technology

With over 7,000 Gamesa G5X-850 kW WTGs installed, the G52 WTG is a standard and mature Gamesa product. Overall, we considered the G52-850 kW as a well-established and mature WTG.

4.1.8 Vestas V52-850 kW

With an installed base of over 2,100 units globally, the V52-850 kW is a mature product with a reputation for reliability within the Vestas product portfolio.

Vestas V52 is a variable speed machine. Vestas' implementation of the double-fed induction generator (DFIG) and its associated control systems goes under the name of "OptiSpeed®".

OptiSpeed® allows rotor speed to vary by 30% above and below the generator synchronous speed, minimizing unwanted fluctuations in the output to the grid supply and reducing loads on the drive train and structure. It also has the ability to modify the noise profile from the blades.

As for the Gamesa G52 WTG, the V52 is a standard and mature product installed in several countries throughout the world. Overall, we consider the V52-850 kW as a well-established and mature wind turbine.

Table 4.9: Technical Summary of Vestas V52

Hub Height	44 – 74 m
Rotor Diameter	52 m
Rated Power	850 kW
IEC Classification	IEC IA/IEC IIA
Certification	Germanischer Lloyd
Cut-in Wind Speed	4 m/s
Nominal Wind Speed	16 m/s
Cut-out Wind Speed	25 m/s
Generator	Asynchronous with Optispeed
Gearbox	Combination of one planetary and two helical stages
Gearbox Ratio	1:62
Power regulation and control	Pitch/OptiSpeed/OptiSpeed

4.1.9 NEG-Micon TAIM-NM750 kW

NEG-Micon has been developing and manufacturing wind turbines since the late seventies and was merged with Vestas in 2004. Vestas continues to develop a selected number of its former rivals' product lines. The technology deployed is 'active-stall', which is less commonly used today. A control system actuates blade pitching to induce stall as a means of control. Since it does not use power converters, there is less control of power quality as compared to a DFIG.

With a substantial track record, the NM750 is a standard and mature model. Overall, we consider the NM750 as a well-established and mature WTG.

Table 4.10: Technical Summary of NM750

Hub Height	46.4m
Rotor Diameter	44 m
Rated Power	750 kW
IEC Classification	IEC IA
Certification	DNV
Cut-in Wind Speed	3 m/s
Nominal Wind Speed	15 m/s
Cut-out Wind Speed	25 m/s
Generator	Asynchronous
Gearbox	Combination of one planetary and two helical stages
Gearbox Ratio	1:56.3
Power regulation and control	Stall Control

4.2 Conclusions

Huaneng Renewables uses several models of WTGs on its sites. Most of the models used by Huaneng Renewables have substantial track records and we consider the technology of these WTGs as mature and the models as reliable. However, Haizhuang did not provide a sufficient track record. Therefore, we consider a warranty period of at least three years as a reasonable mitigation. Huaneng Renewables successfully negotiated a five year warranty period with Haizhuang. Thus, we are satisfied with the mitigation applied by Huaneng Renewables.

5. Wind Resources Assessment

5.1 Introduction

We have reviewed wind resource and energy yield assessments contained within the feasibility studies for each project. Our review focuses on the adopted methodology and assumptions and does not include remodeling or recalculation of the energy yields. In addition we have reviewed the applicable Chinese standards, which set out recommended practices, in order to comment on the approach compared to wider international practice.

The wind resource assessments form a key component of the feasibility studies produced during the development stage of the wind farms, and can provide a useful insight into the expected generation, particularly where limited production data is available. In the case where sufficient production data is available (at least 1 year of normal operation), we prefer to use this as an indicator for future production forecasts since there can often be changes to the wind farm design, or turbine type which compromises the preconstruction estimate.

5.2 Chinese Standards

Although the wind resource assessments for the wind farms in this review were carried out by a number of different Chinese design institutes, the methodology and reporting of results are common to all studies and are based on the Chinese standards; GB/T 18709-2002 — Methodology of Wind Energy Resource Measurement for Wind Farm and GB/T 18710-2002 — Methodology of Wind Resource Assessment for Wind Farm. The former standard covers data collection and reporting, while the latter outlines the procedures for long-term correction, data screening, data processing and reporting.

5.3 Methodology of Wind Resource Assessment for Wind Farm

GB/T 18710-2002 is the Chinese standard for wind resource assessment and outlines the methodology for processing the wind data and reporting the results. This standard covers reference data requirements and long-term corrections as well as data screening, the formulae for extracting relevant parameters (wind shear, turbulence intensity) and reporting of the results. GB/T 18710-2002 references a number of documents including NREL/SR-440-22223 — Wind Resource Assessment Handbook. This is an American publication issued by the National Renewable Energy Laboratory of the U.S. Department of Energy and provides a good overview of the measurement based wind resource assessment method. Much of GB/T 18710-2002 is derived directly from this document and hence the approach to wind resource assessment in China is largely consistent with international practice.

MCP techniques adopted by Huaneng Renewables are based on the correlation analysis of long-term meteorological observation data and relevant historic annual wind speeds. Long-term correlations of the site data is often based on a comparison of historic annual wind speeds, although in some projects reviewed more sophisticated techniques were employed. This depends on the quality and consistency of the reference data records available. In several of the reviewed feasibility studies, where Huaneng Renewables could not achieve confidence in the reference data available, site collected data (of at least one year) was used as the basis for the energy calculations. This shows evidence of diligence in approach.

The culmination of GB/T 18710-2002, in terms of energy yield, is reporting of the average annual wind speed, the wind direction, power density (W/m2) and diurnal and seasonal profiling. In order to calculate the energy yield from a wind farm, it is necessary to calculate the wind speed distributions at each wind turbine location and to integrate these over the power curve for the chosen wind turbine. The wake losses must then be modeled, and other losses, such as electrical efficiency and availability, must be considered, in order to arrive at a Net Energy Yield.

5.4 Methodology of Wind Energy Resource Measurement for Wind Farm

The standard GB/T 18710-2002 covers key principles on meteorological mast configuration and sensor placement, including some guidance on sensor alignment and mitigating the influence from tower shading. We have observed in previous projects that fewer masts were used in the Chinese measurement campaigns compared to our preferred practice. However, in several sites we assessed, we noted that the measurement campaigns carried out by Huaneng Renewables were quite comprehensive, particularly in complex terrain sites, showing evidence of good practice.

5.5 Feasibility Studies for the Representative Wind Farms

In the feasibility studies reviewed, the wind speed distributions at each wind turbine have been modeled by WAsP, which is a software package developed by the Danish wind institution RISO. WAsP is an industry standard tool for evaluating variation in wind flow from topographic and ground cover variation in non-complex environments.

In our experience, it is common to make some modifications to the wind farm layout between the production of the wind resource assessment and construction. In some of the feasibility studies reviewed it was noted that the turbine model, hub height or layout were not consistent with the constructed layout. In these instances the prediction in the feasibility study and actual production will not be directly comparable.

The power curves used in the feasibility studies are standard power curves provided by the WTG manufacturers. We consider these to be a reasonable basis for prediction at the feasibility study stage. The power curves used in some feasibility studies were often not listed numerically and some of the origins were not stated. Huaneng Renewables has informed us that this is due to the need to maintain fairness in the open bidding process for wind turbine selection. To appreciate the accuracy of a wind resource assessment, it is important to understand whether the power curve is theoretical or derived from measurement, and whether it is guaranteed by the manufacturer. By way of conservatism, the energy yield predictions in the Huaneng Renewables feasibility studies have generally been reduced by 5% which is in line with Chinese practice. We consider that this practice provides some comfort and compensation for the lack of detailed information on the power curves.

In some of the feasibility studies we reviewed, air density correction was calculated using a scaling factor derived from the ratio of site average air density to standard air density. In our opinion, this method does not accurately capture the impact of air density on a wind turbine power curve and can result in an over calculation of the energy lost due to air density in high altitude sites and conservative yield forecasts.

Wake modeling was carried out using WAsP software, which is an industry standard method. The results from the wake model appear to be in line with our expectations. In many of the sites visited, the wind farms have been developed in stages, or have other wind farms constructed adjacent to the site. It is understood that the influences of neighboring wind farms and of subsequent phases have not always been captured in the wind resource assessments in the feasibility studies. However, it is noted that Huaneng Renewables often leaves exclusion zones between wind farms extensions in order to reduce the influence of neighboring wakes.

The losses applied to each project vary substantially. The loss evaluations are generous in our opinion, resulting in project efficiencies of approximately 70% on average.

Uncertainty analyses are important for making commercial decisions about wind farm performance, particularly where external debt financing is sought, as they describe the probability, and hence degree of risk associated with a prediction. Adherence to published industry standards does not immunize an energy yield assessment from uncertainty as sources of error are endemic in the process and are not necessarily consistent from site to site. Debt financiers will typically base production forecasts on a higher confidence prediction since they will not benefit from any upside in revenues. Conversely, a large utility with a large portfolio of wind farms such as Huaneng Renewables or an equity investor, will base revenue projections on central-estimate (P50) production forecasts. Chinese standards do not have specific requirements for uncertainty analysis and only central estimates (P50) are provided in the feasibility studies. We have however observed a tendency for conservatism in the energy yield forecasts carried out for Huaneng Renewables which is reflected in the production data. We prefer to use production data as an indicator of future performance where sufficient data is available (one year normal operation).

5.6 Conclusions

From the pool of studies reviewed, we can conclude that there is a consistent approach to wind resource assessment and the adopted methodology is largely consistent with standard international practice. The Chinese standards have been derived from well-known international publications, although due to differences in requirements there are some differences in the approach. For example, the Chinese approach does not place as much emphasis on analyzing uncertainty in the energy yield prediction compared to the wider international practice. Nevertheless, there is evidence of conservatism in the following process and in the assumptions made by Huaneng Renewables. In particular the losses applied to calculate the net yields are, in general, generous compared to those typically seen from our experience in other areas of the world. From the pool of studies reviewed we noted a tendency for the actual production to exceed the prediction.

We consider that the Chinese approach to wind resource assessment has been designed according to the nature of Chinese requirements. From the pool of studies reviewed, the applicable operation data is pretty much in line with the predictions, providing confidence in the methods.

6. Grid Connection Assessment

6.1 Introduction

The purpose of this section is to assess factors which could affect power export to the grid from the wind farms and to identify risks which may affect normal operation of the wind farms. There are usually three key aspects to be considered:

- Power transferring capacity of wind farm including whether all equipment, i.e. main transformers, export cable/overhead line have been rated appropriately to export full generation from the wind farm;
- Grid codes and essential requirements for wind farms, including whether there are sufficient reactive power sources available from the wind farm, so that the wind farm is capable of maintaining the required power factor at the grid connection point for the given voltage ranges and real power output, voltage control capacity, low voltage ride through (LVRT) and power quality indices of the wind farm connected to the grid; and
- Capability of the local power network in view of voltage/frequency deviation, system overloading and potential operational issues which may be caused by the grid connection of the wind farm.

Our assessment on the grid connection was for the twelve representative wind farms and has been undertaken based upon:

- documents provided by Huaneng Renewables;
- meetings and discussions with relevant staff of Huaneng Renewables;
- site visits to the twelve representative power plants; and
- relevant data and information from the public domain, together with our general knowledge in this field and specifically of the Chinese power sector.

We have used the following data as part of our assessment:

- feasibility study reports;
- grid connection study reports;
- single line diagrams of grid connections;
- single line diagrams of internal energy collection systems in the wind farms;
- grid connection agreement;
- grid codes and essential requirements for wind farms;

- renewable energy policy of the Chinese Government;
- feedback to our questionnaire; and
- site visit records.

All data collected from the site visits are assumed to be the latest. During the assessment, we have not undertaken any independent simulation or calculation to validate the inputs and results in the studies conducted by different Chinese design institutes which are independent third parties to Huaneng Renewables.

The results of the studies such as power system load flow study and fault analysis by these Chinese design institutes have shown whether or not the wind farms could be connected to the grid and if any constraints exist in the local networks which could affect the level of power export from the wind farm at any time. The study results provide us with evidence of adequacy of the grid connection schemes and confirm the grid capability to deliver the wind power to the systems.

We expect any change of the network configurations in the local power grids after commissioning of the wind farms to reinforce the local network capability, and to improve the system operation and performance, which will ultimately benefit the wind farm connections and operations.

6.2 Key issues addressed in Grid Connection

Through our data review and analysis, we noted that the twelve representative wind farms are properly connected to 220 kV or 110 kV transmission and distribution network.

The key issues addressed in Grid Connection Studies are summarized in the following sub-sections of our report.

6.2.1 Capacity of the wind farm step-up substation

Capacity of a step-up main transformer

Capacity of a step-up main transformer in the substation at the wind farm site should be sufficient to transfer the power generated to the local grid as well as to provide flexibility in voltage regulation and reactive power compensation.

The step-up transformers at most wind farms have sufficient capability to export full power from the wind farm to the grid, and are equipped with on-load tap changers which are able to maintain required voltage level at the wind farm step-up substation.

It is noted that the main transformer's capacity at Weihai Wind Farm step-up substation is the same as the total installed capacity of WTG connected to. Therefore, we consider that it is likely that the transformer will be overloaded when all WTGs of Weihai (installed capacity 69 MW) and Rongcheng (installed capacity 6 MW) will simultaneously produce at their nominal power range; indeed it is possible for WTGs to produce power at a higher level than the nominal power rating. As a result, WTGs from these wind farms may be curtailed during periods of high output, depending on the grid power factor at the time. However, we understand from Huaneng Renewables that the grid power factor is normally maintained at one, which would avoid the need for curtailment, but there is no commitment to this effect in the Grid Code, which governs grid operation. In addition, we have received the further information from Huaneng Renewables that a new step-up substation will be constructed at Rongcheng Wind Farm and two 3 MW WTGs of Rongcheng wind farm will be connected to the new substation.

Capacity of the wind farm cable/overhead lines

Conductors of a circuit between the wind farm substation and the grid connection point should be designed to have a thermal rating adequate to meet the requirement to export the maximum apparent power output from the wind farm.

All lines are rated appropriately to export full capacity of the wind farms to the grid. All visited wind farms are connected to the grid substation via a single overhead/cable line connection. According to the last version of Chinese Grid Code (Trial) published in 2006, in order to facilitate operation management and control, and to simplify system topology, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

'N-1' security contingency is a typical steady-state test and it means that the power system can operate either within emergency loading and voltage limits immediately after loss of any transmission line or transformer or generator, or with normal limits after system adjustments.

Other equipment capacity

Fault level calculation has been used to choose appropriate switchgear ratings so that the switchgear is capable of withstanding potential fault currents at the wind farm substation.

6.2.2 Capacity of the reactive power compensation and voltage control

Reactive power compliance is an important technical requirement for the wind farm to be connected to the power grid. Maintaining the required power factor needs sufficient reactive power compensation. The purpose of the reactive power compliance study is to examine whether there are sufficient reactive power sources available from the wind farm, so that the wind farm is capable of maintaining the required power factor at the grid connection point for the given voltage ranges and real power output. If study results reveal any insufficiency, reactive power compensation schemes should be considered when designing the grid connection scheme. Even though detailed reactive power studies are not performed for most Chinese wind power projects as they are elsewhere in the world, Chinese grid connection studies usually provide requirements of reactive compensation schemes under typical operating modes.

