1. General

The whole structure and layout of proposed wind turbine schematic is as shown in Figure -1:

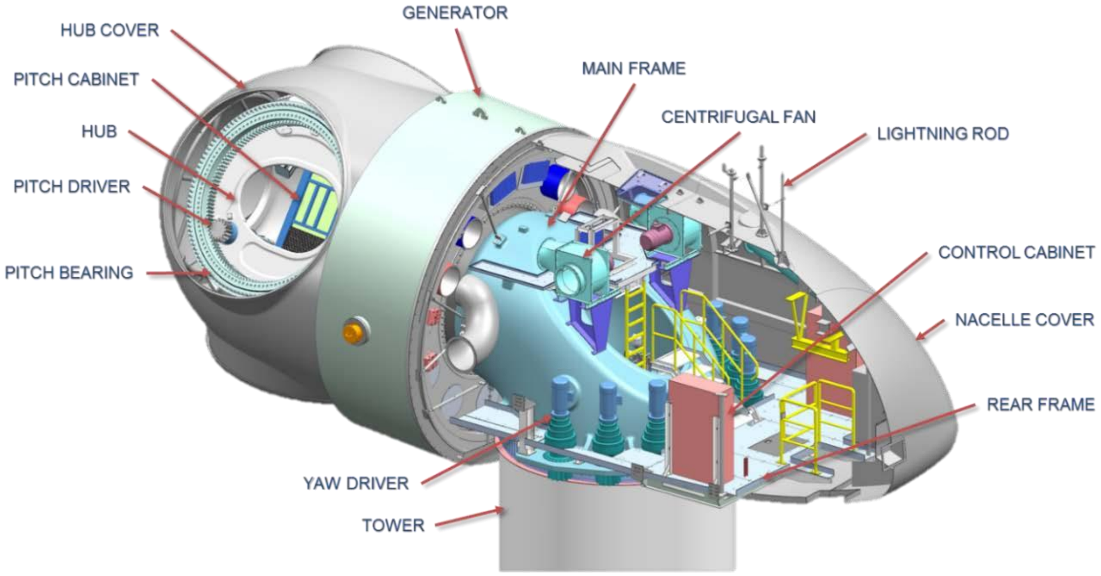

Figure-1 Structure and Layout of Wind Turbine

The proposed wind turbine is of type direct drive and outer rotor permanent magnet synchronous generator and each wind turbine comes with a step-up transformer.

The direct drive permanent magnet wind turbine leaves the vulnerable gearbox out and also the main shaft and shaft coupling, which increases the technical reliability of the wind turbine. The wind rotor is directly connected to the generator rotor, simplifying and shortening the drive chain and improving the reliability and drive efficiency farthest. In addition, it can generate more power than conventional wind turbines. Furthermore, the direct drive permanent magnet wind turbine runs at low speed without any high-speed rotational parts, which allows for optimal operating conditions, prolong the lifecycle of the wind turbine, reduce the noise and greatly improve the reliability of the turbine. All power is converted through one full scale converter and ensures flexible expansibility of LVRT function and power quality.

The proposed wind turbine complies with the following general performances or requirements or has the following features:

1) The operating temperature is suitable the specific environment in the wind farm.
2) The proposed wind turbines feature horizontal axis, upwind, variable speed and variable pitch and on-grid.
3) The designed lifetime of whole wind turbine is not less than 20 years. The main components, including blade, nacelle cover, hub casting, pitch bearing, pitch reducer

and pitch motor, generator (incl. main bearing), main frame casting, yawing bearing, yawing reducer and yawing motor, auxiliary frame, main body of tower, main windings of 690V/33kV step-up transformer shall not be replaced under normal operation during entire lifetime.

4) The proposed wind turbines are designed in accordance with GL wind turbine guidelines 2010 version and refer to IEC 61400-1:2010. The electrical system design complies with IEC 60204-1, IEC 60364 and other relevant IEC standards.

5) The proposed wind turbines are in accordance with relevant EU directives and harmonized standards including Machinery Directive 2006/42/EC and the Low Voltage Directive 2006/95/EC, the delivered wind turbines shall get the permission from authorized accredited organization to mark with "CE" on them before shipment.

6) As well as the EMC Directive 2004/108/EC will be followed. All personnel equipment delivered or self-used by the Bidder complies with the Directive 89/686/EC.

7) The same type of part which serves at same installed position is completely interchangeable, but except for the blades which are limited interchangeable considering balance of weights.

8) The proposed wind turbines use one unique suit of color coding and marking system.

9) The poisonous of used or remaining materials in delivered goods will abide by relevant International standards or EU Directives. Forbidden substances will not be applied in manufacturing and operating process.

2. Blades

The blades are shaped using the latest aerodynamics research results, with excellent aerodynamic performance and high-precision manufacturing technology.

The blade color shall be jointly agreed upon between Contractor and Employer.

The design and testing standard of wind turbine blades:

GB/T 2576	Test Method for Insoluble Matter Content of Fiber Reinforced Plastic Resin
IEC/TS 61400-23	Rotor Blades of Full Size Tests
IEC/TR 61400-24	Wind Turbine Lightning Protection
GL 2010	Germanischer Lloyd Nonmetallic Material Specification Requirements

During periodic maintenance the blade surface will be inspected and tiny cracks or damages conveniently positioned with the help of a series of numbered marks after every one meter on the front edge of the blades. Damages may be caused by external forces during operations such as ice crystals, hailstones etc.

The blade is made of epoxy reinforced glass fiber, with good corrosion resistance and electrical insulation, it also has low density, high strength-to-weight ratio and better fatigue performances compared with metallic material. High modulus glass fiber is used for main spar cap of blade, with that the strength and stiffness of blade is maximized, and the weight can also be reduced, the stiffness is not affected. The surface of the blade is coated with polyurethane which has good anti-corrosion, anti-sand erosion and anti-ultraviolet properties.

The blade root joint is the pre-embedded bolt structure. Compared with the traditional T-joint bolt structure, a larger number of coupling bolts can be designed under the same pitch diameter to ensure the strength and fatigue life of the joint bolt. The rain cover is installed on the blade root to prevent rainwater from entering the hub. An inter place near the tip of the blade is reserved to ensure a balanced mass of the entire rotor.

The blades are equipped with lightning receptor to protect the blades from lightning. A lightning recording device is installed in the blade root to record the maximum lightning current of the blade automatically.

