HE175-5.X MW 技术规范书

HE175-5.X MW technical specifications

哈电风能有限公司

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1. 风电机组总体技术说明

1. Wind turbine technical description

哈电 HE175-5.X MW 直驱永磁风力发电机组采用水平轴、三叶片、上风向、变速变桨调节、直接驱动、低速永磁同步发电机，全功率变流并网发电的总体设计方案。HE175-5.X MW 机组外形见图 1。

HE175-5.X MW is a direct-drive wind turbine with horizontal axis, three blades, upwind, variable-speed, variable pitch power adjustment, rotor direct drive permanent magnet synchronous generator, wind turbine generator connected to the grid through a full-power converter. HE175-5.X MW outside drawing as shown in Figure 1.

图 1 HE175-5.X 风机外形示意图

Figure 1 HE175-5.X MW outside drawing

1.1 总体技术优势

1.1 Technical advantage

HE175-5.X MW 直驱永磁型机组，发电机直接与风轮连接，中间无齿轮箱部件，在同级产品中传动链结构最简单，其紧凑、精简的结构使其在设计寿命期内具有得天独厚的运行维护优势，具体说明如下：

XE175-5000 is direct drive permanent magnet synchronous generator, the generator connect rotor without gearbox , the drive chain structure is the simplest among products of the same level. This type wind turbine’s compact and simplified structure gives it unique advantages in operation and maintenance during its design life, the detailed description as follow:

（1）高可靠性主传动链设计：超低维护成本及超高可靠性主传动链设计，可提高发电效率 3-5%。超紧凑单主轴承直驱结构，结构紧凑、运行可靠，有效降低机械损耗，提高整机机械传动效率。

(1) High-reliability main drive chain design: Ultra-low maintenance cost and ultra-high-reliability main drive chain design can increase power generation efficiency by 3-5%. The ultra-compact single main bearing direct drive structure effectively reduces the mechanical loss and improves the mechanical drive efficiency of the wind turbine. The wind turbine has good environmental adaptability, compact structure and reliable operation.

（2）自适应热管理系统：基于 CFD 热流场模拟仿真发电机内部通风路径结构参数优化方法，提出了协同发电机自然散热系统和机舱-发电机内部强迫通风换热系统的优化匹配准则，实现发电机实时功耗跟踪热管理，可有效提高机组发电量 2%左右。

(2) Adaptive thermal management system: Based on CFD thermal flow field simulation, the structural parameter optimization method of the internal ventilation path of the generator is proposed, and the natural heat dissipation system of the outer stator casing fins of the cooperative generator and the nacelle-generator interior are proposed. The optimized matching criteria of the forced ventilation heat exchange system and the real-time power consumption tracking thermal management technology of the generator can effectively increase the generating capacity of the wind turbine unit by around 2%.

（3）自适应风机控制系统：新一代自适应控制技术，深入挖掘风机潜能、降低机组载荷、提高发电效率；先进的变速恒频控制系统，全功率变流器使输送到电网的高次谐波少；实时优化控制策略，适应不同条件下的场址、机位环境条件。

(3) Adaptive wind turbine control system: A new generation of adaptive control technology, deeply dig the potential of wind turbines, reduces wind turbine unit load, and improves power generation efficiency; advanced variable-speed constant-frequency control system, full-power converter to make high-order harmonic transmission to the grid Less waves; real-time optimization of the control strategy to adapt to the environmental conditions of the site and wind turbine position under different conditions.

（4）超强环境适应能力：高防护等级设计成就超强环境适应能力，环境恶劣地区丰富运行经验支撑方案定制，有效应对高盐雾、高湿度、强台风、高海拔、强沙尘、强雷暴、高/低温等恶劣环境。

(4) Super environmental adaptability: High protection class design achieves super environmental adaptability, rich operating experience in harsh environments, support for customized solutions, and effective respond to high salt spray, high humidity, strong typhoon, high altitude, strong sand and dust, strong thunderstorms, high/low temperature and other harsh environment.

（5）高可达、可维护性：超大维护空间，超高可达性，有效提升维护效率。自维护设计，机组自上到下、从里到外，均配备完善的吊物提升设备，可用于更换驱动、柜体等中小

型部件，极大降低维护成本。

(5) High accessibility and maintainability: Super large maintenance space and super high accessibility can effectively improve maintenance efficiency. Self-maintenance design, the wind turbine unit is equipped with complete lifting equipment from top to bottom and from inside to outside, which can be used to replace small and medium components such as drives and cabinets, greatly reducing maintenance costs.

（6）高电网适应性：全功率变流器的电网支撑能力，并网无冲击、电能质量好、自动调节有功无功。高低电压穿越能力强，满足最新电网标准要求。电网和风机传动链隔离，风机机械部分不受电网振荡的影响。

(6) High grid adaptability: full power converter's grid support ability, grid-connected without impact, good power quality, active and reactive power can be automatically adjusted. High and low voltage ride-through capability is strong, meeting the requirements of the latest grid standards. The power grid and the wind turbine drive chain are isolated, and the oscillation of the power grid will not affect the mechanical part with pulse torque.

1.2 总体技术参数

1.2 Technical parameter

HE175-5.X MW 机组总体技术参数见表 1。

XE175-5.X MW wind turbine technical parameter as shown in Table 1.

表 1 HE175-5.X MW 风力发电机组总体技术参数

Table 1 HE175-5.X MW wind turbine technical parameter

序号 No.	项 目 Item	单 位 Unit	参 数 Parameter
1	额定功率 Rated power	kW	5000/5300/5600
2	风轮直径 Rotor diameter	m	175
3	适用风区 Applicable wind area		IEC S
4	切入风速 Cut in wind speed	m/s	3
5	额定风速 Rated wind speed	m/s	10.5（标空、静态） 10.5 (Standard air、static)
6	切出风速（10 分钟平均值） Cut out wind speed (10 min Average value)	m/s	22
7	极端（生存）风速（3 秒最大值） Extreme (survival) wind speed (3s Max value)	m/s	52.5(50 年一遇) 52.5m/s (50 years return period)

序号 No.	项 目 Item	单 位 Unit	参 数 Parameter
8	设计寿命 Design life	年 year	＞20
9	湍流等级 Turbulence class		B
10	生存温度 Survival temperature	℃	低温型：-40℃～+50℃ 常温型：-20℃～+50℃ Low Temp: -40℃～+50℃ Normal Temp: -20℃～+50℃
11	运行温度 Operation temperature	℃	低温型：-30℃～+40℃ 常温型：-10℃～+40℃ Low Temp: -30℃～+40℃ Normal Temp: -10℃～+40℃
12	接地电阻 Ground resistance	Ω	≤4
13	轮毂中心高度 Hub center height	m	106/定制化设计 106m / Customized
14	功率调节方式 Power adjustment method		变桨变速 Variable pitch and variable speed
15	扫掠面积 Swept area	m^2	24052
16	叶片数 Blade number		3
17	风轮旋转方向 Rotor rotation direction		顺时针 Clockwise

说明：上表中额定风速是指在标准空气密度、静态下的设计值。

Description: The rated wind speed in the above table refers to the design value under standard air density and static state.