All wind turbines at the twelve visited wind farms have controllable power factors at grid connection point as required in Grid Code. Eight representative wind farms have reactive power compensation equipment installed as required by grid connection study report. However, since there is no information in the grid connection study report and the grid connection agreement relating to reactive power compensation scheme, there are no reactive power compensation equipment installed at Changdao, Weihai, Rongcheng and Changyi Wind Farms. In addition, all the main transformers are equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore, we would consider that the wind farms have sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in Chinese Grid Code (Revision).

6.2.3 Capacity of Low Voltage Ride Through (LVRT) and Power Quality

Design principles adopted in wind generators differ from conventional synchronous generators. Connection of numerous WTGs in a wind farm may cause voltage deviation, voltage fluctuation, flicker, and harmonics issues which have impact on the power supply quality of local power grid. The updated Chinese Grid Code

(Revision) of wind farm grid connection requires an assessment of the power quality and LVRT to ensure that the relevant indices are within the given limits and in accordance with technical standards.

The relevant tests are required to be finished before wind farm is connected to the grid. As most existing Chinese wind projects, the twelve representative wind farms will be required to be technically upgraded so that they can meet relevant requirement in the updated Chinese Grid Code (Revision) in the near future.

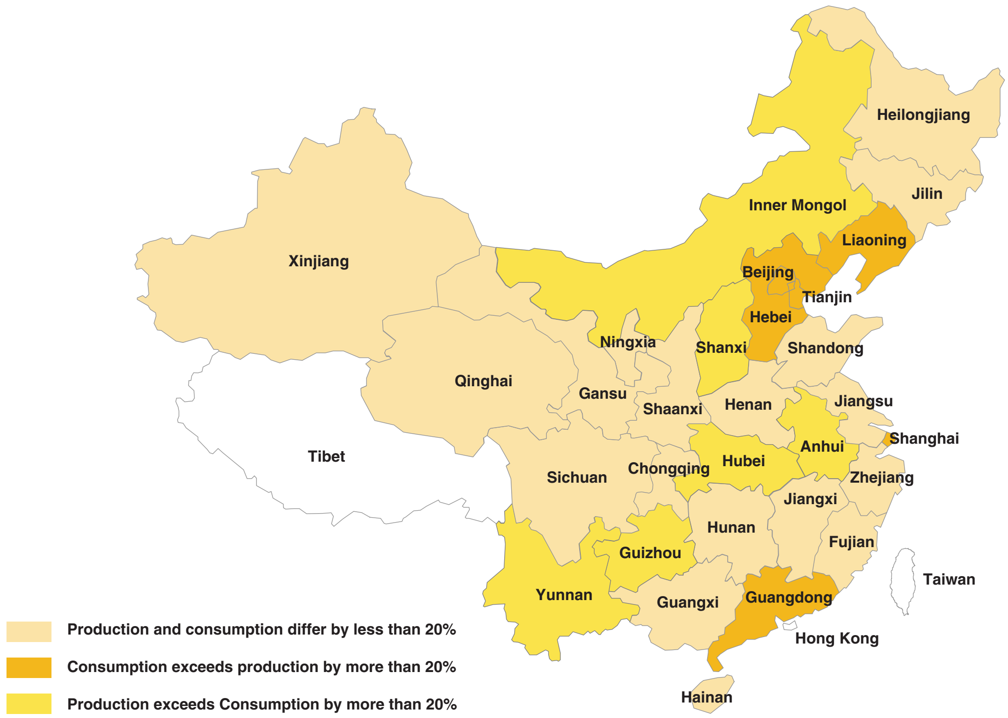
6.2.4 Accommodation capability of the local power network

The feasibility study reports have shown that the power system analysis including the 'N-1' security criteria has been carried out for the transmission network at the grid connection point in each wind farm project in order to assess the steady and dynamic performance of the local power network that the wind farm is connected to.

Connection of wind farms to power networks has a local effect on voltage levels and reactive power flows. However, the primary purpose of the power system operation is to deliver the active power economically and reliably from generation resources to the customers. Clearly, the introduction of distributed and variable wind farms will impact on the scheduling of conventional power system operation and on the accommodation of the local power network. On the other hand, the balance of generation supply and consumption in each power grid will also impact on the accommodation of the local power network. We have provided our analysis of this aspect below.

China is a vast country and the distribution of energy sources versus electricity demand are greatly unbalanced. Indeed, nearly two thirds of hydro resources and coal reserves are distributed in the Southwest, West, Northwest and North of China while two thirds of electricity loads are in the East and South of China, where there is a lack of electricity energy sources. Figure 6.1 shows the distribution of the electricity production and consumption in China.

Figure 6.1: Chinese Energy Production and Consumption



Source: China Statistics Yearbook 2009

As per our analysis, most local power grids are sufficient to accommodate the wind farms to be connected so that they are able to operate in normal conditions and to export the generated power to the grid as expected. However, we noted that in Baolongshan and Zhurihe Wind Farm 1, the power generation may have to be curtailed to some extent due to local power grid's insufficient capability to adjust active power and the requirement of heat supply in winter. We understand that the local network should have sufficient capability to accommodate Huaneng Renewables wind power and we would expect that this problem could be solved by future reinforcement of the local network.

6.3 Grid Connection Assessment on each wind farm

6.3.1 Introduction

As part of our desktop study and site visits, taking into account of the generation — demand balance and local network constraints, we will provide our assessment on the key grid connection issues and consequently identify the potential risks and operational issues for each wind farm.

6.3.2 Fubei Wind Farm Phase II

6.3.2.1 Equipment capacity

With two hundred SL 1.5 MW WTG installed, Fubei has a total installed capacity of 300 MW. Each turbine is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 35 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

Two step-up substations, East and Center step-up substations have been constructed at the site with one 120 MVA — 220/35 kV transformer and two 100 MVA — 220/35 kV transformers equipped with one on-load tap changer. The 35 kV collection lines are connected to the 35 kV bus bar at the substation, and then stepped up to 220 kV via the main transformers. WTG are divided into two groups:

- 74 1.5 MW (111 MW) WTG in one group are connected to the 35 kV bus bar at East area step-up substations, and
- 126 1.5 MW (189 MW) WTG in another group are connected to the 35 kV bus bar at Center step-up substations.

The main transformer is sized at 320 MVA. The size of this transformer will support the full output of the units, which is 300 MW. Therefore, we consider that these transformers are sufficiently rated in order to export the full power from the wind farm to the grid.

East area substation is connected with Center substation by an 11.5 km LGJ-300 220 kV overhead line circuit with a thermal rating of 215.7 MVA. Center substation is connected to the 220 kV Dongliang grid substation via an 50 km LGJ — 400×2 220 kV overhead line circuit with a thermal rating of 644 MVA which is sufficient for the power evacuation from the wind farm to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in the wind farm is 50 kA. Hence the circuit breakers should be able to withstand the fault currents. Appropriate protection schemes have been applied to the wind farm, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.2.2 Reactive power compensation capacity and voltage control capacity

The total capacity of the reactive power compensation device installed at the site is 29.5 MVar. In addition, the transformer is equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore, we would consider the wind farm has sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

6.3.2.3 Local power grid operation

Fubei Wind Farm Phase II is located in west area of Fuxin city in Liaoning province, the end of Northeast China Grid. It is connected to 220 kV Dongliang substation in Fuxin power grid and dispatched by Liaoning Electrical Power Company. Fuxin power grid is located in the end of Liaoning western network. It exports the electricity to the main transmission network in Northeast Grid through 220 kV transmission lines.

As shown in Figure 6.1, electricity consumption exceeds production by more than 20% in Liaoning province. Therefore, the grid connection of Fubei Wind Farm Phase II is a useful complement to electricity consumption. We do not expect curtailments from local dispatch center to happen on Fubei Wind Farm Phase II under the normal situation.

6.3.3 Baolongshan Wind Farm Phase I

6.3.3.1 Equipment capacity

Baolongshan Wind Farm Phase I has thirty-three FD77B 1.5 MW WTG installed with a total capacity of 49.5 MW. Each turbine is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 35 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

A step-up substation has been constructed at the site with two 220/35 kV transformers of 63 MVA and 90 MVA respective capacity. The 35 kV collection lines are connected to the 35 kV bus bar at the substation, and then stepped up to 220 kV via the main transformers.

Two extensions of the wind farm (Phase II and Phase III) of 49.5 MW each have been installed at the same site and shared the 220 kV step-up substation. The main transformers are sized at 153 MVA. The size of these transformers will support the full output of the units, which is 148.5 MW. Therefore, we consider that both transformers are sufficiently rated to export the full power from the wind farm to the grid.

Baolongshan Wind Farm is connected to the 220 kV Baohua substation, via a 220 kV overhead line with the type LGJ-300 and the thermal rating of 353 MVA which is sufficient for the power evacuation from the wind farm to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in the wind farm is 40/31.5 kA. Hence the circuit breakers should be able to withstand the fault currents. Appropriate protection schemes have been applied to the wind farm, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.3.2 Reactive power compensation capacity and voltage control capacity

The total capacity of the reactive power compensation device installed at the site is 40 MVar. In addition, the transformer is equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore, we would consider the wind farm has sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

6.3.3.3 Local power grid operation

Baolongshan Wind Farm Phase I is located near Tongliao city, in the eastern area of Inner Mongolia. It is connected to 220 kV Baohua substation in Tongliao power grid in the eastern Inner Mongolia power grid. However, it is dispatched by Northeast China Grid Company.

Tongliao power grid is located in the Central West part of Northeast China Grid. A main power plant, Tongliao power plant, with an installed capacity of 800 MW provides electricity in order to meet the local demand in Tongliao power grid. It also supplies its remaining generation output to Jilin provincial power grid, one of three provincial power grids in Northeast China Grid.

In winter, many thermal power generators have to be kept in operation in order to supply both electricity and heat in where Baolongshan wind farm is located. As a result, the power output from Baolongshan wind farms may have to be curtailed to some extent due to local power grid’s insufficient capability to adjust active power and the requirement of heat supply by thermal power plants in winter. We understand that the local network should have sufficient capability to accommodate Huaneng Renewables wind power and would expect that this problem could be eliminated in the medium term by future reinforcement of the local network.

6.3.4 Zhurihe Wind Farm 1 Phase III

6.3.4.1 Equipment capacity

Zhurihe Wind Farm 1 Phase III has twenty-four Haizhuang H93 — 2.0 MW WTG installed with a total capacity of 48 MW. Each turbine is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 35 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

A 220 kV step-up substation has been constructed at the site with two 100 MVA — 220/35 kV transformers with an on-load tap changer. The 35 kV collection lines are connected to the 35 kV bus bar at the substation and then stepped up to 220 kV via the main transformers.

Two additional phases (Phase I and Phase II) of 49.5 MW capacity each has been installed at the same site and shared the 220 kV step-up substation. The main transformers are sized at 200 MVA. The size of these transformers will support the full output of the units, which is 147 MW. Therefore, we consider that both transformers are sufficiently rated to export the full power from the wind farm to the grid.

Zhurihe Wind Farm 1 Phase III is connected to the 220 kV Wulijie substation via two 220 kV overhead lines (Kewu overhead line and Wubei transmission line) with total thermal rating of 600 MVA which is sufficient to export all power generated by Zhurihe Wind Farm 1 to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in the wind farm is 50/31.5 kA. Hence the circuit breakers should be able to withstand the fault currents. Appropriate protection schemes have been applied to the wind farm, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.4.2 Reactive power compensation capacity and voltage control capacity

The total capacity of the reactive power compensation device installed at the site is 35 MVar. In addition, the transformer is equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore, we would consider the wind farm has sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

6.3.4.3 Local power grid operation

Zhurihe Wind Farm 1 Phase III is located in Tongliao city in the eastern area of Inner Mongolia. Like Baolongshan Wind Farm, it is also connected to Tongliao power grid in the eastern Inner Mongolia power grid via 220 kV transmission lines. However, it is dispatched by Northeast China Grid Company.

As described previously, in winter, many thermal power generators have to be kept in operation in order to supply both electricity and heat in the area where Zhurihe and Baolongshan wind farms are located. As a result, the power output from Baolongshan wind farms may have to be curtailed to some extent due to local power grid's insufficient capability to adjust active power and the requirement of heat supply by thermal power plants in winter. We understand that the local network should have sufficient capability to accommodate Huaneng Renewables wind power and would expect that this problem could be eliminated in the medium term by future reinforcement of the local network.

6.3.5 Maoming Wind Farm Phase I

6.3.5.1 Equipment capacity

Maoming Wind Farm Phase I has thirty-three Dongfang FD70B 1.5 MW WTG installed with a total capacity of 49.5 MW. Each turbine is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 35 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

A step-up substation has been constructed with one 100 MVA — 220/35 kV transformer with an on-load tap changer. The 35 kV collection lines are connected to the 35 kV bus bar at the substation and then stepped up to 220 kV via the main transformers.

An extension of 49.5 MW total capacity is planned to be built at the same site and will share this 220 kV step-up substation. The main transformer is sized at 100 MVA. The size of the transformer will support the full output of current units, which is 49.5 MW, even the future full output of 99 MW after the commission of Maoming Wind Farm Phase II. Therefore, we consider that the main transformer is sufficiently rated to export the full power from the wind farm to the grid.

Maoming Wind Farm Phase I is connected to the 220 kV Wanghai substation via one 220 kV overhead line with a thermal rating of 250 MVA. We consider that the circuit is sufficient to export all power generated by the wind farm to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in the wind farm is 40/31.5 kA. Hence the circuit breakers should be able to withstand the fault currents. Appropriate protection schemes have been applied to the wind farm, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.5.2 Reactive power compensation capacity and voltage control capacity

The total capacity of the reactive power compensation device installed at the site is 20 MVar. In addition, the transformer is equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore, we would consider the wind farm has sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

6.3.5.3 Local power grid operation

As described in Section 3.4.4, Inner Mongolia Grid Company is an independent provincial Grid Corporation. Maoming Wind Farm is located in Damao, Baotou city in the western area of Inner Mongolia. It is connected to Baotou Power Grid in the western Inner Mongolia power grid via 220 kV transmission line, and hence it is dispatched by Inner Mongolia Grid Company.

Baotou is the load center area where the electricity consumption exceeds production. Therefore, the grid connection of Maoming Wind Farm Phase I is a useful complement to electricity consumption. We do not expect curtailments from local dispatch center to happen on Maoming Wind Farm Phase I under the normal situation.

6.3.6 Niutouling Wind Farm Phase I

6.3.6.1 Equipment capacity

Niutouling Wind Farm Phase I, the first wind farm constructed in Nan'ao Island, is located in Shantou of Guandong province. With eighteen NEG-MICON 750 kW WTGs installed, Niutouling wind farm has a total capacity of 13.5 MW. The WTG is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 10 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

A step-up substation has been constructed with two 31.5 MVA (63 MVA) — 110/10 kV transformers with an on-load tap changer. The 10 kV collection lines are connected to the 10 kV bus bar at the substation, and then stepped up to 110 kV via the main transformer. The main transformer is sized at 63 MVA. The size of the transformer will support the full output of current units, which is 13.5 MW. Therefore, we consider that the main transformer is sufficiently rated to export the full power from Niutouling Wind Farm to the grid.