3. Mechanical System

The mechanical system needs to withstand the bending loads, torque loads and dead load transferred from blades, generator and nacelle. It plays the role as a supporting structure as well as a carrier of the mechanical energy.

The proposed wind turbine has a shortened drive chain, low losses, high efficiency, flexible operation, reasonable loads distribution and reliable supporting parts.

3.1 Rotor

The rotor rotates variably with wind speed, and the rotation of the blades is controlled by a pitch control system. Moreover, independent variable blade pitch systems, driven by AC or DC motor, ensure the system is stable and reliable.

The blades are connected to the hub and the generator via pitch bearings by high-strength bolts. The hub adopts spherical casting structure, and rigorous finite element strength analysis ensures uniform stress distribution.

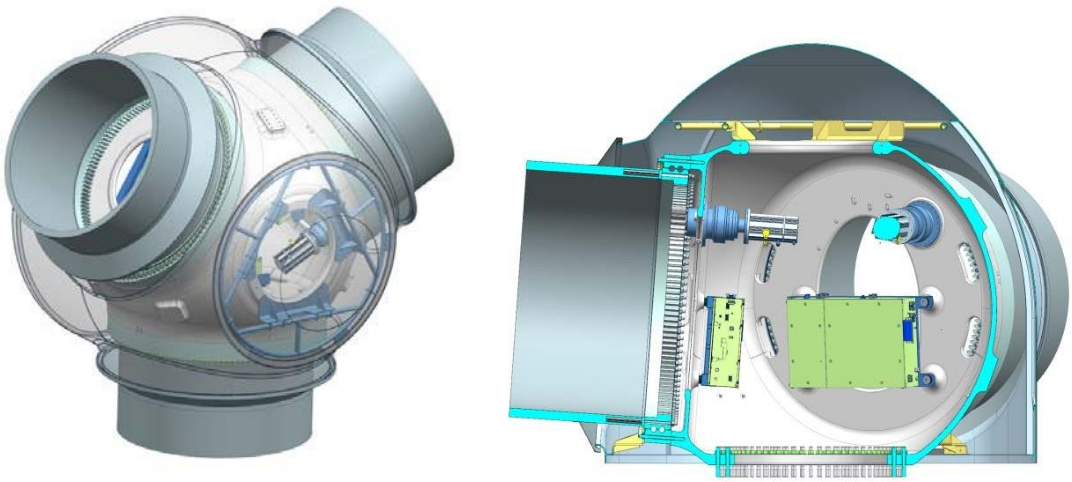

Figure-3 Rotor and Blade

The casting hub with gradual wall-thickness is not only reducing the weight of the part but also providing adequate space for the pitch system and lubricating system. Premium nodular cast iron combines the advantages of excellent mechanical performance and ductility. The nose of the casting hub is covered by a plate, the whole hub is sealed.

The rotor speed automatically adapts the current wind speed change by harmonizing pitch rating and electromagnetic torque under the orders from main controller.

The Bidder has considered treatments to mitigate risk from damage due to unlocking and dropping components inside the hub.

The material is high grade ductile iron of EN-GJS-400-18U-LT （ DIN1563-2012 ） integrating excellent mechanical performance, ductility and low temperature performance and resulting in high strength and good processing property.

3.2 Frame and Nacelle

The frame (including mainframe of the casting structure and the auxiliary frame of the welding structure) introduces compact structure and exquisite design. The mainframe is connected to the generator and tower top with bolts. The auxiliary frame is mounted to the mainframe by bolts. The nacelle cover is made of glass fiber reinforced plastic and enhanced internal stiffening structure to get lower weight and higher strength. Embedded support steel plates into the shell serve mainly as local strength enhancement for each point of concentrated load by mounted accessories.

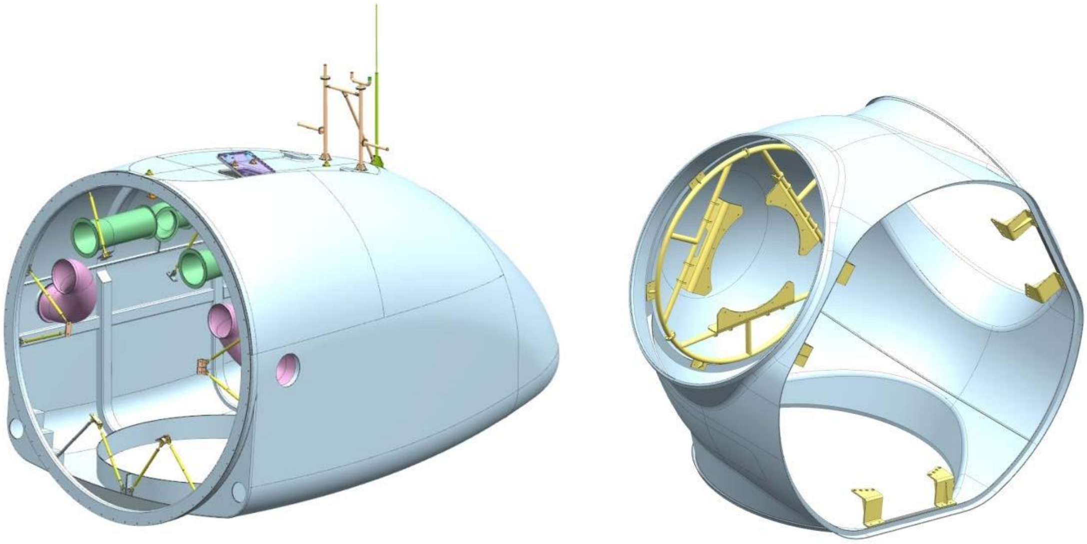

Figure-4 Structure and Layout of Nacelle

Partial wind duct is integrated in the inner wall of the nacelle. Moreover, air inlet and outlet will be closed manually in winter to keep the nacelle warm. There is sufficient space for mounting, debugging and maintaining the equipment. Sound and heat insulation lining is made with inflame retarding foam material in the entire nacelle.

Eight adjustable steel poles are mounted on the main frame against deformation and to reduce vibrations of the nacelle shell. At the same time, the whole shell is divided into several parts to facilitate transportation.

3.3 Drive Chain

The proposed wind turbine is the product of successfully integrating the latest technique. Dongfang has been improving and upgrading this technique with outstanding technical advantages.