2. 风电机组部件技术说明

2. Wind turbine component technical description

2.1 结构布置图

2.1 Structural layout drawings

HE175-5.X MW 直驱永磁机组主要由以下部件及系统构成：叶片、轮毂、机舱、发电机、主轴承、变桨系统、偏航系统、测风系统、自动润滑系统、液压系统、制动系统、电气及控制系统、冷却系统、监控系统、塔筒等，机组结构示意图见图 2。

The HE175-5.X MW direct drive wind turbine unit is mainly composed of the following components and systems: blades, hubs, nacelles, generators, main bearings, pitch systems, yaw systems, wind measurement systems, automatic lubrication systems, hydraulic systems, braking systems, electrical and control system, cooling system, monitoring system, tower, etc.

2.2 风轮总成

2.2 Rotor assembly

风轮用于将空气的动能装换为风轮转动的机械能。风轮由三个叶片通过变桨轴承与刚性轮毂相连构成，轮毂示意图见图 3，参数见表 2。

The rotor is used to convert the kinetic energy of the air into mechanical energy for the rotation of the rotor. The rotor is composed of three blades connected to hub through a pitch bearing. The diagram of the hub is shown in Figure 3, and the parameters are shown in Table 2.

图 3 轮毂示意图

Figure 3　The diagram of the hub

表 2　HE175-5.X MW 风力发电机组风轮技术参数

Table 2　HE175-5.X MW Wind turbine's Rotor technical parameter

序号 **No**	项 目 **Item**	单 位 **Unit**	参 数 **Parameter**
叶片 Blade			
1	叶片长度 Blade length	mm	85000
2	材料 Material		环氧树脂玻璃钢 Epoxy Glass Fiber Reinforced Plastics
3	重量 Weight	t	26.3
4	根部连接件 Root connection component		高强度螺栓连接 High strength bolts connection
轮毂 Hub			
1	型式 Type		球型铸件 Spheroidal casting
2	外形尺寸（长×宽×高） Boundary dimension	mm	Φ5355×4379(高 height)

序号 **No**	项 目 **Item**	单 位 **Unit**	参 数 **Parameter**
	(L×W×H)		
3	重量 Weight	t	63
4	铸件材料 Casting material		QT400

2.3 发电机总成

2.3 Generator assembly

发电机是将风轮转动的机械能转换为电能的部件，风轮通过主轴承直接同发电机转子连接。HE175-5.X MW 直驱永磁发电机的主要由发电机定子、发电机转子、定子支撑、主轴承、轴流风机、锁紧装置等构成，发电机示意图见图 4，技术参数见表 3。

The generator is a component that converts the mechanical energy of the rotor rotation into electric energy. The rotor is directly connected to the generator rotor through the main bearing. XE157-3400 direct drive permanent magnet generator is mainly composed of generator stator, generator rotor, stator support, main bearing, axial fan, locking device, etc. The diagram of the generator is shown in Figure 4, technical parameters see Table 3.

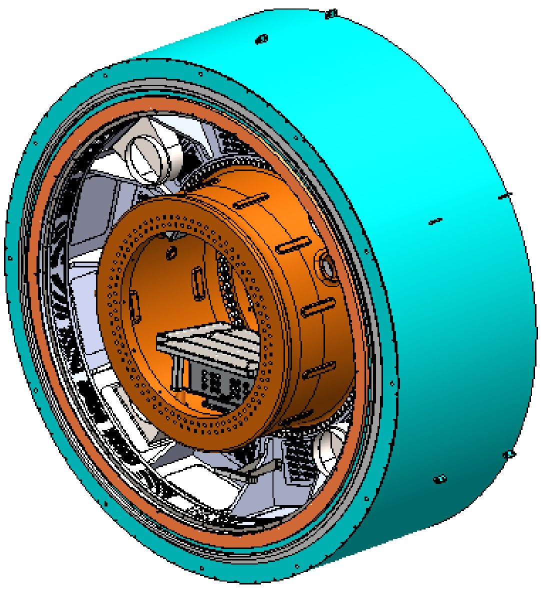

图 4 发电机示意图

Figure 4 Diagram of the Generator

表 3　HE175-5.X MW 风力发电机组发电机技术参数

Table 3　XE175-5.X MW WTG technical parameter

序号 No	项 目 Item	单 位 Unit	参 数 Parameter
1	型式 Type		低速永磁同步发电机 Permanent magnet low speed synchronous generator
2	外形尺寸 Boundary dimension	mm	Φ6000×2705（高 Height）
3	重量 Weight	t	145
4	额定功率 Rated power	kW	5310/5620/5930
5	额定电压 Rated voltage	V	1380
6	功率因数 Power factor		0.93
7	防护等级 Protection class		IP54
8	冷却方式 Cooling method		空冷 Air cooling
9	绝缘等级 Insulation class		F
10	主轴承 Main bearing		三列圆柱滚子轴承 Three-row cylindrical roller bearings
11	润滑方式 Lubrication method		加注润滑脂/自动润滑系统 Add grease / automatic lubrication system

2.4 机舱总成

2.4　Nacelle assembly

机舱总成由机舱铸件、机舱罩、偏航系统、偏航轴承、液压系统、润滑系统、通风系统、测风系统、机舱控制系统、安全系统以及其他附件组成，机舱外形图见图 5，参数见表 4。

The nacelle assembly is composed of nacelle castings, nacelle cover, yaw system, yaw bearing, hydraulic system, lubrication system, ventilation system, wind measurement system, nacelle control system, safety system and other accessories. The diagram of nacelle is shown in Figure 5. Parameters see Table 4.

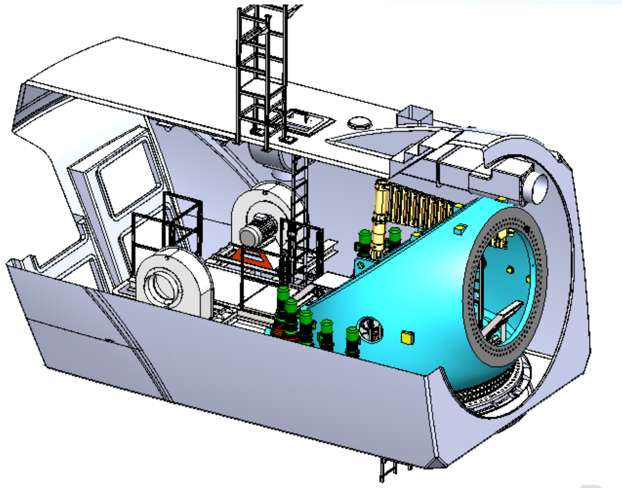

图 5 机舱外形图

Figure 5 The diagram of Nacelle

表 4 HE175-5.X MW 风力发电机组机舱技术参数

Table 4 HE175-5.X MW Nacelle technical parameter

序号 No	项 目 Item	单 位 Unit	参 数 Parameter
1	外形尺寸（长×宽×高） Boundary dimension (L×W×H)	mm	8700×5500×5600
2	重量 Weight	t	55
3	材料 Material		QT400

2.5 传动系统

2.5 Drive system

直驱永磁发电机组传动系统主要分为主传动系统、偏航系统、变桨系统三大部分，相对于双馈机组没有增速齿轮箱，主传动系统采用单轴承结构，可靠性高，可维护性好，主轴承外形图见图 6，传动系统技术参数见表 5。

The direct drive permanent magnet generator drive system is mainly divided into three parts: main driving system, yaw system, and pitch system. Compared with the doubly-fed unit, there is no variable-speed gearbox drive structure, which has high reliability and good maintainability. Main bearing drawing see Figure 6, and Table 5 for the technical parameters of the drive system.