Niutouling Wind Farm Phase I is connected to Jinniu substation located in Nan'ao power grid via one 110 kV overhead line with maximum capacity of 15 MVA. We consider that the circuit is sufficient to export all power generated by the wind farm to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in Jinniu substation is 31.5 kA. Hence the circuit breakers should be able to withstand the fault currents. Appropriate protection schemes have been applied to Niutouling Wind Farm Phase I, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.6.2 Reactive power compensation capacity and voltage control capacity

The feasibility study report indicates that all WTGs installed in the wind farm have an adjustable power factor between 0.97 leading and 0.97 lagging. There is no information in the grid connection report relating to reactive power compensation scheme. In addition, the transformer is equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Hence, we reviewed that there is no specific reactive power compensation equipment required at Niutouling Wind Farm and consider that there are sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

6.3.6.3 Local power grid operation

Niutouling Wind Farm Phase I is located in Nan'ao Island in Shantou of Guangdong province. It is connected to Shantou power grid via 110 kV line and dispatched by Shantou power dispatch and communication center.

Since Shantou is the load center area where the electricity consumption exceeds production by more than 20%, the grid connection of Niutouling Wind Farm Phase I is a useful complement to electricity consumption. We do not expect curtailment from the local dispatch center to be required at Niutouling Wind Farm Phase I under normal conditions.

6.3.7 Qing'ao Wind Farm

6.3.7.1 Equipment capacity

Qing'ao Wind Farm Phase II located in the East part of Nan'ao Island in Shantou, in Guandong province, has fifty-three V52-850 kW installed with a total capacity of 45.05 MW. Each WTG is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 35 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

A 110 kV step-up substation at Qing'ao wind farm Phase II has been constructed with one 50 MVA — 110/35 kV transformer with an on-load tap changer. The 35 kV collection lines are connected to the 35 kV bus bar at the substation and then stepped up to 110 kV via the main transformer. The main transformer sized at 50 MVA will support the full output of current units, which is 45.05 MW. Therefore, we consider that the main transformer is sufficiently rated to export the full power from the wind farm to the grid.

Qing'ao Wind Farm Phase II is connected to Jinniu substation located in Nan'ao power grid via one LGJ-400 110 kV overhead line with the type LGJ — 400 and maximum capacity of 100 MVA. We consider that the circuit is sufficient to export all power generated by the wind farm to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in Qing'ao wind farm is 28.4/23.7 kA. Hence the circuit breakers should be able to withstand the fault currents. Appropriate protection schemes have been applied to the wind farm, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.7.2 Reactive power compensation capacity and voltage control capacity

The feasibility study report indicates that all WTG installed in the wind farm have an adjustable power factor between 0.95 leading and 0.95 lagging. The total capacity of the reactive power compensation device installed at the site is 12 MVar. In addition, the transformer is equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore, we would consider the wind farm has sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

6.3.7.3 Local power grid operation

Qing'ao Wind Farm Phase II is located in Nan'ao Island in Shantou of Guangdong province. It is connected to Shantou power grid via 110 kV line and dispatched by Shantou power dispatch and communication center.

Shantou is the load center area where the electricity consumption exceeds production by more than 20%. Therefore, the grid connection of Qing'ao Wind Farm Phase II is a useful complement to electricity consumption. We do not expect curtailment from the local dispatch center to be required at Qing'ao Wind Farm Phase II under normal conditions.

6.3.8 Dali Dafengba Wind Farm

6.3.8.1 Equipment capacity

With sixty-four WD50/750 kW installed WTGs, Dali Dafengba Wind Farm located in Dali of Yunnan province has a total capacity of 48 MW. Each turbine is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 35 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

One 110 kV step-up substation has been constructed at the site with one 63 MVA — 110/35 kV transformer with an on-load tap changer. The 35 kV collection lines are connected to the 35 kV bus bar at the substation and then stepped up to 110 kV via the main transformer. The size of the transformer at 63 MVA will support the full output of current units, which is 48 MW. Therefore, we consider that the main transformer is sufficiently rated to export the full power from the wind farm to the grid.

A nearby wind farm, Zhemoshan wind farm with a total capacity of 30.75 MW is connected to Dafengba Wind Farm via one 110 kV overhead line. Dali Dafengba Wind Farm is connected to the 110 kV Xinqiwu substation in Dali power grid via one 5.34 km LGJ-240/30 110 kV overhead line. The maximum capacity of these lines is 108 MVA. We consider that the circuit is sufficient to export all power generated by the wind farm to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in Jinniu substation is 31.5 kA. Appropriate protection schemes have been applied to the wind farm, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.8.2 Reactive power compensation capacity and voltage control capacity

The total installed reactive power compensation capacity in Dafengba wind farm consists of +/- 12 MVar shunt capacitor banks and 14.848 MVar shunt reactor group. In addition, the transformer is equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore, we would consider the wind farm has sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code

6.3.8.3 Local power grid operation

Dali Dafengba Wind Farm is located in Dali of Yunnan province. It is connected to Dali power grid where most of the power plants are hydro power stations. In dry season, the local power grid lacks of electrical power supply. Thus, all power generated by Dali Dafengba Wind Farm will be supplied to the grid in order to meet the local demand. However, during the high-season for hydropower generation, in summer, the wind power will be exported to the main transmission grid of Yunnan power grid for provincial or national use.

Yunnan province has the biggest hydro resources in China. Its generation output will be transferred to load Center in South China through the nation's West-to-East power transmission lines. Currently, there are eight AC and five DC transmission lines from West to East with the total installed transmission capacity of 23 GW. The annual electricity transmission reached 115.6 TWh in 2009. Therefore, we consider that the generation output from Dali Dafengba Wind Farm can be evacuated to the power grid properly.

6.3.9 Changdao Wind Farm

6.3.9.1 Equipment capacity

With thirty-two G52-850 kW WTG installed, Changdao Wind Farm located near Yantai city in Shandong province has a total capacity of 27.2 MW. Each turbine is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 35 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

One step-up substation has been constructed at the site with one 31.5 MVA — 110/35 kV transformer with an on-load tap changer. The 35 kV collection lines are connected to the 35 kV bus bar at the substation and then stepped up to 110 kV via the main transformer. The size of the transformer at 31.5 MVA will support the full output of current units, which is 27.2 MW. Therefore, we consider that the main transformer is sufficiently rated to export the full power from the wind farm to the grid.

Changdao Wind Farm is connected to the 110 kV Changshan substation in Yantai power grid via one 2 km YJLW03-64/110 KV cable line with a maximum capacity of 72 MVA. Therefore, we consider that the circuit is sufficient to export all power generated by the wind farm to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in the wind farm is 40 kA. Hence the circuit breakers should be able to withstand the fault currents. Appropriate protection schemes have been applied to the wind farm, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.9.2 Reactive power compensation capacity and voltage control capacity

Since there is no information in the grid connection report and the grid connection agreement relating to reactive power compensation scheme, there is no reactive power compensation equipment installed at Changdao Wind Farm. However, all wind turbines at the site have controllable power factors at grid connection point as required in Grid Code. In addition, all the main transformers are equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore, we would consider the wind farm has sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

6.3.9.3 Local power grid operation

Changdao Wind Farm is located in the island of Changdao area in Yantai city in Shandong province. It is connected to Yantai Power Grid in Shangdong power grid via 110 kV transmission line and it is dispatched by Yantai Power Supply Company.

The demand of Changdao County is primarily supplied from Penglai power grid part of Yantai power grid via 110 kV submarine cables. The standby capacity in Changdao Island is partially covered by diesel power generators. Therefore, the power output from Changdao Wind Farm can compensate the shortage of electricity in the island and we do not expect any curtailment from Yantai power dispatch center to happen on Changdao Wind Farm Phase I under the normal situation.

6.3.10 Weihai Wind Farm Phase I and Rongcheng Wind Farm

6.3.10.1 Equipment capacity

With thirteen SL 1.5 MW WTG installed, Weihai Wind Farm Phase I located in Rongcheng area of Weihai City in Shangdong province has a total capacity of 19.5 MW. Each turbine is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 35 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

One 110 kV step-up substation has been constructed at the site with one 75 MVA — 110/35 kV transformer with an on-load tap changer. The 35 kV collection lines are connected to the 35 kV bus bar at the substation and then stepped up to 110 kV via the main transformer.

Weihai Wind Farm Phase II has been constructed and operated with a total capacity of 49.5 MW. In addition, with two 3 MW WTG installed, Rongcheng Wind Farm has a total capacity of 6 MW. WTG 1 and WTG 2 are respectively connected to 35 kV side of WTG 23 35 kV/690 V transformer and WTG 2 35 kV/690 V transformer in Weihai Wind Farm via 35kV cable. Then, these 35 kV collection lines are connected to the 35 kV bus bar at Weihai Wind Farm step up substation. After connecting Rongcheng 6 MW WTGs, the total capacity connected to Weihai step-up substation has reached 75 MW.

The size of the transformer at 75 MVA will only just support the full output of current units, which is 75 MW. Therefore, we consider that it is likely that the transformer will be overloaded when all WTG of Weihai (installed capacity 69 MW) and Rongcheng (installed capacity 6 MW) will simultaneously produce at their nominal power range; indeed it is possible for WTGs to produce power at a higher level than the nominal power rating. As a result, WTGs from these wind farms may be curtailed during periods of high output, depending on the grid power factor at the time. However, we understand from Huaneng Renewables that the grid power factor is normally maintained at 1, which would avoid the need for curtailment, but there is no commitment to this effect in the Grid Code, which governs grid operation. In addition, we have received the further information from Huaneng Renewables that a new step-up substation will be constructed at Rongcheng Wind Farm and then the two 3 MW WTGs of Rongcheng wind farm will be connected to the new substation.

Weihai Wind Farm is connected to the 110 kV Gangzhong substation in Weihai power grid via one 5.88 km LGJ-240/30 110 kV overhead line. The maximum capacity of this line is 100 MVA which is above the requirements. Therefore, we consider that the circuit is sufficient to export all power generated by the wind farm to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in the wind farm is twenty times of rating currents. Hence the circuit breakers should be able to withstand the fault currents. Appropriate protection schemes have been applied to the wind farm, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.10.2 Reactive power compensation capacity and voltage control

Since there is no information in the grid connection report and the grid connection agreement relating to reactive power compensation scheme, there are no reactive power compensation equipment installed at Weihai and Rongcheng Wind Farms. However, all wind turbines at the site have controllable power factors at grid connection point as required in Grid Code. In addition, all the main transformers are equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore, we would consider the wind farms have sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

6.3.10.3 Local power grid operation

Weihai and Rongcheng Wind Farms are located in Rongcheng area of Weihai city, in Shandong province. Both sites are connected into the Rongcheng 110 kV distribution network, the east part of Weihai power grid via 110 kV transmission line and it is dispatched by Weihai Power Supply Company.

With the local economic development, the load demand in Rongcheng has been increasing recently, exceeding the electricity production. Therefore, the power output from Weihai wind farm and Rongcheng wind farm can compensate the shortage of electricity in Rongcheng area and we do not expect any curtailment from Weihai power dispatch center to happen on Weihai and Rongcheng Wind Farms under the normal situation.

6.3.11 Changyi Wind Farm

6.3.11.1 Equipment capacity

With thirty-three Suzlon S82 1.5 MW WTG installed, Changyi Wind Farm Phase I located in Changyi area of Weifang city in Shangdong province has a total capacity of 49.5 MW. Each turbine is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 35 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

One 110 kV step-up substation has been constructed at the site with one 63 MVA — 110/35 kV transformer with an on-load tap changer. The 35 kV collection lines are connected to the 35 kV bus bar at the substation and then stepped up to 110 kV via the main transformer. The size of the transformer at 63 MVA will support the full output of current units, which is 49.5 MW. Therefore, we consider that the main transformer is sufficiently rated to export the full power from the wind farm to the grid.

Changyi Wind Farm is connected to the 110 kV Daxing substation in Weifang power grid via one 11.8 km LGJ-300110 kV overhead line. The maximum capacity of this line is 100 MVA. We consider that the circuit is sufficient to export all power generated by the wind farm to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in the wind farm is 40/31.5 kA. Hence the circuit breakers should be able to withstand the fault currents. Appropriate protection schemes have been applied to the wind farm, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.11.2 Reactive power compensation capacity and voltage control capacity

Since there is no information in the grid connection report and the grid connection agreement relating to reactive power compensation scheme, there is no reactive power compensation equipment installed at Changyi Wind Farm. However, all wind turbines at the site have controllable power factors at grid connection point as required in Grid Code. In addition, all the main transformers are equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore, we would consider the wind farm has sufficient reactive capacity and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

6.3.11.3 Local power grid operation

Changyi Wind Farm is located in Changyi area of Weifang city, in Shandong province. It is connected into Weifang power grid via 110 kV overhead line and it is dispatched by Weifang Power Supply Company.

With the local economic development, the load demand in Changyi has been increasing recently, exceeding the electricity production. Therefore, the power output from Changyi Wind Farm can compensate the shortage of electricity in Changyi area and we do not expect any curtailment from Weifang power dispatch center to happen on Changyi Wind Farm under the normal situation.

6.3.12 Laoting Wind Farm

6.3.12.1 Equipment capacity

With thirty-three SL 1.5 MW WTG installed, Laoting wind farm Phase I located in Laoting area of Tangshan city in Hebei province has a total capacity of 49.5 MW. Each turbine is connected to a WTG step-up transformer via underground cables. These cables are rated appropriately in order to carry maximum output from each individual turbine. Then these turbines are connected to their own 35 kV collection trunk line circuits. These circuits consist of overhead line connection only, and are rated appropriately to carry the maximum output from the wind turbines.

One 110 kV step-up substation has been constructed at the site with one 50 MVA — 110/35 kV transformer with an on-load tap changer. The 35 kV collection lines are connected to the 35 kV bus bar at the substation and then stepped up to 110 kV via the main transformer. The size of the transformer at 50 MVA will support the full output of current units, which is 49.5 MW. Therefore, we consider that the main transformer is sufficiently rated to export the full power from the wind farm to the grid.

Laoting wind farm is connected to the 110 kV side at 220kV Jinyintan substation in Tangshan power grid via one 20 km LGJ-400 110 kV overhead line. The maximum capacity of this line is 167 MVA. We consider that the circuit is sufficient to export all power generated by the wind farm to the grid. According to the last version of Chinese Grid Code (Trial) published in 2006, it is not required to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point. In the updated version of Chinese Grid Code (Revision) published in December 2009, there is no relevant requirement for the wind farm to meet the 'N-1' security criteria for the transmission network from the wind farm substation to the grid connection point.