The most outstanding feature of the drive chain is the omission of the gearbox which is the weakest point for the reliability during manufacture and operation of the wind turbine and taking main shaft system and generator as the driving components. The wind rotor is directly connected to the generator's outer rotor which simplifies the structure, shortens the drive chain, increases the reliability and efficiency of the system and makes the whole system to operate within a bigger variable ratio than gearbox wind turbines and furthermore capture more wind energy.

Based on a permanent magnet low-speed generator, the system is operated under low speed with no parts running at high speed, which optimizes the working condition for the system, reduces the noise and further increases the reliability of the complete unit. Furthermore, permanent magnet excitation is used instead of electrical exciting system avoiding the excitation loss so that the generator can be exempted from maintenance with compact structure and reasonable load distribution, thus the efficiency of the generator can be increased.

The quality of the drive train components is monitored strictly during manufacturing, based on fatigue strength computation to meet the demands of the design.

3.4 Yaw Subsystem

The proposed wind turbine actively yaws to different wind directions. The rear nacelle is equipped with two sets of ultrasonic wind meters. According to its transmission signal, the controller employs yaw drives targeting the principal wind direction to ensure maximum energy output and avoid additional load caused by inclination inflow.

The hydraulic brakes are loosened automatically to a reduced pressure for the time of yawing. When the yaw Angle reaches 720 degrees, the system will untwist the cable automatically.

The control system of the turbine intelligently untwists the cables when the turbine is in a state with low wind speed, avoiding the loss of power generation caused by yaw and cable unwinding at high wind speed.

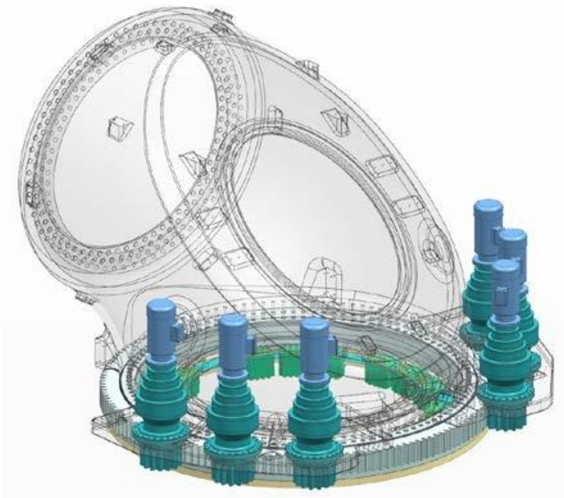

Figure-5 Yaw Subsytem

The yaw bearing adopts a four-point contact ball bearing with “zero-clearance” to enhance the whole unit’s running smoothness and impact load resistance.

The yaw brake is powered by a hydraulic system, locking the nacelle firmly when standstill. Those yaw brakes remain at partial braking pressure to maintain damping to a certain level in order to avoid micro-vibration to protect the yaw system when in operation.

Multi-pole motor drive with soft torque characteristics is used, the yaw speed can be optimized to ensure a small impact based on the working condition of wind farm. The electromagnetic brake system located on the drive shaft of the yaw motor has the function of failure protection. In case of external failure (such as power failure and pressure loss of the hydraulic system), it can keep the yaw system in locking state.

Hard tooth surface of carburizing technology is used for yaw gear. The hardness of tooth surface is more than 50HRC to prevent from abrasion due to long term operation.

3.5 Braking and Hydraulic Subsystem

The wind turbine brake system consists of air braking system and mechanical braking system that implies the design concept of triple redundant protections. The aerodynamic braking system is the primary brake system which parks wind turbine by feathering blades trigged by the control system or safety system.

Four disc-brakes (normally open) are mounted on the generator stator forming the mechanical brake system.

The primary brake system is air brake system to function through blades feathering. With failure of one blade, the pitch-regulate control system can also control the other two blades feathering to reduce the speed to 0, ensuring turbine safety.

Each blade is equipped with a back-up power. In case of a grid failure, the pitch power comes automatically from the back-up power.

In normal brake case, only blade feathering is used without mechanical brake action to reduce the braking impulsion to drive system and increase the life of mechanical brake. Two hydraulic rotor locking devices installed inside the generator is used when maintenance and operation limitation case. The brake block has the function of wearing self-detection and alarm.

The stop procedures are:

1) Normal stop: The blades are driven to the position of 88 degrees with speed of 2 degrees /s and then reach to feathering position at a speed of 0.5 degree/s without using the mechanical brakes.
2) Emergency stop (low-level): The blades are driven to the position of 88 degrees with speed of 3 degrees /s and then reach to feathering position at a speed of 0.5 degree/s to the feather position without using the mechanical brakes. In case of a grid failure, the pitch power comes automatically from the back-up battery
3) Emergency stop (high-level): The blades are driven to the position of 88 degrees with speed of 3 degrees /s and then reach to feathering position at a speed of 0.5 degree/s. The mechanical brakes are used when the rotor speed reduces to 1rpm. In case of a grid failure, the pitch power comes automatically from the back-up battery.

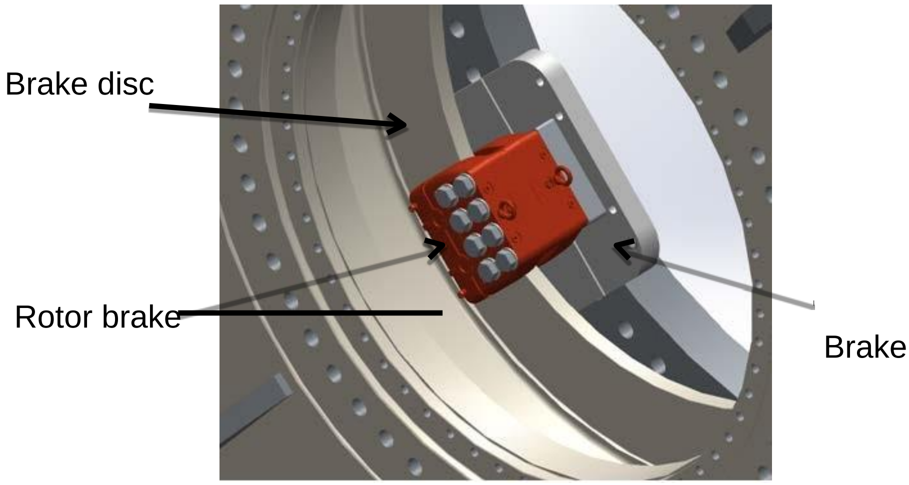

Figure-6 Rotor Brake on Generator

Each blade can be locked by the hydraulic locker at clock positions of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 hour.