主传动系统、偏航系统、变桨系统分别采用相互独立的润滑系统进行润滑，润滑系统启停均由风机主控系统控制，可实现远程运行控制、状态监控及润滑参数修改，通过调整润滑周期与单次润滑量可以实现对主轴承、偏航轴承及齿轮和变桨轴承及齿轮进行精准定时定量润滑。变桨开式齿面采用无气喷射润滑，润滑油膜喷涂均匀且粘附力强，不易掉落产生污染，润滑效果好，可以大大降低叶片零度位置啮合齿轮的磨损。

The main drive system, yaw system and variable pitch system are respectively lubricated by independent lubrication systems. The start and stop of the lubrication system are controlled by wind turbine main control system, which can realize remote operation control, state monitoring and lubrication parameter modification.The main bearing, yaw bearing and gear as well as variable pitch bearing and gear can be lubricated accurately by adjusting lubrication period and single lubrication amount.Variable pitch open gear surface adopts airless jet lubrication, the lubricating oil film is evenly sprayed and has strong adhesion, which is not easy to fall and cause pollution. The lubrication effect is good, which can greatly reduce the wear of meshing gear at zero position of blade.

图 6 主轴承外形图

Figure 6 The diagram of Main bearing

表 5 HE175-5.X MW 风力发电机组传动系统技术参数

Table 5 HE175-5.X MW WTG Driving system technical parameter

序号 No	项 目 Item	单 位 Unit	参 数 Parameter
主传动系统 Main driving system			
1	轴承类型 Bearing type		三列圆柱滚子轴承 Three-row cylindrical roller bearings
2	轴承材料 Bearing material		42CrMo
3	润滑方式 Lubrication method		加注润滑脂/自动润滑系统 Add grease / automatic lubrication system
变桨系统 Variable pitch system			
1	驱动方式 Driving method		齿轮传动 Gear driving
2	变桨轴承 Variable pitch bearing		四点角接触球轴承 Four point angular contact ball bearings

序号 No	项 目 Item	单 位 Unit	参 数 Parameter
3	润滑方式 Lubrication method		加注润滑脂/自动润滑系统 Add grease / automatic lubrication system
4	变桨驱动形式 Variable pitch driving method		电机驱动 Motor driving
偏航系统 **Yaw system**			
1	控制 Control		主动偏航/PLC 控制 Active yaw/PLC control
2	驱动方式 Driving method		齿轮传动 Gear driving
3	偏航轴承 Yaw bearing		四点角接触球轴承 Four point angular contact ball bearings
4	润滑方式 Lubrication method		加注润滑脂/自动润滑系统 Add grease / automatic lubrication system
5	偏航驱动形式 Yaw driving method		电机驱动 Yaw driving method

2.6 制动系统

2.6 Brake system

机组主制动系统为空气制动，采用三套独立的叶片变桨系统，参数见表 6。

The main braking system of the wind turbine is an air brake, using three sets of independent blade pitch systems, see Table 6 for parameters.

表 6 HE175-5.X MW 风力发电机组制动系统技术参数

Table 6 HE175-5.X MW Brake system technical parameter

序号 No	项 目 Item	单 位 Unit	参 数 Parameter
1	主制动 Main brake		气动刹车 Pneumatic brake
2	第二制动 Pneumatic brake		液压/机械制动器（仅用于维护） Hydraulic / Mechanical brake (For maintenance only)

2.7 电气及控制系统

2.7 Electric and control system

HE175-5.X MW 风力发电机组电气控制系统以可编程控制器为核心，控制电路是由 PLC 中心控制器及其功能扩展模块组成，主要包含塔基控制柜、变流器、机舱控制柜、轮毂控制柜、水冷装置等。主要能够实现风机的正常运行控制、风机故障诊断以及自我保护、故障检测及处理、运行参数的设定、数据记录显示以及人工操作，配备有多种通讯接口，能够实现

就地通讯和远程通讯、状态监控系统等，电气系统示意图见图 7，电气及控制系统技术参数见表 7。

HE175-5.X MW wind turbine electrical control system takes programmable controller as the core, the control circuit is composed of PLC central controller and its function expansion modules, mainly including tower base control cabinet, converter, nacelle control cabinet, hub control cabinet, water cooling device, etc, mainly can realize the normal operation control of the wind turbine, wind turbine fault diagnosis and self-protection, fault detection and processing, operating parameter setting, data record display and manual operation. It is equipped with a variety of communication interfaces, which can realize local communication and remote communication, state monitoring system, etc. The electrical system diagram is shown in Figure 7, and the electrical and control system technical parameters are shown in Table 7.

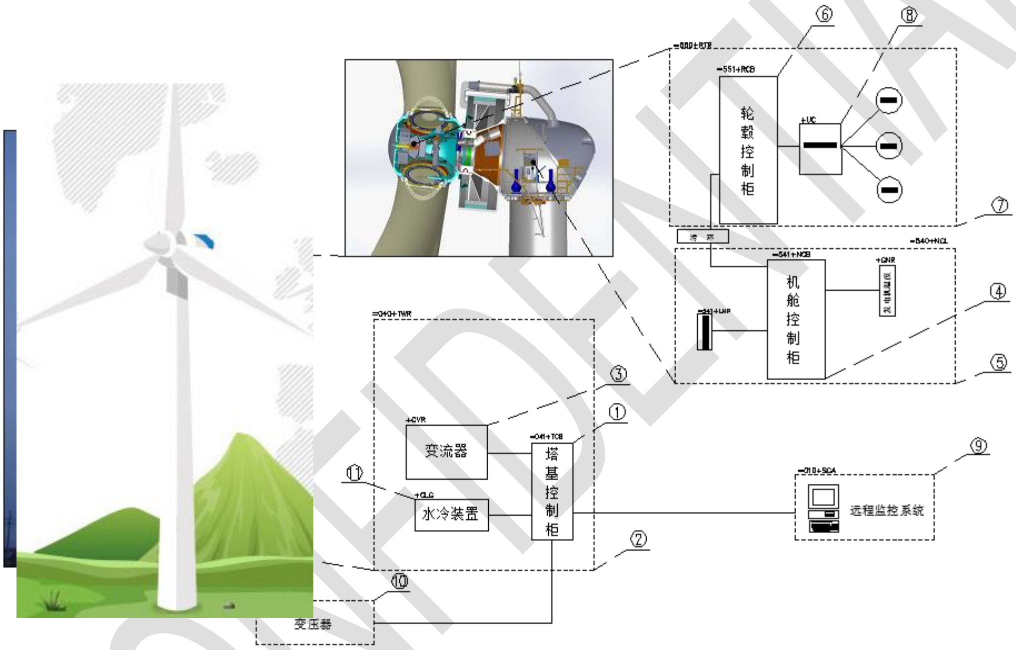

图 7　电气总成示意图

Figure 7　　The electrical system assembly diagram

表 7　HE175-5.X MW 风力发电机组电气及控制系统技术参数

Table 7　HE175-5.X MW wind turbine electrical and control system technical parameter

序号 **No**	项　目 **Item**	单　位 **Unit**	参　数 **Parameter**
电气控制系统 Electrical and control system			
1	控制单元类型 Control unit type		PLC
2	控制类型 Control type		分布式控制，控制系统 PLC 硬件模块主要分布在塔基控制柜、机舱控制柜和轮毂控制柜中，参与进行计算的主站单元安装在塔基控制柜 Distributed control, PLC hardware modules of the control system are mainly distributed in the tower

序号 No	项 目 Item	单 位 Unit	参 数 Parameter
			base control cabinet, nacelle control cabinet and hub control cabinet, and the master station unit involved in the calculation is installed in the tower base control cabinet.

