Offshore Grid Connection Requirements

Annex A_01:

General Requirement for Compliance Studies and Models

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 describes the general requirements for the compliance studies and models for the DC-connected Offshore Windfarm (OWF). It may provide supplementary requirements to [1] and [2].

Beyond the studies defined in the [1] and [2], the DC-connected OWF may perform additional studies if these are required to ensure a safe grid operation and have not yet been defined in this document.

The compliance studies together with the used models are a deliverable of the connectee to secure the interim operation notification. They shall meet all requirement stated in the [1] and [2].

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

4 Definitions

EMT	Electromagnetic Transients
HVDC	High Voltage Direct Current
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
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 Applicability

The requirements stated in this document are applicable for all conformity studies and models that are specified in [1], [2] and other annexes

- Annex A_02: Main Circuit Parameter Report
- Annex A_04: Requirements for RMS Simulation Model
- Annex A_05: Requirements for EMT Simulation Model
- Annex A_06: Requirements for Harmonic Simulation Model
- Annex A_07: Dynamic Performance Study
- Annex A_08: Grid Forming Control Study
- Annex A_09: Harmonic Performance Study
- Annex A_10: Harmonic Stability Study

6 Requirements on conformity study - and model provision during project implementation

The connectee shall provide a list which includes all study outline reports, study reports and models including delivery dates of the documents which needs to be agreed with the TSO. This list shall for each report list which of the requirements in the [1] and [2] will be demonstrated.

The connectee shall provide for all studies a study outline report to the TSO. As part of the study outline report, the connectee shall create a test matrix that lists all simulation scenarios to be considered and fully documents there all operating points, design points, operating modes and states, simulation types, calculation scenarios, simulation durations and sensitivities. To this end, test cases shall be chosen so as to encompass the quasi-steady and dynamic behaviour of all combinations. The study outline report incl. test matrix and number of tests shall be approved by the TSO.

The connectee shall specify the minimum number of test cases and coordinate these with the TSO during the basic design phase:

- Offline simulations
- Real-time simulations

A set overlap shall be simulated both in offline and real time for benchmarking purposes.

If additional assumptions of the connectee are necessary for performing a compliance study, these shall be accepted by the TSO before the start of the study.

The connectee shall provide all models as used in the compliance studies together with study report to the TSO, including models of the DC-connected PPM and the AC network representation, if applicable.

The connectee shall provide preliminary models to the TSO and the HVDC manufacturer in an early stage of the project in order to allow the HVDC manufacturer to design and optimize the control.

The TSO may forward all compliance studies and simulation models to

- Other TSO for regulatory and operation processes,
- A third party, contracted by the TSO for a compliance assessment,
- Or other manufacturers of nearby converter plants (e.g., HVDC, windfarm) for controller interaction analysis and definition of mitigation measures.

The TSO will hand over all information under the validity of a non-disclosure agreement (NDA) excepting the following models:

- Generic model (e.g., open, generic RMS model),
- Blackboxed grid models, which include simulation models of the OWF as part of the overall blackbox,
- Aggregated harmonic grid models, in which the harmonic simulation model of the OWF was incorporated into the aggregation.

All models required by the grid code shall be provided by the connectee in their final and validated version after finalising the hardware tests or compliance test.

The connectee shall report all hard- and software changes with impact on grid code compliance performed during or after hardware tests or commissioning and indicate the changes and the consequences to the TSO.

A change of control shall be considered as relevant if the bandwidth of the changed control may influence study results.

For all reported changes, the connectee shall prove with test cases that the change does not change the already provided study results in a negative manner.

In case a change has or may have an impact on the already provided study results, the connectee shall repeat all affected compliance studies according to the requirements of the TSO as a part of its grid code compliance activities.

7 Specific requirements for simulation model and model documentation

The connectee shall supply the models together with the respective study report in which the models are used. In order to allow the TSO to reproduce the results, the connectee shall provide all necessary tools and data that were used in the study.

The Contractor shall provide the final and validated versions of all models once the validation tests as hardware-in-the-loop or in compliance tests are complete (as-built documentation). If changes are made after this point within the control system, updated and validated models, the Contractor shall supply the updated and validated models within one month.

If for any reasons parameters will be changed during the design or the trial operation phase, affected models shall be updated by the connectee and provided to the TSO within one month after the change.