Red/green alarming lights are installed in the maintenance area indicating the present state of the braking pin at lock or unlock position. These alarming light signals are transferred to the main control system.

Warning signs and safety instructions shall be adhered at an eye-catching place in the nacelle and main frame.

The hydraulic system consists of a hydraulic pump, electromagnetic components, accumulator, pipeline etc., which will provide power for the yaw brake system, rotor brake system and rotor locking device. Good-quality high temperature protection and anti-freezing measurement can be provided according to different operating environment.

The hydraulic system is equipped with a pressure energy accumulator on one side to reduce impulsive load of the oil pump, on the other side to stabilize braking pressure above a pre-set value when accidental power fault occurs.

The cleanliness of hydraulic lubricate oil will be equal to or better than ISO 4409 17/15/12 or ISO 4406/10.

3.6 Automatic Lubrication

There are three individual automatic lubricating systems to separately lubricate yaw bearing tray and tooth surface, pitch bearing tray and tooth surface and main bearing.

Each set of automatic lubricating system consists of lubricating pump, grease dispenser, lubricating pipeline. Each lubricating pump carries a grease container and requires to manually add grease periodically (every half year or one year).

The three sets of automatic lubricating systems adopt the same type of grease.

The selected lubricating grease complies with the relevant environmental standards and is suitable for the climate conditions of the wind farm location.

Certain components will be added to the WTGs to collect the lubrication grease for secondary utilization and to keep the WTG clean, such as plastic oil catcher on pitch bearings and oil-collecting plate under yaw bearings.

3.7 Hoist in Nacelle and Service Elevator

The proposed wind turbine is equipped with an electric chain hoist in the nacelle for exchanging all nacelle components without further assisting hoists or lifts required. The components in the nacelle and hub can be removed or disassembled by manual method with simple tools.

The electric chain hoist is especially designed for maintaining the WTGs. The maximum bearing load of the chain hoist is 650kg. The chain hoist can slide along the rails that are fixed below the ceiling of the nacelle shell.

The length of chain hoist cable is able to lift down or up the component straight to/from the ground level from/to operation position.

The electric chain hoist is equipped with a hook with a swinging protection device, a button for emergency brake, limit switches for lift up and down, a handheld controller with 2 meters long cable.

The maintenance worker uses the service elevator installed in the tower from bottom platform to top of tower, or directly through ladders fixed on the inner surface of the tower to the top.

The service elevator is guided by aluminum alloy ladder fixed on the inner surface of the tower. At maximum two trained persons ride it at once time.

4. Electrical Power System

The electric power system of the direct drive wind turbine is crucial to obtain optimized power output and first-class power supply quality. Permanent magnet synchronous generator and full-scale power conversion technology allows the wind turbine to operate at optimal C_p value at any time. Omitting the gearbox reduces the operational noise and maintenance workload significantly.

The electric power system of the propose WTG has the capacity of low-voltage ride through function complying with common European grid regulations.

4.1 Principles and Topology

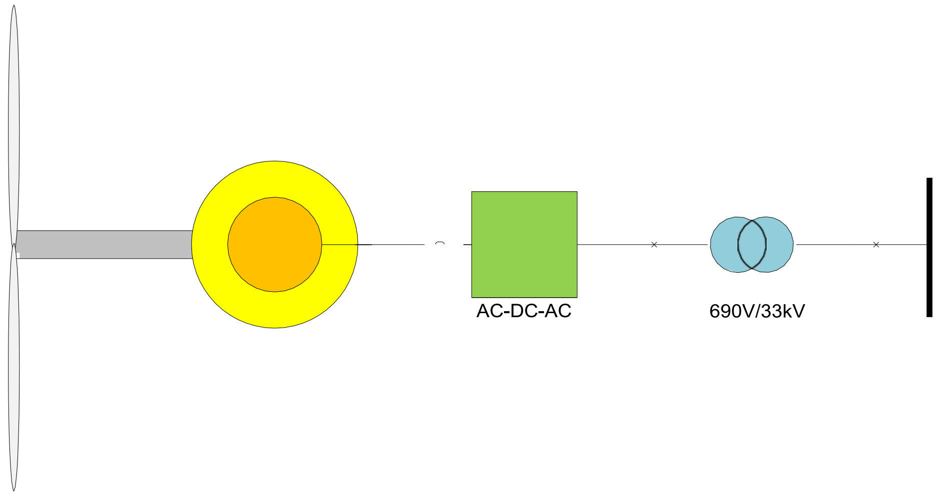

Figure-7 Topology of Power Generating System

Service workers' safety and reliable operation of the generator are all taken into consideration when laying out the electric power system, interface to grid and low-voltage cable type. IEC standards are effectively adhered to during the whole design process.

Direct-drive permanent magnet synchronous generator connects to the grid through full-scale power converter system, which ensures sustained power generation in accordance with the grid voltage and frequency.

The generator provides U, V, W three-phase electrical power. For each phase, copper power cables are used to transfer the power from the main terminal box of the generator to busbars installed at the inner face of the tower.

The busbars transfer the electrical power from the top of the tower to the tower-base. At the tower-base, for each phase, copper power cables conduct the power to the converter cabinet which is located at the base of the tower. The converter cabinet contains the generator side circuit breaker for the converter. The converter controls the circuit breaker.

Again, for each phase, power cables conduct the power from the switch cabinet to the converter. At the grid side of the converter, for each phase, power cables conduct the power from the converter to the WTG step-up transformer. The electrical interoperability is primarily determined by the interoperability between the generator and the converter.

The step-up transformer conducts power to MV switchgear located in the tower, which are connected with other adjacent wind turbines.

The permanent magnet synchronous generator and full power converter system combined with electric-drive variable-pitch regulation system ensures that the power output, efficiency, mechanical loads and power grid voltage quality achieve optimal results. Also, the system avoids over-voltage (surge) and peak loads to the maximum.