2.8 变流系统

2.8 Converter system

机组发电系统通过全功率变流装置和变压器接入电网，变流系统主电路采用交－直－交结构，将永磁同步风力发电机输出的非工频交流电通过变流柜变换成工频交流电，通过变压器并入电网。变流器安装在塔筒底部的平台上。

The power generation system of wind turbine unit is connected to the grid through a full-power converter device and a transformer. The main circuit of the converter system adopts an AC-DC-AC structure, which converts the non-power frequency AC power output by the permanent magnet synchronous wind turbine into a power frequency AC power through the converter cabinet, merged into the grid through a transformer. The converter is installed on the platform at the bottom of the tower.

全功率变流器采用背靠背（Back-to-Back）双 PWM 结构，电机侧变换器实现对发电机功率和转速的控制，后端的电网侧变流器稳定直流母线电压以及控制功率因素和无功功率。

The full-power converter adopts a Back-to-Back dual PWM structure. The motor-side converter realizes the control of generator power and speed. The back-end grid-side converter stabilizes the DC bus voltage and controls the power factor and reactive power.

表 8 HE175-5.X MW 风力发电机组变流器系统技术参数

Table 8 HE175-5.X MW Converter system technical parameter

序号 No.	项 目 Item	单 位 Unit	参 数 Parameter
1	型式 Type		交-直-交/IGBT AC-DC-AC / IGBT
2	输出频率变化范围 Output frequency change range	Hz	47.5～51.5
3	输入/输出电压 Input / output voltage	V	1380/1140
4	输出功率因数 Output power factor		-0.95～+0.95
5	冷却方式 Cooling method		水冷 Water cooling

2.9 监控系统

2.9 Monitoring system

机组监控系统一般分为中央监控系统和远程监测系统。

中央监控系统由就地通讯网络、监控计算机、保护装置、中央监控软件等组成，主要功

能是用于风电厂人员集中管理和控制风机。

远程监测系统由中央监控计算机、网络设备（路由器、交换机）、数据传输介质（电话线、无线网络、Internet）、远程监控计算机、保护系统、远程监控软件等组成，主要功能是让远程用户实时查看风机运行状况、历史资料等。

哈电风能公司自主开发的 SCADA 系统，拥有功能完善的风力发电机中央监控软件及远程监测软件，可实时对多个风电场、多种机型实现远程数据采集和监测，中央监控系统示意图见图 9。

The central monitoring system is composed of local communication network, monitoring computer, protection device, central monitoring software, etc. The main function is to centrally manage and control wind turbines by wind power plant personnel.

The remote monitoring system consists of a central monitoring computer, network equipment (routers, switches), data transmission media (phone lines, wireless networks, Internet), remote monitoring computers, protection systems, remote monitoring software, etc. The main function is to allow remote users to view in real time wind turbine operating status, historical data, etc.

The HEWP-SCADA system independently developed by Harbin Electric Wind Power Co.,Ltd has comprehensive wind turbine central monitoring software and remote monitoring software, which can realize remote data collection and monitoring for multiple wind farms and multiple models wind turbine in real time. Diagram of the central monitoring system see Figure 9.

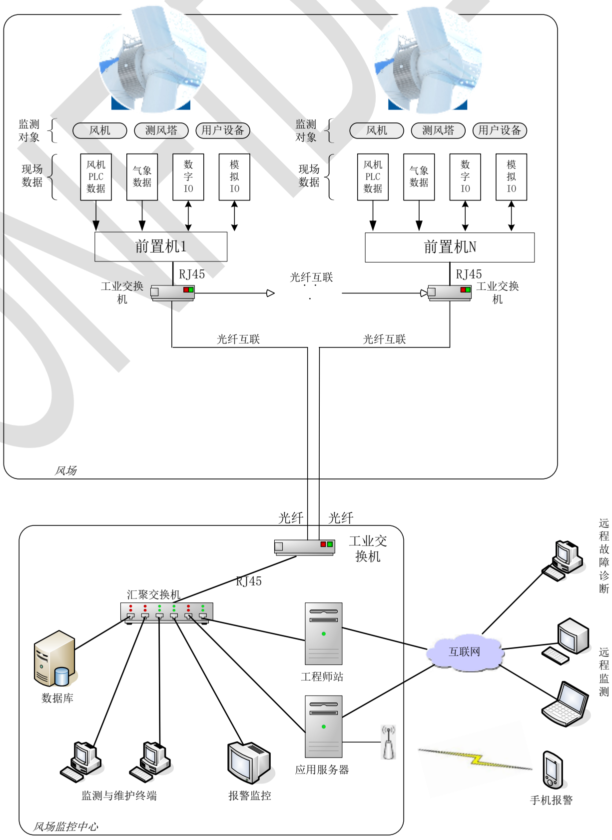

图 9 中央监控系统示意图

Figure 9 Diagram of the central monitoring system

2.10 塔筒

2.10 Tower

HE175-5.X MW 机组轮毂高度为 106m/特定高度设计，塔筒为全钢制锥筒式或钢-混凝土混合型结构设计。锥形钢制塔筒支撑机舱、发电机、风轮并把机组所受的力传送到基础。塔筒每段间，用螺栓及法兰连接。塔筒与基础的连接是通过预埋在基础里面的基础环、锚栓进行连接。偏航轴承通过螺栓直接连接在塔基法兰上。主控柜、变流器等电气设备安装在塔筒底部。

The Hub height of HE175-5.X MW is 106m/specific height design, and the tower is designed with all-steel cone or steel-concrete hybrid structure. The cone-shaped steel tower supports the nacelle, generator, and rotor and transmits the forces experienced by the wind turbine unit to the foundation. Between each section of the tower base, connect with bolts and flanges. The connection between the tower and the foundation is through a foundation ring embedded in the foundation. The yaw bearing is directly connected to the tower base flange by bolts. Electrical equipment such as the main control cabinet and converter are installed at the bottom of the tower.

塔筒内装有爬梯、爬升助力装置和防跌落保护装置。塔筒沿高度方向每隔一段距离有供休息的平台。顶部平台装有进入机舱的爬梯。塔筒和机舱内部装有照明灯。

The tower is equipped with a climbing ladder, a climbing booster device and an anti-fall protection device. The tower has platforms for resting at intervals along the height direction. The top platform is equipped with a ladder to enter the nacelle. The tower and the nacelle are equipped with lights.

塔筒内装有动力电缆和控制电缆，电缆悬挂在塔筒上部以利于机舱偏航。

The tower is equipped with power cables and control cables, and the cables are suspended on the upper part of the tower to facilitate the yaw of the nacelle.

HE175-5.X MW 机组配套塔筒参数说明，详见本规范第 4.2 节内容。

HE175-5.X MW unit supporting tower parameter description, see section 4.2 details.

