Offshore Grid Connection Requirements

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1 Introduction

These Offshore Grid Connection Requirements (OGCR) describe the minimum technical and organizational requirements to be met when establishing and operating sea-side grid connections to the Transmission System Operator (TSO) grid. The goal of this document is to provide characteristics of the offshore grid, grid code requirements and its interfaces with the Offshore Wind Farms (OWF) which are hereinafter mentioned as connection customer.
The OGCR form the basis for corresponding contractual agreements between the TSO and the connection customer in accordance with VDE Application Rule VDE-AR-N 4131 [I] and VDE Application Rule VDE-AR-N 4130 [II].

2 Legal Framework

TSOs are responsible for the operation, maintenance, and the development of its transmission system. Pursuant to § 19 (1) EnWG [3], TSOs are obliged to define minimum technical requirements for connections of OWFs to their respective transmission system.

This obligation is fulfilled by the present OGCR. It is the obligation of the connection customer (OWF) to comply with this OGCR. Compliance with this OGCR shall be suitably demonstrated as part of the operating permit procedure described in this document.

In addition, all requirements of VDE-AR-N 4131 [I] and VDE-AR-N 4130 [II] shall be fulfilled by the OWF.

2.1 Contractual language

German law applies exclusively.

The German version of these OGCR is authoritative. The English translation only has a purely informative character.

3 Codes and Standards

Ref. Nr. + Short text	Title
[I] VDE-AR-N 4131	Verband der Elektrotechnik Elektronik Informationstechnik e.V *Technische Regeln für den Anschluss von HGÜ- Systemen und über HGÜ-Systeme angeschlossene Erzeugungsanlagen* (VDE-AR-N 4131:2019-03), Berlin, 01.03.2019. *Technical connection rules for HVDC systems and power generating plants connected via HVDC systems*

Ref. Nr. + Short text	Title
[II] *VDE-AR-N 4130*	Verband der Elektrotechnik Elektronik Informationstechnik e.V., *Technische Regeln für den Anschluss von Kundenanlagen an das Höchstspannungsnetz und deren Betrieb (TAR Höchstspannung) (VDE-AR-N 4130:2018-11),* Berlin, 01.11.2018. *Technical requirements for the connection and operation of customer installations to the extra high voltage network (TAR extra high voltage*)
[III] EnWG	Bundesrepublik Deutschland, Gesetz über die Elektrizitäts- und Gasversorgung *(Energiewirtschaftsgesetz-EnWG),* vom 07. Juli 2005 (BGBl. I S. 1970, 3621).
[IV] WindSeeG	Windenergie-auf-See-Gesetz vom 13. Oktober 2016 (BGBl. I S. 2258, 2310)
[V] DIN EN 50160	Deutsches Institut für Normung (DIN), *DIN EN 50160 "Merkmale der Spannung in Öffentlichen Elektrizitätsversorgungsnetzen".*
[VI] DACHCZ	Verband der Elektrotechnik Elektronik Informationstechnik e.V., „DACHCZ: Technische Regeln zur Beurteilung von Netzrückwirkungen“.
[VII] DIN VDE 0105-100	Deutsches Institut für Normung (DIN), DIN VDE 0105-100 "Betrieb von elektrischen *Anlagen".*
[VIII]DGUV Vorschrift 3	BG ETEM, DGUV Vorschrift 3 - Unfallverhütungsvorschrift Elektrische Anlagen und *Betriebsmittel.*
[IX] DIN EN 60071-1	DIN EN 60071-1, Isolationskoordination
[X] FNN Hinweis	VDE FNN Hinweis vom Juni 2020, „Spannungseinprägendes Verhalten von HGÜ-Systemen und nichtsynchronen Erzeugungsanlagen mit Gleichstromanbindung“
[XI] DIN EN 62271-100	*Hochspannung-Schaltgeräte und –Schaltanlagen Teil 100: Wechselstrom-Leistungsschalter* *High-voltage switchgear and controlgear Part 100: Alternating-current circuit-breakers*

3.1 Project Phases

Table 1 shows the general project phases for a new offshore connection.

Table 1: Project Phases

1	Planning Phase	Starting immediately after the area has been awarded to the OWF. Includes initial coordination with the TSO and preparation of the plan approval procedure.
2	Design Phase	Following after the Planning Phase and can start with the beginning plan approval process.
3	Plan Approval Process (Plangenehmigungsverfahren)	Implementation of the regulatory procedure at the BSH.
4	Procurement and Production of the OWF equipment	Follows the approval of BSH and includes manufacturing of WTGs, foundations, and AC cables.
5	Construction and Installation	Installation of WTGs, foundations, and AC cable on site.
6	Commissioning and testing	Commissioning and testing of all installed components.
7	Operation	

3.2 Abbreviations

General abbreviations are defined in Table 2. The following abbreviations shall apply additionally only for this document.

Table 2: List of abbreviations

Definition	Meaning
AC Grid of the OWF	Designates submarine cables, plugs and all other equipment owned by the OWF.
AC Submarine Cable	AC grid of the OWF
AC Platform Cable	The AC cable between the GIS and the AC submarine cable at the offshore station and, if applicable, the OWF-OSS.
Bellmouth / Bell mouth	Bell shaped opening which provides guidance for a cable, e.g., used at seabed end of J-tubes or J-tube transition to and from spool pieces or similar
Connection Customer	Installer or operator of the OWF
Converter System	Includes the onshore station and the offshore station, i.e., the scope of the station lot. Does not include the DC cable system. Together with the DC cable system it forms the grid connection system.
C&P	Control and Protection
DMR	Dedicated Metallic Return Conductor

EPC	Emergency Power Control
FO Cable	Are cables and lines made up of optical fibres for the transmission of optical signals Consisting of the FO Submarine Cable and the FO Land Cable.
FRT	Fault Ride-Through
FSM	Frequency Sensitive Mode
GAP	Grid Access Point
GCP	Grid Connection Point: Designates the sea-side interface of the grid connection system to the OWF
GCS	Grid Connection System
GOC	Grid Operation Center: The GOC is the building in which the grid control system is housed
GIS	Gas-insulated switchgear
Hang-Off	system used in offshore units to suspend a cable through clamping armor wires on top of the J-Tubes
J-tube	Tube mounted in or at the substructure for guiding a cable between seabed and topsides, its shape being reminiscent of the letter "J"
LFSM	Low Frequency Sensitive Mode
Offshore Station	Is the station at sea and includes all structures, plants and plant parts, operating equipment, components, assemblies, interfaces, and software at sea
OGCR	Offshore Grid Code Compliance Requirements
OWF Cable Contractor	OWF Contractor responsible for design and installation of the 66 kV offshore HVAC cables
OWF	Offshore Wind Farm: Grouping of one or more offshore wind turbines for the generation of electrical energy.
PE	Permission for Energization
PCC	Point of Common Coupling
Repeater Station	Location by amplifying the optical signals of the optical fibres when the maximum transmission distance reaches a critical point. In addition to the optical amplifiers, the cable monitoring systems are also stationed here.
ROCOF	Rate of Change of Frequency
RSW	Round Single Wire
RMW	Round Multi Wire
UPS	Uninterruptible Power Supply
VSC	Voltage Source Converter
WTG	Wind Turbine Generator

4 Grid Connection and System Design

In the following, the basic structure of offshore Grid Connection System (GCS) is described informatively. The exact grid connection concept may differ from the standard systems described here depending on the project and is defined by the TSO. Figure 1 shows for example a bipolar GCS with DMR. Figure 2 shows the example of a symmetrical monopole GCS.

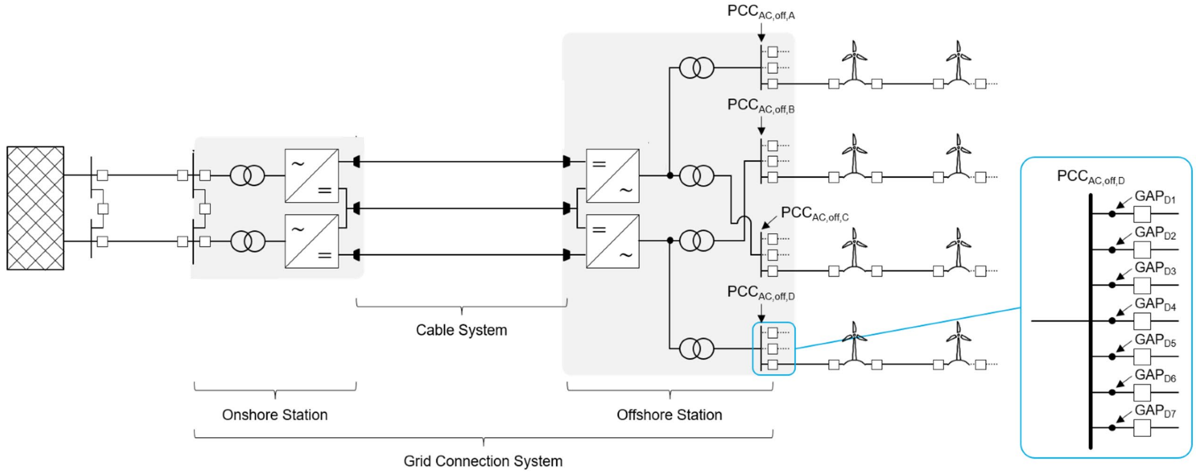

Figure 1: Schematic setup of the Grid Connection Systems and illustration of system boundaries for bipolar systems with DMR HVDC GCS

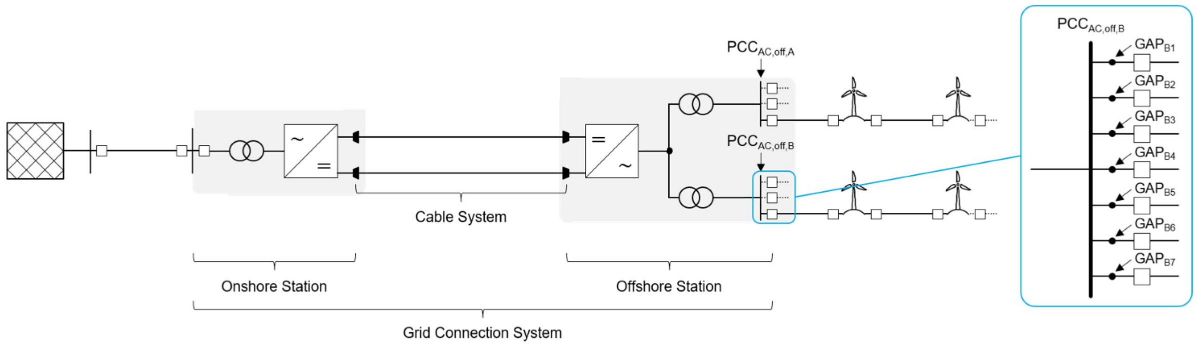

Figure 2: Schematic setup of the Grid Connection Systems and illustration of system boundaries for symmetrical monopole HVDC GCS

A GCS is realized as a HVDC transmission system with multi-level VSC Stations and a cable system, which comprises HVDC cables and a fiber optic cable.