4.2 Outer Rotor Permanent Magnet Generator

The 80 poles low speed permanent magnet synchronous generator features:

1) The generator adopts friction slot design and straight layout of magnets. The structure of rotor and stator both are welding;
2) The protection level of the generator is IP54;
3) The absence of carbon brushes and other vulnerable components reduces the workloads of repair and maintenance;
4) Generator stator integrally soaked and dried by VPI (Vacuum Pressure Impregnation) pledges reliable insulation and heat dissipation;
5) Outer rotor structure makes the fixation of magnets more reliable;
6) The material of the rotor magnet is high residual magnetic, high coercive forced, low weightless NdFeB materials, which completely prevent the effect of demagnetization in external magnetic field from temperature and the state of generator fault. Strengthened surface treatment effectively prevents the magnets from corrosion of salt fog, and damp environment. Moreover, modular Magnets beneficial to the installation and removal.
7) The special hollow shaft structure ensures hub maintenance more convenient.

There are PT100 poles berried in the bearing to detect its present temperature. There are several residual testing points on the bearing and in the inner face of generator stator as standby.

The bearing is lubricated with special high performance grease, the certain amount of grease is accurately added by automatic lubrication system every hour, which ensures the optimal running state of the bearing. Automatic alarm function is added to lubricating system to monitor the running of the oil pump and oil routes jams.

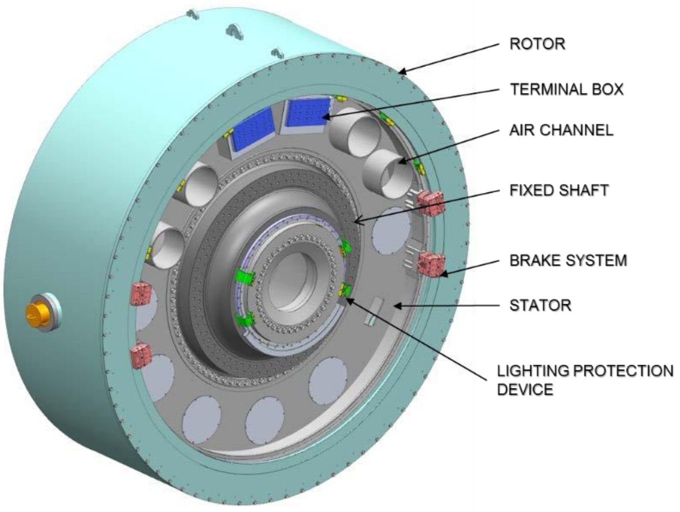

Figure-8 Permanent Magnet Generator

4.3 Full Scale Converter

The core of the converter adopts the world leading fluid-cooling full power IGBT industrial frequency conversion system. Both the front and back end of the converter are equipped with optimized filters.

A rectifier at the generator side optimizes torque and load output requirements to control the generator, while the inverter at the grid side converts the DC power to a stable and premium 50/60 Hz AC power and puts it into the grid.

The power factors of rectifier and inverter can be optimized and adjusted according to the needs of the generator load and inside reactive power compensation.

The converter system adopts an AC-DC-AC full power converter and multiple-harmonic suppression for high-quality power. The converter’s low-voltage ride through function ensures the wind turbine to keep connected to the grid even in fluctuating conditions.

Figure-9 View of Converter

4.4 Cooling System

An air-air self-circulation cooling system is applied on the generator and a liquid cooling system is applied on the converter. Thermal balance has been calculated and tested, making it more reliability. The cycle loops of both sub-cooling systems are independent from outer environment to ensure the turbine's reliable operation.

The liquid system consists of cooling cabinet, pipes and out air-liquid exchanger with fans. The cooling liquid, mixed with deionized water and glycol, shall be considered to change its composition in different seasons according to actual operation of the wind farm.

Figure-10 Outer Cooling Fans of Converter

4.5 Distribution System

The power source point of distribution system is at output port of the converter, through one 690V/400V transformer to supply power to all electrical devices. A power supply switch is installed at 400V side of the 690V/400V transformer to interconnect outer power resource.

5. Control System

5.1 Design Principles and Structure

In very low winds, the control system regulates the rotor speed to the minimum operational value. In low winds, the rotor speed is controlled, within defined limits, by varying generator torque demand in such a way to maximize the energy captured by the turbine. In moderate winds, when the rated rotational speed is reached, the torque demand is adjusted dynamically to regulate the rotor speed to the rated value. In high winds the torque demand reaches the rated value, and pitch control is then used to regulate the speed of the rotor. Torque demand is varied slightly, in inverse proportion to speed variations around the set point, in order to maintain rated power.

According to the torque-speed characteristic, operating regions of the wind turbine under different wind speeds can be divided into three phases:

a) Phase 1: Start-up
When the rotational speed of the generator increases from zero to cut-in speed, the turbine will make mechanical rotation under the action of the wind. The control system does not make variable-speed control and the generator does not enter the stage of power generation. Pitch action has two steps at start-up phase: at step one, since blades gain little aerodynamic force at high angle, blades pitch to 45 degree at fast speed to reduce start-up time; at step two, pitch control is based on rotor speed close loop, rotor speed ramp up to sync. speed gradually. At step two, minimum pitch angle is limited according to the wind speed, it is helpful to reduce load at gust condition and synchronization times at critical wind speed.

b) Phase 2: Operating under the rated wind speed after cutting into the grid
Constant C_p phase: In this phase, the turbine begins to capture wind energy and transforms it into electric energy. At the same time, the control system adjusts the turbine to operate in variable speed. That is below the rated wind speed, the control system captures the optimal C_p curve (keep the optimal C_p value constant) by controlling the rotational speed. And the control of rotational speed is realized by controlling the converter current to control the generator torque. So the generator becomes variable speed one, and the rotational speed can be controlled, varying with wind speed thus to capture the maximum wind energy.
Constant rotational speed phase: The increasing of wind speed makes the rotational speed reach the rated value. The rotational speed will be constant as long as the power is below the rated value. Within this constant rotational speed

phase, the C_p value is increasing with increasing wind speed, but the power will continue increasing.

c) Phase 3: constant-power pitch control

As the wind speed continues increasing, both of the turbine's rotational speed and power reach the limit value and the turbine operates in the constant power phase. Being controlled by pitch control system, the C_p value will is decreasing quickly with the increasing wind speed in order to keep the turbine operating in a constant power situation. Turbine operates at variable speed, using a generator and variable speed drive capable of delivering any demanded level of torque (within limits) at the generator air-gap. This torque control has a high bandwidth, and the demanded torque is achieved at the air-gap with a short delay, which has been modeled as a first order lag.

