Offshore Grid Connection Requirements

Annex A_03:

Grid data provided by the TSO

Area of Application: DC-connected Offshore Windfarms

Revision history

Rev. Number	Date	Change	Author
1.0	28.07.2025	First edition	T. Nguyen (50HzT) E. Wiebe (AMP)

1 General

This annex includes the project-specific grid data, information and description of models delivered by the TSO to DC-connected Offshore Windfarm (OWF) to perform grid code compliance studies.

The TSO will deliver data according to the time schedule agreed between the TSO and the connectee according to the requirements in [1].

At the beginning of the project, not all project specific data especially with view on the HVDC system are available. They will be delivered throughout the project.

The grid data provided by the TSO shall be used for the relevant grid studies related to this project only.

2 Standards

If no explicit standards are specified, the following systems of standards shall be followed in the prioritized order:

i. German standards and regulations, including the grid codes of TSO
ii. Cenelec
iii. IEC
iv. Cigré recommendations
v. IEEE standards and recommendations.

If alternative standards will be used, they shall be approved by TSO. The latest edition including amendments of each standard and regulation shall apply.

SI units and the passive sign convention shall be used in all documents, if it is not otherwise specified by the TSO.

3 References

Parties using this document shall apply the most recent edition of the documents listed in the following paragraphs:

[1] VDE-AR-N 4131: 2019-03: Technische Anschlussbedingungen für HGÜ-Systeme und über HGÜ-Systeme angeschlossene Erzeugungsanlagen (TAR HGÜ).
[2] 50HzT, AMP: Offshore-Netzanschlussregeln
[3] VDE/FNN: Hinweis: Spannungseinprägendes Verhalten von HGÜ-Systemen und nichtsynchro-nen Erzeugungsanlagen mit Gleichstromanbindung, Stand Juni 2020
[4] 50HzT, AMP: Offshore Grid Connection Requirements, Annex A_08 Grid Forming Control Study

4 Definitions

AC	Alternating Current
DC	Direct Current
EMT	Electromagnetic Transients
GCP	Grid Connection Point
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
NDA	Non-disclosure Agreement
OWF	Offshore Windfarm
ONAR	Offshore-Netzanschlussregel
RMS	Root Mean Square
TSO	Transmission System Operator
VDE	Verband der Elektrotechnik Elektronik Informationstechnik e. V.
WTG	Wind Turbine Generator

5 General Grid Data

The following project specific basic design paramters will be provided by the TSO to the connectee:

	Formula character and unit	**Requirement**
Nominal AC voltage	$U_{AC,n}$ in kV	
Reference AC voltage (base for 1 pu)	U_{ref} in kV	
Nominal AC frequency	$f_{AC,n}$ in Hz	
Maximum total active power	$P_{AV,total}$ in MW	
Maximum active power on grid connection point, if applicable	$P_{AV,GCP}$ in MW	
Maximum active power on generator block level, if applicable	$P_{AV,GB}$ in MW	
Maximum active power on HVDC pole level, if applicable	$P_{AV,HVDC}$ in MW	

Nominal reactive power (base for 1 p.u.)	Q_n in Mvar	
Nominal apparent power (base for 1 p.u.)	S_n in MVA	
Minimum short-circuit level 1 phase	$I''_{k1,min}$ in kA	
Maximum short-circuit level 1 phase	$I''_{k1,max}$ in kA	
Minimum short-circuit level 3 phase	$I''_{k3,min}$ in kA	
Maximum short-circuit level 3 phase [1]	$I''_{k3,max}$ in kA	
Earth fault factor	δ	
Grid impedance ratio at maximum short circuit power positive sequence	R_1/X_1	
Grid impedance ratio at minimum short circuit power positive sequence	R_1/X_1	
Grid impedance ratio at maximum short circuit power zero sequence	R_0/X_0	
Grid impedance ratio at minimum short circuit power zero sequence	R_0/X_0	

6 Model exchange

The TSO aims to provide the HVDC converter model and neighboring OWF model (if applicable) to the connectee to perform the dynamic performance and controller interaction study under a valid NDA.

On the other hand, the connectee shall provide the detailled windfarm model to the HVDC converter manufacturer and neighboring OWF for their own study. In this project, the following models from the HVDC and neighboring OWF shall be used:

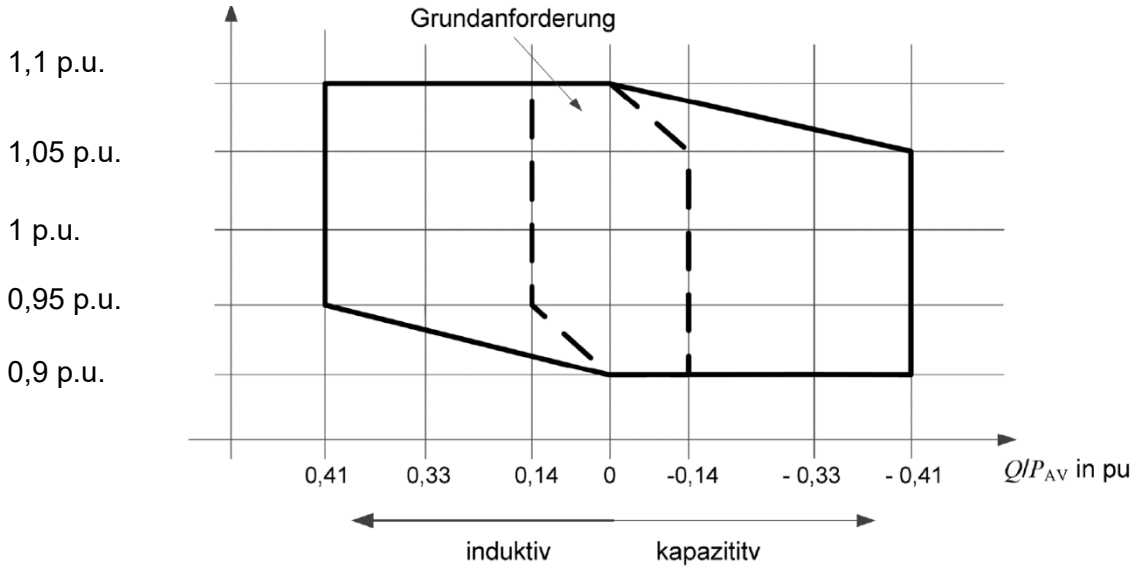
	Name of the manufacturer	Name of the operator	Year of commissioning	Type of model
HVDC				
OWF				

7 Requirement on reactive power provision

The reactive power capability of DC-connected OWF shall fulfill the inner-envolope of the *U*-*Q* diagram according to [1], Section 10.2.8.2 (see figure below) when there is no other

[1] Short circuit current coming from the HVDC converter without the DC-connected OWF

specification by the TSO. The TSO can specify in each individual project a larger envelope for the requirement of reactive power that is inside the outer-envelope shown below.



8 Data for Grid Forming Study

The TSO shall define the methodology and acceptance criteria for the grid forming study [4] with the DC-connected OWF and provide all input data to the OWF in order to design the control system and to demonstrate the compliance to the TSO requirement in terms of instantaneous reserve and dynamic voltage support without reactive current specification (Grid Forming Control). Methodology and acceptance criteria for the assessment are described in the technical guidelines given by [3].

Preliminary reference curves, envelopes and acceptance criteria for instantaneous reserve and dynamic voltage support might be provided by the TSO together with [4].

9 Harmonic levels

Project specific maximum harmonic distortion limits due to harmonic emission at GCP shall be provided by the TSO.

h	Harmonic voltage limits
	$U_{h,GCP}$ in %
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The limit for interharmonics up to 2,5 kHz and supraharmonics above 2,5 kHz is 0.1 % at the GCP.

10 Frequency dependent grid impedances

The TSO provides the frequency dependent grid impedances (impedance envelopes) at the GCP as an annex to this document.

11 Controller settings

If not otherwise specified, the connectee shall implement the following control parameters in the OWF and WTG control

11.1 Frequency Sensitivity Mode (FSM)

Parameter	Unit	Adjustable range	Default Value
Deadband Δ f_{tot}	mHz	0 – 200	±200
Droop s_1[2]	%	2 - 12	6
Permissible tolerance Δ*f* toleranz	mHz	10 - 30	30
Active power range in relation to the in-stantaneously available active power $\|\Delta P_1\|/P_{mom}$	%	1,5 - 10	2

11.2 Limited Frequency Sensitive Mode Overfrequency /Underfrequency (LFSM-O / LFSM-U)

Parameter	Unit	Default Value
Frequency threshold value f_1	Hz	50,2

[2] $s = (\Delta f/f_n) / (\Delta P/P_{ref})$

Droop s_3	%	5
Frequency threshold value f_2	Hz	49,8
Droop s_4	%	5

11.3 Active power gradient

Parameter	Unit	Default Value
Active Power Gradient	% P_{AV}/ min	no

11.4 Default operation mode for Reactive Power Control

All three operation modes shall be implemented and switchable. Reactive Power Control mode is the default mode.

11.5 Reactive Power Control

Parameter	Unit	Default Value
Step response Time $T_{an\_90\%}$	s	5
Settling Time T_{ein}	s	30
Settling tolerance $\Delta Q / Q_{max}$	%	±5
Overshoot Δq_{max} / ΔQ_{max}	%	(25% * (2s/$T_{an\_90\%}$) + 5%)

11.6 Reactive Power/Voltage Characteristic(Q=f(U)) Mode

Parameter	Unit	Adjustable range	Default Value
Reference Voltage / U_n	%	95 – 105 in step of 1%	100
Slope $s=(\Delta U/U_{ref})/(\Delta Q/Q_{max})$	%	2 – 7 in step of 0,5%	7
Deadband / U_n	%	0 – 5 in step of 0,5%	0
Step response Time $T_{an\_90\%}$	s	1 - 5	5
Settling Time T_{ein}	s	5 - 60	30