The main interfaces of the Offshore Station are the Point of Common Coupling AC Offshore ($PCC_{AC,off}$) and the Grid Access Points (GAP_{A1}…GAP_{D7}) of the respective OWFs. The Grid Connection Point (GCP) represents the technical interface between the OWF and the TSO and can be applied to the $PCC_{AC,off}$ or GAP level. The number of GCPs of an OWF depends on the installed generation capacity and number of different OWF operators.

The TSO shall define the specific GCP for the OWF.

Regardless of the technology of the grid connection system, all grid characteristics and grid services of the offshore grid defined in the OGCR apply at each GCP. Requirements of the OGCR shall be fulfilled at each GCP by the OWF.

The TSO shall be informed of the switching status of WTGs and interarray cables (including WTG transformer tap-changer if applicable or WTG transformer tap position and earthing switch) as well as the number of connected and operationally available WTGs at each busbar. This information is used for the operational management of the offshore grid. In addition, the TSO shall be given further signals to ensure safe grid operation.

Figure 3 shows an exemplary representation of the high voltage switchgear at the GCP. The exact design of the high voltage switchgear is project-specific and is specified by the TSO.

The figure visualizes the scope breakdown between the TSO and the OWF.

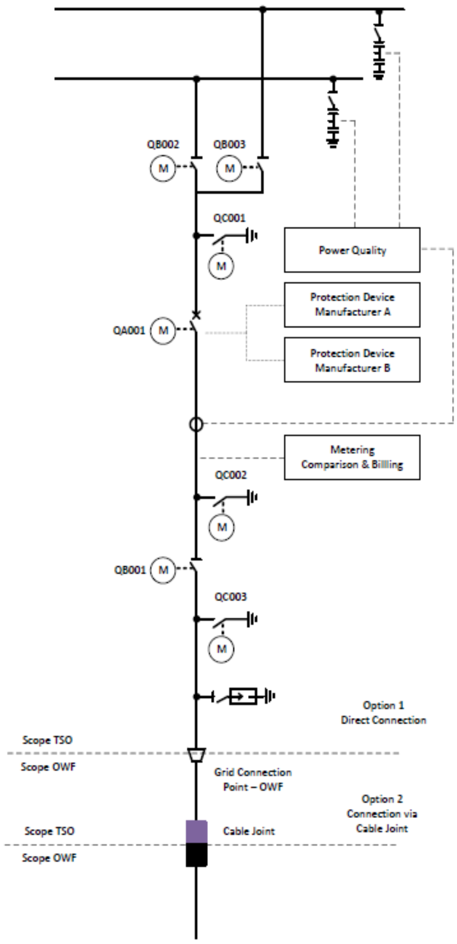

Figure 3: Exemplary overview high voltage switchgear design

The system design of the OWF shall be agreed between the connection customer and the TSO during planning phase. It includes, but is not limited to

- WTG design
- AC cable design (park layout and cable design)
- Earthing design
- Variables to be measured and recorded
- Signals to be processed
- Protection interfaces (if any)
- Control signals (if any)
- OWF operation concept
- Characteristics of the equipment (e.g. rated voltage, short-circuit resistance, earthing concept etc.)

5 Offshore Grid Code Compliance Requirements

5.1 Robustness Requirements regarding Voltage and Frequency

5.1.1 Voltage and Frequency requirements during continuous operation

The nominal grid voltage and the resulting continuous operating voltage for normal operation are determined for each GCP by the TSO. For this document voltages of 66 kV and 132 kV will be applied.

For a nominal grid voltage, the specifications in Table 3 shall apply as additional requirements for OWF grid connection.

Table 3: Voltage Requirements for Offshore Wind Farm Grid Connection

OWF Grid Nominal Voltage Un in pu.	Operating Voltage Range in pu.	Minimum Operating Time
1	0,85 to 0,9	60 min
	0,9 to 1,1	unlimited
	1,1 to 1,15	30 min

Note: Requirements on the voltage ranges 0,85 to 0,9 as well as 1,1 to 1,15 pu. are only applicable when explicitly required by the TSO.

With regard to the time-dependent frequency ranges to be controlled in stationary and quasi-stationary operation modes, the requirements of VDE-AR-N 4131 [I] shall be applicable. Wider frequency ranges or longer minimum time periods for operation may be defined by the TSO as an additional requirement.

ROCOF withstand cability according to VDE-AR-N 4131, chapter 10.2.2 shall be fulfilled by the OWF.

The TSO and the OWF may agree on specific requirements regarding combined frequency and voltage deviations as additional requirements.

Quasi-stationary operation is defined by a voltage gradient of less than 5 % of the rated voltage per minute and a frequency gradient of less than 0.5 % of the rated frequency per minute.

The WTG's rotation field shall be oriented in clockwise direction.

5.1.2 Overvoltages and Insulation Coordination

The standardized insulation levels according to DIN EN 60071-1 (VDE 0111-1) [IX] shall be used for the design of the OWF components. The OWF operator shall align with the TSO about the applicable insulation level for the design of the components.

5.1.3 Voltage Changes due to Switching Activities

Switching activities of OWF will cause voltage variations which shall be limited to the values specified in the VDE-AR-N 4131 [I]. An example is the connection of a cable string which is not energized. This cable string might be connected with or without WTG transformers. Another example is the connection of WTG transformers while a cable is energized. In all cases the OWF shall install appropriate measures on each WTG to lower voltage variation to fulfil this requirement if needed.

5.1.4 Voltage Unbalances

The OWF shall ensure that the contribution to existing voltage unbalances is as low as possible. The maximum contribution of the WTGs in undisturbed conditions shall be agreed with the TSO.

The unbalanced load requirements (robustness) shall be aligned with the TSO.

5.2 Control Capability regarding Active Power and Frequency

5.2.1 Active Power Exchange

When connecting WTGs, the following operating states shall be considered:

- Normal Operation (incl. start-up of the WTG)
- Limited Operation (with feed restriction)

Furthermore, appropriate devices for synchronization, parallel switching or for protection against overloading at the GCP shall be provided in those operating states.

The energization and connection of a WTG to the active grid performed by the OWF shall only be performed after a release by the TSO.

OWF shall install devices at all WTG infeed breakers to avoid grid perturbations like voltage drops, inrush currents and voltage asymmetries. The exact settings and values of the devices, e.g., with regard to phase angle range, voltage and frequency deviations, shall be agreed between the TSO and the OWF operator. Connecting and synchronization tests shall be performed with the connected and energized HVDC system in order to provide a proof of the permissible system perturbations.

Each individual WTG shall be capable of being controlled with reduced power output and shall allow continuous power control over the entire range from 0 % - 100 % nominal power.

Any power boost functionalities shall be announced, explained by the OWF operator to the TSO and approved by the TSO.

The controllability of each individual WTG shall be tested in regular intervals by the OWF Operator and the TSO to avoid technical communication problems and thus an inability to control the WTGs. The TSO and the OWF operator shall commonly define the interval period. Furthermore, the controllability shall be tested after a software update of the WTG and park control function.

Manual actions on-site are permissible in agreement with the TSO if remote-control equipment is out of operation.

The OWF is obliged to inform the TSO in detail about the technical principles of the active power exchange between WTG and the GCP. For this purpose, among other data, power diagrams showing the dependency between output power and the primary energy source, i.e., wind speed, shall be transmitted to the TSO during the grid compliance procedure. The OWF shall verify the power curve with an installed lidar measurement device at different location of the windfarm, with at least a minimum number of two devices in the existing wind farm. The verification of the power curve shall be performed during the commissioning of the OWF (alternatively during the grid compliance test) and after a software update of the WTG or wind farm controller.

WTGs shall be capable of stable operation over the entire range between minimum and maximum short-circuit power as specified in this document.

5.2.2 Active Power Frequency Control

The OWF shall be able to participate in the active power-frequency control. A distinction is made between the three following control modes:

- Frequency Sensitive mode (FSM)
- Limited Frequency Sensitive Mode, Underfrequency (LFSM-U)
- Limited Frequency Sensitive Mode, Overfrequency (LFSM-O)

The implementation of all three control modes shall comply with the specifications of the VDE-AR-N 4131 [I]

5.2.2.1 Frequency Sensitive Mode (FSM)

The exact parameters of the frequency dependent mode are given by the TSO in the range defined in VDE-AR-N 4131, Section 10.2.5.2 [I]. If no deviating requirements are specified by the TSO, the default values according to Table 4 are to be set. The dead band of the frequency-dependent adjustment of the active power output and the statics shall be able to be changed repeatedly by remote control.

Table 4: FSM standard values

Parameter	Standard Value
Active power control range, related to the currently available active power $\|\Delta P_1\|/P_{nom}$	2%
Permitted tolerance Δf tolerance	≤ 30 mHz
Deadband $\|\Delta f_{tot}\|$	200 mHz
Droop s	6%

The OWF shall be able to adjust the power output completely according to frequency for a period of 15 minutes with sufficient primary energy supply.

5.2.2.2 Limited frequency sensitive mode, underfrequency (LFSM-U)

The requirements of VDE-AR-N 4131, Section 10.2.5.4 [I] apply.

5.2.2.3 Limited Frequency Sensitive Mode, overfrequency (LFSM-O)

The requirements of VDE-AR-N 4131, Section 10.2.5.3 [I] apply.

5.2.2.4 Ramping Restriction for Active Power Output

For avoiding system endangering behaviour, the rate of change of active power output at the transition of market time units, due to a planned change of power schedules not requested by relevant system operator, shall be limited to 10 % of the maximum capacity per minute.

5.3 Control Capability with regards to Reactive Power Balance and Voltage Stability

5.3.1 Requirements for OWF in reactive power exchange while active power feed-in

The required operating range for the reactive power supply of the OWF at the GCP in case of power feed-in is determined by the TSO in accordance with the specifications of the VDE-AR-N 4131, Section 10.2.8.2 [I]. The OWF shall apply minimal requirements of the U-Q/P_{AV} envelope if there is no other specific requirements from the TSO.

Specific requirements for reactive power control are defined in VDE AR-N-4131, Section 10.2.9. The preferred operating point and reactive control modes for the stationary exchange of reactive power with active power output is determined by the TSO according to the requirements of the grid and can be changed by the TSO at any time according to the needs of grid operation. The OWF shall be technically equipped to implement the setpoint specifications of the TSO with regard to the exchange of reactive power with the grid at each connection point. The OWF shall be able, after receiving a new setpoint, to approach it within the range specified by the TSO with given voltage at the GCP in maximum 30 sec. This procedure shall be possible at any time during operation.