The fault withstanding capability for switchgear installed in the wind farm is 31.5 kA. Hence the circuit breakers should be able to withstand the fault currents. Appropriate protection schemes have been applied to the wind farm, including differential protection and over-current protection, which seem to be the common practice for most Chinese wind farms. Lightning protection equipment have been installed to prevent lightning impact on the wind farm equipment. No significant issues have been raised regarding the equipment condition.

6.3.12.2 Reactive power compensation capacity and voltage control capacity

The total capacity of the reactive power compensation device installed at the site is 10 MVar. In addition, the transformer is equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the HV winding. Therefore we consider the reactive power compensation installed in the wind farm is sufficient to comply with the grid code.

6.3.12.3 Local power grid operation

Laoting Wind Farm is located in Laoting area of Tangshan city, in Hebei province. It is connected into Tangshan power grid via 110 kV overhead line and it is dispatched by Tangshan Power Supply Company.

As shown in Figure 6.1 Hebei is part of the load center where the electricity consumption exceeds the production by more than 20%. With the local economic development, the load demand in Laoting has been increasing recently, exceeding the electricity production. Therefore, the power output from Laoting Wind Farm can compensate the shortage of electricity in Laoting area and we do not expect any curtailment from Tangshan power dispatch center to be required at Laoting Wind Farm under normal conditions.

6.4 Conclusions

The transformers at most wind farm step-up substations are appropriately sized and have sufficient capacity to export the maximum power under normal operation scenarios. However, it has been noted that the size of the 75 MVA main transformer at Weihai Wind Farm step-up substation will only just support the full output of the current units in Weihai and Rongcheng Wind Farms which are rated at 75 MW. Therefore, we consider that it is likely that the transformer will be overloaded when all WTGs of Weihai (installed capacity 69 MW) and Rongcheng (installed capacity 6 MW) simultaneously produce at their nominal full capacity; indeed it is possible for WTGs to produce power at a higher level than the nominal power rating. As a result, WTGs from these wind farms may be curtailed during periods of high output, depending on the grid power factor at the time. However, we understand from Huaneng Renewables that the grid power factor is normally maintained at one, which would avoid the need for curtailment. However, the Grid Code, which governs grid operation, does not state that a power factor of one will be maintained. In addition, we have received further information from Huaneng Renewables that a new step-up substation will be constructed at Rongcheng Wind Farm and the two 3 MW WTGs from Rongcheng wind farm will be connected to the new substation.

It appears that all overhead/cable lines are rated appropriately to export full capacity of the wind farms to the grid. All wind farms visited are connected to the grid substation via a single line connection. According to the last version of Chinese Grid Code (Trial) of wind farm grid connection published in 2006, in order to facilitate operation management and control, and to simplify system topology, it is not required to meet the ‘N-1’ security criteria for the transmission network between the wind farm substation and the grid connection point. In the updated version of Chinese Grid Code (Revision) of wind farm grid connection published in December 2009 there is no relevant requirement for the wind farm to meet the ‘N-1’ security criteria for the transmission network between the wind farm substation and the grid connection point.

All the representative wind farms have appropriate switchgear installed to withstand fault current at both the wind farm step-up substations and the grid connection substations. No issue regarding switchgear rating has been identified at any of the representative wind farms. Appropriate protection schemes have been applied to all wind farms, including differential and over-current protection, which seems to be the common practice for most Chinese wind farms. Lightning protection equipment has also been installed to prevent lightning damage to the wind farm equipment. No significant issues have been raised regarding the equipment condition.

All wind turbines have controllable power factors at grid connection point as required in the Chinese Grid Code. Most wind farms have reactive power compensation equipment installed to provide reactive power support as required by the grid connection study report. Since there is no requirement to consider the installation of reactive power compensation equipment on the grid connection, there are no reactive power compensation equipment installed at Changdao, Weihai, Rongcheng and Changyi Wind Farms. In addition, all the main transformers are equipped with an on-load tap changer which is able to control voltage between 90% and 110% at the High Voltage winding. Therefore, we would consider that the wind farms have sufficient reactive and voltage control capacity to meet the reactive power demand and voltage regulation as required in the grid code.

The updated Chinese Grid Code (Revision) of wind farm grid connection requires an assessment of the power quality and low voltage ride through (LVRT) to ensure that the relevant indices are within the given limits and in accordance with technical standards. The relevant tests are required to be finished before the wind farm is connected to the grid, as most existing Chinese wind projects, including the twelve representative wind farms, will be required to be technically upgraded so that they can meet relevant requirement in the updated Chinese Grid Code in the near future.

Most of the local power grids have sufficient capability to accommodate the connection of the wind farms so that they will be able to operate during normal conditions and export the generated power to the grid as expected. However, it is noted that in Baolongshan and Zhurihe Wind Farm 1, the power generation may have to be curtailed to some extent due to local power grid's insufficient capability to adjust active power and the requirement of heat supply using thermal power plants in winter. We understand that the local network should have sufficient capability to accommodate Huaneng Renewables wind power and we would expect that this problem could be solved by future reinforcement of the local network.

In general, we consider the grid connection of Huaneng Renewables wind power projects to be well-planned, without any major constraints found to prevent power export under normal system operating conditions. The only exception is when the local power system operates under specific scenarios, like Tongliao power system in winter. However, it is likely that such a situation can be eliminated in the medium term by future network reinforcement.

7. Performance of the Wind Farms

7.1 Definition of Availability

Availability ratio of the WTGs, as defined in the "Assessment Code of Wind Power Equipment Reliability" issued by China Electricity Council (CEC), is calculated according the following formula:

$$\text{Availability Factor} = \frac{AH}{PH} \text{ X } 100\%$$

AH: Available Hours means the hours when the WTG is considered as available to produce power; PH: Physical Hours means the total hours during the availability measurement period.

The Available Hours are defined as being applied when the wind turbines are in their prearranged status, without consideration of the actual power output. All outages due to conditions unrelated to the wind turbines such as wind speed being too high, grid outages, etc, are not covered according to this definition. This is not the internationally recognized standard methodology for calculating the availability of a wind farm. The definition presented above corresponds to the average availability of the wind turbines, excluding sources of downtime unrelated to the wind turbine reliability; however we understand that it is the normal calculation method used within the Chinese wind power sector. Huaneng Renewables followed this method to calculate and assess the performance of the WTGs in its wind farms as would all other Chinese developers and producers.

The internationally recognized methodology for calculating the availability of a wind farm is to multiply the average of all WTG availabilities with the availability of the grid. Huaneng Renewables collects the average availability of all wind turbines as for the whole wind farm from its staff on each site. Then, it uses the data gathered to assess the performance, and operation and maintenance of each wind farm. The average monthly availabilities for all the operational wind farms visited, is reported to be higher than the 95% guaranteed by the WTG manufacturers.

7.2 Wind Farms Performance — Generation and Availability

7.2.1 Fubei Wind Farm Phase II

Fubei Wind Farm Phase II is located in Fuxingdi town and Jiumiaoxiang, in the northwest part of Fuxin city, Liaoning province in Northeast China. Fuxin Wind Farms consist of three phases:

- Fuxin Gaoshanzi Wind Farm Phase I (100.5 MW, operational since October 2008)
- Fuxin Fubei Wind Farm Phase II (300 MW, operational since 1st October 2009)
- Fuxin Zhangbei Wind Farm Phase III (100.5 MW, operational since April 2010)

All Phases are owned and operated by Huaneng Fuxin Wind Power Generation Co. Ltd. Under our scope of work, we only assessed the performance of Fubei Wind Farm — Phase II.

7.2.1.1 Generation and Availability

Fubei Wind Farm Phase II with two hundred SL 1.5 MW WTG installed is constructed on relatively flat scrub/desert land which varies in altitude from 400m to 500m ASL (Above Sea Level). The terrain does not present any concerns regarding shading, channeling or excessive gradient which could cause adverse wind conditions; such as severe wind shear, inflow angles, or turbulence. The site does not seem to present any operational concern.

A control building is located near the step-up substation of the wind farm. This building includes the control center, offices, spare parts store, switchgear housing, and other site facilities. Huaneng Fuxin Wind Power Generation Co. Ltd. employs one wind farm manager and twelve operational personnel, deployed in two teams of six people. The building and facilities are of a high standard and appear to be well-maintained.

Site roads are in good condition and we do not expect any access issue during the winter period. When we visited the site in April 2010, we were able to visit the control building, site facilities and wind turbines.

Sinovel is a well-established Chinese wind turbine manufacturer with a good track record in China. No significant technical issues have been reported since the wind farm was commissioned in October 2009.

Wind resource data at the sites was recorded from two met masts installed on site by the Fuxin Bureau of Meteorology before the construction period began. However, the wind data measured by the sensors on these masts has not been used to monitor records during the operational period after construction started. During the operational period, Huaneng Renewables monitors wind speed through new, permanent met masts installed in May 2010; and the anemometers on the nacelles of the WTGs.

Currently, the WTGs are covered by a manufacturer's warranty; which guarantees the turbine availability at 95%. The warranty period is for two years. The average wind speed at hub height (70 m) has been calculated to be 7.2 m/s and the net capacity factor for Phase II is calculated to be 25%; this is reasonable for an onshore wind farm. The production, wind, and availability data provided by Huaneng Renewables shows that there is an average availability of 99.50% since commissioning in October 2009 (listed in Table 7.1). All monthly availabilities are above the 95% guaranteed value. In 2009, the power generation from the site was 62,458 MWh in October, 83,621 MWh in November and 75,903 MWh in December. There has been insufficient data since commissioning took place in October 2009 (that is at least 12 month of normal operational data) we are therefore unable to comment on wind farm performance.

Table 7.1: Operational Data of Fubei Phase II

Year	Month	Average availability	Total generation (MWh)	Equivalent Full Load Hours	Capacity Factor	Average Wind Speed at 70 m (m/s)
2009	12	99.52%	75,903	253.01	35.14%	5.69
2009	11	99.63%	83,621	278.74	38.71%	5.89
2009	10	99.34%	62,458	208.19	28.89%	5.13

7.2.1.2 Conclusions

Fubei Wind Farm's equipment was supplied by well-known manufacturer by the industry; that employs proven technologies or has credible track records within the market. We are of the view that the turbine technologies are in accordance with current industry standards, and the sites were built to a high standard. O&M is well-managed due to the experience that Huaneng Renewables gained at Fuxin Gaoshanzhi Wind Farm (Phase I). Since commissioning was completed in October 2009, there was insufficient data (at least 12 month of normal operational data) available to comment on wind farm performance.

7.2.2 Baolongshan Wind Farm Phase I

Baolongshan Wind Farm (Phase I) is located in Baolongshan town, Tongliao city in Inner Mongolia. Baolongshan Wind Farms consist of the following three phases:

- Baolongshan Wind Farm Phase I (49.5 MW, operational since July 2009)
- Baolongshan Wind Farm Phase II (49.5 MW, commissioned in February 2009)
- Baolongshan Wind Farm Phase III (49.5 MW, commissioned in April 2009)

These wind farms are owned and operated by Huaneng Tongliao Wind Power Generation Co. Ltd. As per our scope of work, we only assessed the performance of Baolongshan wind farm Phase I.

7.2.2.1 Generation and Availability

Baolongshan Wind Farm (Phase I) with thirty-three FD77B 1.5 MW WTG installed is built on a flat grassland with an altitude of approximately 155m ASL. The terrain does not present any concerns regarding shading, channeling or excessive gradient which could cause adverse wind conditions, such as severe wind shear, inflow angles, or turbulence. Sand storms are common in the area and the climate is very cold, resulting in long periods of subzero temperatures.

A control building is located near the step-up substation of the wind farm. This building includes the control center, offices, spare parts store, switchgear housing, and other site facilities. Huaneng Baolongshan Wind Power Generation Co. Ltd. employs one wind farm manager and fifteen operational personnel, deployed in three teams of five people. The building and facilities are of a high standard and appear to be well-maintained.

The access roads on site are rough. When we went to the site in April 2010, we were able to visit the control building, site facilities and wind turbines.

Baolongshan Wind Farm Phase I used two permanent met masts on site to monitor the wind resources at the sites before construction. The wind data measured by the anemometers on the WTGs and the permanent met mast, left after construction, are used to monitor the wind during the operational period.

Currently the WTGs are covered by a manufacturer's warranty which guarantees the WTG availability at 95%. The warranty period is for two years. The average wind speed at hub height (70 m) has been calculated to be 7.5 m/s and the net capacity factor for Phase I is calculated to be 25%; which is reasonable for an onshore wind farm. According to the production, wind, and availability data provided by Huaneng Renewables and listed in Table 7.2, the wind farm has shown an average availability of 98.14% since July 2009. All monthly availabilities are above the 95% guaranteed value. In 2009, the total power generation from July to December was 47,207.6 MWh. In 2010, the total power generation from January to April was 37,453.4 MWh. There has been insufficient data (less than 12 months of normal operation data) since commissioning took place in July 2009. Therefore, we are unable to comment on wind farm performance.

Table 7.2: Operational Data of Baolongshan Phase I

Year	Month	Average availability	Total generation (MWh)	Equivalent Full Load Hours	Capacity Factor
2010	1-4	98.02%	37,453.4	756.63	26.27%
2009	7-12	98.14%	47,207.6	953.69	21.6%

7.2.2.2 Conclusions

Equipment at Baolongshan Wind Farm was supplied by manufacturers well-known by the industry; that employs proven technologies or has credible track records within the market. We are of the view that the turbine technologies are in accordance with current industry standards, and the sites were built to a high standard. O&M is well-managed. Since commissioning was completed in July 2009, there was insufficient data (at least 12 month of normal operational data) available to comment on wind farm performance.

7.2.3 Zhurihe Wind Farm 1 Phase III

Zhurihe Wind Farm (Phase III) is located in west of Kezuozhongqi, 80 km far from Tongliao city in Inner Mongolia. Zhurihe Wind Farms consist of the following three phases:

- Zhurihe Wind Farm 1 Phase I (49.5 MW, commissioned in November 2009)
- Zhurihe Wind Farm 1 Phase II (49.5 MW, commissioned in December 2009)
- Zhurihe Wind Farm 1 Phase III (48 MW, operated on 1 April 2010)

All three phases are owned and operated by Huaneng Tongliao Wind Power Generation Co. Ltd. As per our scope of works, we only assessed the performance of Zhurihe Wind Farm 1 Phase III.

7.2.3.1 Generation and Availability

Zhurihe Wind Farm 1 (Phase III) with twenty-four Haizhuang H93 — 2.0 MW WTG installed is built on a relatively flat grass land which varies in altitude from 190 m to 210m ASL. The terrain is simple and does not present any concerns regarding shading, channeling or excessive gradient which could cause adverse wind conditions, such as severe wind shear, inflow angles, or turbulence. Sand storms are common in the area and the climate is very cold, resulting in long periods of subzero temperatures.

A control building is located near the step-up substation of the wind farm. This building includes the control center, offices, spare parts store, switchgear housing, and other site facilities. Huaneng Baolongshan

Wind Power Generation Co., Ltd. employs one wind farm manager and twelve operational personnel, deployed in three teams of four people. The building and facilities are of a high standard and appear to be well-maintained.