2.11 基础

2.11 Foundation

根据不同的质地条件，可选择重力式基础（块状基础）或承台桩基础。主要依靠自身重力和基桩的抗拔力来平衡自塔筒传来的上部倾覆力矩、水平荷载以及竖向荷载。基础外观主要为八边形和圆形。

HE175-5.X MW 机组标准基础资料说明详见本规范第 4.1 节内容。

According to different texture conditions, a gravity foundation (block foundation) or a pile cap foundation can be selected. Mainly rely on its own gravity and the pull-out force of the foundation pile to balance the upper overturning moment, horizontal load and vertical load transmitted from the tower. The basic appearance is mainly octagonal and circular.

HE175-5.X MW unit standard foundation information description, see section 4.1 details.

2.12 并网系统

2.12 Grid connection system

机组并网系统采用 AC-DC-AC 变流方式，将发电机发出的低频交流电经整流转变为直流电(AC/DC)，再经 DC/AC 逆变器变为与电网同频率同相的交流电，最后经变压器并入电网，完成向电网输送电能的任务。机组的输出电压是 1140V,频率为 50Hz，由变压器转变成 10/35KV 的高压并入电网。

The grid-connected system of the wind turbine unit adopts the AC-DC-AC conversion method, which converts the low-frequency alternating current from the generator into direct current (AC/DC) through rectification, and then into alternating current with the same frequency and phase as the grid through a DC/AC inverter. Finally, it is merged into the power grid through the transformer to complete the task of delivering electric energy to the power grid. The output voltage of the wind turbine unit is 690V, the frequency is 50Hz, which is transformed into a 10/35KV high voltage by a transformer and connected to the grid.

风力发电机组与电网联接采用一机一变的形式，送电回路由风机的进线主开关通过直埋电缆与箱变低压侧相连，机组与电网联接示意图见图 10。

The connection between the wind turbine and the power grid adopts the form of one machine and one variable. The power transmission circuit is connected to the low-voltage side of the box substation through the main switch of the wind turbine input line through a direct buried cable. The diagram of the connection between the wind turbine unit and the power grid is shown in Figure 10.

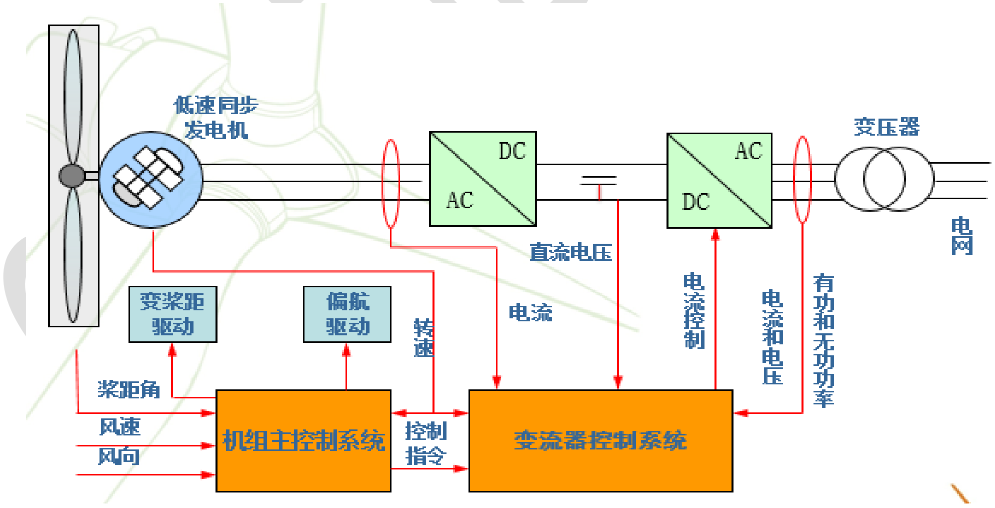

图 10 风力发电机组与电网联接示意图

Figure 10 Diagram of the connection between the wind turbine and the grid

2.13 防雷保护

2.13 Lightning protection

HE175-5.X MW 风力发电机组的防雷系统，从叶尖到机组基础，各部分均采用了严密的

防雷击保护措施。根据相应的防雷标准，将风力发电系统分为多个电磁兼容性防雷保护区（如图 11）。针对不同防雷区域采取有效的防护手段，主要包括雷电接受和传导系统、过电压保护和等电位连接等措施，充分针对雷电的特点而设计。

The lightning protection system of HE175-5.X MW wind turbines adopts strict lightning protection measures from the blade tip to the foundation of the wind turbine unit. According to the corresponding lightning protection standards, the wind power generation system is divided into multiple electromagnetic compatibility lightning protection zones (Figure 11). Effective protection measures are taken for different lightning protection areas, mainly including lightning receiving and conduction systems, overvoltage protection and equipotential connection, etc., which are fully designed for the characteristics of lightning.

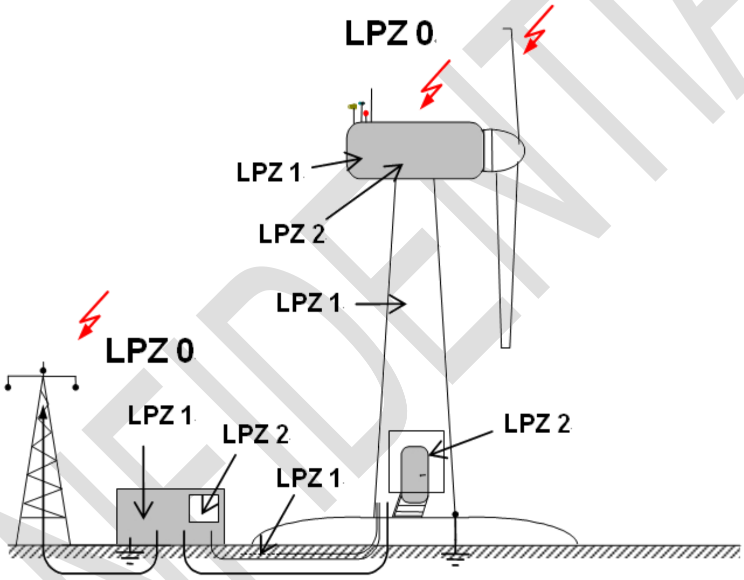

图 11 风机防雷系统图

Figure 11 Lightning protection system diagram of wind turbine

表 9 机组防雷设计说明

Table 9 Lightning protection design description of wind turbine

序号 No	项 目 Item	单 位 Unit	参 数 Parameter
1	防雷设计标准 Lightning protection design standard		按照 IEC61400-1、IEC61024-1、IEC61312 设计，符合 GL 认证规范 Designed in accordance with IEC61400-1 IEC61024-1 IEC61312, in line with the GL certification specification
2	防雷措施 Lightning protection measure		电气防雷、叶尖防雷等 Electric lightning protection、 Blade tip lightning protection etc.
3	机组接地电阻值	Ω	≤4

序号 **No**	项 目 **Item**	单 位 **Unit**	参 数 **Parameter**
	Wind turbine grounding resistance value		

机舱顶部设计有避雷针，叶片设置有多组接闪器，接闪器通过叶片内部预埋的引下线与叶片根部中心位置的叶片避雷接线柱连接。风电机组防雷接地设计示意图见图 12。

The top of the nacelle is designed with lightning rods, and the blades are equipped with multiple sets of air-termination devices. The air-termination devices are connected to the blade lightning protection terminal at the center of the blade root through the down conductor embedded in the blade. The diagram of lightning protection grounding design for wind turbines is shown in Figure 12.