The following requirements apply with regard to the OWF control behaviour without further specification by the TSO:

- The step response time $T_{an\_90\,\%}$ amounts to a maximum of 5 sec
- The settling time T_{ein} is a maximum of 30 sec
- The settling tolerance ΔQ is a maximum of ±5 % of the maximum reactive power output.
- The permissible overshoot is maximum ΔQ_{max} = (25 % (2 sec/$T_{an\_90\,\%}$) + 5 %) of the setpoint step change.

5.3.1.1 Reactive Power-Voltage Characteristic

In this mode the reference voltage is an input for the reactive power controller. The reactive power controller determines the required reactive power according to the voltage at the connection and to the reactive power voltage characteristic specified in the VDE-AR-N 4131 [I].

5.3.1.2 Reactive Power Control Mode

In this mode a reactive power setpoint (Q_{set}) is directly transferred to the reactive power controller, whereby the specifications of the VDE-AR-N 4131 [I], Section 10.2.9.3 are applicable.

- Q_{set} negative: means capacitive reactive power (overexcited)
- Q_{set} positive: means inductive reactive power (underexcited)

5.3.1.3 Power Factor Control Mode

In this mode, the WTGs shall be able to control the power factor at the GCP in accordance with the specifications of the VDE-AR-N 4131 [I], Section 10.2.9.4. Following definition will be applied:

- $cos\varphi_{set}$ negative: means capacitive reactive power (overexcited)
- $cos\varphi_{set}$ positive: means inductive reactive power (underexcited)

5.3.2 Requirements for OWF in Reactive Power Exchange while Active Power Consumption

In this mode, the OWF shall be able to control the power factor and ensure the reactive power exchange at the GCP in accordance with the specifications of the VDE-AR-N 4131, 10.2.8.3 [I].

The switching of energized compensation equipment is not allowed.

5.3.3 Switching Capability of the Capacitive Charging Current

The OWF shall calculate the maximum resulting capacitive current at the GCP depending on the interarray cable design taking into account longest cable section configuration. If the permissible limit value in accordance with DIN EN 62271-100, Table 9 [XI] is exceeded, the OWF shall implement corresponding measures in order to comply with this requirement and align with the TSO.

5.3.4 Concept for Reactive Power/ Voltage Control

The OWF's control concept and the setting values are to be agreed with the TSO during design phase and before commissioning.

5.4 System Perturbations and Power Quality

5.4.1 General

The electrical components of the OWF shall be designed and installed in such a way that during their operation any unacceptable interference at the GCP with the grid of the TSO and third parties is avoided. Furthermore, information and signal transmissions shall not be influenced in a disturbing way.

The energization of WTGs by the OWF shall also be realized in such a way that grid interferences and disturbances are kept to a minimum.

The requirements applicable for this purpose are defined below and can be found in the relevant international standards and technical regulations (see e.g., DIN EN 50160 [V] and D-A-CH-CZ [VI]).

The OWF shall demonstrate the grid compliance of his system based on the mentioned technical regulations and take remedial action if necessary. The details of any remedial actions that may be necessary shall be agreed between the TSO and the OWF.

5.4.2 Power Quality

The requirements of the VDE-AR-N 4131 [I] in chapter 10.2.11 apply with regard to power quality.

5.4.3 Harmonic Stability – OWF Interaction

The offshore grid has different system-dependent grid resonances. Their stimulation can lead to overvoltages and -currents. Consequently, overloading of equipment and protective shutdowns can occur.

Due to the non-linearity of the grid, the occurrence of instabilities can also lead to a steady state in which voltages and currents with one or more frequencies oscillate permanently.

Therefore, the frequency-dependent behaviour of the actively controlled as well as passive equipment of the OWF shall also be taken into account.

The OWF shall ensure that each individual WTG behaves in a stable manner and do not cause any impermissible grid repercussions in normal operation through interaction with grid resonances or interaction between the individual WTGs.

An implementation of active damping function in the WTGs up to min. 650 Hz is required. This shall be implemented in coordination with the TSO.

The WTGs shall behave passively at frequencies deviating from 50 Hz in a frequency range between 0...2500 Hz at each operating point, i.e., oscillations occurring in the grid in this frequency range shall not be amplified by the WTGs. The real part of the WTG frequency dependent impedance shall be positive over the entire frequency range between 0...2500 Hz.

The OWF shall provide the TSO appropriate grid models, which allow an evaluation of the interaction between the individual wind farms within the scope of the dynamic control behaviour but also a simulation of the harmonic stability.

5.5 Specific requirements on OWF/WTG's behaviour during system contingencies

5.5.1 Troubleshooting and Clarification

Both the TSO and the OWF operator shall inform each other immediately of any special events which have become known to them, insofar as these may be of relevance to the other.

The TSO and the OWF operator shall cooperate in the context of fault rectification and clarification.

5.5.2 Behaviour when the HVDC converter is blocked

If the HVDC converter is blocked, the fundamental overvoltage U/Un at the GCP caused by the WTGs may not cause a violation of the upper limit of the voltage band according to the FRT profile in section 5.5.7.2. Similary the WTG may not cause a violation of the frequency band according to VDE-AR-N 4131, Chapter 10.2.1 [I] in case of a HVDC blocking event.

5.5.3 Behavior in Island Operation

The OWF shall ensure that any possible isolated operation of the system (island mode) is reliably detected and stopped after time t1 at the latest by disconnecting the WTGs from the grid. Time t1 shall be provided by the TSO.

It may be necessary and can be requested by the TSO, that the WTGs are capable of island operation. It means that the control of frequency and voltage is guaranteed within the permissible limits. Besides, functions for synchronization with the island grid shall be implemented. In this case, WTGs may not be switched off.

In both operation cases described above, the details of such solutions shall be agreed and coordinated between the TSO and OWFs.

In this island mode, the WTGs shall be able to behave as minimum requirement in accordance with the specifications of the VDE-AR-N 4131 [I], Section 10.2.22.

The OWF must be able to supply itself.

5.5.4 Behaviour in Black-Start

The requirements of VDE-AR-N 4131 [I], Chapter 10.2.20 apply.

5.5.5 Behaviour at Frequency Deviations

The requirements of VDE-AR-N 4131 [I], Chapter 10.2.5 apply.

As an additional requirement, WTGs shall be able to activate instantaneous reserve within their design limits. The aim of the instantaneous reserve is to react on a change in the frequency and thus to contribute to limiting the maximum gradient of the frequency change. The TSO specifies further details including the time response of the instantaneous reserve control.

5.5.6 Behaviour in case of Stability Problems

WTGs shall automatically disconnect from the grid in case of loss of transient stability. The criteria and the disconnection concept are to be agreed between the TSO and the OWF depending on the project.

The point of disconnection is always the terminal of each individual WTG. The disconnection of more WTGs than necessary shall be avoided.

5.5.7 Behaviour in case of voltage deviations caused by failures

5.5.7.1 Over-/Undervoltage protection

An overvoltage/undervoltage protection according to the TSO requirements shall be implemented in the WTG. The time staggering can be agreed upon differently depending on the project.

The voltage shall be measured at each WTG on the low-voltage side of the machine transformer. Alternatively, a measurement on the high voltage side of the machine transformer is also permitted. A two-stage system automatic against overvoltages and a one-stage system automatic against undervoltages are provided by the TSO.

For clarification, it should be pointed out that the measured voltages in the individual generating units are different depending on the impedances of the equipment and the current flow. This means that the individual overvoltage/undervoltage protection devices do not excite simultaneously and thus do not trip simultaneously. Simultaneous tripping is also not necessary.

In the event of tripping, the respective generating unit shall be switched off. The generator or converter shall be disconnected from the grid (generator circuit breaker). If desired and technically possible, the own requirements can still be obtained from the main grid if the converter is not in island mode.

Requirements for system automatic in case of undervoltage

The protection systems and settings for electrical faults or undervoltage within the WTG shall not endanger the dynamic behaviour of the wind turbines according to requirements specified in this document. For the system automation in case of undervoltage, the starting threshold shall be defined by the TSO depending on the requirement in 5.1.1. of the nominal grid voltage (highest value of the three linked voltages). The drop-out ratio is 1.02 or the hysteresis is 2 %.

The triggering shall be multi-stage according to the following scheme for the OWF:

- ¼ of the WTGs after t1
- ¼ of the WTGs after t2
- ¼ of the WTGs after t3
- ¼ of the WTGs after t4

The TSO shall set the times t1...t4 individually.

Requirements for system automatic in case of overvoltage

The protection systems and settings for overvoltage within the WTG shall not endanger the dynamic behaviour of the wind turbines according to requirements specified in this document.

For the system automation in case of overvoltage, the 1st triggering threshold should be 125 % of the nominal voltage Un (lowest value of the three voltages). The drop-out ratio is 0.98 or the hysteresis is 2 %. The time delay for tripping shall be 0.2 s for all WTGs. (see Figure 15, VDE 4131 [I])

The 2nd triggering threshold should be 120 % of the nominal voltage Un (lowest value of the three voltages). The drop-out ratio is 0.98 or the hysteresis is 2 %. The time delay for tripping shall be 2 s for all WTGs (see Figure 15, VDE 4131 [I]).

5.5.7.2 FRT Requirements

With regard to the FRT capability, the requirements of the VDE-AR-N 4131 [I], Chapter 10.2.12 apply to the OWF. However, the TSO shall be able to adapt the FRT curve on the specific project in accordance with the requirement in section 5.1.1.

The protection systems and settings for electrical faults within the WTG shall not endanger the dynamic voltage control (without provision of reactive current setpoints) according to requirements specified in 5.5.7.3.

A temporary blocking of the WTG's converter (e.g., due to an overcurrent in this area) is only permissible in justified exceptional cases and should not exceed a duration of 10 ms. Outside of the FRT curve, the converter of a WTG may be blocked longer due to required technical reasons. Final disconnection with the circuit breaker is only permitted after 1.5 s at the earliest.

The TSO will provide, when requested by the OWF, conditions to be considered at the GCP with regard to FRT capability before and after a fault:

- Minimal short-circuit current before the fault at each GCP
- Operating point of the WTGs before the fault (active and reactive power delivered at GCP and voltage at the GCP
- Minimal short-circuit current after the fault at each GCP

Alternatively, the TSO can specify generic values derived from typical cases (based on experience).

The values given in Tabel 5 can be used for min. and max. short circuit power at the GCP. This takes the contribution from HVDC as well as other OWF into account.

Table 5: General assumptions regarding the short-circuit power in the offshore grid before and after a fault

Failure Case	Min. Short Circuit Power at GCP	Max. Short Circuit Power at GCP
Failure without blocking or outage of the HVDC	c_{min} * Pmax HVDC	c_{max} * Pmax HVDC
Failure with blocking or outage of the HVDC	0 MVA	c_{max} * Pmax HVDC

The TSO shall provide c_{min} and c_{max} to the OWF operator.