The access roads on site are rough. When we went to site in April 2010, we were able to visit the control building, site facilities and wind turbines.

Zhurihe Wind Farm 1 Phase III used four permanent met masts on site to monitor the wind resources at the sites before construction. The wind data measured by the anemometers on the WTGs and the permanent met masts are used to monitor the wind during the operational period. We have been provided with the wind resources data measured since 1 January 2010.

Currently the WTGs are covered by a manufacturer's warranty which guarantees the turbine availability at 95%. The warranty period is two years. The average wind speed at hub height (70 m) has been calculated to be 7.39 m/s and the net capacity factor for Phase II is calculated to be 25%; this is reasonable for an onshore wind farm. Production and wind data have been provided by Huaneng Renewables and are listed in Table 7.3. Since the operational period of the wind farm started in April 2010, the operational data, including monthly production and availability, was only available for April 2010.

Table 7.3: Operational Data of Zhurihe Wind Farm 1 Phase III

Year	Month	Average availability	Total generation (MWh)	Average Wind Speed at 70 m (m/s)
2010	4	98.91%	604.53	6.8

7.2.3.2 Conclusions

Zhurihe Wind Farm 1 Phase III's equipment was supplied by manufacturer well-known in the industry that employs proven technologies or has credible track records within the market. We are of the view that the turbine technologies are in accordance with current industrial standards, and the sites were built to a high standard. O&M is well-managed due to the experience Huaneng Renewables gained at Zhurihe Wind Farm 1 (Phase I and II) projects. Since commissioning was completed in April 2010, there has been insufficient data (at least 12 months of normal operational data) available to allow us to comment on wind farm performance.

7.2.4 Maoming Wind Farm Phase I

Maoming Wind Farm (Phase I) is located in Damao, Baotou city in Inner Mongolia. Maoming Wind Farms consist of the following two phases:

- Maoming Wind Farm Phase I (49.5 MW, operated in February 2010)
- Maoming Wind Farm Phase II (49.5 MW, to be constructed)

7.2.4.1 Generation and Availability

Maoming Wind Farm (Phase I) with thirty-three Dongfang FD70B 1.5 MW WTG installed is located in Damao of Baotou city in Inner Mongolia. It is built on flat scrub/desert land which is at an altitude of approximately 1,600 m ASL. The terrain does not present any concerns regarding shading, channeling or excessive gradient which could cause adverse wind conditions, such as severe wind shear, inflow angles, or turbulence. Sand storms are common in the area and the climate is very cold, resulting in long periods of subzero temperatures.

A control building is located near the step-up substation of the wind farm. This building includes the control center, offices, spare parts store, switchgear housing, and other site facilities. Huaneng Renewables employs one wind farm manager and eight operational personnel, deployed in two teams of four people. The building and facilities are of a high standard and appear to be well-maintained.

The access roads on site are rough. When we went to site in April 2010, we were able to visit the control building, site facilities and wind turbines.

Maoming Wind Farm Phase I used four permanent met masts on site to monitor the wind resources before construction. The wind data measured by the anemometers on the WTGs and the permanent met masts is used to monitor the wind during the operational period. We have been provided with the wind resources data since 01 January 2010.

Currently the WTGs are covered by a manufacturer's warranty which guarantees the turbine availability at 95%. The average wind speed at hub height (70 m) has been calculated to be 7.8 m/s and the net capacity factor for Phase I is calculated to be 25.0% which is typical for an onshore wind farm. Production and wind data from February to April in 2010 have been provided by Huaneng Renewables, as shown in Table 7.4. Since the wind farm has only been operational since February 2010, the operational data, including monthly production and availability, are only available from February to April 2010. Operational data during the commissioning period was heavily influenced by commissioning activities and standard teething issues. Thus, it may not be a good indicator of future performance.

Table 7.4: Operational Data of Maoming Wind Farm Phase I

Year	Month	Average availability	Total generation (MWh)	Average Wind Speed at 70 m (m/s)
2010	4	96.10%	14,371.90	9.04
2010	3	92.02%	11,156.30	9.50
2010	2	95.27%	8,427.30	8.04

7.2.4.2 Conclusions

The equipment used at Maoming Wind Farm I was supplied by manufacturer well-known to the industry that employs proven technologies or has credible track records within the market. We are of the view that the turbine technologies are in accordance with current industry standards, and the site was built to a high standard. O&M is well-managed. Since commissioning was completed in February 2010, there was insufficient data (at least 12 month normal operational data) available to allow us to comment on wind farm performance.

7.2.5 Niutouling Wind Farm Phase I

Niutouling Wind Farm Phase I is a 13.5 MW Wind Farm consist of 18 NEG-MICON 750 kW wind turbines, located in very complex terrain on Nan'ao Island near Shantou, Guangdong Province, approximately 12 miles east from the Shantou coast. The project began commercial operation in 2000. Niutouling Wind Farm Phase I was originally a demonstration project, and then became Phase I of Huaneng Renewables Nan'ao Wind Farm. The project was developed by Shantou Grid Company and is co-owned by Huaneng Renewables and the Shantou Grid Company.

Nan'ao Island has many wind farms owned by different utility companies. The island experiences winds prevailing from the north east. The site is located on hill tops. The landscape is rural and the wind farms are surrounded by fisheries, a port and tourist areas.

Niutouling Wind Farm Phase I's layout comprises of a single row of WTGs situated along one of the most exposed ridges on the island. The layout was designed by Guangdong Electrical Design Institute. Huaneng Renewables has a control building with permanent staff for monitoring and O&M activities at the wind farm. The site facilities include connector cables, an office building with a control room, meeting rooms, spare parts storage and workers' accommodation. Nan'ao Island experiences typhoons. Niutouling has experienced wind speeds up to 51 m/s (design max wind speed of turbine is 60m/s) during the operational period since 2000. In our view, the facilities and building on site appear well-maintained and well organized. This wind farm is the first wind farm Huaneng Renewables commissioned. This wind farm is also the training center of O&M for Huaneng Renewables and other domestic power producers.

Phase III is currently under construction. It was noted during our site visit that some of the phase III's turbine positions encroach on the Niutouling site and we expect that they may impact slightly on future performance of affected WTGs in phase I. It is reported that this impact has been taken into consideration when designing phase III.

7.2.5.1 Generation and Availability

The preconstruction wind resource assessment was carried out by the Guangdong Electrical Design Institute in 1998 using wind data from a meteorological station; which has been on Nan'ao Island since 1957. Huaneng Renewables installed ten met masts around the island to monitor the wind resources at the sites before construction. However, all ten masts have been now dismantled. Huaneng Renewables monitors the wind speed through the anemometers on turbine nacelles throughout the operational period. We have been provided the wind resources data measured from the masts. Huaneng Renewables has recently installed a permanent met mast on site to record future wind speeds.

The preconstruction energy yield calculations were made for a 660 kW WTG and are therefore not consistent with the constructed wind farm. The power curve for an unknown 660 kW wind turbine has been used in conjunction with WAsP software to calculate a gross yield and wake reduction. The accuracy of this method is compromised by complex terrain and we consider that there is uncertainty in these results. A series of losses totalling 25% was applied to calculate the predicted net yield of 34,835 MWh/year. We have identified significant discrepancies in the production of this figure and consider it unreliable.

Achieved production records are a much better indicator of future performance. We have been provided with the recorded production since 2001 which shows that the average capacity factor achieved is 27.5%; which is in line with our expectations.

Data provided by Huaneng Renewables shows that the wind farm has a good average availability of 98.94% since 2008 as listed in Table 7.5, and are all above the 95% guaranteed value. The availability data from 2000 to 2006 cannot be found by Huaneng Renewables.

Table 7.5: Operational Data of Niutouling Wind Farm Phase I

Date	Average availability	Total generation (MWh)	Equivalent Full Load Hours	Capacity Factor	Average Wind Speed at 60 m (m/s)
Jan-Mar 2010	99.9%	10217	757	35.04%	6.46
2009	99.3%	32,942	2,444	27.9%	6.71
2008	98.6%	34,493	2,558	29.2%	6.81
2007	99.0%	33,768	2,505	28.6%	
2006		33,281	2,462	28.1%	
2005		29,200	2,164	24.7%	
2004		31,277	2,313	26.4%	
2003		32,853	2,435	27.8%	
2002		30,477	2,258	25.8%	
2001		34,036	2,523	28.8%	

7.2.5.2 Conclusions

Niutouling began as a demonstration project; constructed and commissioned by a local construction company and the grid company in 2000. The grid company is a project shareholder and is the power off-taker. The project has been operational since 2001 and has been used to train operators for other wind farms. The reported availability is high. Records for the entire operational period could not be made available and are reported to have been lost. The recorded production for the operational period is consistent and meets our expectations following our analysis of the site and wind conditions.

7.2.6 Qing'ao Wind Farm phase II

Qing'ao is a 45 MW Wind Farm consisting of 53 Vestas V52-850 kW WTGs, located in very complex terrain and in a saline environment on Nan'ao Island near Shantou, Guangdong Province, southeast coast of China facing the South Sea. The project was developed and is co-owned by Huaneng Renewables and the Shantou Grid Company. The project began commercial operation in 2007 and forms Phase II of Huaneng Renewables Nan'ao Wind Farm.

Nan'ao Island has many wind farms owned by different utility companies. The island experiences onshore winds, prevailing from the south east. The site is located on the top of the hills in a coastal area. The landscape is rural and the wind farms are surrounded by fish cultivating pools, a port and tourist areas. Huaneng Renewables has a control building with permanent staff for monitoring and O&M activities at the wind farm. The site facilities include WTGs; connector cables; substation equipment; an office building with a control room, meeting rooms, spare parts storage, basketball ground and workers' accommodation. In our view the facilities and building on the sites appear to be well-maintained, well-organized and are of a high standard.

The island is close to the typhoon zone and it has been reported that wind speeds as high as 51 m/s have been experienced in the last ten years. According to historical records, 25 to 28 storms and typhoons enter the South Sea per year; two to three of them bring major weather patterns (strong wind and heavy rain) to Nan'ao Island. On average, one typhoon directly hits Nan'ao Island every three to five years. The typhoon alarm is broadcasted by the central and local weather station two or three days beforehand using satellite mapping technology. Prevention approaches adopted by the project company include: drainage methods, equipment reinforcement, switching the WTGs to pause and protecting status, and shutting off the HV switches to take the wind farm off-load if necessary. In our view, these approaches are sensible.

The wind farm layout, used in the feasibility study energy yield assessment, was originally designed by a Chinese design institute, following a pre-feasibility study by PB Power. The original layout was later altered due to complications over land approval and a new layout was designed which Vestas describe as 'more aggressive'. Vestas carried out a study of the constructed layout including flow modeling using CFD (Computational Fluid Dynamics).

The complex terrain increases the likelihood of demanding wind conditions such as high turbulence, steep inflow angles and severe wind shear. These factors increase the loading on wind turbine rotors and increase wear and fatigue in the drive train components. To mitigate against this, Vestas imposed a significant sector management program whereby certain WTGs will be switched off when the wind is coming from particular directions. This program affects 13 out of 53 WTGs and includes the easterly and south easterly wind directions. The implementation of this measure is a condition of the Vestas warranties and has been put in place by the wind farm operators.

The original wind resource assessment was carried out by a Chinese design institute in 2006; using wind data collected between 2002 and 2003, primarily from six different masts ranging between 50m and 70m. During this period the average wind speed across the site was measured to be between 5.1 m/s and 7.8 m/s. Following a comparison with a reference data set extending back to 1996, which showed that the 2002 to 2003 period experienced lower than average wind speeds, it was shown that wind speeds increased by approximately 8%. The long-term corrected wind speeds at 50m, calculated in the feasibility study, vary from 6.0 m/s to 8.11 m/s. The wide range of wind speeds across the site reflects the significant variation in ground height (up to 555m). The average wind speed recorded across the nacelle anemometers between January 2008 and December 2009 is 6.9 m/s. The wind speeds at Nan'ao are about average for an onshore wind farm.

The energy yield prediction developed by a Chinese design institute assumed a hub height of 65m for all WTGs, however a mixture of 55m and 65m hub heights was eventually used. The power curve used in the feasibility study is reported to be provided by the WTG manufacturer.

WAsP was used to calculate the energy yield and wake losses at the turbine positions. The accuracy of this method is compromised by complex terrain and we consider that there is uncertainty in these results. A series of losses totalling 25% was applied to calculate the predicted net yield which does not include the losses associated with the Vestas sector management program described above. The net yield predicted in the feasibility study is 100,965 MWh/year, which equates to a capacity factor of 25.6% which is in line with our expectations for the reported wind speeds. We have, however identified a number of inconsistencies between the assumptions made for the feasibility energy yield prediction and the constructed wind farm which affected the accuracy of the figures.

Vestas has conducted an energy yield analysis for Qing'ao considering the constructed layout using a mixture of 55m and 65m hub heights and a site specific power curve. The study is based on a single year of data from 2002/3 which the design institute determined to be a low wind speed year, therefore results are expected to be conservative. The scope of Vestas study did not cover analysis of losses; therefore results presented by Vestas do not consider reductions for availability or electrical efficiency. The study calculated that the average hub height wind speed is 7.0 m/s and the annual gross production (not including losses or sector management) is 110 GWh/year.

7.2.6.1 Generation and Availability

The achieved production in 2008 was 121.1 GWh which is higher than predicted by both studies. The average hub height wind speed recorded at the nacelle anemometers was 7.0 m/s. In 2009 the wind farm produced 95.9 GWh which was slightly below the predicted yield despite a recorded hub height wind speed of

6.9 m/s. However during this period the wind farm was hampered by the installation of a new under sea transmission line and the replacement of eleven generators due to a faulty batch (all of which were replaced under warranty).

Based on the recorded production during 2008 and 2009 Huaneng Renewables has set a future target energy yield of 118 GWh/year for Qing'ao. This figure has been calculated by comparing the first 24 months production at Qing'ao to the concurrent production at Niutouling Wind Farm Phase I, which has been operating since 2001. The 2008/9 production has been adjusted using the Niutouling records between 2001 and 2009 to arrive at a 'long-term average' production estimate. The calculation is quite rough; however the principle behind it is sound and should produce a reasonable estimate, which will include the effects of losses and the sector management program.

The wind farm availability calculated as provided by Huaneng was 99.5% for 2007, 98.7% for 2008 and 98.9% for 2009. The availability achieved is good, indicating efficient O&M practice. Records show the replacement of 11 generators in 2009 due to a faulty batch from ABB. This was carried out under warranty and had minimum impact on availability due to efficient planning. Other maintenance activities include resolving six gearbox oil leakages and the regular replacement of the pitch control actuators. During 2009 the installation and connection of the new subsea cable accounted for approximately eight days of lost production; however, this source of downtime is not included in the availability presented in Table 7.6. Assuming all sources of downtime and including the subsea cable issue, availability for 2009 is 84.0%.