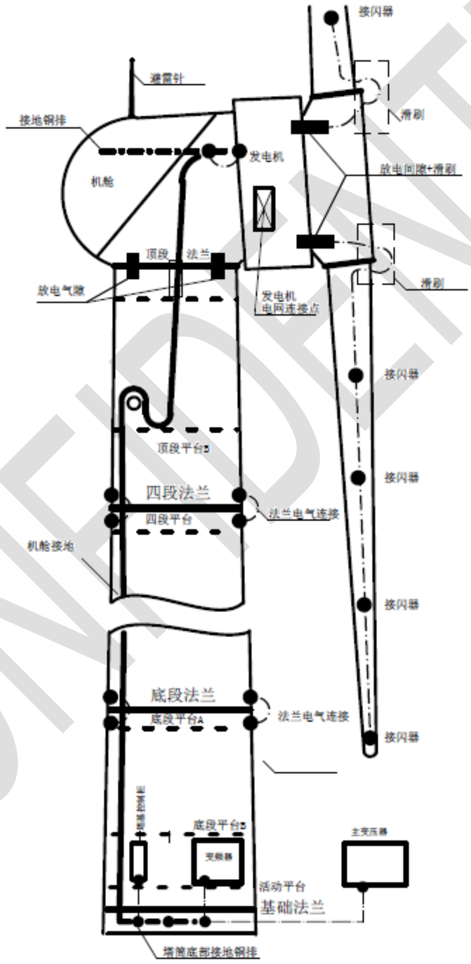

图 12 风电机组防雷接地设计示意图

Figure 12 The diagram of lightning protection grounding design for wind turbines

3 机组功率曲线

3 Wind turbine power curve

表 9 HE175-5.X 机组标准空气密度下动态功率曲线、推力系数

Table 9 Dynamic power curve and thrust coefficient of HE175-5.X unit under standard air density

	标准空气密度(1.225kg/m3) Standard air density (1.225kg/m3)			
	15m/s 湍流度平均值：0.1 15 m/s Turbulence average value: 10%			
风速 Wind speed （m/s）	功率 Power（kW） (HE175-5000)	功率 Power（kW） (HE175-5300)	功率 Power（kW） (HE175-5600)	推力系数 Thrust coefficient
3.0	106.2	106.2	106.2	1.2051
3.5	225.8	225.8	225.8	1.0539
4.0	387.3	387.3	387.3	0.9416
4.5	585.1	585.1	585.1	0.8534
5.0	821.9	821.9	821.9	0.8134
5.5	1104.3	1104.3	1104.3	0.8144
6.0	1438.8	1438.8	1438.8	0.8136
6.5	1829.8	1829.8	1829.8	0.814
7.0	2280.9	2280.9	2280.9	0.8142
7.5	2794.8	2794.8	2794.8	0.8146
8.0	3371.7	3371.7	3371.7	0.7691
8.5	3988.4	3988.4	3988.4	0.7239
9.0	4520.0	4600.0	4640.0	0.681
9.5	4854.1	5034.1	5154.1	0.641
10.0	4958.6	5198.6	5378.6	0.6025
10.5	4981.8	5281.8	5501.8	0.5646
11.0	5000	5300	5580	0.4687
11.5	5000	5300	5600	0.3939
12.0	5000	5300	5600	0.339
12.5	5000	5300	5600	0.2956
13.0	5000	5300	5600	0.26
14.0	5000	5300	5600	0.2055
15.0	5000	5300	5600	0.1662
16.0	5000	5300	5600	0.1368
17.0	5000	5300	5600	0.1144

18.0	5000	5300	5600	0.0969
19.0	5000	5300	5600	0.083
20.0	5000	5300	5600	0.0718
21.0	5000	5300	5600	0.0627
22.0	5000	5300	5600	0.0551

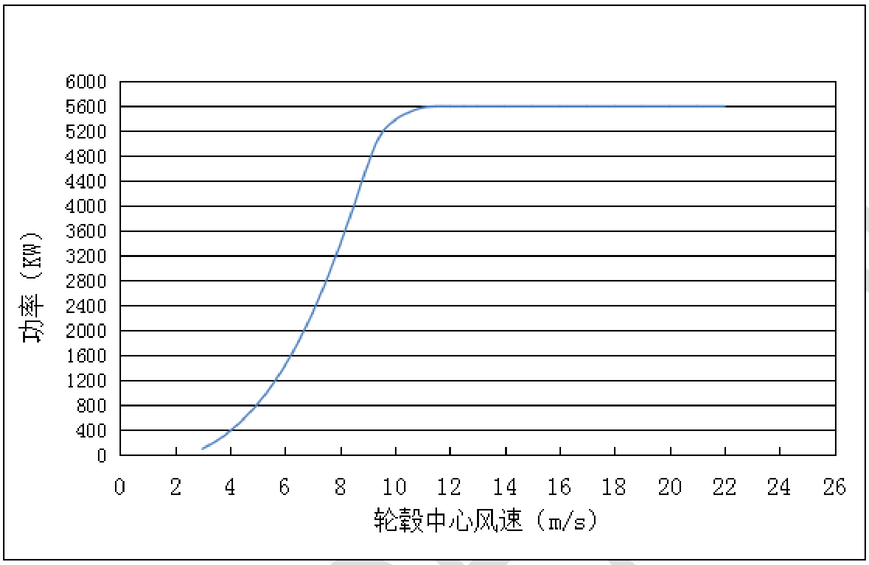

图 13　HE175-5600 标准空气密度下动态功率曲线图

Figure 13　Dynamic power curve of HE175-5600 unit under standard air density

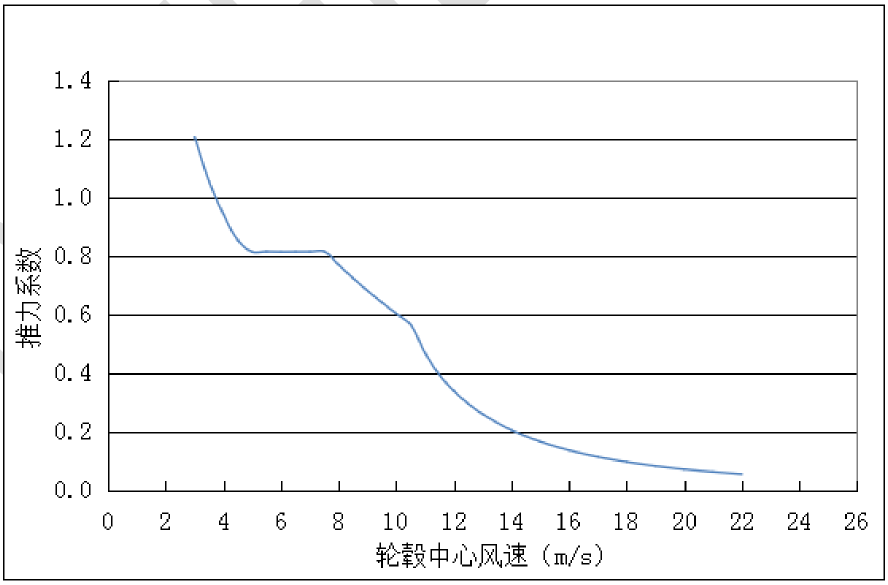

图 14　HE175-5600 标准空气密度下推力系数图

Figure 14　Thrust coefficient of HE175-5600 unit under standard air density

4 机组工程评估参数

4　Wind turbine engineering assessment parameter

4.1 标准基础资料

4.1 Standard foundation information

基础载荷参考坐标系采用塔筒载荷坐标系（如图 15 所示），原点位于塔筒底部截面中心，不随着机舱旋转，并与基础保持固定。

The foundation load reference coordinate system adopts the tower load coordinate system (as shown in Figure 15). The origin is located at the center of the bottom section of the tower, does not rotate with the nacelle, and remains fixed to the foundation.

