GL Garrad Hassan

TECHNICAL REVIEW OF THE UP1500 AND UP3000 WIND TURBINES

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List of Abbreviations

The following table lists all abbreviations used in this report.

Abbreviation	Meaning
ASL	Above Sea Level
CCS	China Classification Society
CCSC	China Classification Society Certification
CEPRI	China Electric Power Research Institute
CGC	China General Certification
CGDC	China Guodian Corporation
CNAS	China National Accreditation Service for Conformity Assessment
CNCA	Certification and Accreditation Administration of China
CQGC	Chongqing Gearbox Co., Ltd.
CWEA	China Wind Energy Association
DD	Direct Drive
DDWT	Direct Drive Wind Turbine
DFIG	Doubly Fed Induction Generator
FGD	Flue Gas Desulfurization
GDLYEC	Guodian Longyuan Electrical Co., Ltd.
GDPD	Guodian Power Development Co., Ltd.
GDTE	Guodian Technology & Environment Group Corporation Limited
GFRE	Glass Fiber Reinforced Epoxy
GHP	Garrad Hassan and Partner Limited
GL	Germanischer Lloyd
GL GH	Garrad Hassan (Beijing) Technology and Service Co. Ltd
GUP	Guodian United Power Technology Company Ltd.
HALT	Highly Accelerated Lifetime Testing
HKEx	Hong Kong Stock Exchange
HRS	HRS Wind Power Technologies Ltd.
IE	Independent Engineering
IEC	International Electrotechnical Committee
IPO	Initial Public Offering
IPR	Intellectual Property Rights
Longyuan	China Longyuan Power Group Corporation Limited
LRQA	Lloyd's Register Quality Assurance Limited

Abbreviation	Meaning
LRQASH	Lloyd's Register Quality Assurance (Shanghai) Co. Ltd.
LVRT	Low Voltage Ride Through
LYC	Luoyang LYC Bearing Co., Ltd.
MOST	Ministry of Science and Technology of China
MTBF	Mean Time Between Failure
NEB	National Energy Bureau
NGC	Nanjing High-Speed & Accurate Gear Group Co., Ltd.
NTC	Nanjing Turbine & Electric Machinery (Group) Co., Ltd.
O&M	Operation and Maintenance
OHSAS	Occupational Health and Safety Assessment Series
PDCA	Plan, Do, Check, Adjustment
PMG	Permanent Magnet Generator
PMSG	Permanent Magnet Synchronous Generator
R&D	Research and Development
SCADA	Supervisory Control and Data Acquisition
SGCC	State Grid Corporation of China
SoC	Statement of Compliance
UKAS	United Kingdom Accreditation Service
WTG	Wind Turbine Generator
XEMC	Xiangtan Electric Manufacturing Co., Ltd.
XREB	Xuzhou Rothe Erde Slewing Bearing Co., Ltd.
ZREC	Zhejiang Rifeng Electric Co., Ltd.
ZVRT	Zero Voltage Ride Through

EXECUTIVE SUMMARY

Introduction

At the request of Guodian Technology & Environment Group Corporation Limited ("GDTE" or "the Client"), Garrad Hassan (Beijing) Technology and Service Co. Ltd ("GL GH") has performed an independent technical review of the UP1500 and UP3000 wind turbines which are manufactured by Guodian United Power Technology Company Ltd. ("GUP"). GDTE holds 70% of the shares of GUP.

The objective of the review is to provide an independent opinion from GL GH on the UP1500 and UP3000 wind turbines for GDTE's Initial Public Offering (IPO) on the Hong Kong Stock Exchange (HKEx). This report presents the findings of the independent technical review of the UP1500 and UP3000 turbines and an overview of GUP.

GUP Overview

GUP is a relatively new turbine manufacturer, with around a five-year history of developing, assembly, commissioning and servicing of wind turbines in the Chinese market. However, when it started the wind turbine business, GUP's predecessor had had a history (of more than 12 years) of retrofitting steam turbines for thermal power plants, which provides a basis for the quality control and service of wind turbines.

GDTE, the major shareholder of GUP, is a subsidiary of China Guodian Corporation (CGDC), which is a large, state-owned electric power utility and which owns China Longyuan Power Group Corporation Limited (Longyuan)—the largest wind farm operator in China. The connection to CGDC and LongYuan may provide market access and further growth potential for GUP in both China and the overseas' markets. GUP has been working on building up a proven track record for its turbine products, and on enhancing its in-house research and development (R&D) capabilities during the past few years.

GUP has built up an in-house R&D team, consisting of 118 staff currently in its head office currently. The team is equipped with well known software tools, including Ansys for FEM calculation and GH Bladed for turbine simulation and load calculations. The team has completed joint design work with Aerodyn and the localization of the UP1500 turbine. GUP has worked with leading wind consultants, including Aerodyn and Garrad Hassan and Partners Ltd (GHP), for new product development, performance measurement and certification, which partially offsets its relative inexperience in the industry. In parallel to R & D activities, GUP has invested resources to manage the Intellectual Property Rights (IPR) of its turbine products and technologies, including applying for patents and copyrights.

The GUP product portfolio includes a 1.5 MW platform (UP1500/70; UP1500/77; UP1500/82 and UP1500/86) with 2,223 units installed by the end of July 2011 and a new 3 MW turbine with a doubly fed induction generator (DFIG) with one unit prototype unit installed. In addition, GUP is developing three new turbine products: a 2 MW turbine with DFIG; a 3 MW direct drive (DD) turbine and a 6 MW turbine with DFIG. Amongst these turbines, the 3 MW DFIG and DD turbines and the 6 MW DFIG turbine will be appropriate for offshore application. GL GH considers that the product portfolio (including both existing and new developments) is in line with industry practice and market development in China.

GUP can currently perform the assembly of the nacelle, hub and control panels, and the manufacturing of blades, gearboxes and generators in-house. GUP has three turbine assembly facilities in operation, which are located in Baoding of Hebei province, Lianyungang of Jiangsu province and Chifeng of Inner Mongolia. The total assembly capacity is 3,900 MW per year according to GUP. Rotor blade production takes place in the three assembly facilities. In addition, GUP owns a gearbox manufacturing plant with annual capacity of 400 units in Baotou of Inner Mongolia and a generator manufacturing plant with annual production capacity of 1,000 units in Yixing of Jiangsu province. Although GUP still sources a significant portion of gearboxes and generators from external suppliers, GL GH considers that GUP is pursuing a strategy of vertically integration of key components in addition to turbine design and assembly. This is in accordance with the practice of many of the industry leaders.

GUP has a supplier selection standard in place and GL GH finds that the supply chain for GUP turbines is managed in accordance with industry practice. GL GH has visited the GUP manufacturing facility which is located in Baoding of Hebei province, China. Based on the visit to the workshops and on discussions with the GUP staff, GL GH concludes that GUP has the equipment and processes in places to manufacture wind turbines according to industry standards.

GUP and its three turbine assembly bases hold separate certificates for quality management. In addition GUP holds certificates for environmental management and OHSAS. All these certificates are in their valid period. GL GH considers that GUP has a sympathetic approach to its manufacturing processes and quality management system. This lends comfort that GUP treats all aspects of quality as important issues.

GUP has built up a turbine commissioning and service team with over 500 staff working in its after-sales department. GUP is enhancing its capability for wind farm operation and maintenance (O&M), aiming to provide complete solutions to its clients. GL GH considers this strategy to be common in the industry and it is being adopted by several other leading wind turbine manufacturers.

In summary, GUP is equipped with most of the essential elements (turbine products, in-house R&D, turbine assembly and key component production facilities, supply chain management, quality control and after-sales service team) that are required to become a leading wind turbine manufacturer in the wind industry. Despite the relatively short history of its turbine manufacturing business, GUP has demonstrated early stage success in the Chinese market. GL GH considers that GUP has the potential to grow its business in China, if it continues to execute its strategies of product development, supply chain management, services and quality control in efficient ways despite the increasing competition. GL GH has noted that GUP is working in a few overseas markets (including South Africa and the US) and its connection with Longyuan may provide access to new markets.

UP1500 Turbine

The UP1500 turbine is a 3-bladed, horizontal axis, upwind, pitch regulated turbine, incorporating a doubly fed induction generator which provides variable speed operation over a range of ± 30 % of nominal speed.

The UP1500 turbine platform includes four turbine versions: the UP1500/70, UP1500/77, UP1500/82, and UP1500/86. These turbines are nearly identical; the principal difference between them being the rotor diameter, along with other resultant modifications, such as rotational speed. Design wind class is adjusted for the individual variant of turbine, to compensate for the larger rotor. The turbine loading behind the rotor is similar across the four variants.

The UP1500 turbine design is based on well-known and proven design concepts. The UP1500/77 and UP1500/82 were developed in cooperation between Aerodyn and GUP. Aerodyn is regarded as one of the leading consulting companies which provide services in wind turbine design. However, the UP1500/70 and UP1500/86 were developed by GUP itself, based on the previous design. In addition, GUP developed variants to accommodate special site conditions, such as high altitude and coastal areas, etc.

GUP has obtained design certification for the UP1500/77 and UP1500/82, issued by China Classification Society (CCS) and China General Certification (CGC), which adds comfort in the design of the turbine. In addition, GUP also obtained C-design certification for the UP1500/77, issued by Germanischer Lloyd (GL), which indicates that GUP turbines can be documented according to the industry standard. The C-design certificate has now expired and GUP is in the process of obtaining an A-design assessment from GL.

GL GH has reviewed part of the Low Voltage Ride Through (LVRT) certificate, performed by China Electric Power Research Institute (CEPRI), for the UP1500/82 turbine. In addition, GL GH has reviewed part of the Zero Voltage Ride Through (ZVRT) test report for UP1500, performed by GL Garrad Hassan Deutschland GmbH during 2011. The CEPRI test shows compliance with the current Chinese grid code and the GL Garrad Hassan Deutschland GmbH test confirms it can perform to a higher standard than is currently required in China.

GL GH finds that the power curves for the UP1500 turbines are in line with other 1.5 MW turbines offered to the market in China.

GUP has installed a considerable number of the UP1500 turbines since 2009—a relatively short time period. According to GUP, as of the end of July 2011, 2,223 units of the UP1500 had been installed or were being installed, of which 704 units are UP1500/77, 1,344 unites are UP1500/82 and 175 units are UP1500/86.

The turbine availability information provided by GUP is limited, and it may not be representative of the entire fleet of UP1500 turbines. For all variants of the UP1500 except

UP1500/70 which is a new turbine model, the data shows that it is capable of operating with an average availability of about 98.4% following the GUP definition of availability which is quite similar to other turbine manufacturers' definitions defined in turbine supply agreements.

Based on the information provided by GUP, GL GH finds that the UP1500/77 and UP1500/82 are commercially proven in China and the UP1500/86 will soon meet the criteria for commercially proven assuming installations continue.

UP3000 DFIG Turbine

The UP3000 DFIG is a newly designed 3.0 MW wind turbine, designed by GUP with the support of GHP, an experienced international wind design consultancy. The initial design of the turbine has been completed and the verification phase of the development has been started. GL GH has been provided with three agreements related to certification signed by GUP with CCS, CGC and GL respectively, for the UP3000 offshore turbine. All certification work is in progress.

There has been one UP3000 DFIG prototype in operation (onshore) since April 19, 2011. According to GUP, the prototype has passed a 240 hours reliability test which provided some comfort that GUP is on the right track. The first offshore prototype is being installed at Binhai wind farm in Weifang, Shandong province.

The design of the UP3000 DFIG indicates that the turbine will be able to meet the requirements for a modern wind turbine of a 3.0 MW size. Based on the information provided to GL GH, the design has been performed based on current industry standards. However, only the completion of the turbine verification, validation and establishment of a track record can confirm this.

In summary, the UP3000 DFIG includes many concepts and components that are commonly used by modern, megawatt class turbines. The overall design concept has been proven to be just as reliable in these turbines. However, reliability is determined by each individual detail of the design. The final determination of turbine reliability can only be proven by track records.

UP3000 DD Turbine

The UP3000 DD is a 3.0 MW turbine which is currently under development and is jointly designed by GUP and HRS Wind Power Technologies Ltd. (HRS). The initial design of the turbine is, as far as GL GH is aware, not yet completed yet. GL GH has been provided with two agreements signed by GUP with CCS for the UP3000 DD offshore turbine and with CGC for the UP3000 DD onshore turbine. All certification work is in progress. It should be noted that the information concerning the UP3000 DD provided to GL GH was limited.

GL GH expects that the UP3000 DD uses the rotor, yaw system and tower design from the UP3000 DFIG, of which a prototype has been installed in China. However, the drive train and bedplate design is new to accommodate a multi-pole variable speed permanent magnet generator (PMG) with a fully-rated converter system in order to provide variable speed operation. The fully-rated converter system provides more options for compliance with the new (and more arduous) grid code requirements compared to turbine designs without full power conversion.

Direct-drive turbines have a number of attendant advantages which arise from the elimination of the gearbox. They have fewer parts overall, which has the potential to reduce operations and maintenance costs. However, so far, direct-drive turbines have also had a higher capital cost than comparable geared turbines.

The information provided to GL GH on the design of the UP3000 DD indicates that the turbine will be able to meet the requirements for a modern wind turbine of a 3.0 MW size. However, only the completion of the turbine verification and validation can confirm this.

In summary, GL GH finds that the design concept of the UP3000 DD for the drive train is in accordance with the most recent developments within the wind industry. The design concept of the remaining parts of the turbine is based on concepts and components that are commonly used by modern, megawatt class turbines. However, reliability is determined by each individual detail of the design. The final determination of turbine reliability can only be proven by track records.

1 INTRODUCTION

At the request of Guodian Technology & Environment Group Corporation Limited ("GDTE" or "the Client"), Garrad Hassan (Beijing) Technology and Service Co. Ltd ("GL GH") has performed an independent technical review of the UP1500 and UP3000 wind turbines which are manufactured by Guodian United Power Technology Company Ltd. ("GUP"). GDTE holds 70% of the shares of GUP.

The scope of work was defined in GL GH Proposal 106076/CP/01 Issue F, dated July 04, 2011.

The review was based on information that GL GH:

- Requested through the proposal;
- Obtained during a meeting with GUP during the week starting January 10, 2011;
- Obtained during a visit to the manufacturing facility of GUP on January 11, 2011;
- Obtained during inspection of an UP1500 (UP77) on January 12, 2011; and
- Found in the public domain.

The objective of the review is to provide an independent opinion from GL GH on the UP1500 and UP3000 wind turbines for GDTE's Initial Public Offering (IPO) on the Hong Kong Stock Exchange (HKEx).

Turbine technical specifications were recorded, using product information that was either made available in the public domain or was directly supplied by the turbine manufacturer—GUP. GL GH cannot be held responsible for the accuracy of information supplied by GUP. However, GL GH has applied a test of reasonableness to the information and if there are any obvious errors these will be indicated in the text.

References are provided throughout this report in square parenthesis: for example, 1. A list of references is also provided at the end of this report.

This report presents the findings of the independent technical review of the UP1500 and UP3000 turbines and an overview of GUP.

Description of GL GH

Garrad Hassan (Beijing) Technology and Service Co. Ltd. is a member of the Germanischer Lloyd SE (GL) group of companies, and is part of GL's renewable energy consulting business, trading under the GL Garrad Hassan brand.

Although the GL Garrad Hassan name is new, the business has accrued a rich heritage from the renewable energy specialists within GL, including: Garrad Hassan, Windtest, Helimax and Noble Denton. GL Garrad Hassan provides an integrated global service, with more than 750 staff in over 40 locations worldwide, offering services and software products across the entire project lifecycle.

GL Garrad Hassan is the leading provider of technical and engineering services, software products and training, not only for onshore and offshore wind, but also for the rapidly developing wave, tidal and solar sectors. With experience gained over almost three decades, GL Garrad Hassan has an unsurpassed technical understanding of renewable energy technologies, projects and markets, and its client list includes the majority of all major turbine manufacturers, developers, lenders, investors and owners.

GL Garrad Hassan has vast experience in providing independent wind energy consulting services. The breadth and depth of its project lifecycle experience helps to provide superior intelligence which is based on real projects. GL Garrad Hassan has an Independent Engineering (IE) Team which is dedicated to the performance of due diligence projects. GL Garrad Hassan acts as the third party advisor in major markets (all over the world) in which wind, solar and marine energy technologies are being deployed. Based upon this extensive experience, the IE team offers clients various on-demand technical due diligence services.

Independence of GL GH

GL Garrad Hassan has no equity stake in any device or project. This rule of operation is central to its philosophy and is something which sets it apart from many other players and underlines its independence.

Details of the full range of services and products can be found at www.gl-garradhassan.com.

2 COMPANY PROFILE

2.1 GDTE Background

Guodian Technology & Environment Group Corporation Limited (GDTE) was founded on November 26, 2004. It is an integrated group of the technology and environment subsidiaries of China Guodian Corporation (CGDC). In GDTE, there are 18 holding and minority holding enterprises, with a total registered capital of CNY 1.5 billion. However, GDTE changed the holding status from wholly-owned by CGDC to jointly owned by CGDC with 51 % shares, Guodian Power Development Co., Ltd. (GDPD) holding the remaining shares. It was registered again for this change on May 16, 2011 with a total registered capital of CNY 4.85 billion. CGDC is one of the top five electrical power utilities in China and it is state-owned. GDPD is listed on the Shanghai Stock Exchange and has power plants and subsidiaries across 23 provinces of China. By the end of 2010, CGDC held 51.72 % shares of GDPD.

The main business of GDTE covers two areas. One is for renewable energy including wind turbine and solar power equipment manufacturing etc. The other is for energy saving and environmental protection in thermal power plants, including flue gas desulfurization (FGD), De-NOx, plasma ignition, air cooling system, power plant control, waste water treatment, etc.

2.2 GUP Background

Guodian United Power Technology Company Ltd. (GUP) is jointly owned by GDTE, which holds 70 % of the shares and China Longyuan Power Group Corporation Limited (Longyuan), which holds the remaining shares. Longyuan was founded in January 1993 and its main business is in renewable energy development such as wind power, solar, tidal, biomass, etc. It is the largest wind farm operator in China. Longyuan's IPO in HKEx was in December 2009 and CGDC is its shares holding company.

