NVF guide to offshore wind installations

Introduction

For facility owners wishing to connect to the Norwegian power grid, the technical requirements are currently described in the fos §14[1] supplementary document *Nasjonal veileder for funksjonskrav i kraftsystemet* (NVF)[2], which is a guideline for all owners and developers who plan to a) install *new* electrical facilities in the regional or transmission grid, or b) perform changes to *existing* electrical facilities in the regional or transmission grid.

Statnett, as the system operator, is currently mandated to make individual resolutions for approving the electrical functionality of the installation. This process starts with the facility owner initiating a formal fos §14 application. The NVF version that applies for the facility is determined in the final fos §14 approval document. Updated requirements in new revisions of the NVF are not enforced retroactively but will apply when changes or expansions are made to the facility.

The application must be submitted well in advance of commissioning so that the facility owner has the opportunity to incorporate the technical requirements at an early stage of project development. Any doubt or uncertainty regarding the functional requirements must be clarified with the system operator during the application process, including any potential need for clarification of general requirements, demand-driven requirements, and analysis/simulation studies.

In this document, Statnett as system operator aims to give a brief introduction to offshore wind developers on the technical requirements in the Norwegian power system, where the requirements can be found in the NVF, and how they are practiced by Statnett. It should be noted that the requirements themselves are not given in this document, and it is referred to the main NVF-document[2] for details regarding these.

More detailed information regarding the fos §14 application process can be found on the Statnett homepage and the fos §14 guideline (Norwegian only).

Note 1: This guide contains an unofficial translation of regulations, guidelines and supplementary documents. In case of any discrepancies, the Norwegian wording is correct.

Note 2: The guide will be updated should new information arise, for example through updated technical requirements in the NVF or change in common practice. Relevant updates or changes will be described in the revision log presented at the end of this document.

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[1] Forskrift om systemansvaret i kraftsystemet

[2] Only available in Norwegian. An unofficial translation of chapters 14 and 15 of the 2021 NVF version can be provided upon request.

NVF and European network codes

The European network codes are not implemented into Norwegian law, however, the NVF captures a majority of the requirements described in the European network codes Requirements for Generators (RfG) and High Voltage Direct Current Connections (HVDC) respectively.

What does the NVF contain?

The NVF describes the technical requirements for, but not limited to:

- Voltage and frequency tolerance
- Frequency dependent active power control
- Reactive power capability and reactive power control
- Fault ride through capability and fast fault current injection
- Protection schemes
- Analyses, simulation and testing
- Substation design

The below table shows the relevant NVF chapters for different connection topologies for offshore power park modules.

Connection type	Technical requirements	Documentation requirements
AC connected	Chapter 14	Chapter 16
DC connected	Chapter 15 (for power park only)	Chapter 16
	Chapter 18 (for HVDC system only)	Chapter 19

Tolerance-, regulation- and capability requirements shall be met in either the point of common coupling or point of connection, defined as follows:

Point of common coupling (PCC)	Primary side of the power park main transformer.
Point of connection (POC)	Point where the ownership transfers from facility owner to grid owner (TSO or DSO).

PCC and POC can either coincide or be at different locations, depending on ownership boundaries. See **Feil! Fant ikke referansekilden.** for examples on various base cases (AC and DC connected power park modules). The examples illustrated are simplified and the exact PCC/POC may vary, depending on the connection topology and complexity.

Relevant topics - common practice and future requirements

In the following sections, clarifications are provided for the common practice and developments of the requirements regarding:

I. Reactive power control
II. Reactive power capability
III. Frequency dependent active power control
IV. Frequency withstand capability and protection
V. Grid forming capabilities
VI. Analyses and verification studies
VII. Breaker topology and redundancy design in substations

I. Reactive power control

Unless otherwise decided by Statnett, the power park or HVDC controller shall always be set to automatic voltage control mode (Q(U) mode) without deadband.

II. Reactive power capability

Reactive power capability is normally required at the PCC. However, in case of a long AC subsea cable, Statnett may decide that the requirements shall be met at the onshore side of the transmission cable.

The reactive power capability of $Q/P_{max} \geq 0,33$ is the requirement historically practiced by Statnett, and currently this is considered as the standard requirement.

At least 85% of the required reactive capability at the PCC shall be dynamic, i.e. not to be provided from stepwise regulating components such as capacitor banks. Static (non-rotating) components with dynamic regulating abilities, typically VSC/STATCOM, could be required onshore to meet the dynamic capability requirements for AC connected power park modules.

There shall be no functionality that actively limits the reactive power capability to the minimum reactive power capability requirement when operating in $P < P_{max}$ (power park) or $P_{max,export} < P < P_{max,import}$ (HVDC system).

III. Frequency dependent active power control

From 01.01.2025 it is mandatory for power park modules ≥10 MVA to enable frequency control with the following maximum settings:

- Droop: 6 %
- Deadband: ±0,1 Hz

It should be noted that values for droop and deadband may be subject to change in the future. The requirements are described in a separate resolution[3] from Statnett.