5.5.7.3 Requirements Dynamic Voltage Control without provision reactive current setpoint

According to the specifications in VDE-AR-N 4131 [I], WTGs shall have the capability of dynamic voltage control without reactive current setting as a basic requirement. In addition, technical guidelines given by "FNN Guideline: Grid forming behaviour of HVDC systems and DC-connected non-synchronous generation units" [X] have to be considered and methods and procedures given there have to be followed.

5.5.7.4 Requirements Dynamic Voltage Control with provision reactive current setpoint

TSO shall align with OWF on requirements for reactive current injection capabilities.

The TSO shall have the right to choose the operation mode between 5.5.7.3 or 5.5.7.4 in VDE-AR-N 4131 [I] during operation. It is not necessary to switch between the two modes during operation.

5.5.7.5 Return of active power infeed after a failure

The requirements of the VDE-AR-N 4131 [I] have to be fulfilled.

5.5.8 Behaviour in case of a communication failure with regards to set-point reaction

In case the communication between the TSO control centre and the OWF controller or between the WTGs and the OWF controller fails, the OWF controller or respectively WTGs shall hold the last received value as fallback value for provided setpoint (e.g., active power, voltage, reactive power). The OWF shall inform the TSO immediately and take all actions to re-establish controllability.

5.5.9 Failure analysis

The TSO conducts a systematic analysis of failures at the GCP. In the same way, the OWF is obliged to prepare a fault analysis. The TSO will provide the required power quality and protection records to the OWF. In cooperation with the affected OWFs, the TSO develops suitable solutions for preventive and corrective measures based on the results.

The OWF shall provide the information necessary (power quality and protection files) for root cause analysis and failure clarification. This also includes detailed information (e.g., failure plots and transient measurements) on the individual WTGs. After completion of the fault analysis, the TSO will inform the affected OWFs about the results.

5.6 Restart of Offshore Grid

The reconnection of a WTG or energization of a cable string after disconnection from the grid is only permissible after approval by the TSO. An automatic reconnection of the individual WTGs or the string is not allowed.

5.7 Requirements on congestion management

5.7.1 General

During operation, participation of the OWFs in power generation management concept of the TSO may be necessary for a limited period of time in order to ensure secure grid operation and to protect equipment from damage. Each OWF shall participate in generation management on the instructions of the TSO and provide all requested information. OWF shall be able to reduce the power output in different operating states and from different operating points to the active power setpoint (as maximum limit) defined by the TSO. The TSO determines active power setpoint values in the grid control procedures listed below. Setpoint values received at the same time from the TSO shall be prioritized in the following order given:

1. protective function (e.g., emergency power control = EPC)
2. stationary maximum active power production

5.7.2 Emergency Power Control (EPC)

EPC system automation is used to ensure that the seaside and land-based grids are decoupled from each other in terms of frequency maintenance by the DC link. The main goal of the EPC system automation is the rapid reduction of the active power fed into the grid in case of disturbances in the shore-side transmission grid (see relevant section of the VDE-AR-N 4131 [I].

To start or trigger this system automation, the signals EPC 1, EPC2, EPC3, EPC4 and EPC5 are transferred from the TSO to the OWF controller.

5.7.2.1 EPC1, EPC 2, EPC 3. EPC 4 and EPC 5

When receiving the different EPC signals, the active power output should be limited to corresponding values as shown in the table 6 below:

Table 6: EPC signals and corresponding active power setpoint

EPC Signal Type	Active Power Setpoint equivalent with
1	0 MW
2	25% of the active power infeed $P_{AV,E}$
3	50% of the active power infeed $P_{AV,E}$
4	75% of the active power infeed $P_{AV,E}$
5	Deactivation, 100% of the active power infeed $P_{AV,E}$

The final value specified by the EPC signal shall be reached as soon as technically possible. As a minimum requirement, the active power output shall be in accordance with the specifications of VDE-AR-N 4131 [II] and shall have an average speed of at least 25% of the agreed active power infeed level per second. The TSO shall have the right to require a larger average speed. Delay time of EPC function shall be smaller than 100 ms which means that after receiving the EPC signal, the OWFs shall start to reduce their active power within 100 ms.

The power reduction shall also be executed for signals EPC1, EPC2, EPC3 and EPC4 if the respective signal is only present for a short time (e.g., <1 s). The reaction is therefore independent from the duration or later repetitions of the signal. Furthermore, no reaction is required if the instantaneous power of the OWF is lower than the maximum permissible power of the respective stage. In this case, however, it shall be ensured that the power does not rise above the respective maximum value in the future (e.g., due to a higher wind speed).

If a signal with a higher order, e.g., EPC3 signal is sent after an EPC2 signal has already been sent, the OWF has to consider the corresponding active power setpoint of EPC3 signal instead of EPC2 signal. The EPC3 signal is of higher value than the EPC2 signal. This means exemplary that with an EPC3 signal and a simultaneously active EPC2 signal (if applicable) there shall always be a reduction of active power to 50% of the agreed connection active power.

If an EPC3 signal has been sent and an EPC2 signal follows, the EPC2 signal shall not be used under any circumstances. This means that the EPC3 signal remains active with a maximum allowed active power infeed of 50% until the EPC mode is deactivated via EPC5.

5.7.2.2 EPC 5

With the EPC5 signal the active power reduction is cancelled again. The active power may then increase at a maximum gradient of 10% of the agreed connection active power per minute to the setpoint provided by the TSO or another valid setpoint. The EPC5 signal is of higher value than the EPC1, EPC2, ECP3 and EPC4 signal. This means that no active power limitation (anymore) is required when the ECP5 signal is present.

5.7.2.3 Prioritization of EPC signals

The EPC2, EPC3 and EPC4 Emergency Power Control system automation units are ranked above the signals of the power management system. Only after receiving the EPC5 signal the power management signals are valid again.

5.7.2.4 Signal exchange of the EPC signals

For the transfer of signals EPC1 to 5, the TSO shall provide binary contacts to OWFs. Details shall be agreed with OWF. The signals are transmitted logged by the TSO.

The EPC signals are provided for each GCP and shall be applied to the generating units connected to the respective GCP.

A possible future extension of the EPC functionality shall be taken into account when designing prioritization of EPC signals

5.7.3 Maximum Active Power Production

The TSO provides the OWF with a limit value for the maximum permissible active power feed-in per GCP. This limit value corresponds to a percentage or absolute value related to the awarded active power infeed value. The OWF shall be able to implement any set point requirements for the active power feed-in with a specified gradient.

The gradients are specified by the TSO, whereby a value of 10% of the agreed connected active power per minute applies without further specification.

The active power control of OWF shall be designed in such a way that a reduction of the power output to the signalled value with a gradient of at least 10% of the agreed connected active power per minute can take place without disconnecting the WTGs from the grid.

The OWF shall ensure that the control signal transmitted by the TSO is given priority over the setpoints of other parties with access rights (e.g., direct marketers).

The OWF shall absolutely not exceed the maximum power value specified by the TSO, even not for a short time, based on the dynamic requirements for active power output according to Section 4.2.1, since this can lead to an immediate protective shutdown of the whole offshore converter and thus to a failure of the power distribution. It is permissible to fall below the limit value specified by the TSO at any time.

5.7.4 Requirements for the Information Technology - Provision of Control Reserve

In order to ensure flexible and safe operation of the OWFs in different markets, the information technology shall at least comply with the requirements set out in the related TSO Appendix

- "Minimum requirements for the reserve provider's information technology for the provision of control reserve"

5.8 Electrical Protection Devices

Protection concepts and protection settings at the interfaces between the TSO on the one hand and the OWF on the other hand are agreed by mutual consent in such a way that any danger to the connected grid and equipment or installations is excluded.

The TSO implements protective devices at the GAP for the equipment of the TSO and for the OWF infeed cables on the platform.

These protection devices are specified, installed, commissioned, and owned by the TSO. Protection functions shall be in detail aligned between OWF and the TSO during design phase.

The OWF shall therefore submit the final agreed protection setting values and protection studies for the GAP protection devices. These settings are then only imported and tested by the TSO. In order to ensure permanent functionality, these protective devices are checked at regular intervals by the TSO. The protection tests and their results are verified by test reports. Substantial changes to the protective devices or their adjustment are coordinated between the TSO and the OWF.

For each GAP, two protection devices from different manufacturers are used.

The following basic protection requirements apply:

- 100% protection of all plant components in fast time (switch-off times ≤150 ms)
- 100 % selectivity
- a circuit breaker failure protection shall be foreseen (if a circuit breaker fails, the fault clearance time is then increased to a maximum of 250 ms)
- The TSO specifies the permissible end times at the GAP, whereby the end times in the superordinate grid may be set lower than in the subordinate grid
- For the components of the OWF the function of the remote reserve protection of the TSO cannot always be guaranteed and especially not for faults on the undervoltage side of transformers (OWF side)
- In case of failure of a protective device or a circuit breaker, even in the extra-high-voltage grid, much higher fault clearance times than 150 ms can occur.

The protection and control devices are prioritized in the following descending order:

1. protection of the grid and the WTGs
2. frequency control (adjustment of the active power output)
3. power limitation/generation management
4. limiting the power gradient

In the design of electrical protection and in the operational documentation, a clear separation between protective devices and system automation shall be ensured.

5.9 Fault Records

In the event of protection trips, the relevant measurement files will be provided to the respective other party for analysis purposes. In addition to the measurement files of the protection devices, event-based high-resolution plots of the power quality analysis devices installed at the affected GAP shall be exchanged. Format of measurement files shall be aligned between the TSO and the OWF.

The evaluation of the protection trip is performed by both the OWF and the TSO.

The TSO shall be provided with the detailed analysis report which shall be approved by the TSO before reconnection.

5.10 Grid Code Compliance Studies and Models

5.10.1 Procedure

The OWF shall provide the TSO with corresponding models and network parameters immediately after allocation of the tendered area (planning phase). A detailed listing of the models to be provided by the OWF and related model requirements, network data, and a timeline on the submission by the OWF, will be provided by the TSO.

5.10.2 Simulation Software Requirements

The simulation software is specified by the TSO and the connection customer shall request this information from the TSO at the beginning of the planning phase in due time before the system studies are carried out or contracted to a third party. The simulation software used for the different studies shall be stated in the respective results report including the version number.

5.10.3 Model Requirements

The OWF shall provide a suitable model of the entire wind farm and a separate WTG model (harmonic, RMS and EMT). For each study, a separate model shall be provided that can be used to reproduce the study results. OWF shall request model requirements from the TSO.

In addition, a tool independent model shall be provided by the OWF, details shall be specified by the TSO.