The main business of GUP includes research and development (R&D) of wind turbines and key components, turbine assembly, sales, installation supervision, commissioning, maintenance and after-sale servicing of wind turbines and components.

GUP, formerly called Longwei Generation Technology Service Co., Ltd., was a steam turbine service provider for thermal power plants in China founded in 1994; it entered the turbine manufacturing industry in 2006 by signing a technology transfer contract for a 1.5 MW turbine with Aerodyn, a well established turbine and rotor blade design consultancy in Germany. Longwei was restructured and incorporated as GUP in April 2007, with the registered capital of CNY 903 million. GUP has grown rapidly since it was founded. A summary of the history of GUP is presented below:

- 2006: Signed technology transfer contract with Aerodyn;
- 2007: Founded and set up Baoding facility;
- 2008: One-hundredth 1.5 MW wind turbines were produced;

- 2009: All 66 wind turbines in the Guodian Power Uliji wind farm passed a 240 hours reliability test;

- 2009: The Lianyungang facility came into operation and construction of the Yixing generator factoryconstruction began;

- 2009: The Chifeng facility came into operation and construction of the Baotou gearbox factory was completed;

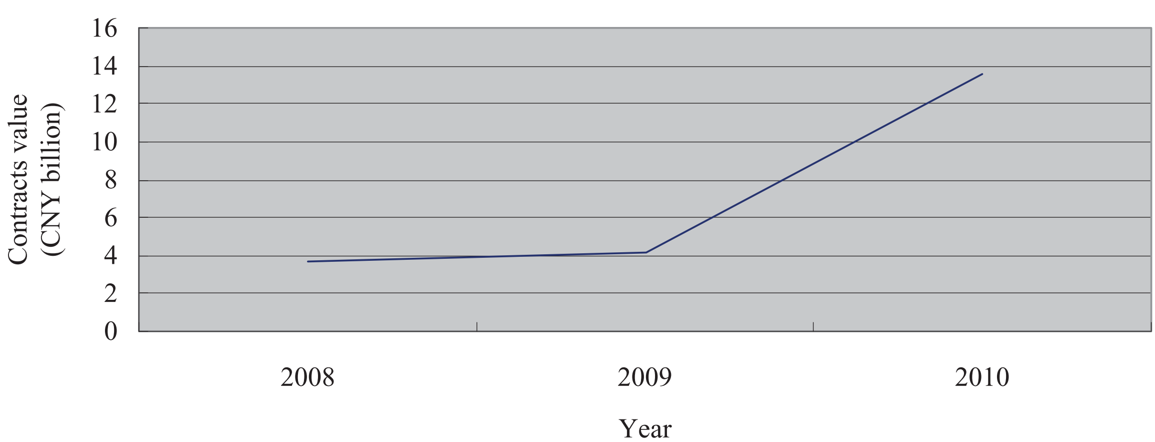
- 2009: The design contract for the 3 MW DFIG wind turbine was signed with Garrad Hassan and Partners Limited (GHP);

- 2010: The 1.5 MW turbine passed Low Voltage Ride Through (LVRT) test and the 3 MW wind turbine prototype was produced;

- 2010: A contract for a pilot project in the overseas market was signed;

- 2010: Awarded "Deloitte Technology Fast 50 China 2010".

According to GUP, its contracts value (mainly from wind turbine sales) in 2008, 2009 and 2010 was about CNY 3.672 billion, CNY 4.164 billion and CNY 13.604 billion, respectively. Figure 2.1 shows how the contract value increased from 2007 to 2010. The contract value has increased rapidly since 2009, when wind turbines realized batch production. As of the mid of August 2011, the contract value had achieved about CNY 10.589 billion, which surpassed the value at the same time last year.



Source: *GUP*

Figure 2.1—Contract value of GUP

In 2010, China was the world's largest wind turbine market with an estimated 18.9 GW newly installed and 44.7 GW cumulatively installed 1. GUP ranked fourth for wind turbine deliveries in the Chinese market in 2010 with a newly installed capacity of 1,643 MW and a cumulative capacity of 2,435 MW. All the track records were for the 1.5 MW turbines. Table 2.1 shows the installed capacity of the top ten wind turbine manufacturers in 2010 in China. Please note that these figures consider installed capacity, not operating capacity.

Manufacturer	Cumulative Delivered Capacity in China as of End of Year (MW)			Deliveries in 2010 (MW)
	2008	2009	2010	2010
Sinovel	2,157	5,652	10,038	4,386
Goldwind	2,629.05	5,351.05	9,078.85	3,735
Dongfang	1,290	3,328.5	5,952	2,623.5
Guodian United Power	**—**	**792**	**2,435**	**1,643**
Mingyang	175.5	895.5	1,945.5	1,050
Vestas	1,455.2	2,011.5	2,903.6	892.1
Shanghai Electric	201.25	475.5	1,073.35	597.85
Gamesa	1,552.5	1,828.75	2,424.3	595.55
XEMC	128	582	1,089	507
China Creative Wind	—	198.5	682.5	486
Other Manufacturers	2,564.5	4,690	7,111.19	2,411.99
Total	**12,153**	**25,805.3**	**44,733.29**	**18,927.99**

Source: China Wind Energy Association (CWEA) 2

Table 2.1—Installed capacity of largest manufacturers in China (based on total installation by the end of 2010)

GUP's headquarter are in Beijing and it has fifteen departments, including human resources, finance and property, development and operation, quality assurance, information, marketing and sales, international business, project management, safe production, procurement, equipment and logistics management, and a technical department as well as other supporting departments. In addition, GUP owns two institutes, Guodian Wind Power Equipment Technology Research Institute and Guodian Wind Power Equipment Commissioning Department. These institutes conduct turbine technology research & development and commissioning & operation, respectively. GUP's organization chart is shown in Figure 2.2. GUP had over 4,000 staff as of the end of 2010.

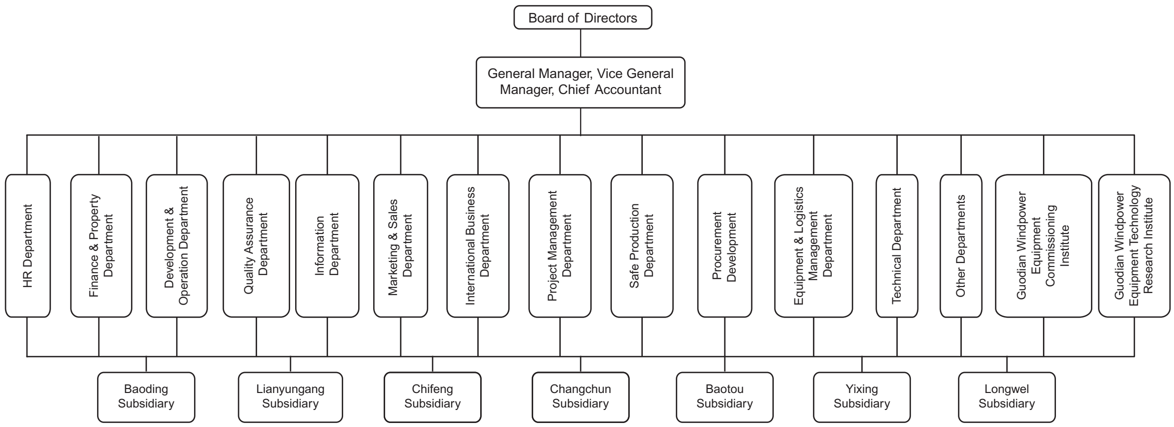


Figure 2.2—Organization chart of GUP

GUP has five wholly-owned subsidiaries and three holding companies. GUP has set up six manufacturing facilities and these are located in Baoding of Hebei province, Lianyungang of Jiangsu province, Chifeng in Inner Mongolia, Changchun of Jilin province, Baotou in Inner Mongolia and Yixing of Jiangsu province. GUP can assemble turbines in the Baoding, Lianyungang, Chifeng and Changchun facilities. However, the Changchun facility is under construction and is expected to be finished by the end of 2011. In addition, GUP can produce gearboxes in the Baotou facility, generators in the Yixing facility and blades in the Baoding, Lianyungang and Chifeng facilities. According to GUP, there are also facilities under development in Jiuquan of Gansu province, Xinzhou of Shanxi province, Zhangbei of Hebei province and Zhanhua of Shandong province.

Currently, GUP's main products are the UP1500/77/82/86 wind turbine generators (WTGs), each with a rated power of 1.5 MW. This turbine has a modular drive train, with gearbox, doubly fed induction generator (DFIG), pitch control, and double main bearings. GUP signed a joint turbine design agreement with the Turbine Group of GHP for a UP3000 offshore turbine in 2009 and one prototype has already been erected and is currently undergoing commissioning. GUP is also currently developing UP2000 DFIG turbines, UP3000 direct drive (DD) turbines with a permanent magnet generator (PMG) and UP6000 DFIG offshore turbines. GUP has got some turbine certificates from GL Renewable Certification, China Classification Society (CCS) and China General Certification (CGC), and much turbine certification work is also ongoing with the above.

According to CWEA, the market share of GUP in 2010 in China was 8.7 %, in terms of annual installed capacity, which ranked it in 4th place in the Chinese market. During 2010, 1,410 units of UP 1500 turbines had been installed or were being installed in China, and 756 units had been connected to the grid according to GUP's statistics. By the end of July 2011, 2,223 units of UP1500 turbines had been installed in China.

2.3 Product Line

GUP began to produce the UP1500/77 through a technology transfer contract with Aerodyn. Since then GUP has developed the UP1500/82 and UP1500/86 turbines. These are on the same UP1500 turbine platform but have different variants. UP1500 turbines have been installed in large areas in China with different conditions, including low wind speed areas, high altitude areas and costal areas, etc. GUP has made some modifications according to different conditions for the site suitability. GUP also developed a UP1500/82 with a 60 Hz frequency, for exporting to North America and Brazil, etc.

Besides the UP1500, GUP also developed the UP3000 DFIG offshore turbine, which was designed jointly with GHP. The prototype for the UP3000 DFIG is under commissioning now. New turbine types which are being developed by GUP include the UP3000 DD turbine, UP2000 DFIG turbine and UP6000 DFIG offshore turbine.

In Table 2.2, the current product portfolio from GUP is shown.

GUP Product	Rated Power	Type	IEC Class	Remarks
UP1500/70	1500 kW	DFIG	I A	A new model, based on the UP1500 platform. In the manufacturing stage.
UP1500/77	1500 kW	DFIG	IIA	Batch production. Produced under a technology transfer contract with Aerodyn.
UP1500/82	1500 kW	DFIG	IIIA	Batch production. Produced under a technology transfer contract with Aerodyn. 60 Hz variant is available for export.
UP1500/86	1500 kW	DFIG	IIIB	Batch production. The high altitude variant is available. GUP owns its independent intellectual property.
UP2000/96	2000 kW	DFIG	IIIA	The prototype was produced in August 2011. GUP owns its independent intellectual property.
UP3000/100	3000 kW	DFIG	IIA & IIIA	The first prototype installed onshore began operation in April 2011 and has passed the 240 hours test. GUP owns its independent intellectual property.
UP3000/100	3000 kW	DD	IIA & IIIA	In the design stage. GUP owns its independent intellectual property.
UP6000/136	6000 kW	DFIG	IIA	In the design stage. GUP owns its independent intellectual property.

Table 2.2—Current product portfolio from GUP

According to GUP, the prototypes of the UP3000 DD turbine and UP6000 DFIG turbine are expected to be produced by the end of this year.

In all, there are three turbine platforms for the current product portfolio from GUP. The first platform is for 1.5—2 MW turbines. The second platform is for 3 MW turbines. The third platform is for 6 MW turbines. GUP is now doing some feasibility study work for the 12 MW turbine development. GUP's product portfolio is similar to a few other leading Chinese turbine manufacturers. The fact that GUP is developing a 3 MW DD turbine product indicates that GUP is exploring direct drive route in addition to the geared drive train configuration that its current products offers.

In this report, the turbine platform will be referred to as the UP1500 or UP3000 when the discussion is generic to all of the variants. Specific turbine variants will be identified according to the nomenclature used by GUP: UP1500/{rotor diameter} and UP3000/{rotor diameter}, e.g. UP1500/77 and UP3000/100.

2.4 Research and Development

GUP currently has a total of 118 staff, including 20 doctors and 62 masters, working for R&D in the head office. GUP also has a consultancy commission, composed of 25 experts in the Chinese renewable energy industry, in order to be involved in defining key R&D directions, new products development and technical staff training.

GUP has seven in-house R&D teams for the following items respectively:

- Structure and load calculation;
- Blade;
- Electrical and control;
- R&D projects;
- Integration and standardization;
- Drive train and overall turbine;
- Generator and power storage.

GUP informed GL GH that it applied to the National Key Laboratory of Wind Power Equipment and Control to the Ministry of Science and Technology of China (MOST), and obtained approval in January 2010. In May 2010, MOST organized an expert team to check the feasibility of this laboratory building plan and then approved it. Now the laboratory is being built near the GUP's Baoding manufacturing facility.

According to GUP, the R&D work performed in the laboratory will be focused on overall turbine design and simulation, drive train fatigue and advanced manufacturing technology, blades and turbines control, as well as grid connection. GUP also informed GL GH that the Beijing Wind Power Equipment Reliability Engineering Technology R&D Center was approved in August 2011. The R&D work performed in this center aims to improve the reliability of wind turbines and key components.

Both the National Key Laboratory of Wind Power Equipment and Control and Beijing Wind Power Equipment Reliability Engineering Technology R&D Center will support GUP's R&D work further. In addition, GDTE is now developing a wind farm located in Chifeng in Inner Mongolia with the total capacity of 198 MW. GL GH was informed that this wind farm can be utilized to test new wind turbines.

GUP signed a technology transfer contract with a German consultancy company Aerodyn, in November 2006, to develop a 1.5 MW turbine. The first prototype was commissioned in May 2008. GUP has informed GL GH that the turbines were developed through cooperation between Aerodyn and the GUP R&D department.

Aerodyn was founded in 1983 in Rendsburg, Germany, by the engineer Sönke Siegfriedsen, and the company has subsequently been involved in the development of numerous wind turbines at many levels, including complete turbine design, component design, load calculations and certification work. Aerodyn is regarded as one of the leading consulting companies providing services related to wind turbine design.

However, there is very limited information available on the actual involvement of Aerodyn in any specific turbine or component design. GL GH finds this to be only natural, as manufacturers will not usually disclose to what extent they are using consultants. In fact, many manufacturers regard the use of consultants as confidential information.

GUP uses well known software tools in its R&D centres, including Ansys for FEM calculation and GH Bladed for turbine simulation and load calculations.

The R&D centres have completed the joint design with Aerodyn and the localization of the UP1500 turbines. In the development of the UP1500, GL GH understands that Aerodyn has performed the basic design of the turbine and that GUP subsequently made some modifications to the design; these modifications include:

- Implementation of Chinese suppliers for the main components—the original design from Aerodyn was based on European suppliers;
- Optimize the structure in the nacelle and decrease the weight;
- Re-design three transformers into one transformer in the turbine;
- Re-design of the control of the converter;
- Re-design of the gearbox cooling system from an air-to-water-to-oil system to an air-to-oil system;
- Design of the lightning protection system, based on input from Aerodyn;
- Design of the UP42 blades for the UP1500/86 turbine.

Along with more and more UP1500 turbines being installed and in operation, GUP has made some upgrades on sites, considering both specific site conditions and comments from its clients and grid companies, including:

- Upgrading the torque control strategy;
- Upgrading the yaw control strategy;
- Upgrading the circuit of lightning protection system;
- Upgrading the monitoring function of SCADA;
- Upgrading the circuit of back-up power source for control system;
- Upgrading the cooling system in the nacelle and tower base;
- Upgrading the warm protection solution in the nacelle;
- Realizing the LVRT function.

GL GH considers these upgrading measures based on operating turbines are beneficial for reducing turbines' faults and improving turbine reliability. In addition, GUP assigned China Electric Power Research Institute (CEPRI) and GL Garrad Hassan Deutschland GmbH as the third party for carrying out tests for UP1500 performance, such as power curve, power quality, LVRT and noise.

GUP signed a joint design contract with GHP in 2009, to develop the UP3000 DFIG offshore wind turbine. The first onshore prototype has been in operation since April 19, 2011 and passed the 240 hours test. The first offshore prototype is being installed in Binhai wind farm which is in Weifang of Shandong province. GUP has informed GL GH that the turbine is developed in cooperation between GHP and the GUP R&D department.

GUP defines four major directions for its R&D development, which GL GH considers represent the wind turbine technology development trend to some extent, including:

- Wind turbine control and electrical characteristics for grid connection;
- Offshore wind turbine with a capacity of over 5 MW;
- Environmentally friendly design and material used;
- Front-end adjustable speed synchronous generator and large scale power storage system.

GUP's strategy of working with leading wind consultants, including Aerodyn and GHP, has bridged the gap of its limited R & D experience and need to develop new wind turbine products.

GUP has set up an Intellectual Property Rights (IPR) management system and strategy and has dedicated staff for this. GUP works positively to apply IPR to related authorities. In addition, special training in IPR knowledge is provided for GUP staff. To date, GUP has applied for nearly one hundred patents and has obtained 23 patents for its R&D performance.

2.5 Turbine Manufacturing Capacity

GUP performs the assembly of the nacelle, hub and control panels and relies on its supply chain for many of the major turbine components, with the exception of blade manufacturing. GUP also has the capacity to manufacture both gearboxes and generators but it has not realized the batch production until this year. Currently, GUP relies on the supply of gearboxes and generators from both external suppliers and itself.

GUP has three assembly production bases in operation, mainly for 1.5 MW WTGs, and these are located in Baoding of Hebei province, Lianyungang of Jiangsu province and Chifeng in Inner Mongolia. The Changchun facility is under construction and is expected to be finished by the end of this year. According to GUP, the total production capacity is 3,900 MW per year. Blades are also produced in these assembly production bases. GUP has gained the authority from the local government to develop wind farms in Chifeng city with a capacity over 500 MW, as a consequence of the Chifeng facility being founded in this city.