The connectee shall provide to the TSO updated models during the lifetime of the DC-connected OWF, if applicable.

The connectee shall provide the TSO with support for at least 24 months after the submission of each updated model. This support shall encompass at least 40 hours per model.

If during the trial or permanent operation phase phenomena will be observed, which cannot be reproduced by using the prior provided models of the connectee, these models shall be checked and improved by the connectee in order to enable the TSO to simulate these phenomena.

The connectee shall provide trainings required for the proper use of all submitted models which shall be held during the official review period of the respective model.

Each model must be documented with the model description and model validation. All model documentation must be approved by the TSO. The model documentation shall be updated with each model delivery.

The model documentation shall at least include the following aspects:

- Model user manual,
- Model validation documentation,
- Used software, compiler and visual studio incl. version number
- Literature and bibliography,
- Authors,
- Creation date,
- Stage of development of the models and its control functions, control modes and control parameters (if applicable),
- Types of studies/analyses for which the model is valid.

The model documentation shall contain a fitting description of the model with at least the following:

- The control schema is described by means of block diagrams.
- The documentation shall contain single line diagrams that shows the input and output parameters and variables.
- The names of input and output parameters and variables shall be described in detail.
- Handling of the submitted models, particularly how one integrates it into the simulation tool, shall be described.
- All limits with regard to the simulation scenarios, time increments etc. shall be described.

The model validation documentation shall at least include the following aspects:

- Summary and interpretation of results,
- Justification for any deviation from the grid code,
- Assumptions and data used,
- Literature and bibliography,
- Authors,
- Creation date and
- Applied software, incl. the version number (incl. simulation software, compiler, visual studio…).

8 General requirements for study documentation

The study documentation shall include the following general information:

- Description of the task and the objective of the respective study
- Creation date
- List of references
- Presentation of limit values or requirements given by standards or guidelines
- The methodology as well as simplifications shall be described.

Documents and reports submitted by the connectee shall be readable and understandable.

Tables, figures, graphs and pictures shall be explained in documents and reports. They shall be referenced at a suitable point in the study.

All figures shall have a clear and readable axis labeling including their units.

If different graphs are shown in one figure the connectee shall label all graphs with a name which is described in the text.

Graphs shall be fully clearly and readable labelled (units, axes, relevant value points, etc.) and presented with sufficient resolution, if necessary, with colour representation

The connectee shall use a minimum font size of 10 pt in figures.

If reports contain per unit or percentage values, the reference value shall be given in the report.

The language of the documents and reports shall be either German or English and shall be agreed upon with the TSO before the start of the study.

Documents and reports shall contain a list of all used references.

Documents and reports shall contain all assumptions.

Documents and reports shall contain all input parameters, input data relevant for the respective study, if necessary, with reference to the belonging documents incl. its version information. Experience values from reference projects shall not be used, if possible, rather the values that correspond to the actual design for this project shall be used.

Documents and reports shall contain a list of all used grid data.

Documents and reports shall contain the MD5 checksum of used models.

In the study reports the connectee shall confirm that all respective grid code requirements are fulfilled. If grid code requirements are not fulfilled, these requirements shall be clearly indicated, and the study reports shall contain an evaluation of the impact.

Software name and its version used for calculations shall be mentioned in study reports. All reports shall enable a review of the results by qualified staff and industrial standard software without further information.

Analyses and conclusions shall be completely comprehensible; a simple statement about a performance parameter such as "values are met" is not accepted. The comparison of target and actual values shall be directly shown.

The connectee shall describe if internal limits of the unit or of the park are reached and outline for how long the limits are reached.

Indication of min., max., or mean values, RMS-values, etc. are to be done, and, if necessary, use suitable indices.

Indication shall be done, whether calculation values (e.g., calculated current) or design values (e.g., rated current of an operating device) are used.

Simulation results are to be submitted as time curves of relevant variables in digital form (e.g., in Comtrade as well as pdf format) for all cases considered.

The result assessment contains a table in which the conformity (performance in accordance with the system and control requirement) as well as status signals (e.g., block, emergency out including corresponding cause) and maximum values of relevant electrical variables are summarised for all cases of the test matrix. The table shall be clearly designed, for example with colour coding, so that the user can instantly see the conformity with the system and control requirements.