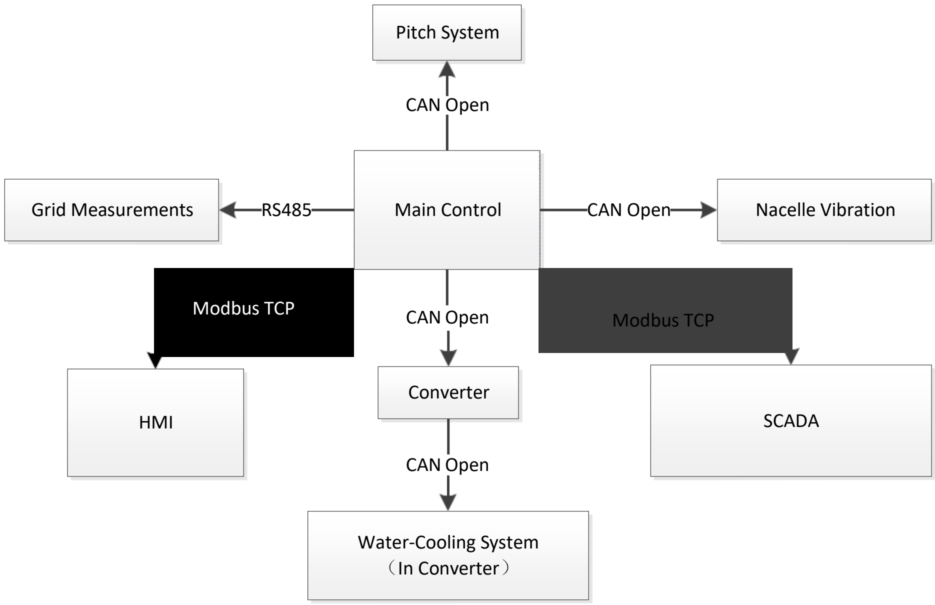

Figure-11 Structure of Control System

5.2 Main Control Subsystem

Based on the understanding of various kind of products in domestic and international wind turbine markets and the current status of the wind power industry, combining our rich experience in hydropower and thermal power and the wind energy industry features, the matured embedded-modularized industry PC hardware and popular software development environment are chosen for our wind turbine's main control system.

The main controller uses 24V DC power resource. Both analog and digital terminals are applied as interfaces between main controller and actuators or sensors. The optical fiber cable is positioned inside the tower leading from the nacelle control cabinet to the tower base cabinet. The master communication station in the tower base cabinet collects signals from other slave substations located in the hub, nacelle control cabinet, converter and liquid cooling system and then feedback orders to them.

5.3 Pitch Control Subsystem

The pitch system adjusts the angle of blade to ensure the optimum energy output in a certain range of wind speed. It includes servo drivers, AC/DC servo motor, backup power supply, position encoder and limit switches. The AC/DC power is supplied by distribution system of wind turbines via slip ring.

Each blade has the capacity of feathering independently, which ensures at least one blade can realize pitch control even if the other two blades fail to feather. There is one group of lead-acid batteries or one ultra-capacitor as backup power resource in each battery cabinet or pitch control cabinet. If the network voltage experiences a brown-out accident from the slip ring, the backup power resource makes the blade successfully implement feathering and the wind turbine can be safely shut down. There are redundancy designs for important components, such as limit switches, blade position encoders, power supplies. There are two safety signals between pitch control system and the main control system, pitch brake signal (safety signal from the main control system to pitch system), safety chain signal (safety signal from pitch system to the main control system or internal safety chain in pitch system). There are sufficient structures, components fixation and wiring designs for vibration proof.

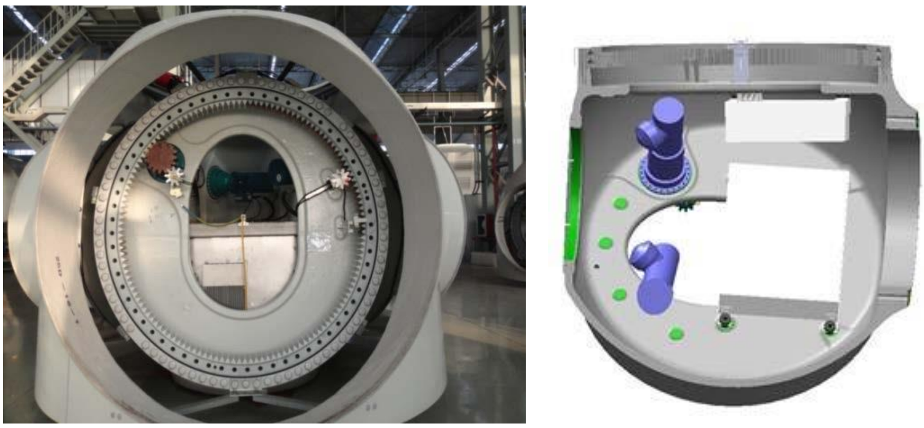

Figure-12 Pitch System

5.4 Yaw Control Subsystem

The yawing rotation of the nacelle is controlled by main controller. In addition, there are two position encoders engaging with the gear of yaw bearing to monitor the yaw angle of the nacelle and twisting angle of the cable. When the twisting angle reaches 620 degrees the software yaw position limit is triggered, the cable will untwist automatically. When the twisting angle reaches 720 degrees and the hardware limited switch is triggered, the power supply of yaw motors will be cut off immediately to protect cables. In this situation, it is necessary to carry out manual untwist maintenance for safety consideration. The minimum accuracy of automatic aiming to wind flow direction reaches ±5 degrees.

Figure-13 Yaw System

6. Safety Operating System

6.1 Design Principles

The wind power generation system consists of several parts, while the control and safety system runs through every part of the wind power system as the nerve of the wind power system. Therefore, the quality of control and safety system is directly related to wind generator's operating states, power generation, as well as the safety of the equipment. Both the efficiency and quality of power generation are closely related to the control and safety system.

1) If faults occur inside or outside of the turbine, or monitored parameters exceed the limit value, or the control system does not work, the safety system will start up to keep the turbine in a safe condition.
2) The design principle of the safety system is fail-safe. If any single part or power source of the system fails to work, the safety system can still protect the turbine.
3) The trigger level of the safety system is adjusted just below the limit value which is regarded as fundamental design. This can protect the turbine from danger and also protects the control system from being undesirably interfered by the safety system.
4) The safety system has the priority to employ at least two sets of brake systems and grid-off devices. If the operating value is abnormal, the safety system will be triggered immediately to keep the turbine in a safe condition. It is not necessary to break the grid away at the same time when the safety system is triggered. It shall be avoided under any circumstance to accelerate the wind turbine beyond the set value or to run it as an electric motor.
5) The software design will take appropriate measures to prevent incorrect operation of the user or other persons which leads to the malfunction of the turbine.