The site benefits from 16 resident operators and technicians working in two shift patterns. This crew is responsible for both Qing'ao and Niutouling Wind Farm (58.5 MW in total). Many of the O&M team including the wind farm manager have been involved throughout the construction and operating phases and are well-experienced. The two year Vestas service agreement, which included an availability guarantee of 95%, expired in 2009. However, two Vestas technicians have been kept on until September 2010 to provide additional technical support and training.

Table 7.6: Operational Data of Qing'ao Phase II

Year-Month	Average availability (incl. all downtime)	Total generation (MWh)	Equivalent Full Load Hour	Capacity Factor %	Average Wind Speed at hub height m/s (55/65 m)
Jan-Mar 2010	99.6%	30,611	680	31.5	8.06
2009	98.9%	95,947	2,129	24.3	6.90
2008	98.7%	121,051	2,689	30.7	6.95
2007	99.5%				

7.2.6.2 Conclusions

Qing'ao Wind Farm is located in complex terrain in a saline environment. The wind resource is average. Conditions are therefore challenging. Equipment and facilities are of a high standard and well-maintained. The design, construction and installation are acceptable, safe and appropriate. O&M is well-resourced and well-managed due to the experience Huaneng Renewables gained in Niutouling Wind Farm Phase I project.

We identified some discrepancies which compromise the preconstruction energy production estimates and the achieved production is much higher than predicted. Huaneng Renewables has calculated a revised annual energy yield forecast which we consider to be a reasonable estimation.

7.2.7 Dali Dafengba Wind Farm

Dali Dafengba Wind Farm is a 48 MW wind farm consisting of 64 Zhejiang Windey WD50/750 kW wind turbines with 50m hub height which were manufactured under the license of Repower. The project is situated on a ridge overlooking the city of Dali in Yunnan Province, Southwest China. It is co-owned by Huaneng Renewables and Hongkong Electric Company Limited. The wind farm terrain is complex in nature and the site altitude is very high, located in a highland area ranging from 2,420m to 2,820m. The ground cover consists of dense foliage. The wind turbines are visible from piedmont downtown, and have become a sightseeing attraction of this tourist city. The wind farm layout consists of a single row running along a high ridgeline which runs perpendicular to the prevailing south westerly winds, minimizing wake losses. The complex terrain increases the likelihood of demanding wind conditions such as high turbulence, steep inflow angles and severe wind shear. These factors increase the loading on wind turbine rotors and increase wear and fatigue in the drive train components. The availability reported for the first 15 months operation is 97.62% and thus far there is no evidence of excessive wear and tear.

Huaneng Renewables has a control building with permanent staff for the monitoring and O&M activities for the wind farm. The site facilities include WTGs, connector cables, substation equipment, an office building with a control room and meeting rooms, spare parts storage, basketball ground and workers' accommodation. In our view the facilities and building on the sites appear clean, well-maintained, well-organized and are of a high standard. The O&M staff resources are adequate and have generally been recruited locally. There are two wind farms currently under construction nearby, which have been developed following the success of Dafengba.

Our inspection of the wind farm showed that at one or two turbine positions the adjacent surroundings had been compromised by the extensive excavation work required to cut the crane pads, although in general the turbine layout seems reasonable given the complexity of the terrain.

The layout was designed by Kunming Hydropower Investigation, Design and Research Institute. The site benefits from the strong prevailing south westerly winds which are a characteristic of the region. Given the strong winds and complex terrain, we consider that the site offers good potential for a wind farm albeit with challenging conditions.

The wind resource assessment was carried out by the design institute in 2006 during the feasibility study. The energy yield calculations for the constructed layout were carried out in a 2007 study by the same institute and the turbine manufacturer.

The preconstruction wind study made use of wind data collected between 2005 and 2006 using five 60m met masts spaced along the ridge, although only three of them were used to calculate the wind regime as two were damaged by lightning or found to be faulty. The 60m wind speed averaged over masts 1, 2 &3 during this period, is 8.1 m/s which shows a high wind resource. We have been provided the wind resources data measured from these three masts since year 2005. Met mast 3 has been retained and is presently used to monitor the performance of the wind farm. Between 2005 and 2006 mast 3 recorded an average wind speed of 7.9 m/s at 60m. These wind speeds have not been long-term corrected using reference data, which introduces some uncertainty as to whether they represent the long-term average conditions that can be expected over the life of the wind farm. The wind speed recorded at mast 3 during a four year period between 2006 and 2010 is 8.1 m/s suggesting that the 05/06 period used in the energy yield study may slightly conservative. We visited mast 3 during our site visit. We observed that it is very close to some of the turbine positions and is expected to be influenced by the turbine wakes. Wind data recorded here since the end of 2008 is therefore not consistent with that recorded prior to construction and likely to be under-recording.

The energy yield study uses WAsP to calculate the energy yield and wake losses at the turbine positions. The accuracy of this method is compromised by complex terrain and we consider that there is uncertainty in these results.

Owing to the high altitude, the site air density is very low. A power curve corrected to an air density of 0.894 kg/m^3 has been used in the analysis report of energy yield calculation issued by Zhejiang Windey and Kunming Hydropower Investigation, Design & Research Institute in October 2007. It is noted that this power curve limits the turbine output to 680 kW, effectively reducing the wind farm rating by 9%. This power curve (reportedly guaranteed by the manufacturer) has been used in conjunction with the calculated wind regime to produce a gross yield prediction. It is reported that the power curve recorded by the SCADA system for the operational period is substantially higher than the warranted curve in the 3-15 m/s wind speed range. The SCADA power curve uses nacelle sensors to record wind speed and is subject to some uncertainty; however it does provide a good indication that the power curve used in the energy yield study is conservative.

A series of losses have been proposed to cover availability, electrical efficiency and other expected losses. These allowances amount to 23.3% listed in analysis report of energy yield calculation in December 2007, which we consider to be very high.

The Dafengba area experiences thunderstorms on average 55 days per year. Lightning has caused damage and faults to the sensors on the met masts and turbines. The safety of facilities, equipment and site persons has been addressed by installing adequate lightning conductors at the substation, office and yard.

The energy yield assessment in the feasibility study predicts that the expected annual yield from Dafengba Dali is 82,600 MWh/year which translates to a capacity factor of 19.6%. This is very low for a wind farm which exhibits such a good wind resource implying that the prediction is very conservative.

The wind farm began commercial operation in January 2009 and generated 125,400 MWh in 2009 which is substantially higher than predicted. The average wind speed recorded at 60 m on mast 3 during this period is 8.22 m/s, indicating that 2009 was a windier than average year. Availability during this period is reported to be exceptionally high.

Based on this achieved production Huaneng Renewables headquarter has issued a new target of 118 GWh per year, which is calculated based on the history production records and approved by Huaneng Renewables headquarter.

7.2.7.1 Generation and Availability

The wind farm began commercial operation in January 2009 and generated 125.4 GWh in 2009 which is substantially higher than predicted 85 GWh made in the feasibility study report. The availability during this period is reported to be 99.8% which is exceptionally high.

During 2009 two major component changes were carried out, one generator and one gearbox. Regular minor maintenance activities include replacing brake pads, oil hoses, gear oil filters and nacelle sensors.

Currently the wind turbines are covered by a manufacturer's warranty which guarantees the WTG availability at 97%. This warranty expires at the end of 2010. Availability figures have been provided by Huaneng and compiled in Table 7.7.

Table 7.7: Operational Data of Dali Dafengba

Year	Month	Average availability (including grid)	Total generation (MWh)	Equivalent Full Load Hours	Capacity Factor	Average Wind Speed at hub height (60 m)
2010	1-3	99.9	44,559	928	42.5%	8.4
2009	1-12	99.8	125,426	2,613	29.8%	8.2

7.2.7.2 Conclusions

Dafengba Dali is situated in challenging terrain and experiences an excellent wind resource. Our inspection of the site and facilities showed that the wind farm is well-equipped and well-maintained. Recorded production in the first year of operation is higher than predicted in the preconstruction estimates; however we consider that the preconstruction estimate was very conservative. The recorded production and revised future estimates are more in line with our expectations for a site exhibiting such a good wind resource. The wind turbine availability is good for a young wind farm and the O&M program is well-resourced and well-managed. The wind turbines have performed well in the challenging wind climate although we note that two major component changes have been required.

7.2.8 Changdao Wind Farm

Changdao Wind Farm is located in Changdao county of Yantai city which is the only island county in Shandong Province. The installed capacity of Changdao Wind Farm is 27.2 MW comprising 32 units of Gamesa G52-850 kW turbines. The hub height of the turbines is 55m.

The project company, HNEEP-CLP Changdao Wind Power Co. Ltd., was jointly established by Huaneng Renewables and CLP Investment Co. Ltd. with 55% and 45% of interest respectively. It was formed and registered on 02 December 2004. However, the O&M works have been managed by Huaneng Renewables staff since being commissioned on 1 May 2006.

7.2.8.1 Generation and Availability

Changdao County comprises 32 islands. The WTGs were erected on the two main islands, Nan Changshan Island and Bei Changshan Island, arranged along the top of a hill going through both islands. 22 WTGs are located in Bei Changshan Island and 10 in Nan Changshan Island. The altitude of the hill is between 90m and 200m above sea level. There are no other buildings or wind farms nearby and the access road was built specifically for the wind farm before construction and is still in good condition. However it is prone to become blocked by heavy snow in winter. In this case the project company staff or an external professional company will be tasked with clearing the road as soon as possible. As has been confirmed by Huaneng Renewables that this situation happens rarely and only lasts for short period, and so we do not consider it as a material issue for the site accessibility. Also, while corrosion is expected to occur because of the salty offshore wind, we did not witness any sign of material corrosion of the visited wind turbine.

A control building with substation is located in Nan Changshan Island. This building includes the SCADA room, offices, storage area for spare parts, switchgear housing, and other site facilities. Because the warranty period expired in 2008, the spare parts and tools for O&M are stored by Huaneng Renewables itself. According to the spare parts list provided by Huaneng Renewables and our visit on site, we consider that the management of spare parts on site is well-prepared. Huaneng Renewables employs nine staffs to do the O&M, deployed in two teams. The building and facilities are of a high standard and appear to be well-maintained.

Changdao Wind Farm used wind resource data from two met masts on site for the feasibility study, measured during one year from 01 August 2003 to 31 July 2004 and located in Nan Changshan Island and Bei Changshan Island respectively with a measurement height of 50m. The integrity ratios of the data from two met masts were 99.99% and 99.54%. According to the first met mast, the annual average wind speed was 7.0 m/s and the biggest average wind speed was 19.8 m/s. According to the second met mast, the annual average wind speed was also 7.0 m/s and the biggest average wind speed was 26.3 m/s. The prevailing wind direction was west. However the operational data shows that the prevailing wind direction is northwest. In April 2010, one of the met masts was reconstructed as a permanent met mast for the wind farm. The wind data measured by the turbine anemometers and the mast is used to monitor records during the operational period.

The average wind speed at hub height (55m) has been calculated to be 7.0 m/s. According to production, wind, and availability data provided by Huaneng Renewables headquarter and site office, the wind farm showed good average availability of 98.79% in 2006, 97.44% in 2007, 98.76% in 2008 and 98.98% in 2009 which are listed in Table 7.8. All of them are above the 97% warranted availability figure. Comparing the annual production forecast of 58,160 MWh from the feasibility study report, we find that the actual annual production is almost similar to the forecast. In 2007 and 2009 the actual production figures were 54,817.4 MWh and 57,194.2 MWh respectively which were less than the forecast. It could be explained by the low average wind speeds measured at these times. However, in 2008 the actual production was 60,859.1 MWh which was more than the forecast with an average wind speed similar to the value from the feasibility study.

During operational period, major component failures were main shaft of No.10 WTG and the gearbox of No.5 WTG. They have now been replaced. Minor component failures include VOG sensors, contractors and low voltage switches in box transformers, which have also been repaired or replaced as necessary. When we visited site on 28 April 2010, there were no accidents or incidents since the wind farm had been commissioned.

Table 7.8: Operational Data of Changdao

Year	Month	Average availability	Total generation (MWh)	Utilization hours	Capacity factor	Average wind speed at 55m (m/s)
2009	1-12	98.98%	57,194.2	2,103	0.24	6.92
2008	1-12	98.76%	60,859.1	2,237	0.26	6.99
2007	1-12	97.44%	54,817.4	2,015	0.23	6.00
2006	4-12	98.79%	43,961.1	1,616	0.24	5.07

7.2.8.2 Conclusions

Performance at Changdao Wind Farm exceeded prediction in 2008 but was lower in 2007 and 2009. Lower than average wind speeds could account for the poor performance. However, the availabilities are good. Design, construction and installation are acceptable, safe and in line with our expectations. O&M appears to be well-managed.

7.2.9 Weihai and Rongcheng Wind Farm

Weihai Wind Farm Phase I is located in Rongcheng of Weihai City in Shandong province. It is to the north of the road along the Yellow Sea. Currently Weihai Wind Farm consists of two phases in operation:

- Weihai Wind Farm Phase I (19.5 MW, Sinovel FL1500/77*13)
- Weihai Wind Farm Phase II (49.5 MW)

As per our scope of work, we only considered Weihai Wind Farm Phase I. HNEEP-CLP Weihai Wind Power Co. Ltd. is the project company jointly established by Huaneng Renewables and CLP Investment Co. Ltd. with 55% and 45% stakes respectively. However, the O&M works have been the responsibility Huaneng Renewables staff since its operation. The commissioning date for the last WTG was 01 December 2008.

Huaneng Renewables planned to develop the offshore Wind Farm, more than 4 km off the shore in Rongcheng. But no offshore wind projects are currently under development in China as technologies and expertise for offshore WTGs, foundations, construction and wind resources assessment are considered by Chinese developers as immature. Therefore, Huaneng Renewables built Rongcheng Wind Farm and erected two WTG on a beach near Weihai Wind Farm as the prototype for its future offshore wind farm. The WTG used is Sinovel SL3000/100 with the hub height 80m and a maximum rating of 3 MW.

Huaneng Rongcheng Wind Power Co. Ltd, which is the project company for Rongcheng Wind Farm and future offshore Wind Farm is wholly owned by Huaneng Renewables and was founded on 31 December 2008. Currently two WTGs are still under testing. This work is carried out by Sinovel engineers and supported by staff from the project company at Weihai Wind Farm.

7.2.9.1 Generation and Availability

Weihai Wind Farm Phase I is constructed on a plain beach area. There are few buildings near the WTGs. There are some sea water pools for breed shrimps. The altitude of Weihai Wind Farm Phase I is 22m ASL. As all WTGs are located near the road along the sea front they have an easy and convenient access route. However, due to heavy rain in summer and heavy snow in winter accessibility can become problematic. Although some corrosion could be expected due to the salty offshore wind, there was no obvious corrosion on the WTGs we inspected during our visit.

There is a control building and substation at Weihai Wind Farm. This building includes the SCADA room, offices, spare parts store, switchgear housing, and other site facilities. Because it is still in the warranty period, the O&M works are the responsibility of the Sinovel engineers. Sinovel will transfer spare parts defined in the contract to the Weihai Wind Farm Project Company before the warranty period expires. However, we note that the warranty period is due to expire very soon and understand that Huaneng Renewables intends to extend the warranty period with Sinovel. Huaneng Renewables employs ten staff in its site office, deployed in two teams. Currently, Huaneng Renewables' employees manage Weihai Wind Farm Phases I and II and Rongcheng Wind Farm with Sinovel's resident site engineers. The building and facilities are of a high standard and appear to be well-maintained.