A detailed model description for the software implementation shall be provided. The description shall also describe all parameters and possible parameter changes.

Model simplifications are only permitted if they do not lead to any falsification of results. This shall be demonstrated by the OWF to the TSO in the form of reports. In these reports a function of the simplified model equivalent to the exact model shall be proven.

The results of the system studies and model descriptions shall be documented in separate reports in accordance with the specifications described in Annexes B.2 to B.6 to the VDE-AR-N 4131 [I]. In addition, a document shall be provided to the TSO summarising all data and equipment parameters required in Annexes B.2 to B.6 of the VDE-AR-N 4131 [I].

The TSO may require additional requirements on the models, beyond VDE 4131 Annexes B.2 to B.6, to ensure system stability.

All models must be validated. Validation requirements must be agreed with the TSO.

If in the course of the OWF lifetime changes occur with regard to the control functions, data and equipment parameters which have an influence on documents and models already submitted, these shall be updated and submitted to the TSO for renewed approval.

5.10.4 Scope of studies

The scope of modeling details, calculation scenarios and documentation to be performed by the OWF shall be determined by the TSO.

Beyond the basic requirements for conformity simulation in chapter 6.4.2, the TSO may request the OWF to perform additional or alternative series of power system simulations when the information provided for conformity simulation in accordance with Annexes B.2 to B.6 of VDE-AR-N 4131 [I] is not sufficient to demonstrate compliance with the requirements of the OGCR.

5.11 Earthing System

The earthing system of the WTGs shall be designed by the OWF taking into account the earthing system of the offshore platform (planning phase). Details are to be agreed with the TSO.

6 Operation Permit Procedure

6.1 Overview of the Process

The documents, data and information to be exchanged between the TSO and the OWF shall comply with the requirements of the VDE-AR-N 4131 [I], Section 4.2.2 [I] 4.2.

If, during the project phase or in later operation, changes are made to the electrical system of the OWF or if equipment failures occur which have an influence on the information provided within the scope of the approval procedure, the TSO shall be notified immediately.

6.2 Requirements for the Permission for Energization

The TSO issues a permit for energization if all preliminary works and complex tests for a safe connection of the WTG/OWF has been completed including the onshore substation, export cables, offshore platform, etc. For this purpose, the certificates listed in Section 6.3 shall be submitted and confirmed by the TSO. Additionally, all required contracts shall be agreed and signed with the TSO. Further requirements on alignment and testing between the OWF operator and the TSO are specified in VDE-AR-N- 4130, Section 4.2.3. In addition, a signal test shall be carried out in cooperation with the TSO before the first energization.
With the Permission for Energization (PE), the OWF internal grid and OWF's auxiliary devices can be energized. The OWF is also allowed to consume electricity from the TSO grid. For the electricity supply, the OWF operator is required name the responsible electricity supplier to the TSO and provides to the supplier the necessary metering point number. The supplier shall register itself as the supplier of the respective metering point at the TSO.

6.3 Installation Certificates

The following certificates shall be submitted to the TSO before the first energization. The OWF is obliged to report changes immediately at any time.

- Certificate TSO Regulations and Standards
- Certificate TSO Primary Technical Data
- Certificate TSO Secondary Technical Data
- Certificate TSO Registration for Commissioning
- Certificate TSO Authorization List

Certificate forms will be made available to the OWF upon request. The TSO can request other certificates from the OWF's operator besides those from the list above if needed.

6.4 Requirements for the Temporary Operating Permission

The TSO will issue a temporary operating permission under the condition that permission for energization has been granted and the review of the data, models and grid compliance studies described in this section has been completed. Further, the scope of the compliance test shall be aligned and agreed between the connection customer and the TSO.

Additionally, the OWF's operator shall name the responsible electricity seller at the power stock exchange for the OWF. The responsible electricity seller shall align with the TSO on the data exchange in order to ensure a well-functioning registration of electricity sale and corresponding dispatch plan at the TSO later on.

With the temporary operating permission, the OWF is allowed the start with the active power production and feed them into the transmission grid.

6.4.1 Verification for Temporary Operating Permission

In order to acquire the temporary operating permission, the connection customer shall submit the following data and studies to the TSO:

1. Detailed technical data of WTG as specified in Annex B.1 of VDE-AR-N 4131 [I];
2. Installation certificates for WTG issued by an authorized certification authority, as far as they are part of the proof of conformity;
3. The simulation models specified in Annex B.6 of of VDE-AR-N 4131 [I] for the system studies in accordance with Annexes B.2 to B.5 of VDE-AR-N 4131 [I];

The TSO can request additional data which are not listed here.

Furthermore, the connection customer shall demonstrate with several power system studies the capability to fulfil static and dynamic operating requirement defined in the grid codes or specified by the TSO for the grid compliance procedure.

Additionally, the OWF should submit certificates confirming the functionality of the system automations. Such certificates are:

1. Installer’s Certificate - System Automation Voltage and Frequency Protection
2. Installer's Certificate - System Automation Underexcitation Monitoring
3. Installer's Certificate - System Automation Active power output in case of Frequency Deviation
4. Installer's Certificate - System Automation Emergency Power Control

The TSO can request additional certificates which are not listed here. Certificate forms will be made available to the OWF upon request.

Lastly, the OWF and the TSO shall align and agree a detailed scope of the conformity tests required for the final operation permit according to section 6.5.

Independently from any approval by the TSO, the OWF is obliged to take all necessary measures to ensure a safe grid operation.

6.4.2 Power System Studies and Demonstration of Compliance

The studies and proof of conformity to be carried out by the OWF within the scope of the operating approval procedure serve the purpose of evidencing and documenting to the TSO that the basic and, if applicable, additional requirements for system behaviour required by the OGCR have been fulfilled:

1. The results of the system studies and proof of conformity are a binding element of the operating approval procedure. The required documentation shall be prepared in accordance with the requirements specified in the OGCR.
2. The TSO reserves the right to commission third parties to evaluate the system studies, models and proofs of conformity.
3. The models and their characteristics to be exchanged in accordance with the OGCR shall be documented with all details by the OWF and submitted to the TSO for testing, including any model simplifications and associated measurements.

6.5 Requirements for the Final Operating Permission

The TSO will issue a final operating permission certificate under the condition that a temporary operating permission has been issued and the conformity tests described in the VDE-AR-N 4131 [I] and detailed in the following sections have been successfully performed and accepted by the TSO.

The TSO reserves the right to carry out additional or alternative test series in cases where the information provided to the TSO on the conformity tests described in this section is not sufficient to prove that the requirements of the OGCR are fulfilled.

Upon request, the TSO shall also be provided with updated applicable technical data, simulation models and studies in accordance with Section 6.4, including the values measured in the conformance tests.

The TSO may participate in the conformity tests either on site or from control center. For this purpose, the OWF shall provide the monitoring equipment necessary to record all relevant test signals and measured values and shall ensure that the necessary representatives of the OWF and WTG manufacturer are available on site during the entire test period.

The signals necessary to evaluate the various tests shall be transmitted to the TSO.

6.5.1 Test of the Controllability of the Active Power Output

It is to be proven that the OWF can be operated with the limit values specified by the TSO. In this context, the requirements for active power control mentioned in sections 5.2.1 shall be demonstrated.

This test shall also prove if the requirements described in Section 5.2 with regard to the priority of the active power limit value specification by the TSO are fulfilled.

The test shall be considered successful if the evidence has been provided in accordance with

VDE-AR-N 4131 [I] and confirmed by the TSO. Furthermore, a completed test report shall be provided to the TSO. Template for the test report will be provided by the TSO.

6.5.2 Test of the Reactive Power Supply

It shall be demonstrated that the OWF can be operated under the conditions specified in Section 5.3.1. When testing the provision of reactive power, the parameters specified in VDE-AR-N 4131 [I] shall be considered as a basic requirement.

The test shall be declared successful if the proofs according to VDE-AR-N 4131 [I] have been provided and confirmed by the TSO. Furthermore, a completed test report shall be provided to the TSO. Template for the test report will be provided by the TSO.

6.5.3 Test of the Reactive Power Control Modes

It shall be demonstrated that the OWF can be operated under the conditions specified in this document in

- reactive power control mode with reactive power-voltage characteristic
- reactive power control mode
- power factor control mode

When testing this mode, the parameters specified in VDE-AR-N 4131 [I] shall be considered as a basic requirement.

The test shall be declared successful if the proofs according to VDE-AR-N 4131 [I] have been provided and confirmed by the TSO. Furthermore, a completed test report shall be provided to the TSO. Template for the test report will be provided by the TSO.

6.5.4 Tests for Frequency Control Capability

The results of the test shall be used to prove that the dynamic and the static parameters comply with the requirements according to section 5.2.2 and to verify the behaviour of the OWF in case of frequency deviations as already confirmed by OWF.

The test shall be declared successful if the proofs according to VDE-AR-N 4131 [I] have been provided and confirmed by the TSO. Furthermore, a completed test report shall be provided to the TSO. Template for the test report will be provided by the TSO.

6.5.4.1 Frequency Sensitive Mode (FSM)

The test of the FSM is performed according to the specifications of VDE-AR-N 4131 [I].

6.5.4.2 Overfrequency LFSM-O

The test of the LFSM-O is performed according to the specifications of VDE-AR-N 4131 [I].

6.5.4.3 Underfrequency LFSM-U

The test of the LFSM-U is performed according to the specifications of VDE-AR-N 4131 [I].

6.5.5 Test of the System Automatics and the Fast Signal Reaction

The function of the system automations shall be verified within the scope of the verification and commissioning tests according this OGCR. In addition, the interface tests check will be performed if the transmission of the EPC signals from the TSO secondary equipment to the binary input of the OWF controller is working correctly.

The requirements for the EPC system automations described in this document shall be verified by conformity certificates. This also includes the verification of the functionalities which have already been confirmed within the scope of the temporary operation permission.

Furthermore, the functionalities already confirmed within the scope of the temporary operating permit by the relevant certificates have to be verified by conformity tests (commissioning and testing phase).

6.5.6 Measurement of Harmonic Emissions

Measurements are taken to prove that the operation of OWF complies with the grid harmonic emission level permitted at the GCP in accordance with VDE-AR-N 4131 [I].

The measurement procedure shall comply with the requirements of VDE-AR-N 4131 [I].

6.6 Restricted Operating Permission

The connection customer requests for a restricted operating permission when the generation plant is temporarily not able to comply with the grid code requirements after receiving the final operating permission from the TSO and being in the full operation. The issue of a restricted operating permission is subject to the requirements of VDE-AR-N 4131 [I].

If the request of the OWF for the issue of a restricted operating licence was rejected, the TSO may prevent the operation of the OWF until the non-conformity was eliminated and the OWF meets the requirements in the opinion of the TSO.