GUP also has two component production bases in operation, one for manufacturing gearboxes (with a gearbox production capacity of 400 units/year), which is located in Baotou in Inner Mongolia, and one for manufacturing generators (with a generator production capacity of 1,000 units/year), which is located in Yixing of Jiangsu province.

The manufacturing capacity of the GUP facilities in operation is shown in Table 2.3.

Facility	Production Type	Manufacturing Capacity	Manufacturing Quantity 2008	2009	2010	Jan-Mar 2011	Turbine Type	Note
Baoding	Turbines*	1,500 MW	100 units	680 units	900 units	129 units	1.5 MW	
	Blades	1,500 MW	100 sets	332 sets	762 sets	185 sets	1.5 MW	Blades for UP 37.5/40.25/42.
Lianyungang	Turbines*	1,200 MW	—	80 units	592 units	53 units	1.5 & 3 MW	The manufacturing capacity for 3 MW will be 200 units per year.
	Blades	1,200 MW	—	8 sets	475 sets	90 sets	1.5 & 3 MW	Blades for UP 37.5/40.25/42/50.
Chifeng	Turbines*	1,200 MW	—	—	158 units	36 units	1.5 MW	
	Blades	1,200 MW	—	—	202 sets	69 sets	1.5 MW	Blades for UP 37.5/40.25/50
Baotou	Gearboxes	400 units	—	—	—	1 unit	1.5 MW	It is expected to that batch production will be realized by the end of this year.
Yixing	Generators	1000 units	—	—	—	90 units	1.5 & 3 MW	

1 Based on information from GUP 3
2 * means nacelles and hubs assembly.

Table 2.3—Manufacturing capacity per year

On January 11, 2011, GL GH visited the facility in Baoding of Hebei province. The process for nacelle and hub assembly is based on the workstation principal, which is widely used in the wind industry. However, there has been some movement towards the moving line assembly principal. The workstations used by GUP are, as follows:

- Drive train assembly (note that the gearbox is supplied with the oil lubrication system installed);
- Yaw system assembly;
- Complete nacelle assembly;
- Final test of the nacelle;
- Cover installation;
- Hub assembly with final test.

The assembly facility has two sets of work stations. At the final workstation in the nacelle and hub assembly, GUP performs a final inspection of the assembled nacelle and hub before it is prepared for transport to the site and stored outside the assembly hall.

The nacelle and hub test includes checking the function of all sub-systems, electrical connections in the nacelle and hub, and rotation of the drive train using an electrical motor connected to the drive train at the end of the main shaft. GL GH finds that the final testing of the nacelle is in line with industry standards.

GUP has informed GL GH that the test stand for the nacelle is designed to test the nacelle at full power up to 2.0 MW, and that it is performing an extended test on the first three nacelles of a new variant, or with a new supply of main components. GUP supplied GL GH with a full power testing reports sample for the new generator 4 and converter 5 installed in the nacelle, which prove that GUP follows its procedure. The test stand is shown in Figure 2.3.

Figure 2.3—Nacelle final test

During the visit to the manufacturing facility, GL GH noted that the cleanliness of the workshop was in accordance with industry standards and that GUP does not perform any machining or welding in the assembly workshop.

The incoming parts for the assembly process are stored in the centre of the assembly hall. According to GUP an inspection is performed on the incoming parts. There is a system in place, which ensures that the parts are used in assembly in the same sequence as they arrive at GUP. The stock in the assembly hall is relatively small. However, GL GH is not aware of any additional stock for incoming parts.

The assembly of the control panels is conducted in a separate workshop, and the cleanliness of this workshop is as one would require for the assembly of control panels.

All control panels are subject to final testing and inspection, either before leaving GUP for transfer to the site or before installation in the nacelle. All control panels are stored within the workshop until they are shipped.

GL GH considers that the layout of the production facility is very similar to other turbine assembly facilities. In general, GL GH finds that the manufacturing facility at Baoding includes all that is needed to ensure both the quality of the product and the efficiency of the plant. However, some optimization of the current production flow may make assembly more efficient.

During the visit to the Baoding facility GL GH also visited the blade manufacturing workshops. The manufacturing process used by GUP for manufacturing the blades is the vacuum infusion of resin method; this process is commonly used in the wind industry.

The set up of the blade manufacturing facility is in line with what GL GH has seen at other blade manufacturing facilities around the world. GUP has the equipment available to analyze the materials used in the blade manufacturing, including the final laminate. Therefore, GUP should be capable of ensuring the quality of its blades.

2.6 Supply Chain

GUP can perform the assembly of the nacelle, hub and control panels and some major component manufacturing, including blades, gearboxes and generators currently. However GUP also sources gearboxes and generators from external suppliers and this will continue in the future. The purpose of GUP partly producing these is mainly to support GUP R&D work for new turbine development. In this case, GUP can produce key components by itself which accord with the specific requirements of the new turbine development and make key components maintenance and replacement more convenient. GL GH considers this beneficial for GUP R&D progress and after-sales servicing.

In addition, GUP is in cooperation with other affiliate companies which are also subsidiaries of GDTE, such as Guodian Longyuan Electrical Co., Ltd. (GDLYEC) and Huadian Tianren Electrical Control Technology Co., Ltd. GUP buys converters from the former company and researches pitch controllers with the latter company.

In order to compare GUP's production strategy, Table 2.4 presents a summary of the production strategies for all the main manufacturers. These range from vertically integrated companies, such as Enercon, through to companies including GE, REpower and Nordex, which source almost all their components from third parties.

Manufacturer	Buy All Components	In-house Production of Key Turbine Technology Components		In-house Production	
		Partial[5]	Full[6]	Partial	Full
Vestas			●		
GE	●[1]				
Enercon					●
Gamesa		○[4]		●	
Suzlon			○	●	
Siemens			●		
Repower	○	●			
Nordex	○	●			
Sinovel		●			
Goldwind	⭘[2] →	◉[3]			
GUP		⭘ →	◉		

1 ●—Main position today
2 ⭘—Position today, but in process of changing direction
3 ◉—Anticipated position in coming years
4 ○—Former position
5 Partial indicates that the manufacture only manufactures some of the components it needs, and that the remaining components are supplied by sub-suppliers
6 Full indicates that the manufacture manufactures all of the components it needs

Table 2.4—Supply chain of main turbine manufacturers

GUP has a standard in place for supplier selection. It defines that the potential suppliers must have at least a three-year track record and must pass the quality system evaluation (carried out by the GUP quality department), the technology and process evaluation (carried out by the GUP technical department) and the commercial capability evaluation (carried out by the GUP purchase department). If the potential suppliers can meet these requirements, they can produce prototypes for GUP. The potential suppliers can be considered as qualified only after the prototypes pass both the workshop testing and on-site testing when installed in the wind turbine.

GUP has quality engineers especially for batch suppliers. The quality engineers carry out management work and inspect the manufacturing and delivery for key components before shipment to the major supplier facilities. For key batch suppliers, GUP implements an audit for products quality, process and quality management systems every six months.

GL GH finds that the supply chain for GUP turbines is managed in accordance with industry practice.

Table 2.5 summarizes the suppliers of main components to GUP.

Component	Supplier			Comments
	1.5 MW	3 MW DFIG	3 MW DD	
Blade	• GUP	• GUP	• GUP	UP37.5/40.25 is based on Aerodyn's design. UP34/42 is designed by GUP. UP50 is jointly designed by Windnovation and GUP.
Pitch system	• MOOG • SSB	• MOOG	• Mita	SSB, MOOG and Mita are experienced worldwide suppliers.
Gearbox	• NGC • CQGC • GUP	• NGC	• N/A	NGC and CQGC are two of the major gearbox suppliers to Chinese wind turbine manufacturers.
Generator	• XEMC • NTC • GUP	• XEMC	• GUP	XEMC is one of the major generator suppliers to Chinese wind turbine manufacturers. GL GH has no experience on NTC, regarding the generators which are used in wind turbines.
Converter	• ABB • ZREC • GDLYEC	• ABB	• ABB	ABB is an experienced worldwide supplier. ZREC is a joint venture company by Zhejiang Runfeng Energy Engineering Co., Ltd and the Hitachi Group. GDLYEC is also a wholly-owned subsidiary of GDTE. GUP is its only customer for converters. GL GH has no experience with ZREC and GDLYEC.
Main bearing	• SKF	• SKF	• SKF	SKF is an experienced supplier worldwide.
Blade bearings	• SKF • XREB	• XREB	• XREB	XREB is a joint venture company established by ThyssenKrupp AG (Rothe Erde GmbH) of Germany and Xuzhou Construction and Machinery Group. Rothe Erde is an experienced slewing bearing supplier worldwide.
Yaw bearing	• LYC • XREB	• XREB	• XREB	LYC is one of the major bearing manufacturers in China.
Controller, Hardware	• Beckoff	• Bachmann	• Mita	Beckoff, Bachmann, Mita are experienced worldwide suppliers.
Controller, Software	• Aerodyn/GUP	• GUP	• GUP	

Table 2.5—Component suppliers

2.7 Quality Control

The predecessor company of GUP was Longwei Generation Technology Service Co., Ltd., which was founded in 1994 and was a joint venture with Westinghouse and Siemens. Its main business was updating steam turbines to improve their energy efficiency. The quality control of GUP is based on that of its predecessor, and it follows PDCA (Plan, Do, Check, and Adjustment) principles in terms of turbine design, supply chain control, component design and manufacture, assembly and tests on-site, etc. It is worth noting that there are quality assurance departments in both the head office and its subsidiaries.

GL GH has been given a copy of an ISO 9001:2008 Quality Management System Certificate 6, which includes certification of GUP for the design, development, sale, installation supervision, commissioning, maintenance and after-sales service, related technical and engineering consulting services, and production supervision of the tower for the wind turbine systems. This certificate was originally issued to GUP on February 07, 2010, and it will expire on February 06, 2013. The certificate was issued by Lloyd's Register Quality Assurance (Shanghai) Co. Ltd. (LRQASH), on behalf of Lloyd's Register Quality Assurance Limited (LRQA).

GL GH has also been given three other copies of ISO 9001:2008 Quality Management System Certificates, also issued by LRQASH. One of these is for GUP's Baoding subsidiary 7, and it covers WTG assembly, blades and blade mould manufacturing. This certificate was originally issued to GUP on February 23, 2010, and will expire on February 22, 2013. The second certificate is for GUP's Lianyuangang subsidiary 8 and relates to WTG assembly and blade manufacturing. This certificate was originally issued to GUP on February 01, 2010, and it will expire on January 31, 2013. The third certificate is for GUP's Chifeng subsidiary 9 and also relates to WTG assembly and blade manufacturing. This certificate was originally issued to GUP on January 26, 2011, and it will expire on January 25, 2014. All these certificates are within the valid period.

GL GH has discussed the quality management system with GUP, and GL GH has seen the quality records from the assembly process of the nacelle and hub in Baoding. During the visit to the assembly workshop, GL GH saw clear indications that the quality management system had been implemented. However, GL GH also noticed that there were no checklists or work introductions present at the workstations.

All in all, GL GH finds the quality management system of GUP to be in line with international industry standards, and the system certification by Lloyd's Register provides additional comfort on this.

GL GH also holds an ISO 14001:2004 Environmental Management System Certificate 10 copy from GUP. This certificate was issued by LRQASH on January 06, 2011 and is valid until January 05, 2014. In addition, GUP has been certified in accordance with BS OHSAS 18001:2007 Occupational Health and Safety Management System 11. This certification was issued by LRQASH on January 06, 2011 and is valid until January 05, 2014.

Neither of the above certificates is directly relevant when evaluating the product quality that one should expect from GUP. However, the fact that GUP has obtained these certificates shows that the company has a sympathetic approach to the manufacturing processes and is capable of documenting these. It therefore lends comfort that GUP treats all aspects of quality as important issues.

2.8 After-sales Service

The Guodian Wind Power Equipment Commissioning Department which belongs to GUP is in charge of turbine installation supervision, turbine commissioning and operation and maintenance (O&M) as well as related software development such as Supervisory Control and Data Acquisition (SCADA). In addition the commissioning department also defines the regulations for management, safety, quality and technical aspects related to its services, and monitors their implementation. Based on the strategy of GUP, which is that the capability of wind farm development and wind turbines O&M should be enhanced to make GUP a complete wind power solution supplier, a special engineering company created from the commissioning department will be founded this year. There will be seven sub-divisions in terms of general management, safety and quality, equipment management, production, engineering management, client services and business development.

GUP now has a service team of over 500 staff with relevant experience. There is a four-level system for spare parts store and supply. The first level comprises the central warehouse located in Baoding of Hebei province. The second level comprises six regional warehouses located in Lianyungang of Jiangsu province, Changchun of Jilin province, Baotou and Chifeng in Inner Mongolia, Zhangbei of Hebei province and Alashankou of Xinjiang province. The third level comprises warehouses for several concentrated wind farms areas. The fourth level comprises warehouses for individual wind farms. GL GH considers this four-level system can adequately support GUP's O&M work.

GUP has a 24-hour technical service hotline to ensure that spare parts and services can be delivered on time. Various technical training is provided to clients' technical staff, to let them know the technical performance of WTGs.

There is a feedback system for problems occurring on sites. Firstly, staffs on site report any problems to senior technical staff in the commissioning department. If they can not solve these problems, they will report to the R&D department and Quality department in order to find solutions. When the solutions are available, the commissioning department will be in charge of their implementation on-site.

According to GUP, it pays much attention to "on the job" training for new employees. Normally, the training is composed of three parts, safety and quality study, theoretical study and practical study. New employees will spend two months on the first two parts of the training and three months on the last training in the assembly factory, under the supervision of skilled workers.

As the SCADA system is developed by GUP itself, timely adjustments and optimizations can be given, according to clients' requirements and the actual running situations of WTGs.

As of April 16, 2011, there are a total of 72 wind farms which have been serviced by the commissioning department, 1,900 wind turbines have been installed or are being installed in these wind farms, including 1,200 wind turbines which were completed commissioning according to GUP.

GUP supplied GL GH with the Top 5 clients from 2008 to 2011, along with sales quantities. However, the quantity for 2011 is not for the whole year, as it only covers the period from January to July. Among these clients, GL GH finds that most are subsidiaries of CGDC and Longyuan. This shows the tight relationship between GUP and its affiliate companies which are wind farm developers and subsidiaries of CGDC and Longyuan. The sales quantity for the Top 5 clients of 2011 from January to July has been 519 units, which has surpassed the quantity of 2010 from January to December, which was 429 units.

2.9 Company Conclusions

GUP is a relatively new turbine manufacturer, with around a five-year history of developing, assembly, commissioning and servicing of wind turbines in the Chinese market. However, when it started the wind turbine business, GUP's predecessor had had a history (of more than 12 years) of retrofitting steam turbines for thermal power plants, which provides a basis for the quality control and service of wind turbines.

GDTE, the major shareholder of GUP, is a subsidiary of China Guodian Corporation (CGDC), which is a large, state-owned electric power utility and which owns China Longyuan Power Group Corporation Limited (Longyuan)—the largest wind farm operator in China. The connection to CGDC and LongYuan may provide market access and further growth potential for GUP in both China and the overseas' markets. GUP has been working on building up a proven track record for its turbine products, and on enhancing its in-house research and development (R&D) capabilities during the past few years.

GUP has built up an in-house R&D team, consisting of 118 staff currently in its head office currently. The team is equipped with well known software tools, including Ansys for FEM calculation and GH Bladed for turbine simulation and load calculations. The team has completed joint design work with Aerodyn and the localization of the UP1500 turbine. GUP has worked with leading wind consultants, including Aerodyn and Garrad Hassan and Partners Ltd (GHP), for new product development, performance measurement and certification, which partially offsets its relative inexperience in the industry. In parallel to R & D activities, GUP has invested resources to manage the Intellectual Property Rights (IPR) of its turbine products and technologies, including applying for patents and copyrights.

The GUP product portfolio includes a 1.5 MW platform (UP1500/70; UP1500/77; UP1500/82 and UP1500/86) with 2,223 units installed by the end of July 2011 and a new 3 MW turbine with a doubly fed induction generator (DFIG) with one unit prototype unit installed. In addition, GUP is developing three new turbine products: a 2 MW turbine with DFIG; a 3 MW direct drive (DD) turbine and a 6 MW turbine with DFIG. Amongst these turbines, the 3 MW DFIG and DD turbines and the 6 MW DFIG turbine will be appropriate for offshore application. GL GH considers that the product portfolio (including both existing and new developments) is in line with industry practice and market development in China.

GUP can currently perform the assembly of the nacelle, hub and control panels, and the manufacturing of blades, gearboxes and generators in-house. GUP has three turbine assembly facilities in operation, which are located in Baoding of Hebei province, Lianyungang of Jiangsu province and Chifeng of Inner Mongolia. The total assembly capacity is 3,900 MW per year according to GUP. Rotor blade production takes place in the three assembly facilities. In addition, GUP owns a gearbox manufacturing plant with annual capacity of 400 units in Baotou of Inner Mongolia and a generator manufacturing plant with annual production capacity of 1,000 units in Yixing of Jiangsu province. Although GUP still sources a significant portion of gearboxes and generators from external suppliers, GL GH considers that GUP is pursuing a strategy of vertically integration of key components in addition to turbine design and assembly. This is in accordance with the practice of many of the industry leaders.

GUP has a supplier selection standard in place and GL GH finds that the supply chain for GUP turbines is managed in accordance with industry practice. GL GH has visited the GUP manufacturing facility which is located in Baoding of Hebei province, China. Based on the visit to the workshops and on discussions with the GUP staff, GL GH concludes that GUP has the equipment and processes in places to manufacture wind turbines according to industry standards.

GUP and its three turbine assembly bases hold separate certificates for quality management. In addition GUP holds certificates for environmental management and OHSAS. All these certificates are in their valid period. GL GH considers that GUP has a sympathetic approach to its manufacturing processes and quality management system. This lends comfort that GUP treats all aspects of quality as important issues.

GUP has built up a turbine commissioning and service team with over 500 staff working in its after-sales department. GUP is enhancing its capability for wind farm operation and maintenance (O&M), aiming to provide complete solutions to its clients. GL GH considers this strategy to be common in the industry and it is being adopted by several other leading wind turbine manufacturers.