6.2 Safety Chain and Parking Progress

Two braking programs are designed in order to ensure the safe brake of wind turbine in normal parking and safety chain triggering.

Brake system 1- Air brake: The control system will make the pitch control system feathering to realize the air brake in normal stop.

Brake system 2- Mechanical hydraulic brake: Two brakes are installed on the rotor brake disc of generator. Two independent hydraulic circuits and pressure reservoirs provide pressure source to brakes. Thus, it is impossible that the brakes completely fail to work so that the security of the system is enhanced greatly. The role mechanical and hydraulic brake is to keep the wind rotor standstill when repairing and maintenance.

Two sets of the brakes will be started to ensure reliable brake when safety chain is triggered.

1) Hydraulic rotor locking device

Two hydraulic rotor locking devices are installed to ensure wind turbine IS safe when repair and maintenance is in progress.

2) Safety system (Safety chain)

This safety system is completely independent from the control system. When the listed blow faults occur, the safety chain will be directly triggered and acted without the orders from main control system. And there are three levels:

a) Wind turbine safety protection chain Includes:
   i) Rotor over-speed
   ii) Nacelle impact/vibration
   iii) Over-power
   iv) Short-circuit
   v) Other over protective limitations
b) Personal safety protection chain
c) Faults detection or alarm protection chain

6.3 Power Disconnection

The wind turbine is connected with the WTG step-up transformer through one withdrawable circuit breaker at the grid-side of the converter. The circuit breaker can connect with or disconnect from the grid automatically.

At the output port of the generator before input the port of the converter, one contactor is employed to switch the generator side on or off in normal operation.

For conveniently and safely maintaining each wind turbine without effecting normal operation of adjacent, electrical connected wind turbines, the MV switchgear of each wind turbine has the capability to independently disconnect from the grid.

6.4 Protection to Electrical Power System

There following protection functions are available in the WTG:

Phase to Phase Voltage Imbalance of Generator Side
Phase to Phase Currency Imbalance of Generator Side
Speed Signal Over-tolerance from Converter and Encoder

Speed Signal over Limitation
Speed Signal Left/Right Lost
Speed Signal Over-tolerance from Left/Right Encoder
Timeout of Converter Turn On/Off Contactor
Direct Bus Over-voltage
Direct Bus Under-voltage
Phase to Phase Over-voltage of Grid Side
Phase to Phase Under-voltage of Grid Side
Grid Frequency too High
Grid Frequency High Long Time
Grid Frequency too Low
Grid Frequency Low Long Time
Grid Vector Jump
Grid Phase Angle Wrong
Grid Line Currency Imbalance
Grid Line Currency Over Limitation
Time Delay after Grid Instability or Power Drop
Over Power of Grid Side
Power Down of Grid Side
Grid Phase-Neutral Under-voltage
Timeout of Converter Turn On/Off Breaker

The preliminary relay protection settings specified as follows are satisfied in each WTG step-up transformer.

6.5 Earthing System

The earthing system shall be designed for lightning strokes and electrical earth connection. To disperse lightning currents flowing from a wind turbine into the earth, it is necessary to provide a suitable earth termination system to limit over-voltage that can be dangerous to both humans and equipment. This is achievable by the provision of a low impedance earth termination system. Each wind turbine must be equipped with its own earth termination system, even if it is connected to a larger wind farm earthing system. The lightning protection system earth termination for a single turbine should be designed in accordance with IEC 61400-24.

The Bidder recommends the earthing resistance of each wind turbines shall be blow four ohms. In case that subject to the limitation of geological conditions, four ohms is impossible to be satisfied, the earthing resistance of each wind turbine shall not reach up to 4 ohm, then the equi-potential bonding is very important for personnel safety, some strict measurement will be taken.

6.6 Rescue Equipment

One rescue bag is equipped in the nacelle. In case of emergency, according to the safety manual, the personnel shall utilize it through the maintenance hatch in the auxiliary frame directly slipping down to ground, at maximum two persons is permitted at once. The rescue bag is mounted below the nacelle ceiling.

If there are more than two persons working on the top of the tower, every additional person shall carry on one backup rescue bag before entering into the top of the tower.

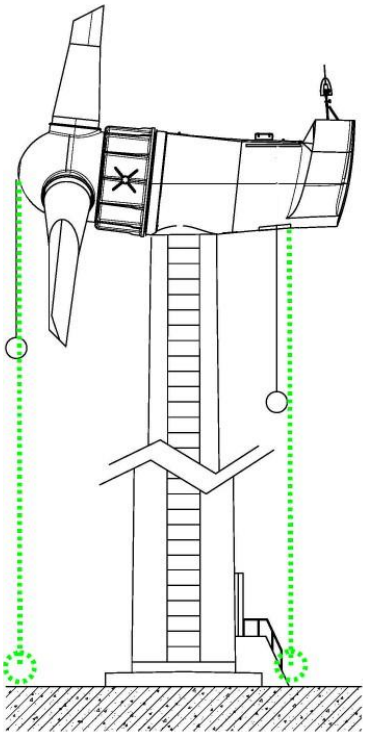

Figure 3-14 Evacuation Approaches

The specifications of a rescue bag are as follows:

Materials: aircraft-grade aluminum
Descent speed: 0.9m/s
Capacity: max. 280kg
Standards: EN341

In an emergency case where it is impossible to escape through the maintenance hatch or not possible to reach the nacelle through the man-hole in the stator of the generator, the person can hook the carry-on rescue bag over the points of suspension on the topof the outside of nacelle or on the surface of the hub.

More details of rescue routines and equipment usage can be found in the Safety Manuals.

7. Lightning Protection

7.1 Zoning

According to the corresponding standards and taking full consideration of the characteristics of lightning, the entire wind turbine generation system is divided into several protection zones with electromagnetic compatibility: The interior and exterior of the nacelle, tower and main control room. The blade can be subdivided into three protection zones: LPZ0, LPZ1 and LPZ2. The lightning protection system includes lightning reception and conducting system, over-voltage protection, equipotential bonding and electronic control system lightning protection, etc.

Lightning detection and alarm system is included. A remote monitoring for the lightning detection and alarm system is available as an option.