The OWF may refer the matter to the regulatory authority within six months of notification of the decision by the TSO if the TSO does not extend the period of validity of the restricted operation permit as described in VDE-AR-N 4131 [I] or rejects the operation of the OWF.

6.7 Repeated Tests during Operation

The TSO will test the conformity of the OWF with the requirements of this OGCR during the entire life cycle.

The OWF has to ensure that WTGs behave in accordance with the OGCR requirements throughout their entire life cycle.

The TSO shall be informed immediately of any deviations from the submitted and tested concept. These requirements also apply to deviations from already approved system studies.

7 Connection Technology and Interfaces

The content of this chapter describes the interfaces to be considered by the OWF as a planning basis. Further detailed information and in particular the cable pull-in and grid connection process shall be agreed with the TSO in the planning phase.

7.1 Technical Scope-Split (Design, Specification, Supply, Installation, Testing)

The overview diagram of the high-voltage system at the GCP (Figure 1, 2, 3) shows the intended ownership boundary between the TSO and OWF. The scope of supplies and services is described in detail in the following sections in addition to the technical supply services. Table 7 provides an overview of the division of responsibility.

Table 7: Interface Matrix

1	**General Requirements**	**TSO**	**OWF**
1.1	Supply of equipment and services in relation to the platform and logistics in accordance with this document and general construction standards	X	
1.2	Design, specification, supply and installation of the necessary permanent cable trays and cable ducts for the installation of all necessary cables on the platform, including the J-Tube or an alternative system for introducing the submarine cable	X	
1.3	Acceptance of TSO design and specification		X
1.4	Supply of the necessary health, safety and emergency equipment and measures for all work to be performed on the platforms	X	X
1.5	Provision of the power supply for the installation work required to connect the OWF's submarine cables offshore		X
1.6	Provision of a Single Line diagram (SLD) including all electrical data		X
2	**OWF Cable Pull-In and Termination**	**TSO**	**OWF**

2.1	General arrangement and cable corridor including service corridor and exclusion zones.	X	
2.2	Design basis incl. scour analysis	X	
2.3	Design requirements and input for bellmouth, J-tube, hang-off, cable routing on seabed and on Offshore Station, messenger wires, structural interfaces for winch and any other pull-in equipment, fixation of OWF's cables, short-circuit forces of OWF's cables, earthing, access, scaffolding, and mechanical handling needs for pull-in equipment (Description of needs and specification of requirements for HV cable pulling and termination operations including dimensions, weights, loads, free space requirements, winch and pulling devices data sheets, footprint, integration needs), transportation and installation (T&I) criteria such as maximum allowed acceleration and forces, etc..		X
2.4	Design, supply, and installation of scour protection for OWF submarine cables		X
2.5	Design, delivery, laying, and installation including temporary cable protection of the OWF's submarine cables incl. FO cables to the TSO 's Offshore Station		X
2.6	Design, supply, and installation of cable protection system (CPS), including J-tube bellmouth. Bellmouths shall be installed onshore in yard.		X
2.7	Cable Support Weights on scour protection to stabilize cable protection systems (CPS) of OWF. (If necessary)		X
2.8	Design, supply, and installation of flanges (welded to platform or J-tube) for J-tube bellmouth	X	
2.9	Delivery and installation of flanges for strain relief (hang-off) (welded to the platform or J-tube)	X	
2.10	Delivery and installation of the Hang-off		X
2.11	Design and provision of interfaces for pull-in equipment such reinforced foundation with threaded holes, or strong points for winches and padeyes or strong points for pulleys, sheave blocks, roller boxes, etc.	X	
2.12	Check and accept whether the fabricated Offshore Station interfaces, such as J-tubes, foundations, strong points, etc. for pull-in equipment are fabricated according to design		X
2.13	Check and accept whether the topside conditions are ready to install the OWF equipment including pull-in equipment on the OSS		X
2.14	Design, Supply, Installation and Demobilization of suitable assembly jigs/adapters for the deck covering jigs, e.g. deck eyes and deck reinforcements for the winch and delivery of other necessary equipment		X
2.15	Provision of platform access for cable pulling equipment and personnel on site, including crane equipment to the cable deck and all necessary work areas	X	
2.16	Lifting and handling gear for pull-in equipment as e.g., pull-in quadrants, rollers, temporary scaffolding		X
2.17	Design, supply and installation of the winch and any other cable pull-in equipment (quadrants, scaffold, auxiliary winches, etc.) for the cable pulling work.		X
2.18	Power supply of the winch		X
2.19	Dismantling the winch and related equipment		X
2.20	Design, supply, and installation of messenger wires in J-tubes.	X	
2.21	Design, delivery, and commissioning of connection point / GIS for connecting the OWF cables	X	
2.22	Design, supply, and installation of the cable termination female part (socket or bushing) of connection point / GIS for connecting the OWF cables	X	

2.23	Supply and installation of the cable termination male part (plug) for the OWF cables based on the TSO requirements		X
2.24	Design/Layout for all OWF cable routes on OSS	X	
2.25	Design and delivery of cable trays, support structures, cable penetrations and ducts	X	
2.26	Design, supply, and installation of cable cleats or any fixations or fastenings to cable trays/ladders		X
2.27	Design, supply, and installation of seafastening of entire OWF equipment including (temporary) pull-in equipment		X
2.28	Design, supply, and installation of attachment points for seafastening of pull-in equipment	X	
2.29	Acceptance of entire OWF cable pull-in and termination design	X	
2.30	Preparation and execution of cable pull-in mock up in yard		X
2.31	Removal and disposal of any waste produced during OWF cable pull-in and termination activities (incl. cable mock-up in yard)		X
2.32	Specification, design, supply, and installation of earthing connection points	X	
2.33	Design, supply, and installation of earthing connection compliant to overall earthing specification and design up to earthing connection point of Offshore Station		X
2.34	Issuance of risk assessment and method statement for cable pull-in and termination activities		X
2.35	Issuance of as-built drawings and documentation		X
3	**Secondary technical Equipment and auxiliary power supply concept**	**TSO**	**OWF**
3.1	Design, supply, installation, and testing of the necessary telecommunication equipment for the respective inter-array cable bay for the control system and the fiber optic interface of OWF	X	
3.2	Provision of a protection concept and protection block diagram		X
3.3	Design, supply, and installation of the fibre optic cables (FOC) from the repeater station on land to the Offshore Station of the TSO	X	
3.4	Design, supply, and installation of the fibre optic splice boxes near the hang-offs of the OWF submarine cables	X	
3.5	Design, supply, and installation of cable trays for fibre optic cables	X	
3.6	Design requirements (i.e., fire protection class) for FO cables in OWF submarine cable	X	
3.7	Design compliant to TSO requirements, supply, installation (including splicing to splice cassette in FO splice box) and testing of the fiber optic cables from hang-off of the OWF submarine cables to the fibre optic splice box near the hang-off		X
3.8	Design, supply, and installation (including splicing to splice cassette in FO splice box and to splice cassette in OWF patch panel) of the fibre optic cables (intermediate topside FO cables) from fibre optic splice box to fibre optic OWF patch panel on the plattform	X	
3.9	Provision of a splice and patch plan for the connection of the intermediate topside FO cable (connection from fibre optic splice box to fibre optic OWF patch panel)		X
3.10	Design, supply, installation, and testing of TSO fibre optic patch panel on the plattform	X	
3.11	Design requirements for OWF fibre optic patch panel and splice cassette	X	
3.12	Supply, installation, and testing of OWF fibre optic patch panel on the plattform		X
3.13	Issuance of risk assessment and method statement for FO cable installation and testing		X

7.2 Scope of Deliveries and Services of the TSO

The scope of supplies and services of the TSO shall be limited to the design and construction of the HVDC transmission system up to and including the seaside HVDC converter station and the associated components (e.g., primary and secondary technical equipment). All the components not specified in this OGCR shall be provided by the OWF.

7.3 Scope of Deliveries and Services of OWF

In this context, it is particularly important that the OWF submits the following documents required and ensures compliance with the described requirements during the project design phase as well as construction and installation phase:

1. Coordination of the schedule (e.g., MS-Project) and designation of the persons responsible for the activities.
2. Submitting the project documentation and input as of 7.1 for review in accordance with due dates given by TSO in sense of overall project.
3. Early coordination of necessary requirements regarding HSE qualifications for the onshore assembly site and offshore work.

7.4 General Conditions for HVAC Cable Routing and Installation

7.4.1 Direct Connection to GIS / Cable Joint

Based on the platform design and technical feasibility of the cable pull-in concept, the TSO decides how the OWF submarine cables will be connected, both solutions are feasible (refer to Figure 1 and Figure 2):

1. Direct Connection of OWF submarine cables to GIS
2. Jointing of OWF submarine cables on the platform via a cast resin joint

Option 1: TSO will provide a connector socket at the high voltage GIS. Type to be advised by TSO. The cable connectors (plugs) will be supplied, mounted to the cable cores and connected to the high voltage GIS by OWF.

Option 2: TSO will provide a half joint connector socket, type to be determined by the TSO.

The location of the cable joint will be near the J-tubes on a support structure in an isolated condition ready for being connected by OWF. The mechanical strength of the cable support structures shall be designed according to the short circuit current calculated for the relevant cable design.

All OWF cables between the jointing position including the cast resin joint and the high voltage GIS will be completely installed and fully tested by TSO at the yard or onshore assembly site.

The OWF then executes the OWF submarine cable pull-in and connection at the cable joint.

The design of the cable trays will be designed as such that:

- straight cable route of a minimum of 1 m above the hang-offs available before the first bend
- space around cable routing to allow cable pulling, installation works and handling, including racking with cable fixation points strong enough to withstand the applicable short circuit forces is installed
- thermal overload of the cables due to proximity of heat generating equipment or services is prevented

In both options an inner cone cable connector shall be used by OWF.

7.4.2 Cable pull-in preparation concepts

To validate the cable pull-in interface, pull-in concepts considering requirements stated within this document shall be developed by the OWF (planning phase) based on provided layout and infrastructure (e.g. strong points, cable routes) and aligned with the TSO according to OWF cable pull-in concept input milestone.

The pull-in concept, risk assessment and method statement shall include at least following information:

- general overview of the pull-in areas, spaces, adjacent equipment
- messenger wire and bellmouth cover
- major work steps as story board
- The pull-in concepts shall as well confirm input data provided by TSO, including but not limited to:
  - Winch position, foundation and SWL
  - Maximum winch wire length between winch and hang-off
  - Position and WLL of deflection pulleys and strong points
  - Cable route from hang-off to terminations incl. Cable fixation
  - Fixation of Splice Box close to Hang-off
  - Maximum forces to be applied at the hang-offs
- List of pull-in equipment including weight, sizes, interfaces to structure
- Output from HAZID and HAZOP as input for risk assessment covering all activities

The TSO will provide all required information to OWF for purpose of creating a pull-in concept. OWF shall request additional information, if necessary, at an early stage to perform this task.