In summary, GUP is equipped with most of the essential elements (turbine products, in-house R&D, turbine assembly and key component production facilities, supply chain management, quality control and after-sales service team) that are required to become a leading wind turbine manufacturer in the wind industry. Despite the relatively short history of its turbine manufacturing business, GUP has demonstrated early stage success in the Chinese market. GL GH considers that GUP has the potential to grow its business in China, if it continues to execute its strategies of product development, supply chain management, services and quality control in efficient ways despite the increasing competition. GL GH has noted that GUP is working in a few overseas markets (including South Africa and the US) and its connection with Longyuan may provide access to new markets.

3 UP1500 TURBINE

3.1 General Description of Turbine

The GUP UP1500 turbine platform includes four turbine versions: the UP1500/70, the UP1500/77, UP1500/82, and the UP1500/86. These turbines are nearly identical; the principal difference between them is the rotor diameter, along with other resultant modifications, such as rotational speed. Design wind class is adjusted for the individual variant of turbine, in order to compensate for the larger rotor. The turbine loading behind the rotor is similar across the four variants.

The UP1500 turbine is a 3-bladed, horizontal axis, upwind, pitch regulated turbine, incorporating a doubly fed induction generator which provides variable speed operation over a range of ± 30 % of nominal speed. A picture of an UP1500/77 is shown in Figure 3.1.

Figure 3.1—UP1500/77 turbine

The UP1500 turbine has a number of basic characteristics which are recognized as industry standards, including electric pitch control and variable speed via a doubly fed induction generator.

The three variants of the UP1500 (the UP1500/77, UP1500/82 and UP1500/86) are designed for medium and low wind speed sites e.g. the UP1500/77 for IEC wind class IIA, the UP1500/82 for IEC wind class IIIA and the UP1500/86 for IEC wind class IIIB. The UP1500/70 is designed for high wind speed sites for IEC class IA. However, the UP1500/70 is a new model and is under development. So currently, the UP1500/77, UP1500/82 and UP1500/86 are three main variants among GUP UP1500 products. The description and comments below are based on these three main variants.

In addition to the three main variants of the UP1500, there are also variants available to accommodate special site conditions.

A high altitude variant for installation at up to 4,000 metres above sea level (ASL) is the UP1500/86, with modification to the design of the electrical components in order to compensate for the decreased cooling effect of the air at low air density. It should be noted that most turbines today only are designed for installation at up to 1,000 metres ASL.

Variants of the UP1500/77, UP1500/82 and UP1500/86, for coastal areas, have improved corrosion protection and modifications to the ventilation of the nacelle, ensuring that all air going into the nacelle is filtered. These variants also include modifications to the cooling system for the generator and gearbox, ensuring that the air need for cooling of these components does not need to be taken through the nacelle.

The UP1500/77, UP1500/82 and UP1500/86 are designed for a 50 Hz grid. However, there is a 60 HZ version of the UP1500/82 available, which is suitable for installation in countries using a 60 Hz grid, such as North America.

Table 3.1 presents a summary of the main characteristics of the UP1500/77, UP1500/82 and UP1500/86 turbines.

Model	UP1500/77	UP1500/82	UP1500/86
Hub height	65 m and 75 m	65 m and 80 m	75 - 80 m
Rotor diameter	77. m	82 m	86 m
Rated power	1500 kW	1500 kW	1500 kW
IEC classification	IIA	IIIA	IIIB
No. of rotor blades	3	3	3
Rotor orientation	Upwind	Upwind	Upwind
Rotor tilt	5°	5°	5°
Rotor coning	3.5°	3.5°	3.5°
Power regulation	Blade pitching and variable rotor speed	Blade pitching and variable rotor speed	Blade pitching and variable rotor speed
Rotational speed	9.7 to 19.5 rpm	9.7 to 19.5 rpm	9.7 to 19.5 rpm
Rotational speed at rated power	17.4 rpm	17.4 rpm	17.4 rpm
Blades supplier	GUP Type: UP37.5	GUP Type: UP40.25	GUP Type: UP42
Generator supplier	XEMC DFWG-1500/4 12	XEMC DFWG-1500/4 13	XEMC DFWG-1500/4 14
Gearbox supplier	NGC PPSC1290MY 12	NGC PPSC1290MY 13	NGC FD1660 14
Tower	Tubular steel	Tubular steel	Tubular steel

Table 3.1—Summary description of the UP1500/77/82/86 turbines

The GUP 1.5 MW turbine platform includes turbine versions which are suitable for a wide range of site conditions.

3.2 Turbine Technology

The turbine is entirely conventional; the rotor is connected to a cast spherical hub, using three pitch bearings in a slew ring configuration. The rotor shaft is made from forged steel, and is supported by two spherical roller main bearings. The bedplate is a welded construction. The generator is located on the rear of the bedplate. All main electrical equipments, including the converter and transformer, are located at the base of the tower.

Sub System / Component	Proven Industry Concept
Rotor blades	✓
Hub	✓
Pitch system	✓
Main shaft / bearing	✓
Gearbox	✓
Generator	✓
Converter	✓
Yaw system	✓
Tower	✓
Control system	✓

Table 3.2—Comparison of UP1500 technology with the industry standard

As illustrated in Table 3.2 above, the concepts used in the UP1500 turbine are based on technologies which have already been proven in the wind industry.

A more detailed description of the turbine components is presented in the following sections.

3.2.1 Rotor Blade

The blades for the UP1500/77 (the UP37.5) and UP1500/82 (the UP40.25) are designed by Aerodyn. Aerodyn has designed a large number of different blades over the years, from small blades for a 20 kW turbine to large blades for 5.0 MW turbines. However, the blades for the UP1500/86 (the UP42) are designed by GUP.

The structure of the blades incorporates two longitudinal webs, and these are made of glass fibre reinforced epoxy (GFRE). A sandwich construction is used for the two shells of the blades, with a core of PVC plastic foam and GFRE; a design that is commonly used for blades of this size.

The blades are manufactured by GUP, and the manufacturing process used is the vacuum infusion of resin method, a process that is commonly used in the wind industry for the manufacture of blades.

The UP37.5 and UP40.25 blades are certified by GL 15,16, according to the GL Guideline for Certification of Wind Turbines, Edition 2003, with Supplement 2004. GL GH considers that the certification of the blades adds comfort to their structural design. Part of the documentation reviewed by GL is the test results from the static load testing, according to IEC

TS 61400-23. This test has also been witnessed by GL Renewable Certification. However, fatigue load testing—normally performed according to “Wind Turbine Generator Systems—Part 23: Full Scale Structural Testing of Rotor Blades, 2001-04”—has not been performed on the UP40.25 blades. GL GH advises that fatigue testing of blades is consistent with industry best practice and is typically performed by top-tier international turbine suppliers, despite the fact that it is not specifically recommended by the design guidelines.

Fatigue load testing of blade design is performed to verify the structure strength of the blade with regard to the fluctuating loading which the blade is subject to during the operation of the turbine. The failure mechanism from the fluctuating loading is different from the failure mechanism from the static loading (extreme loads). Therefore, the standard static extreme load testing will not reveal the shortcoming in the structure design of the blade with regard to the ability to withstand fluctuating loading (fatigue loading). Therefore, the risk of getting failures due to the fatigue loading is higher for the blade which has not been subject to fatigue load testing.

However, the fatigue load testing is costly and time consuming. It will normally take 3 to 6 months to perform the fatigue load testing. It is noted by GL GH that although it is the normal practice for the international blade manufacturers, it is not the normal practice for Chinese blade manufacturers. And it is not a compulsory requirement to perform such test according to the current technical standards in China. However, GL GH would recommend that full fatigue load testing is performed on any blade design. But GL GH considers that the GL certification of the blades adds comfort to their structural design. According to GUP, there have not been any issues reported due to the fatigue load testing not being performed up to date.

The information provided on the UP42 blades had been very limited and GL GH is not aware of the status of certification and testing performed on the design of this blade.

3.2.2 Pitch System and Rotor Hub

The UP1500 turbine uses a double-row four-point contact ball bearing to connect the blade to the hub. The gearing and pitch bearing are manually greased, and re-greasing is required once every six months. It is becoming common for modern turbines to be equipped with an automatic greasing system for the pitch bearings, in order to ensure the proper lubrication of pitch bearings at all times. According to GUP, the automatic greasing system can be supplied with the turbine as an option.

The blade position is controlled by three electric motors, one acting on each blade. During normal operating conditions, when the turbine is connected to the grid, the motors are powered from the grid. In the event of grid loss or emergency braking, power is provided via a set of batteries or super capacitors for each motor.

The UP1500 turbine uses independent, electric blade pitch actuation. This concept is now relatively common in larger variable-pitch turbines. Although each blade can pitch independently, an identical control signal is sent to each drive motor.

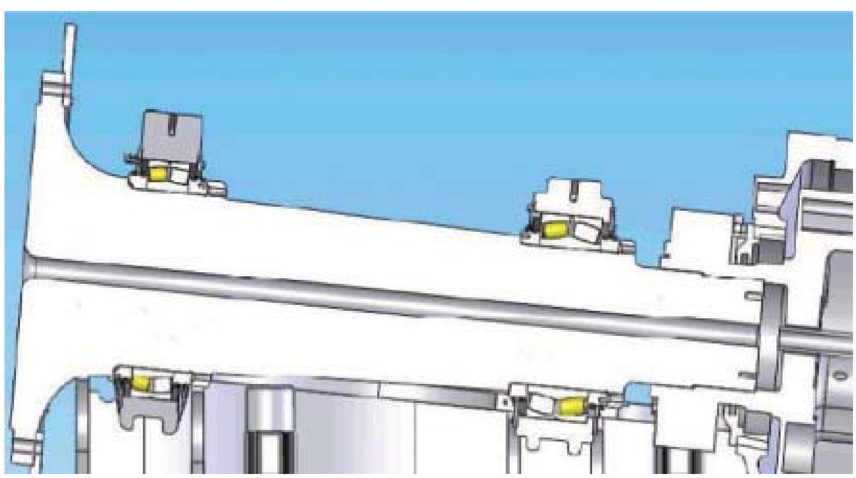
The pitch system also provides the primary source of braking for the turbine, and the independent pitch capability provides the necessary redundancy. On turbines of this size, this is considered to be standard practice.

The hub is a machined casting.

The supplier of the pitch system motors and associated control is either Lust DriveTronics GMBH, which is now owned by MOOG, Inc., or SSB. Both SSB and Lust are experienced suppliers of electric pitch systems to the wind industry.

3.2.3 Drive Train and Gearbox

The UP1500 turbine uses a common shaft support arrangement, utilizing two spherical roller bearings (one at the rotor end, and one at the gearbox), as presented in Figure 3.2. The front bearing is a non-located bearing, which means that the back bearing will take the entire thrust load from the rotor of the turbine. The concept is commonplace in wind turbine design and it is proven.



1 Source GUP 17

Figure 3.2—UP1500 main shaft

The main bearing is manually grease lubricated, and re-greasing is required once every six months. It is becoming common for modern turbines to be equipped with an automatic greasing system for the main bearings, to ensure proper lubrication of the main bearings at all times. According to GUP, such system can be supplied as an option.

The gearbox is a three-stage unit. The high speed (or output) stage is a parallel shaft arrangement. The two low-speed stages are planetary arrangements. The gearbox is manufactured by NGC.

The gearbox is force lubricated. It is equipped with a cooling and filtering system for the gearbox oil, which incorporates a 10/50 µm inline filter. The gearbox is not, as standard, equipped with an offline filter system, which is becoming more and more common in the industry. However, an offline filter system is available as an option. GL GH recommends that this option is taken by any potential customer for the UP1500 turbine. The reason for this is that the reliability of the gearbox is improved when the cleanliness level of the gearbox oil is improved.

The expected cleanliness level of the gearbox oil during operation of the turbine is 17/15/12, according to ISO4406:1999, and this is along the lines of the industry standard. However, GUP has not provided GL GH with data from operating turbines in order to verify this.

As part of GUP's own design verification process in the full load test stand (see section 2.6), GUP has undertaken testing of the gearbox, including the following tests at some load steps (up to rated power):

- Tooth contact pattern;
- Lubrication testing;
- Temperature testing.

The workshop testing is more-or-less in line with industry standards. In recent years, some manufacturers have introduced accelerated lifetime testing, which was not part of the workshop testing performed by GUP. Such Highly Accelerated Lifetime Testing (HALT) might include:

- Gearbox operation at elevated torque levels;
- Load peaks in the range of -200 % to 300 %;
- Test duration ~500 h, without failure;
- High numbers of measurement channels (~60);
- Frequent visual inspection and oil sampling (e.g. every 80 h);
- Gearbox endoscopy at 160 h and 320 h;
- Disassembly, after testing and detailed checking.

GL GH considers that HALT contributes to confidence in the design. However, HALT of the gearbox is not a requirement for certification of the turbine. It is of significant importance for newly launched turbines and/or gearboxes. As turbine operating track record is gained, the importance of the testing lessens.

The cooling system for the UP1500 was originally designed as an oil-to-water-to-air cooling system. However, GUP has modified the design to an oil-to-air system.

3.2.4 Generator

The UP1500 uses a high-speed doubly fed generator, with a wound rotor and slip ring. This is the most common generator type used in the wind industry at present, and the technology, design and manufacture of these units is well understood.

The rotor is connected, via the slip ring, to the converter. This generator arrangement is fundamentally less reliable than a simple induction generator. The main sources of unreliability are the slip rings and associated brushes. The brushes wear, and require adjustment and cleaning. However, the design of slip rings is improving, and many such implementations provide reliable service.

One of the generator suppliers is XEMC with the model DFWG-1500/4.

The generator cooling system is an air-to-air heat exchanger system. The lower housing of the generator contains the active electrical part of the generator, stator and rotor. On top is housing, consisting of a heat exchanger with tubes pointing in the axial direction of the generator. There is an inner cooling air circuit, where the air will not come directly into contact with the outside ambient air; this concept is common and proven.

As far as GL GH understands, the prototype generator has undergone workshop testing that is in line with the industry standard.

3.2.5 Power Converter

The power converter associated with the UP1500 is located on a platform at the base of the turbine tower. Locating the power converter in the tower base has the advantage of ease of access for maintenance and repair; this is significant, given that the converter is a major point of failure and is a contributor to downtime in modern wind turbines. Locating the converter in the base also avoids the issue of vibrations present in the nacelle.

The disadvantage of locating the converter in the tower base lies in the fact that two sets of three phase (low voltage) cables (for the stator and rotor circuits) are required to run from the generator down the tower. Although this results in a significant number of flexible cables running down the tower, this type of design is common in the industry, and it should not present a significant risk to a purchaser.

GL GH understands that the converter will be provided by ABB, which is considered to be an experienced supplier of converters to the wind industry. It should be noted that GUP stated that other qualified suppliers can be used.

The cooling of the converter is carried out through an air-to-air cooling system, using the air in the tower. This may be an issue in high ambient temperature applications.

As stated previously, power converters are often the cause of a significant number of turbine faults. However, most converter problems can be addressed through the replacement of component parts. Therefore, these issues do not necessarily result in significant downtime, as long as sufficient spare parts are held by the maintenance provider at an appropriate location.

3.2.6 Yaw System

A slew ring bearing (four-point contact ball bearing) is used to connect the tower to the machine bedplate (a welded construction). The bearing allows the rotor to be orientated to face the wind. The orientation of the turbine is controlled by four electric geared motors, equipped with motor brakes.

In addition to the brakes on the yaw motors, there are ten passive brakes acting on the brake disk (mounted on the top of the tower), in order to maintain the nacelle position when the turbine is not yawing. This is a standard configuration.

The gearing and yaw bearing are manually greased, and re-greasing is required once every six months. It is becoming common for modern turbines to be equipped with an automatic greasing system for the yaw bearing, to ensure proper lubrication of the yaw bearing at all times. According to GUP, the automatic greasing system can be supplied with the turbine as an option.

The yaw bearing is supplied by LYC and the yaw brakes are supplied by Svendborg brakes. It should be noted that GUP stated that other qualified suppliers can be used.

3.2.7 Tower

The UP1500 wind turbine is available with tubular steel towers, giving hub heights of 65, 75 and 80 metres, depending on the turbine type. The tower is made from a tubular steel construction, similar to the towers supplied by other turbine manufacturers, and it is in line with industry standards.

The converter, main switch and control cabinet are located at the bottom of the tower. The main transformer is, as standard, placed in a small building outside the tower. As an option, GUP can provide a tower design with the transformer located in the tower bottom. However, GUP expects that additional cooling of the converter will be needed in this case.

As an option, GUP can provide towers with a lift. GL GH recommends that any prospective purchaser of the turbine confirms that the equipment configuration, complies with local Health and Safety requirements.

3.3 Turbine Technical Assessment

3.3.1 Certification Status

There are three design classes that are typically used internationally, for the purposes of certification. These are Classes I, II and III of the International Electrotechnical Committee's standard IEC 61400-1. Class I is the most severe, with a mean wind speed of 10 m/s, Class II requires a mean wind speed of 8.5 m/s be considered, and Class III requires a mean wind speed of 7.5 m/s.

The UP1500/77/82/86 holds design certification, issued by the China Classification Society (CCS) and China General Certification (CGC, according to the CCS and CGC rules for wind turbine generator systems for IEC wind class—as shown in Table 3.3.

Model	Hub Height	IEC Wind Class	Issued By	Issued Date
UP1500/77	65 m	IEC IIA	CCS	May 2011 20
UP1500/77	65 m	IEC IIA	CGC	September 2009 21
UP1500/77	75 m	IEC IIA+[1]	CCS	May 2011 12
UP1500/82	65 m	IEC IIIA+	CCS	May 2011 13
UP1500/82	80 m	IEC IIIA and IEC IIIA+	CCS	May 2011 18,19
UP1500/86	78.744 m	IEC IIIB	CGC	September 2010 14

1 The + indicates that the extreme wind speed conduction has been increased for the certification, compared to the standard IEC definition—see Table 3.4.