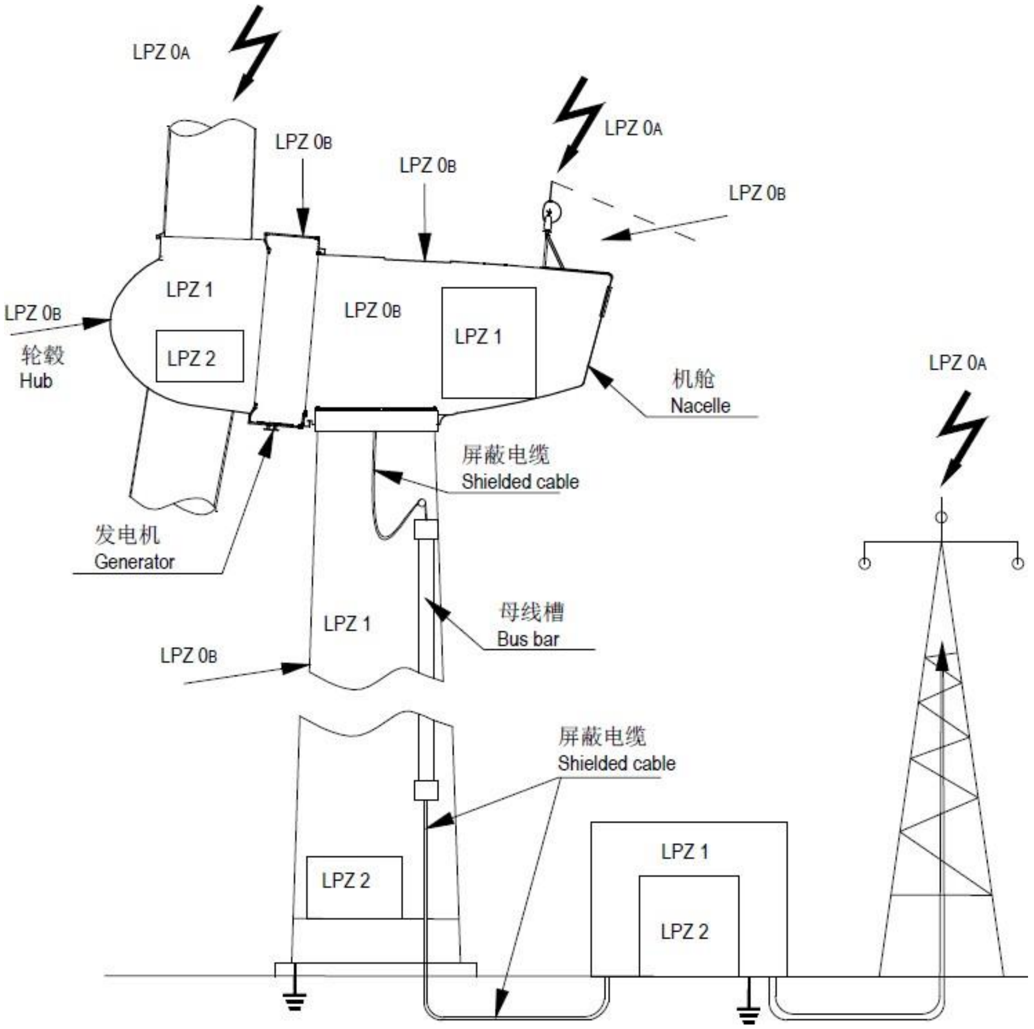

Figure-15 Zoning of Lightning Protection

7.2 Design and Implementation

The lightning protection system for the wind turbine is designed to protect the wind turbine from damage through lightning strikes. The structure of the lightning protection is divided into an external lightning protection system and an internal lightning protection system. The aim of the external lightning protection system is to reduce the physical damage caused by the lightning strike by intercepting the lightning flash, leading the lightning current to the ground, dispersing the current into the earth and avoiding sparking inside the wind turbine. The technical measures include air-terminations, down conductor and earthing system. The aim of the internal lightning protection system is to prevent electrical or electronic system faults that may be caused by over-voltage.

As mentioned above, the external lightning protection system includes the air-termination system, down-conductor and the earthing of the wind turbine.

The air-terminations include two blade tip receptors for each blade and the lightning rod on the outside of the nacelle to protect the wind speed measurement devices and wind direction measurement devices.

The down-conductor system includes:

- a 70mm^2 copper cable for each blade to electrically connect the blade tip receptors to the hub; this is also taken as a mean to divert lightning current from the pitch system bearing;
- brushes and 120mm^2 cables to connect the hub with the main frame in nacelle; this is also taken as a mean to divert lightning current from the main shaft, the main bearing and the outer rotor;
- 120mm^2 cable to connect the lightning rod with the auxiliary frame in nacelle;
- the flange for the main frame to be fixed on the tower;
- earthing electrodes that connect the tower with the earthing system.

The internal lightning protection system is designed to avoid the occurrence of dangerous sparking within the wind turbine and protect electronic systems from high voltage transients. The measures taken include equi-potential bonding, shielding and coordinated SPD protection.

The equi-potential bonding in wind turbine is achieved by interconnecting metal installations of the wind turbine and ensuring equi-potential bonding is established at ground level.

As for the shielding, the control system, pitch system, converter, cooling system and power distribution system are all shielded by separate metal enclosures. The cables in the wind turbine are all shielded cables. The line routing takes into consideration that cable loops are avoided as much as possible.

As for the coordinated SPD protection, wind turbine is divided into specific lightning protection zones. For the power cables or the signal cables going from a LPZ to another LPZ with different LPZ number, SPD(s) are located at the line entrance into each LPZ.

For the supervision connections from WTGs to SCADA controller in the sub-station, optical cables are used, which excludes the necessity of surge arrestors.

Also, for the grid connections of the WTG, surge arrestors are provided. Surge arrestors placed at two positions are required to coordinate the behavior of those with the switchgear and the power transformer equipment.

The first position is at the grid side of the converter. The converter grid side is connected with the LV (low voltage) side of the WTG step-up transformer. The second position is at the entry of the tower-base power distribution cabinet. The converter grid side is also connected with the entry of the tower-base power distribution cabinet. In this way, a connection between the tower-base power distribution cabinet and the WTG step-up transformer is fulfilled.

One group of oxide materials lightning arrestors are equipped between step-up transformer and input port of MV switchgear which is placed in the tower.

Normally, the grounding resistance shall be less than 4Ω.