All power cable routes shall be considered with a maximum free length of 15 m including reserve length for OWF cable re-termination after Hang-Off-Flange of pulled-in cables.

FO cable routes shall be considered with a maximum free length of 5 m after Hang-Off-Flange of pulled-in cables.

7.4.3 Technical Parameters for HVAC Submarine Cable Parameter

The diameter of HVAC cables for connection between the OWF and the Offshore Station varies subject to the maximum transmission capacity, the cable route length, and the cable manufacturer.

For a maximum transmission capacity of active power per string, e.g., a single three-core submarine cable system with a max. 630-1000 mm² conductor cross-section may be a technical solution. As an example, the guide values of diameter, minimum bending radius, maximum pulling force etc. stated in table 8 are considered for first iteration of station design.

They are indicative only while the final values shall be provided, agreed, and confirmed by OWF's cable supplier and the TSO's station supplier when exchanging design details during planning and design phase.

Table 8: Example values of the 66 kV AC cables

Type	three cores (armored)	single core (unarmored)
Max. conductor cross-section	3 x 630 - 1000 mm^2	1000 mm^2
Nominal voltage	66 kV	66 kV
Max. outside diameter	approx. 200 mm	approx. 80 mm
Max. allowed minimum Bending Radius during Pull-In operation (MBR_pull-in)	approx. 3500 mm	N/A
Minimum Bending Radius during routing operation (MBR_routing)	N/A	approx. 1700 mm
Maximum permitted pulling force straight	approx. 100 kN	approx. 30 kN
Maximum permitted pulling force at MBR	approx. 100 kN	
Maximum permitted sidewall pressure – over sheave	approx. 35 kN	
Maximum heat emission of cable	110 W/m	
Maximum allowed conductor temperature	90°C	

7.4.4 Technical Parameters for High Voltage Inner Cone Cable Connector

The following table describes the exemplary technical parameters of the cable connector (male part) to be installed by the OWF. Specific type and brand of connector to be advised by TSO in engineering phase.

Table 9: Example values of the 66 kV inner cone connector

Material	Cu or Al
Diameter over conductor RM	stranded circular 17.5-36 mm
Conductor size	35-800 mm²
Diameter over conductor RE	solid circular 10.5-36 mm
Conductor size	95-1000 mm²

7.5 J-Tubes and Bellmouth Design Requirements

The following chapter describes design requirements for station designer concerning the J-Tubes and Bellmouths. These are indicative values only and will be confirmed during interface meetings in the project.

The TSO will install J-tubes to guide the OWF submarine cables into the platform. One J-tube will be required for each HVAC cable. The distance between two adjacent J-tube bellmouth centres will be ≥ 2 m. Fanning of j-tubes will be considered to reach a distance cable to cable of ≥ 5 m at the edge of scour protection (point of commencing cable burial). DNV RP 0360 will be used as a general guideline for arrangement of j-tubes, but project specific deviations may occur.

The thermal stability of the cable in the J-tube shall be considered in the design of the OWF subsea cables. For this the thermal parameters in Table 8 of the cable shall be taken into account.

The final design values will be provided and confirmed by the TSO's Offshore-Station supplier when exchanging design details.

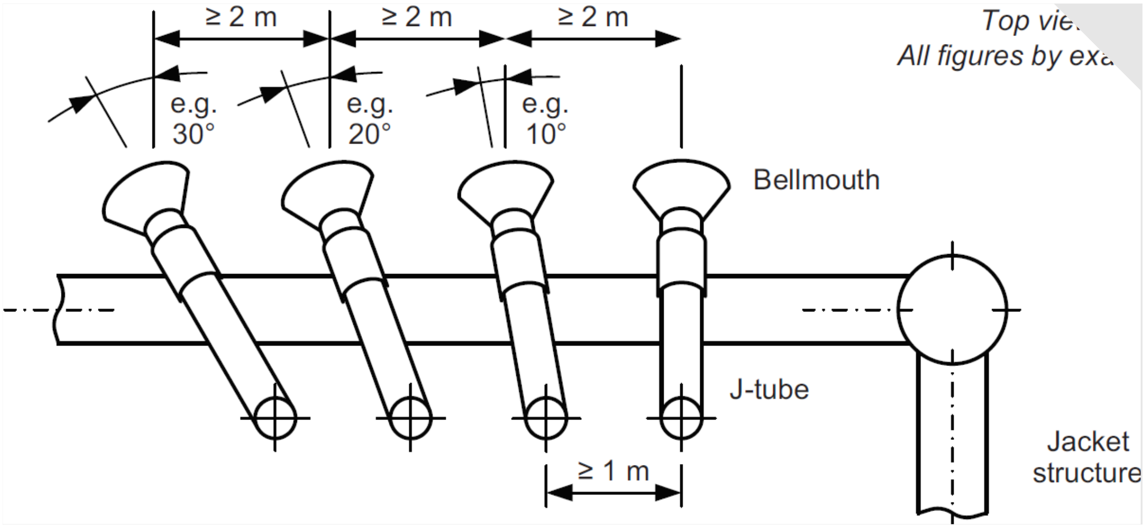

Figure 4: Minimum distances between and fanning of J-Tubes and Bell mouths

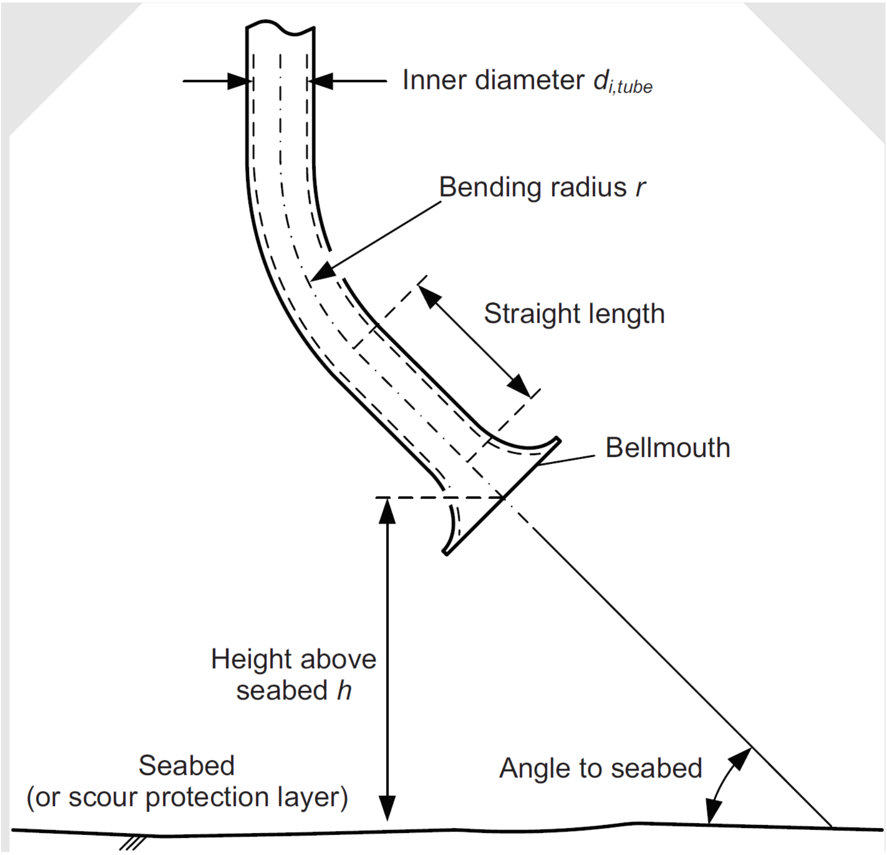

Figure 5: J-Tube Parameter definitions

Table 10: OWF submarine cable Pull-In Design Parameter

Parameter	OWF submarine cable 66 kV
Angle to seabed	20° to 45°
Height above seabed	2 to 2.5 ± 0.3 m
Straight length of J-tube before bellmouth	Min. 1.5 m
Inner diameter $d_{i,tube}$	Min. 2.5 times the overall cable diameter or following, whatever value is higher: 500 mm
Bending Radius $r_{J\text{-}Tube}$	≥4.0 m

Final seabed or scour protection layer has to be taken into account. Design Parameter in Table 10 are indicative only while the final values shall be provided, agreed and confirmed by the TSO station supplier when exchanging design details.

7.5.1 Bell mouth Cover

The Bell mouth will be closed by a bell-mouth cover or plug to prevent ingress of debris or sediment into the J-Tubes before a cable is pulled in. The Bell mouth cover will be connected to the messenger wire in a way, that easy recovery of messenger wire incl. cover by ROV is possible.

7.6 Cable Hang-Off

The hang-off is the strong point to which a submarine cable is anchored on the platform, normally onto a circular flange welded onto the top of the J-tube (J-tube flange). One J-tube flange will be provided for each three-core OWF submarine cable being installed on the platform.

The design of the J-tube flange will be advised by the TSO. Standard ISO flange designs are preferred with hole sizes suited to readily available bolt sizes.

OWF's cable supplier has to pull-in the OWF submarine cables and permanently secure them with the hang-offs.

7.7 Fibre Optic Splice Boxes and OWF Patch Panels

The optical fibres (FO) from the OWF submarine cable shall be connected to the FO splice boxes near the hang-off. Splice boxes will be connected via the intermediate topsides FO cables to the OWF FO patch panels. The OWF shall design, provide, install, and test the patch panels at yard on the platform. Afterwards, the patch panels become the property of the TSO.

7.8 Pull-In Winch Specification

OWF shall install winch(es) on the offshore station which shall be suitable to pull-in all OWF submarine cables from all installed J-tubes directly to the jointing location.

If a direct pull-in is not feasible, provisions shall be included. Winch(es) shall be fully installed, commissioned and tested by the OWF prior to sail-out. If needed, OWF shall supply and install sea-fastening and protection for offshore environment during transport and installation phase.

The predetermined position of the winch(es) on the platform, the relevant pulling pathways and necessary pad eyes, blocks and running gear will be advised by the TSO and shall be further elaborated with the TSO.

If the offshore station design or the pulling pathway (route of the pulling wire on the platform) limitations require more than one winch, relocation of the winch (or parts of it) between the positions is only allowed if retesting in between different positions is not required. OWF is responsible for concept of relocation and approval by certifier.

Winch(es) have to be designed in such a way that the winch should be dismountable in small parts and can be removed easily with a pallet truck and without removing parts of the platform.

7.9 Handling of Damages

The OWF shall document (e.g., position, picture, time) and reimburse all damages caused by OWF or its contractors on TSO´s platform.

7.10 OWF Equipment on the TSO Offshore Station

The objective is to reduce the interfaces on the Offshore Station as much as possible. The reason for this is the resulting reduction in space, as well as decoupled inspection and maintenance campaigns and the avoidance of ad-hoc troubleshooting measures.