For participation in market-based frequency containment reserves (FCR), it is referred to a separate prequalification process with corresponding technical requirements.

IV. Frequency withstand capability and protection

Frequency protection schemes for network components (i.e. transformers, switchgear) is generally not allowed and must be clarified with Statnett.

Frequency protection schemes for production units are not mandatory. If activated, Statnett may require that both power park modules and HVDC systems are able to withstand large and short-term and frequency deviations without disconnection from the grid. This may therefore differ from the general requirements regarding frequency withstand capability outlined in the RfG and NVF.

V. Grid forming capabilities

Statnett may decide to require that HVDC systems and power park modules of type C and D have grid forming functionality. Grid forming functionality is generally understood as control strategies which enable power electronic interfaced devices to

[3] *Vedtak om levering og betaling for systemtjenester 2025 – jf. forskrift om systemansvaret i kraftsystemet (fos) §§ 9 og 27*

function as a controlled voltage source behind an impedance, having the ability to self-synchronize with the grid. The voltage source behaviour implies keeping a nearly constant internal voltage phasor in the sub-transient or transient timeframe after a disturbance and thus inherently inject or absorb active and reactive power. Grid forming behaviour is especially favourable in weak grids and in areas with a high density of converter-based facilities. Work is currently being done on harmonized Nordic requirements for grid forming converters.

VI. Analyses and verification studies

The facility owner shall provide analyses demonstrating compliance with requirements in the fos §14 application phase. To date, this is mandatory for reactive power capability and fault ride through capability, and Statnett may require further analyses and/or studies as described in NVF chapter 2.3.1.

NVF chapter 14.2.5 and chapter 18.2.5 describes the requirement for the power park or the HVDC system to operate stably. Statnett is currently working on a guidance note on verifications studies to provide compliance with this stability requirement. The guidance note can be handed out on request until it is made public.

VII. Breaker topology and redundancy design in substations

NVF chapter 5.1 describes the requirements regarding redundancy design in substations for different nominal voltage levels.

For an **onshore** substation, Statnett as the system operator may require a substation design that ensures uninterrupted power supply during planned or unplanned outages. This is normally provided through redundancy in switchgear and current transformers. Note that this also implies a two-busbar solution. Connections to existing substations will normally require the incoming breaker bay(s) to follow the same topology as the rest of the facility.

For an **offshore** substation, if applicable, there has currently not been outlined any standard requirements in the NVF. Statnett as the system operator shall approve the breaker/busbar design for each case. The total capacity of the wind farm will have an impact on the requirements. For large wind farms, it is important that faults on single components such as breakers, transformers and busbars do not lead to an outage of the entire production facility. Designs using single busbars and bus-ties in addition to circuit breakers for sectioning of the facility and minimizing the risk of large outages will be allowed as an alternative to the two-busbar solutions commonly described in the NVF.

The NVF does not contain requirements regarding the number of power transformers, cables/lines or switchgear bays connected to a substation. Such design shall be handled in the concept study of the project, which the facility owner is responsible for.

Note that separate regulations regarding substation design may apply, such as the regulation for emergency preparedness in the power system[4]. The latter regulation is managed by The Norwegian Water Resources and Energy Directorate (NVE), and relevant questions shall be directed to this authority.

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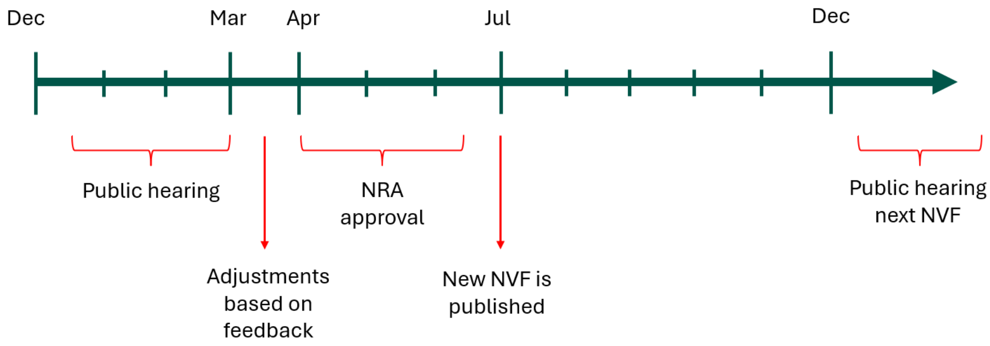
[4] Forskrift om sikkerhet og beredskap i kraftforsyningen (kraftberedskapsforskriften)

NVF update process

Currently the NVF is being revised on a yearly basis, with new revisions made public for a 2,5-month hearing process starting from 15th December, during which feedback on the proposed changes can be provided. Note that it is possible to give feedback to existing NVF requirements at any time and enter dialogue with Statnett to clarify and/or improve technical requirements for future revisions of the NVF.

The timeline for the update process is illustrated in the figure below. New hearing versions of the NVF are published on the Statnett homepage.