Table 3.3—UP1500 design certification by CCS and CGC

CCS is a specialized international inspection body which is authorized by international organizations and governments to provide inspection, certification and technical service for transportation, offshore exploitation, energy, manufacture, service, trade and insurance industries, through the provision of technical criteria and standards on ships, offshore facilities and other land-based industrial products. Its on-land inspection and certification businesses are undertaken by China Classification Society Certification (CCSC).

CCSC is an organization which was established in 1992 and was duly registered by the State Administration of Industry and Commerce in China to perform management system certification business; it is one of the earliest certification bodies in China. It is approved by Certification and Accreditation Administration of China (CNCA) and accredited by China National Accreditation Service for Conformity Assessment (CNAS) and the United Kingdom Accreditation Service (UKAS). Since its reorganization in April 2008, it has completed the integration of its four major businesses, i.e. system certification, product certification, industrial product inspection and container inspection. CCS has its own rule—Wind Turbine Standard for its certification, which is mainly in accordance with IEC 61400.

CGC was founded in 2003 and it is backed by the National Institute of Metrology, which is subordinate to the State General Administration of Quality Supervision, Inspection and Quarantine of China. CGC has its own rules and also uses the GL guidelines for certification.

The UP1500/77, with a hub height of 65 metres, has obtained certification from CGC 21, according to the modules of the WT01:2001 standard for design evaluation, type testing and manufacturing evaluation. These are all the modules, according to WT01:2001, that are needed to obtain full Type certification. Therefore, GL GH considers this certification to be equal to a Type certification, even though the certificate does not state this specifically. The Type certification of the UP1500/77 is according to Wind Class IIA, with extension of the operating and extreme temperature range, according to cold climate conditions. The certification was issued in September 2009. Type certification is the highest level of certification, according to the IEC rules (of which design certification is just one part). Full type certifications of any turbine provide the highest level of comfort possible.

The type certification scheme (according to IEC WT01:2001) is divided into three modules which are mandatory and two modules which that are optional. It is possible to obtain certification for each of these modules. A description of the IEC WT 01:2001 certification scheme is given in Appendix I.

GUP has also obtained a C-Design Certification for the UP1500/77 with a hub height of 65 m (for IEC wind class IIA conditions), issued by GL Renewable Certification 22 and acceding to the GL Guidelines for the Certification of Wind Turbines, Edition 2003. The GL Guidelines are based on the IEC standard IEC 61400-1 for design certification. This provides some further comfort that the turbine has been designed in accordance with IEC standards. However it should be noted that a design certification of Type C is only valid for the installation of a prototype turbine. The GL certification was issued in February 2009, and is only valid until February 2011, or for 4,000 full load hours of operation of the turbine. So this certificate has expired.

According to GUP, it has signed a contact with GL Renewable Certification for an A-design certification and a Type certification of the UP1500/77 for IEC IIA conditions. In addition, DEWI is undertaking the test in the Alashankou wind farm for UP1500/77 Type Certification. GUP is working with GL RC on the A-Design assessment and is expecting to get the certificate by the end of 2011.

The IEC Class IIIB, IIIA and IIA design conditions are presented in Table 3.4:

Parameter	Class IIIB	Class IIIA	Class IIIA+	Class IIA	Class IIA+
Mean wind speed, m/s	7.5	7.5	7.5	8.5	8.5
Extreme wind speed, m/s	52.5	52.5	59.5	59.5	70.0
Turbulence, %	16.0	18.0	18.0	18.0	18.0
Density, kg/m^3	1.225	1.225	1.225	1.225	1.225
Wind Flow Angle, degrees	8	8	8	8	8

Table 3.4—IEC Class IIIB, IIIA & IIA conditions

The design certifications issued by GL, CCS and CGC for the UP1500 turbines provide significant comfort.

The UP1500 turbines are designed to withstand the conditions that are shown in Table 3.5, with regard to temperature, and these temperature conditions have been included in the turbine certification issued by CCS.

	UP1500	IEC Range
Operating Temperature Range	-30^o C to +40^o C	-10^o C to +30^o C
Standby Temperature Range	-40^o C to +50^o C	-20^o C to +40^o C

Table 3.5—Temperature range

3.3.2 Grid Compliance

The UP1500 turbine is a full-span pitch regulated turbine, with a doubly-fed induction generator. This means that the turbine is (partially) variable speed, and that it uses a partly rated (AC-to-DC-to-AC) power converter for the generator rotor circuit. The generator stator remains directly connected to the grid.

Electrical machines with the doubly-fed configuration have been common in recent years and are flexible enough to meet most Grid Code requirements, perhaps with some adjustments.

The main sources of technical information used to evaluate the grid code compatibility of the turbines have been the wind turbine specification 23, as well as power quality 24 and low voltage ride through 25 test certificates. The power quality certificate relates to tests of a GUP UP1500/77-IIA wind turbine, and the fault ride through certificate relates to tests of a UP1500/82 turbine. Although the test reports relate to two different turbine types, i.e. the UP1500/77 and UP1500/82, GL GH finds that the turbines are part of the same family with the same drive train implementation and similar controller implementations, so that the results can be assumed to represent the performance to be expected from the UP1500 range.

The certificates have been issued by the China Electric Power Research Institute (CEPRI) who undertook the testing of the UP turbines during late 2009 and early 2010. The CEPRI was established in 1952 and is a multi-disciplinary and comprehensive research institute in China's electric power sector as well as a subsidiary research institute of the State Grid Corporation of China (SGCC). Its research areas include power generation, transmission, distribution, power supply and utilization, electric project design, construction, commissioning, operation, monitoring and maintenance as well as renewable energy etc. The Renewable Energy Research Institute is one of CEPRI's institutes and was established in 1994. It is one of the earliest research institutes for wind energy in China. Currently there are four departments, a grid connection research department, a resource assessment department, a renewable energy generation department and a solar energy department.

The CEPRI has been establishing its testing facilities for wind turbines over several years. Now it can perform tests for power quality, LVRT and acoustic noise, etc. The Wind Power Technology and Testing Research Centre have been set up recently in Zhangbei county of Hebei province with an area of 24.6 km2. It is now the largest and the most advanced testing center in China. However, GL GH's experience with CEPRI is limited to China.

The converter is an ACS 800-67 model from ABB, with an active crowbar which has been used on several wind turbine DFIG implementations. ABB is considered to be one of the world leaders in this type of technology implementation. GL GH considers that a turbine designed with the ABB converter and active crowbar topology should be suitable for allowing compliance with modern grid requirements relating to the performance of the electrical drive (such as power quality and fault ride through etc).

Table 3.6 summarizes the capabilities of the UP 1500 turbine, with respect to Grid Codes 25 and other issues, as identifiable.

Grid Code Requirement	Comments
Power control	Capable. (Wind farm control system to be confirmed.)
Ramp rate	Capable. Turbine maximum ramp rate 15 % of rated power per second.
Reactive power provision	Capable. PF range from capacitive 0.95 leading to inductive 0.95 lagging.
Voltage control	Inherently capable, but requires provision of wind farm control system (which is tbc)
Voltage tolerance	Range 690 VAC ± 10 %.
LVRT	Capable.
Frequency tolerance	Capable within the range 48.5 Hz to 51.5 Hz on 50 Hz grid. Extension of the range for abnormal frequencies may be required.
Frequency control	Capability unknown.
Power quality—flicker	Typical factors for DFIG technology.
Power quality—harmonics	THD (current) = 2.3 %.

Table 3.6—Summary table of main Grid Code requirements for the UP1500

Modern grid codes require wind turbines to be capable of riding through low voltage events which may occur as a result of major faults on the transmission system. A typical requirement is represented in Figure 3.3 which illustrates the fault ride through requirements for the proposed Grid Code for China as represented in standard GB/T 19963—20.

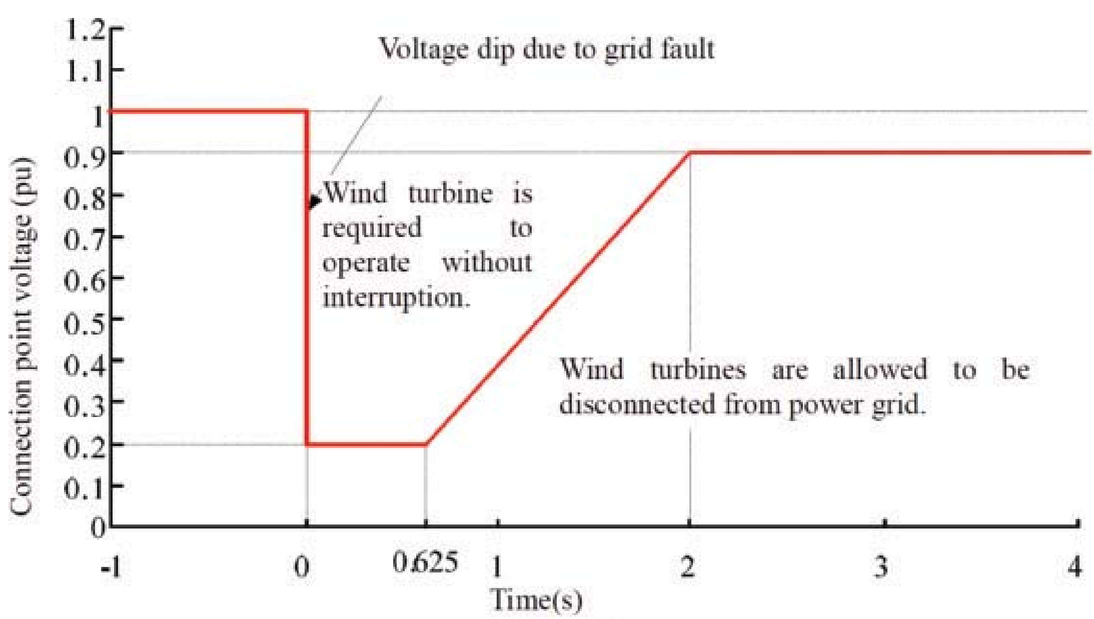


Figure 3.3—Fault Ride Through Performance requirements of proposed Chinese Grid Code GB/T 19963—20

GL GH has reviewed the fault ride through certificate 26 extracted from the test report produced for the UP1500/82 turbine installed in the Shuanglong Wind Farm in China. According to GUP, UP1500/82 is the first turbine in China which passed the LVRT test done by CEPRI. The document states that the basis for the tests was IEC 61400-21:2008, which relates to the measurement and assessment of power quality of grid connected wind turbines. The performance of the wind turbine has been tested against the Technical Regulations for wind farms accessing the grid (Q/GDW392-2009) as issued by the State Grid.

The table of results representing tests at various power levels and sustained voltage depression levels, has been provided. The results represent the requirements in IEC 61400-21:2008 and the figures presented indicate the turbine operation during low voltage events is in compliance with the 20% voltage ride through curve represented in Figure 3.3.

Although GL GH has not seen the details of the test report the results presented confirm that the turbine has been tested in accordance with international standard IEC 61400-21:2008 and complies with the requirements of the latest version of the Grid Code for China. Given the results of the tests provided for review GL GH considers the fault ride through performance of the UP1500 turbine to be in line with current industry practice.

GL GH also notes that recent tests by GL Garrad Hassan Deutschland GmbH in China 27 indicate that the UP1500 turbine can stay connected for faults across two to three phases, which causes voltage dips to 0 Volts, and that in such conditions the turbine can remain connected for 200 ms. So, the CEPRI test shows compliance with the current Chinese grid code and the GL Garrad Hassan Deutschland GmbH tests confirm it can perform to a higher standard than is currently required in China. GL GH notes that this capability is a useful function given the continuous evolution of Grid Codes around the world, and the fact that many already demand so-called ‘Zero Voltage Ride Through (ZVRT)’ capability.

An example of a market where such a capability is required is the German market, as per the Figure 3.4 below taken from the German Offshore Grid Code 28 which shows that connected generation must be capable of staying connected for 150ms at conditions down to zero voltage conditions.

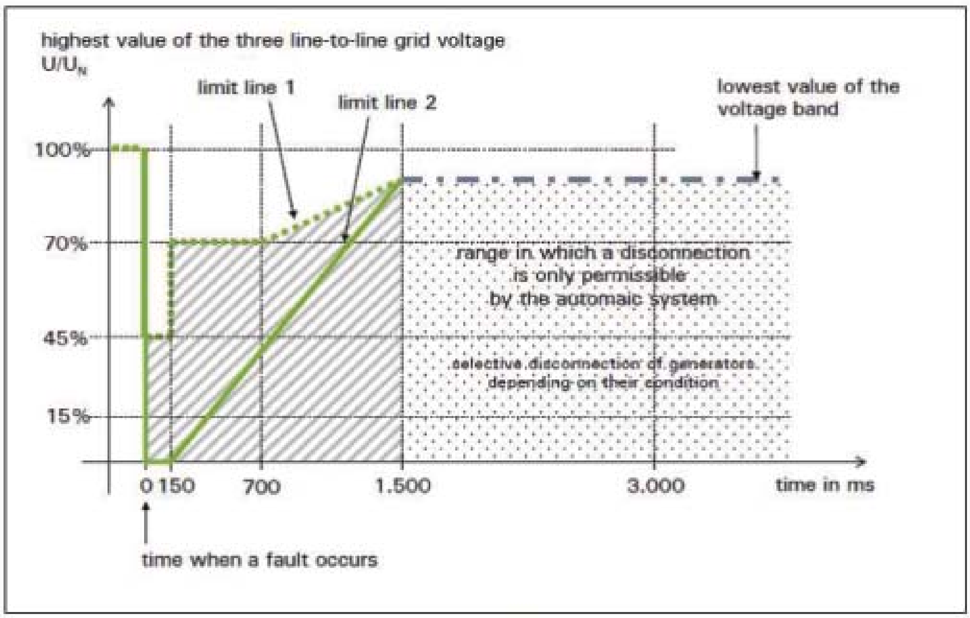


Figure 6 Limit curves for the voltage/time pattern at the grid connection for Type 2 generating plants in the event of a fault in the grid

Figure 3.4: Fault Ride Through requirements for offshore German installations

In general, GL GH expects that the UP1500 turbine will be able to meet the grid code requirement in China; however, in some cases GL GH has not been provided with the information to confirm this. GL GH additionally notes the Zero Voltage Ride Through capability of the UP1500 machine.

3.3.3 SCADA

The SCADA system on any wind project must provide three important functions. These are:

- Facilitate the O&M of the project;
- Collect data for reporting and for warranty claims, if required; and
- Control the wind farm in accordance with the requirements of the revised Grid Code.

GUP offers a SCADA system that, according to the GL GH understanding, is developed in-house. The system is capable of facilitating the O&M of a wind farm, and of providing data for reporting, including warranty claims.

According to GUP, the SCADA supports the functionality of wind farm control in accordance with the requirements of the revised Grid Code. GUP has provided GL GH with a description of reactive power control and active power control at park level. This clearly indicated that the system is capable of providing wind farm control. However, GL GH has not been able to verify whether the control fully meets the grid code requirements.

3.3.4 Lightning Protection

The lightning protection system is (according to GUP) dimensioned according to IEC TR 61400-24 for lightning protection Class 1 level, which is the highest range of protection. The lightning protection system is also designed according to IEC 62305-2/3/4 and the GL guidelines for certification of wind turbines. Based on the description of lightning protection systems provided by GUP, GL GH has no reason to question this.

The lightning protection system incorporates a receptor in the tip of each blade. There is a slip ring/brush system to divert direct lightning current away from the main bearings and the yaw bearing.

The lightning current is directed away from the pitch bearing by means of a cable which connects the lightning conductor in the blade to the hub.

It is noted that there is no faraday cage protecting the nacelle, as GUP assumes that a lightning rod and steel frame on the nacelle and blades will provide sufficient protection for the nacelle.

GL GH finds that the design of the lightning protection system is typical for a multi-megawatt wind turbine.

3.4 Power Curve

The power curves for the UP1500/77/82/86 turbine have been calculated by GUP, as is shown in the Turbine Technical Specification from GUP. The power curve and corresponding power curve efficiency (Cp) for the UP1500/77/82/86 is shown in the figures below.