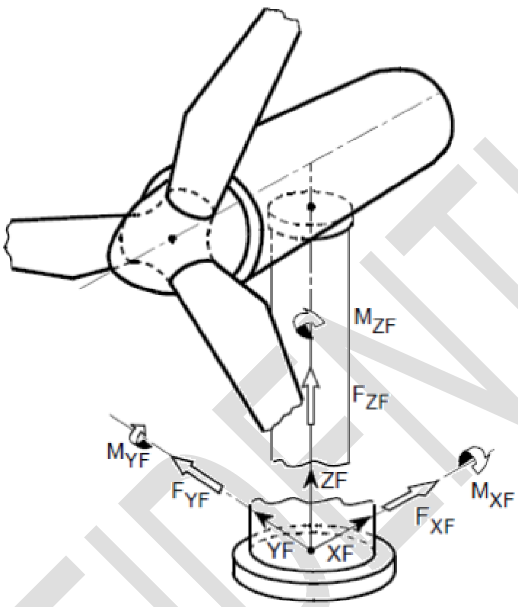

图 15 塔筒载荷坐标系图

Figure 15 Tower load coordinate system diagram

表 10 极限载荷（塔筒底部）

Table 10 Ultimate load (Bottom of Tower)

受力类型 Force-bearing types	Fz	Fxy	Mxy	Mz
单位 Unit	kN	kN	kNm	kNm
安全系数 Safety coefficient	1.1	1.1	1.1	1.1
已包含安全系数 Safety coefficient included	-8204.16	1282.10	156508.97	17.22

表 11　HE175-5.X 机组标准基础工程量

Table 11　HE175-5.X wind turbine standard foundation work amount

材料 Material	混凝土 Concrete	钢筋 Rebar
单位 Unit	m^3	t
数量 Quantity	679（C40）	64.1

注：本节提供的基础数据是在假设硬质粘土的基础进行的标准基础设计，具体的基础设计需根据当地的地质详勘报告做专项设计。

Note: The basic data provided in this section is a standard basic design based on the assumption of hard clay. The specific basic design needs to be specially designed according to the local detailed geological survey report.

4.2 机组塔筒数据

4.2 Wind turbine tower data

表 12　HE175-5.X MW 机组配套塔筒数据

Table 12　HE175-5.X MW wind turbine supporting tower data

序号 No.	名称 Name	外形尺寸(mm) Boundary dimensions (mm)	单重(t) Weight(t)
1	第 1 节 Section one	φ5200×22400	95.91
2	第 2 节 Section two	Φ5200×25200	76.54
3	第 3 节 Section three	Φ5200×28000	72.67
4	第 4 节 Section four	（φ5200～φ4180）×27400	61.35
5	塔架总重（含附件） Tower total weight	高度 H=103000 Height	316.46
6	锚栓组件 Anchor bolt component		21.5

说明：该塔筒参数为机型标准塔筒参数，具体项目塔筒参数需根据项目风资源等运行环境情况特定设计。

Note: The tower parameters are the standard tower parameters of the wind turbine, and the specific project tower parameters need to be specifically designed according to the project's wind resources and other operating environment conditions.

5　机组电网适应性说明

5　Adaptability description of wind turbine power grid

风力发电机组设计满足电网在以下条件下正常运行的要求，对于并网有特殊要求的，需要根据当地电网实际情况进行差异性设计。

The design of wind turbine meets the requirements of the normal operation of the power grid under the following conditions. If there are special requirements for grid connection, it is necessary to carry out a differential design according to the actual situation of the local power grid.

5.1 电能品质

机组电能品质符合 IEC61400-21 的标准要求以及《国家电网公司风电场接入电网技术规定（试行）》：风力发电机组能满足风电场所接入公共连接点的闪变值 GB12326 的要求；风力发电机组能确保风电场所接入公共连接点的谐波注入电流满足 GB/T14549 的要求。当风电场并网点的闪变满足 GB12326、谐波满足 GB/T14549、三相电压不平衡度满足 GB/T15543 的规定时，风电场内的风力发电机组能正常运行。

The power quality of the wind turbine meets the standard requirements of IEC61400-21 and the 《Technical Regulations for Connecting Wind Farms of the State Grid Corporation of China (Trial)》": Wind turbines can meet the requirements of GB12326 for the flicker value of public connection points connected to wind farm; The wind turbines can ensure that the harmonic injection current of the public connection point of the wind farm meets the requirements of GB/T14549. When the flicker of the wind farm grid connection point meets GB12326, the harmonics meets GB/T14549, and the three-phase voltage unbalance meets the requirements of GB/T15543, the wind turbines in the wind farm can operate normally.

表 13 电能品质要求

Table 13 Power quality requirement

项目 **Item**	要求 **Requirement**
电压 Voltage	-10%/+10%
频率 Frequency	50Hz+/-0.5Hz
电压的不对称限值 Voltage asymmetric limit value	4%
机组功率因数 Wind turbine power factor	感性 0.95～容性 0.95 之间可调 Inductive 0.95 ～ Capacitive 0.95 (adjustable)
变压器低压侧总电流谐波含量 Harmonic content of total current of transformer low voltage side	<5%

5.2 频率

5.2 Frequency

当风电场并网点电网频率偏离时，风力发电机组能按照表 14 的要求运行。

When the grid frequency of the wind farm grid connection point deviates, the wind turbine can operate according to the requirements of Table 14.

表 14 频率偏离下的风电场运行

Table 14 Wind farm operation under frequency deviation

电网频率范围 **Grid frequency range**	要求 **Requirements**
低于 47.5Hz Lower than 47.5Hz	根据风电场发电机组允许运行的最低频率而定。 It is determined according to the lowest frequency allowed to operate the wind farm’s wind turbine.
47.5Hz—49.5 Hz	每次频率低于 49.5 Hz 时要求至少能运行 10 分钟。 Each time the frequency is lower than 49.5 Hz, it is required to run for at least 10 minutes.
49.5Hz—50.5Hz	连续运行。 Run Continuously
50.5Hz—51Hz	每次频率高于 50.5Hz 时，至少能运行 2 分钟；并且当频率高于 50.5Hz 时，不允许停止状态的风力发电机组并网。 Each time the frequency is higher than 50.5Hz, it can run for at least 2 minutes; and when the frequency is higher than 50.5Hz, wind turbines in the stopped state are not allowed to be connected to the grid.
高于 51Hz Higher than 51 Hz	根据电网调度部门的指令限功率运行。 Higher than 51 Hz

5.3 低电压穿越能力说明

5.3 Low voltage ride through capability description

机组对风电场电网的低电压穿越性能满足图 16 要求。风电场并网点电压在图中电压轮廓线及以上的区域内时，场内风力发电机组必须保证不间断并网运行；并网点电压在图中电压轮廓线以下时，场内风力发电机组允许从电网切出。其中：

The low voltage ride-through performance of the wind turbine to the wind farm grid meets the requirements of Figure 16. When the grid connection point voltage of the wind farm is in the area above the voltage contour line in the figure, the on-site wind turbine generators must ensure uninterrupted grid connection operation; when the grid connection point voltage is below the voltage contour line in the figure, the wind turbine grid is cut out.