Weihai Wind Farm used wind resource data from Daxi met mast on site for its feasibility study undertaken between July 2003 and December 2004. The integrity ratio of the data from the met mast was 99.99%. The average wind speed at hub height (70m) was calculated to be 6.6 m/s and the annual average power density was calculated to be 388.8 W/m2 showing good wind regime. The prevailing wind came from the north whilst the strongest wind came from the northwest. In March 2010, the met mast was reconstructed as permanent met mast. The wind data is measured by the WTG anemometers and the mast during the operational period.

Production, wind, and availability data provided by Huaneng Renewables headquarters and site office show an improving average availability of 94.00% in 2007, 95.00% in 2008 and 97.69% in 2009 as listed in Table 7.9. All annual availabilities are equal or above the 95% warranted availability figure; apart from 2007 when the availability was slightly lower. We compared the annual production forecast of 39,203 MWh in the feasibility study report and found slight discrepancies. In 2008 the actual production was 31,704.2 MWh; less than the forecast. However, in 2009 the actual production was higher than forecasted at 42,873.2 MWh. These variations are due to the wind speeds being below average in 2008 and above average in 2009. In addition, Ronggang transmission line could not be used to export power from January 2008 to November in 2008. This impacted on power output to the grid. During this period WTGs for phase II were undergoing testing and commissioning which also impacted on the power output for Phase I.

During the operational period, component failures included failures relating to the box transformer, converters, fuses, batteries and slip rings. These components failures have now been rectified.

Huaneng Renewables provided us with power curves for some WTGs at Weihai Wind Farm Phase I, obtained during the 500 hrs preliminary acceptance test. These power curves were taken from the SCADA system. From the power curve figures we can see that the cut-in speed is around 3 m/s; rated speed is approximately 11 m/s, cut-out speed is approximately 26 m/s and rated power is 1.5 MW. These are the same as parameters provided by Sinovel except for the cut-out speed which is above 21 m/s.

Table 7.9: Operational Data of Weihai Wind Farm Phase I

Year	Month	Average availability	Total generation (MWh)	Utilization hours	Capacity factor	Average wind speed at 70m (m/s)
2009	1-12	97.69%	42,873.2	2,199	0.25	6.8
2008	1-12	95.00%	31,704.2	1,626	0.19	6.1
2007	4-12	94.00%	29,902.5	1,533	0.23	6.6

The terrain at Rongcheng Wind Farm is similar to Weihai Wind Farm. The two WTGs are located near WTG# 2 and WTG# 23 of Weihai Wind Farm Phase I. Rongcheng and Weihai Wind Farms share the same control building, substation and staff.

No feasibility study had been undertaken; however we have seen a project application report which covers many of the same necessary contents, albeit in a simpler style. Huaneng Renewables undertook a feasibility study for the future offshore wind farm, including the two existing WTGs. A met mast was installed on 1 September 2009. The average wind speed measured at hub height was 6.7 m/s. The prevailing wind direction is northwest and annual on-grid power output forecast is 12,033 MWh.

Installation was completed on 7 December 2009 and snagging and testing have started. Several faults in the WTGs and SCADA system have been identified and have been investigated. Historical records such as power output, availability, and average wind speeds can not be provided by the SCADA system. Huaneng Renewables informed us that the commissioning has been completed in July 2010.

7.2.9.2 Conclusions

Performance at Weihai Wind Farm Phase I was better than the predicted in 2007 and 2009 and below predicted levels in 2008. We understand that the wind speeds in 2008 was below average. In addition, 110 kV Ronggang transmission line could not be used from January 2008 to November 2008. This outage impacted on power output to the grid for Phase I and Phase II. During this period, WTGs for Phase II were undergoing testing and commissioning. All WTG availabilities are above 95% except in 2007. However, the 2007 capacity factor was higher than the forecasted feasibility study value.

Following the connection of the 6 MW Rongcheng Wind Farm, the total capacity connected to Weihai step-up substation reached 75 MW which is equal to the rating of the 75 MVA — 110/35 kV transformer at the site. It is recommended that the transformer should be sized slightly bigger than the installed generation capacity to avoid overloading. Huaneng Renewables confirmed that the two WTGs at Rongcheng Wind Farm will be connected to Rongcheng step-up substation, which will be operational in 2012.

The commissioning date for the two WTGs at Rongcheng Wind Farm has been delayed and has been completed in July 2010. Due to the delay in commissioning, Huaneng Renewables has requested that the turbine manufacturer, Sinovel, extends the warranty period at Rongcheng Wind Farm. We understand that Huaneng Renewables reserves its right to claim against Sinovel for losses incurred. As the two WTGs erected are a newly designed prototype, there may be some unexpected faults and will need a longer period to snag and test. To ensure successful take-over the Project Company is working closely with Sinovel engineers during the testing phase.

7.2.10 Changyi Wind Farm

Changyi Wind Farm is located in the north of Changyi city in Shandong Province. The installed capacity of Changyi Wind Farm is 49.5 MW with 33 units of Suzlon S82 LTV wind turbines with a hub height of 78m.

Huaneng Changyi Wind Power Co., Ltd. which is the project company was wholly owned by Huaneng Renewables. It was formed and registered in November 2008. The commissioning date of Changyi Wind Farm was January 2010.

7.2.10.1 Generation and Availability

Changyi Wind Farm is constructed on a beach area near to a dyke. The terrain is flat, with limited flora. There are shrimp breeding pools and salt collection pools at the base of some WTGs. Changyi Wind Farm is at an altitude of 1 to 5m above sea level. Access to the wind farm is via soil track which appear unaffected by heavy rain or snow. Due to the salt air, corrosion is expected to occur in the WTGs. After inspection we found that bolts connecting the bottom section of WTG tower to the foundation had been corroded. However, Huaneng Renewables and Suzlon have adopted some measures, such as using rubber caps covering each screw, to mitigate against excessive corrosion. We understand that Huaneng Renewables plans to build Phase II near this wind farm and it is currently at the feasibility stage. We have confirmed that the feasibility study will consider a sufficient distance from Phase I in order to reduce impact on phase I as much as possible.

There is a control building with substation at Changyi Wind Farm. This building includes the SCADA room, offices, spare parts store, switchgear housing, data room and other site facilities. We note that document control at this site is of a high quality. As the WTG are still within the warranty period, the O&M Works are undertaken by Suzlon engineers. The construction company and manufacturers are responsible for the BOP O&M during the first year warranty period. The spare parts store room we visited was clean and all parts were clearly identified. Huaneng Renewables intends to undertake all O&M works itself once the warranty period has expired. Huaneng Renewables employs ten staff in its site office, deployed in two teams on a five day rota basis. The building and facilities are of a high standard and appear to be well-maintained.

Wind data had been gathered prior to construction through a single 70m met mast installed on site. The furthest turbine is located 4 km from the met mast, which is a reasonable setup for a measuring campaign. Met mast data was collected between September 2006 and August 2007. Wind speeds for a hub height of 78m have been predicted as 6.67 m/s; resulting in a projected annual on-grid energy yield of 111,874.6 MWh. The prevailing wind direction is southeast.

From the information Huaneng Renewables provided, Changyi Wind Farm has been connected to the grid in June 2009 and it was in commissioning period until December 2009.

During the operational period, there was a major component failure when a generator failed. This has now been replaced. Minor failures occurred at box transformers, sensors and pitch motors. These have now all repaired or replaced as necessary. We are not aware of any health and safety accidents and incidents since the wind farm has been operational.

Table 7.10: Operational Data of Changyi Project

Year-Month	Average availability	Total generation (MWh)	Equivalent Full Load hours	Capacity Factor	Average Wind Speed at 78m (m/s)
2010 (Jan-Mar)	97.25%				7.2

7.2.10.2 Conclusions

Changyi Wind Farm was commissioned less than a year ago and as such, there is insufficient operational data to undertake an assessment of the wind farm's performance. Performance was instead based on a review of a pre-construction wind/feasibility study. We have been provided with a high level review of the measuring campaign undertaken to predict the energy yield at Changyi Wind Farm. However, due to the lack of available information, we were unable to assess the quality of measuring equipment, the quality of collected data or the methods used to calculate the energy yield.

Greater comfort could be gained through a review of the detailed information collected during the pre-construction wind study. Suzlon and Huaneng Renewables have taken acceptable measures to prevent corrosion at the WTGs. The building, facilities and equipment are of a high standard and appear to be well-maintained. The design, construction and installation are acceptable. O&M is well-managed and all faults have dealt with in an acceptable manner.

7.2.11 Laoting Wind Farm

Laoting Wind Farm is located in Laoting County near the sea in Hebei Province. The installed capacity of Laoting Wind Farm is 49.5 MW with thirty-three Sinovel SL1500 WTGs. These have a hub height of 70m.

Huaneng Laoting Wind Power Co. Ltd. is the Project Company. It was established on 13 June 2008 by Huaneng Renewables and Hongkong Electric Laoting Co. Ltd., with 55% and 45% stake respectively. O&M works have been undertaken by Huaneng Renewables staff throughout its operational life. The commissioning date was 11 December 2008.

7.2.11.1 Generation and Availability

Laoting Wind Farm is constructed on a beach area. Laoting Wind Farm sits at an altitude of between 0 and 3m ASL. The nearest village is about 2 km from the wind farm and there is no other wind farm in the vicinity. Access to the wind farm is gained via a soil track. We understand that for a short period of time, twice a year, the track becomes impassable due to heavy rain and snow. As the wind farm is located in an area of salty offshore wind, corrosion is expected. However we could find no obvious sign of corrosion at the time of our visit.

Laoting Wind Farm has a control building with substation. This building includes the SCADA room, offices, spare parts store, switchgear housing, garage, SVC room and other site facilities. As it is still in its warranty period, the O&M works are undertaken by Sinovel engineers. BOP O&M, including the access road, WTG foundations, cables and box transformers are undertaken by the on-site staff. The spare parts store room we visited was clean and all parts were clearly identified. Huaneng Renewables has eight staffs at its site office, deployed in two teams on a three days rota basis. The building and facilities are of a high standard and appear to be well-maintained.

Three met masts were installed at Laoting Wind Farm. Wind resources data collected from No.1 met mast was used for the feasibility study undertaken between 1 October 2004 and 1 October 2005; data collected from the other two met masts was used as validation. The integrity ratio of the data from the No.1 met mast was 96.5%. The average wind speed at hub height (70m) was calculated to be 6.9 m/s and the prevailing wind direction is north to northeast. Data gathered by the WTG anemometers and the met masts is used to monitor wind conditions during the operational period.

According to the production, wind and availability data provided by Huaneng Renewables headquarters and site office, the wind farms showed a very good average availability of 98.36% in 2009 (listed in Table 7.11), above the 97% warranted availability figure. However, it is worth noting that the calculation of availability, as presented by Huaneng Renewables, includes a few caveats such as wind turbines are considered as available when they are actually down due to extreme weather conditions, or grid problems. This is in line with European market practices. Therefore, we consider the actual availability of the wind farms to be potentially lower than the figures Huaneng Renewables provided to us. We compared the annual production figure of 101,470 MWh in the feasibility study, and found it was higher than the actual 2009 annual production figure of 90,774.5 MWh. The average wind speed in 2009 was 5.15 m/s, much lower than 6.9 m/s calculated in feasibility study. We are aware that wind regime in 2009 was poor and would have contributed to the lower output figure achieved. In addition, grid connection was not achieved until February 2009 and commissioning was not completed until 28 April 2009. Full production did not commence until May 2009, resulting in power generation being lower than the forecasted amount. We understand from Huaneng Renewables that the actual power generation from January 2010 to May 2010 was 50,230.1 MWh, much higher than the 40,638.3 MW generated during the same period in 2009.

During the operational period, component failures have included pitch, converter and sensors. These have been repaired or replaced as necessary.

Table 7.11: Operational Data of Laoting

Year-Month	Average availability	Total generation (MWh)	Equivalent Full Load hours	Capacity Factor	Average Wind Speed at 70m (m/s)
2009 (Jan-Dec)	98.36%	90,774.5	1,834	20.9%	5.15

It is worth noting that there are two different rotor diameters among 33 WTGs. The rotor diameter of five of the WTGs (4, 6, 21, 28 and 29) is 82m. These five wind turbines were erected as prototypes to assess the different output between two WTG models. The rotor diameter of the remaining WTGs is 77m.

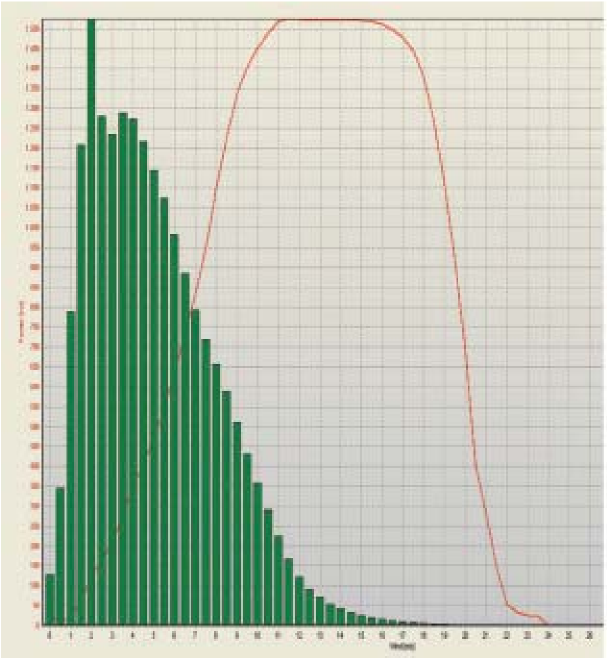
Monthly production figures and power curves provided by Huaneng Renewables headquarters and site office show that performance of WTGs with 82m rotor diameter was better than those with 77m rotor diameter. The figures in Table 7.12 show that, with the exception of June 2009, average power generation of the 82m WTG was greater than that of the 77m WTG by an average of 7.9%. Huaneng Renewables has stated that the June 2009 below average power generation reading of 82m WTG was due to a meter reading error by the Programmable Logic Controller's (PLC). This fault has been rectified by Sinovel. Performance of 82m WTG appears to be better than 77m WTG under the same conditions.