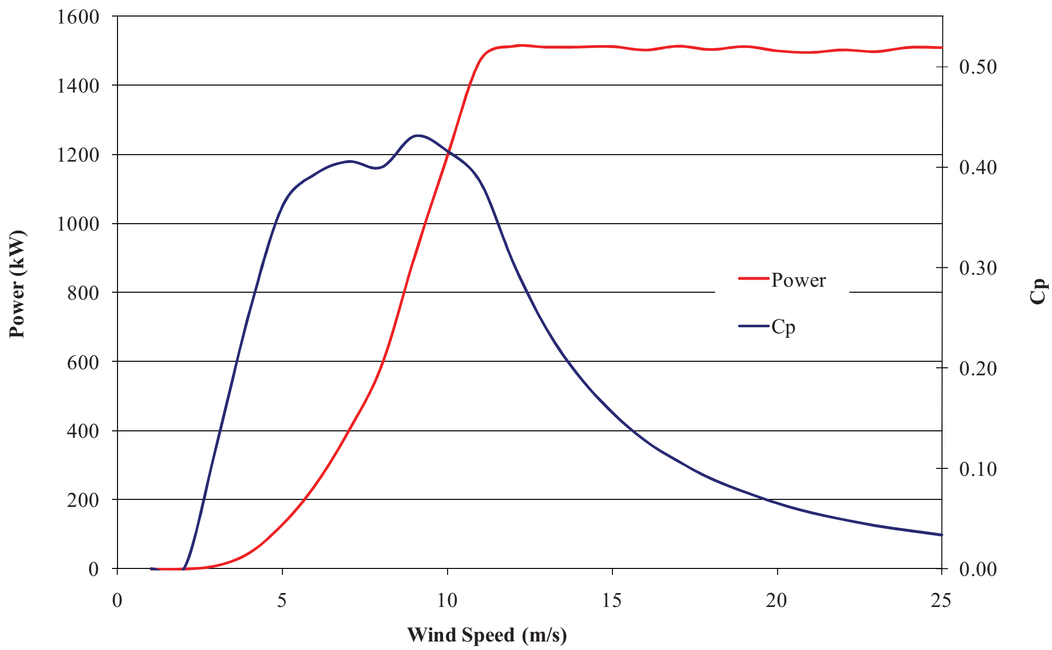


Figure 3.5—Power curve and Cp for the UP1500/77

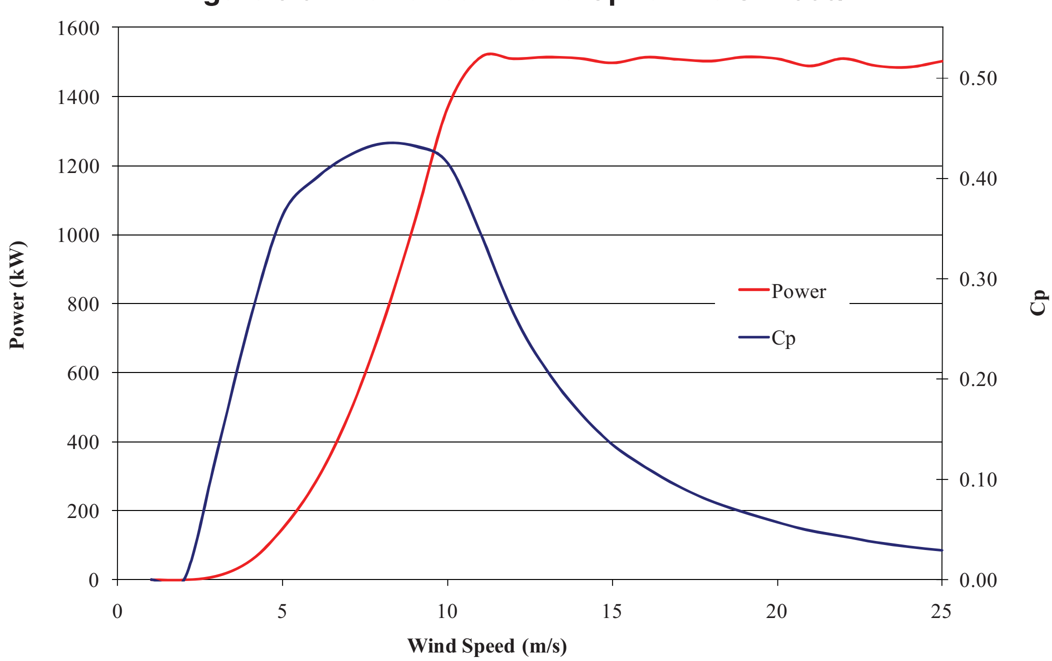


Figure 3.6—Power curve and Cp for the UP1500/82

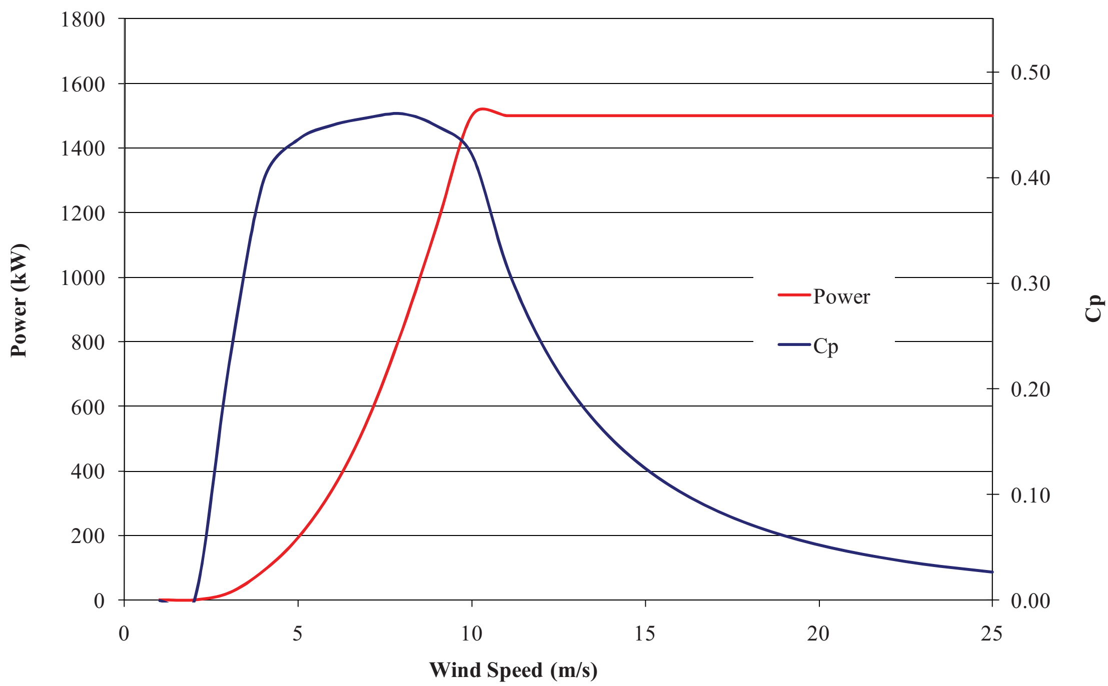


Figure 3.7—Power curve and Cp for the UP1500/86

GL GH has analyzed the calculated power curves provided for the UP1500/77/82/86 by comparing the Cp curve to other selected turbine types (of similar size and design concept) from other manufacturers. The comparison of the Cp curves shows that the Cp curve for the UP1500 is in accordance with expectations. Therefore, GL GH would not expect that it would be an issue for the UP1500 turbines to meet the calculated power curve. However, GL GH always recommends that a power performance test is carried out (according to IEC 61400-12) by an independent and suitably qualified third party.

A measurement has been performed on a UP1500/82 turbine, located at the Changling site, Jilin Province, China, from December 11, 2010 to April 26, 2011, by GL Garrad Hassan Deutschland GmbH. GL GH has seen the report from this measurement 29 and the measurement has been performed according to the industry standard (IEC 61400-12-1) without any deviations from this standard.

In Figure 3.6, the measured power curve is compared to the calculated power curves for the UP1500/82 by comparing the power curve efficiency (Cp).

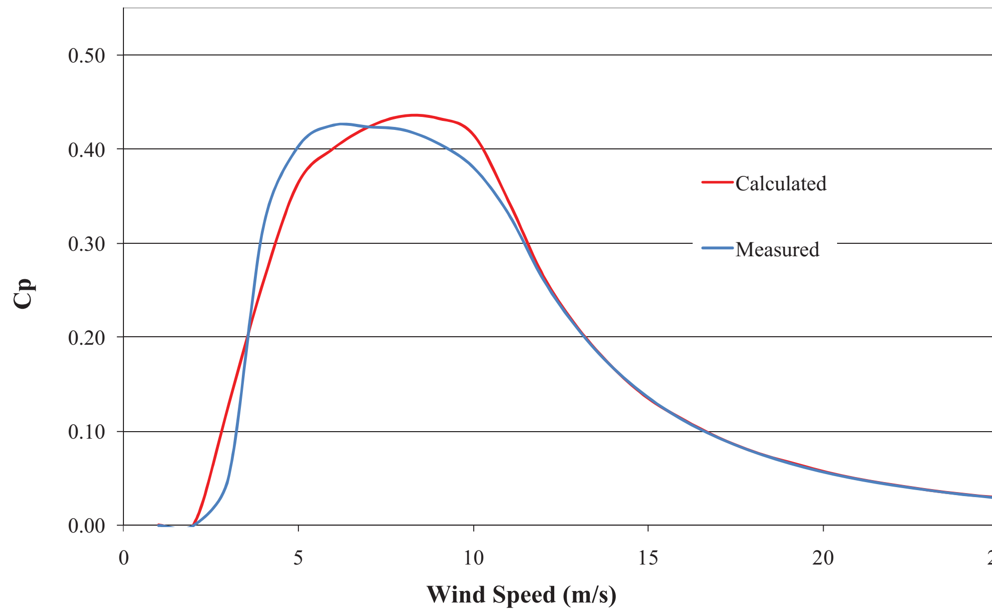


Figure 3.8—Cp curve for the UP1500/82

The comparison shows that the UP1500/82 is underperforming at some wind speeds and over performing at other wind speeds. Overall, the effect on the power output from the turbine is around 2% underperformance for sites, with a mean wind speed of between 6 m/s to 8 m/s. The comparison shows that the UP1500/82 may not be able to comply with the calculated power curve. However, this is still well within the uncertainty of the power curve measurement and the uncertainty of this measurement exists for any power curve measurement. Therefore, GL GH finds that the measurement confirms the power curve of the UP1500/82 following its calculated figures.

GL GH has no information on the power curve tested by a third party for the UP1500/77 and UP1500/86; therefore, it cannot comment on this.

In summary, GL GH finds that the power curves for the UP1500 turbines are in line with other 1.5 MW turbines offered to the market in China. However, GUP still needs to complete the verification measurement of power curves for the UP1500/77 and UP1500/86.

3.5 Acoustic Noise

The noise level of the UP1500/82 turbine was measured by CEPRI in March 2010, on a turbine in the Shuanglong Wind Farm, Changling, Jilin Province of China. The measurement was performed according to IEC 61400-11 Ed. 2.1 30.

The sound power level, at a wind speed of 10 m/s and at a height of 10 metres, is 105.4 dB(A); it is 105.1 dB(A) at 8 m/s, at the same height. The noise level measured is in line with what GL GH would expect for a turbine such as the UP1500/82.

The turbine produces no audible tones, according to the 61400-11 standard.

GL GH has no information on the noise level for the UP1500/77 and UP1500/86; therefore, it cannot comment on this.

3.6 Turbine Historical Performance

3.6.1 Turbine Track Record

The first three units (prototypes) of the UP1500/77 were installed during 2008, and these were in operation by October 2008.

The first wind farm project with UP1500/77 was installed during 2009. This wind farm has two phases and 66 units installed. All of these units were in operation by the end of August 2009.

The first wind farm project with the UP1500/82 was installed during 2009 and all units were in operation by December 2009. This wind farm has 33 units installed.

The UP1500/86 turbine is relatively new compared to the UP1500/77 and UP1500/82. GUP provided GL GH with availability data for only one wind farm using the UP86. This wind farm has 33 units and all units were in operation by April 2011.

GUP has installed a considerable number of the UP1500 turbines since 2009—a relatively short time period. According to GUP, as of the end of July 2011, 2,223 units of the UP1500 had been installed or were being installed, of which 704 units are UP1500/77, 1,344 unites are UP1500/82 and 175 units are UP1500/86.

3.6.2 Turbine Availability

In general, GUP warrants an availability of 95 % as an average for a complete wind farm within a two-year warranty period.

GUP defines the availability of a turbine in the turbine supply agreement as:

$$\text{Availability} = [1\text{-}A/24\times365]\times100\%$$

Wherein:

- A is the downtime hours for the unit, not including the following situation:
  - — Grid fault and power outage;
  - — Weather conditions (including wind conditions and environment temperature) exceeding the operational range of the technical specifications;

— Force majeure; and

— Scheduled maintenance defined in the agreement (three times the first year, twice the second year, not exceeding 20 hours each time).

GUP includes maintenance time in its availability calculation, which is limited to 60 hours in the first year and 40 hours in the second year. In the GL GH definition of availability, maintenance time is allocated as downtime, and this difference in the definition of availability corresponds to around 0.5 % of availability.

GUP has provided GL GH with information on monthly availability from January 2010 to June 2011 for eighteen wind farms, all with UP1500/77, UP1500/82 or UP1500/86 turbines installed. The data provided is shown in Table 3.7, where availability is as per the GUP definition. The wind farm names are considered to be confidential by GUP.

	Type	Units	2010 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2011 Jan	Feb	Mar	Apr	May	Jun	Ave.
WF-1	UP1500/77	66	96.2	98.7	98.0	99.5	98.7	98.9	93.9	98.7	99.2	98.9	98.9	97.2	98.3	98.1	98.8	99.1	99.3	98.7	**98.3**
WF-2	UP1500/77	17	98.8	95.8	99.2	99.4	99.5	99.8	99.1	99.4	99.1	99.9	98.3	98.5	98.8	98.9	99.2	99.5	98.5	98.3	**98.9**
WF-3	UP1500/77	11	93.4	92.9	93.2	98.7	95.1	97.1	98.1	94.0	88.6	99.2	96.6	95.0	98.0	98.2	99.1	99.0	99.4	100	**96.4**
WF-4	UP1500/77	33	—	99.3	99.1	97.5	95.9	98.5	97.8	97.8	97.6	95.2	97.5	97.6	97.1	98.0	98.0	98.3	98.0	98.0	**97.7**
WF-5	UP1500/82	33	—	—	—	—	95.5	97.9	98.2	98.1	99.0	99.3	98.8	95.6	99.0	99.4	99.4	99.5	99.4	98.6	**98.4**
WF-6	UP1500/77	33	—	—	—	—	—	98.3	98.6	98.9	98.7	99.7	99.3	99.1	97.8	99.0	99.1	99.3	99.0	98.8	**98.9**
WF-7	UP1500/82	33	—	—	—	—	—	—	99.1	99.2	98.4	97.4	97.3	97.0	97.9	99.3	98.8	99.4	98.6	97.1	**98.3**
WF-8	UP1500/82	33	—	—	—	—	—	—	98.4	99.6	99.3	99.6	99.4	98.5	98.3	97.2	98.3	97.7	97.4	97.5	**98.4**
WF-9	UP1500/82	2	—	—	—	—	—	—	97.3	97.2	98.5	99.0	98.9	98.3	95.8	98.2	97.0	97.6	98.3	98.2	**97.9**
WF-10	UP1500/82	33	—	—	—	—	—	—	98.8	95.4	96.7	97.5	97.1	97.1	98.5	98.2	99.2	98.7	99.0	98.4	**97.9**
WF-11	UP1500/82	33	—	—	—	—	—	—	—	97.9	99.0	97.1	97.5	97.3	98.1	97.8	98.9	99.1	97.0	98.7	**98.0**
WF-12	UP1500/82	33	—	—	—	—	—	—	—	99.7	99.3	98.0	99.3	99.8	99.7	99.7	99.8	99.6	99.5	99.4	**99.4**
WF-13	UP1500/82	66	—	—	—	—	—	—	—	98.4	98.5	98.6	98.8	98.9	97.2	98.6	98.6	99.1	99.0	99.6	**98.7**
WF-14	UP1500/77	33	—	—	—	—	—	—	—	97.5	97.6	97.0	97.6	97.4	97.1	97.8	97.9	98.2	98.0	98.1	**97.7**
WF-15	UP1500/77	33	—	—	—	—	—	—	—	—	—	99.4	99.0	97.4	97.4	98.3	98.4	98.3	99.2	98.9	**98.5**
WF-16	UP1500/77	33	—	—	—	—	—	—	—	—	—	—	99.0	99.0	99.6	99.5	99.3	99.7	99.4	99.2	**99.3**
WF-17	UP1500/82	33	—	—	—	—	—	—	—	—	—	—	—	98.7	98.7	99.6	99.8	99.2	99.4	98.7	**99.2**
WF-18	UP1500/82	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	99.0	98.6	**98.8**

Table 3.7—Availability of 18 projects from January 2010 to June 2011

The information provided on availability shows that the UP1500/77 is capable of operating with an average availability of about 98.2 %. The UP1500/82 is capable of operating with an average availability of about 98.5 % and the UP1500/86 is capable of operating with an average availability of about 98.8 %, following the GUP definition of availability. All variants of the UP1500 are capable of operating with an average availability of about 98.4 %. It is not possible to estimate the influence of the allocation of scheduled maintenance time as available time in the GUP definition. However, GL GH would assume that this would at least show an availability of about 97.9 %, when scheduled maintenance time is allocated as downtime.

GL GH has also been provided with information on the Mean Time Between Failure (MTBF) for the UP1500 turbines. According to GUP, the MTBF for the fleet of UP1500 from May to November 2010 is 18.6 days which is in line with what GL GH would expect for a turbine type with an availability of above 97.9 %.

It should be noted that the information provided on availability only covers a limited amount of the total operating time for the fleet of UP1500 turbines and GL GH has no way of knowing whether these data are representative of the entire fleet of UP1500 turbines. If these can be validated as representative of the UP1500 fleet as a whole, an availability of above 97.9 %

gives confidence that the UP1500 is capable of operation in accordance with the industry standard, which indicates reliable operation of the turbine.

3.6.3 Turbine Inspection

On January 12, 2011, GL GH inspected one UP1500/77 turbine in a wind farm located in the southeast of Shangyi County, Zhangjiakou City, Hebei Province, China. The turbine was installed in June 2009, and passed a 240-hour reliability test in September 2010. During the inspection, the wind speed was between 8 and 10 m/s. The turbine was operating before the inspection started, and there were no unusual issues or noises to be reported.

The turbine had produced 6,071,943 kWh, with an availability of 98.2 %, during the period from October 01, 2009 to January 11, 2011.

In general, the turbine is in a condition expected for a turbine that has been in operation for around 18 months.

In Table 3.8, a summary of the inspection is provided.

Item	Comment
Blades	No comment.
Pitch system	Was not inspected, as GUP informed GL GH that work in the hub was not allowed due to the wind speed on the day of the inspection.
Pitch bearing	Was not inspected, as GUP informed GL GH that work in the hub was not allowed due to the wind speed on the day of the inspection.
Rotor hub	Was not inspected, as GUP informed GL GH that work in the hub was not allowed due to the wind speed on the day of the inspection.
Nacelle controller	Unused. PGs were not plugged.
Generator	No comment; the generator was not inspected inside.
Brake and coupling	No comment on the coupling. Brake disk had some scarring.
Gearbox	No comment; the gearbox was not inspected inside.
Main bearing	No comment.
Nacelle in general	Access to the nacelle from the tower is difficult. The design would benefit from a ladder.
Yaw system	No comment.
Yaw bearing	No comment.
Tower	No comment.
Lift	No comment.
Converter	No comment.
Controller	Unused. PGs were not plugged.

Table 3.8—Inspection summary

In general, the detailed design of the turbine is not of the standard seen in many European-manufactured turbines. However, the design is considered to be in line with the standard set by other Chinese turbine manufacturers.

During the inspection of the turbine, GL GH noted the following with regard to personal safety:

- Safety notices are partially in place;
- One fire extinguisher in the nacelle is not clearly marked;
- There is no fire extinguisher in the tower bottom; and,
- No evacuation equipment is present in the nacelle.