（1）风力发电机组在并网点电压跌至 20%额定电压时能够维持并网运行 625ms 的低电压穿越能力；

(1) When the grid-connected point voltage drops to 20% of the rated voltage, the wind turbine can maintain a low voltage ride-through capability of 625ms for grid-connected operation.

（2）风电场并网点电压在发生跌落后 2s 内能够恢复到额定电压的 90%时，风力发电机组保持并网运行；

（2） When the voltage at the grid-connected point of the wind farm can be restored to 90% of the rated voltage within 2s after the occurrence of a drop, the wind turbine will maintain grid-connected operation.

（3）对故障期间没有切出电网的风电场，其有功功率在故障切除后快速恢复，以至少10%额定功率/秒的功率变化率恢复至故障前的值。

（3）For wind farms that have not been cut out of the grid during the fault, their active power will quickly recover after the fault is removed, and return to the value before the fault with a power change rate of at least 10% of the rated power per second.

5.4 高电压穿能力说明

5.4 High voltage ride through capacity description

风力发电机组具备高穿能力满足《风力发电机组 故障穿越能力测试规程》送审稿中对高电压穿越能力的要求，具体如下：

Wind turbines have high penetration capability to meet the requirements for high voltage ride through capability in the draft of the《Test Procedures for Wind Turbine Fault Ride Through Capability》submitted for review, as follows:

a） 风电机组具有在风电场并网点电压升高至130%标称电压时能够保证不脱网连续运行500ms的能力；

The wind turbine has the ability to ensure continuous operation for 500ms without going off the grid when the voltage at the grid connection point of the wind farm increases to 130% of the nominal voltage.

b） 风电机组具有在风电场并网点电压升高至125%标称电压时能够保证不脱网连续运行1000ms的能力；

The wind turbine has the ability to ensure continuous operation for 1000ms without going off the grid when the voltage at the grid connection point of the wind farm increase to 125% of the nominal voltage.

c） 风电机组具有在风电场并网点电压升高至120%标称电压时能够保证不脱网连续运行10s的能力；

The wind turbine has the ability to guarantee continuous operation for 10s without going off the grid when the voltage at the grid connection point of the wind farm increases to 120% of the nominal voltage;

d） 风电机组具有在风电场并网点电压升高至110%标称电压时能够保证不脱网连续运行的能力。

Wind turbines have the ability to ensure continuous operation without going off the grid when the voltage at the grid connection point of the wind farm rises to 110% of the nominal voltage.

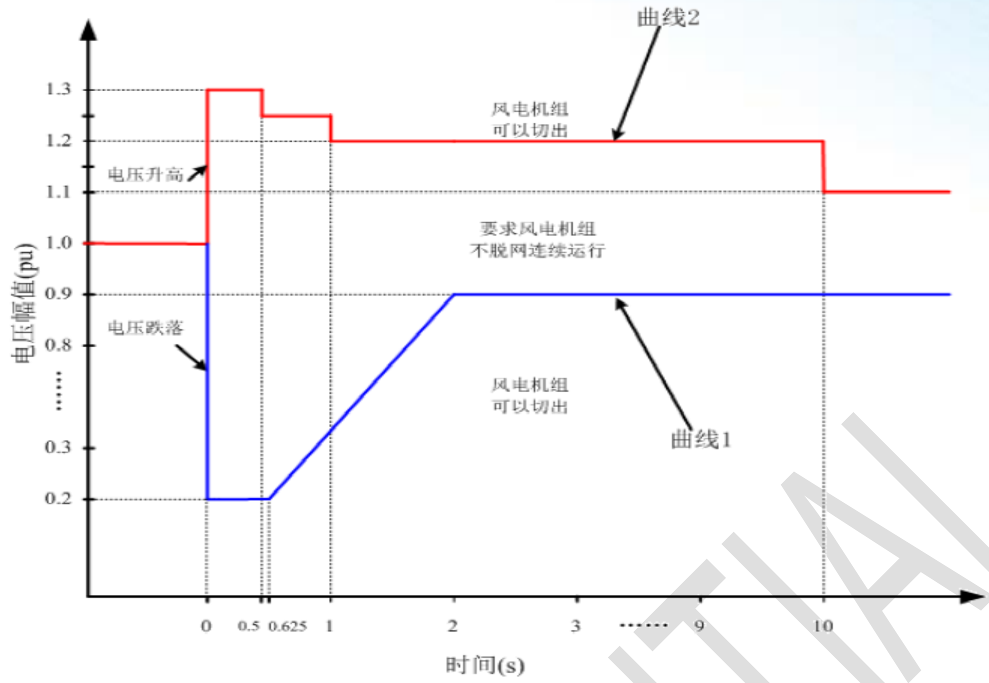

图 16 故障穿越能力曲线

Figure 16 Fault Ride Through Capability

5.5 有功/无功调节能力

5.5 Active/reactive power adjustment capability

风力发电机组控制系统能够根据电网调度和风电场运行人员的指令在风机的能力范围内实现风电场有功、无功的调节。

The wind turbine control system can realize the adjustment of the active and reactive power of the wind farm within the capability of the wind turbine according to the power grid dispatch and the instructions of the wind farm operators.

有功、无功调节系统具有本地和远端有功功率与无功功率控制的能力，机组在正常发电运行状态下可依据电网调度或风电场运行人员的指令通过控制软件对每台风机进行在线有功、无功功率调节。

The active and reactive power regulation system has the ability to control local and remote active power and reactive power. The wind turbine unit can perform online active and reactive power control on each wind turbine through the control software according to the power grid dispatching or the wind farm operator’s instructions under normal power generation operation、reactive power regulation.

风力发电机组具有有功功率控制能力，接收并自动执行风电场发送的有功功率控制信号，有功功率控制范围可以在 20%～100%（对应风况的最大输出功率）的范围内平稳调节，无功控制范围在 0.95（感性）～0.95（容性）的范围内平稳调节。

The wind turbine has the ability to control active power. It receives and automatically executes the active power control signal sent by the wind farm. The active power control range can be smoothly adjusted within the range of 20% to 100% (corresponding to the maximum output power of the wind condition). The control range is smoothly adjusted within the range of 0.95 (inductive) to 0.95 (capacitive).

当风电场并网点的电压偏差在-10%～+10%之间时，风力发电机组能正常运行；当风电场并网点电压偏差超过+10%时，风电场的运行状态由风电场卖方风力发电机组的性能确定；当风电场并网点电压低于额定电压 90%时，风电场能满足低电压穿越能力要求。

When the voltage deviation of the wind farm grid connection point is between -10% and +10%, the wind turbine can operate normally; when the voltage deviation of the wind farm grid connection point exceeds +10%, the operation status of the wind farm is determined by the wind farm seller. The performance of the generator set is determined; when the voltage at the grid connection point of the wind farm is lower than 90% of the rated voltage, the wind farm can meet the requirements of low voltage ride through capability.