The following points describe the respective interfaces in detail.

7.10.1 Protection

The protection devices are owned, specified, installed and commissioned by the TSO. The protection devices are function-redundant and from two different manufacturers. Automatic reclosing of a circuit breaker by a protection relay is not foreseen.

7.10.2 Power Quality Devices

The Power Quality Devices are owned, specified, installed and commissioned by the TSO. These devices will be connected to resistive capacitive voltage dividers of the busbar. This enables a resonance-free measurement of the voltage quality.

7.10.3 Wind Farm Controller

The control cabinets of the wind farm controllers are not installed on the TSO's converter platform. The installation site is at the decision of the OWF and can be either onshore or offshore on one of the WTGs. The measurements transmitted by the windfarm and the set points as well as control commands sent by the TSO to the OWF are exchanged using a state-of-the-art communication protocol agreed upon both parties. Requirements for fast control processes (e.g., FRT behaviour) shall be implemented directly in the converter control of the WTGs in a decentralized manner. The German grid connection requirement VDE 4131/ 4130 / 4120 should serve as a baseline. Exceptions to that guidelines are possible in case of severe reasons.

The controller must have a defined sequence for starting up the OWF after a) a blackout in the high voltage grid, and b) a large area blackout in the transmission grid of the TSO AC grid. The requirements of the "Maßnahmenkatalog der vier deutschen Übertragungsnetzbetreiber mit Regelzonenverantwortung zum Netzwiederaufbauplan gemäß Artikel 4 Absatz 2c sowie Artikel 23 Absatz 4c Verordnung (EU) 2017/2196 zur Festlegung eines Netzkodex über den Notzustand und den Netzwiederaufbau des Übertragungsnetzes" must be fullfiled by the windfarm controller. Further a start-up process after a large-scale blackout must work out automatically, i.e., with no personnel required offshore. Constrains (operational, time-based (blackout duration, etc.) in terms of starting up the windfarm should be kept to a minimum and must be communicated to the TSO in advance to the commissioning, at the earliest possible point in planning.

7.10.4 Fiscal Metering

The fiscal metering devices are owned and operated by the TSO.

To ensure the quality of the billing values, billing and comparison metering is set up at all GCPs.

The OWF has to ensure that just “green energy” is fed in. If this cannot be guaranteed technically, the OWF shall ensure that the energy quantities for “grey electricity” are determined by means of measurement in accordance with the Measurement and Calibration Act and transmitted to the TSO. This transfer shall be made by using Edifact MSCONS messages.

Online measured values can be made available to the OWF. The exact scope must be agreed, as these values are not available by default. This transfer is based on standard protocols. The TSO assigns a metering point designation (identification code) for each metering point.

Fed in points shall be disclosed to the TSO so that the TSO can develop the metering concept together with the OWF.

7.11 Design of High Voltage Switchgear

The design of the high-voltage switchgear is project-dependent. The OWF shall take the project-specific requirements of the TSO into account when designing it’s OWF submarine cables and FO submarine cables.

7.12 Switch-On/Switch-Off Strategy

In the planning phase, the OWF shall submit a description of the switch-on/switch-off strategy and agree it with the TSO.

7.13 Offshore Auxiliary Supply

The TSO will not provide an auxiliary power supply for the OWF. In the event of failure of the HVDC transmission system or disconnection of the HVDC transmission system in the course of maintenance and repair work, the WTG shall be able to supply themselves and all OWF equipment permanently.

7.14 Signal Exchange between OWF and the TSO

The minimum scope of information to be exchanged between the TSO and the OWF is defined in the annex 'Data Communication for Type 2 Generation Plants' to this ONAR. Should the scope of the required information exchange change in the future, the parties shall consult on this in a timely manner and document this appropriately.

The signal transmission between the control system of the OWF and the control system of the TSO shall take place via a redundantly designed protocol interface. The TSO specifies which protocol is used. All signals to be transmitted via the protocol interface shall be agreed during the detailed planning phase. A signal list will be made available to the OWF in the process of the grid connection procedure. Signals shall be able to be processed with three decimal places, details to be agreed with the TSO.

The OWF shall ensure at all times that the communication interface and thus the signal exchange for the setpoint value input works at all times. To ensure this, the OWF shall monitor the interface cyclically in terms of control technology and agree a test procedure with the TSO for verification.

The communication between the control centers of the OWF and the TSO shall be coordinated by telephone.

Concept for WTG illumination of the helicopter corridor shall be aligned between the OWF and the TSO.

7.15 FO Connection and Rental of FO by the OWF

In the connection concept described in chapter 4, the OWF does not have its own offshore platform. The high voltage submarine cable (with integrated optical fibres) of a string is fed directly into the TSO's converter platform.

The OWF can rent optical fibers from the TSO for onshore/offshore communication. The business details are regulated by the fiber optic cable lease contract. This can be requested from the TSO.

The lease of optical fibres does not include any active technology (i.e. only dark fibres). The technology used by the OWF shall therefore be able to cover the entire distance between the offshore platform and the onshore transition point. The maximum damping value of the fiber optic cable per splice is determined by the TSO (ITU-T G652). After installation of export cable and connection of FO cables, the OWF will measure the entire FO cable section and transmit the measured data to TSO.

The connection point on land is normally located near the onshore substation, but an alternative connection point can also be aligned between OWF and TSO. The TSO will set up a further cable connection cabinet at its connection point on land. The TSO will not provide any land area or power supply and/or other services for the OWF's own communication systems. The OWF is responsible for the procurement of all suitable conditions and services.

8 Operations and Grid Management

8.1 Switching Authority and Responsibility OWF/TSO

In general the TSO has the remote and local switching authority for all switches of the high voltage switchgear on the offshore station. The TSO uses remote control devices to secure against re-connection, local operation of the devices shall be prevented. The signalling and interlocking systems used for this purpose shall be reliable. The interlocking concept is specified by the TSO.

The boundary of the switching authority for the high voltage switchgear also is the boundary for the switching responsibility. The TSO is responsible for switching of the high voltage switchgear on the offshore station (Figure 6).

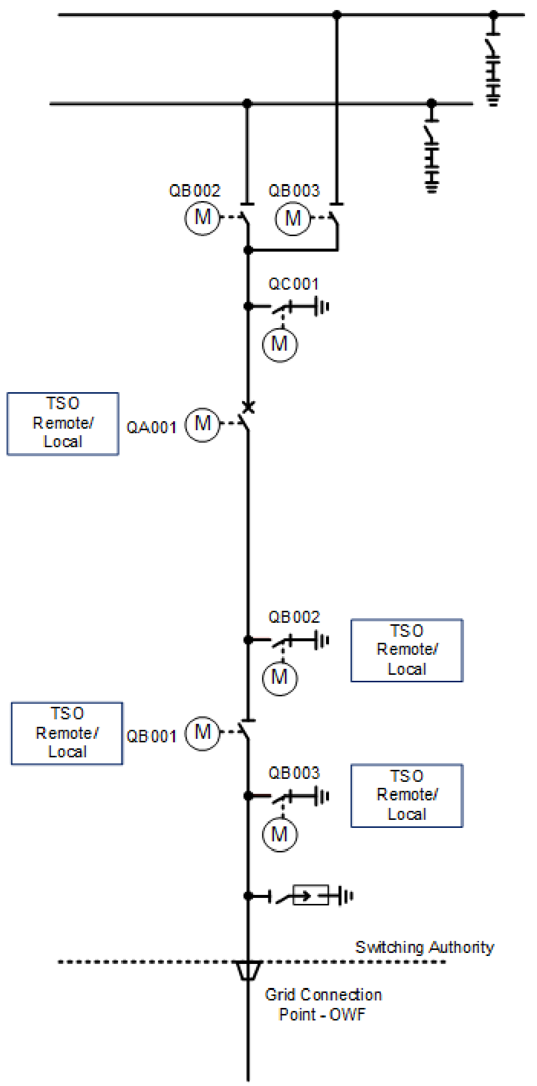

Figure 6: Definition Switching Authority TSO/OWF

8.2 Personnel Qualification and Authorization

The switchgear and all other electrical installations of the TSO are an enclosed electrical plant (abgeschlossene elektrische Betriebsstätte) according to DIN VDE 0105-100 [VII]. Access shall be limited according to DIN VDE 0105-100 [VII] and is only possible in the presence of a TSO plant manager (Anlagenverantwortlicher). In addition to that, for the access to the offshore station an additional instruction by the TSO is required. An OWF contact person with switching authorization for the OWF grid shall be available to the TSO at all times. The OWF shall appoint persons with the appropriate switching authorization and authority to carry out switching operations and provide the contact details of such persons to the TSO.

8.3 Coupling of Grid Connection Points

If an OWF has more than one GCP connected to the TSO converter station or to other TSO grids, these GCPs may not be operated electrically linked to each other by the equipment of the OWF without the approval of the the TSO.

8.4 Right of Instruction of the TSO

The TSO is entitled and obliged to instruct actions for purposes of maintaining or to re-establishing a safe grid configuration and to return the system from a critical to a non-critical state.

Planned shutdowns shall be announced by the OWF in sufficient time in advance. Details of the shutdown process and required times are to be agreed between the OWF and TSO in advance of the operating phase.

The respective responsible GOC of the TSO is authorized to issue switching orders and instructions to the OWF for the safe operation and performance of the system. The OWF shall follow such instructions immediately. The safe system operation and its restoration in the event of failure thus takes priority over the interests of the OWFs.

If corrective measures are unsuccessful or if there is still the risk of an extension of the malfunction, the TSO shall be entitled to temporarily shut down grid areas in order to maintain safe system operation or to restore the system quickly.

In the event of a malfunction, the OWF shall implement the corresponding instructions immediately.

To clarify the fault or similar, operating data, measured values, fault and message protocols, records, etc. shall be exchanged.

8.5 Maintenance

The TSO and the OWF are each responsible for the maintenance of equipment and system components owned by them.

All system components shall be maintained in accordance with the state of the art and the minimum requirements of the TSO in order to ensure proper operation in conformity with the grid connection regulations.

Safety-relevant system components, e.g., circuit breakers, batteries, protective devices, etc. shall be regularly inspected according to a maintenance plan.

8.6 Conformity Assessment during Operation

The OWF ensures that each WTG meets the requirements of the OGCR throughout the life of the plant. The OWF shall immediately notify the TSO in advance of any planned change if it does not comply with OGCR. Changes shall be approved by the TSO. If a situation occurs on the OWF that does not ensure the compliance of the OGCR, the TSO shall be notified immediately.

OWF shall inform the TSO in a timely manner of the testing programs and procedures planned to demonstrate compliance with the OGCR requirements and obtain prior approval from the TSO.