In general, GL GH finds the personal safety design of the turbine to be in line with the standard set by other Chinese turbine manufacturers. However, this is recognized as being somewhat below European/US standards.

GL GH recommends that potential customers of the UP1500 turbines discuss these personal safety issues with GUP, based on the actual requirements within the country where the turbines are to be installed and the internal policy of the Client.

3.6.4 Known Technical Issues

GL GH has discussed the technical issues which GUP has encountered with the UP1500 turbines to date. There have been a number of technical issues mainly regarding the generator and converter. For example the cooling fans in the generator cooling system were broken and the bearings in the generator were therefore broken due to the high temperature. However, according to GUP, these issues have now been resolved.

According to GUP there have also been a limited number of failures in the high speed bearing in the gearbox on the early turbines. Again, GUP states that this issue has been resolved.

Information on the root cause analyses of the failures to date was limited, and it is therefore difficult for GL GH to evaluate whether these issues really have been resolved. However, if the availability data provided by GUP are representative of the UP1500 fleet as a whole, GL GH expects that the majority of these technical issues have been resolved.

3.7 Commercially Proven Technology Assessment

3.7.1 GL GH Approach

In estimating a project's availability, GL GH has historically made an effort to determine whether the turbine design is "proven" for a given set of site conditions, often defined by a given country or region. A commercially proven turbine design is one that is sufficiently mature to enable a judgment to be made about the long-term availability of the turbine based upon the turbine's track record at the time of the review.

GL GH considers a turbine model to be commercially proven for a given set of site conditions when:

1 The manufacturer is capable of performing all contractual and commercial obligations in the country of installation;

2 The manufacturer can demonstrate the ability to support warranty, O&M, and supply chain obligations in the country of installation;

3 The version of the turbine that will be supplied carries a valid Design Statement of Compliance (SoC) to IEC 64100-1, or type certification according to IEC WT01 standards issued by an accredited certification agency;

4 The turbine model has at least 100 turbine years of experience in site conditions which are comparable to those at the site in question, operating at 95 % fleet turbine availability or greater.

In the course of GL GH's client work with the concept of proven/unproven turbine designs, it has became evident that a finer gradation is required than was afforded by the strict proven and unproven definitions. GL GH's observations of turbine performance have made it clear that it is important to better characterize certain distinctions. Therefore, a turbine technology status between proven and unproven has been defined. This interim status is termed a "qualified" turbine design.

In order for a turbine model to be considered "qualified", it first must meet the points one to three of the general criteria, similar to proven turbines as described above. There are then three situations where the definition of "qualified" turbine design can be used. These are:

- Variants: Evolutionary variants of turbines already proven under the given site conditions. Examples include rotor diameter changes for new wind classes, cold weather packages, or other modifications sufficient to require a new IEC certification but not a fundamental re-design.

  — The original turbine on which the variant is based must be proven. For more significant modifications, GL GH expects there will be at least one prototype unit with more than 4,000 hours of operation.

- Imported designs: A turbine which is proven in its home market but is new under the given site conditions.

  — The turbine model must be proven in its original region. Furthermore, for manufacturers that do not have extensive wind experience within the market in question, GL GH looks for at least one prototype unit in this market that has operated for more than 4,000 hours.

- New design: Turbines that have been performing well under the given site conditions for some time but are still without sufficient track record to be designated as proven.

  — The model has at least 25 turbine years of experience with 95% demonstrated turbine availability during the past 12 months under the given site conditions. In contrast to the other criteria listed above, earlier model years may be excluded in this assessment; in other words, early units do not necessarily have to be averaged into the turbine's "fleet" availability, which is evaluated for this purpose. For new designs in particular, GL GH looks for signs of demonstrated experience, so a broader review of overall turbine performance, quality, or manufacturing may be suggested at GL GH's discretion.

GL GH frequently receives requests to estimate performance of a turbine model that is being introduced to the new market, based solely on the track record in its current market. GL GH has found it necessary, however, to evaluate the fleet in the new market separately. An example of this is the North American market.

The requirement that turbine models are independently evaluated on their North American performance, rather than allowing reliance solely on home experience, grew from a notable disparity between the performance of turbines new to North America and that in their original market.

Ultimately, GL GH uses the degree to which a turbine is commercially proven in determining its default ramp-up and long-term availability. Some of GL GH's clients may use the classification to support investment decisions. For a given project, GL GH may then consider the project specifics, in order to revise these defaults. See GL GH's position paper on ramp-up and long-term availability for more discussion on this subject 31.

3.7.2 UP 1500 Assessment

Based on the information provided by GUP, GL GH finds that the UP1500/77 and UP1500/82 meet all four criteria for being commercially proven for installation in China. However, the design certification have been issues by CCS and CGC and the value of the certification from CCS and CGC is not clearly understood in the wind industry worldwide as CCS and CGC do not have a long track record of certifying wind turbines.

As far as GL GH can establish, the UP86 does not yet have the track record needed to be considered commercially proven. The design certification of the UP86 is still outstanding except for a type C design certification (prototype certification) issued by CGC. However, as the UP86 is a variant on the UP1500 platform, GL GH considers the turbine design to be qualified for installation in China.

With regards to installation of the UP1500 platform turbines outside China, GL GH can not make any evaluations regarding criteria one and two. However, assuming that GUP can meet these in due time, GL GH will consider the UP1500 turbines to be qualified for installation in many countries around the world.

3.8 Turbine Conclusions

The design is based on well-known and proven design concepts and is developed in cooperation between Aerodyn and GUP. Aerodyn is regarded as one of the leading consulting companies currently providing services in wind turbine design.

GUP has obtained design certification for the UP1500/77 and UP1500/82 issued by CCS and CGC, which adds comfort in the design of the turbine. However, the value of the certification from CCS and CGC is not clearly understood in the wind industry worldwide, as CCS and CGC do not have a long track record of certifying wind turbines.

GUP has also obtained C-design certification for the UP1500/77 issued by GL, which indicates that GUP turbines can be documented according to the industry standard. The C-design certificate has now expired and GUP is in a process to obtain an A-design assessment from GL.

GL GH finds that the power curves for the UP1500 turbines are in line with other 1.5 MW turbines offered to the market in China.

GUP has installed a considerable number of the UP1500 turbines since 2009—a relatively short time period. According to GUP, as of the end of July 2011, 2,223 units of the UP1500 had been installed or being installed, of which 704 units are UP1500/77, 1,344 unites are UP1500/82 and 175 units are UP1500/86.

The information provided by GUP on availability shows that the UP1500 turbines can be operated at an availability of about 97.9 %, when scheduled maintenance time is allocated as downtime.

It should be noted that the information provided on availability only covers a limited amount of the total operating time for the fleet of UP1500 turbines, and GL GH has no way of knowing whether these data are representative of the entire fleet of UP1500 turbines. If these can be validated as representative of the UP1500 fleet as a whole, an availability of above 97.9 % gives confidence that the UP1500 is capable of operation in accordance with the industry standard, which indicates reliable operation of the turbine.

Based on the information provided by GUP, GL GH finds that the UP1500/77 and UP1500/82 are commercially proven and the UP1500/86 will soon meet the criteria for commercially proven assuming installations continue.

4 UP3000 TURBINE

4.1 UP3000 DFIG Turbine

4.1.1 General Description of Turbine

The UP3000 DFIG turbine is a 3-bladed, horizontal axis, upwind pitch-regulated turbine, incorporating a doubly-fed induction generator, which provides variable speed operation over a range of -40% and +10% of nominal speed. The rated power is 3.0 MW with a rotor diameter of 100.8 metres.

The turbine has been designed for IEC IIA and IIIA wind conditions according to IEC 61400-1 edition 3 with different rotor diameters. This makes it suitable for most sites within China.

The main characteristics of the UP3000 DFIG turbine are summarized in Table 4.1:

Model	UP3000/100 DFIG	UP3000/108 DFIG
Hub height	90 m	90 m
Rotor diameter	100.8 m	108 m
Rated power	3,000 kW	3,000 kW
IEC classification	IIA	IIIA
Number of rotor blades	3	3
Rotor orientation	Upwind	Upwind
Rotor tilt	5°	5°
Rotor coning	3°	3°
Power regulation	Blade pitching / variable speed	Blade pitching / variable speed
Rated Rotational speed	14.3 rpm	14.3 rpm
Tower type	Tapered, tubular steel	Tapered, tubular steel

Table 4.1—Summary description of the UP3000 DFIG

The UP3000 DFIG turbine is jointly designed by GUP and the Turbine Group of GHP. The initial design phase has been completed and the prototype turbine has been installed in China.

The Turbine Group of GHP is well known in the industry for provision of consulting services to wind turbine manufacturers during the design of new products. The services provided by GHP include concept studies, load calculation, structural design, component specification (excluding blades) and control software development.

The initial design of the turbine has been completed. The first onshore prototype has been in operation since April 19, 2011 and passed a 240 hours reliability test. The first offshore prototype is being installed in Binhai wind farm which is in Weifang of Shandong province. In this wind farm 16 UP3000 DFIG turbines will be installed. According to GUP, another 16 wind turbines will be installed in Shanxi province in October this year.

4.1.2 Turbine Technology

The general concept of the UP3000 DFIG turbine is based on proven technologies in the wind industry, as well as some newer features. Table 4.2 indicates whether each sub-system concept of the turbine is well-known in the wind industry or not.

Sub System / Component	Proven Industry Concept	Comments
Rotor blades	✓	
Hub	✓	
Pitch system	✓	
Main shaft / bearing	✓	
Gearbox		The gearbox of a differential, or torque splitting, planetary arrangement is a relative new concept in the wind turbine industry.
Generator	✓	
Converter	✓	
Yaw system	✓	
Tower	✓	
Control system	✓	

Table 4.2—Comparison of UP3000 DFIG turbine with the industry standard

The layout of the nacelle in this turbine is shown in Figure 4.1.

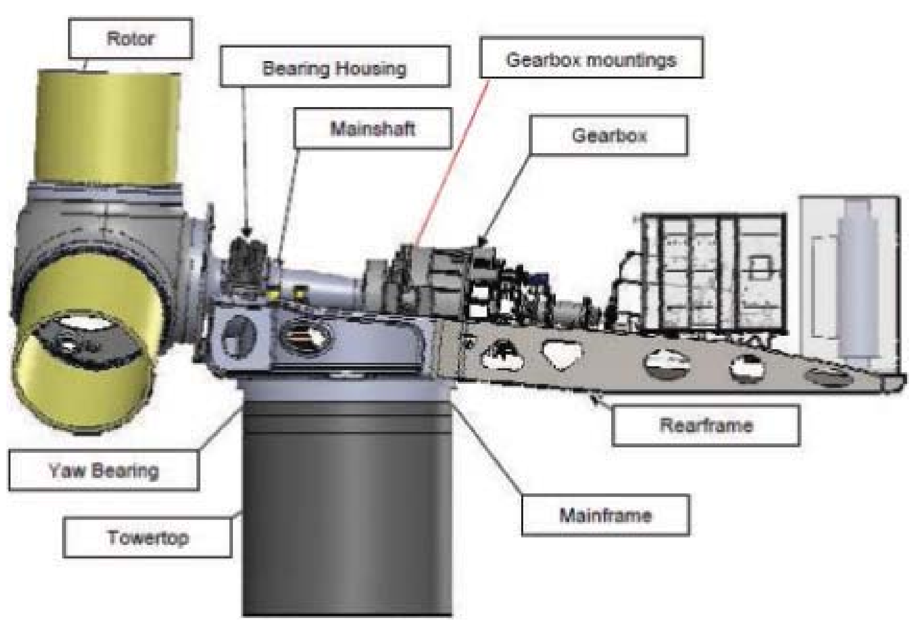


Figure 4.1—UP3000 DFIG nacelle layout

The turbine is entirely conventional, with the exception of the gearbox. The gearbox, whilst superficially similar to previous units, uses an arrangement of gears which is relatively new to the wind turbine industry. The rotor is connected to a cast spherical hub, using three pitch bearings in a slew ring configuration. The rotor shaft is supported by a single spherical roller main bearing. The bedplate is cast with a fabricated rear section. The gearbox provides the other shaft support. The generator is located on the rear of the bedplate. All the main electrical equipment, including the converter and transformer, is located in the nacelle. A rolling element, slew ring bearing is used.

The blade for the 100.8 meters rotor is a 49 meters blade which has been designed by Windnovation Germany which is a design consultant company. Windnovation was founded in 2007 by a group of engineers with experience in the wind industry, mainly from the blade manufacturer EUROS, Germany. Windnovation should have the capability to design blades meeting the requirements of a modern wind turbine. However, GL GH's experience with blades designed by Windnovation is limited. The blade for the 108 meters rotor is a 53 meters blade. However, GL GH has no information on this blade.

The blade is 49 m long and is made of GFRE. Based on the limited information available, GL GH expects the structure of the blade to be according to industry standards for blades of this size. GL GH has not been provided with any information on the aerodynamic design of the blades other than that the blade airfoil is a new airfoil that has been jointly designed by Windnovation and GUP.

The UP3000 DFIG turbine uses an electric system to adjust the pitch of the blades in operation, above the rated wind speed and for aerodynamic braking. The pitch system is according to industry standards.

A gearbox of a differential (or torque splitting) planetary arrangement is used. This concept is relatively new to the wind turbine industry. However, today it is used by a number of the major turbine manufacturers in the industry for turbines of a size of around 3.0 MW.

The only gearbox manufacturer with experience in supplying differential gearboxes to the wind industry is, as far as GL GH is aware, Bosch Rexroth from Germany. GL GH knows from GUP that the gearbox supplier is NGC. However, GL GH is not aware the capability of NGC to supply such a gearbox.

The UP3000 DFIG uses a doubly-fed induction generator, with wound rotor and slip ring. The rotor is connected via the slip ring. This generator arrangement is fundamentally less reliable than a simple induction generator. The main sources of unreliability are the slip rings and the associated brushes. The brushes tend to wear and require adjustment and cleaning. However, the use of doubly-fed induction generator is very common in the wind industry and in recent years the reliability of the slip rings has improved.

Most of the electrical equipments are located in the nacelle. These include the converter which provides the variable speed capability of the turbine. The converter is supplied by ABB. ABB has a long track record of supplying converters to the wind industry. The medium voltage transformer, which increases the voltage to what is required for the collection system, is also located in the nacelle.

GUP has informed GL GH that the UP3000 DFIG is equipped with an automatic lubrication system for pitch, main and yaw bearing(s) to insure proper lubrication at all times.

GL GH assumes that the SCADA system developed for the UP1500 also can be used for the UP3000 DFIG turbines, see section 3.3.3.

4.1.3 Turbine Technical Assessment

To assess any wind turbine design GL GH would normally require that at least part of the verification for the turbine design hade been completed. Turbine design verification includes turbine design certification, power performance verification, grid code compliance verification and noise level verification. However, as the UP3000 DFIG is a newly developed, such verification has not yet been completed.

GUP provided three agreements, signed with CCS, CGC and GL respectively, for UP3000 DFIG certification work. It is summarized in Table 4.3. The three certification agreements are for Type Certification which includes design assessment, type testing and manufacturing evaluation. However, CCS calls it the Product Certification. Currently, all certification work is in progress for its offshore turbine type and no certifications have been issued to GUP, as yet.

Certification Authority	Model	Signed Date	IEC Class	Type	Comment
CCS	UP3000/100 DFIG	November 2, 2011 32	IIA	Offshore	In progress
CGC	UP3000/100 DFIG	May 11, 2011 33	IIA	Offshore	In progress
GL	UP3000/100 DFIG	October 8, 2010 34	IIA	Offshore	In progress

Table 4.3—Certification agreements for UP3000 DFIG

Based on the information available, GL GH assumes that GUP will conduct the design verification according to industry standards.

On August 26, 2011, GUP got the National Energy Science and Technology Achievement Verification Certification from National Energy Bureau (NEB) for its UP3000 DFIG offshore turbine. GL GH views this as an expert opinion on the design of the turbine. However, GL GH has no information available on the background or requirements for the issue of such an expert opinion from NEB. Therefore, GL GH cannot comment on the value of this expert opinion.

As the verification and validation of the UP3000 DFIG design is about to begin, the information available around issues such as certification, power performances, verification grid code compliance, etc. is limited. However, based on the information available, GL GH assumes that GUP will conduct the design verification according to industry standards.

GL GH does not have any information about the timeline for the design verification. Therefore, GL GH cannot comment on when GUP will have completed this and be able to document to what extent the turbine can meet the requirements for a modern wind turbine of a 3.0 MW size.

4.1.4 Turbine Conclusions

The UP3000 DFIG is a newly designed 3.0 MW wind turbine, designed by GUP with the support of a design consultancy company. The initial design of the turbine has been completed and the verification phase of the development has been started. However, as of August 2011, turbine certification and power curve verification had not yet been completed and GL GH had not been informed of when the completion of such could be expected.

As of August 2011, there is only very limited operating experience with the UP3000 DFIG, as the first onshore prototype has been in operation since April 19, 2011. However, according to GUP, the prototype has passed the 240 hours test, which provided some comfort that GUP are on the right track.

The first offshore prototype is being installed in Binhai wind farm, in Weifang of Shandong province. Sixteen UP3000 DFIG turbines will be installed in this wind farm. According to GUP, another 16 wind turbines will be installed in Shanxi province in October 2011. Therefore, GL GH expects that, during 2012, there will be operating experience available for the UP3000 DFIG, as an offshore turbine providing sufficient information for the evaluation of expectations for the further operation of the UP 3000 DFIG turbines.

The design of the UP3000 DFIG indicates that the turbine will be able to meet the requirements for a modern wind turbine of a 3.0 MW size. Based on the information provided to GL GH, the design has been performed based on the current industry standards. However, only the completion of the turbine verification, validation and establishment of a track record can confirm this.

In summary, the UP3000 DFIG includes many concepts and components that are commonly used by modern, megawatt class turbines. The overall design concept has been proven reliable in these turbines. However, reliability is determined by each individual detail of the design. The final determination of turbine reliability can only be proven by track records.