Table 7.12: Monthly Average Generation of 82m and 77m WTG

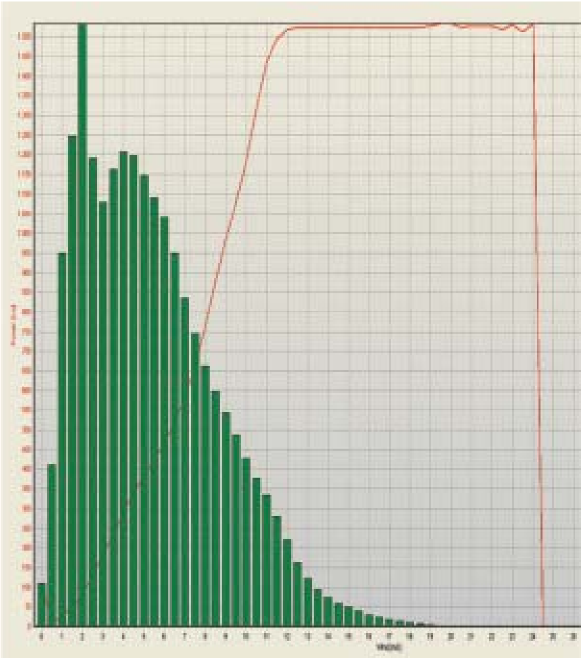
Month	Average generation per unit of 82m WTG (MWh)	Average generation per unit of 77m WTG (MWh)	Increasing ratio (%)
April	348.0	321.2	8.3
May	287.8	267.4	7.6
June	238.3	249.4	-4.5
July	160.2	145.7	9.9
August	181.0	168.7	7.3
September	N/A	N/A	N/A
October	231.3	211.6	9.3
November	265.5	250.2	6.1
December	294.5	274.9	7.1
Average	252.6	234.2	7.9

Huaneng Renewables provided us with power curves for five 82m WTGs and five 77m WTGs from their first Quarterly Report in 2009. We can see from these figures that rated wind speed of 82m WTG was around 11 m/s but rated wind speed of 77 m WTG was around 12 m/s. Also the curve of 82m WTGs showed better performance especially from cut-in speed to rated speed than the curve of 77m WTGs and wind turbines usually operate within this range. Figure 7.1 shows clearly that the rated wind speed of No.21 WTG was 11 m/s and No.10 WTG was 12 m/s.

Figure 7.1: Power Curve of No.21 and 10 WTG



No.21 WTG Power Curve



No.10 WTG Power Curve

7.2.11.2 Conclusions

Laoting Wind Farm has shown a good availability which was 99.19% in its first year of operation. But the power out-put was lower than forecast. It was mainly because the wind speed in 2009 was lower than the long-term average wind speed. Average wind speed was just 5.15m/s. In addition, before May 2009 all WTGs were under commissioning and their power generation was lower than forecast. We got further information from Huaneng Renewables that the power generation from January to May in 2010 was much higher than in 2009.

Laoting Wind Farm has two WTG models, with a rotor diameter of 82m and 77m respectively. Huaneng Renewables' data shows that the 82m WTG model outperforms the 77m WTG.

The site benefits from good access to each WTG. We did not see any obvious signs of corrosion at the WTG we visited. The building, facilities and equipment are of a high standard and appear to be well-maintained. O&M is well-managed.

7.3 General Conclusions

Of the twelve representative wind farms reviewed, six wind farms only started commercial operation in the last year, therefore those wind farms do not have enough operational data (at least 12 months of normal operational data is usually required) in order to assess whether the production would be in line with the estimates from the feasibility studies.

Nevertheless, within the six remaining wind farms, five projects have higher annual productions than planned with the same annual average wind speed as in the feasibility study.

Moreover, regarding Laoting Wind Farm which showed lower performances than expected, we understand, from the available information, that lower annual average wind speed was the main reason for the lower performance. In addition, 2009 is the first operational year of the wind farm. Indeed, before May 2009, all WTGs were under commissioning and their power generation was lower than forecasted.

Overall, the equipment and facilities are well-maintained and of a high standard. The design, construction and installation are in line with our expectations.

8. Operating & Maintenance

8.1 Introduction

To operate its wind farms, Huaneng Renewables' strategy is to rely on wind turbine manufacturers during the warranty period of the wind turbines and to subsequently handover this responsibility to its own O&M team on site.

The warranty provided by the manufacturers for the Huaneng Renewables wind farms usually lasts for a two year period, in line with current industry standards, and wind farms in other countries. We consider this warranty duration generally acceptable for WTG technologies with proven track records. However, Haizhuang did not provide a satisfactory track record. Therefore, we consider a warranty period of at least three years as a reasonable mitigant. Huaneng Renewables has successfully negotiated a five years warranty period with Haizhuang. Thus, we are satisfied with the mitigation applied by Huaneng Renewables.

We are aware of only one unresolved major commercial issue related to WTG performance in Rongcheng Wind Farm, which only contains two offshore wind turbines of 3 MW. Huaneng Renewables has requested the turbine manufacturer Sinovel to extend the warranty period of Rongcheng Wind Farm, due to the delay of commissioning. The performance of the two pilot turbines at Rongcheng could not meet the design value and are still under commission. There are clear delay damage clauses in the turbine contract with Sinovel. Huaneng Renewables has not requested any delay damage compensation, considering the long-term working relationship with Sinovel and protecting the domestic WTG industry development. Meanwhile, Huaneng Renewables reserves the rights to claim appropriate compensation from Sinovel at any time.

The wind farm electrical equipment are maintained by the O&M team themselves after the warranty period has expired. Few faults occurred in those devices, as those products are mature in the industry. The voltage level, current and capacity of electrical equipment are all standard specifications. Most technicians are experienced and trained in operating and maintaining WTGs. In our view, the safety and performance targets should be achieved based upon adequate experience of technicians and compliance with proper procedures laid out by WTG manufacturers.

The maintenance of road access to the wind farms is sub-contracted to local transportation service & maintenance. This is a common practice in the industry. The export lines connected to the grid are managed and maintained by the local grid company, as required by industry regulations.

8.2 O&M Structural Organization

The number of O&M people on site is decided by Huaneng Renewables headquarters based on internal principles. The employees are recruited and trained by the Huaneng Renewables headquarters, which ensure control of the qualification and competency of the employees on site.

The organizational structure of each wind farm is proposed by each project company, and then approved by Huaneng Renewables headquarters. They assign the general manager and other senior managers. Other O&M employees are hired by each project company.

Project companies usually set three divisions for production, maintenance and execution. The maintenance team usually has two shifts, one foreman for each shift with three or four maintenance employees. This arrangement could satisfy most daily requirements, e.g. replacement of consumable parts; meanwhile manufacturer supports are needed during major overhauls. This organization set-up minimizes reaction time for small maintenance tasks on the WTGs. It also improves the availability and, therefore, the production and the revenues generated by the wind farm. Most of the wind farms visited are still in warranty period, which means that the maintenance services from manufacturers are covered by the warranty fee.

8.3 O&M Arrangements

In order to maximize revenue, high power availability is critical for a wind turbine. A number of factors can affect this availability; O&M arrangements are likely to be one of these factors and will have a very high impact. A commercial balance between the O&M cost and availability exists and these need to be considered carefully in contract negotiations. Liquidated damages are the key protection against poor availability. Finally, care is needed during the O&M contract negotiation with respect to the definition of 'availability'. WTG suppliers will typically exclude a number of events as part of the contracted availability calculation, allowing them to limit their responsibilities over events outside their control (e.g. network outages). During site visits we raised these points and requested evidence of the relevant documentation. In our view these issues have been, in general, properly addressed by Huaneng Renewables in the O&M negotiation agreements. We are satisfied with this arrangement.

All O&M agreements that have been reviewed include training programs arranged by the manufacturers. These are usually comprehensive, and include four weeks training in factories and on site, covering most topics and problems that may occur on site. The service team is trained by using the maintenance manual, keeping records of faults, operation and control of turbines, erection method for replacement, maintenance procedures, trouble shooting and spare part management. We understood that in addition to the standard training, Huaneng Renewables' staffs also assist the manufacturer's team during scheduled and unscheduled maintenance. We are satisfied that experience can be gained by the team through this arrangement.

As previously discussed, most of the wind farms we visited started commercial operation in the past two years and are still in the warranty period and continue to be maintained by the manufacturers. According to the maintenance records on site, and interviews with the manufacturers' onsite staff, the scheduled maintenance has been carried out in accordance with definitions in the agreements. We noticed that the WTG Maintenance form elaborates on inspection and items to be checked by the manufacturer's maintenance staff regularly. The form is comprehensive and includes all the main items. Once the warranty period expires, the regular maintenance of turbines will be done by site personal from Huaneng Renewables. Manufacturer servicing will still be accessible, as most of the WTG suppliers have a regional service center in the area where the wind farms are located. As Huaneng Renewables is one of the major wind power producers in China and with the ongoing relationship with most of the major turbine manufacturers, we expect the manufacturer to respond rapidly to service requests.

In our view, plant maintenance by an external specialized company allows for more confidence in the quality of the service. However, we acknowledge that there are few companies other than the WTG manufacturers, with a significant track record in the Chinese market and Huaneng Renewables may consider it cost effective to manage this service internally. This could help to set a solid foundation for the rapid expansion of its wind portfolio that has taken place in recent years and may contribute to its ambitious plans for future growth. Some companies with large wind farm portfolios use the same strategy as Huaneng Renewables and have their own service team. However, we consider that it is necessary to have a corporate strategy and guidance documents for training and O&M that defines best practice principles during these activities in order to ensure the same quality of maintenance and to share experiences. Huaneng Renewables indicates that the guidance documents of O&M is in the drafting stage, and will be issued before the end of 2010. Currently, the O&M procedure and work of Huaneng Renewables' wind farms follow two national O&M standards which are called 'DL/T 666-1999 Code on Operation of Wind Farm' and 'DL/T 797-2001 Code on Operation of Wind Farm' which were issued by the national authority.

According to the Huaneng Renewables' statement, its plan for maintaining the wind turbines after the warranty period is to sign a long-term service agreement with the manufacturers in order to solve all technical problems during operation. During this period Huaneng Renewables will train a professional team for WTG servicing to meet instant service requirements on site. Finally, Huaneng Renewables plans to establish a long-term contract with an external maintenance company so costs can be optimized. In our view, this strategic scheme seems reliable and could be cost effective.

The storage of spare parts is well-registered, well-managed and well-recorded at all the wind farms visited. According to Huaneng Renewables headquarters' plan, spare parts are separated into three categories. The consumable parts e.g. sensors, tools, brake pieces and sealing are purchased by the site project company regularly according to a fixed rate. The intermediate spare parts e.g. switches and frequency converters, which have a typically higher failure rate and low costs, are purchased according to the headquarters' annual plan. Major spare parts e.g. generators and gearboxes are managed by headquarters. Huaneng Renewables has agreements with the WTG manufacturers which request that those major spare parts shall be stored in a manufactory for use by Huaneng Renewables. In our view, the management of the spare parts by Huaneng Renewables seems efficient, practical and cost-effective.

We considered Huaneng Renewables quality control as adequate. The high energy production and availability of the representative wind farms also provides confidence in this matter. The procurement, construction, recruitment and training, primary controlled by Huaneng Renewables headquarter, show good management capabilities. The Health & Safety and Environment (HSE) system is well-established and well-implemented among the wind farms. The personal protection equipment is sufficient on site and the employees are required to follow procedures before they start working on site. Quality, Health & Safety and Environment manuals and relevant system files are drafted and executed based on the Huaneng Renewables headquarters' QHSE system requirements.

8.4 Conclusions

Overall, Huaneng Renewables' O&M arrangements for its wind farms are above our expectations and in line with international standards. We consider that these arrangements should be suitable for Huaneng Renewables as they have similarities with other O&M structures from other companies while being specifically developed in order to be integrated within Huaneng Renewables' organizational structure.

Although we believe that the preventive maintenance strategy for WTG main components could be improved, the structural organization of O&M, the treatment to the outage, the purchase and storage of spare parts and the QHSE requirements of Huaneng Renewables wind farms are generally acceptable and well-organized.

Appendices

Ref	Document Title
1	Huaneng Renewables' feedback to MM's Questionnaires for 12 respective wind farm
2	Feasibility study report for each wind farm
3	Grid connection report for each wind farm
4	Project Progress for each wind farm
5	Project Schedule & Construction Report for each wind farm
6	Wind Turbine Supply Agreement for each wind farm
7	WTG tech Specification for each wind farm
8	Single Line Diagram (electronic version) for each wind farm
9	Met mast data during operational period for each wind farm
10	WTG Layout for each wind farm
11	Operational monthly data (availability, generation) for each wind farm
12	Spare parts list for each wind farm
13	Technical specification (main transformer, WTG transformer, inter-array cables, export cables) for each wind farm
14	Grid connection agreement for each wind farm
15	Grid Code for connecting the Wind Farm
16	SGCC Annual Report in 2009 and in 2008
17	CSG Annual Report in 2009 and in 2008
18	SGCC, CSG and Inner Mongolia Power Company's website
19	Safety requirement and assessment of Wind Farm Grid Connection
20	QA list from Huaneng Renewables
21	MML internal information
22	Information from public website
23	State Electricity Regulatory Commission's website

Glossary

ASL	Above Sea Level
BCSE	Business Council for Sustainable Energy
BOP	Balance Of Plant
CEC	China Energy Council
Chinese Grid Code/Chinese Grid Code (Revision)	Chinese Grid Code (Revision) of wind farm grid connection published in December 2009
Chinese Grid Code (Trial)	Chinese Grid Code (Trial) of wind farm grid connection published in 2006
COD	Commercial Operation Date
CREIA	Chinese Renewable Energy Industries Association
CSG	China Southern Power Grid Co., Ltd.
Cut-in Wind Speed	Wind speed at which a wind turbine begins to generate electricity.
Cut-out Wind Speed	Wind speed at which a wind turbine ceases to generate electricity.
DFIG	Double-Fed Induction Generator
GB/T	Guobiao/Tujian, Chinese National Standard, Recommended
GE	General Electric Company, Energy
Gearbox Ratio	Ratio of the speed of rotation of the powered gear to that of the final gear.
GL	Germanischer Lloyd
GWEC	Global Wind Energy Council
HSE	Health & Safety and Environment
Hub Height	Distance from the ground to the centre-line of the turbine rotor
IEC	International Electrotechnical Commission
IPE	Implementation in Production and Erection
LVRT	Low Voltage Ride Through
MCP	Measure Correlate Predict
MM	Mott MacDonald Limited
NCAR	National Center for Atmospheric Research
O&M	Operation and Maintenance
Project Efficiency	Difference between net yield and gross yield
QHSE	Quality, Health & Safety and Environment
Rated Power	Maximum power that a WTG can produce at constant wind speed
SCADA	System Control and Data Acquisition
SGCC	State Grid Corporation of China
TC	Technical Consultant
UK	United Kingdom
US	United States
WAsP	Wind Atlas Analysis and Application Program
WTG	Wind Turbine Generator

GW	Giga Watt (electric)
GWh	Giga Watt hour (electric generation)
Hz	Hertz (frequency)
kA	kilo Ampere (power)
km	kilometer (length)
kV	kilo voltage (electric)
m	meter (length)
m^2	square meter (area)
m/s	meter per second (velocity)
MPa	Mega Pascal (pressure)
MW	Mega Watt (electric)
MVA	Mega Volt Ampere (apparent power)
MVar	Mega Volt-ampere reactance (reactive power)
TWh	Tera Watt hour (electric generation)
V	Voltage (electric)
W/m^2	Watt per square meter (power density)
%	Percent
°C	Degrees Centigrade (temperature)