Appendix 1 – PCC and POC

AC connected power park modules

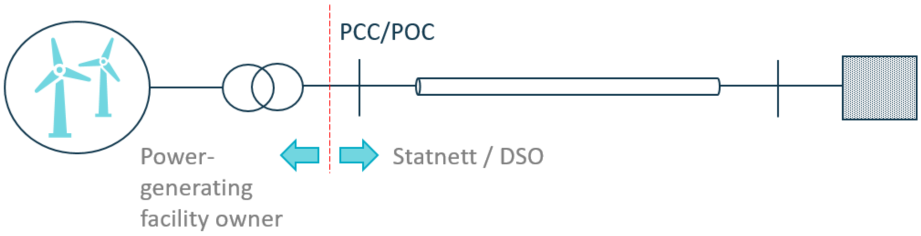


Figure 1: Subsea cable owned by TSO or DSO. PCC and POC coincide.

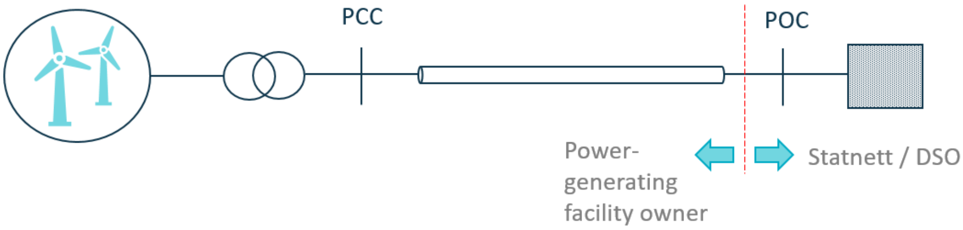


Figure 2: Subsea cable owned by the facility owner. PCC and POC are located at different points; offshore side and onshore side of the subsea cable.

DC connected power park modules

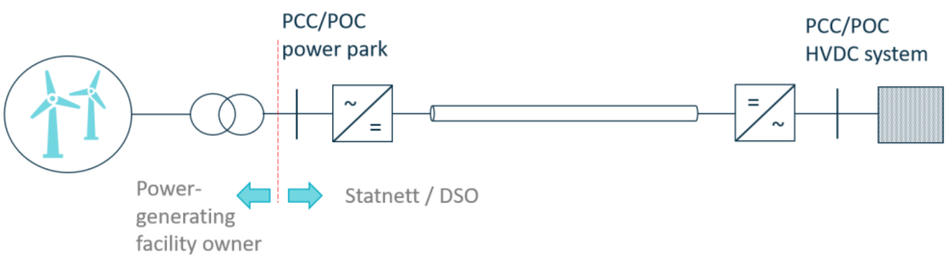


Figure 3: HVDC system owned by TSO or DSO. PCC and POC coincides for the facility owner. The TSO/DSO is responsible for the HVDC system meeting the technical requirements.

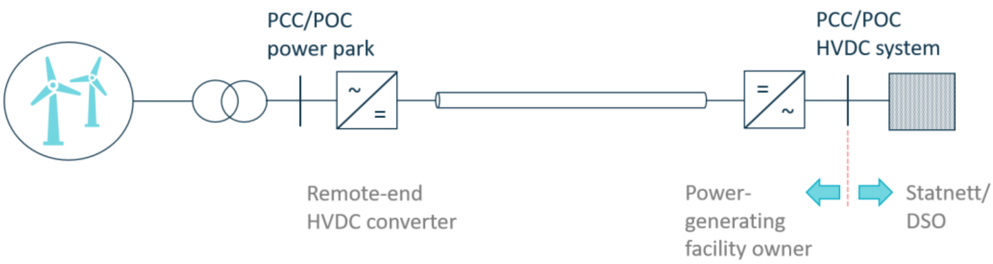


Figure 4: HVDC system owned by the facility owner, whom must meet the technical requirements in two sets of PCC/POCs; one for the power park itself and one for the HVDC system.

Appendix 2 – Revision log

Rev.	***Date***	***Description***
0	*10.03.2023*	- *First issue*
1	*14.09.2023*	- *Chapter 1.4 V – elaboration of system operator requirements for redundancy and reference to other relevant national regulations*
2	*25.08.2025*	- *Section II – Removed text describing possible future requirements, as there is no ongoing work looking into the need for additional reactive power capability beyond Q/P_max >= 33%.* - *Section III - Updated settings for frequency dependent active power control, as previous exemption from activating FSM/LFSM has been lifted since 01.01.2025.* - *New section IV regarding frequency withstand capability.* - *Section V (previously IV) – updated text describing grid forming capabilities. Removed text with references to the RfG and synchronous condensers.* - *New section IV regarding analyses and verification studies.* - *Section VII (previously V) – requirements regarding substation design divided into onshore and offshore substations.* - *New note that in case of discrepancies, the official Norwegian documents apply.* - *Other minor adjustments and general clarifications*