4.2 UP3000 DD Turbine

4.2.1 General Description of Turbine

The GUP 3 MW direct drive wind turbine UP3000 DD is a 3-bladed, horizontal axis, upwind, pitch regulated turbine. The rated power is 3.0 MW and it is being developed in two versions. The main difference between the two versions is the rotor diameter. One version is designed for IEC wind class IIA and one is designed for IEC wind class IIIA, with rotor diameters of 100.8 and 108 m respectively.

The UP3000 DD turbine is jointly designed by GUP and HRS Wind Power Technologies Ltd. (HRS). HRS is a turbine design consultancy company from Switzerland and it is experienced in generator design. However GL GH has no experience of HRS.

Based on the information provided by GUP on the design of the UP3000 DD, GL GH expects that it is based on the UP3000 DFIG modifying the drive train concept of the turbine in order to utilize a multi-pole variable speed permanent magnet generator (PMG) with a fully-rated converter system, providing variable speed operation.

The main characteristics of the UP3000 DD turbine are summarized in Table 4.4:

Model	UP3000/100 DD	UP3000/108 DD
Hub height	90 and 100 m	90 and 100 m
Rotor diameter	100.8 m	108 m
Rated power	3,000 kW	3,000 kW
IEC classification	IIA	IIIA
Number of rotor blades	3	3
Rotor orientation	Upwind	Upwind
Rotor tilt	5°	5°
Rotor coning	3°	3°
Power regulation	Blade pitching / variable speed	Blade pitching / variable speed
Rated Rotational speed	14.3 rpm	14.3 rpm
Tower type	Tapered, tubular steel	Tapered, tubular steel

Table 4.4—Summary description of the UP3000 DD

The UP3000 DD turbines are currently under development by GUP. Therefore, the information available on the design is limited and, possibly, subject to modification. GL GH has not been provided with information on the status of the development. However, based on the information provided on the design GL GH expects that the development is well underway.

GUP has not installed any UP3000 DD turbines to date; therefore, no operating experience is available.

4.2.2 Turbine Technology

The UP3000 DD utilizes a multi-pole variable speed permanent magnet generator (PMG) with a fully-rated converter system, to provide variable speed operation. The fully-rated converter system provides more options for compliance with the new (and more arduous) grid code requirements compared to turbine designs without full power conversion.

The unique feature of the UP3000 DD turbine is a direct drive generator. Most current turbines use a gearbox to increase the speed of the rotor from approximately 15 rpm to a speed of 1,000 or 1,500 rpm (50 Hz). Wind turbine gearboxes have been a source of major type failures in recent years.

Direct drive turbines have a number of attendant advantages which arise from the elimination of the gearbox. They have fewer parts overall, which has the potential to reduce operations and maintenance costs. However, so far direct-drive turbines have also had a higher capital cost than comparably geared turbines.

The rotor hub is connected to a main shaft, supported by two main bearings which are in turn supported by the steel structure of the generator stator. The rotor part of the generator is connected to the main shaft between the two main bearings, and the stator of the generator is connected to the main frame, as is seen in Figure 4.2.

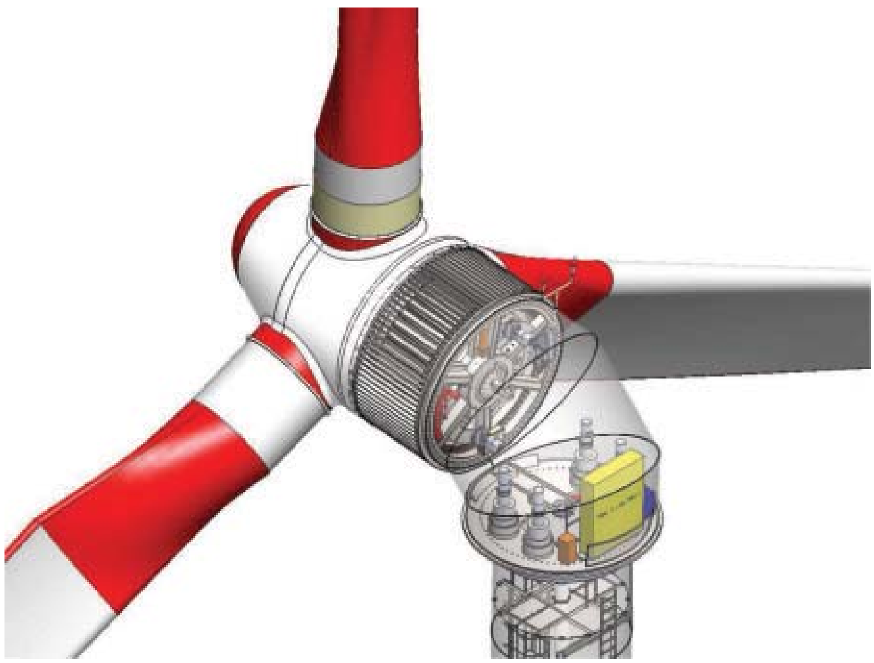


Figure 4.2—UP3000 DD nacelle layout

The general concept of the UP3000 DD turbines is based on technological features that are well known within the wind industry, with the exception of certain relatively novel components, as noted above. Table 4.5 indicates whether the subsystem concept of GUP is well known within the wind industry or not.

Sub System / Component	Proven Industry Concept	Comments
Rotor blades	✓	
Hub	✓	
Pitch system	✓	
Main bearings	✓	
Main bearings support	✓	The structure around the bearings is new, due to the generator arrangement.
Direct-drive topology	✓	Proven in Europe and China, although it is only now being introduced to North America.
Generator	✓	The use of a PMG is proven in large-scale turbines in Europe and China, although it is only now being introduced to North America.
Converter	✓	
Yaw system	✓	
Tower	✓	
Control system	✓	

Table 4.5—Comparison of UP3000 DD with industry standards

The blades for the 100.8 meter rotor are the same as those used on the UP3000 DFIG described in section 4.1.2. The blade for the 108 m rotor is a 53 m blade. However, GL GH has no information on this blade.

The UP3000 DD turbine uses an electric system to adjust the pitch of the blades in operation, above the rated wind speed and for aerodynamic braking. The pitch system is according to industry standards. GL GH expects the pitch system to be identical to the pitch system of the UP3000 DFIG.

The UP3000 DD turbine uses a permanent magnet synchronous generator (PMSG), the generator rotor turns around inside of the stator and the magnets are located on the rotor. According to GUP, the generator will be produced by itself.

The cooling of the generator is passive and is provided by air flow around the generator stator.

Most of the electrical equipment is located in the tower. This includes the converter, which provides the variable speed capability of the turbine. The converter is supplied by ABB. ABB has a long track record of supplying converters to the wind industry.

4.2.3 Turbine Technical Assessment

To assess any wind turbine design GL GH normally would require that at least part of the verification of the turbine design to have been completed. Turbine design verification includes turbine design certification, power performances, verification grid code compliance verification and noise level verification. However, as the UP3000 DD is currently being developed, such verification has not yet been completed.

GUP provided two agreements, signed with CCS for UP3000 DD offshore certification work and CGC for UP3000 DD onshore certification work, respectively. It is summarized in Table 4.6. The two certification agreements are for Type Certification which includes design assessment, type testing and manufacturing evaluation; however, CCS calls it the Product Certification. Currently, all certification work is in progress and no certifications have been issued to GUP yet.

Certification Authority	Model	Signed Date	IEC Class	Type	Comment
CCS	UP3000/100 DD	2 November 2011 35	IIA	Offshore	In progress
CGC	UP3000/100 DD	11 May 2011 36	IIA	Onshore	In progress

Table 4.6—Certification agreements for UP3000 DD

Based on the information available, GL GH assumes that GUP will conduct the design verification according to the industry standard.

GL GH does not have any information about the timeline for the design verification; it therefore cannot comment on when GUP will have completed this and will be able to document to what extent the turbine can meet the requirements for a modern wind turbine of a 3.0 MW size.

4.2.4 Turbine Conclusions

The UP3000 DD is a 3.0 MW turbine which is under development and has been jointly designed by GUP and HRS. However, GL GH has no experience with HRS. The initial design of the turbine is, as far as GL GH is aware, not yet completed. It should be noted that the UP3000 DD information provided to GL GH has been limited.

GL GH expects that the UP3000 DD is based on the UP3000 DFIG, of which a prototype has been installed in China, modifying the drive train concept of the turbine to utilize a multi-pole variable speed permanent magnet generator (PMG) with a fully-rated converter system, in order to provide variable speed operation. The fully-rated converter system provides more options for compliance with the new (and more arduous) grid code requirements, compared to turbine designs without full power conversion.

Direct drive turbines have a number of attendant advantages which arise from the elimination of the gearbox. They have fewer parts overall, which has the potential to reduce operations and maintenance costs. However, so far direct-drive turbines have also had a higher capital cost than the comparable turbines which are geared.

The information provided to GL GH on the design of the UP3000 DD indicates that the turbine will be able to meet the requirements for a modern wind turbine of a 3.0 MW size. However, only the completion of the turbine verification and validation can confirm this.

In summary, GL GH finds that the design concept of the UP3000 DD for the drive train is in accordance with the most recent developments within the wind industry. The design concept of the remaining parts of the turbine is based on concepts and components that are commonly used by modern, megawatt class turbines. However, reliability is determined by each individual detail of the design. The final determination of turbine reliability can only be proven by track records.

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APPENDIX I

Type Certification Process According to IEC WT01:2001

1 TYPE CERTIFICATION PROCESS ACCORDING TO IEC WT01:2001

The type certification scheme according to IEC WT01:2001 is divided into three mandatory modules and two optional modules. It is possible to obtain certification for each of these modules. The certificates are normally called Statements of Compliance.

A diagram of the certification scheme is shown in Figure AI.1.

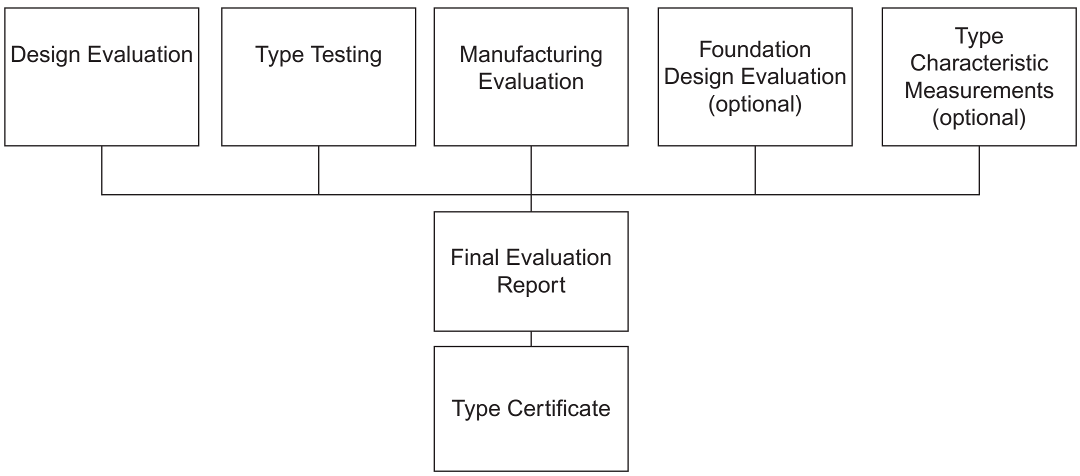

Figure AI.1—Diagram of the certification scheme according to IEC WT01:2001

1.1 Design Certification / Assessment / Evaluation

The design evaluation is carried out via a review of the design documentation, supplied by the turbine manufacturer. The design documentation must cover the whole turbine, except the turbine foundation, which is optional.

The design evaluation is based on the safety requirements stipulated in IEC 61400-1. The following elements form part of the design evaluation:

- Control and protection system;
- Load and load cases;
- Structural, mechanical and electrical components;
- Components tests;
- Foundation design requirements; and
- Personnel safety.

The manufacture, installation and maintenance documentation will be reviewed, to make sure that the pre-conditions stated in the design documentation are also reflected in this documentation also.

The certifying institutes, GL and DNV, have three levels of design evaluation. These are:

C-Design Evaluation

The C-Design evaluation (for wind turbine prototypes) is a check of prototype plausibility. It will be performed on the basis of the design documentation. This type of design evaluation can be used to erect a prototype wind turbine. It is based on a load assessment and a complete design plausibility check of the rotor blades and machinery components, as well as the tower and foundation.

Depending on national or local regulations, a C-design evaluation is necessary to enable erection of the prototype turbine.

C-Design evaluation is normally only valid for test operation comprising a 2-year operating period.

A and B-Design Evaluation

A or B-Design evaluations are the next steps in certification. Both evaluations consist of a complete examination of the design analyses, with all the required material and component tests.

The B-Design evaluation allows for certain items to be left outstanding, as long as these items are not directly relevant to safety. The certificate has a validity period that is normally limited to one year. This period can be used to fulfill the missing requirements for the A-Design evaluation. This does not allow for outstanding items, and does not expire unless the design is modified.

1.2 Type Testing & Type Characteristics Measurements

Within the scope of power curve type testing measurements, tests of wind turbine behavior and load measurements are to be carried out, as well as blade testing.

Noise emission and electrical properties form part of the Type Characteristics Measurements, which are optional under the IEC WT01:2001 standard.

Topics (as indicated in the Table AI.1, below) are to be verified by measurements that can be based on the relevant standards mentioned. The measured results are to be evaluated and documented. Test reports will be checked for the plausibility of measured results and compared to assumptions in the design documentation.

Topics for Measurements	Codes or Standards which can be Applied
Power curve	IEC 61400-12
Noise emissions	IEC 61400-11
Actions, loads and stresses, dynamic behavior	IEC TS 61400-13
Electrical characteristics	IEC 61400-21
Blade tests	IEC TS 61400-23
Commissioning, safety and function test	IEC 61400-1

Table AI.1—Elements of prototype testing and respective standards

In order to incorporate measurements into the certification process, measurements shall be performed by independent institutions accredited according to ISO / IEC 17025. Alternatively, witnessing of measurement calibration and plausibility checks by an accredited institute will be required.

1.3 Manufacturing Evaluation

The evaluation of manufacturer quality management covers the whole range of activities necessary to confirm the quality of a product. The manufacturers' quality management system certification, according to ISO 9001 (including design), covers a large portion of these requirements. However, the link between quality management and product quality needs particularly to be addressed. It shall be ensured that the requirements stipulated in the technical documentation (with respect to components) are observed and implemented in the production, installation and maintenance of the turbine.

APPENDIX II

Permanent Magnet Generators in the Wind Industry

The permanent magnet generator (PMG) is a relative newcomer in utility-scale wind turbines, though they have attracted increased interest from new and experienced turbine manufacturers alike. Examples of direct drive and PMG turbines currently on the market, or prototyped, are listed in the table below.

Operational experience with turbines using PMG generators is so far increasing, without any signs of major technical issues with the concept. The most widely installed PM direct-drive turbine is the Goldwind GW1.5 Series turbine with nearly 1,800 units installed in China as of June 2010, as well as three (3) in the USA. The prototype Vensys 1.2 MW generator in Sitzerath, Germany, which uses essentially the same design, has been operating since 2003 without any significant issues.

The PMG offers a number of benefits. The use of permanent magnets for excitation purposes avoids the need for external energy for excitation and this in theory increases the overall efficiency of the generator. One of the PMG's key advantages is its high partial-load efficiency; this is especially significant for wind turbines, which operate below rated power most of the time. Furthermore, no slip rings are required for rotor power as they are for doubly fed induction generator (DFIG) machines. In some turbine designs the multi-pole generator rotates so slowly that the need for a speed-increasing gearbox is eliminated (i.e. direct-drive turbines).

One of the challenges of permanent magnets in general is that they can be demagnetized by very high temperatures, as might occur during an electrical fault or an undetected coolant failure; therefore a PMG system must be designed with cooling in mind as well as protection from overheating and faults. Refer to the body of this report for a discussion of how this issue is addressed in the subject turbine.

Manufacturer	Model(s)	In Operational	Diameter m	Rated Power MW	Direct-drive / Geared	Generator Type
Goldwind / Vensys[(1)]	GW70, GW77, GW82	Yes	70, 77, 82	1.5	DD	PMG
Northern Power Systems[(2)]	NPS2.2-93	Prototype	93.1	2.2	DD	PMG
GE—Scanwind[(3)]	SW3500 DL	Yes	100, 91	3.5	DD	PMG
Siemens	SWT-2.3-113, SWT-3.0-101	Yes	113, 101	2.3, 3.0	DD	PMG
Leitwind	LTW70, 77, 80	No	70, 77, 80	1.5 – 1.7	DD	PMG
XEMC (Darwind)	DD115	No	115	5	DD	PMG
STX Heavy Industries et al.[(4)]	Z72	No	70.65	2.0	DD	PMG
Clipper	Liberty Series	Yes	89 – 99	2.5	G	PMG
GE	2.5	Yes	100	2.5	G	PMG
Samsung	TBD	Prototype	TBD	TBD	G	PMG
Vestas	V112	Prototype	112	3.0	G	PMG
AREVA—Multibrid[(5)]	M5000	Yes	116	5	G	PMG
Enercon	E70, E112, etc.	Yes	66 – 114	1.8 – 6	DD	Synch, wound rotor
MTorres	MT TWT 77/1500 etc.	Yes	70-88	1.5, 1.65	DD	Synch, wound rotor

Notes:

(1) Goldwind Technology Science & Technology Co. Ltd. bought a majority share of Vensys Energy AG in 2008. Vensys has licensed this and related technology to other manufacturers as well.

(2) Northern Power Systems' NPS2.2-93 is in the prototype-testing phase, planned to be commercially available about 2011.

(3) GE acquired Scanwind in 2009 with an eye to the offshore market.

(4) The turbine design originated with Lagerwey and since then has a lineage involving Zephyros, Harakosan, and Xiangtan Electric Manufacturing Corporation Ltd (XEMC)'s Hara XEMC Windpower Co., Ltd.

(5) The Multibrid turbine is also an offshore turbine. WinWinD Oy offers a DD turbine related to the Multibrid.

Figure AII.1—Examples of direct-drive and PMG turbines over 1.2 MW